SECOND EDITION

Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook

EARTHQUAKE HAZARDS REDUCTION SERIES 41

FEMA Foreword

The Federal Emergency Management Agency (FEMA) is pleased to present the second edition of the widely used *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, and its companion, *Supporting Documentation.* The policy of improving reports and manuals that deal with the seismic safety of existing buildings as soon as new information and adequate resources are available is thus being reaffirmed. Users should take note of some major differences between the two editions of the *Handbook*. The technical content of the new edition is based more on experiential data and less on expert judgment than was the case in the earlier edition, as is explained in the *Supporting Documentation*. From the presentational point of view, the *Handbook* retains much of the material of the earlier edition, but the material has been rather thoroughly rearranged to further facilitate the step-by-step process of conducting the rapid visual screening of a building. By far the most significant difference between the two editions, however, is the need for a higher level of engineering understanding and expertise on the part of the users of the second edition. This shift has been caused primarily by the difficulty experienced by users of the first edition in identifying the lateral-force-resisting system of a building without entry—a critical decision of the rapid visual screening process. The contents of the *Supporting Documentation* volume have also been enriched to reflect the technical advances in the *Handbook*.

FEMA and the Project Officer wish to express their gratitude to the members of the Project Advisory Panel, to the technical and workshop consultants, to the project management, and to the report production and editing staff for their expertise and dedication in the upgrading of these two volumes.

The Federal Emergency Management Agency

Preface

In August 1999 the Federal Emergency Management Agency (FEMA) awarded the Applied Technology Council (ATC) a two-year contract to update the FEMA 154 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, and the companion FEMA-155 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*, both of which were originally published in 1988.

The impetus for the project stemmed in part from the general recommendation in the FEMA 315 report, *Seismic Rehabilitation of Buildings: Strategic Plan 2005*, to update periodically all existing reports in the FEMA-developed series on the seismic evaluation and rehabilitation of existing buildings. In addition, a vast amount of information had been developed since 1988, including: (1) new knowledge about the performance of buildings during damaging earthquakes, including the 1989 Loma Prieta and 1994 Northridge earthquakes; (2) new knowledge about seismic hazards, including updated national seismic hazard maps published by the U. S. Geological Survey in 1996; (3) other new seismic evaluation and damage prediction tools, such as the FEMA 310 report, *Handbook for the Seismic Evaluation of Buildings – a Prestandard*, (an updated version of FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings*), and HAZUS, FEMA's tool for estimating potential losses from natural disasters; and (4) experience from the widespread use of the original FEMA 154 *Handbook* by federal, state and municipal agencies, and others.

The project included the following tasks: (1) an effort to obtain users feedback, which was executed through the distribution of a voluntary FEMA 154 Users Feedback Form to organizations that had ordered or were known to have used FEMA 154 (the Feedback Form was also posted on ATC's web site); (2) a review of available information on the seismic performance of buildings, including a detailed review of the HAZUS fragility curves and an effort to correlate the relationship between results from the use of both the FEMA 154 rapid visual screening procedure and the FEMA 178 detailed seismic evaluation procedures on the same buildings; (3) a Users Workshop midway in the project to learn first hand the problems and successes of organizations that had used the rapid visual screening procedure on buildings under their jurisdiction; (4) updating of the original FEMA 154 *Handbook* to create the second edition; and (5) updating of the original FEMA 155 *Supporting Documentation* report to create the second edition.

This second edition of the FEMA 154 *Handbook* provides a standard rapid visual screening procedure to identify, inventory, and rank buildings that are potentially seismically hazardous. The scoring system has been revised, based on new information, and the *Handbook* has been shortened and focused to facilitate implementation. The technical basis for the rapid visual screening procedure, including a summary of results from the efforts to solicit user feedback, is documented in the companion second edition of the FEMA 155 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation.*

ATC gratefully acknowledges the personnel involved in developing the second editions of the FEMA 154 and FEMA 155 reports. Charles Scawthorn served as Co-Principal Investigator and Project Director. He was assisted by Kent David, Vincent Prabis, Richard A. Ranous, and Nilesh Shome, who served as Technical Consultants. Members of the Project Advisory Panel, who provided overall review and guidance for the project, were: Thalia Anagnos, John Baals, James R. Cagley (ATC Board Representative), Melvyn Green, Terry Hughes, Anne S. Kiremidjian, Joan MacQuarrie, Chris D. Poland, Lawrence D. Reaveley, Doug Smits, and Ted Winstead. William T. Holmes served as facilitator for the Users Workshop, and Keith Porter served as recorder. Stephanie A. King verified the Basic Structural Hazard Scores and the Score Modifiers. A. Gerald Brady, Peter N. Mork, and Michelle Schwartzbach provided report editing and production services. The affiliations of these individuals are provided in the list of project participants.

ATC also gratefully acknowledges the valuable assistance, support, and cooperation provided by Ugo Morelli, FEMA Project Officer. In addition, ATC acknowledges participants in the

FEMA 154 Users Workshop, which included, in addition to the project personnel listed above, the following individuals: Al Berstein, U. S. Bureau of Reclamation; Amitabha Datta, General Services Administration; Ben Emam, Amazon.com; Richard K. Eisner, California Office of Emergency Services; Ali Fattah, City of San Diego; Brian Kehoe, Wiss Janney Elstner Associates, Inc.; David Leung, City and County of San Francisco; Douglas McCall, Marx/Okubo; Richard Silva, National Park Service; Howard Simpson, Simpson Gumpertz & Heger Inc.; Steven Sweeney, U. S. Army Civil Engineering Research Laboratory; Christine Theodooropoulos, University of Oregon; and Zan Turner, City and County of San Francisco. Those persons who responded to ATC's request to complete the voluntary FEMA 154 Users Feedback form are also gratefully acknowledged.

Christopher Rojahn, Principal Investigator
ATC Executive Director

Summary and Application

This FEMA 154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook,* is the first of a two-volume publication on a recommended methodology for rapid visual screening of buildings for potential seismic hazards. The technical basis for the methodology, including the scoring system and its development, are contained in the companion FEMA 155 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*. Both this document and the companion document are second editions of similar documents published by FEMA in 1988.

The rapid visual screening procedure (RVS) has been developed for a broad audience, including building officials and inspectors, and government agency and private-sector building owners (hereinafter, the "RVS authority"), to identify, inventory, and rank buildings that are potentially seismically hazardous. Although RVS is applicable to all buildings, its principal purpose is to identify (1) older buildings designed and constructed before the adoption of adequate seismic design and detailing requirements, (2) buildings on soft or poor soils, or (3) buildings having performance characteristics that negatively influence their seismic response. Once identified as potentially hazardous, such buildings should be further evaluated by a design professional experienced in seismic design to determine if, in fact, they are seismically hazardous.

The RVS uses a methodology based on a "sidewalk survey" of a building and a Data Collection Form, which the person conducting the survey (hereafter referred to as the screener) completes, based on visual observation of the building from the exterior, and if possible, the interior. The Data Collection Form includes space for documenting building identification information, including its use and size, a photograph of the building, sketches, and documentation of pertinent data related to seismic performance, including the development of a numeric seismic hazard score.

Once the decision to conduct rapid visual screening for a community or group of buildings has been made by the RVS authority, the screening effort can be expedited by pre-planning, including the training of screeners, and careful overall management of the process.

Completion of the Data Collection Form in the field begins with identifying the primary structural lateral-load-resisting system and structural materials of the building. Basic Structural Hazard Scores for various building types are provided on the form, and the screener circles the appropriate one. For many buildings, viewed only from the exterior, this important decision requires the screener to be trained and experienced in building construction. The screener modifies the Basic Structural Hazard Score by identifying and circling Score Modifiers, which are related to observed performance attributes, and which are then added (or subtracted) to the Basic Structural Hazard Score to arrive at a final Structural Score, *S*. The Basic Structural Hazard Score, Score Modifiers, and final Structural Score, *S*, all relate to the probability of building collapse, should severe ground shaking occur (that is, a ground shaking level equivalent to that currently used in the seismic design of new buildings). Final *S* scores typically range from 0 to 7, with higher *S* scores corresponding to better expected seismic performance.

Use of the RVS on a community-wide basis enables the RVS authority to divide screened buildings into two categories: those that are expected to have acceptable seismic performance, and those that may be seismically hazardous and should be studied further. An *S* score of 2 is suggested as a "cut-off", based on present seismic design criteria. Using this cut-off level, buildings having an *S* score of 2 or less should be investigated by a design professional experienced in seismic design.

The procedure presented in this *Handbook* is meant to be the preliminary screening phase of a multi-phase procedure for identifying potentially hazardous buildings. Buildings identified by this procedure must be analyzed in more detail by an experienced seismic design professional. Because rapid visual screening is designed to be performed from the street, with interior inspection not always possible, hazardous details will not always be visible, and seismically hazardous buildings may not be identified as such. Conversely, buildings initially identified as potentially hazardous by RVS may prove to be adequate.

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1-1, A-1 to 11	Maps credited to Nilesh Shome / ABS Consulting / EQE Engineers / USGS
5-5, 6, 12, 14, F-11	Richard Ranous / ABS Consulting / EQE Engineers
2-1,8; 3-10 to 12, 15, 16, 18, 19; Table 3-1, Building Type W1, W2, S1 to S5, C1 to C3, PC1 (top), PC2, RM1, RM2, URM; 5-9, 10, D-1 to 5; E-1, 2, 4, 6 to 10, 13 to 16, 17 to 19, 21, 22, 24, 26 to 29, 32 to 34, 36 to 40, 42, 44, 46, 50, 51, 53 to 55; F-5 to 10, 12; Table D-1c to e; Table D-2 b to o; Table D-3a to e, h	Charles Scawthorn / ABS Consulting / EQE Engineers
2-5, 6, 7	Sanborn Maps
2-9	Oakland, California and Mecklenberg County, North Carolina, web pages
3-8, 9; E-43, 45	Drawings by Kit Wong
5-1, F-1 to 4	USGS web site
5-3	Los Angeles/San Pedro, California; city GIS
D-6, 8, 9, 10 D-13 to 17; Table D-1a, b; Table D-3f, g	Photographs by Kit Wong
D-7	Robert Bruce
D-11, 12	Allen, E., 1985, *Fundamentals of Building Construction and Methods*, John Wiley and sons, New York.
E-3, 23, 25,30; E-35, 41, 47, 48, 49	Lagorio, H., Friedman, H., and K. Wong (1986). *Issues for Seismic Strengthening of Existing Buildings: A Practical Guide for Architects.* Center for Environmental Design, University of California at Berkeley.
E-5, 12	Drawing from *National Multihazard Survey Instructions*. FEMA, TR-84.
E-11, 20	Steinbrugge, K. (1982). *Earthquakes, Volcanoes, and Tsunamis, An Anatomy of Hazards.* Skandia American Group, New York.
E-31	James Stratta
E-52	Ramsay/Sleeper *Architectural Graphic Standards,* Seventh Edition (1981). R.T. Packard, AIA, ed., John Wiley & Sons, New York.
Table D-2a	*A Field Guide to American Architecture* (1980), The New American Library, Inc., New York.
Table 3-1, Building Type PC1 (lower)	Earthquake Engineering Research Institute.
E-39	Anonymous, but greatly appreciated

Chapter 1

Introduction

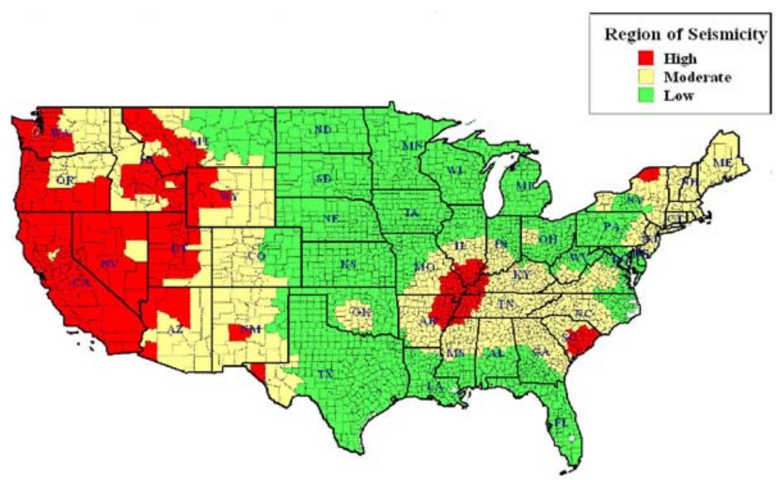
1.1 Background

Rapid visual screening of buildings for potential seismic hazards, as described herein, originated in 1988 with the publication of the FEMA 154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*. Written for a broad audience ranging from engineers and building officials to appropriately trained nonprofessionals, the *Handbook* provided a "sidewalk survey" approach that enabled users to classify surveyed buildings into two categories: those acceptable as to risk to life safety or those that may be seismically hazardous and should be evaluated in more detail by a design professional experienced in seismic design.

During the decade following publication of the first edition of the FEMA 154 *Handbook*, the rapid visual screening (RVS) procedure was used by private-sector organizations and government agencies to evaluate more than 70,000 buildings nationwide (ATC, 2002). This widespread application provided important information about the purposes for which the document was used, the ease-of-use of the document, and perspectives on the accuracy of the scoring system upon which the procedure was based.

Concurrent with the widespread use of the document, damaging earthquakes occurred in California and elsewhere, and extensive research and development efforts were carried out under the National Earthquake Hazards Reduction Program (NEHRP). These efforts yielded important new data on the performance of buildings in earthquakes, and on the expected distribution, severity, and occurrence of earthquake-induced ground shaking.

The data and information gathered during the first decade after publication (experience in applying the original *Handbook*, new building earthquake performance data, and new ground shaking information) have been used to update and improve the rapid visual screening procedure provided in this second edition of the FEMA 154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards*: *A Handbook*. The revised RVS procedure retains the same framework and approach of the original procedure, but incorporates a revised scoring system compatible with the ground motion criteria in the FEMA 310 Report, *Handbook for Seismic Evaluation of Buildings—A Prestandard* (ASCE, 1998), and the damage estimation data provided in the recently developed FEMA-funded HAZUS damage and loss estimation methodology (NIBS, 1999). As in the original *Handbook*, a Data Collection Form is provided for each of three seismicity regions: low, moderate, and high. However, the boundaries of the low, moderate, and high seismicity regions in the original *Handbook* have been modified (Figure 1-1), reflecting new knowledge on the expected distribution, severity, and occurrence of earthquake ground shaking, and a change in the



Note: Seismicity regions are based on ground motions having a 2% probability of exceedance in 50 years.

Figure 1-1 High, moderate, and low seismicity regions of the conterminous United States. A different RVS Data Collection Form has been developed for each of these regions. Enlarged maps are available in Appendix A.

recurrence interval considered, from a 475-year average return period (corresponding to ground motions having a 10% probability of exceedance in 50 years) to a 2475-year average return period (corresponding to ground motions having a 2% probability of excedance in 50 years).

This second edition of the FEMA 154 *Handbook* has been shortened and focused to facilitate implementation. Other improvements include:

- guidance on planning and managing an RVS survey, including the training of screeners and the acquisition of data from assessor files and other sources to obtain more reliable information on age, structural system, and occupancy;
- more guidance for identifying the structural (lateral-load-resisting) system in the field;
- the use of interior inspection or pre-survey reviews of building plans to identify (or verify) a building's lateral-load-resisting system;
- updated Basic Structural Hazard Scores and Score Modifiers that are derived from analytical calculations and recently developed HAZUS fragility curves for the model building types considered by the RVS methodology;
- the use of new seismic hazard information that is compatible with seismic hazard criteria specified in other related FEMA documents (see Section 1.4 below); and
- a revised Data Collection Form that provides space for documenting soil type, additional options for documenting falling hazards, and an expanded list of occupancy types.

1.2 Screening Procedure Purpose, Overview, and Scope

The RVS procedure presented in this *Handbook* has been formulated to identify, inventory, and rank buildings that are potentially seismically hazardous. Developed for a broad audience that includes building officials and inspectors, government agencies, design professionals, private-sector building owners (particularly those that own or operate clusters or groups of buildings), faculty members who use the RVS procedure as a training tool, and informed appropriately trained, members of the public, the RVS procedure can be implemented relatively quickly and inexpensively to develop a list of potentially hazardous buildings without the high cost of a detailed seismic analysis of individual buildings. If a building receives a high score (i.e., above a specified cut-off score, as discussed later in this *Handbook*), the building is considered to have adequate seismic resistance. If a building receives a low score on the basis of this RVS procedure, it should be evaluated by a professional engineer having experience or training in seismic design. On the basis of this detailed inspection, engineering analyses, and other detailed procedures, a final determination of the seismic adequacy and need for rehabilitation can be made.

During the planning stage, which is discussed in Chapter 2, the organization that is conducting the RVS procedure (hereinafter, the "RVS authority") will need to specify how the results from the survey will be used. If the RVS authority determines that a low score automatically requires that further study be performed by a professional engineer, then some acceptable level of qualification held by the inspectors performing the screening will be necessary. RVS projects have a wide range of goals and they have constraints on budget, completion date and accuracy, which must be considered by the RVS authority as it selects qualification requirements of the screening personnel. Under most circumstances, a well-planned and thorough RVS project will require engineers to perform the inspections. In any case, the program should be overseen by a design professional knowledgeable in seismic design for quality assurance purposes.

The RVS procedure in this *Handbook* is designed to be implemented without performing structural analysis calculations. The RVS procedure utilizes a scoring system that requires the user to (1) identify the primary structural lateral-load-resisting system; and (2) identify building attributes that modify the seismic performance expected of this lateral-load-resisting system. The inspection, data collection, and decision-making process typically will occur at the building site, taking an average of 15 to 30 minutes per building (30 minutes to one hour if access to the interior is available). Results are recorded on one of three Data Collection Forms (Figure 1-2), depending on the seismicity of the region being surveyed. The Data Collection Form, described in greater detail in Chapter 3, includes space for documenting building identification information, including its use and size, a photograph of the building, sketches, and documentation of pertinent data related to seismic performance, including the development of a numeric seismic hazard score. The scores are based on average expected ground shaking levels for the seismicity region as well as the seismic design and construction practices for that region[1]. Buildings may be reviewed from the sidewalk without the benefit of building entry, structural drawings, or structural calculations. Reliability and confidence in building attribute determination are increased, however, if the structural framing system can be verified during interior inspection, or on the basis of a review of construction documents.

The RVS procedure is intended to be applicable nationwide, for all conventional building types. Bridges, large towers, and other non-building structure types, however, are not covered by the procedure. Due to budget or other constraints, some RVS authorities may wish to restrict their RVS to identifying building types that they consider the most hazardous, such as unreinforced masonry or nonductile concrete buildings. However, it is recommended, at least initially, that all conventional building types be considered, and that elimination of certain building types from the screening be well documented and supported with office calculations and field survey data that justify their elimination. It is possible that, in some cases, even buildings designed to modern codes, such as those with configurations that induce extreme torsional response and those with abrupt changes in stiffness, may be potentially hazardous.

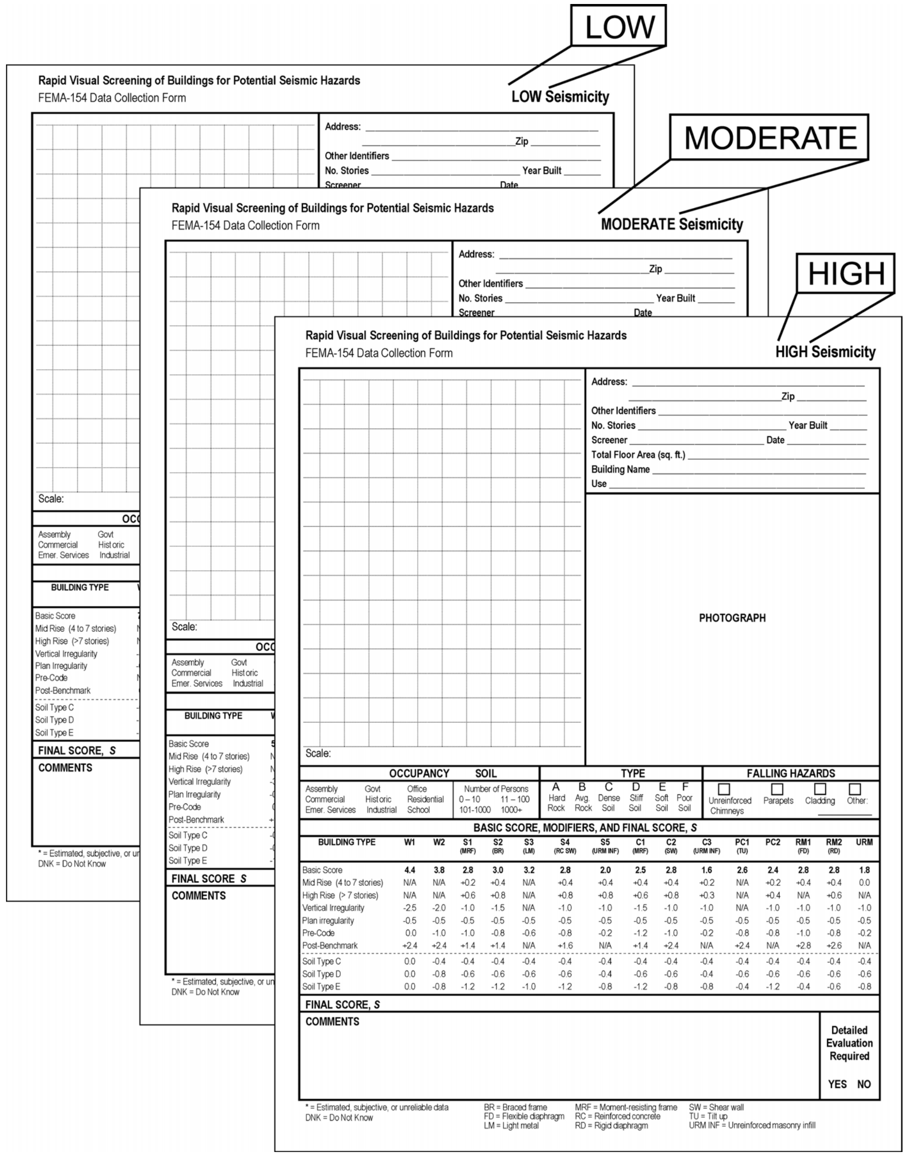


Figure 1-2 Data Collection Forms for the three designated seismicity regions (low, moderate, and high).

1.3 Companion FEMA 155 Report

A companion volume to this report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation (second edition)* (FEMA 155) documents the technical basis for the RVS procedure described in this *Handbook*, including the method for calculating the Basic Structural Scores and Score Modifiers. The FEMA 155 report (ATC, 2002) also summarizes other information considered during development of this *Handbook*, including the efforts to solicit user feedback and a FEMA 154 Users Workshop held in September 2000. The FEMA 155 document is available from FEMA by

[1] Seismic design and construction practices vary by seismicity region, with little or no seismic design requirements in low seismicity regions, moderate seismic design requirements in moderate seismicity regions, and extensive seismic design requirements in high seismicity regions. The requirements also vary with time, and are routinely updated to reflect new knowledge about building seismic performance.

dialing 1-800-480-2520 and should be consulted for any needed or desired supporting documentation.

1.4 Relationship of FEMA 154 to Other Documents in the FEMA Existing Building Series

The FEMA 154 *Handbook* has been developed as an integral and fundamental part of the FEMA report series on seismic safety of existing buildings. It is intended for use by design professionals and others to mitigate the damaging effects of earthquakes on existing buildings. The series includes:

- FEMA 154 (this handbook), which provides a procedure that can be rapidly implemented to identify buildings that are potentially seismically hazardous.
- FEMA 310, *Handbook for Seismic Evaluation of Buildings—A Prestandard* (ASCE, 1998), which provides a procedure to inspect in detail a given building to evaluate its seismic resisting capacity (an updated version of the FEMA 178 *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* [BSSC, 1992]). The FEMA 310 Handbook is ideally suited for use on those buildings identified by the FEMA 154 RVS procedure as potentially hazardous.

  FEMA 310 is expected to be superseded in 2002 by ASCE 31, a standard of the American Society of Civil Engineers approved by the American National Standards Institute (ANSI). References in this *Handbook* to FEMA 310 should then refer to ASCE 31.
- FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings* (ASCE, 2000), which provides recommended procedures for the seismic rehabilitation of buildings with inadequate seismic capacity, as determined, for example, by a FEMA 310 (or FEMA 178) evaluation. The FEMA 356 Prestandard is based on the guidance provided in the FEMA 273 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (ATC, 1997a), and companion FEMA 274 *Commentary on the NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (ATC, 1997b).

1.5 Uses of RVS Survey Results

While the principal purpose of the RVS procedure is to identify potentially seismically hazardous buildings needing further evaluation, results from RVS surveys can also be used for other purposes. These include: (1) ranking a community's (or agency's) seismic rehabilitation needs; (2) designing seismic hazard mitigation programs for a community (or agency); (3) developing inventories of buildings for use in regional earthquake damage and loss impact assessments; (4) planning postearthquake building safety evaluation efforts; and (5) developing building-specific seismic vulnerability information for purposes such as insurance rating, decision making during building ownership transfers, and possible triggering of remodeling requirements during the permitting process. Additional discussion on the use of RVS survey results is provided in Chapter 4.

1.6 How to Use this Handbook

The *Handbook* has been designed to facilitate the planning and execution of rapid visual screening. It is assumed that the RVS authority has already decided to conduct the survey, and that detailed guidance is needed for all aspects of the surveying process. Therefore, the main body of the *Handbook* focuses on the three principal activities in the RVS: planning, execution, and data interpretation. Chapter 2 contains detailed information on planning and managing an RVS. Chapter 3 describes in detail how the Data Collection Form should be completed, and Chapter 4 provides guidance on interpreting and using the results from the RVS. Finally, Chapter 5 provides several example applications of the RVS procedure on real buildings.

Relevant seismic hazard maps, full-sized Data Collection Forms, including a Quick Reference Guide for RVS implementation, guidance for reviewing design and construction drawings, and additional guidance for identifying a building's seismic lateral-load-resisting system from the street are provided in Appendices A, B, C, and D, respectively. Appendix E provides additional information on the building types considered in the RVS procedure, and Appendix F provides an overview of earthquake fundamentals, the seismicity of the United States, and earthquake effects.

Chapter 2

Planning and Managing Rapid Visual Screening

Once the decision to conduct rapid visual screening (RVS) for a community or group of buildings has been made by the RVS authority, the screening effort can be expedited by pre-planning and careful overall management of the process. This chapter describes the overall screening implementation sequence and provides detailed information on important pre-planning and management aspects. Instructions on how to complete the Data Collection Form are provided in Chapter 3.

2.1 Screening Implementation Sequence

There are several steps involved in planning and performing an RVS of potentially seismically hazardous buildings. As a first step, if it is to be a public or community project, the local governing body and local building officials should formally approve of the general procedure. Second, the public or the members of the community should be informed about the purpose of the screening process and how it will be carried out. There are also other decisions to be made, such as use of the screening results, responsibilities of the building owners and the community, and actions to be taken. Some of these decisions are specific to each community and therefore are not discussed in this *Handbook*.

The general sequence of implementing the RVS procedure is depicted in Figure 2-1. The implementation sequence includes:

- Budget development and cost estimation, recognizing the expected extent of the screening and further use of the gathered data;
- Pre-field planning, including selection of the area to be surveyed, identification of building types to be screened, selection and development of a record-keeping system, and compilation and development of maps that document local seismic hazard information;

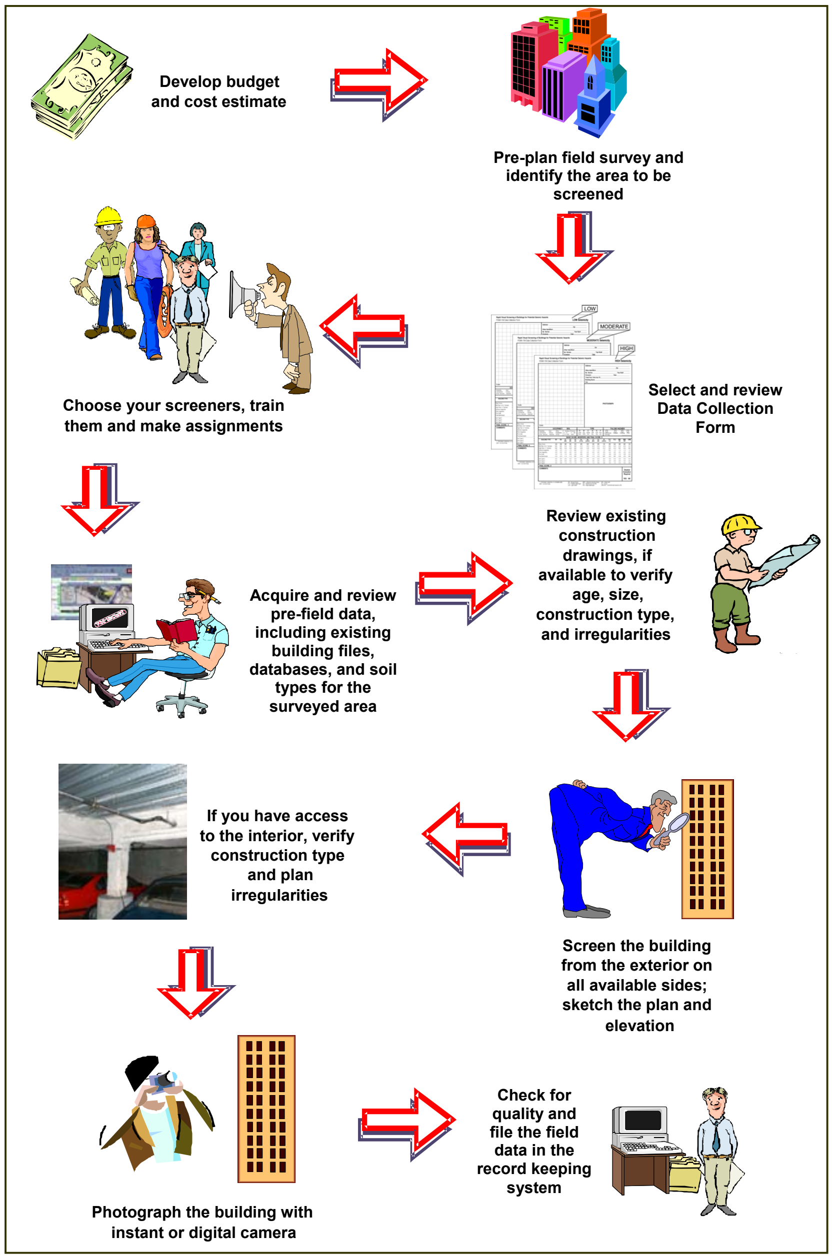


Figure 2-1 Rapid visual screening implementation sequence.

- Selection and review of the Data Collection Form;
- Selection and training of screening personnel;
- Acquisition and review of pre-field data; including review of existing building files and databases to document information identifying buildings to be screened (e.g., address, lot number, number of stories, design date) and identifying soil types for the survey area;
- Review of existing building plans, if available;
- Field screening of individual buildings (see Chapter 3 for details), which consists of:
  1. Verifying and updating building identification information,
  2. Walking around the building and sketching a plan and elevation view on the Data Collection Form,
  3. Determining occupancy (that is, the building use and number of occupants),
  4. Determining soil type, if not identified during the pre-planning process,
  5. Identifying potential nonstructural falling hazards,
  6. Identifying the seismic-lateral-load-resisting system (entering the building, if possible, to facilitate this process) and circling the Basic Structural Hazard Score on the Data Collection Form,
  7. Identifying and circling the appropriate seismic performance attribute Score Modifiers (e.g., number of stories, design date, and soil type) on the Data Collection Form,
  8. Determining the Final Score, *S* (by adjusting the Basic Structural Hazard Score with the Score Modifiers identified in Step 7), and deciding if a detailed evaluation is required, and
  9. Photographing the building; and
- Checking the quality and filing the screening data in the record-keeping system, or database.

2.2 Budget Development and Cost Estimation

Many of the decisions that are made about the level of detail documented during the rapid visual screening procedure will depend upon budget constraints. Although the RVS procedure is designed so field screening of each building should take no more than 15 to 30 minutes (30 minutes to one hour if access to the interior is obtained), time and funds should also be allocated for pre-field data collection. Pre-field data collection can be time consuming (10 to 30 minutes per building depending on the type of supplemental data available). However, it can be extremely useful in reducing the total field time and can increase the reliability of data collected in the field. A good example of this is the age, or design date, of a building. This might be readily available from building department files but is much more difficult to estimate from the street. Another issue to consider is travel time, if the distance between buildings to be screened is large. Because pre-field data collection and travel time could be a significant factor in budget allocations, it should be considered in the planning phase.

Other factors that should be considered in cost estimation are training of personnel and the development and administration of a record-keeping system for the screening process. The type of record keeping system selected will be a function of existing procedures and available funds as well as the ultimate goal of the screening. For example, if the screening is to be used solely for potential seismic damage estimation purposes, administrative costs will be different from those of a screening in which owners of low-scoring buildings must subsequently be notified, and compliance with ordinances is required.

2.3 Pre-Field Planning

The RVS authority may decide due to budget, time or other types of constraints, that priorities should be set and certain areas within the region should be surveyed immediately, whereas other areas can be surveyed at a later time because they are assumed to be less hazardous. An area may be selected because it is older and may have a higher density of potentially seismically hazardous buildings relative to other areas. For example an older part of the RVS authority region that consists mainly of commercial unreinforced masonry buildings may be of higher priority than a newer area with mostly warehouse facilities, or a residential section of a city consisting of wood-frame single-family dwellings.

Compiling and developing maps for the surveyed region is important in the initial planning phase as well as in scheduling of screeners. Maps of soil profiles, although limited, will be directly useful in the screening, and maps of landslide potential, liquefaction potential, and active faults provide useful background information about the relative hazard in different areas. Maps of lots will be useful in scheduling screeners and, as data are collected, in identifying areas with large numbers of potentially hazardous buildings.

Another important phase of pre-field planning is interaction with the local design profession and building officials. Discussions should include verification of when certain aspects of seismic design and detailing were adopted and enforced. This will be used in adjusting the scoring system for local practices and specifying benchmark years.

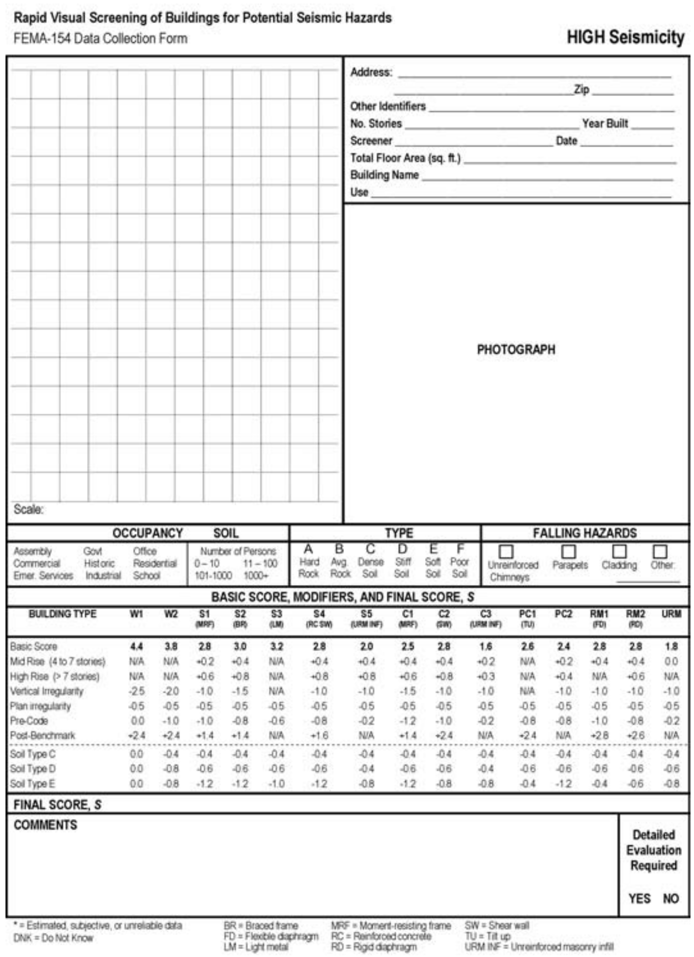
The record-keeping system will vary among RVS authorities, depending on needs, goals, budgets and other constraints, and may in fact consist of several systems. Part of this planning phase may include deciding how buildings are to be identified. Some suggestions are street address, assessor's parcel number, census tract, and lot number or owner. Consideration should be given to developing a computerized database containing location and other building information, which could easily be used to generate peel-off labels for the Data Collection Form, or to generate forms that incorporate unique information for each building.

The advantage of using a computerized record generation and collection system is that graphical data, such as sketches and photographs, are increasingly more easily converted to digital form and stored on the computer, especially if they are collected in digital format in the field. This can be facilitated through the use of personal digital assistants (PDAs), which would require the development of a FEMA 154 application, and the use of digital cameras.

If a computerized database is not used, microfilm is a good storage medium for original hard copy, because photographs, building plans, screening forms and subsequent follow-up documentation can be kept together and easily copied. Another method that has been used is to generate a separate hard-copy file for each building as it is screened. In fact, the screening form can be reproduced on a large envelope and all supporting material and photographs stored inside. This solves any problems associated with attaching multiple sketches and photographs, but the files grow rapidly and may become unmanageable.

2.4 Selection and Review of the Data Collection Form

There are three Data Collection Forms, one for each of the following three regions of seismicity: low (L), moderate (M), and high (H). Full-sized versions of each form are provided in Appendix B, along with a Quick Reference Guide that contains definitions and explanations for terms used on the Data Collection Form. Each Data Collection Form (see example, Figure 2-2) provides space to record the building identification information, draw a sketch of the building (plan and elevation views), attach a photograph of the building, indicate the occupancy, indicate the soil type, document the existence of falling hazards, develop a Final Structural Score, *S*, for the building, indicate if a detailed evaluation is required, and provide additional comments. The structural scoring system consists of a matrix of Basic Structural Hazard Scores (one for each building type and its associated seismic lateral-force-resisting system) and Score Modifiers to



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

HIGH Seismicity

Address:
Zip
Other Identifiers
No. Stories
Year Built
Screener
Date
Total Floor Area (sq. ft.)
Building Name
Use

PHOTOGRAPH

Scale:

OCCUPANCY			SOIL							FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Unreinforced Chimneys, Parapets, Cladding, Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required
YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 2-2 Example RVS Data Collection Form (high seismicity).

account for observed attributes that modify seismic performance. The Basic Structural Hazard Scores and Score Modifiers are based on (1) design and construction practices in the region, (2) attributes known to decrease or increase seismic resistance capacity, and (3) maximum considered ground motions for the seismicity region under consideration. The Basic Structural Hazard Score, Score Modifiers, and Final Structural Score, *S*, all relate to the probability of building collapse, should the maximum ground motions considered by the RVS procedure occur at the site. Final *S* scores typically range from 0 to 7, with higher *S* scores corresponding to better seismic performance.

The maximum ground motions considered in the scoring system of the RVS procedure are consistent with those specified for detailed building seismic evaluation in the FEMA 310 Report, *Handbook for the Seismic Evaluation of Buildings—A Prestandard*. Such ground motions generally have a 2% chance of being exceeded in 50 years, and are multiplied by a 2/3 factor in the FEMA 310 evaluation procedures and in the design requirements for new buildings in FEMA 302, *Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (BSSC, 1997). (Ground motions having a 2% probability of being exceeded in 50 years are commonly referred to as the maximum considered earthquake (MCE) ground motions.)

2.4.1 Determination of Seismicity Region

To select the appropriate Data Collection Form, it is first necessary to determine the seismicity region in which the area to be screened is located. The seismicity region (H, M, or L) for the screening area can be determined by one of two methods:

1. Find the location of the surveyed region on the seismicity map of Figure 1-1, or one of the enlarged seismicity maps provided in Appendix A, and identify the corresponding seismicity region, or;

2. Access the U.S. Geological Survey web page (http://geohazards.cr.usgs.gov/eq/), select "Hazard by Zip Code" or "Hazard by Lat/Long" under the "Seismic Hazard" heading, enter the appropriate values of zip code or latitude and longitude, select the spectral acceleration value (SA) for a period of 0.2 seconds and the SA value for a period of 1.0 second, multiply the SA values by 2/3, and use the criteria of Table 2-1 to select the appropriate seismicity region, assuming that the highest seismicity level defined by the parameters in Table 2-1 shall govern.

   Use more recent additions of these maps when they become available.

The web site approach of Method 2, which uses seismicity region definitions used in other recently developed FEMA documents, is preferred as it enables the user to determine seismicity based on a more precisely specified location. In contrast, each county shown in Figure 1-1 is assigned its seismicity on the basis of the highest seismicity in that county, even though it may only apply to a small portion of the county.

Table 2-1 Regions of Seismicity with Corresponding Spectral Acceleration Response (from FEMA 310)

Region of Seismicity	*Spectral Acceleration Response, SA (short-period, or 0.2 sec)*	*Spectral Acceleration Response, SA (long-period or 1.0 sec)*
Low	less than 0.167 *g* (in horizontal direction)	less than 0.067 *g* (in horizontal direction)
Moderate	greater than or equal to 0.167 *g* but less than 0.500 g (in horizontal direction)	greater than or equal to 0.067 *g* but less than 0.200 g (in horizontal direction)
High	greater than or equal to 0.500 *g* (in horizontal direction)	greater than or equal to 0.200 *g* (in horizontal direction)

Notes: *g* = acceleration of gravity

2.4.2 Determination of Key Seismic Code Adoption Dates and Other Considerations

The Data Collection Form is meant to be a model that may be adopted and used as it is presented in this *Handbook*. The form may also be modified according to the needs of the RVS authority. Therefore, another aspect of the screening planning process is to review the Data Collection Form to determine if all required data are represented or if modifications should be made to reflect the needs and special circumstances of the authority. For example, an RVS authority may choose to define additional occupancy classes such as "parking structure" or "multi-family residential."

One of the key issues that must be addressed in the planning process is the determination of (1) the year in which seismic codes were initially

Table 2-2. Benchmark Years for RVS Procedure Building Types (based on FEMA 310)

Building Type	BOCA	SBCC	UBC	NEHRP
	Model Building Seismic Design Provisions			
W1: Light wood-frame residential and commercial buildings smaller than or equal to 5,000 square feet	1992	1993	1976	1985
W2: Light wood-frame buildings larger than 5,000 square feet	1992	1993	1976	1985
S1: Steel moment-resisting frame buildings	**	**	1994	**
S2: Braced steel frame buildings	1992	1993	1988	1991
S3: Light metal buildings	*	*	*	*
S4: Steel frame buildings with cast-in-place concrete shear walls	1992	1993	1976	1985
S5: Steel frame buildings with unreinforced masonry infill walls	*	*	*	*
C1: Concrete moment-resisting frame buildings	1992	1993	1976	1985
C2: Concrete shear-wall buildings	1992	1993	1976	1985
C3: Concrete frame buildings with unreinforced masonry infill walls	*	*	*	*
PC1: Tilt-up buildings	*	*	1997	*
PC2: Precast concrete frame buildings	*	*	*	*
RM1: Reinforced masonry buildings with flexible floor and roof diaphragms	*	*	1997	*
RM2: Reinforced masonry buildings with rigid floor and roof diaphragms	1992	1993	1976	1985
URM: Unreinforced masonry bearing-wall buildings	*	*	1991	*

*No benchmark year; **contact local building department for benchmark year.
BOCA: Building Officials and Code Administrators, *National Building Code*
SBCC: Southern Building Code Congress, *Standard Building Code*.
UBC: International Conference of Building Officials, *Uniform Building Code*
NEHRP: National Earthquake Hazard Reduction Program, *FEMA 302 Recommended Provisions for the Development of Seismic Regulations for New Buildings*

adopted and enforced by the local jurisdiction, and (2) the year in which significantly improved seismic codes were adopted and enforced (this latter year is known as the benchmark year). In high and moderate seismicity regions, the Basic Structural Hazard Scores for the various building types are calculated for buildings built after the initial adoption of seismic codes, but before substantially improved codes were adopted. For these regions, Score Modifiers designated as "Pre Code" and "Post Benchmark" are provided, respectively, for buildings built before the adoption of codes and for buildings built after the adoption of substantially improved codes. In low seismicity regions, the Basic Structural Hazard Scores are calculated for buildings built before the initial adoption of seismic codes. For buildings in these regions, the Score Modifier designated as "Pre Code" is not applicable (N/A), and the Score Modifier designated as "Post Benchmark" is applicable for buildings built after the adoption of seismic codes.

Therefore, as part of this review process, the RVS authority should identify (1) the year in which seismic codes were first adopted and enforced in the area to be screened, (2) the "benchmark" year in which significantly improved seismic code requirements were adopted for each building type considered by the RVS procedure (see Table 2-2), and (3) the year in which the community adopted seismic anchorage requirements for heavy cladding. If the RVS authority in high and moderate seismicity regions is unsure of the year(s) in which codes were initially adopted, the default year for all but one building type is 1941 (the default year specified in the HAZUS criteria; NIBS, 1999). The one exception is PC1 (tilt-up) buildings, for which it is assumed that seismic codes were initially adopted in 1973, the year in which wall-diaphragm (ledger) connection requirements first appeared in the *Uniform Building Code* (ICBO, 1973).

During the review of the Data Collection Form, the RVS authority should confer with the

1. Model Building Types and Critical Code Adoption and Enforcement Dates		Year Seismic Codes Initially Adopted and Enforced*	Benchmark Year When Codes Improved
Structure Types			
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	_______	_______
W2	Wood frame buildings, > 5000 square feet	_______	_______
S1	Steel moment-resisting frame	_______	_______
S2	Steel braced frame	_______	_______
S3	Light metal frame	_______	_______
S4	Steel frame with cast-in-place concrete shear walls	_______	_______
S5	Steel frame with unreinforced masonry infill	_______	_______
C1	Concrete moment-resisting frame	_______	_______
C2	Concrete shear wall	_______	_______
C3	Concrete frame with unreinforced masonry infill	_______	_______
PC1	Tilt-up construction	_______	_______
PC2	Precast concrete frame	_______	_______
RM1	Reinforced masonry with flexible floor and roof diaphragms	_______	_______
RM2	Reinforced masonry with rigid diaphragms	_______	_______
URM	Unreinforced masonry bearing-wall buildings	_______	_______

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: _______

Figure 2-3 Sections 1 and 2 of Quick Reference Guide (for use with Data Collection Form).

chief building official, plan checkers, and other design professionals experienced in seismic design to identify the years in which the affected jurisdiction initially adopted and enforced seismic codes (if ever) for the building lateral-force-resisting structural systems considered by the RVS procedure. Since municipal codes are generally adopted by the city council, another source for this information, in many municipalities, is the city clerk's office. In addition to determining the year in which seismic codes were initially adopted and enforced, the RVS authority should also determine (1) the benchmark years in which substantially improved seismic codes were adopted and enforced for the various lateral-load-resisting systems and (2) the year in which anchorage requirements for cladding were adopted and enforced. These dates should be inserted on the Quick Reference Guide (Appendix B) that has been created to facilitate the use of the Data Collection Form (see Figure 2-3).

During the Data Collection Form review process, it is critically important that the Basic Structural Hazard Scores and Score Modifiers, which are described in detail in Chapter 3, not be changed without input from professional engineers familiar with earthquake-resistant design and construction practices of the local community. A checklist of issues to be considered when reviewing the Data Collection Form is provided in Table 2-3.

Table 2-3 Checklist of Issues to be Considered During Pre-Field Work Review of the Data Collection Form

- ☐ Evaluate completeness of occupancy categories and appropriateness of occupancy loads
- ☐ Determine year in which seismic codes were initially adopted in the jurisdiction
- ☐ Determine "benchmark" years in which the jurisdiction adopted and enforced significantly improved seismic codes for the various building types considered by the RVS procedure
- ☐ Determine year in which the jurisdiction adopted and enforced anchorage requirements for heavy cladding

2.4.3 Determination of Cut-Off Score

Use of the RVS on a community-wide basis enables the RVS authority to divide screened buildings into two categories: those that are expected to have acceptable seismic performance, and those that may be seismically hazardous and should be studied further. This requires that the RVS authority determine, preferably as part of the pre-planning process, an appropriate “cut-off” score.

An *S* score of 2 is suggested as a “cut-off”, based on present seismic design criteria. Using this cut-off level, buildings having an *S* score of 2 or less should be investigated by a design professional experienced in seismic design (see Section 3.9, 4.1 and 4.2 for additional information on this issue).

2.5 Qualifications and Training for Screeners

It is anticipated that a training program will be required to ensure a consistent, high quality of the data and uniformity of decisions among screeners. Training should include discussions of lateral-force-resisting systems and how they behave when subjected to seismic loads, hw to use the Data Collection Form, what to look for in the field, and how to account for uncertainty. In conjunction with a professional engineer experienced in seismic design, screeners should simultaneously consider and score buildings of several different types and compare results. This will serve as a “calibration” for the screeners.

This process can easily be accomplished in a classroom setting with photographs of actual buildings to use as examples. Prospective screeners review the photographs and perform the RVS procedure as though they were on the sidewalk. Upon completion, the class discusses the results and students can compare how they did in relation to the rest of the class.

2.6 Acquisition and Review of Pre-Field Data

Information on the structural system, age or occupancy (that is, use) may be available from supplemental sources. These data, from assessor and building department files, insurance (Sanborn) maps, and previous studies, should be reviewed and collated for a given area before commencing the field survey for that area. It is recommended that this supplemental information either be written directly on the Data Collection Forms as it is retrieved or be entered into a computerized database. The advantage of a database is that selected information can be printed in a report format that can be taken into the field, or printed onto peel-off labels that can be affixed to the Data Collection Form (see Figure 2-4). In addition, screening data can be added to the databases and

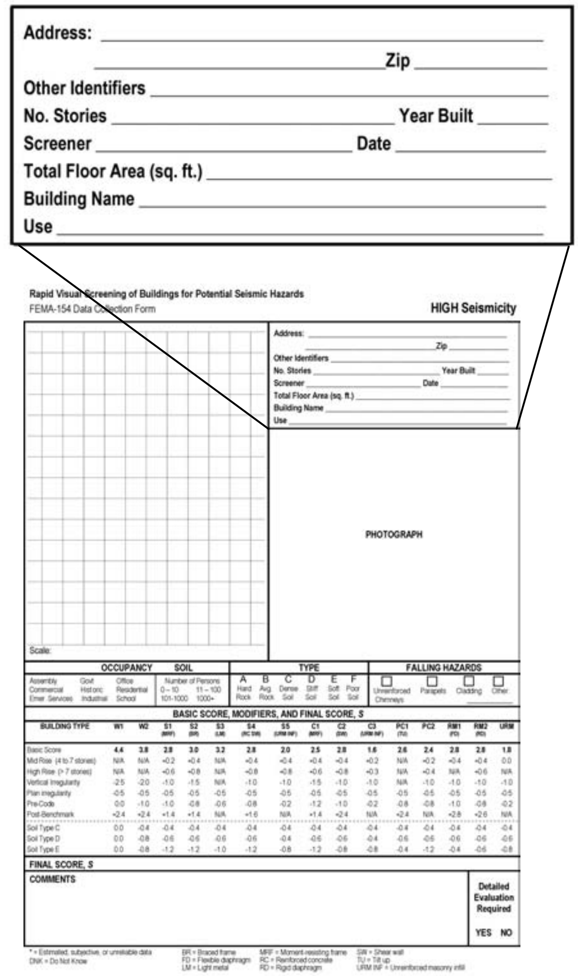


Figure 2-4 Building identification portion of RVS Data Collection Form.

used to generate maps and reports. Some sources of supplemental information are described in Sections 2.6.1 through 2.6.5.

2.6.1 Assessor's Files

Although assessor’s files may contain information about the age of the building, the floor area and the number of stories, most information relates to ownership and assessed value of the land and improvements, and thus is of relatively little value for RVS purposes. The construction type indicated is often incorrect and in most cases should not be used. In addition, the age of a building retrieved from assessor’s files may not, and most likely is not, the year that the structure was built. Usually assessor’s files contain the year that the building was first eligible for taxation. Because the criteria for this may vary, the date may be several years after the building was designed or constructed. If no other source of information is available this will give a good estimate of the period during which the building was constructed. However, this date should not be used to establish conclusively the code under which the a building was designed. Assessor's offices may have parcel or lot maps, which may be useful for locating sites or may be used as a template for sketching building adjacencies on a particular city block.

2.6.2 Building Department Files

The extent and completeness of information in building department files will vary from jurisdiction to jurisdiction. For example, in some locations all old files have been removed or destroyed, so there is no information on older buildings. In general, files (or microfilm) may contain permits, plans and structural calculations required by the city. Sometimes there is occupancy and use information, but little information about structural type will be found except from the review of plans or calculations.

2.6.3 Sanborn Maps

These maps, published primarily for the insurance industry since the late 1800s, exist for about 22,000 communities in the United States. The Sanborn Map Company stopped routinely updating these maps in the early 1960s, and many communities have not kept these maps up-to-date. Thus they may not be useful for newer construction. However, the maps may contain useful data for older construction. They can be found at the library or in some cases in building department offices. Figure 2-5 provides an example of an up-to-date Sanborn map Figure 2-6 shows a key to identifiers on Sanborn maps.

Information found on a Sanborn map includes:

- height of building,
- number of stories,
- year built,
- thickness of walls,
- building size (square feet),
- type of roof (tile, shingle, composite),
- building use (dwelling, store, apartment),
- presence of garage under structure, and
- structural type (wood frame, fireproof construction, adobe, stone, concrete).

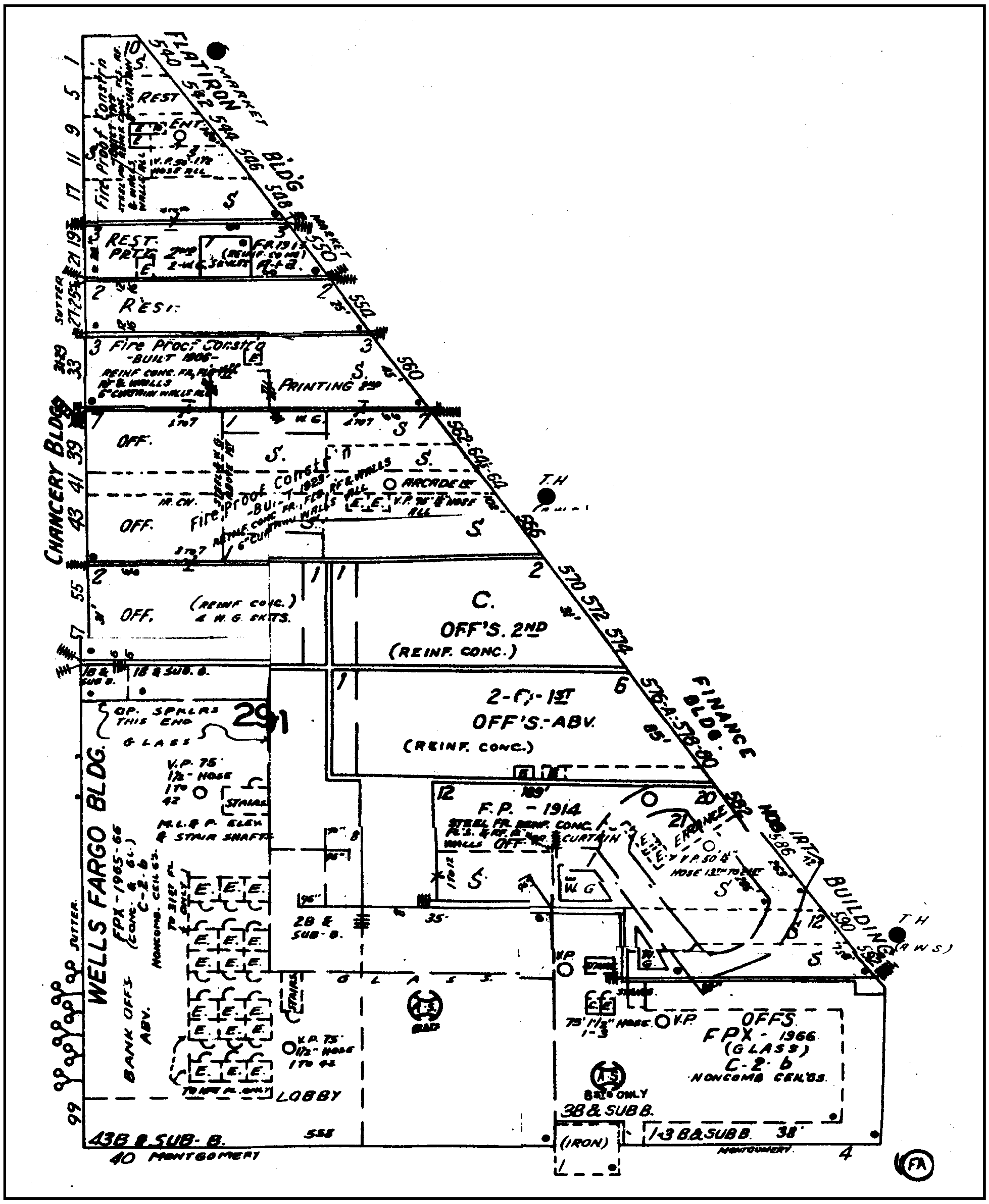


Figure 2-5 Example Sanborn map showing building information for a city block.

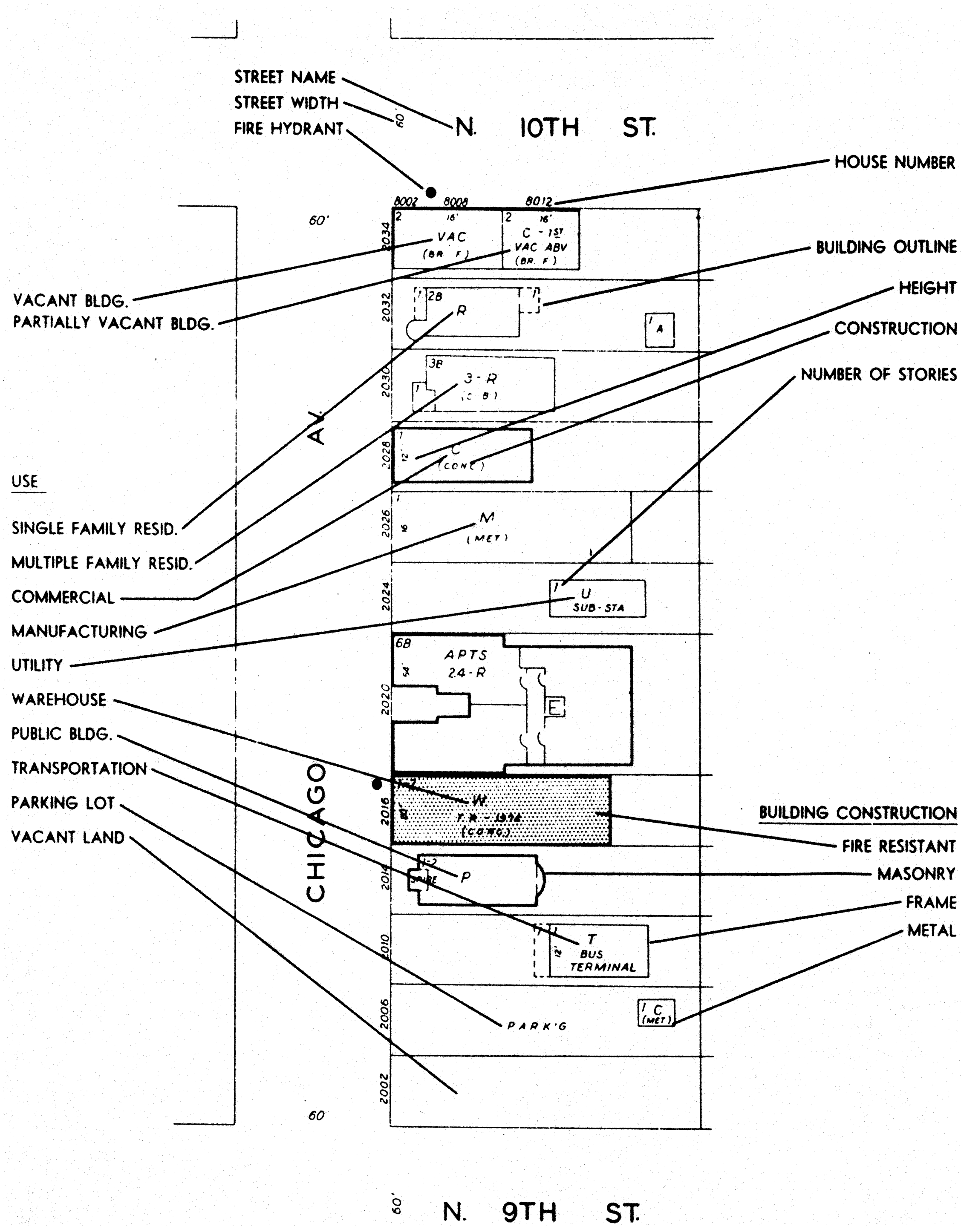
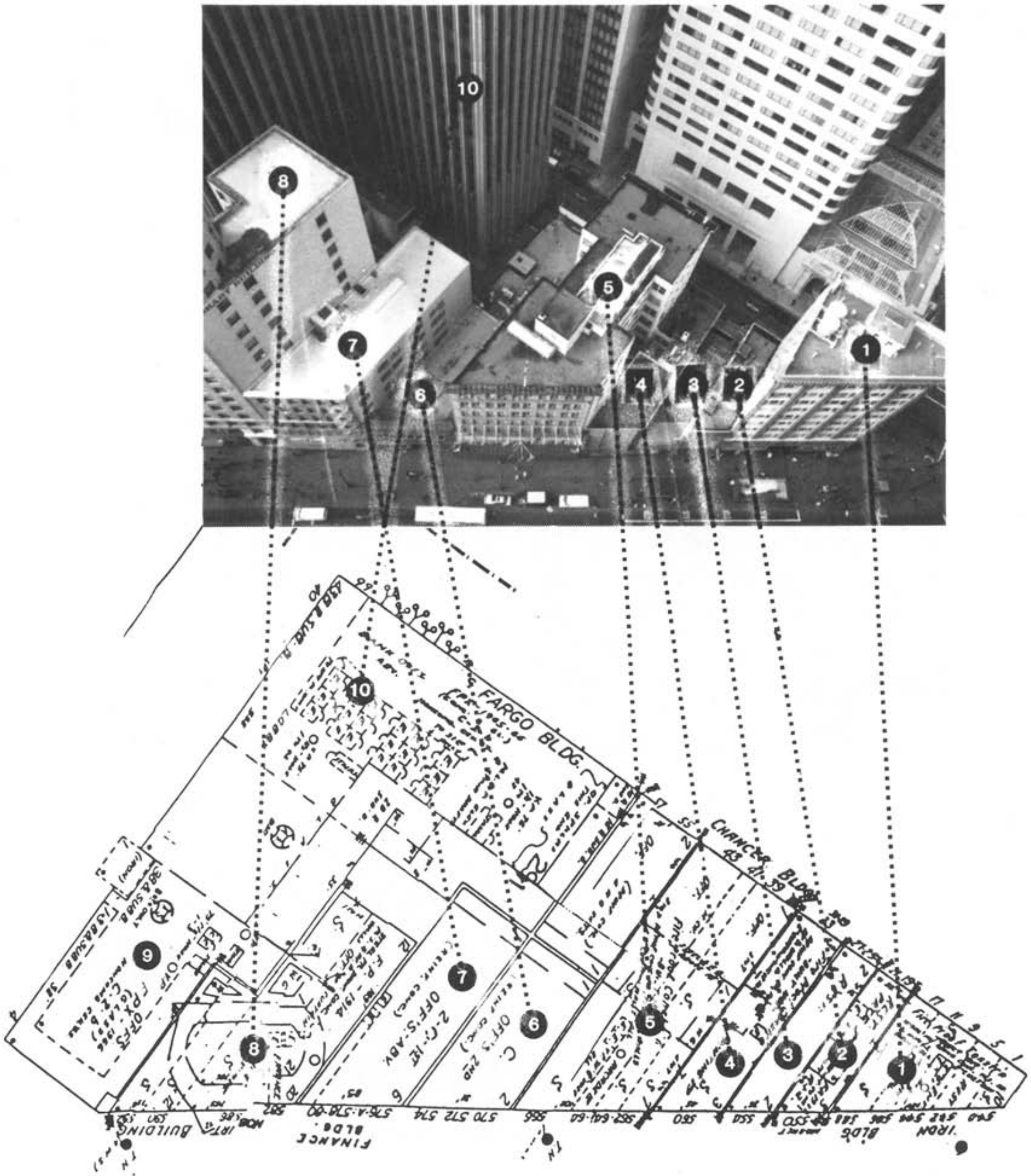


Figure 2-6 Key to Sanborn map symbols. Also, see the Internet, www.sanbornmap.com.

Parcel maps are also available and contain lot dimensions. If building size information cannot be obtained from another source such as the assessor's file, the parcel maps are particularly helpful for determining building dimensions in urban areas where buildings cover the entire lot. However, even if the building does not cover the entire lot, it will be easier to estimate building dimensions if the lot dimensions are known.

Figures 2-7 and 2-8 show a Sanborn map and photographs of a city block. Building descriptions obtained from the Sanborn maps are also included.



1. 10 story commercial office
2. 3 story commercial, built 1913
3. 2 story commercial
4. 3 story commercial, reinforced concrete frame, built 1906
5. 7 story commercial office, reinforced concrete frame, built 1923
6. 2 story commercial, reinforced concrete
7. 5 story commercial office, reinforced concrete
8. 20 story commercial office, steel frame with reinforced concrete, built 1914
9. 4 story commercial, built 1966
10. 40 story commercial office, built 1965-66, concrete and glass exterior

Figure 2-7 Sanborn map and corresponding aerial photograph of a city block.

Although the information on Sanborn maps may be useful, it is the responsibility of the screener to verify it in the field.

2.6.4 Municipal Databases

With the widespread use of the internet, many jurisdictions are creating "on-line" electronic databases for use by the general public. These databases provide general information on the various building sites within the jurisdiction. These databases are not detailed enough at this point in time to provide specific information about the buildings; they do, however, provide some good demographic information that could be of use. As the municipalities develop more comprehensive information, these databases will become more useful to the RVS screening. Figure 2-9 shows examples of the databases from two municipalities in the United States.

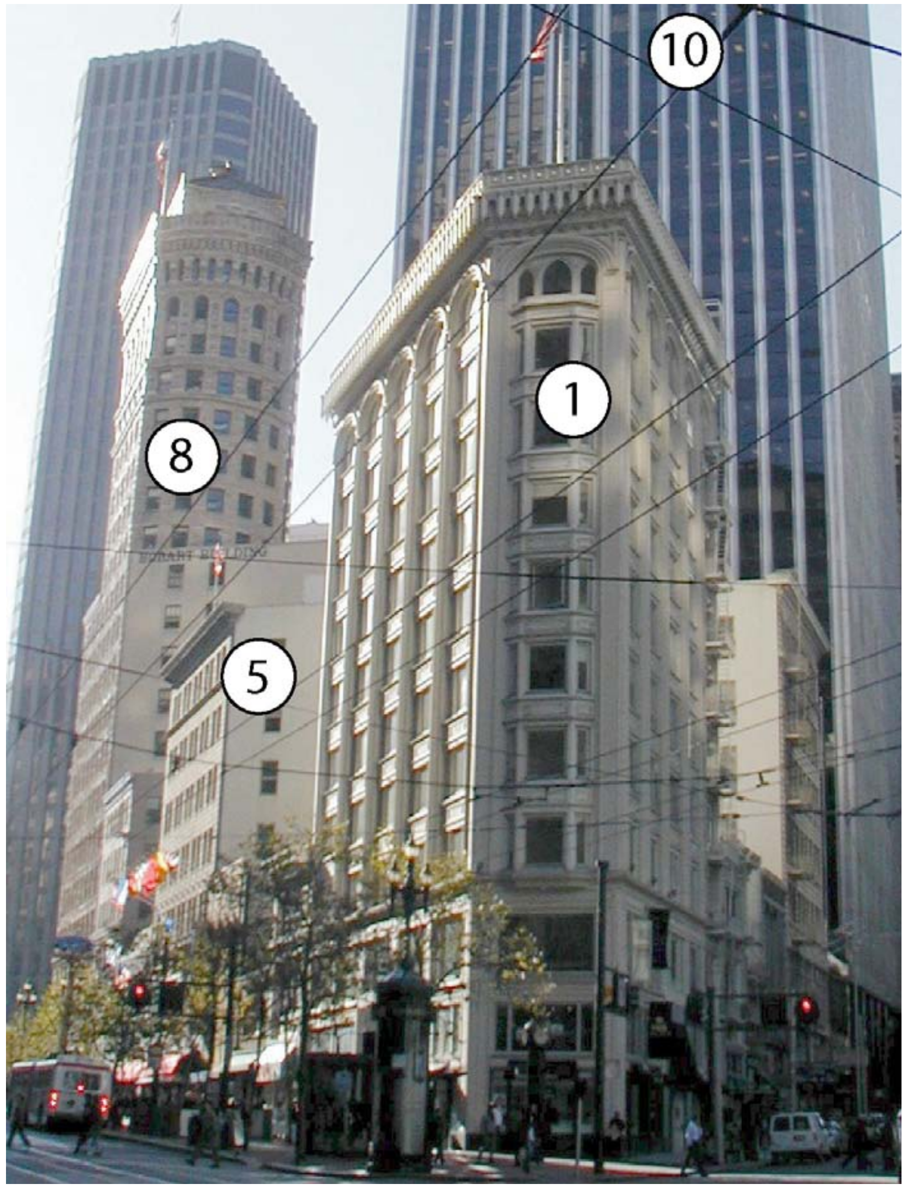


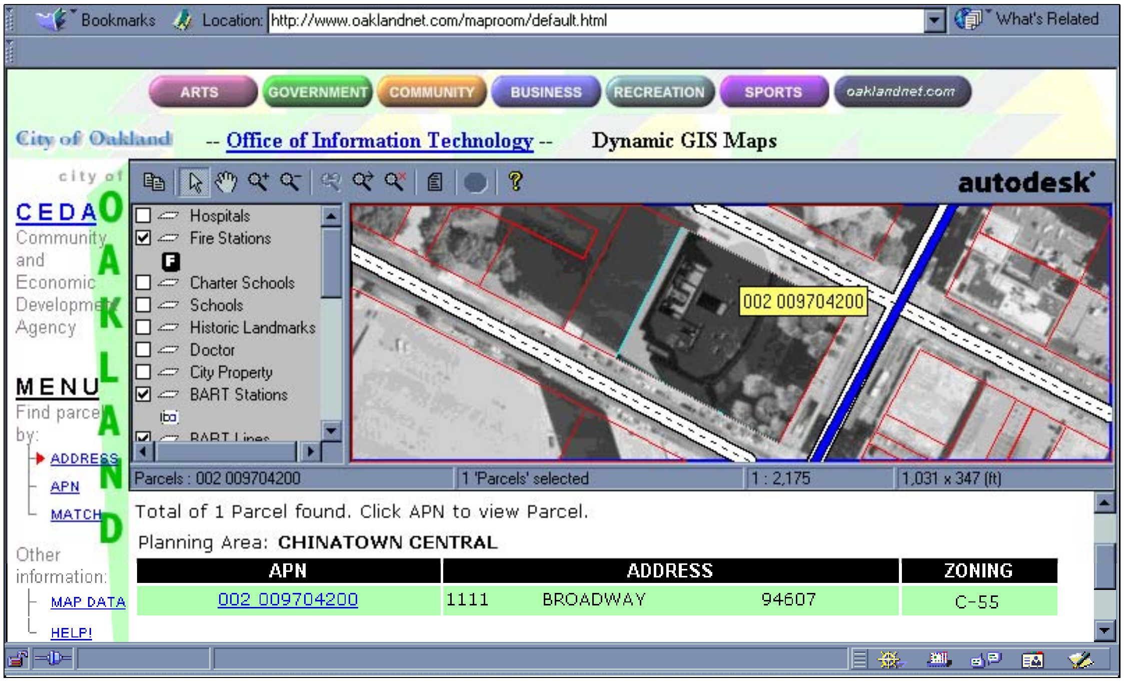
Figure 2-8 Photographs of elevation views of buildings shown in Figure 2-7.

2.6.5 Previous Studies

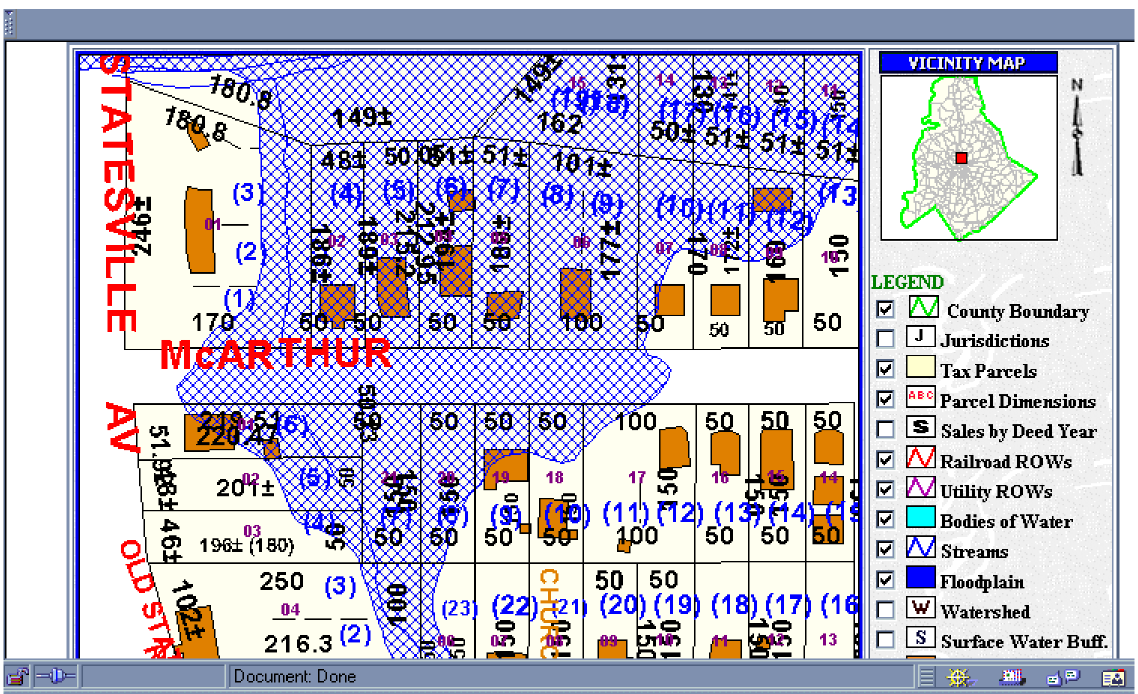
In a few cases, previous building inventories or studies of hazardous buildings or hazardous non-structural elements (e.g., parapets) may have been performed. These studies may be limited to a particular structural or occupancy class, but they may contain useful maps or other relevant structural information and should be reviewed. Other important studies might address related seismic hazard issues such as liquefaction or landslide potential. Local historical societies may have published books or reports about older buildings in the community. Fire departments are often aware of the overall condition and composition of building interiors.

2.6.6 Soils Information

Soil type has a major influence on amplitude and duration of shaking, and thus structural damage. Generally speaking, the deeper the soils at a site, the more damaging the earthquake motion will be. The six soil types considered in the RVS procedure are the same as those specified in the FEMA 302 report, *NEHRP Recommended Provisions for the Seismic Design of New Buildings and Other Structures* (BSSC, 1997): hard rock (type A); average rock (type B); dense soil (type C), stiff soil (type D); soft soil (type E), and poor soil (type F). Additional information on these soil types and how to identify



City of Oakland, California



Mecklenburg County, North Carolina

Figure 2-9 Examples of in-house screen displays of municipal databases.

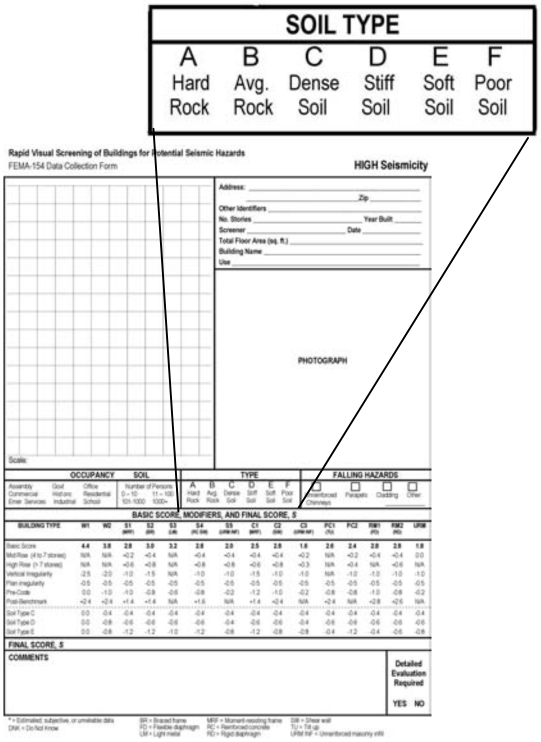


Figure 2-10 Location on Data Collection Form where soil type information is recorded.

them are provided in the side bar. Buildings on soil type F cannot be screened effectively by the RVS procedure, other than to recommend that buildings on this soil type be further evaluated by a geotechnical engineer and design professional experienced in seismic design.

Since soil conditions cannot be readily identified by visual methods in the field, geologic and geotechnical maps and other information should be collected during the planning stage and put into a readily usable map format for use during RVS. During the screening, or the planning stage, this soil type should also be documented on the Data Collection Form by circling the correct soil type, as designated by the letters A through F, (see Figure 2-10). If sufficient guidance or data are not available during the planning stage to classify the soil type as A through E, a soil type E should be assumed. However, for one-story or two-story buildings with a roof height equal to or less than 25 feet, a class D soil type may be assumed when site conditions are not known. (See the note in preceding paragraph regarding soil type F.)

2.7 Review of Construction Documents

Whenever possible, design and construction documents should be reviewed prior to the conduct of field work to help the screener identify the type of lateral-force- resisting system for each building. The review of construction documents to identify the building type substantially improves the confidence in this determination. As described in Section 3.7, the RVS procedure requires that each building be identified as one of 15 model building types[2]. Guidance for reviewing design and construction drawings is provided in Appendix C.

Soil Type Definitions and Related Parameters

The six soil types, with measurable parameters that define each type, are:

Type A (hard rock): measured shear wave velocity, v_s > 5000 ft/sec.

Type B (rock): v_s between 2500 and 5000 ft/sec.

Type C (soft rock and very dense soil): v_s between 1200 and 2500 ft/sec, or standard blow count N > 50, or undrained shear strength s_u > 2000 psf.

Type D (stiff soil): v_s between 600 and 1200 ft/sec, or standard blow count N between 15 and 50, or undrained shear strength, s_u between 1000 and 2000 psf.

Type E (soft soil): More than 100 feet of soft soil with plasticity index PI > 20, water content w > 40%, and s_u < 500 psf; or a soil with $v_s \le 600$ ft/sec.

Type F (poor soil): Soils requiring site-specific evaluations:

- Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly-sensitive clays, collapsible weakly-cemented soils.
- Peats or highly organic clays (H > 10 feet of peat or highly organic clay, where H = thickness of soil.).
- Very high plasticity clays (H > 25 feet with PI > 75).
- More than 120 ft of soft or medium stiff clays.

The parameters v_s, N, and s_u are, respectively, the average values (often shown with a bar above) of shear wave velocity, Standard Penetration Test (SPT) blow count and undrained shear strength of the upper 100 feet of soils at the site.

[2]The 15 model building types used in FEMA 154 are an abbreviated list of the 22 types now considered standard by FEMA; excluded from the FEMA 154 list are sub-classifications of certain framing types that specify that the roof and floor diaphragms are either rigid or flexible.

2.8 Field Screening of Buildings

RVS screening of buildings in the field should be carried out by teams consisting of two individuals. Teams of two are recommended to provide an opportunity to discuss issues requiring judgment and to facilitate the data collection process. If at all possible, one of the team members should be a design professional who can identify lateral-force-resisting systems.

Relatively few tools or equipment are needed. Table 2-4 contains a checklist of items that may be needed in performing an RVS as described in this *Handbook.*

2.9 Checking the Quality and Filing the Field Data in the Record-Keeping System

The last step in the implementation of rapid visual screening is checking the quality and filing the RVS data in the record-keeping system established for this purpose. If the data are to be stored in file folders or envelopes containing data for each building that was screened, or on microfilm, the process is straightforward, and requires careful organization. If the data are to be stored in digital form, it is important that the data input and verification process include either double entry of all data, or systematic in-depth review of print outs (item by item review) of all entered data.

It is also recommended that the quality review be performed under the oversight of a design professional with significant experience in seismic design.

Table 2-4 Checklist of Field Equipment Needed for Rapid Visual Screening

- ☐ Binoculars, if high-rise buildings are to be evaluated
- ☐ Camera, preferably instant or digital
- ☐ Clipboard for holding Data Collection Forms
- ☐ Copy of the FEMA 154 *Handbook*
- ☐ Laminated version of the Quick Reference Guide defining terms used on the Data Collection Form (see Appendix B)
- ☐ Pen or pencil
- ☐ Straight edge (optional for drawing sketches)
- ☐ Tape or stapler, for affixing photo if instant camera is used

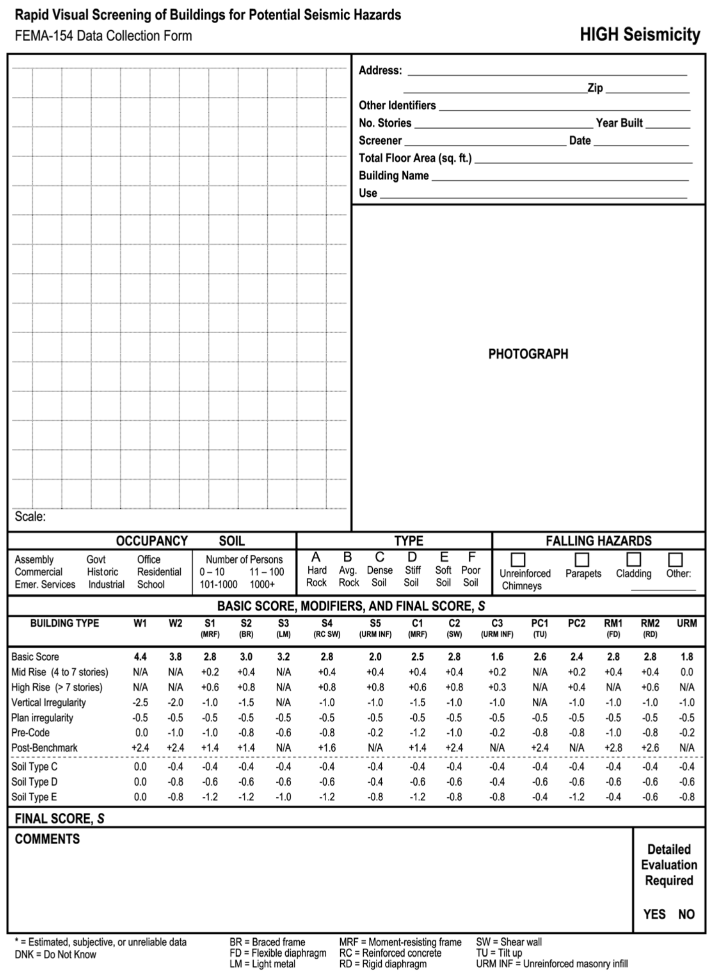
Chapter 3

Completing the Data Collection Form

3.1 Introduction

This chapter provides instructions on how to complete the Data Collection Form (Figure 3-1). It is assumed that the Data Collection Form has already been selected, based on the seismicity level of the area to be screened (as per Chapter 2). The Data Collection Form is completed for each building screened through execution of the following steps:

1. Verifying and updating the building identification information;
2. Walking around the building to identify its size and shape, and sketching a plan and elevation view on the Data Collection Form;
3. Determining and documenting occupancy;
4. Determining soil type, if not identified during the pre-planning process;
5. Identifying potential nonstructural falling hazards, if any, and indicating their existence on the Data Collection Form;
6. Identifying the seismic lateral-load resisting system (entering the building, if possible, to facilitate this process) and circling the related Basic Structural Hazard Score on the Data Collection Form;
7. Identifying and circling the appropriate seismic performance attribute Score Modifiers (e.g., number of stories, design date, and soil type) on the Data Collection Form;
8. Determining the Final Score, *S* (by adjusting the Basic Structural Hazard Score with the Score Modifiers identified in Step 7), and deciding if a detailed evaluation is required; and
9. Photographing the building and attaching the photo to the form (if an instant camera is used), or indicating a photo reference number on the form (if a digital camera is used).



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form **HIGH Seismicity**

Address: ______________________
______________________ **Zip** ________
Other Identifiers ______________________
No. Stories ______________ **Year Built** ________
Screener ______________ **Date** ________
Total Floor Area (sq. ft.) ______________________
Building Name ______________________
Use ______________________

Scale:

PHOTOGRAPH

OCCUPANCY			SOIL						TYPE		FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil		☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other: ____

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required
YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 3-1 Example RVS Data Collection Form (high seismicity).

Full-sized copies of the Data Collection Forms (one for each seismicity region) are provided in Appendix B, along with a Quick Reference Guide defining terms used on the Data Collection Form. The form has been designed to be filled out in a progressive manner, with a minimum of writing (most items simply can be circled).

Following are detailed instructions and guidance for each of the nine steps above.

3.2 Verifying and Updating the Building Identification Information

Space is provided in the upper right-hand portion of the Data Collection Form (see Figure 3-2) to document building identification information (i.e., address, name, number of stories, year built, and other data). As indicated in Chapter 2, it is desirable to develop and document this information during the pre-planning stage, if at all possible. This information may be entered manually, or be printed on a peel-off label.

Proper identification and location of the building is critically important for subsequent use in hazard assessment and mitigation by the RVS authority. As described in Chapter 2, the authority may prefer to identify and file structures by street address, parcel number, building owner, or some other scheme. However, it is recommended that as a minimum the street address and zip code be recorded on the form. Zip code is important because it is universal to all municipalities, is an especially useful item for later collation and summary analyses. Assessor parcel number or lot number is also useful for jurisdictional record-keeping purposes.

Assuming the identification information is provided on a peel-off label, which is then affixed to the form, or preprinted directly on the form, such information should be verified in the field. If the building identification data are not developed during the pre-planning stage, it must be completed in the field. Documentation of the building address information and name, if it exists, is straightforward. Following is guidance and discussion pertaining to number of stories, year built, identification of the screener, and estimation of total floor area.

3.2.1 Number of Stories

The height of a structure is sometimes related to the amount of damage it may sustain. On soft soils, a tall building may experience considerably stronger and longer duration shaking than a shorter building of the same type. The number of stories is a good indicator of the height of a building (approximately 9-to-10 feet per story for residential, 12 feet per story for commercial or office).

Counting the number of stories may not be a straightforward issue if the building is constructed on a hill or if it has several different roof levels. As a general rule, use the largest number (that is,

Address: ______________________________

______________________ Zip __________

Other Identifiers ______________________

No. Stories ____________________ Year Built ______

Screener ___________________ Date ___________

Total Floor Area (sq. ft.) ________________

Building Name _________________________

Use _________________________________

Figure 3-2 Portion of Data Collection Form for documenting building identification.

count floors from the downhill side to the roof). In addition, the number of stories may not be unique. A building may be stepped or have a tower. Use the comment section and the sketch to indicate variations in the number of stories.

3.2.2 Year Built

This information is one of the key elements of the RVS procedure. Building age is tied directly to design and construction practices. Therefore, age can be a factor in determining building type and thus can affect the final scores. This information is not typically available at the site and thus should be included in pre-field data collection.

There may be no single "year built." Certain portions of the structure may have been designed and constructed before others. If this should be the case, the construction dates for each portion can be indicated in the comment section or on the sketch (see Section 3.3). Caution should also be used when interpreting design practices from date of construction. The building may have been designed several years before it was constructed and thus designed to an earlier code with different requirements for seismic detailing.

If information on "year built" is not available during the RVS pre-field data acquisition stage (see Section 2.6), a rough estimate of age will be made on the basis of architectural style and building use. This is discussed in more detail in Appendix D, which provides additional guidance on determining building attributes from streetside. If the year built is only an approximation, an asterisk is used to indicate the entry is estimated.

3.2.3 Screener Identification

The screener should be identified, by name, initials, or some other type of code. At some later time it may be important to know who the screener was for a particular building, so this information should not be omitted.

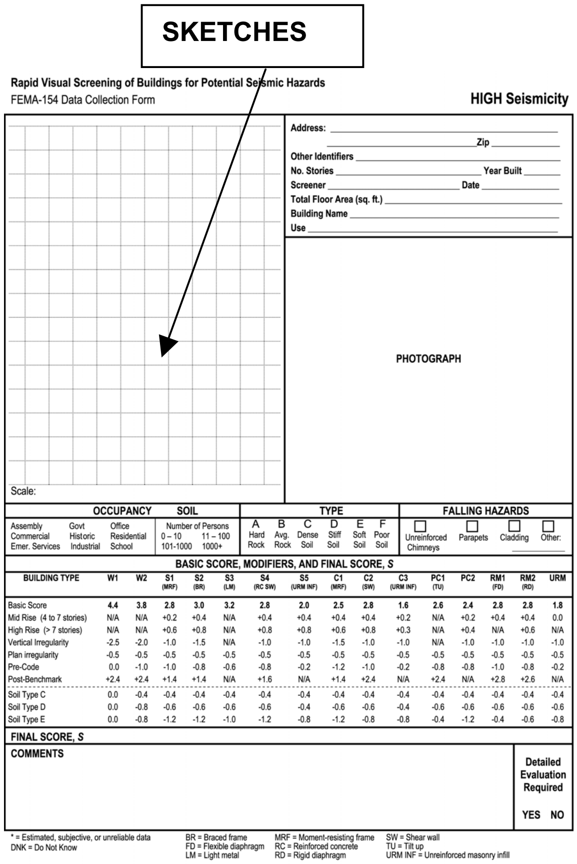


Figure 3-3 Sample Data Collection Form showing location for sketches of building plan and elevation views.

3.2.4 Total Floor Area

The total floor area, in some cases available from building department or assessor files (see Section 2.6), will most likely be estimated by multiplying the estimated area of one story by the total number of stories in the building. The length and width of the building can be paced off or estimated (during the planning stage) from Sanborn or other parcel maps. Total floor area is useful for estimating occupancy load (see Section 3.5.2) and may be useful at a later time for estimating the value of the building. Indicate with an asterisk when total floor area is estimated.

3.3 Sketching the Plan and Elevation Views

As a minimum, a sketch of the plan of the building should be drawn on the Data Collection Form (see Figure 3-3). An elevation may also be useful in indicating significant features. The sketches are especially important, as they reveal many of the building's attributes to the screener as the sketch is made. In other words, it forces the screener to systematically view all aspects of the building. The plan sketch should include the location of the building on the site and distance to adjacent buildings. One suggestion is to make the plan sketch from a Sanborn map as part of pre-field work (see Chapter 2), and then verify it in the field. This is especially valuable when access between buildings is not available. If all sides of the building are different, an elevation should be sketched for each side. Otherwise indicate that the sketch is typical of all sides. The sketch should note and emphasize special features such as existing significant cracks or configuration problems.

Dimensions should be included. As indicated in the previous section, the length and width of the building can be paced off or estimated (during the planning stage) from Sanborn or other parcel maps.

3.4 Determining Soil Type

As indicated in Section 2.6.6, soil type should be identified and documented on the Data Collection Form (see Figure 3-4) during the pre-field soils data acquisition and review phase. If soil type has not been determined as part of that process, it needs to be identified by the screener during the

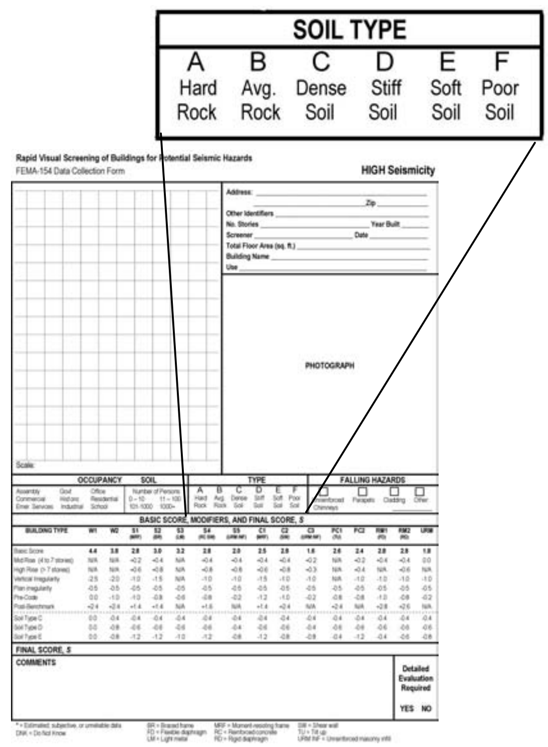


Figure 3-4 Location on Data Collection Form where soil type information is documented (circled).

building site visit. If there is no basis for classifying the soil type, a soil type E should be assumed. However, for one-story or two-story buildings with a roof height equal to or less than 25 feet, a class D soil type may be assumed when site conditions are not known.

3.5 Determining and Documenting Occupancy

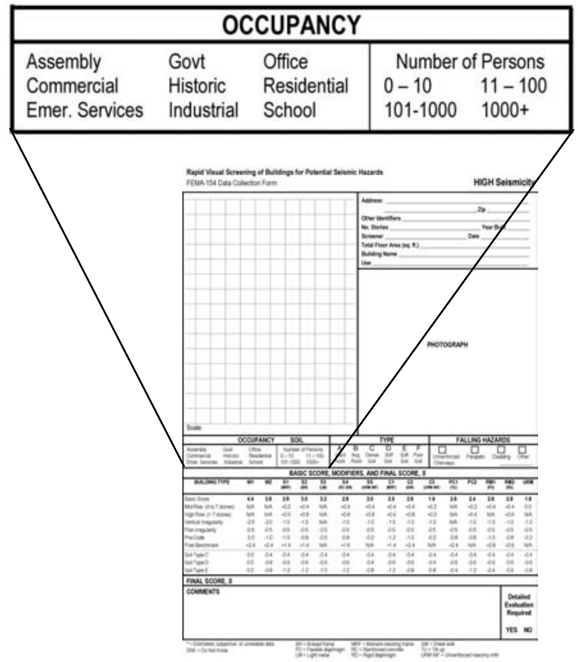
Two sets of information are needed relative to occupancy: (1) building use, and (2) estimated number of persons occupying the building.

3.5.1 Occupancy

Occupancy-related information is indicated by circling the appropriate information in the left-center portion of the form (see Figure 3-5). The occupancy of a building refers to its use, whereas the occupancy load is the number of people in the building (see Section 3.5.2). Although usually not bearing directly on the structural hazard or probability of sustaining major damage, the occupancy of a building is of interest and use when determining priorities for mitigation.

Nine general occupancy classes that are easy to recognize have been defined. They are listed on the form as Assembly, Commercial, Emergency Services (Emer. Services), Government (Govt), Historic, Industrial, Office, Residential, School buildings. These are the same classes used in the first edition of FEMA 154. They have been retained in this edition for consistency, they are easily identifiable from the street, they generally represent the broad spectrum of building uses in the United States, and they are similar to the occupancy categories in the *Uniform Building Code* (ICBO, 1997).

The occupancy class that best describes the building being evaluated should be circled on the form. If there are several types of uses in the building, such as commercial and residential, both should be circled. The actual use of the building may be written in the upper right hand portion of the form. For example, one might indicate that the building is a post office or a library on the line titled "use" in the upper right of the form (see Figure 3-2). In both of these cases, one would also circle "Govt". If none of the defined classes seem to fit the building, indicate the use in the upper right portion of the form (the building identification area) or include an explanation in the comments section. The nine occupancy classes are described below (with general indications of occupancy load):



- *Assembly.* Places of public assembly are those where 300 or more people might be gathered in one room at the same time. Examples are theaters, auditoriums, community centers, performance halls, and churches. (Occupancy load varies greatly and can be as much as 1 person per 10 sq. ft. of floor area, depending primarily on the condition of the seating—fixed versus moveable).
- *Commercial.* The commercial occupancy class refers to retail and wholesale businesses, financial institutions, restaurants, parking structures and light warehouses. (Occupancy load varies; use 1 person per 50 to 200 sq. ft.).
- *Emergency Services.* The emergency services class is defined as any facility that would likely be needed in a major catastrophe. These include police and fire stations, hospitals, and communications centers. (Occupancy load is typically 1 person per 100 sq. ft.).
- *Government.* This class includes local, state and federal non-emergency related buildings (Occupancy load varies; use 1 person per 100 to 200 sq. ft.).
- *Historic.* This class will vary from community to community. It is included because historic buildings may be subjected to specific ordinances and codes.

- *Industrial.* Included in the industrial occupancy class are factories, assembly plants, large warehouses and heavy manufacturing facilities. (Typically, use 1 person per 200 sq. ft. except warehouses, which are perhaps 1 person per 500 sq. ft.).
- *Office.* Typical office buildings house clerical and management occupancies (use 1 person per 100 to 200 sq. ft.).
- *Residential.* This occupancy class refers to residential buildings such as houses, townhouses, dormitories, motels, hotels, apartments and condominiums, and residences for the aged or disabled. (The number of persons for residential occupancies varies from about 1 person per 300 sq. ft. of floor area in dwellings, to perhaps 1 person per 200 sq. ft. in hotels and apartments, to 1 per 100 sq. ft. in dormitories).
- *School.* This occupancy class includes all public and private educational facilities from nursery school to university level. (Occupancy load varies; use 1 person per 50 to 100 sq. ft.).

When occupancy is used by a community as a basis for setting priorities for hazard mitigation purposes, the upgrade of emergency services buildings is often of highest priority. Some communities may have special design criteria governing buildings for emergency services. This information may be used to add a special Score Modifier to increase the score for specially designed emergency buildings.

3.5.2 Occupancy Load

Like the occupancy class or use of the building, the occupancy load may be used by an RVS authority in setting priorities for hazard mitigation plans. The community may wish to upgrade buildings with more occupants first. As can be seen from the form (Figure 3-5), the occupancy load is defined in ranges such as 1-10, 11-100, 101-1000, and 1000+ occupants. The range that best describes the average occupancy of the building is circled. For example, if an office building appears to have a daytime occupancy of 200 persons, and an occupancy of only one or two persons otherwise, the maximum occupancy load is 101-1000 persons. If the occupancy load is estimated from building size and use, an inserted asterisk will automatically indicate that these are approximate data.

3.6 Identifying Potential Nonstructural Falling Hazards

Nonstructural falling hazards such as chimneys, parapets, cornices, veneers, overhangs and heavy cladding can pose life-safety hazards if not adequately anchored to the building. Although these hazards may be present, the basic lateral-load system for the building may be adequate and require no further review. A series of four boxes have been included to indicate the presence of nonstructural falling hazards (see Figure 3-6). The falling hazards of major concern are:

- *Unreinforced Chimneys.* Unreinforced masonry chimneys are common in older masonry and wood-frame dwellings. They are often inadequately tied to the house and fall when strongly shaken. If in doubt as to whether a chimney is reinforced or unreinforced, assume it is unreinforced.
- *Parapets*. Unbraced parapets are difficult to identify from the street as it is sometimes difficult to tell if a facade projects above the roofline. Parapets often exist on three sides of the building, and their height may be visible from the back of the structure.
- *Heavy Cladding*. Large heavy cladding elements, usually precast concrete or cut

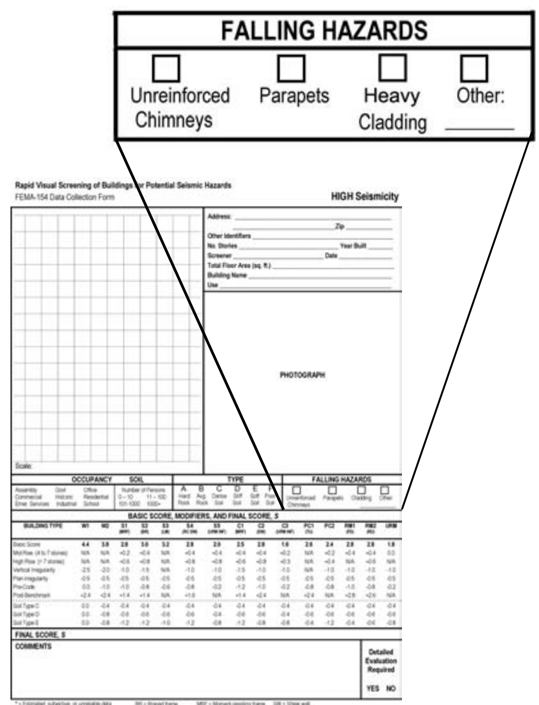


Figure 3-6 Portion of Data Collection Form for documenting nonstructural falling hazards.

stone, may fall off the building during an earthquake if improperly anchored. The loss of panels may also create major changes to the building stiffness (the elements are considered nonstructural but often contribute substantial stiffness to a building), thus setting up plan irregularities or torsion when only some fall. (Glass curtain walls are not considered as heavy cladding in the RVS procedure.) The existence of heavy cladding is of concern if the connections were designed and installed before the jurisdiction adopted seismic anchorage requirements (normally twice that for gravity loads). The date of such code adoption will vary with jurisdiction and should be established by an experienced design professional in the planning stages of the RVS process (see Section 2.4.2).

If any of the above nonstructural falling hazards exist, the appropriate box should be checked. If there are any other falling hazards, the "Other" box should be checked, and the type of hazard indicated on the line beneath this box. Use the comments section if additional space is required.

The RVS authority may later use this information as a basis for notifying the owner of potential problems.

3.7 Identifying the Lateral-Load-Resisting System and Documenting the Related Basic Structural Score

The RVS procedure is based on the premise that the screener will be able to determine the building's lateral-load-resisting system from the street, or to eliminate all those that it cannot possibly be. It is further assumed that the lateral-load-resisting system is one of fifteen types that have been observed to be prevalent, based on studies of building stock in the United States. The fifteen types are consistent with the model building types identified in the FEMA 310 Report and the predecessor documents that have addressed seismic evaluation of buildings (e.g., ATC, 1987; BSSC, 1992)). The fifteen model building types used in this document, however, are an abbreviated subset of the 22 types now considered standard by FEMA; excluded from the FEMA 154 list are sub-classifications of certain framing types that specify that the roof and floor diaphragms are either rigid or flexible.

3.7.1 Fifteen Building Types Considered by the RVS Procedure and Related Basic Structural Scores

Following are the fifteen building types used in the RVS procedure. Alpha-numeric reference codes used on the Data Collection Form are shown in parentheses.

1. Light wood-frame residential and commercial buildings smaller than or equal to 5,000 square feet (W1)
2. Light wood-frame buildings larger than 5,000 square feet (W2)
3. Steel moment-resisting frame buildings (S1)
4. Braced steel frame buildings (S2)
5. Light metal buildings (S3)
6. Steel frame buildings with cast-in-place concrete shear walls (S4)
7. Steel frame buildings with unreinforced masonry infill walls (S5)
8. Concrete moment-resisting frame buildings (C1)
9. Concrete shear-wall buildings (C2)
10. Concrete frame buildings with unreinforced masonry infill walls (C3)
11. Tilt-up buildings (PC1)
12. Precast concrete frame buildings (PC2)
13. Reinforced masonry buildings with flexible floor and roof diaphragms (RM1)
14. Reinforced masonry buildings with rigid floor and roof diaphragms (RM2)
15. Unreinforced masonry bearing-wall buildings (URM)

For each of these fifteen model building types, a Basic Structural Hazard Score has been computed that reflects the estimated likelihood that building collapse will occur if the building is subjected to the maximum considered earthquake ground motions for the region. The Basic Structural Hazard Scores are based on the damage and loss estimation functions provided in the FEMA-funded HAZUS damage and loss estimation methodology (NIBS, 1999). For more information about the development of the Basic Structural Hazard Scores, see the companion FEMA 155 report (ATC, 2002).

The Basic Structural Scores are provided on each Data Collection Form in the first row of the

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*															
BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8

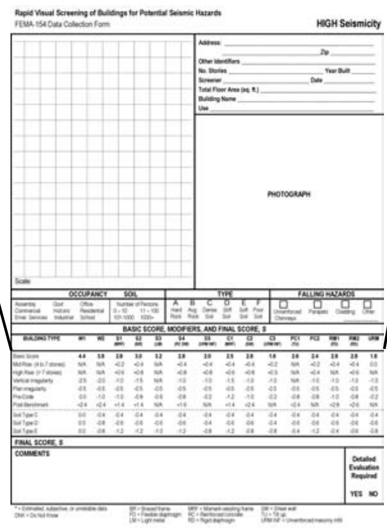


Figure 3-7. Portion of Data Collection Form containing Basic Structural Hazard Scores.

structural scoring matrix in the lower portion of the Data Collection Form (see Figure 3-7). In high and moderate seismicity regions, these scores apply to buildings built after the initial adoption and enforcement of seismic codes, but before the relatively recent significant improvement of codes (that is, before the applicable benchmark year, as defined in Table 2-2). In low seismicity regions, they apply to all buildings except those designed and constructed after the applicable benchmark year, as defined in Table 2-2.

A key issue to be addressed in the planning stage (as recommended in Section 2.4.2) is the identification of those years in which seismic codes were initially adopted and later significantly improved. If the RVS authority in high and moderate seismicity regions is unsure of the year(s) in which codes were initially adopted, the default year for all but PC1 (tiltup) buildings is 1941, (the default year specified in the HAZUS criteria, NIBS, 1999). For PC1 (tiltup) buildings, the initial year in which effective seismic codes were specified is 1973 (ICBO, 1973). As described in Sections 3.8.5 and 3.8.6, the Data Collection Form includes Score Modifiers that provide a means for modifying the Basic Structural Hazard Score as a function of design and construction date.

Brief summaries of the physical characteristics and expected earthquake performance of each of the fifteen model building types, along with a photograph of a sample exterior view, and the Basic Structural Scores for regions of low (L), moderate (M), and high (H) seismicity are provided in Table 3-1.

Additional background information on the physical characteristics and earthquake performance of these building types, not essential to the RVS procedure, is provided in Appendix E.

3.7.2 Identifying the Lateral-Force-Resisting System

At the heart of the RVS procedure is the task of identifying the lateral-force-resisting system from the street. Once the lateral-force-resisting system is identified, the screener finds the appropriate alpha-numeric code on the Data Collection Form and circles the Basic Structural Hazard Score immediately beneath it (see Figure 3-7).

Ideally, the lateral-force-resisting system for each building to be screened would be identified prior to field work through the review and interpretation of construction documents for each building (i.e., during the planning stage, as discussed in Section 2.7).

If prior determination of the lateral-force-resisting system is not possible through the review of building plans, which is the most likely scenario, this determination must be made in the field. In this case, the screener reviews spacing and size of windows, and the apparent construction materials to determine the lateral-force resisting system. If the screener cannot identify with complete assuredness the lateral-force-resisting system from the street, the screener should enter the building interior to verify the building type selected (see Section 3.7.3 for additional information on this issue.)

If the screener cannot determine the lateral-force-resisting system, and access to the interior is not possible, the screener should eliminate those lateral-force-resisting systems that are not possible and assume that any of the others are possible. In this case the Basic Structural Hazard Scores for all possible lateral-force-resisting systems would be circled on the Data Collection Form. More guidance and options pertaining to this issue are provided in Section 3.9.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
W1 Light wood frame residential and commercial buildings equal to or smaller than 5,000 square feet		H = 2.8 M = 5.2 L = 7.4	• Wood stud walls are typically constructed of 2-inch by 4-inch vertical wood members set about 16 inches apart (2-inch by 6-inch for multiple stories). • Most common exterior finish materials are wood siding, metal siding, or stucco. • Buildings of this type performed very well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low rise. • Earthquake-induced cracks in the plaster and stucco (if any) may appear, but are classified as non-structural damage. • The most common type of structural damage in older buildings results from a lack of connection between the superstructure and the foundation, and inadequate chimney support.
W2 Light wood frame buildings greater than 5,000 square feet		H = 3.8 M =4.8 L = 6.0	• These are large apartment buildings, commercial buildings or industrial structures usually of one to three stories, and, rarely, as tall as six stories.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

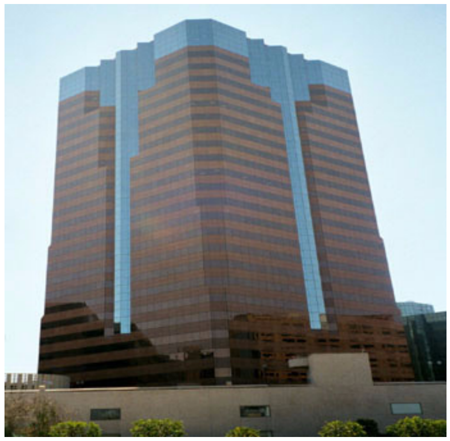
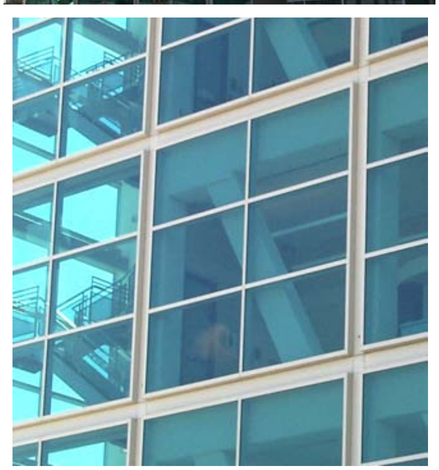
Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S1 Steel moment-resisting frame		H = 2.8 M = 3.6 L = 4.6	• Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal directions, around 20-30 ft. • The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional and public buildings. • The 1994 Northridge and 1995 Kobe earthquakes showed that the welds in steel moment- frame buildings were vulnerable to severe damage. The damage took the form of broken connections between the beams and columns.
S2 Braced steel frame	  Zoom-in of upper photo	H = 3.0 M = 3.6 L = 4.8	• These buildings are braced with diagonal members, which usually cannot be detected from the building exterior. • Braced frames are sometimes used for long and narrow buildings because of their stiffness. • From the building exterior, it is difficult to tell the difference between steel moment frames, steel braced frames, and steel frames with interior concrete shear walls. • In recent earthquakes, braced frames were found to have damage to brace connections, especially at the lower levels.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S3 Light metal building		H = 3.2 M = 3.8 L = 4.6	• The structural system usually consists of moment frames in the transverse direction and braced frames in the longitudinal direction, with corrugated sheet-metal siding. In some regions, light metal buildings may have partial-height masonry walls. • The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily. • Insufficient capacity of tension braces can lead to their elongation and consequent building damage during earthquakes. • Inadequate connection to a slab foundation can allow the building columns to slide on the slab. • Loss of the cladding can occur.
S4 Steel frames with cast-in-place concrete shear walls		H = 2.8 M = 3.6 L = 4.8	• Lateral loads are resisted by shear walls, which usually surround elevator cores and stairwells, and are covered by finish materials. • An interior investigation will permit a wall thickness check. More than six inches in thickness usually indicates a concrete wall. • Shear cracking and distress can occur around openings in concrete shear walls during earthquakes. • Wall construction joints can be weak planes, resulting in wall shear failure below expected capacity.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S5 Steel frames with unreinforced masonry infill walls		H = 2.0 M = 3.6 L = 5.0	• Steel columns are relatively thin and may be hidden in walls. • Usually masonry is exposed on exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • Infill walls are usually two to three wythes thick. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.
C1 Concrete moment-resisting frames		H = 2.5 M = 3.0 L = 4.4	• All exposed concrete frames are reinforced concrete (not steel frames encased in concrete). • A fundamental factor governing the performance of concrete moment-resisting frames is the level of ductile detailing. • Large spacing of ties in columns can lead to a lack of concrete confinement and shear failure. • Lack of continuous beam reinforcement can result in hinge formation during load reversal. • The relatively low stiffness of the frame can lead to substantial nonstructural damage. • Column damage due to pounding with adjacent buildings can occur.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

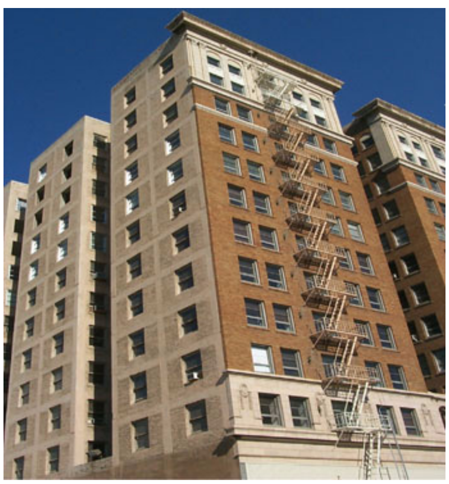
Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
C2 Concrete shear wall buildings		H = 2.8 M = 3.6 L = 4.8	• Concrete shear-wall buildings are usually cast in place, and show typical signs of cast-in-place concrete. • Shear-wall thickness ranges from 6 to 10 inches. • These buildings generally perform better than concrete frame buildings. • They are heavier than steel-frame buildings but more rigid due to the shear walls. • Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration.
C3 Concrete frames with unreinforced masonry infill walls		H =1.6 M = 3.2 L = 4.4	• Concrete columns and beams may be full wall thickness and may be exposed for viewing on the sides and rear of the building. • Usually masonry is exposed on the exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • This type of construction was generally built before 1940 in high-seismicity regions but continues to be built in other regions. • Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral out-of-plane forces. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
PC1 Tilt-up buildings	  Partial roof collapse due to failed diaphragm-to-wall connection	H = 2.6 M = 3.2 L = 4.4	• Tilt-ups are typically one or two stories high and are basically rectangular in plan. • Exterior walls were traditionally formed and cast on the ground adjacent to their final position, and then "tilted-up" and attached to the floor slab. • The roof can be a plywood diaphragm carried on wood purlins and glulam beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. • Weak diaphragm-to-wall anchorage results in the wall panels falling and the collapse of the supported diaphragm (or roof).

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
PC2 Precast concrete frame buildings	 Building under construction  Detail of the precast components  Building nearing completion	H = 2.4 M = 3.2 L = 4.6	• Precast concrete frames are, in essence, post and beam construction in concrete. • Structures often employ concrete or reinforced masonry (brick or block) shear walls. • The performance varies widely and is sometimes poor. • They experience the same types of damage as shear wall buildings (C2). • Poorly designed connections between prefabricated elements can fail. • Loss of vertical support can occur due to inadequate bearing area and insufficient connection between floor elements and columns. • Corrosion of metal connectors between prefabricated elements can occur.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM1 Reinforced masonry buildings with flexible diaphragms	  Truss-joists support plywood and light-weight concrete slab  Detail showing reinforced masonry	H = 2.8 M = 3.6 L = 4.8	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM2 Reinforced masonry buildings with rigid diaphrams		H = 2.8 M = 3.4 L = 4.6	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.
URM Unreinforced masonry buildings		H = 1.8 M = 3.4 L = 4.6	• These buildings often used weak lime mortar to bond the masonry units together. • Arches are often an architectural characteristic of older brick bearing wall buildings. • Other methods of spanning are also used, including steel and stone lintels. • Unreinforced masonry usually shows header bricks in the wall surface. • The performance of this type of construction is poor due to lack of anchorage of walls to floors and roof, soft mortar, and narrow piers between window openings.

Determining the lateral-force-resisting system in the field is often difficult. A useful first step is to determine if the building structure is a frame or a bearing wall. Examples of frame structures and bearing wall structures are shown in Figure 3-8, 3-9, and 3-10.

Information to assist the screener in distinguishing if the building is a bearing wall or frame structure is provided in the side bar. Once this determination has been made and the

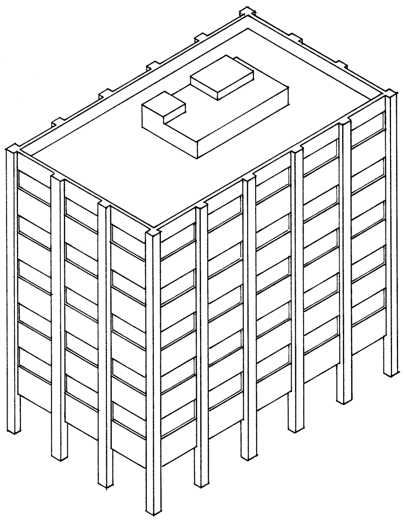


Figure 3-8 Typical frame structure. Features include: large window spans, window openings on many sides, and clearly visible column-beam grid pattern.

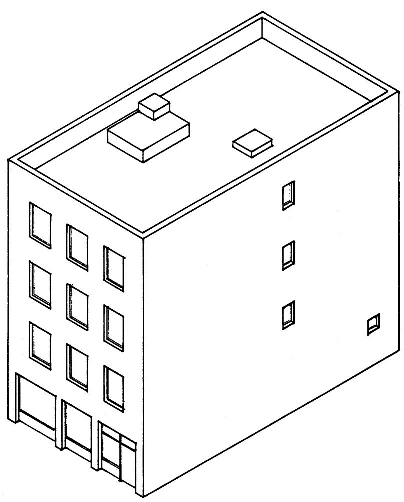


Figure 3-9 Typical bearing wall structure. Features include small window span, at least two mostly solid walls, and thick load-bearing walls.

Distinguishing Between Frame and Bearing Wall Building Systems.

A frame structure (for example, S1, S2, S3, S4, C1, PC2) is made up of beams and columns throughout the entire structure, resisting both vertical and lateral loads. A bearing wall structure (for example, PC1 and URM) uses vertical-load-bearing walls, which are more or less solid, to resist the vertical and lateral loads.

When a building has large openings on all sides, it is probably a frame structure as opposed to a bearing wall structure. A common characteristic of a frame structure is the rectangular grid patterns of the facade, indicating the location of the columns and girders behind the finish material. This is particularly revealing when windows occupy the entire opening in the frame, and no infill wall is used. A newer multistory commercial building should be assumed to be a frame structure, even though there may exist interior shear walls carrying the lateral loads (this would be a frame structure with shear walls).

Bearing wall systems carry vertical and lateral loads with walls rather than solely with columns. Structural floor members such as slabs, joists, and beams, are supported by load-bearing walls. A bearing wall system is thus characterized by more or less solid walls and, as a rule of thumb, a load-bearing wall will have more solid areas than openings. It also will have no wide openings, unless a structural lintel is used.

Some bearing-wall structures incorporate structural columns, or are partly frame structures. This is especially popular in multistory commercial buildings in urban lots where girders and columns are used in the ground floor of a bearing wall structure to provide larger openings for retail spaces. Another example is where the loads are carried by both interior columns and a perimeter wall. Both of these examples should be considered as bearing wall structures, because lateral loads are resisted by the bearing walls. Bearing wall structures sometimes utilize only two walls for load bearing. The other walls are non-load-bearing and thus may have large openings. Therefore, the openness of the front elevation should not be used to determine the structure type. The screener should also look at the side and rear facades. If at least two of the four exterior walls appear to be solid then it is likely that it is a bearing wall structure.

Window openings in older frame structures can sometimes be misleading. Since wide windows were excessively costly and fragile until relatively recently, several narrow windows separated by thin mullions are often seen in older buildings. These thin mullions are usually not load bearing. When the narrow windows are close together, they constitute a large opening typical of a frame structure, or a window in a bearing wall structure with steel lintels.

Whereas open facades on all sides clearly indicate a frame structure, solid walls may be indicative of a bearing wall structure or a frame structure with solid infill walls. Bearing walls are usually much thicker than infill walls, and increase in thickness in the lower stories of multi-story buildings. This increase in wall thickness can be detected by comparing the wall thickness at windows on different floors. Thus, solid walls can be identified as bearing or non-bearing walls according to their thickness, if the structural material is known.

A bearing wall system is sometimes called a box system.

Example of a Frame Building

Example of a Bearing Wall Structure

Figure 3-10 Frame and bearing wall structures

principal structural material is identified, the essential information for determining the lateral-force-resisting system has been established. It is then useful to know that:

- unreinforced masonry and tilt-up buildings are usually bearing-wall type,
- steel buildings and pre-cast concrete buildings are usually frame type, and
- concrete and reinforced masonry buildings may be either type.

A careful review of Table 3-1 and the information provided in Appendices D and E, along with training by knowledgeable building design professionals, should assist the screener in the determination of lateral-force-resisting systems. There will be some buildings for which the lateral-force-resisting system cannot be identified because of their facade treatment. In this case, the screener should eliminate those lateral-force-resisting systems that are not possible and assume that any of the others are possible.

3.7.3 Interior Inspections

Ideally, whenever possible, the screener should seek access to the interior of the building to identify, or verify, the lateral-force-resisting system for the building. In the case of reinforced masonry buildings, entry is particularly important so that the screener can distinguish between RM1 buildings, which have flexible floor and roof diaphragms, and RM2 buildings, which have rigid floor and roof diaphragms.

As with the exterior inspection, the interior process should be performed in a logical manner, either from the basement to the roof, or roof to basement. The screener should look at each floor thoroughly.

The RVS procedure does not require the removal of finish materials that are otherwise permanently affixed to the structure. There are a number of places within a building where it is possible to see the exposed structure. The following are some ways to determine the structure type.

1. If the building has a basement that is not occupied, the first-floor framing may be exposed. The framing will usually be representative of the floor framing throughout the building.
2. If the structural system is a steel or concrete frame, the columns and beams will often be exposed in the basement. The basement walls will likely be concrete, but this does not mean that they are concrete all the way to the roof.
3. High and mid-rise structures usually have one or more levels of parking below the building. When fireproofed steel columns and girders are seen, the screener can be fairly certain that the structure is a steel building (S1, S2, or S4 see Figure 3-11).
4. If the columns and beams are constructed of concrete, the structure type is most likely a concrete moment-frame building (C1, see Figure 3-12). However, this is not guaranteed as some buildings will use steel framing above the ground floor. To ascertain the building type, the screener will need to look at the columns above the first floor.
5. If there is no basement, the mechanical equipment rooms may show what the framing is for the floor above.

Figure 3-11 Interior view showing fire-proofed columns and beams, which indicate a steel building (S1, S2, or S4).

6. If suspended ceilings are used, one of the ceiling tiles can be lifted and simply pushed back. In many cases, the floor framing will then be exposed. Caution should be used in identifying the framing materials, because prior to about 1960, steel beams were encased in concrete to provide fireproofing. If steel framing is seen with what appears to be concrete beams, most likely these are steel beams encased in concrete.
7. If plastered ceilings are observed above suspended ceilings, the screener will not be able to identify the framing materials; however, post-1960 buildings can be eliminated as a possibility because these buildings do not use plaster for ceilings.
8. At the exterior walls, if the structural system is a frame system, there will be regularly spaced furred out places. These are the building columns. If the exterior walls between the columns are constructed of brick masonry and the thickness of the wall is 9 inches or more, the structure type is either steel frame with unreinforced masonry infill (S5) or concrete frame with unreinforced masonry infill (C3).
9. Pre-1930 brick masonry buildings that are six stories or less in height and that have wood-floor framing supported on masonry ledges in pockets formed in the wall are unreinforced masonry bearing-wall buildings (URM).

3.7.4 Screening Buildings with More Than One Lateral-Force-Resisting System

In some cases, the screener may observe buildings having more than one lateral-force-resisting system. Examples might include a wood-frame building atop a precast concrete parking garage, or a building with reinforced concrete shear walls in one direction and a reinforced moment-resisting frame in the other.

Buildings that incorporate more than one lateral-force-resisting system should be evaluated for all observed types of structural systems, and the lowest Final Structural Score, *S*, should govern.

Figure 3-12 Interior view showing concrete columns and girders, which indicate a concrete moment frame (C1).

Score Modifier

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*															
BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

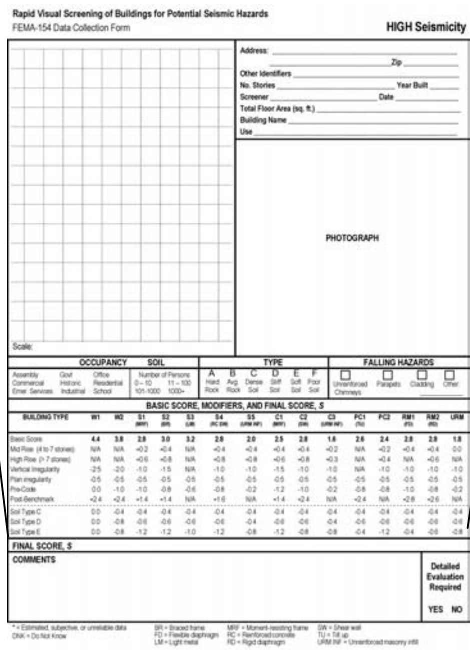


Figure 3-13. Portion of Data Collection Form containing attributes that modify performance and associated score modifiers.

3.8 Identifying Seismic Performance Attributes and Recording Score Modifiers

This section discusses major factors that significantly impact structural performance during earthquakes, and the assignment of Score Modifiers related to each of these factors (attributes). The severity of the impact on structural performance varies with the type of lateral-force-resisting system; thus the assigned Score Modifiers depend on building type. Score Modifiers associated with each performance attribute are indicated in the scoring matrix on the Data Collection Form (see Figure 3-13). Score Modifiers for the building being screened are circled in the appropriate column (i.e., under the reference code for the identified lateral-force-resisting system for that building).

Following are descriptions of each performance attribute, along with guidance on how to recognize each from the street. If a performance attribute does not apply to a given building type, the Score Modifier is indicated with "N/A", which indicates "not applicable."

3.8.1 *Mid-Rise Buildings*

If the building has 4 to 7 stories, it is considered a mid-rise building, and the score modifier associated with this attribute should be circled.

3.8.2 *High-Rise Buildings*

If the building has 8 or more stories, it is considered a high-rise building, and the score modifier associated with this attribute should be circled.

3.8.3 *Vertical Irregularity*

This performance attribute applies to all building types. Examples of vertical irregularity include buildings with setbacks, hillside buildings, and buildings with soft stories (see illustrations of example vertical irregularities in Figure 3-14).

If the building is irregularly shaped in elevation, or if some walls are not vertical, then apply the modifier (see example in Figure 3-15).

If the building is on a steep hill so that over the up-slope dimension of the building the hill rises at least one story height, a problem may exist because the horizontal stiffness along the lower side may be different from the uphill side. In addition, in the up-slope direction, the stiff short columns attract the seismic shear forces and may fail. In this case the performance modifier is applicable. See Figure 3-14 for an example.

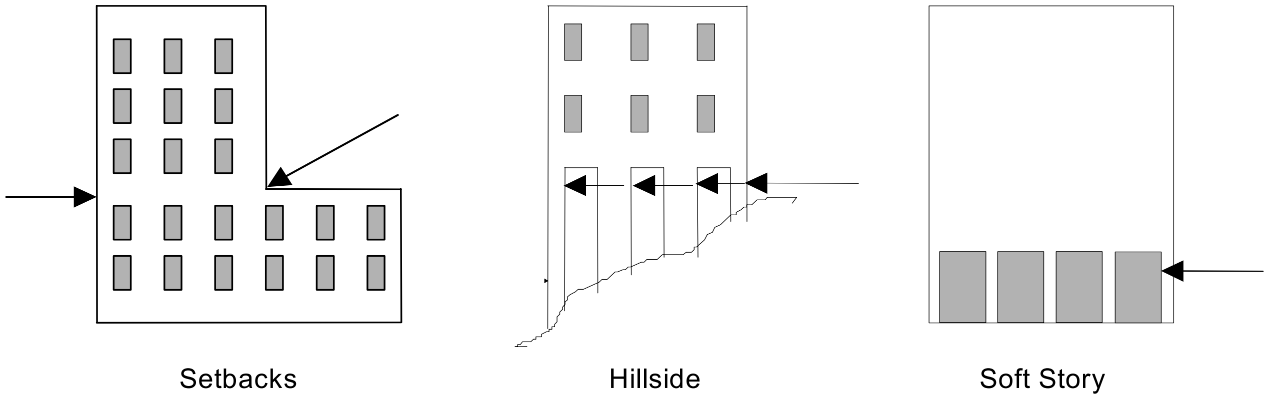


Figure 3-14 Elevation views showing vertical irregularities, with arrows indicating locations of particular concern.

A soft story exists if the stiffness of one story is dramatically less than that of most of the others (see Figure 3-15). Examples are shear walls or infill walls not continuous to the foundation. Soft stories are difficult to verify without knowledge of how the building was designed and how the lateral forces are to be transferred from story to story. In other words, there may be shear walls in the building that are not visible from the street. However, if there is doubt, it is best to be conservative and indicate the existence of a soft story by circling the vertical irregularity Score Modifier. Use an asterisk and the comment section to explain the source of uncertainty. In many commercial buildings, the first story is soft due to large window openings for display purposes. If one story is particularly tall or has windows on all sides, and if the stories above have fewer windows, then it is probably a soft story.

A building may be adequate in one direction but be "soft" in the perpendicular direction. For example, the front and back walls may be open but the side walls may be solid. Another common example of soft story is "tuck under" parking commonly found in apartment buildings (see Figure 3-16). Several past earthquakes in California have shown the vulnerability of this type of construction.

Vertical irregularity is a difficult characteristic to define, and considerable judgment and experience are required for identification purposes.

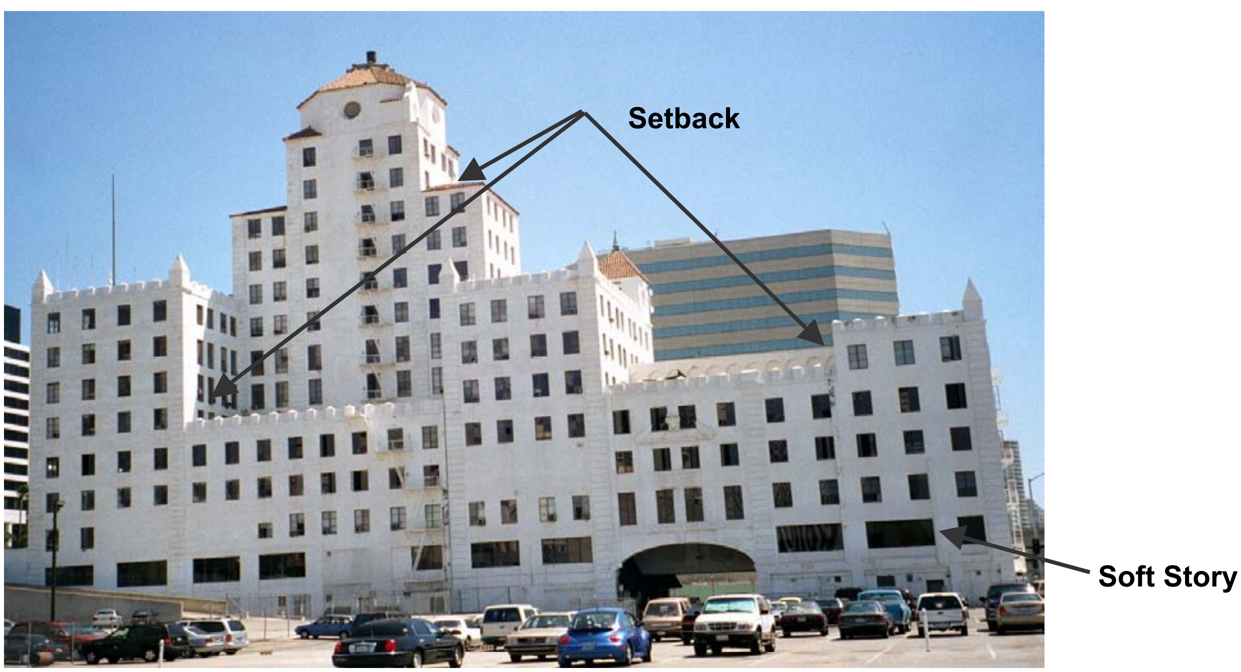


Figure 3-15 Example of setbacks (see Figure 3-14) and a soft first story.

Figure 3-16 Example of soft story conditions, where parking requirements result in large weak openings.

3.8.4 Plan Irregularity

If a building has a vertical or plan irregularity, as described below, this modifier applies. Plan irregularity can affect all building types. Examples of plan irregularity include buildings with re-entrant corners, where damage is likely to occur; buildings with good lateral-load resistance in one direction but not in the other; and buildings with major stiffness eccentricities in the lateral-force-resisting system, which may cause twisting (torsion) around a vertical axis.

Buildings with re-entrant corners include those with long wings that are E, L, T, U, or + shaped (see Figures 3-17 and 3-18). See SEAOC (1996) for further discussion of this issue.)

Plan irregularities causing torsion are especially prevalent among corner buildings, in which the two adjacent street sides of the building are largely windowed and open, whereas the other two sides are generally solid. Wedge-shaped buildings, triangular in plan, on corners of streets not meeting at 90°, are similarly susceptible (see Figure 3-19).

Although plan irregularity can occur in all building types, primary concern lies with wood, tilt-up, pre-cast frame, reinforced masonry and unreinforced masonry construction. Damage at connections may significantly reduce the capacity of a vertical-load-carrying element, leading to partial or total collapse.

3.8.5 Pre-Code

This Score Modifier applies for buildings in high and moderate seismicity regions and is applicable if the building being screened was designed and constructed prior to the initial adoption and enforcement of seismic codes applicable for that building type (e.g., steel moment frame, S1). The year(s) in which seismic codes were initially adopted and enforced for the various model building types should have been identified as part

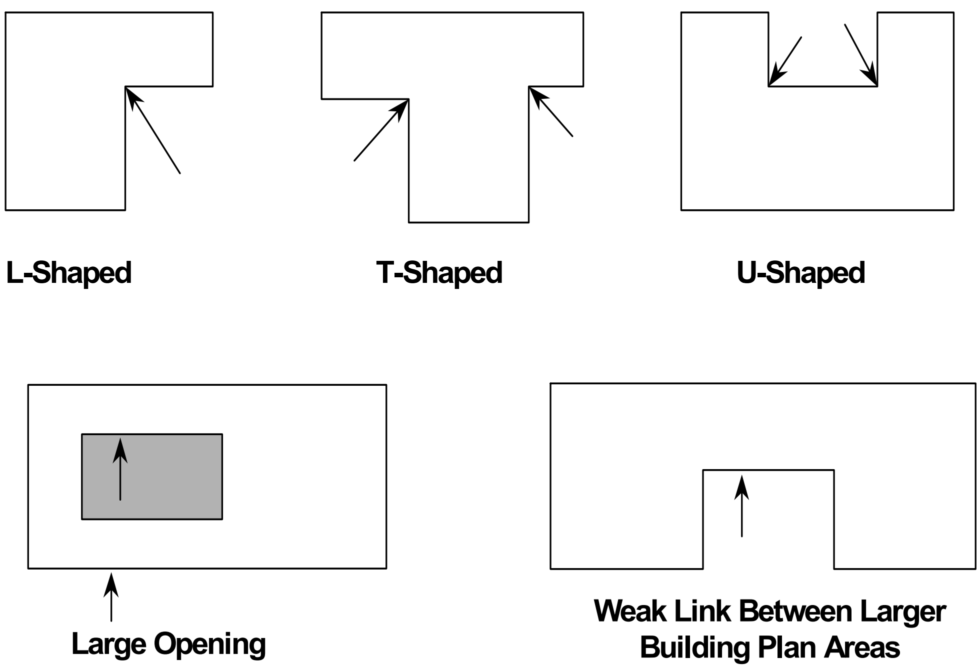


Figure 3-17 Plan views of various building configurations showing plan irregularities; arrows indicate possible areas of damage.

Figure 3-18 Example of a building, with a plan irregularity, with two wings meeting at right angles.

of the Data Collection Form review process during the pre-planning stage (as recommended in Section 2.4.2). If this determination was not made during the planning stage, the default year is 1941, for all building types except PC1, in which case it is 1973. Because of the method used to calculate the Basic Structural Hazard Scores, this modifier does not apply to buildings in the low seismicity region.

3.8.6 *Post-Benchmark*

This Score Modifier is applicable if the building being screened was designed and constructed after significantly improved seismic codes applicable for that building type (e.g., concrete moment frame, C1) were adopted and enforced by the local jurisdiction. The year in which such improvements were adopted is termed the "benchmark" year. Benchmark year(s) for the various model building types should have been identified as part of the Data Collection Form review process during the pre-planning stage (as recommended in Section 2.4.2). Benchmark years for the various building types (designed in accordance with various model codes) are provided in Table 2-2.

3.8.7 *Soil Type C, D, or E*

Score Modifiers are provided for Soil Type C, Type D, and Type E. The appropriate modifier should be circled if one of these soil types exists at the site (see Section 3.4 for additional discussion regarding the determination of soil type). If sufficient guidance or data are not available during the planning stage to classify the soil type as A

Figure 3-19 Example of a building, triangular in plan, subject to torsion.

through E, a soil type E should be assumed. However, for one- or two-story buildings with a roof height equal to or less than 25 feet, a class D soil type may be assumed if the actual site conditions are not known.

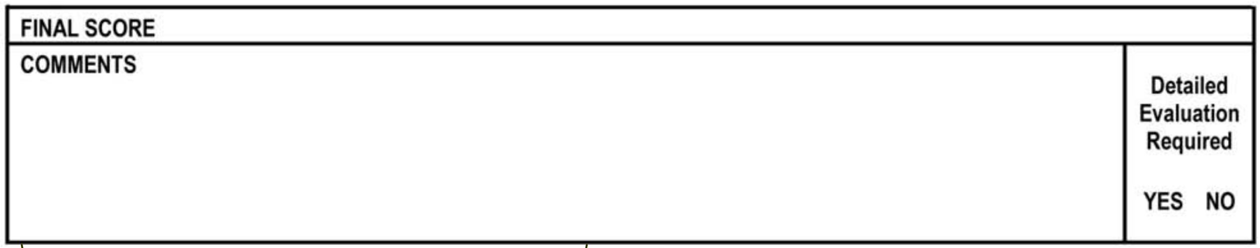
There is no Score Modifier for Type F soil because buildings on soil type F cannot be screened effectively by the RVS procedure. A geotechnical engineer is required to confirm the soil type F and an experienced professional engineer is required for building evaluation.

3.9 Determining the Final Score

The Final Structural Score, *S*, is determined for a given building by adding (or subtracting) the Score Modifiers for that building to the Basic Structural Hazard Score for the building. The result is documented in the section of the form entitled Final Score (see Figure 3-20). Based on this information, and the "cut-off" score selected during the pre-planning process (see Section 2.4.3), the screener then decides if a detailed evaluation is required for the building and circles "YES" or "NO" in the lower right-hand box (see Figure 3-20). Additional guidance on this issue is provided in Sections 4.1, and 4.2.

When the screener is uncertain of the building type, an attempt should be made to eliminate all unlikely building types. If the screener is still left with several choices, computation of the Final Structural Score *S* may be treated several ways:

1. The screener may calculate *S* for all the remaining options and choose the lowest



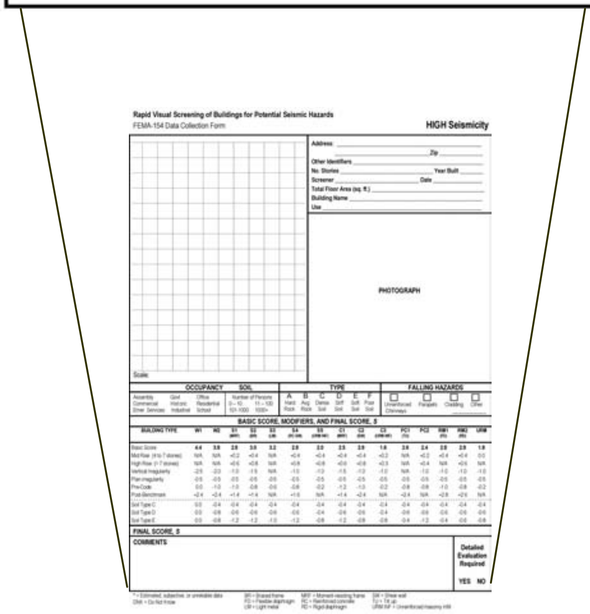


Figure 3-20 Location on Data Collection Form where the final score, comments, and an indication if the building needs detailed evaluation are documented.

score. This is a conservative approach, and has the disadvantage that it may be too conservative and the assigned score may indicate that the building presents a greater risk than it actually does. This conservative approach will not pose problems in cases where all the possible remaining building types result in scores below the cut-off value. In all these cases the building has characteristics that justify further review anyway by a design professional experienced in seismic design.

2. If the screener has little or no confidence about any choice for the structural system, the screener should write DNK below the word "Building Type" (see Figure 3-7), which indicates the screener does not know. In this case there should be an automatic default to the need for a detailed review of the building by an experienced design professional. A more detailed field inspection would include entering the building, and examining the basement, roof, and all structural elements.

Which of these two options the RVS authority wishes to adopt should be decided in the RVS planning phase (see Section 2.3).

3.10 Photographing the Building

At least one photograph of the building should be taken for identification purposes. The screener is not limited to one photograph. A photograph contains much more information, although perhaps less emphasized, than the elevation sketch. Large buildings are difficult to photograph from the street and the camera lens introduces distortion for high-rise buildings. If possible, the photograph should be taken from a sufficient distance to include the whole building, and such that adjacent faces are included. A wide angle or a zoom lens may be helpful. Strong sunlit facades should be avoided, as harsh contrasts between shadows and sunlit portions of the facade will be introduced. Lastly, if possible, the front of the building should not be obscured by trees, vehicles or other objects, as they obscure the lower (and often the most important) stories.

3.11 Comments Section

This last section of the form (see Figure 3-20) is for recording any comments the screener may wish to make regarding the building, occupancy, condition, quality of the data or unusual circumstances of any type. For example, if not all significant details can be effectively photographed or drawn, the screener could describe additional important information in the comments area. Comments may be made on the strength of mortar used in a masonry wall, or building features that can be seen at or through window openings. Other examples where comments are helpful are described throughout Chapter 3.

Chapter 4
Using the RVS Procedure Results

The rapid visual screening procedure presented in this *Handbook* is meant to be the preliminary screening phase of a multi-phase procedure for identifying earthquake-hazardous buildings. Buildings identified by this procedure as potentially hazardous must be analyzed in more detail by an experienced seismic design professional. Because rapid visual screening is designed to be performed from the street, with interior inspection not always possible, hazardous details will not always be visible, and seismically hazardous buildings may not be identified as such. Conversely, buildings identified as potentially hazardous may prove to be adequate.

Since the original publication of FEMA 154 in 1988, the RVS procedure has been widely used by local communities and government agencies. A critical issue in the implementation of FEMA 154 has been the interpretation of the Final Structural Score, *S*, and the selection of a "cut-off" score, below which a detailed seismic evaluation of the building by a design professional in seismic design is required.

Following are discussions on: (1) interpretation and selection of the "cut-off" score; (2) prior uses of the FEMA 154 RVS procedure, including decisions regarding the "cut-off" score; and (3) other possible uses of the FEMA 154 RVS procedure, including resources needed for the various possible uses. These discussions are intended to illuminate both the limitations and potential applications of the RVS procedure.

4.1 Interpretation of RVS Score

Having employed the RVS procedure and determined the building's Final Structural Score, *S*, which is based on the Basic Structural Hazard Score and Score Modifiers associated with the various performance attributes, the RVS authority is naturally faced with the question of what these *S* scores mean. Fundamentally, the final *S* score is an estimate of the probability (or chance) that the building will collapse if ground motions occur that equal or exceed the maximum considered earthquake (MCE) ground motions (the current FEMA 310 ground motion specification for detailed seismic evaluation of buildings). These estimates of the score are based on limited observed and analytical data, and the probability of collapse is therefore approximate. For example, a final score of $S = 3$ implies there is a chance of 1 in 10^3, or 1 in 1000, that the building will collapse if such ground motions occur. A final score of $S = 2$ implies there is a chance of 1 in 10^2, or 1 in 100, that the building will collapse if such ground motions occur. (Additional information about the basis for the RVS scoring system is provided in the second edition of the companion FEMA 155 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*.) An understanding and appreciation of the physical essence of the scoring system, as described above, will facilitate the interpretation of results from implementation of the RVS procedure.

4.2 Selection of RVS "Cut-Off" Score

One of the most difficult issues pertaining to rapid visual screening is answering the question, "What is an acceptable *S*?" This is a question for the community that involves the costs of safety versus the benefits. The costs of safety include:

- the costs of reviewing and investigating in detail hundreds or thousands of buildings in order to identify some fraction of those that would actually sustain major damage in an earthquake; and
- the costs associated with rehabilitating those buildings finally determined to be unacceptably weak.

The most compelling benefit is the saving of lives and prevention of injuries due to reduced damage in those buildings that are rehabilitated. This reduced damage includes not only less material damage, but fewer major disruptions to daily lives and businesses. The identification of hazardous buildings and the mitigation of their hazards are critical because there are thousands of existing buildings in all parts of the United States that may suffer severe damage or possible collapse in the event of strong ground shaking. Such damage or collapse can be accompanied by loss of life and serious injury. In a great earthquake deaths could number in the thousands.

Each community needs to engage in some consideration of these costs and benefits of seismic safety, and decide what value of *S* is an appropriate "cut-off" for their situation. The final decision involves many non-technical factors, and is not straightforward. Perhaps the best quantification of the risk inherent in modern building codes was a study regarding design practice by the National Bureau of Standards (NBS, 1980), which observed:

> *In selecting the target reliability it was decided, after carefully examining the resulting reliability indices for the many design situations, that a $\beta_0 = 3$ is a representative average value for many frequently used structural elements when they are subjected to gravity loading, while $\beta_0 = 2.5$ and $\beta_0 = 1.75$ are representative values for loads that include wind and earthquake, respectively*[3].

In other words, present design practice is such that a value of *S* of about 3 is appropriate for day-to-day loadings, and a value of about 2, or somewhat less, is appropriate for infrequent, but possible, earthquake loadings.

More recently, recommendations for seismic design criteria for new steel moment-frame buildings (SAC, 2000) concluded that:

> *…it is believed that…structures designed in accordance with [these recommendations] provide in excess of 90% confidence of being able to withstand [shaking that has a 2% probability of exceedance in 50 years] without global collapse….*

This statement can be shown to be equivalent to the findings in the NBS (1980) study.

Unless a community itself considers the cost and benefit aspects of seismic safety, an *S* value of about 2.0 is a reasonable preliminary value to use within the context of RVS to differentiate adequate buildings from those potentially inadequate and thus requiring detailed review. Use of a higher cut-off *S* value implies greater desired safety but increased community-wide costs for evaluations and rehabilitation; use of a lower value of *S* equates to increased seismic risk and lower short-term community-wide costs for evaluations and rehabilitation (prior to an earthquake).

Further guidance on cost and other societal implications of seismic rehabilitation of hazardous buildings is available in other publications of the FEMA report series on existing buildings (see FEMA-156 and FEMA-157, *Typical Costs for Seismic Rehabilitation of Buildings*, 2nd Edition, Volumes 1 and 2, and FEMA-255 and FEMA-256, *Seismic Rehabilitation of Federal Buildings – A Benefit/Cost Model*, Volumes 1 and 2 (VSP, 1994).

4.3 Prior Uses of the RVS Procedure

During the decade following publication of the first edition of the FEMA 154 *Handbook*, the rapid visual screening procedure was used by private-sector organizations and government agencies to evaluate more than 70,000 buildings nationwide (ATC, 2002). As reported at the FEMA 154 Users Workshop in San Francisco in September 2000 (see second edition of FEMA 155 report for additional information), these applications included surveys of (1) commercial buildings in Beverly Hills, California, (2) National Park Service facilities, (3) pubic buildings and designated shelters in southern Illinois; (4) U. S. Army facilities, (5) facilities of the U. S. Department of the Interior and (6) buildings in other local communities and for other government agencies. The results from some of these efforts are described below.

In its screening of 11,500 buildings using the FEMA 154 RVS procedure, the U. S. Army Corps of Engineers Civil Engineering Research Laboratory (CERL) used a cut-off score of 2.5, rather than 2.0 (S. Sweeney, oral communication, September 2000), with the specific intent of using a more conservative approach. As a result of the FEMA 154 screening, approximately 5,000 buildings had final *S* scores less than 2.5. These buildings, along with a subset of buildings that had FEMA 154 scores higher than 2.5, but were of concern for other reasons, were further evaluated in detail using the FEMA 178 *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* [BSSC, 1992]). Results from the subsequent FEMA 178 evaluations indicated that some buildings that failed the FEMA 154 RVS procedure (that is, had scores less than 2.5) did not fail the FEMA 178 evaluations and that some that passed the FEMA 154 RVS procedure (with scores higher than 2.5) did not pass the FEMA 178 evaluation (that is, were found to have inadequate seismic resistance). This finding emphasizes the

[3] β_0 as used in the National Bureau of Standards study is approximately equivalent to *S* as used herein.

concern identified at the beginning of this chapter that the use of FEMA 154 may not identify potentially earthquake hazardous buildings as such, and that buildings identified as potentially hazardous may prove to be adequate.

Other conclusions and recommendations pertaining to the use of the FEMA 154 RVS procedure that emanated from these applications included the following:

- Involve design professionals in RVS implementation whenever possible to ensure that the lateral-force-resisting structural systems are correctly identified (such identification is particularly difficult in buildings that have been remodeled and added to over the years);
- Conduct intensive training for screeners so that they fully understand how to implement the methodology, in all of its aspects;
- Inspect both the exterior and, if at all possible, the interior of the building;
- Review construction drawings as part of the screening process;
- Review soils information prior to implementation of the methodology in the field; and
- Interpret the results from FEMA 154 screenings in a manner consistent with the level of resources available for the screening (for example, cut-off scores may be dictated by budget constraints).

Most of these recommendations were incorporated in the updated RVS procedure described in this *Handbook*.

4.4 Other Possible Uses of the RVS Procedure

In addition to identifying potentially seismically hazardous buildings needing further evaluation, results from RVS surveys can also be used for other purposes, including: (1) designing seismic hazard mitigation programs for a community (or agency); (2) ranking a community's (or agency's) seismic rehabilitation needs; (3) developing inventories of buildings for use in regional earthquake damage and loss impact assessments; (4) developing inventories of buildings for use in planning postearthquake building safety evaluation efforts; and (5) developing building-specific seismic vulnerability information for purposes such as insurance rating, decision making during building ownership transfers, and possible triggering of remodeling requirements during the permitting process.

Following are descriptions of how RVS results could be used for several of these purposes.

4.4.1 Using RVS Scores as a Basis for Hazardous Building Mitigation Programs

Communities need to develop hazard mitigation plans to establish a solid foundation for the detailed seismic evaluation and rehabilitation of buildings. In developing any hazardous buildings mitigation program, the cost effectiveness of the seismic evaluation and rehabilitation work must be determined. The costs should be evaluated against the direct benefits of the seismic rehabilitation program (that is, reduced physical damage, reduced injuries and loss of life). Additionally, secondary benefits to the community should be considered with the direct benefits. These secondary benefits are difficult to quantify in dollars, but must be considered. Secondary benefits are those that apply to the community as a whole. Examples include:

- reduced interruption to business;
- reduced potential for secondary damage (for example, fires) that could impact otherwise undamaged structures;
- reduced potential for traffic flow problems around areas of significant damage; and
- other reduced economic impacts.

The process of selecting buildings to be rehabilitated begins with the determination of the cut-off Structural Score, *S*, below which detailed building seismic evaluation is required (e.g., by use of the FEMA 310 procedures). Such a determination allows estimates to be made on the costs of additional seismic evaluation and rehabilitation work. From this the benefits are determined. The most cost-effective solution will be the one where the least amount is spent in direct costs to gain the greatest direct and secondary benefits.

After the RVS authority establishes the appropriate cut-off score and completes the screening process, it needs to determine the best way to notify building owners of the need for more review of buildings that score less than the cut-off (if the authority is not the owner of the buildings being screened). At the same time the community needs to develop the appropriate standards (for example, adoption of FEMA 356, *Prestandard and Commentary on the Seismic Rehabilitation of Buildings* [ASCE, 2000]) to accomplish the goal of the mitigation program. Ultimately, the mitigation program needs to address those buildings that represent the largest potential threat to life safety and the community. Timelines for compliance with the new standards and the mitigation program should be developed on a priority basis, such that the first priority actions relate to those buildings posing the most significant risk, after which those posing a lesser risk are addressed.

4.4.2 Using RVS Data in Community Building Inventory Development

RVS data can be used to establish building inventories that characterize a community's seismic risk. For example, RVS data could be used to improve the HAZUS (NIBS, 1999) characterization of the local inventory, which has a default level based on population, economic factors, and regional trends. Similarly, RVS could be incorporated directly into a community's Geographic Information System (GIS), allowing the community to generate electronic and paper maps that reflect the building stock of the community. Electronic color coding of the various types of buildings under the RVS authority, based on their ultimate vulnerability, allows the community to see at a glance where the vulnerable areas of the community are found.

4.4.3 Using RVS Data to Plan Post-earthquake Building-Safety-Evaluation Efforts

In a postearthquake environment one of the initial response priorities is to determine rapidly the safety of buildings for continued occupancy. The procedure most often used is that represented in the ATC-20 Report, *Procedures for Postearthquake Safety Evaluation of Buildings* (ATC, 1989, 1995). This procedure is similar in nature to that of the RVS procedure in that initial rapid evaluations are performed to find those buildings that are obviously unsafe (Red placard) and those that have no damage or damage that does not pose a threat to continued occupancy (Green placard). All other buildings fall into a condition where occupancy will need to be restricted in some form (Yellow placard).

The database developed following the completion of the RVS process in a given community will be valuable in setting the priorities of where safety evaluation will be performed first, after a damaging earthquake. For example, a community could use HAZUS software, in combination with RVS-based inventory information, to determine areas where significant damage may exist for various earthquake scenarios. Similarly, a community could use an existing GIS containing RVS inventory data and computer-generated maps of strong ground shaking, such as the ShakeMaps developed by the USGS (ATC, in progress), to estimate the location and distribution of damaged buildings. With such information, community officials would be able to determine those areas where building safety evaluations should be conducted.

Later, the data collected during the postearthquake building safety evaluations could be added to the RVS authority's RVS-based building inventory database. Using GIS, maps can then be prepared showing the damage distribution within the community based on actual building damage. Building locations could be electronically color-coded in accordance with the color of the safety-evaluation placard that is placed on the building: Green, Yellow, or Red.

4.4.4 Resources Needed for the Various Uses of the RVS Procedure

For most applications of the RVS procedure, the resources needed to implement the process are similar, consisting principally of an RVS manager (the RVS authority), technical specialists to train screeners, a team of screeners, materials to be taken into the field (e.g., the *Handbook* and other items listed in Section 2.8), and building construction drawings. Most applications are assisted by the development and maintenance of a computerized database for recordkeeping and the use of geographic information systems (GIS). A matrix showing recommended resources for various FEMA 154 RVS applications is provided in Table 4-1.

Table 4-1 Matrix of Recommended Personnel and Material Resources for Various FEMA 154 RVS Applications*

	Application	*RVS Manager*	*RVS Trainer*	*Screeners*	*Screening Equipment and Supplies*	*Building Drawings*	*Computerized Record Keeping System*	*GIS*
		Resources						
1.	Ranking seismic rehabilitation needs	X	X	X	X	X	X	X
2.	Designing seismic hazard mitigation programs	X	X	X	X	X	X	X
3.	Developing inventories for regional earthquake damage and loss studies	X	X	X	X	X	X	X
4.	Planning postearthquake building safety evaluation efforts	X	X	X	X	X	X	X
5.	Developing building specific vulnerability information	X	X	X	X	X		

*It is recommended that rapid visual screening projects be carried out under the oversight of a design professional with significant experience in seismic design.

Chapter 5

Example Application of Rapid Visual Screening

Presented in this chapter is an illustrative application of the rapid visual screening procedure in the hypothetical community of Anyplace USA. The RVS implementation process (as depicted in Figure 2-1) is described, from budget development to selection of the appropriate Data Collection Form, to the screening of individual buildings in the field. Prior to implementation of the RVS procedure, the RVS authority (the Building and Planning Department of Anyplace) has reviewed the *Handbook* and established the purpose for the RVS.

5.1 Step 1: Budget and Cost Estimation

The RVS authority has been instructed by the city council to conduct the RVS process to identify all buildings in the city, excluding detached single-family and two-family dwellings, that are potentially earthquake hazardous and that should be further evaluated by a design professional experienced in seismic design (the principal purpose of the RVS procedure). It is understood that, depending on the results of the RVS, the city council may adopt future ordinances that establish policy on when, how and by whom low-scoring buildings should be evaluated and on future seismic rehabilitation requirements. It is also desired that the results from the RVS be incorporated in the geographic information system that the city recently installed to map and describe facilities throughout the city, including all buildings and utility systems within the city limits.

The RVS authority has determined there are approximately 1,000 buildings in the city that are not detached single-family or two-family dwellings and that some of the buildings are at least 100 years old. The RVS authority plans (1) to conduct a pre-field data collection and evaluation process to examine and assess information in its existing files and to document building location, size, use, and other information on the Data Collection Forms prior to field screening; (2) to review available building plans prior to field screening; (3) to inspect the interiors of buildings whenever possible; (4) to establish an electronic RVS record-keeping system that is compatible with its GIS; and (5) to train screeners prior to sending them into the field.

Costs to conduct these activities have been estimated, assuming an average of $40 per hour (salary plus benefits) for personnel who perform data evaluation, screening, and record management. Costs are in 2001 dollars. It is assumed that three persons will carry out the pre-field data collection and evaluation process, that four two-person teams of design professionals will conduct the review of building plans and the field screening, that two persons will file all screening data, and that the entire RVS process will take approximately six months. Based on these rates and assumed times to conduct the various activities, the following RVS budget has been established:

1. Pre-field data collection, evaluation, and processing (1,000 buildings × 0.4 hr/building × $40/hr)	$16,000
2. Training, including trainer time (24 hours), screener time (8 hours per screener), and materials	4,000
3. Review of available building plans (500 plan sets × 0.75 hr/plan set × $40/hr)	15,000
4. Field screening (1,000 buildings × 0.75 hr/building × $40/hr)	30,000
5. Record-keeping system development	5,000
6. Electronic filing of Data Collection Forms, including verification of data input (1,000 forms × 0.75 hour/form × $40/hour)	30,000
7. Subtotal	$100,000
8. Management (10% of item 7)	10,000
9. Total	$110,000

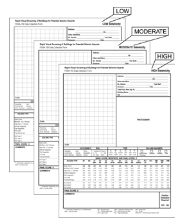
5.2 Step 2: Pre-Field Planning

During the pre-field planning process the RVS authority confirmed that the existing geographic information system was capable of being expanded to include RVS-related information and results. In addition, the RVS authority decided that sufficient soil information was available from the State Geologist to develop an overlay for their GIS containing soils information for the entire city. While not required as part of the RVS process, it was also determined that the city included an area that had isolated pockets of low liquefaction potential, and that there was no area with landslide potential. Consequently the RVS authority concluded that GIS overlays for liquefaction and landslide potential were not warranted.

The RVS authority also verified that the existing GIS had reference tables containing address information for most of the properties in the city (developed earlier from the tax assessor's files) and that these tables could be extracted and included in a new GIS-compatible electronic relational database containing the RVS results. It was also determined that other building and planning department's files contained reliable information on building name, use, size (height and area), structural system, and age for buildings built or remodeled within the last 30 years, and that Sanborn maps, which contain size, age, and other building attribute information (see Section 2.6.3) were available (at the local library) for most of the downtown sector.

Based on this information, the RVS authority confirmed its prior preliminary decision under Step 1 to develop an electronic RVS record keeping system (relational database) that could be imported into the existing GIS. The RVS authority also decided to focus on the downtown sector of Anyplace during the initial phase of the RVS field work, and to expand to the outlying areas later.

5.3 Step 3: Selection and Review of the Data Collection Form



To choose the correct Data Collection Form, the RVS authority elected to establish the seismicity for Anyplace USA by using Method 2 (see Section 2.4.1), rather than by selecting the seismicity region from the maps in Appendix A. Method 2, using the zip-code option, provides more precision than the Appendix A maps which use county boundaries. Method 2 was executed by accessing the USGS seismic hazard web site (http://geohazards.cr.usgs.gov/eq/), selecting Hazard by Zip Code, entering the zip code, 91234, and obtaining spectral acceleration (SA) values for 0.2 second and 1.0 second for ground motions having a 2% probability of being exceeded in 50 years (see Figure 5-1). The values of 2.10 *g* and 0.88 *g* for 0.2 second and 1.0 second, respectively, were multiplied by 2/3 to obtain the reduced values of 1.40 *g* and 0.59 *g*, respectively, for 0.2


```
The input zip-code is 91234.
   ZIP CODE                          91234
   LOCATION                          33.7754 Lat. -118.1860 Long.
   DISTANCE TO NEAREST GRID POINT    3.0229 kms
   NEAREST GRID POINT                33.8 Lat. -118.2 Long.
   Probabilistic ground motion values, in %g, at the Nearest Grid
   point are:
               10%PE in 50 yr    5%PE in 50 yr    2%PE in 50 yr
      PGA       51.809940         70.680931        96.476959
   0.2 sec SA  118.997299        157.833496       210.008403
   0.3 sec SA  114.200897        148.213104       194.634995
   1.0 sec SA   42.566330         60.786320        88.084427
```

Figure 5-1 Screen capture of USGS web page showing SA values for 0.2 sec and 1.0 sec for ground motions having 2% probability of being exceeded in 50 years (values shown in boxes).

second and 1.0 second. These reduced values were compared to the criteria in Table 2-1 to determine that the reduced (using the 2/3 factor) USGS assigned motions met the "high seismicity" criteria for both short-period and long-period motions (that is, 1.40 *g* is greater than 0.5 *g* for the 0.2 second [short-period] motions, and 0.59 *g* is greater than 0.2 *g* for the 1.0 second [long-period] motions). All other zip codes in Anyplace were similarly input to the USGS web site, and the results indicated high seismicity in all cases. On this basis the RVS authority selected the Data Collection Form for high seismicity (Figure 5-2).

Using the checklist of Table 2-3, the RVS authority reviewed the Data Collection Form to determine if the occupancy categories and occupancy loads were useful for their purposes and evaluated other parameters on the form, deciding that no changes were needed. The RVS authority also conferred with the chief building official, the department's plan checkers, and local design professionals to establish key seismic code adoption dates for the various building lateral-load-resisting systems considered by the RVS and for anchorage of heavy cladding. It was determined that Anyplace adopted seismic codes for W1, W2, S1, S5, C1, C3, RM1, and RM2 building types in 1933, and that seismic codes were never adopted for URM buildings (after 1933 they were no longer permitted to be built). For S2, S3, S4 and PC2 buildings, it was assumed for purposes of the RVS procedure that seismic codes were adopted in 1941, using the default year recommended in Section 2.4.2. For PC1 buildings, it was assumed that seismic codes were first adopted in 1973 (per the guidance provided in Section 2.4.2). It was also determined that seismically rehabilitated URM buildings should be treated as buildings designed in accordance with a seismic code (that is, treated as if they were designed in 1933 or thereafter). Because Anyplace has been consistently adopting the *Uniform Building Code* since the early 1960s, benchmark years for all building types, except URM, were taken from the "UBC" column in Table 2-2. The year in which seismic anchorage requirements for heavy cladding was determined to be 1967. These findings were indicated on the Quick Reference Guide (See Figure 5-3).

5.4 Step 4: Qualifications and Training for Screeners

Anyplace USA selected RVS screeners from two sources: the staff of the Department of Building and Planning, and junior-level engineers from local engineering offices, who were hired on a temporary consulting basis. Training was carried out by one of the department's most experienced plan checkers, who spent approximately 24 hours reading the FEMA 154 *Handbook* and preparing training materials.

As recommended in this *Handbook*, the training was conducted in a classroom setting and consisted of: (1) discussions of lateral-force-resisting systems and how they behave when subjected to seismic loads; (2) how to use the Data Collection Form and the Quick Reference Guide; (3) a review of the Basic Structural Hazard Scores and Score Modifiers; (4) what to look for in the field; (5) how to account for uncertainty; and (6) an exercise in which screeners were shown interior and exterior photographs of buildings and asked to identify the lateral-load-resisting system and vertical and plan irregularities. The training class also included focused group interaction sessions, principally in relation to the identification of structural systems and irregularities using exterior and interior photographs. Screeners were also instructed on items to take into the field.

5.5 Step 5: Acquisition and Review of Pre-Field Data

As described in the Pre-Field Planning process (Step 2 above), the RVS authority of Anyplace USA already had electronic GIS reference tables containing street addresses and parcel numbers for most of the buildings in the city. These data (addresses and parcel numbers) were extracted from the electronic GIS system (see screen capture of GIS display showing parcel number and other available information for an example site, Figure 5-4) and imported into a standard off-the-shelf electronic database as a table. To facilitate later

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

HIGH Seismicity

Scale:

Address: ____________________
____________________ **Zip** ________
Other Identifiers ____________________
No. Stories ____________ **Year Built** ________
Screener ____________ **Date** ________
Total Floor Area (sq. ft.) ____________________
Building Name ____________________
Use ____________________

PHOTOGRAPH

OCCUPANCY			SOIL		TYPE						FALLING HAZARDS			
Assembly	Govt	Office	Number of Persons		A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	☐ Unreinforced Chimneys	☐ Parapets	☐ Cladding	☐ Other: ________
Commercial	Historic	Residential	0 – 10	11 – 100										
Emer. Services	Industrial	School	101-1000	1000+										

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 5-2 High seismicity Data Collection Form selected for Anyplace, USA.

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)

Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		Year Seismic Codes Initially Adopted and Enforced*	Benchmark Year when Codes Improved
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	1933	1976
W2	Wood frame buildings, > 5000 square feet.	1933	1976
S1	Steel moment-resisting frame	1933	1994
S2	Steel braced frame	1941	1988
S3	Light metal frame	1941	None
S4	Steel frame with cast-in-place concrete shear walls	1941	1976
S5	Steel frame with unreinforced masonry infill	1933	None
C1	Concrete moment-resisting frame	1933	1976
C2	Concrete shear wall	1941	1976
C3	Concrete frame with unreinforced masonry infill	1933	None
PC1	Tilt-up construction	1973	1997
PC2	Precast concrete frame	1941	None
RM1	Reinforced masonry with flexible floor and roof diaphragms	1933	1997
RM2	Reinforced masonry with rigid diaphragms	1933	1976
URM	Unreinforced masonry bearing-wall buildings	1933	N/A

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: 1967

3. Occupancy Loads

Use	Square Feet, Per Person	Use	Square Feet, Per Person
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

4. Score Modifier Definitions

Mid-Rise:	4 to 7 stories
High-Rise:	8 or more stories
Vertical Irregularity:	Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity	Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Pre-Code:	Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.
Post-Benchmark:	Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).
Soil Type C:	Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.
Soil Type E:	Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

Figure 5-3 Quick Reference Guide for Anyplace USA showing entries for years in which seismic codes were first adopted and enforced and benchmark years.

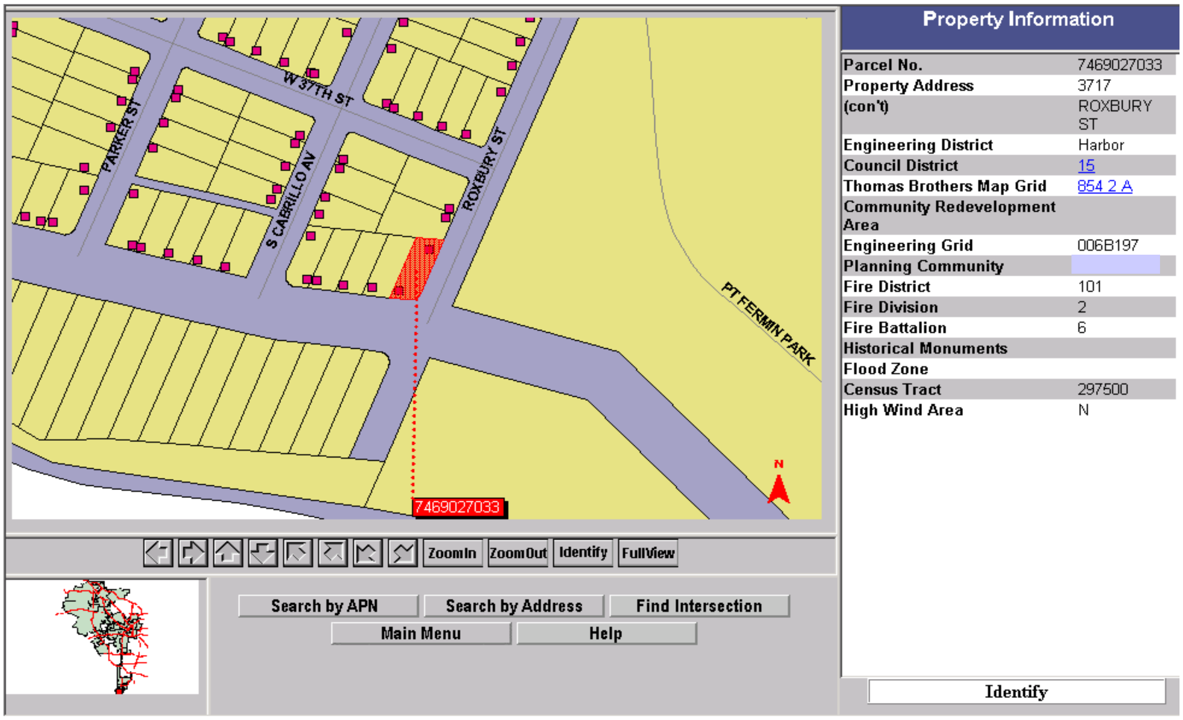


Figure 5-4 Property information at example site in city's geographic information system.

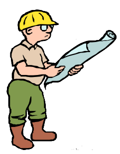
use in the GIS, the street addresses were subdivided into the following fields: the numeric part of the address; the street prefix (for example, "North"); the street name; and the street suffix (for example, "Drive"). A zip code field was added, zip codes for each street address were obtained using zip code lists available from the US Postal Service, and these data were also added to the database. This process yielded 950 street addresses, with parcel number and zip code, andestablished the initial information in Anyplace's electronic "Building RVS Database".

Permitting files, which contained data on buildings constructed or remodeled within the last 30 years (including parcel number), were then reviewed to obtain information on building name (if available), use, building height (height in feet and number of stories), total floor area, age (year built), and structural system. This process yielded information (from paper file folders) on approximately 500 buildings. Fields were added to the Building RVS Database for each of these attributes and data were added to the appropriate records (searching on parcel number) in the database; in the case of structure type, the entry included an asterisk to denote uncertainty. If an address was missing in the database, a new record containing that address and related data was added. On average, 30 minutes per building were required to extract the correct information from the permitting files and insert it into the electronic database.

The city's librarian provided copies of available Sanborn maps, which were reviewed to identify information on number of stories, year built, building size (square footage), building use, and limited information on structural type for approximately 200 buildings built prior to 1960. These data were added to the appropriate record (searching on address) in the Building RVS Database; in the case of structure type, the entry included an asterisk to denote uncertainty. If an address was missing in the database, a new record containing that address and related data was added. For this effort, 45 minutes per building, on average, were required to extract the correct information from the Sanborn maps and insert it into the electronic database.During the pre-field data collection and review process the RVS authority also obtained an electronic file of soils data (characterized in terms of the soil types described in Section 2.6.6) from the State Geologist and created an overlay of this information in the city's GIS system. Points defined by the addresses in the GIS reference tables (including newly identified addresses added to the references tables as a result of the above-cited efforts) were combined with the soils type overlay, and soil type was then assigned to each point (address) by a standard GIS operating procedure. The soils type information for each address was then transferred back to the Building RVS Database table into a new field for each building's soil type.

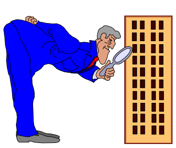
Based on the above efforts, Anyplace's Building RVS Database was expanded to include approximately 1,000 records with address, parcel number, zip code, and soils information, and approximately 700 of these records also contained information on building name (if any), use, number of stories, total floor area, year built, and structure type.

5.6 Step 6: Review of Construction Documents



Fortuitously, the city had retained microfilm copies of building construction documents submitted with each permit filing during the last 30 years, and copies of these documents were available for 500 buildings (the same subset described in Step 5 above). Teams consisting of one building department staff member and one consulting engineer reviewed these documents to verify, or identify, the lateral-force-resisting system for each building. Any new or revised information on structure type derived as part of this process was then inserted in the Building RVS Database, in which case, previously existing information in this field, along with the associated asterisk denoting uncertainty, was removed. On average, this effort required approximately 30 minutes per plan set, including database corrections.

5.7 Step 7: Field Screening of Buildings



Immediately prior to field screening (that is, at the conclusion of Step 6 above), the RVS authority acquired an electronic template of the Data Collection Form from the web site of the Applied Technology Council (www.atcouncil.org) and used this template to create individual Data Collection Forms for each record in the Building RVS Database. Each form contained unique information in the building identification portion of the form, with "Parcel Number" shown as "Other Identifiers" information (see Figure 5-2). In those instances where structure type information was included in the database, this information was also added as "Other Identifiers" information, with an asterisk if still uncertain. Soil type information was indicated on each form by circling the appropriate letter (and brief description) in the "Soil Type" section of the form (see Figure 5-2).

The Data Collection Forms, including blank forms for use with buildings not yet in the Building RVS Database, were distributed to the RVS screeners along with their RVS assignments (on a block-by-block basis). Screeners were advised that some of the database information printed on the form (e.g., number of stories, structure type denoted with an *) would need to be verified in the field, that approximately 700 of the 1,000 Data Collection Forms had substantially complete, but not necessarily verified, information in the location portion of the form, and that all 1,000 forms had street, address, parcel number, zip code, and soil type information.

Prior to field work, each screener was reminded to complete the Data Collection Form at each site before moving on to the next site, including adding his or her name as the screener and the screening date (in the building identification section of the form).

Following are several examples illustrating rapid visual screening in the field and completion of the Data Collection Form. Some examples use forms containing relatively complete building identification information, including structure type, obtained during the pre-field data acquisition and review process (Step 5); others use forms containing less complete building identification information; and still others use blank forms completely filled in at the site.

Example 1: 3703 Roxbury Street

Upon arriving at the site the screeners observed the building as a whole (Figure 5-5) and began the process of verifying the information in the building identification portion of the form (upper right corner), starting with the street address. The building's lateral-force-resisting system (S2, steel braced frame) was verified by looking at the building with binoculars (see Figure 5-6). The number of stories (10), use (office), and year built (1986) were also confirmed by inspection. The base dimensions of the building were estimated by pacing off the distance along each face, assuming 3 feet per stride, resulting in the determination that it was 75 ft x 100 ft in plan.

Figure 5-5 Exterior view of 3703 Roxbury Street.

On this basis, the listed square footage of 76,000 square feet was verified as correct (see Figure 5-7). The screeners also added their names and the date of the field screening to the building identification portion of the form.

A sketch of the plan and elevation views of the building were drawn in the "Sketch" portion of the form.

The building use was circled in the "Occupancy" portion, and from Section 3 of the Quick Reference Guide, the occupancy load was estimated at 75,000/150 = 500. Hence, the occupancy range of 101-1000 was circled.

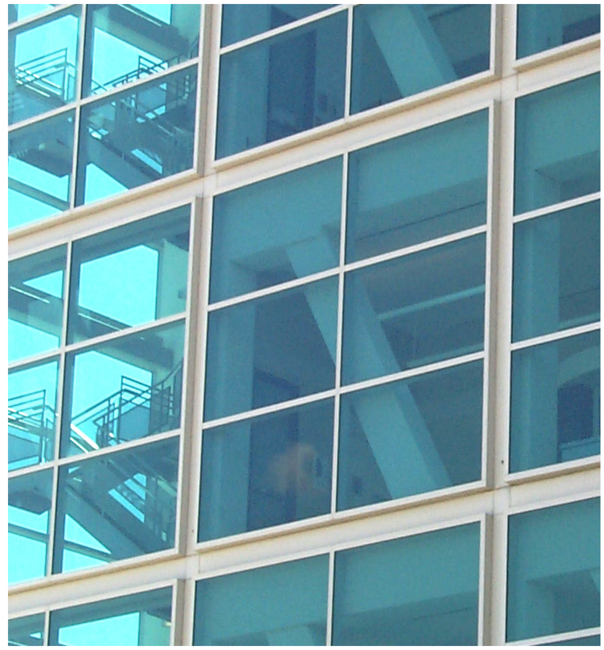
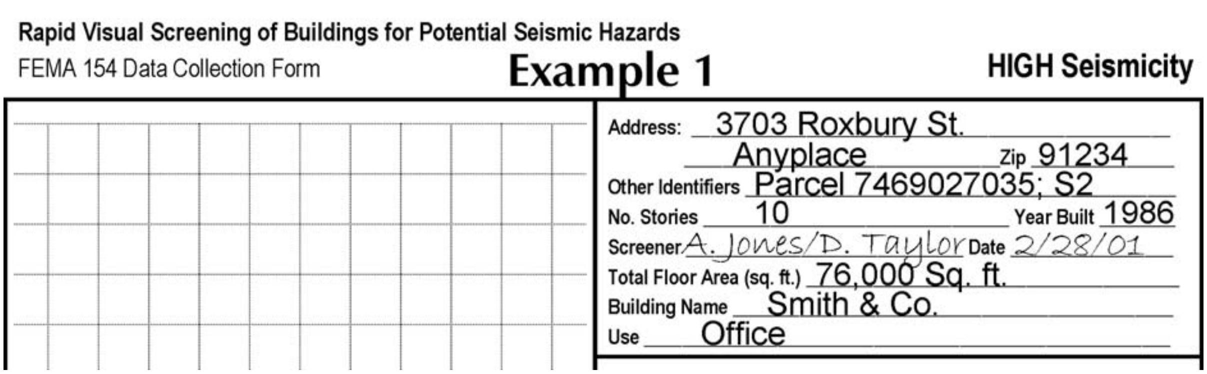


Figure 5-6 Close-up view of 3703 Roxbury Street exterior showing perimeter braced steel framing.

No falling hazards were observed, as glass cladding is not considered as heavy cladding.

The next step in the process was to circle the appropriate Basic Structural Hazard Score and the appropriate Score Modifiers. Having verified the lateral-force-resisting system as S2, this code was circled along with the Basic Structural Score beneath it (see Figure 5-8). Because the building is high rise (8 stories or more) this modifier was circled. Noting that the soil is type D, as already determined during the pre-field data acquisition phase and indicated in the Soil Type portion of the form, the modifier for Soil Type D was circled. By adding the column of circled numbers, a Final Score of 3.2 was determined. Because this score was greater than the cut-off score of 2.0, the building did not require a detailed evaluation by an experienced seismic design professional. Lastly, an instant camera photo of the building was attached to the form.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA 154 Data Collection Form
Example 1
HIGH Seismicity

Address: 3703 Roxbury St.
Anyplace Zip 91234
Other Identifiers Parcel 7469027035; S2
No. Stories 10 Year Built 1986
Screener A. Jones/D. Taylor Date 2/28/01
Total Floor Area (sq. ft.) 76,000 Sq. ft.
Building Name Smith & Co.
Use Office

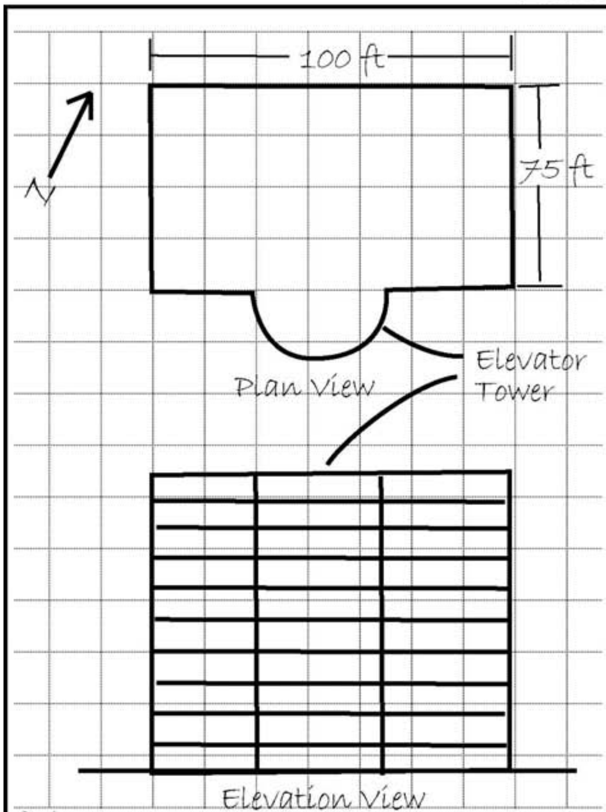
Figure 5-7 Building identification portion of Data Collection Form for Example 1, 3703 Roxbury Street.

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

Example 1

HIGH Seismicity



Scale:

Address: 3703 Roxbury St.
Anyplace **Zip** 91234
Other Identifiers Parcel 7469027035; S2
No. Stories 10 **Year Built** 1986
Screener A. Jones/D. Taylor **Date** 2/28/01
Total Floor Area (sq. ft.) 76,000 Sq. ft.
Building Name Smith & Co.
Use Office

OCCUPANCY			SOIL	TYPE	FALLING HAZARDS
Assembly, Commercial, Emer. Services	Govt, Historic, Industrial	Office, Residential, School	Number of Persons: 0 – 10, 11 – 100, 101-1000, 1000+	A Hard Rock, B Avg. Rock, C Dense Soil, D Stiff Soil, E Soft Soil, F Poor Soil	☐ Unreinforced Chimneys, ☐ Parapets, ☐ Cladding, ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S				3.2											

COMMENTS

Detailed Evaluation Required

YES **NO**

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 5-8 Completed Data Collection Form for Example 1, 3703 Roxbury Street.

Example 2: 3711 Roxbury Street

Upon arrival at the site, the screeners observed the building as a whole (Figure 5-9). Unlike Example 1, there was little information in the building identification portion of the form (only street address, zip code, and parcel number were provided). The screeners determined the number of stories to be 12 and the building use to be commercial and office. They paced off the building plan dimensions to estimate the plan size to be 58 feet x 50 feet. Based on this information, the total square footage was estimated to be 34,800 square feet (12 x 50 x 58), and the number of stories, use, and square footage were written on the form. Based on a review of information in Appendix D of this *Handbook*, the year of construction was estimated to be 1944 and this date was written on the form.

A sketch of the plan and elevation views of the building were drawn in the "Sketch" portion of the form.

The building use was circled in the "Occupancy" portion, and from Section 3 of the Quick Reference Guide, the occupancy load was estimated at 34,800/135♦ = 258. Hence, the occupancy range of 101-1000 was circled.

The cornices at roof level were observed, and entered on the form.

Noting that the estimated construction date was 1944 and that it was a 12-story building , a review of the material in Table D-6 (Appendix D), indicated that the likely options for building type were S1, S2, S5, C1, C2, or C3. On more careful examination of the building exterior with the use of binoculars (see Figure 5-10), it was determined the building was type C3, and this alpha-numeric code, and accompanying Basic Structural Score, were circled on the Data Collection Form.

Because the building was high-rise (more than 7 stories), this modifier was circled, and because the four individual towers extending above the base represented a vertical irregularity, this modifier was circled. Noting that the soil is type D, as already determined during the pre-field data acquisition phase and indicated in the Soil Type portion of the form, the modifier for Soil Type D was circled.

By adding the column of circled numbers, a Final Score of 0.5 was determined. Because this score was less than the cut-off score of 2.0, the building required a detailed evaluation by an experienced seismic design professional. Lastly, an instant camera photo of the building was attached to the Data Collection Form (a completed version of the form is provided in Figure 5-11).

Figure 5-9 Exterior view of 3711 Roxbury.

Figure 5-10 Close-up view of 3711 Roxbury Street building exterior showing infill frame construction.

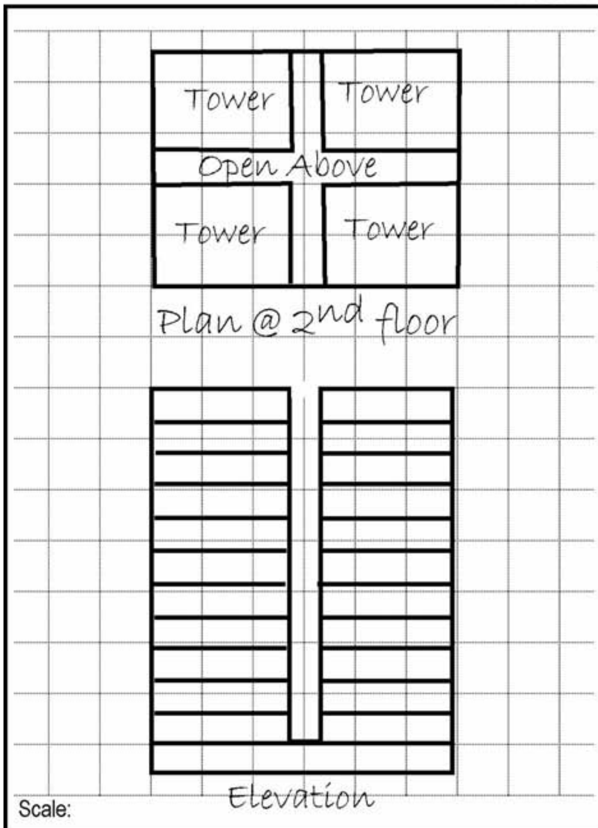
♦ The "135" value is the approximate average of the mid-range occupancy load for commercial buildings (125 sq. ft. per person) and the mid-range occupancy load for office buildings (150 sq. ft. per person).

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

Example 2

HIGH Seismicity



Address: 3711 Roxbury St.
Anyplace Zip 91234
Other Identifiers Parcel 7469027034
No. Stories 12 Year Built 1944
Screener A. Jones/D. Taylor Date 2/28/01
Total Floor Area (sq. ft.) 34,800
Building Name
Use Commercial and Offices above

OCCUPANCY			SOIL	TYPE	FALLING HAZARDS
Assembly, Commercial, Emer. Services	Govt, Historic, Industrial	Office, Residential, School	Number of Persons: 0 – 10, 11 – 100, 101-1000, 1000+	A Hard Rock; B Avg. Rock; C Dense Soil; D Stiff Soil; E Soft Soil; F Poor Soil	☐ Unreinforced Chimneys; ☐ Parapets; ☐ Cladding; ☒ Other: Cornices

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S										0.5					

COMMENTS

Detailed Evaluation Required

YES **NO**

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 5-11 Completed Data Collection Form for Example 2, 3711 Roxbury Street.

Example 3: 5020 Ebony Drive

Example 3 was a high-rise residential building (Figure 5-12) in a new part of the city in which new development had begun within the last few years. The building was not included in the electronic Building RVS Database, and consequently there was not a partially prepared Data Collection Form for this building. Based on visual inspection, the screeners determined that the building had 22 stories, including a tall-story penthouse, estimated that it was designed in 1996, and concluded that its use was both commercial (in the first story) and residential in the upper stories. The screeners paced off the building plan dimensions to estimate the plan size to be approximately 270 feet x 180 feet. Based on this information and considering the symmetric but non-rectangular floor plan, the total square footage was estimated to be 712,800 square feet. These data were written on the form, along with the names of the screeners and the date of the screening. The screeners also drew a sketch of a portion of the plan view of the building in the space on the form allocated for a "Sketch".

The building use (commercial and residential) was circled in the "Occupancy" portion, and from Section 3 of the Quick Reference Guide, the occupancy load was estimated at 712,800/200 = 3,564. Based on this information, the occupancy range of 1000+ was circled.

While the screeners reasonably could have assumed a type D soil, which was the condition at the adjacent site approximately ½ mile away, they concluded they had no basis for assigning a soil type. Hence they followed the instructions in the *Handbook* (Section 3.4), which specifies that if there is no basis for assigning a soil type, soil type E should be assumed. Accordingly, this soil type was circled on the form.

Given the design date of 1996, the anchorage for the heavy cladding on the exterior of the building was assumed to have been designed to meet the anchorage requirements initially adopted in 1967 (per the information on the Quick Reference Guide). No other falling hazards were observed.

The window spacing in the upper stories and the column spacing at the first floor level indicated the building was either a steel moment-frame building, or a concrete moment-frame building. The screeners attempted to view the interior but were not provided with permission to do so. They elected to indicate that the building was either an S1 or C1 type on the Data Collection Form and circled both types, along with their Basic Structural Scores. In addition, the screeners circled the modifiers for high rise (8 stories or more) and post-benchmark year, given that the estimated design date (1996) occurred after the benchmark years for both S1 and C1 building types (per the information on the Quick Reference Guide). They also circled the modifier for soil type E (in both the S1 and C1 columns).

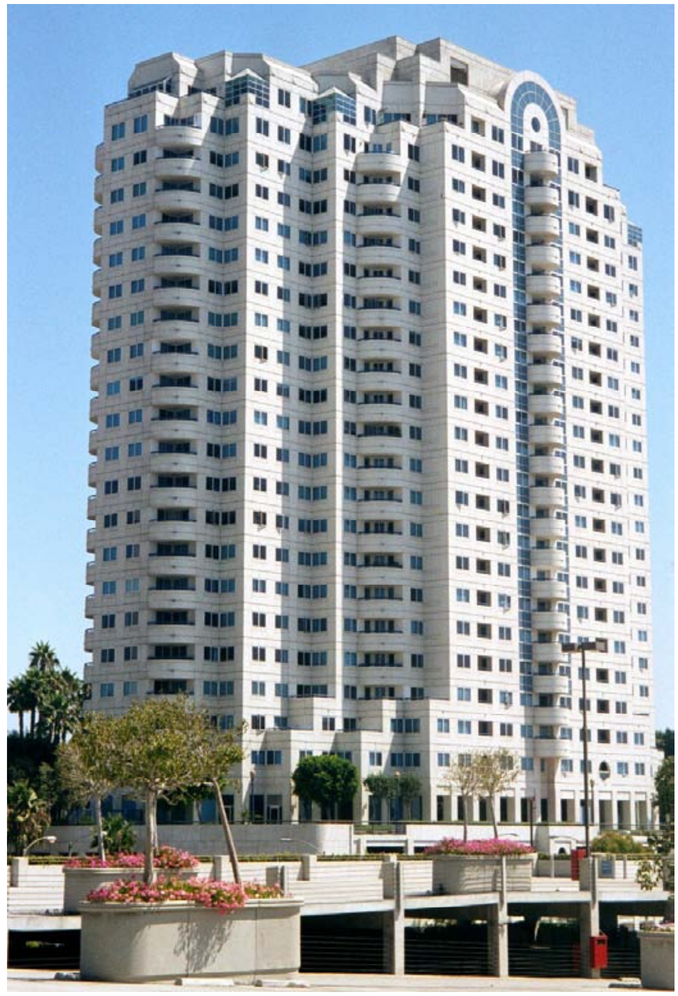


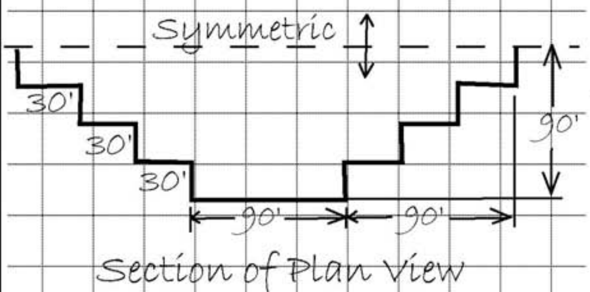
Figure 5-12 Exterior view of 5020 Ebony Drive.

By adding the circled numbers in both the S1 and C1 columns, Final Scores of 3.6 and 3.3 respectively were determined for the two building types. Because both scores were greater than the cut-off score of 2.0, a detailed evaluation of the building by an experienced seismic design professional was not required. Before leaving the site, the screeners photographed the building and attached the photo to the Data Collection Form. A completed version of the Data Collection Form is provided in Figure 5-13.

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

Example 3

HIGH Seismicity



Scale:

Address: 5020 Ebony Drive
Anyplace Zip 91011
Other Identifiers
No. Stories 22 Year Built 1996
Screener A. Jones/D. Taylor Date 2/28/01
Total Floor Area (sq. ft.) 712,800
Building Name
Use Residential and Commercial

OCCUPANCY			SOIL						TYPE	FALLING HAZARDS
Assembly	Govt	Office	Number of Persons	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Unreinforced Chimneys
Commercial	Historic	Residential	0 – 10	11 – 100						Parapets
Emer. Services	Industrial	School	101-1000	1000+						Cladding
										Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S			3.6					3.3							

COMMENTS Screeners could not determine if building type was C1 or S1; hence both types were scored, with similar results.

Detailed Evaluation Required
YES **NO**

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 5-13 Completed Data Collection Form for Example 3, 5020 Ebony Drive.

Figure 5-14 Exterior view of 1450 Addison Avenue.

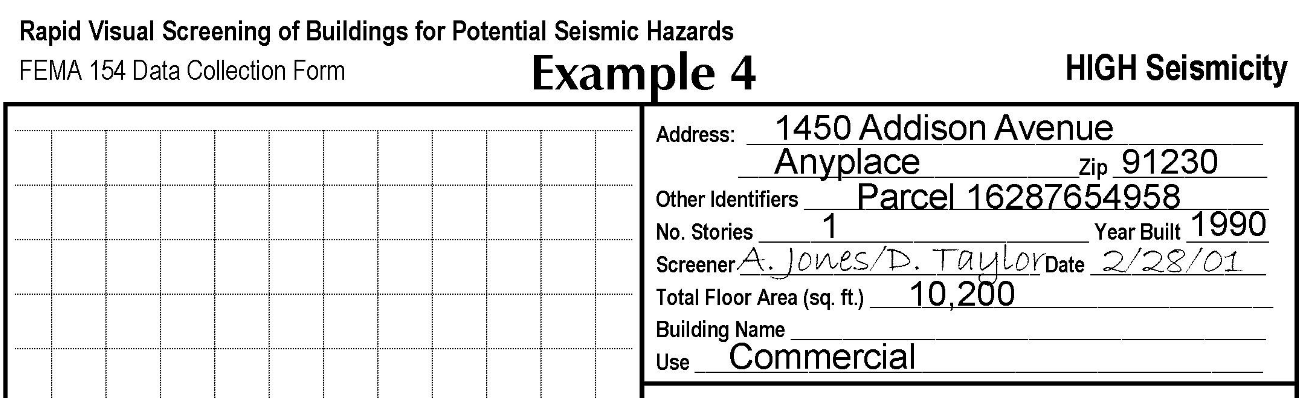
Example 4: 1450 Addison Avenue

The building at 1450 Addison Avenue (see Figure 5-14) was a 1-story commercial building designed in 1990, per the information provided in the building identification portion of the Data Collection Form. By inspection the screeners confirmed the address, number of stories, use (commercial), and year built (Figure 5-15). The screeners paced off the building plan dimensions to estimate the plan size (estimated to be 10,125 square feet), confirming the square footage shown on the identification portion of the form. The L-shaped building was drawn on the form, along with the dimensions of the various legs.

The building's commercial use was circled in the "Occupancy" portion, and from Section 3 of the Quick Reference Guide, the occupancy load was estimated at 10,200/125 = 80. Hence, the occupancy range of 11-100 was circled. No falling hazards were observed.

The building type (W2) was circled on the form along with its Basic Structural Score. Because the building was L-shaped in plan the modifier for plan irregularity was circled. Because soil type C had been circled in the Soil Type box (based on the information in the Building RVS Database) the modifier for soil type C was circled.

By adding the column of circled numbers, a Final Score of 5.3 was determined. Because this score was greater than the cut-off score of 2.0, the building did not require a detailed evaluation by an experienced seismic design professional. Lastly, an instant camera photo of the building was attached to the Data Collection Form. A completed version of the form is provided in Figure 5-16.



Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA 154 Data Collection Form

Example 4

HIGH Seismicity

Address: 1450 Addison Avenue

Anyplace Zip 91230

Other Identifiers Parcel 16287654958

No. Stories 1 Year Built 1990

Screener A. Jones/D. Taylor Date 2/28/01

Total Floor Area (sq. ft.) 10,200

Building Name

Use Commercial

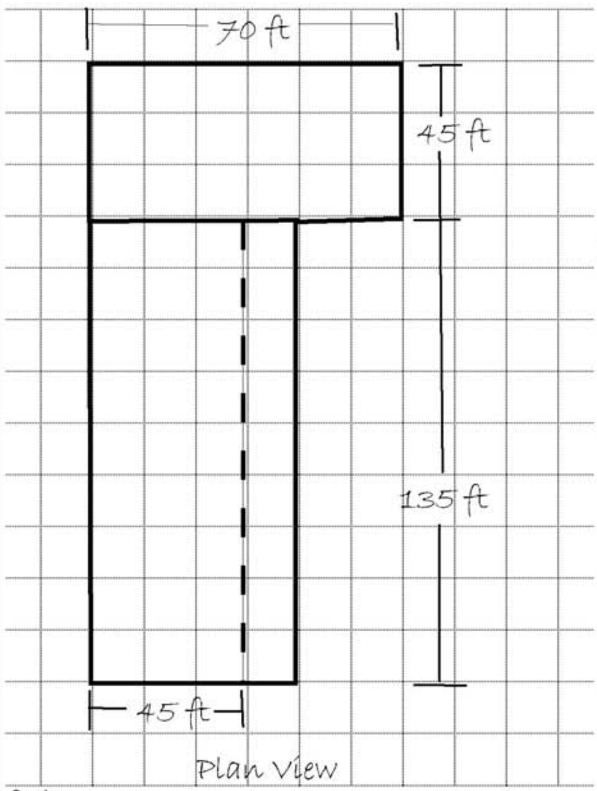
Figure 5-15 Building identification portion of Data Collection Form for Example 4, 1450 Addison Avenue.

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

Example 4

HIGH Seismicity



Scale:

Address: 1450 Addison Avenue
Anyplace **Zip** 91230
Other Identifiers Parcel 16287654958
No. Stories 1 **Year Built** 1990
Screener A. Jones/D. Taylor **Date** 2/28/01
Total Floor Area (sq. ft.) 10,200
Building Name
Use Commercial

OCCUPANCY				SOIL						TYPE	FALLING HAZARDS			
Assembly	Govt	Office	Number of Persons	A	B	C	D	E	F		Unreinforced Chimneys	Parapets	Cladding	Other:
Commercial	Historic	Residential	0 – 10 / 11 – 100	Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil					
Emer. Services	Industrial	School	101-1000 / 1000+											

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, *S*		5.3													

COMMENTS

Detailed Evaluation Required

YES **NO**

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 5-16 Completed Data Collection Form for Example 4, 1450 Addison Avenue.

5.8 Step 8: Transferring the RVS Field Data to the Electronic Building RVS Database

The last step in the implementation of rapid visual screening for Anyplace USA was transferring the information on the RVS Data Collection Forms into the relational electronic Building RVS Database. This required that all photos and sketches on the forms be scanned and numbered (for reference purposes), and that additional fields (and tables) be added to the database for those attributes not originally included in the database.

For quality control purposes, data were entered separately into two different versions of the electronic database, except photographs and sketches, which were scanned only once. A double-entry data verification process was then used, whereby the data from one database were compared to the same entries in the second database to identify those entries that were not exactly the same. Non-identical entries were examined and corrected as necessary. The entire process, including scanning of sketches and photographs, required approximately 45 minutes per Data Collection Form.

After the electronic Building RVS Database was verified, it was imported into the city's GIS, thereby providing Anyplace with a state-of-the-art capability to identify and plot building groups based on any set of criteria desired by the city's policy makers. Photographs and sketches of individual buildings could also be shown in the GIS simply by clicking on the dot or symbol used to represent each building and selecting the desired image.

Appendix A

Maps Showing Seismicity Regions

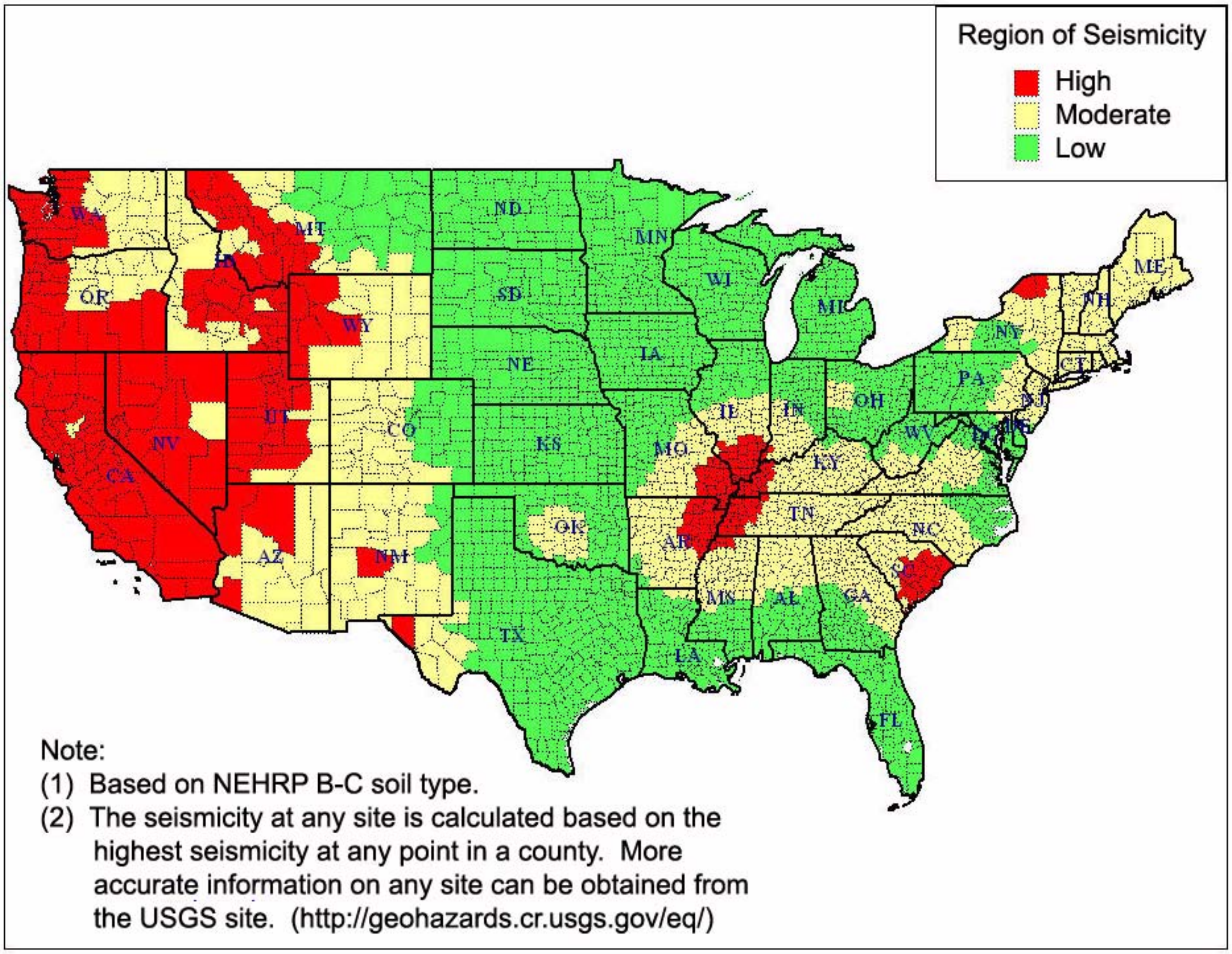


Figure A-1 Seismicity Regions of the Conterminous United States.

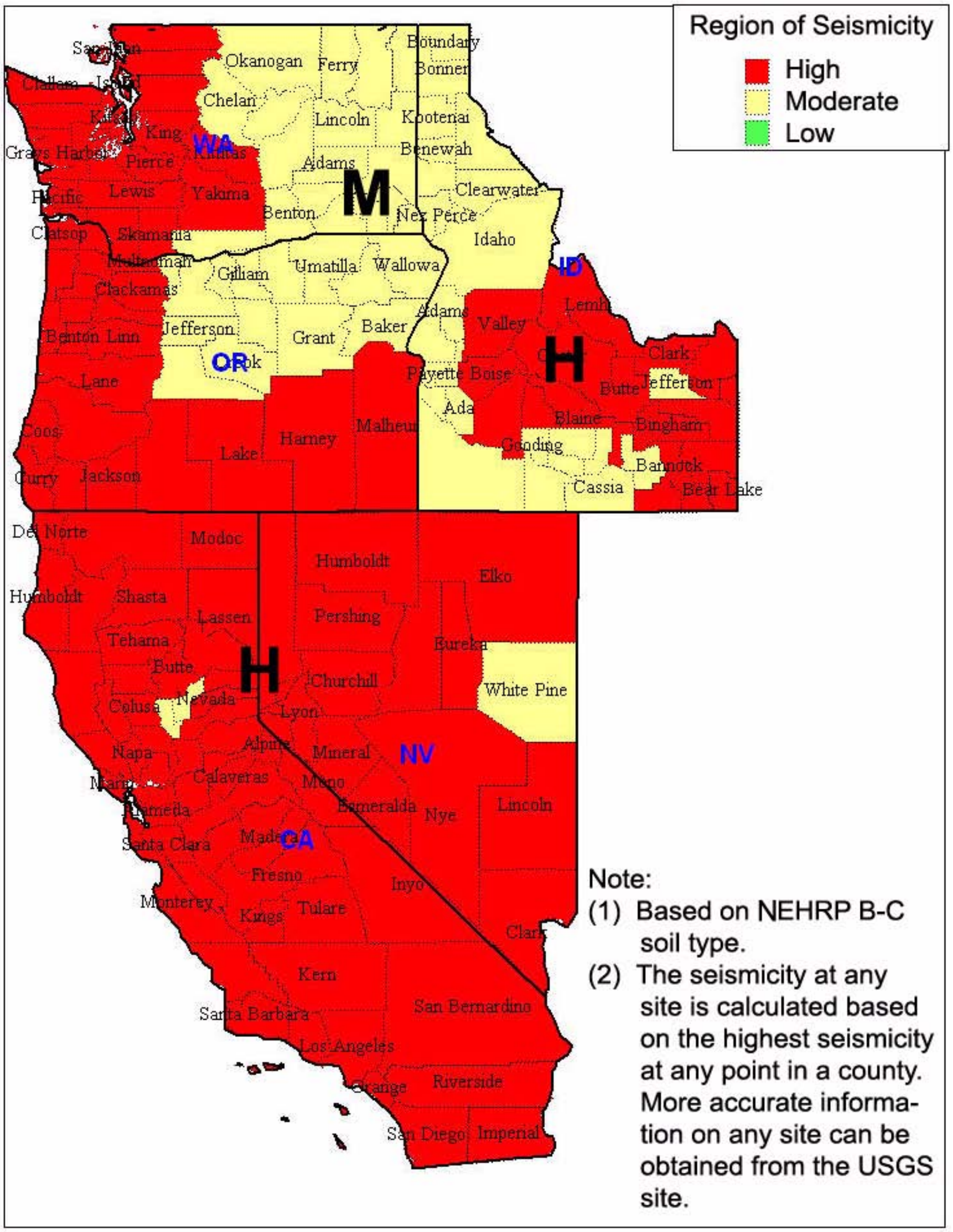


Figure A-2 Seismicity Regions in California, Idaho, Nevada, Oregon, and Washington.

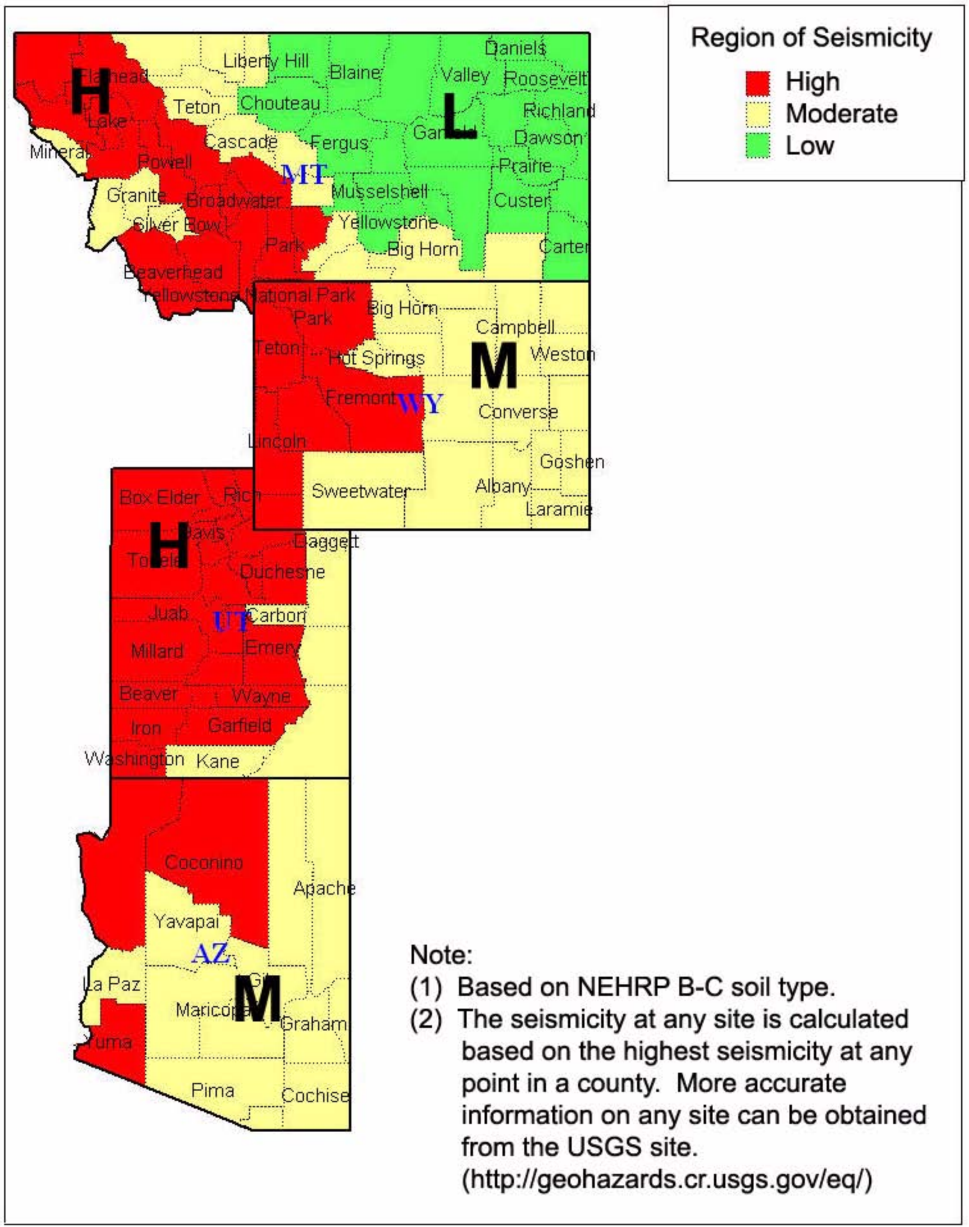


Figure A-3 Seismicity Regions in Arizona, Montana, Utah, and Wyoming.

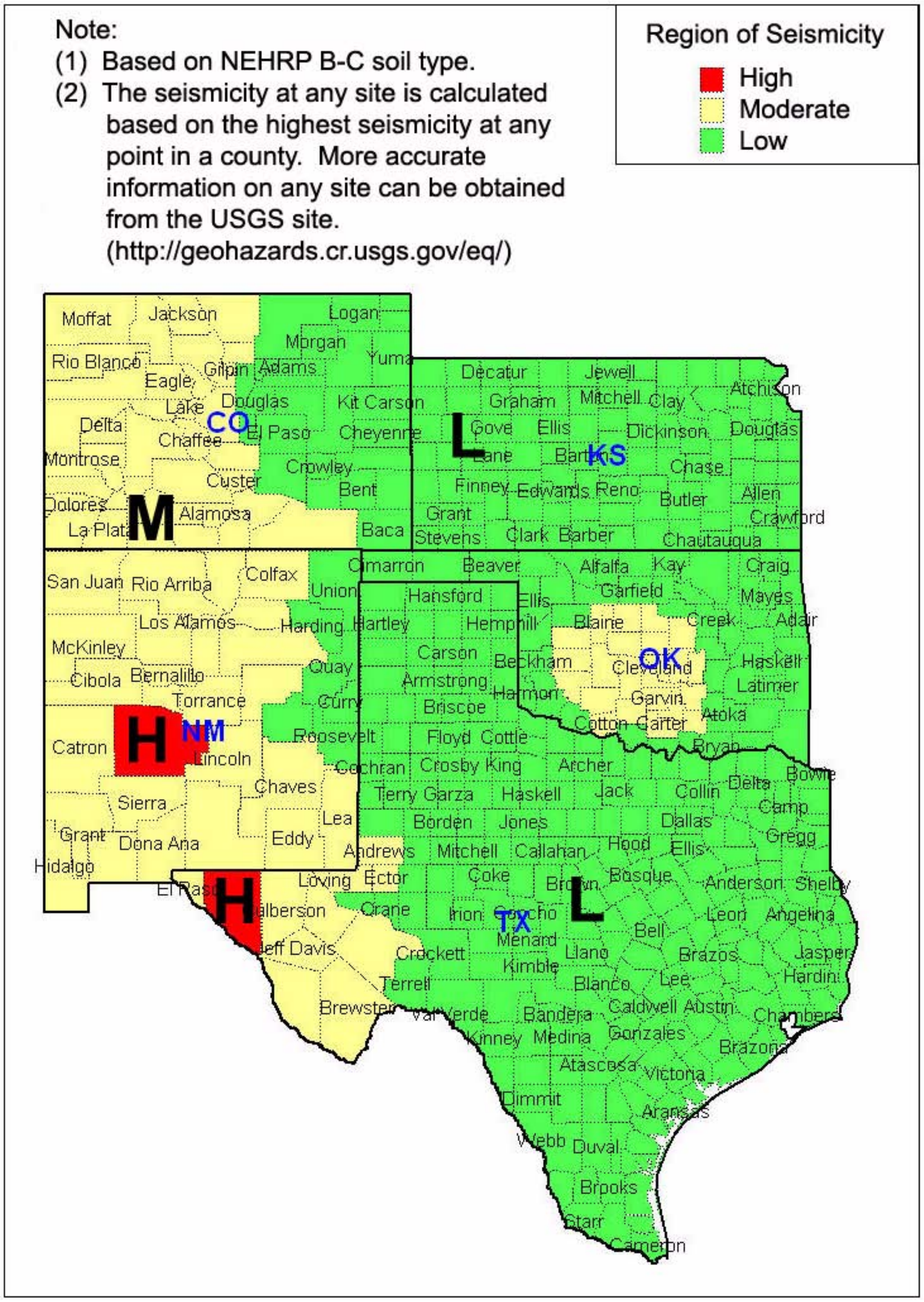


Figure A-4 Seismicity Regions in Colorado, Kansas, New Mexico, Oklahoma, and Texas.

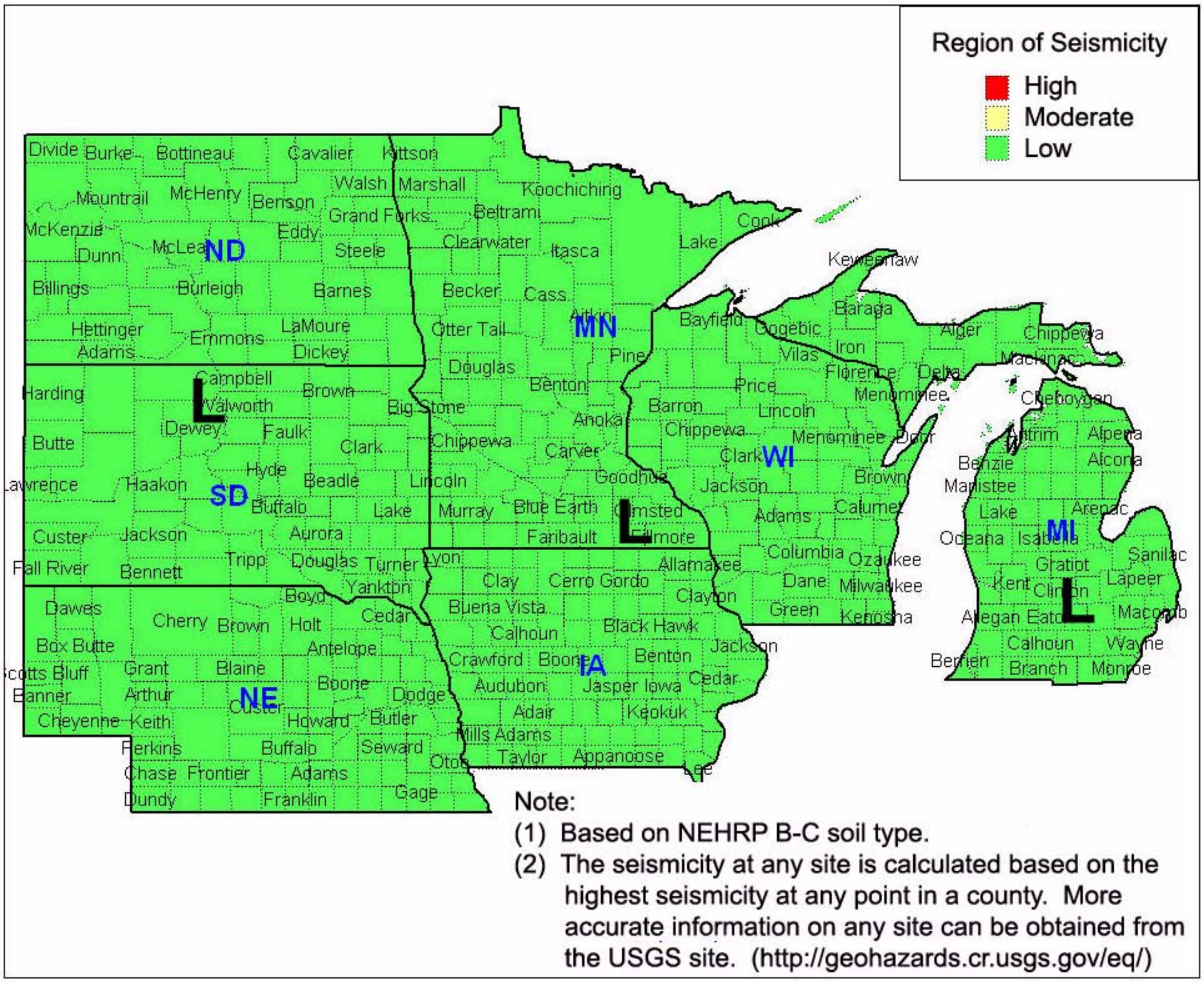


Figure A-5 Seismicity Regions in Iowa, Michigan, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin.

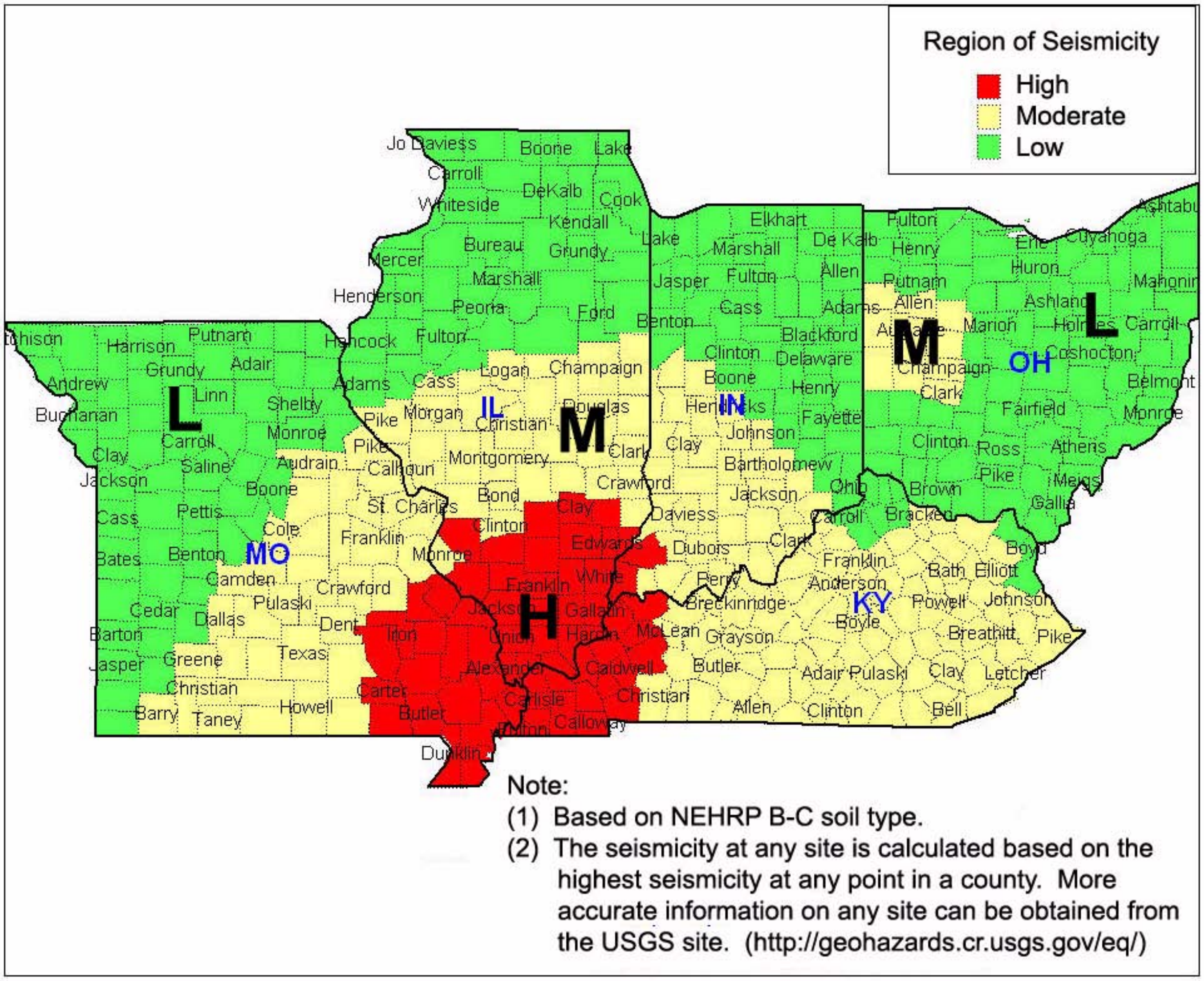


Figure A-6 Seismicity Regions in Illinois, Indiana, Kentucky, Missouri, and Ohio.

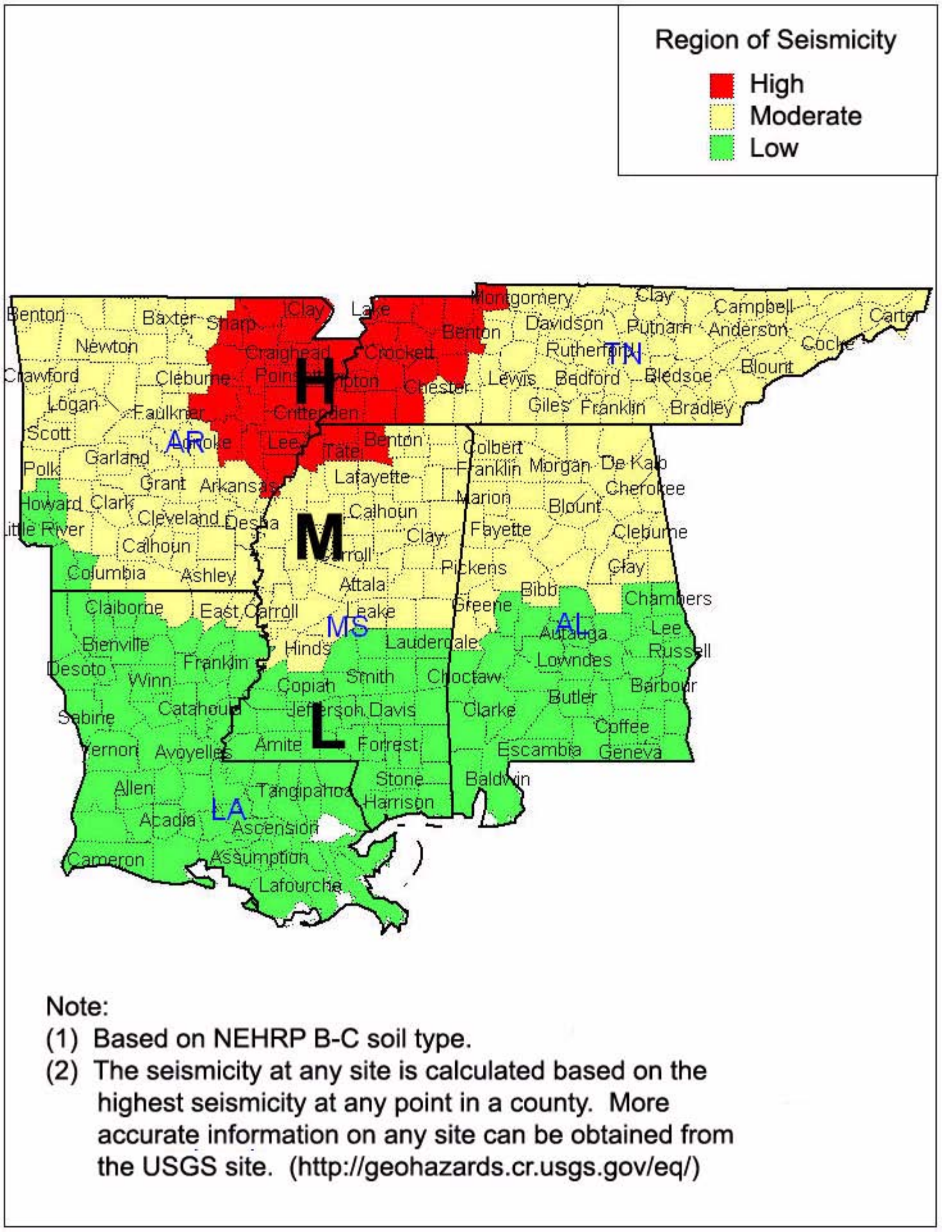


Figure A-7 Seismicity Regions in Alabama, Arkansas, Louisiana, Mississippi, and Tennessee.

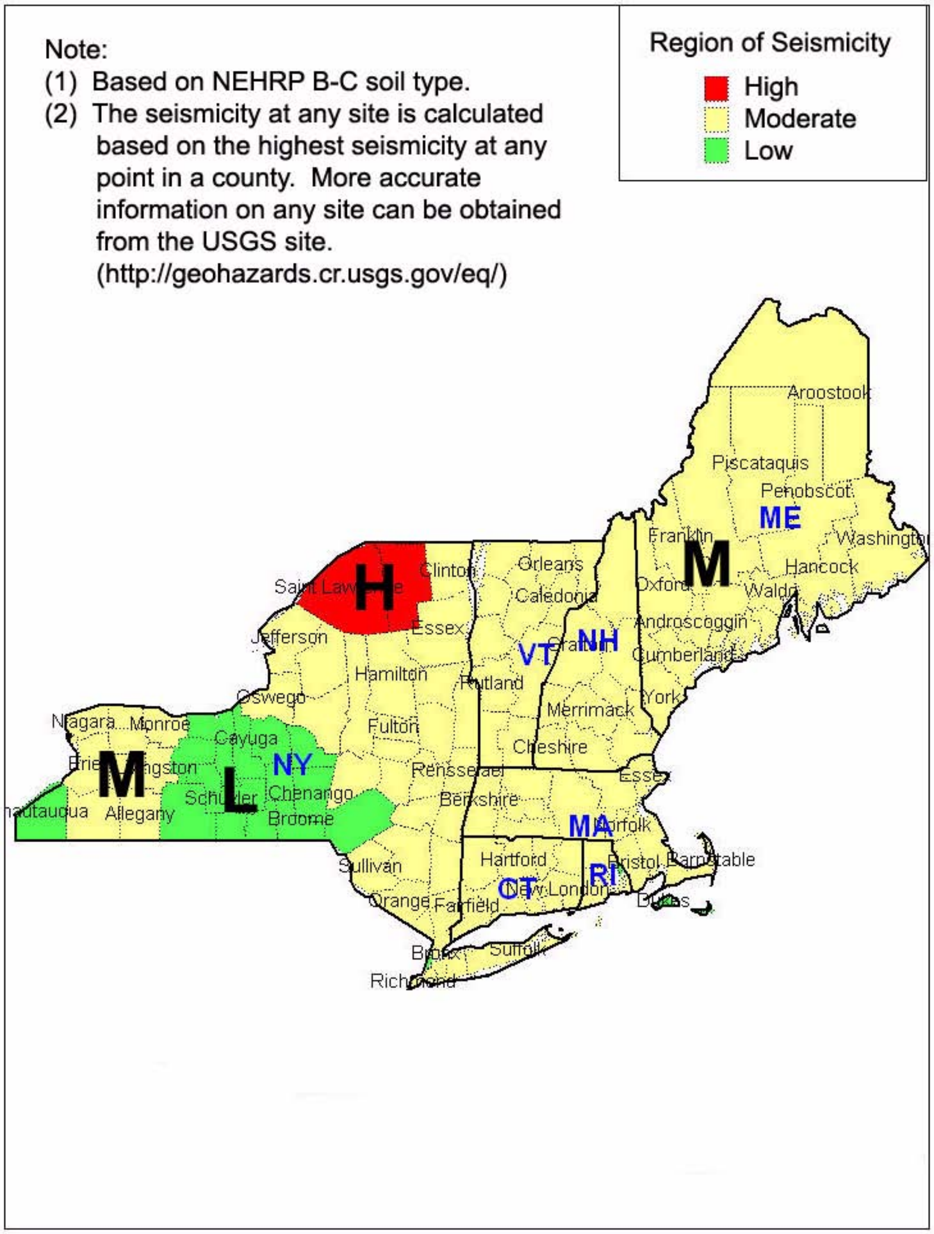


Figure A-8 Seismicity Regions in Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.

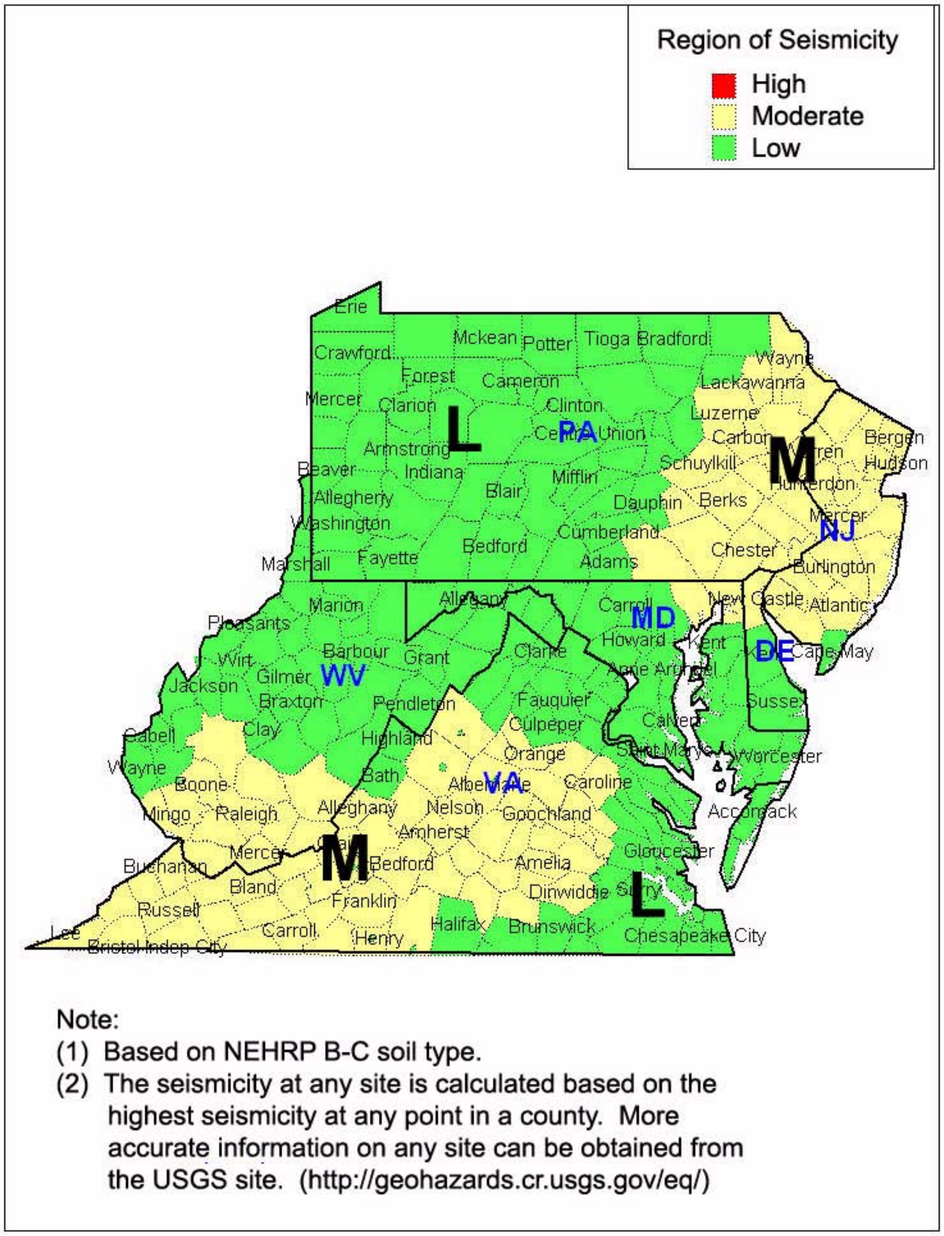


Figure A-9 Seismicity Regions in Delaware, Maryland, New Jersey, Pennsylvania, Virginia, and West Virginia.

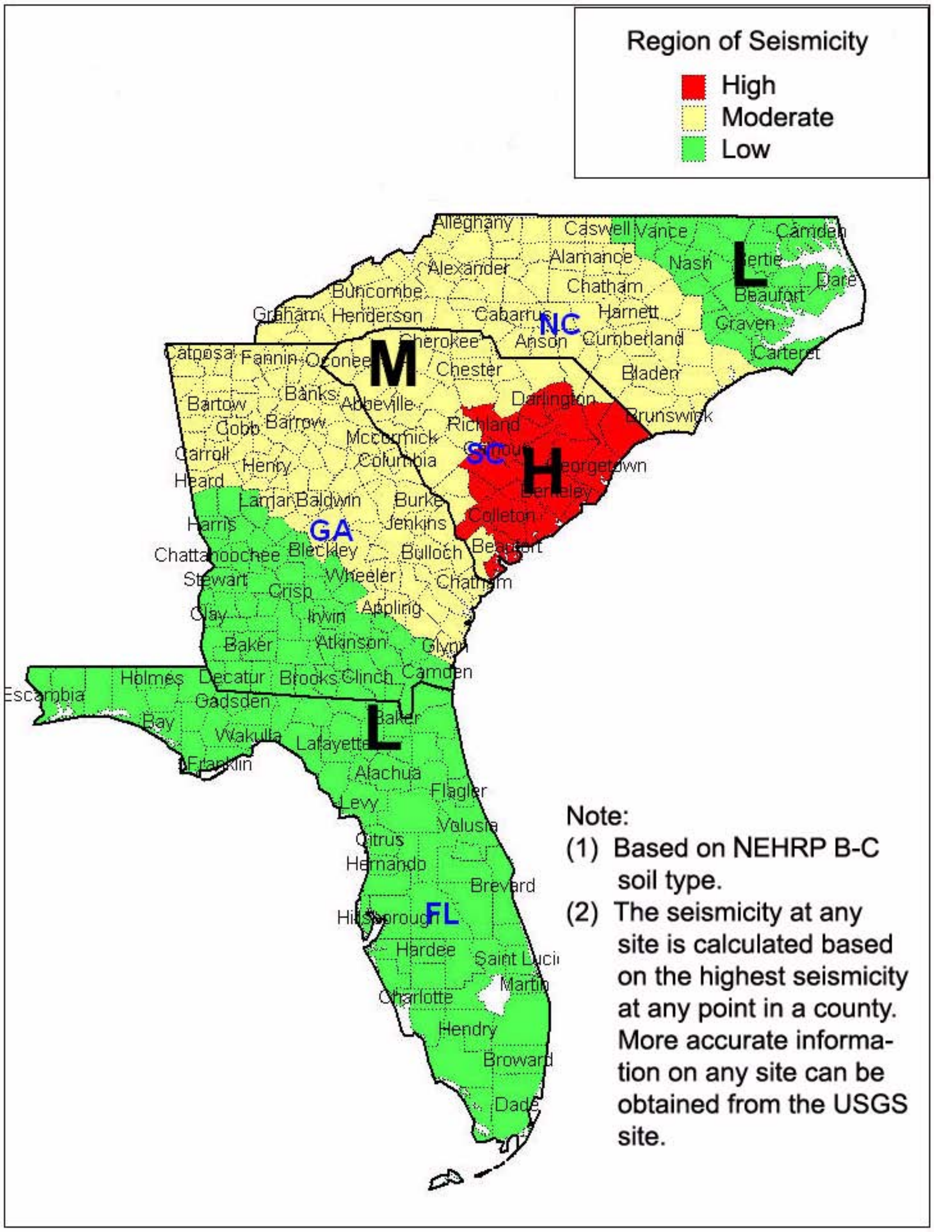


Figure A-10 Seismicity Regions in Florida, Georgia, North Carolina, and South Carolina.

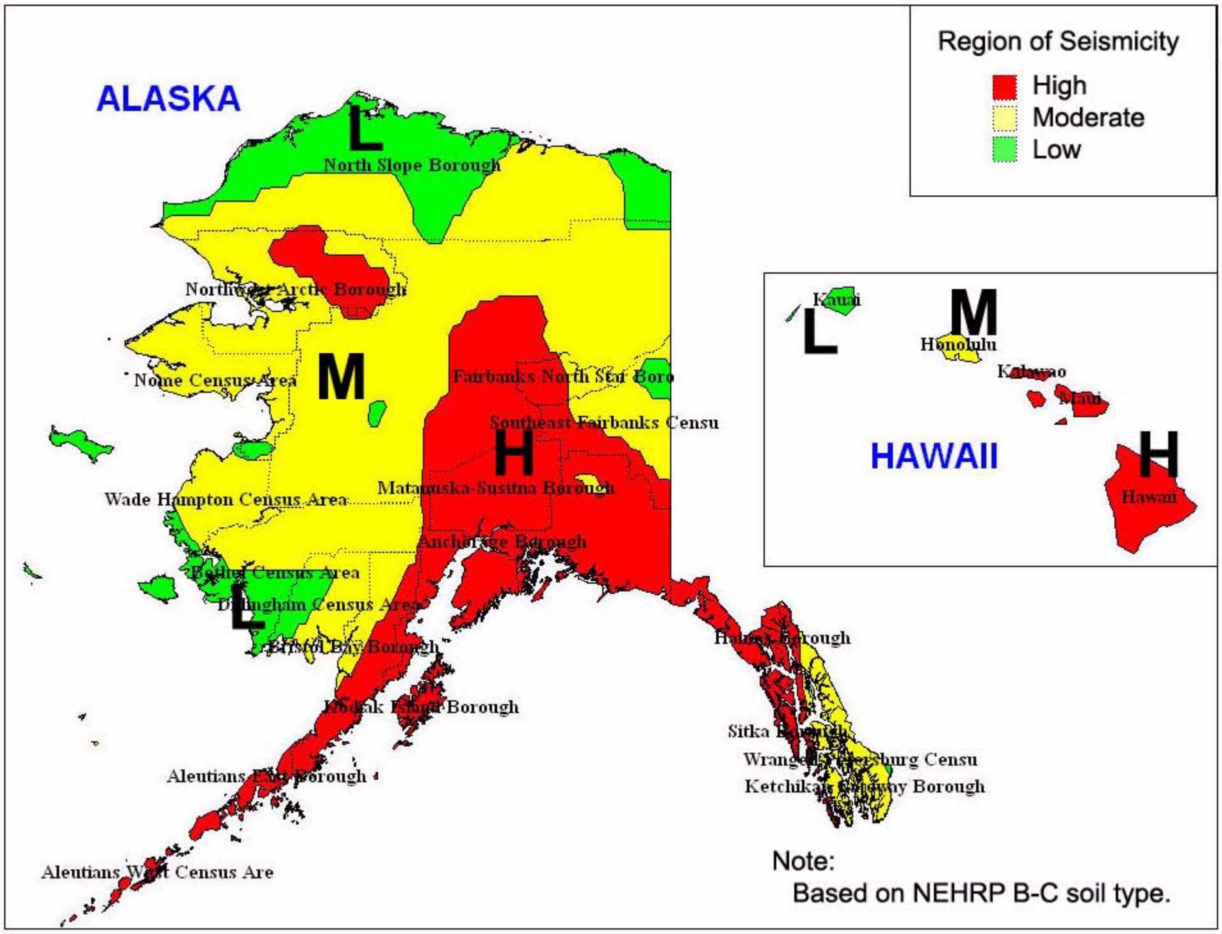


Figure A-11 Seismicity Regions in Alaska and Hawaii.

Appendix B

Data Collection Forms and Quick Reference Guide

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

LOW Seismicity

Address: ____________________

____________________ Zip ________

Other Identifiers ____________________

No. Stories ____________ Year Built ________

Screener ____________ Date ________

Total Floor Area (sq. ft.) ____________

Building Name ____________________

Use ____________________

Scale:

PHOTOGRAPH

OCCUPANCY			SOIL
Assembly	Govt	Office	Number of Persons
Commercial	Historic	Residential	0 – 10 / 11 – 100
Emer. Services	Industrial	School	101-1000 / 1000+

TYPE

A	B	C	D	E	F
Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil

FALLING HAZARDS

☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other: ________

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**7.4**	**6.0**	**4.6**	**4.8**	**4.6**	**4.8**	**5.0**	**4.4**	**4.8**	**4.4**	**4.4**	**4.6**	**4.8**	**4.6**	**4.6**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7 stories)	N/A	N/A	+1.0	+1.0	N/A	+1.0	+1.2	+1.0	0.0	-0.4	N/A	-0.2	N/A	0.0	N/A
Vertical Irregularity	-4.0	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-1.5	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Pre-Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post-Benchmark	0.0	+0.2	+0.4	+0.6	N/A	+0.6	N/A	+0.6	+0.4	N/A	+0.2	N/A	+0.2	+0.4	+0.4
Soil Type C	-0.4	-0.4	-0.8	-0.4	-0.4	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4
Soil Type D	-1.0	-0.8	-1.4	-1.2	-1.0	-1.4	-0.8	-1.4	-0.8	-0.8	-0.8	-1.0	-0.8	-0.8	-0.8
Soil Type E	-1.8	-2.0	-2.0	-2.0	-2.0	-2.2	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

MODERATE Seismicity

Scale:

Address: ____________________

____________________ Zip ________

Other Identifiers ____________________

No. Stories ____________ Year Built ________

Screener ____________ Date ________

Total Floor Area (sq. ft.) ____________________

Building Name ____________________

Use ____________________

PHOTOGRAPH

OCCUPANCY			SOIL	
Assembly	Govt	Office	Number of Persons	
Commercial	Historic	Residential	0 – 10	11 – 100
Emer. Services	Industrial	School	101-1000	1000+

TYPE					
A	B	C	D	E	F
Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil

FALLING HAZARDS

☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other: ________

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**5.2**	**4.8**	**3.6**	**3.6**	**3.8**	**3.6**	**3.6**	**3.0**	**3.6**	**3.2**	**3.2**	**3.2**	**3.6**	**3.4**	**3.4**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

HIGH Seismicity

Scale:

Address: ______________________________

______________________ Zip ________

Other Identifiers ______________________

No. Stories ______________ Year Built ________

Screener ______________ Date ________

Total Floor Area (sq. ft.) ______________

Building Name ______________________

Use ______________________

PHOTOGRAPH

OCCUPANCY			SOIL		TYPE						FALLING HAZARDS			
Assembly	Govt	Office	Number of Persons		A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	☐ Unreinforced Chimneys	☐ Parapets	☐ Cladding	☐ Other: ______
Commercial	Historic	Residential	0 – 10	11 – 100										
Emer. Services	Industrial	School	101-1000	1000+										

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)

Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		Year Seismic Codes Initially Adopted and Enforced*	Benchmark Year when Codes Improved
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	_______	_______
W2	Wood frame buildings, > 5000 square feet.	_______	_______
S1	Steel moment-resisting frame	_______	_______
S2	Steel braced frame	_______	_______
S3	Light metal frame	_______	_______
S4	Steel frame with cast-in-place concrete shear walls	_______	_______
S5	Steel frame with unreinforced masonry infill	_______	_______
C1	Concrete moment-resisting frame	_______	_______
C2	Concrete shear wall	_______	_______
C3	Concrete frame with unreinforced masonry infill	_______	_______
PC1	Tilt-up construction	_______	_______
PC2	Precast concrete frame	_______	_______
RM1	Reinforced masonry with flexible floor and roof diaphragms	_______	_______
RM2	Reinforced masonry with rigid diaphragms	_______	_______
URM	Unreinforced masonry bearing-wall buildings	_______	_______

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: _______

3. Occupancy Loads

Use	Square Feet, Per Person	Use	Square Feet, Per Person
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

4. Score Modifier Definitions

Mid-Rise: 4 to 7 stories

High-Rise: 8 or more stories

Vertical Irregularity: Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.

Plan Irregularity Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).

Pre-Code: Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.

Post-Benchmark: Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).

Soil Type C: Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.

Soil Type D: Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.

Soil Type E: Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

Appendix C

Review of Design and Construction Drawings

Drawing styles vary among engineering offices, but the conventions used are very consistent. The following are some of the common designations:

1. Around the perimeter of the building, the exterior walls will be shown as a double line, if the space between the lines is empty, this will usually be a wood stud wall.
2. Concrete walls will be shaded.
3. Masonry walls will be cross hatched.
4. Horizontal beams and girders will be shown with a solid line for steel and wood, and a double solid or dotted line for concrete.
   - Steel framing will have a notation of shape, depth, and weight of the member. The designations will include W, S, I, B and several others followed by the depth in inches, an "x," and the weight in pounds per lineal foot. An example would be W8x10 (wide flange shape, 8" deep, 10 lbs/ft).
   - Wood framing will have the width and depth of the member. An example would be 4x10 (4" wide and 10" deep). Floor joists and roof rafters will be shown with the same call-out except not all members will be shown. A few at each end of the area being framed will show and there will be an arrow showing the extent and the call-out of the size members.
   - Concrete framing will have the width and depth. Where steel and wood are shown as single line, concrete will be shown as a double line. An example of the call out would be 12x24 (12" wide and 24" deep). Additionally, or in lieu of the number call-out, the member might be given a letter and number (B-1 or G-1) with a reference to a schedule for the size and reinforcing. "B" stands for beam and "G" stands for girder. Usually, beams are smaller than girders and span between girders while girders will be larger and frame between columns.
5. Columns will show on the floor plans as their shape with a shading designation where appropriate:
   - Steel column will be shown as an "H" rotated to the correct orientation for the location on the plan.
   - Wood column will be an open square.
   - Concrete column will be either a square or a circle depending on the column configuration. The square or circle will be shaded.
6. Steel moment frames will show the columns with a heavy line between the columns representing the beam or girder. At each end of the beam or girder at the column will be a small triangle shaded. This indicates that the connection between the beam or girder and the column is fully restrained.

Appendix D

Exterior Screening for Seismic System and Age

D.1 Introduction

A successful evaluation of a building is dependent on the screener's ability to identify accurately the construction materials, lateral-force-resisting system, age, and other attributes that would modify its earthquake performance (e.g., vertical or plan irregularities). This appendix includes discussions of inspection techniques that can be used while viewing from the street.

D.2 What to Look for and How to Find It

It may be difficult to identify positively the structural type from the street as building veneers often mask the structural skeleton. For example, a steel frame and a concrete frame may look similar from the outside. Features typical of a specific type of structure may give clues for successful identification. In some cases there may be more than one type of frame present in the structure. Should this be the case, the predominant frame type should be indicated on the form.

Following are attributes that should be considered when trying to determine a building lateral-force-resisting system from the street:

1. *Age*: The approximate age of a building can indicate the possible structure type, as well as indicating the seismic design code used during the building design process. Age is difficult to determine visually, but an approximation, accurate within perhaps a decade, can be estimated by looking at the architectural style and detail treatment of the building exterior, if the facade has not been renovated. If a building has been renovated, the apparent age is misleading. See Section D.3 for additional guidance.
2. *Facade Pattern*: The type of structure can sometimes be deduced by the openness of the facade, or the size and pattern of window openings. The facade material often can give hints to the structure beneath. Newer facade materials likely indicate that modern construction types were used in the design and may indicate that certain building types can be eliminated.
3. *Height*: The number of stories will indicate the possible type of construction. This is particularly useful for taller buildings, when combined with knowledge of local building practice. See Section D.4 for additional guidance.
4. *Original Use*: The original use can, at times, give hints as to the structural type. The original use can be inferred from the building character, if the building has not been renovated. The present use may be different from the original use. This is especially true in neighborhoods that have changed in character. A typical example of this is where a city's central business district has grown rapidly, and engulfed what were once industrial districts. The buildings' use has changed and they are now either mixed office, commercial or residential (for office workers).

D.3 Identification of Building Age

The ability to identify the age of a building by considering its architectural style and construction materials requires an extensive knowledge of architectural history and past construction practice. It is beyond the scope of this *Handbook* to discuss the various styles and construction practices. Persons involved in or interested in buildings often have a general knowledge of architectural history relevant to their region. Interested readers should refer to in-depth texts for more specific information.

Photographs, architectural character, and age of (1) residential, (2) commercial, and (3) mixed use and miscellaneous buildings, are illustrated in Tables D-1 through D-3, respectively. Photographs of several example steel frame and concrete frame buildings under construction are provided in Figure D-1. The screener should study these photographs and characteristics closely to assist in differentiating architectural styles and facade treatment of various periods. Facade renovation (see photos b and c in Figure D-1) can clearly alter the original appearance. When estimating building age, the screener should look at the building from all sides as facade renovation often occurs only at the building front. A new building will seldom look like an old one. That

Table D-1 Photographs, Architectural Characteristics, and Age of Residential Buildings

Examples	*Characteristics*
 a. 1965-1980  b. 1965-1980	**<u>Low-Rise Buildings (1-3 stories):</u>** • Typically wood or masonry • May have ground floor or basement parking, a soft story • Older buildings typically have more architectural detail, ornamentation • 1950s and later are more ‘modern’ – lacking ornamentation, typically with more horizontal lines Common structural types: W2, RM1, RM2, URM
 c. 1965-1980  d. 1960-1975 reinforced concrete shear wall  e. Pre-1933 URM (rehabilitated)	**<u>Mid-Rise (4-7 stories) and High-Rise Buildings (8 stories and higher):</u>** • Typically, reinforced concrete (older, URM) • May have commercial ground floor, a soft story • Older buildings typically have more cornices, architectural detail, ornamentation • 1950s and later are lacking ornamentation, typically with stronger vertical or horizontal lines Common structural types: W2, RM1, RM2, URM

Table D-2 Illustrations, Architectural Characteristics, and Age of Commercial Structures

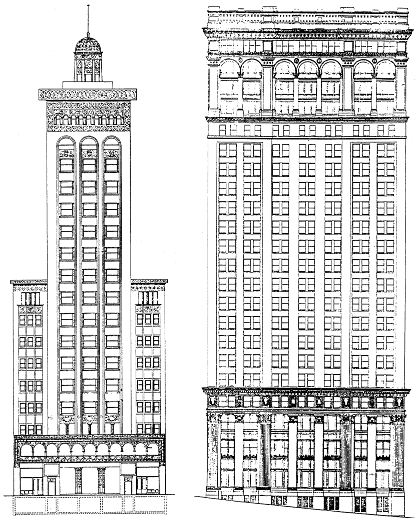
Examples	*Characteristics*
 a. Pre-1930  b. 1910-1920 (Steel frame with unreinforced masonry infill that has been seismically rehabilitated)  c. 1920-1930  d. 1920-1930  e. 1890-1900	**<u>Pre-1950</u>** • Building has flat roof with cornices, or several set-backs. • Ornate decorative work in concrete, terra cotta, cast stone or iron. • Large bell tower or clock tower is common. • Simple pattern of windows on all sides. • Floors are concrete slabs on steel or concrete beams. • Exterior is stone, terra cotta or concrete. Common Structure Types: S2, S5, C2, C3

Table D-2 Illustrations, Architectural Characteristics, and Age of Commercial Structures (Continued)

Examples	*Characteristics*
 f. 44 story, 1960s, L-shape on the left; 20 story, 1914, with setback on the right  g. 1950-1975  h. 1940-1950  i. 1950-1975  j. 1950-1975	<u>**1950-1975**</u> ● Flat roof, typically with no cornice. ● Building is square or rectangular full height, fewer setbacks. ● First story and top story can be taller than other stories. In some cases the top story could be shorter than others. ● Exterior finishes metal or glass, pre-cast stone or concrete. ● Floors are concrete slab over steel or concrete beams. Common Structure Types: S1, S2, S4, C1, C2

Table D-2 Illustrations, Architectural Characteristics, and Age of Commercial Structures (Continued)

<table>
<tr><th>Examples</th><th>Characteristics</th></tr>
<tr><td>

k. Post-1975

l. Post-1975

m. Post-1975

n. Post-1975

o. Post-1975
</td><td>
<u>Post-1975</u>
• Flat roof, typically with no cornice.
• Building is square or rectangular for its full height, fewer setbacks.
• First story and top story can be taller than other stories. (In some cases, though, the top story could be shorter than others.)
• Exterior finishes: metal or glass, pre-cast stone or concrete, with little ornamentation
• Floors are concrete slabs over steel or concrete beams.
Common Structure Types:
S1, S2, S4, C1, C2
</td></tr>
</table>

is, a building is usually at least as old as it looks. Even when designed to look old, telltale signs of modern techniques can usually be seen in the type of windows, fixtures, and material used.

D.4 Identification of Structural Type

The most common inspection that will be utilized with the RVS procedure will be the exterior or "sidewalk" or "streetside" survey. First, the evaluation should be as thorough as possible and performed in a logical manner. The street-facing front of the building is the starting point and the evaluation begins at the ground and progressively moves up the exterior wall to the roof or parapet line. For taller buildings, a pair of binoculars is useful. When a thorough inspection of the street-front elevation has been completed, the procedure is repeated on the next accessible wall. From the exterior, the screener should be able to determine the approximate age of the building, its original occupancy, and count the number of stories.

Table D-3 Photographs, Architectural Characteristics, and Age of Miscellaneous Structures

<table>
<tr><th>Examples</th><th>Characteristics</th></tr>
<tr><td>


a. 1920-1930

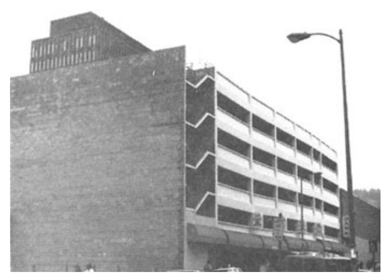
b. 1920-1950

c. 1990-2000

e. 1920-1930; windows create coupled shear walls.

d. 1990-2000; airport terminal

f. Pre-1930



g. 1950 – 1965 parking structure

h. 1920-1930; theater and shops complex, reinforced concrete
</td><td>
Mixed use (residential with a commercial first floor), places of assembly, theatres, triangular buildings, halls, parking structures:

- Long spans
- Tall first story (for commercial use) – soft or weak story
- Atria or irregular floor-to-floor layout
</td></tr>
</table>

a. Building above is a high-rise steel dual system – moment frame (heavy columns and beams on upper facade) with bracing around elevator core. Fireproofing is being applied to steel at mid-height (inside the shroud) and precast facade elements are being attached to frame in lower stories.

b. Reinforced concrete frame under renovation – demolition of older facade units.

c. New precast facade units being applied to reinforced concrete frame buildings.

Figure D-1 Photos showing basic construction, in steel-frame buildings and reinforced concrete-frame buildings.

With this information, Tables D-4 through D-7 provide the most likely structural system type, based on original occupancy and number of stories. (These tables are based on expert judgment and would benefit from verification by design professionals and building regulatory personnel familiar with local design and construction practices.)

In addition to using information on occupancy and number of stories, as provided in Tables D-4 through D-7, the following are some locations that

Table D-4 Most Likely Structural Types for Pre-1930 Buildings

	Number of Stories					
Original Occupancy	*1-2*	*3*	*4-6*	*7-15*	*15-30*	*30+*
Residential	W URM	W URM	S5 C3 URM	S5 C3		
Commercial	W S4 S5 C1 C2 C3 URM	W S4 S5 C1 C2 C3 URM	S1 S2 S4 S5 C1 C2 C3 URM	S1 S2 S4 S5 C1 C2 C3	S1 S2 S4 S5 C1 C2 C3	
Industrial	W S1 S2 S3 S5 C1 C2 C3 URM	W S1 S2 S5 C1 C2 C3 URM				

Note: If it is not possible to identify immediately the structural type for a pre-1930 building, the original occupancy and number of stories will provide some guidance. The building will need further inspection for precise identification.

Table D-5 Most Likely Structural Types for 1930-1945 Buildings

	Number of Stories					
Original Occupancy	*1-2*	*3*	*4-6*	*7-15*	*15-30*	*30+*
Residential	W URM	W URM	S1 S2 S5 URM	S1 S2 S5		
Commercial	W S1 S2 S5 C1 C2 C3 RM1 RM2 URM	W S1 S2 S5 C1 C2 C3 RM1 RM2 URM	S1 S2 S5 C1 C2 C3 RM1 RM2 URM	S1 S2 S5 C1 C2 C3	S1 S2 S5 C1 C2 C3	S2 S5
Industrial	S3 S5 C1 C2 C3 RM1 RM2 URM	S3 S5 C1 C2 C3 RM1 RM2 URM	C1 C2 C3			

Note: If it is not possible to identify immediately the structural type for a 1930-1945 building, the original occupancy and number of stories will provide some guidance. The building will need further inspection for precise identification.

Table D-6 Most Likely Structural Types for 1945-1960 Buildings

	Number of Stories					
Original Occupancy	*1-2*	*3*	*4-6*	*7-15*	*15-30*	*30+*
Residential	W RM URM*	W RM URM*	S1 S2 C1 C2 RM1,2 URM*	S1 S2 C1 C2	S1 S2 C1 C2	S1 S2 C1 C2
Commercial	W S1 S2 C1 C2 RM1,2 URM*	W S1 S2 C1 C2 RM1,2 URM*	S1 S2 C1 C2 RM1 RM2 URM*	S1 S2 C1 C2	S1 S2 C1 C2	S1 S2 C1 C2
Industrial	C1 C2 PC1 RM1 RM2 URM*	S1 S2 C1 C2 RM1,2 URM*	S1 S2 C1 C2 RM1,2 URM*			

Notes: If it is not possible to identify immediately the structural type for a 1945-1960 building, the original occupancy and number of stories will provide some guidance. The building will need further inspection for precise identification.

*By this period, URM was generally not permitted in California or other high-seismicity locations, so that only in the central or eastern U.S. would buildings of this age be URM.

Table D-7 Most Likely Structural Types for Post-1960 Buildings

	Number of Stories					
Original Occupancy	*1-2*	*3*	*4-6*	*7-15*	*15-30*	*30+*
Residential	W S1 S2 C1 C2 PC2 RM1,2	W S1 S2 C1 C2 PC2 RM1,2	W S1 S2 C1 C2 PC2 RM1,2	S1 S2 C1 C2 PC2 RM1 RM2		
Commercial	W S1 S2 C1 C2 PC1 PC2 RM1,2	W S1 S2 C1 C2 PC1 PC2 RM1,2	W S1 S2 C1 C2 PC2 RM1 RM2	S1 S2 C1 C2 PC2 RM1 RM2	S1 S2 C1 C2 PC2	S1 S2 C1 C2
Industrial	S1 S2 S3 C1 C2 PC1 PC2 RM1,2	S1 S2 C1 C2 PC1 PC2 RM1 RM2	S1 S2 C1 C2 PC2 RM1 RM2	S1 S2 C1 C2 PC2	C1 C2 PC2	

Note: If it is not possible to identify immediately the structural type for a post-1960 building, the original occupancy and number of stories will provide some guidance. The building will need further inspection for precise identification.

the screener can look, without performing destructive investigations, to gain insight into the structure type:

1. In newer frame construction the columns are often exposed on the exterior in the first story. If the columns are covered with a facade material, they are most likely steel columns, indicating a steel frame. If the frames are concrete, they are usually exposed and not covered with a facade. See Figures D-2 and D-3.
2. Some structures use a combination of shear walls in the transverse direction and frames in the longitudinal direction. This can be seen from the exterior as the shear walls usually extend through the exterior longitudinal wall and are exposed there. This is most common in hotels and other residential structures where balconies are included. See Figure D-4.
3. An inspection of doorways and window framing can determine wall thickness. When the thickness exceeds approximately 12 inches, the wall is most likely unreinforced masonry (URM).

Figure D-2 Building with exterior columns covered with a facade material.

4. If there are vertical joints in the wall, regularly spaced and extending to the full height, the wall is constructed of concrete, and if three or less stories in height, the structure type is most likely a tilt-up (PC1). See Figure D-5.
5. If the building is constructed of brick masonry without header courses (horizontal rows of visible brick ends), and the wall thickness is approximately 8 inches, the structural type is most likely reinforced masonry (RM1 or RM2). See Figure D-6.

Figure D-3 Detail of the column facade of Figure D-2.

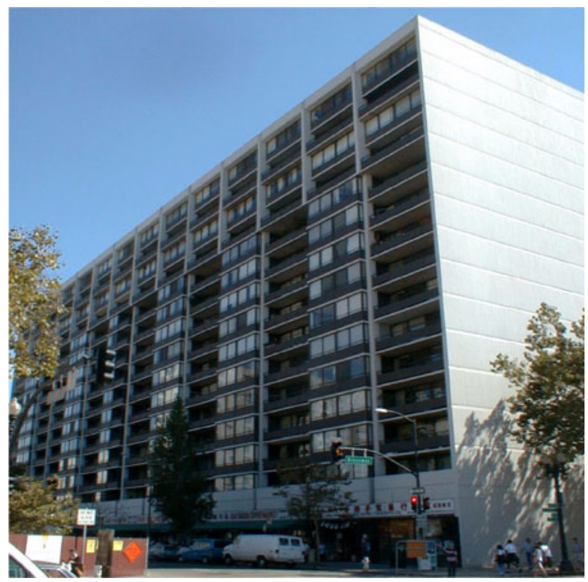


Figure D-4 Building with both shear walls (in the short direction) and frames (in the long direction).

6. If the exterior wall shows large concrete block units (approximately 8 to 12 inches high and 12 to 16 inches in length), either smooth or rough faced, the structure type may be reinforced concrete block masonry. See Figure D-7.

Because many buildings have been renovated, the screener should know where to look for clues to the original construction. Most renovations are done for commercial retail spaces, as businesses like to have an up-to-date image. Most exterior renovations are only to the front of the building or to walls that attract attention. Therefore, the original construction

Figure D-5 Regular, full-height joints in a building's wall indicate a concrete tilt-up.

Figure D-6 Reinforced masonry wall showing no course of header bricks (a row of visible brick ends).

can often be seen at the sides, or the rear, where people generally do not look. If the original material is covered in these areas, it is often just painted or lightly plastered. In this case, the pattern of the older material can often still be seen.

Clues helping identify the original material are apparent if one is looking for them. Two examples are included here:

- Figure D-8 shows a building with a 1970s polished stone and glass facade. The side of the building indicates that it is a pre-1930 URM bearing-wall structure.
- Figure D-9 shows a building facade with typical 1960s material. The side was painted. Showing through the paint, the horizontal board patterns in the poured-in-place concrete wall of pre-1940 construction could still be seen.

Figure D-7 Reinforced masonry building with exterior wall of concrete masonry units, or concrete blocks.

Figure D-8 A 1970s renovated facade hides a URM bearing-wall structure.

D.5 Characteristics of Exposed Construction Materials

Accurate identification of the structural type often depends on the ability to recognize the exposed construction material. The screener should be familiar

Figure D-9 A concrete shear-wall structure with a 1960s renovated facade.

Figure D-10 URM wall showing header courses (identified by arrows) and two washer plates indicating wall anchors.

with how different materials look on existing buildings as well as how they have been installed. Brief descriptions of some common materials are included here:

- *Unreinforced Masonry*—Unreinforced masonry walls, when they are not veneers, are typically several wythes thick (a wythe is a term denoting the width of one brick). Therefore, header bricks will be apparent in the exposed surface. Headers are bricks laid with the butt end on the exterior face, and function to tie wythes of bricks together. Header courses typically occur every six or seven courses. (See Figures D-10 and D-11.) Sometimes, URM infill walls will not have header bricks, and the wythes of brick are held together only by mortar. Needless to say, URM will look old, and most of the time show wear and weathering. URM may also have a soft sand-lime mortar which may be detected by scratching with a knife, unless the masonry has been repointed.
- *Reinforced Masonry*—Most reinforced brick walls are constructed using the hollow grout method. Two wythes of bricks are laid with a hollow space in between. This space contains the reinforcement steel and is grouted afterward (see Figure D-12). This method of construction usually does not include header bricks in the wall surface.
- *Masonry Veneer*—Masonry veneers can be of several types, including prefabricated panels, thin brick texture tiles, and a single wythe of brick applied onto the structural backing. Figures D-13 shows brick veneer panels. Note the discontinuity of the brick pattern interrupted by the vertica1 gaps. This indicates that the surface is probably a veneer panel. The scupper opening at the top of the wall, probably to let the rainwater on the roof to drain, also indicates that this is a thin veneer rather than a solid masonry

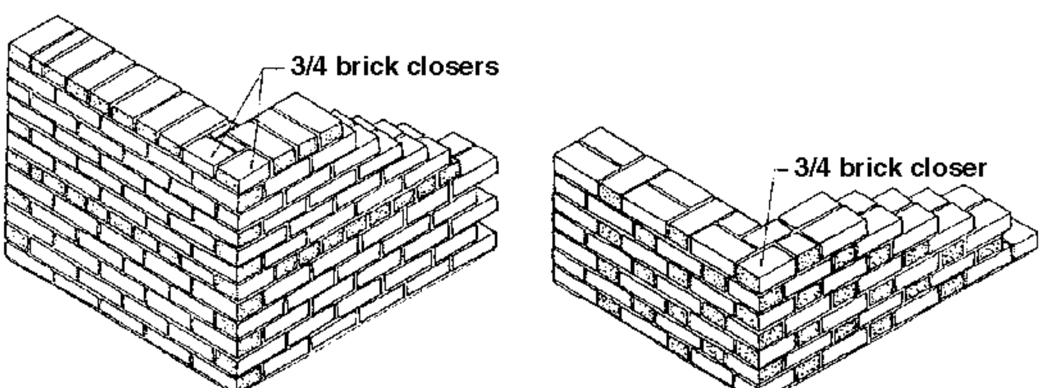


Figure D-11 Drawing of two types of masonry pattern showing header bricks (shown with stipples).

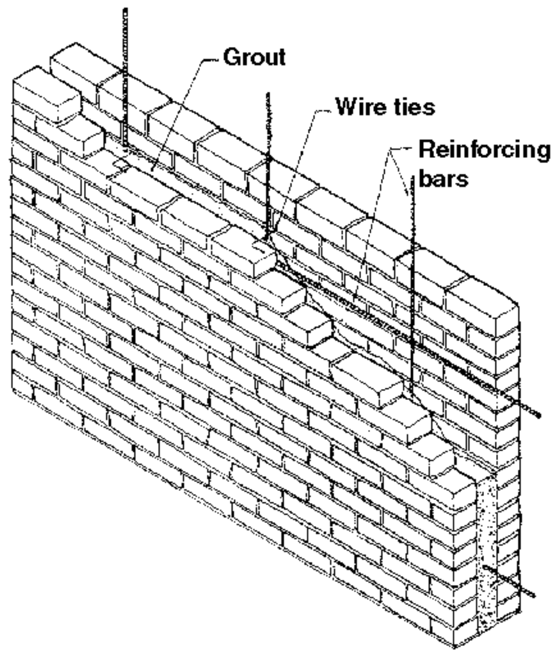


Figure D-12 Diagram of common reinforced masonry construction. Bricks are left out of the bottom course at intervals to create cleanout holes, then inserted before grouting.

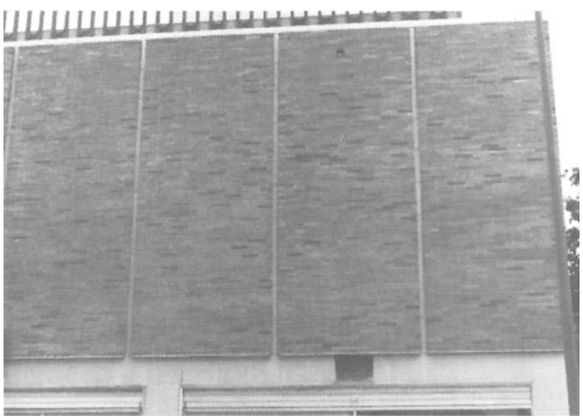


Figure D-13 Brick veneer panels.

wall. Good places to look for the evidence of veneer tile are at door or window openings where the edge of the tile will usually show.

- *Hollow Clay Tile*—The exposed area of a hollow clay tile masonry unit is approximately 6 inches by 10 inches and often has strip indentations running the length of the tile. They are fragile, unreinforced, and without structural value, and usually are used for non-load-bearing walls.

Figure D-14 Hollow clay tile wall with punctured tile.

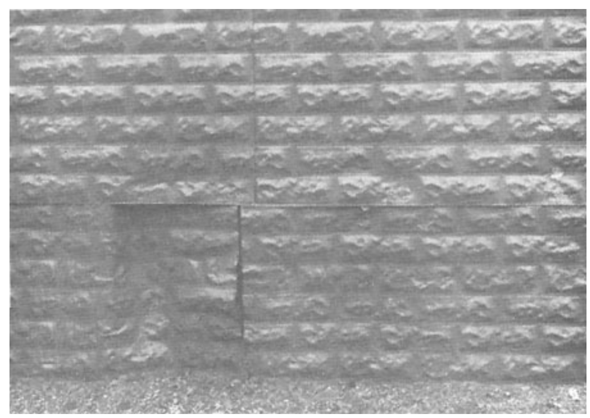


Figure D-15 Sheet metal siding with masonry pattern.

Figure D-14 shows a typical wall panel which has been punctured.

- *False Masonry*—Masonry pattern sidings can be made from sheet metal, plastic, or asphalt material (see Figures D-15 and D-16). These sidings come in sheets and are attached to a structural backing, usually a wood frame. These sidings can be detected by looking at the edges and by their sound when tapped.
- *Cast-in-Place Concrete*—Cast-in-place concrete, before the 1940s, will likely show horizontal patterns from the wooden formwork. The formwork was constructed with wood planks, and therefore the concrete also will often show the wood grain pattern. Since the plank edges were not smooth,

the surface will have horizontal lines approximately 4, 6, 8, 10, or 12 inches apart (see Figure D-17). Newer cast-in-place concrete comes in various finishes. The most economic finish is that in which the concrete is cast against plywood formwork, which will reflect the wood grain appearance of plywood, or against metal or plastic-covered wood forms, which normally do not show a distinctive pattern.

Figure D-16 Asphalt siding with brick pattern.

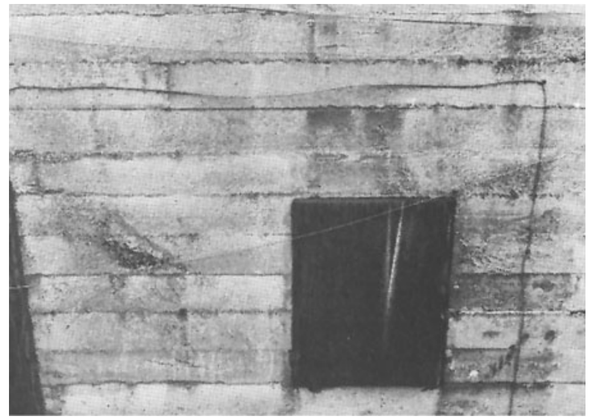


Figure D-17 Pre-1940 cast-in-place concrete with formwork pattern.

Appendix E

Characteristics and Earthquake Performance of RVS Building Types

E.1 Introduction

For the purpose of the RVS, building structural framing types have been categorized into fifteen types listed in Section 3.7.1 and shown in Table 3-1. This appendix provides additional information about each of these structural types, including detailed descriptions of their characteristics, common types of earthquake damage, and common seismic rehabilitation techniques.

E.2 Wood Frame (W1, W2)

E.2.1 Characteristics

Wood frame structures are usually detached residential dwellings, small apartments, commercial buildings or one-story industrial structures. They are rarely more than three stories tall, although older buildings may be as high as six stories, in rare instances. (See Figures E-1 and E-2)

Figure E-1 Single family residence (an example of the W1 identifier, light wood-frame residential and commercial buildings less than 5000 square feet).

Wood stud walls are typically constructed of 2-inch by 4-inch wood members vertically set about 16 inches apart. (See Figures E-3 and E-4). These walls are braced by plywood or equivalent material, or by diagonals made of wood or steel. Many detached single family and low-rise multiple family residences in the United States are of stud wall wood frame construction.

Figure E-2 Larger wood-framed structure, typically with room-width spans (W2, light, wood-frame buildings greater than 5000 square feet).

Post and beam construction, which consists of larger rectangular (6 inch by 6 inch and larger) or sometimes round wood columns framed together with large wood beams or trusses, is not common and is found mostly in older buildings. These buildings usually are not residential, but are larger buildings such as warehouses, churches and theaters.

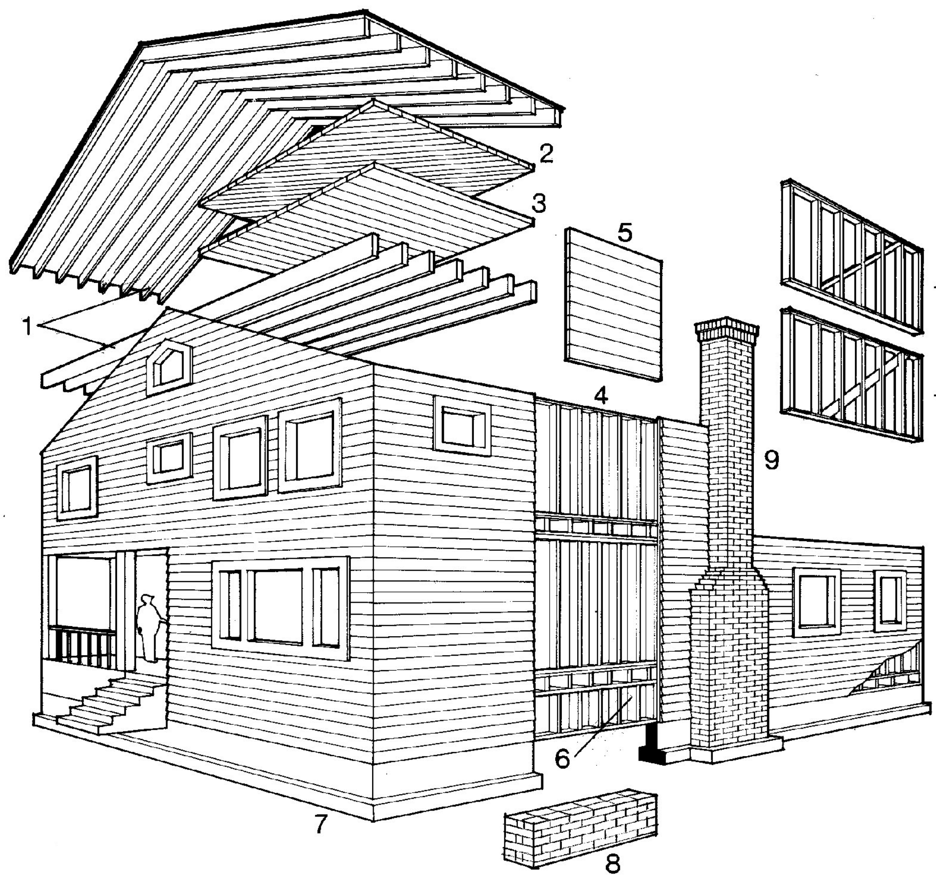
Timber pole buildings (Figures E-5 and E-6) are a less common form of construction found mostly in suburban and rural areas. Generally adequate seismically when first built, they are more often subject to wood deterioration due to the exposure of the columns, particularly near the ground surface. Together with an often-found “soft story” in this building type, this deterioration may contribute to unsatisfactory seismic performance.

In the western United States, it can be assumed that all single detached residential houses (i.e., houses with rear and sides separate from adjacent structures) are wood stud frame structures unless visual or supplemental information indicates otherwise (in the Southwestern U.S., for example, some residential homes are constructed of adobe, rammed earth, and other non-wood materials). Many houses that appear to have brick exterior facades are actually wood frame with nonstructural brick veneer or brick-patterned synthetic siding.

In the central and eastern United States, brick walls are usually not veneer. For these houses the

Roof and span systems:
1. wood joist and rafter
2. diagonal sheathing
3. straight sheathing

Wall systems:
4. stud wall (platform or balloon framed)
5. horizontal siding



Foundations and connections:
6. unbraced cripple wall
7. concrete foundation
8. brick foundation

Bracing and details:
9. unreinforced brick chimney
10. diagonal blocking
11. let-in brace (only in later years)

Figure E-3 Drawing of wood stud frame construction.

brick-work must be examined closely to verify that it is real brick. Second, the thickness of the exterior wall is estimated by looking at a window or door opening. If the wall is more than 9 inches from the interior finish to exterior surface, then it may be a brick wall. Third, if header bricks exist in the brick pattern, then it may be a brick wall. If these features all point to a brick wall, the house can be assumed to be a masonry building, and not a wood frame.

In wetter, humid climates it is common to find homes raised four feet or more above the outside grade with this space totally exposed (no foundation walls). This allows air flow under the house, to minimize decay and rot problems associated with high humidity and enclosed spaces. These houses are supported on wood post and small precast concrete pads or piers. A common name for this construction is post and pier construction.

E.2.2 Typical Earthquake Damage

Stud wall buildings have performed well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low-rise. Cracks in any plaster or stucco may appear, but these seldom degrade the strength of the building and are classified as nonstructural damage. In fact, this

Figure E-4 Stud wall, wood-framed house.

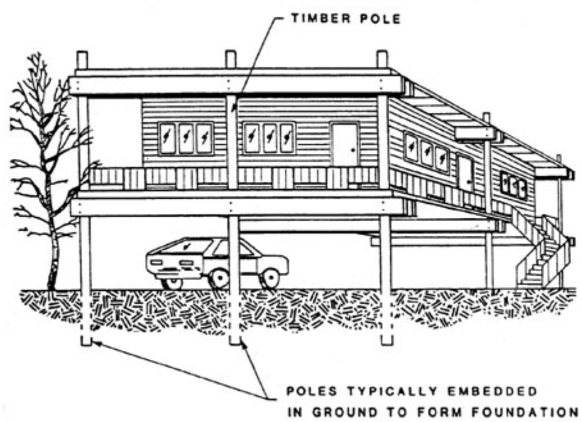


Figure E-5 Drawing of timber pole framed house.

Figure E-6 Timber pole framed house.

type of damage helps dissipate the earthquake-induced energy of the shaking house. The most common type of structural damage in older buildings results from a lack of adequate connection between the house and the foundation. Houses can slide off their foundations if they are not properly bolted to the foundations. This movement (see Figure E-7) results in major damage to the building as well as to plumbing and electrical connections. Overturning of

Figure E-7 House off its foundation, 1983 Coalinga earthquake.

the entire structure is usually not a problem because of the low-rise geometry. In many municipalities, modern codes require wood structures to be adequately bolted to their foundations. However, the year that this practice was adopted will differ from community to community and should be checked.

Many of the older wood stud frame buildings have no foundations or have weak foundations of unreinforced masonry or poorly reinforced concrete. These foundations have poor shear resistance to horizontal seismic forces and can fail.

Another problem in older buildings is the stability of cripple walls. Cripple walls are short stud walls between the foundation and the first floor level. Often these have no bracing neither in-plane nor out-of-plane and thus may collapse when subjected to horizontal earthquake loading. If the cripple walls collapse, the house will sustain considerable damage and may collapse. In some older homes, plywood sheathing nailed to the cripple studs may have been used to rehabilitate the cripple walls. However, if the sheathing is not nailed adequately to the studs and

Figure E-8 Failed cripple stud wall, 1992 Big Bear earthquake.

foundation sill plate, the cripple walls will still collapse (see Figure E-8).

Homes with post and pier perimeter foundations, which are constructed to provide adequate air flow under the structure to minimize the potential for decay, have little resistance to earthquake forces. When these buildings are subjected to strong earthquake ground motions, the posts may rotate or slip of the piers and the home will settle to the ground. As with collapsed cripple walls, this can be very expensive damage to repair and will result in the home building "red-tagged" per the ATC-20 post-earthquake safety evaluation procedures (ATC, 1989, 1995). See Figure E-9.

Figure E-9 Failure of post and pier foundation, Humboldt County.

Garages often have a large door opening in the front wall with little or no bracing in the remainder of the wall. This wall has almost no resistance to lateral forces, which is a problem if a heavy load such as a second story is built on top of the garage. Homes built over garages have sustained damage in past earthquakes, with many collapses. Therefore the house-over-garage configuration, which is found commonly in low-rise apartment complexes and some newer suburban detached dwellings, should be examined more carefully and perhaps rehabilitated.

Unreinforced masonry chimneys present a life-safety problem. They are often inadequately tied to the house, and therefore fall when strongly shaken. On the other hand, chimneys of reinforced masonry generally perform well.

Some wood-frame structures, especially older buildings in the eastern United States, have masonry veneers that may represent another hazard. The veneer usually consists of one wythe of brick (a wythe is a term denoting the width of one brick) attached to the stud wall. In older buildings, the veneer is either insufficiently attached or has poor quality mortar, which often results in peeling of the veneer during moderate and large earthquakes.

Post and beam buildings (not buildings with post and pier foundations) tend to perform well in earthquakes, if adequately braced. However, walls often do not have sufficient bracing to resist horizontal motion and thus they may deform excessively.

E.2.3 Common Rehabilitation Techniques

In recent years, especially as a result of the Northridge earthquake, emphasis has been placed on addressing the common problems associated with light-wood framing. This work has concentrated mainly in the western United States with single-family residences.

The rehabilitation techniques focus on houses with continuous perimeter foundations and cripple walls. The rehabilitation work consists of bolting the house to the foundation and providing plywood or other wood sheathing materials to the cripple walls to strengthen them (see Figure E-10). This is the most cost-effective rehabilitation work that can be done on a single-family residence.

Little work has been done in rehabilitating timber pole buildings or post and pier construction. In timber pole buildings rehabilitation techniques are focused on providing resistance to lateral forces by bracing (applying sheathing) to interior walls, creating a continuous load path to the ground. For homes with post and pier perimeter foundations, the work has focused on providing partial foundations and bracing to carry the earthquake loads.

Figure E-10 Seismic strengthening of a cripple wall, with plywood sheathing.

E.3 Steel Frames (S1, S2)

E.3.1 Characteristics

Steel frame buildings generally may be classified as either moment-resisting frames or braced frames, based on their lateral-force-resisting systems. Moment-resisting frames resist lateral loads and deformations by the bending stiffness of the beams and columns (there is no diagonal bracing). In concentric braced frames the diagonal braces are connected, at each end, to the joints where beams and columns meet. The lateral forces or loads are resisted by the tensile and compressive strength of the bracing. In eccentric braced frames, the bracing is slightly offset from the main beam-to-column connections, and the short section of beam is expected to deform significantly in bending under major seismic forces, thereby dissipating a considerable portion of the energy of the vibrating building. Each type of steel frame is discussed below.

Moment-Resisting Steel Frame

Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal direction, around 20-30 ft (Figure E-11). The load-bearing frame consists of beams and columns distributed throughout the building. The floor diaphragms are usually concrete,

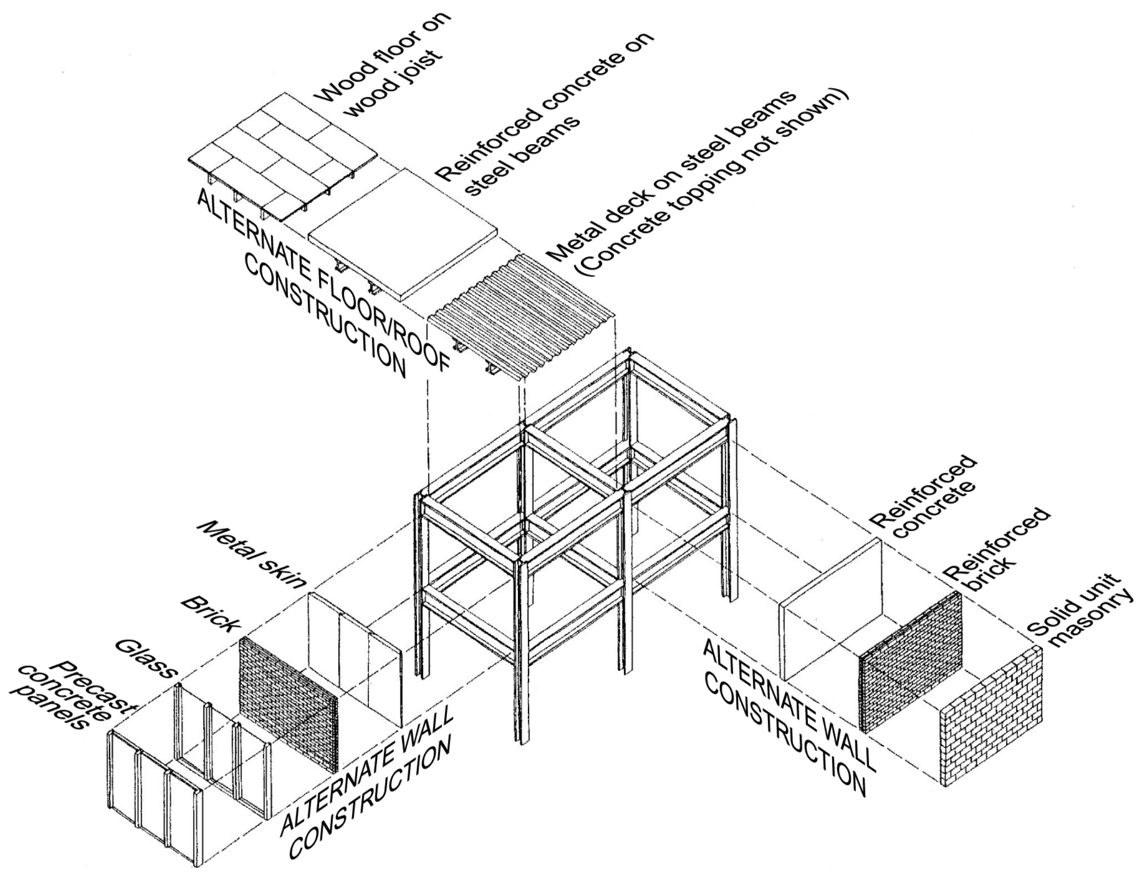


Figure E-11 Drawing of steel moment-resisting frame building.

sometimes over steel decking. Moment-resisting frame structures built since 1950 often incorporate prefabricated panels hung onto the structural frame as the exterior finish. These panels may be precast concrete, stone or masonry veneer, metal, glass or plastic.

This structural type is used for commercial, institutional and other public buildings. It is seldom used for low-rise residential buildings.

Steel frame structures built before 1945 are usually clad or infilled with unreinforced masonry such as bricks, hollow clay tiles and terra cotta tiles and therefore should be classified as S5 structures (see Section E.6 for a detailed discussion). Other frame buildings of this period are encased in concrete. Wood or concrete floor diaphragms are common for these older buildings.

Braced Steel Frame

Braced steel frame structures (Figures E-12 and E-13) have been built since the late 1800s with similar usage and exterior finish as the steel moment-frame buildings. Braced frames are sometimes used for long and narrow buildings because of their stiffness. Although these buildings are braced with diagonal members, the bracing members usually cannot be detected from the building exterior.

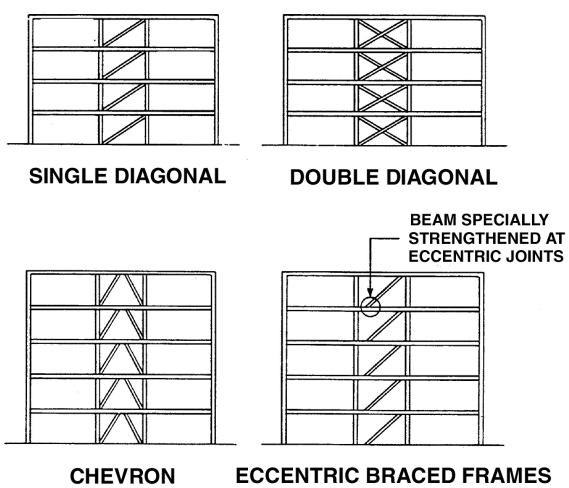


Figure E-12 Braced frame configurations.

From the building exterior, it is usually difficult to tell the difference between steel moment frames, braced frames, and frames with shear walls. In most modern buildings, the bracing or shear walls are located in the interior or covered by cladding material. Figure E-14 shows heavy diagonal bracing for a high rise building, located at the side walls, which

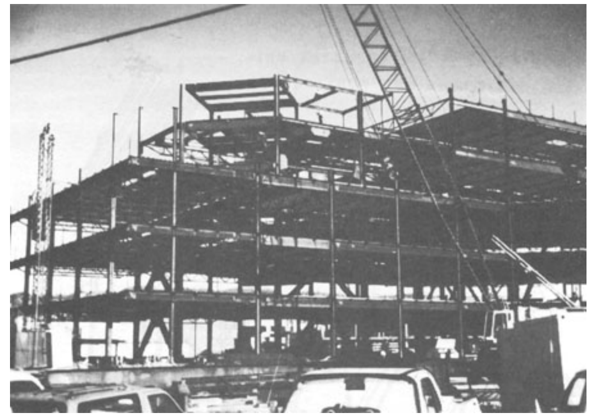


Figure E-13 Braced steel frame, with chevron and diagonal braces. The braces and steel frames are usually covered by finish material after the steel is erected.

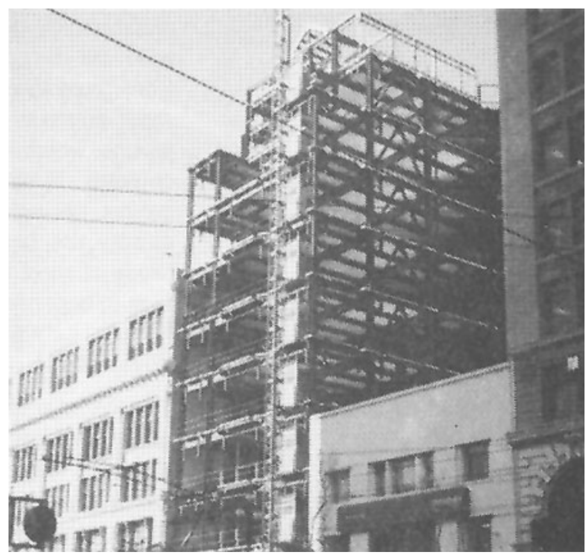


Figure E-14 Chevron bracing in steel building under construction.

will be subsequently covered by finish materials and will not be apparent. In fact, it is difficult to differentiate steel frame structures and concrete frame structures from the exterior. Most of the time, the structural members are clad in finish material. In older buildings, steel members can also be encased in concrete. There are no positive ways of distinguishing these various frame types except in the two cases listed below:

1. If a building can be determined to be a braced frame, it is probably a steel structure.

2. If exposed steel beams and columns can be seen, then the steel frame structure is apparent. (Especially in older structures, a structural frame which appears to be concrete may actually be a steel frame encased in concrete.)

E.3.2 Typical Earthquake Damage

Steel frame buildings tend to be generally satisfactory in their earthquake resistance, because of their strength, flexibility and lightness. Collapse in earthquakes has been very rare, although steel frame buildings did collapse, for example, in the 1985 Mexico City earthquake. In the United States, these buildings have performed well, and probably will not collapse unless subjected to sufficiently severe ground shaking. The 1994 Northridge and 1995 Kobe earthquakes showed that steel frame buildings (in particular S1 moment-frame) were vulnerable to severe earthquake damage. Though none of the damaged buildings collapsed, they were rendered unsafe until repaired. The damage took the form of broken welded connections between the beams and columns. Cracks in the welds began inside the welds where the beam flanges were welded to the column flanges. These cracks, in some cases, broke the welds or propagated into the column flange, "tearing" the flange. The damage was found in those buildings that experienced ground accelerations of approximately 20% of gravity (20%g) or greater. Since 1994 Northridge, many cities that experienced large earthquakes in the recent past have instituted an inspection program to determine if any steel frames were damaged. Since steel frames are usually covered with a finish material, it is difficult to find damage to the joints. The process requires removal of the finishes and removal of fireproofing just to see the joint.

Possible damage includes the following.

1. Nonstructural damage resulting from excessive deflections in frame structures can occur to elements such as interior partitions, equipment, and exterior cladding. Damage to nonstructural elements was the reason for the discovery of damage to moment frames as a result of the 1994 Northridge earthquake.
2. Cladding and exterior finish material can fall if insufficiently or incorrectly connected.
3. Plastic deformation of structural members can cause permanent displacements.
4. Pounding with adjacent structures can occur.

E.3.3 Common Rehabilitation Techniques

As a result of the 1994 Northridge earthquake many steel frame buildings, primarily steel moment frames, have been rehabilitated to address the problems discovered. The process is essentially to redo the connections, ensuring that cracks do not occur in the welds. There is careful inspection of the welding process and the electrodes during construction. Where possible, existing full penetration welds of the beams to the columns is changed so more fillet welding is used. This means that less heat is used in the welding process and consequently there is less potential for damage. Other methods include reducing welding to an absolute minimum by developing bolted connections or ensuring that the connection plates will yield (stretch permanently) before the welds will break. One other possibility for rehabilitating moment frames is to convert them to braced frames.

Figure E-15 Rehabilitation of a concrete parking structure using exterior X-braced steel frames.

The kind of damage discovered was not limited to moment frames, although they were the most affected. Some braced frames were found to have damage to the brace connections, especially at lower levels.

Structural types other than steel frames are sometimes rehabilitated using steel frames, as shown for the concrete structure in Figure E-15. Probably the most common use of steel frames for rehabilitation is in unreinforced masonry bearing-wall buildings (URM). Steel frames are typically used at the storefront windows as there is no available horizontal resistance provided by the windows in their plane. Frames can be used throughout the first floor perimeter when the floor area needs to be open, as in a restaurant. See Figure E-16.

When a building is encountered with this type of rehabilitation scheme, the building should be considered a frame type building S1 or S2.

E.4 Light Metal (S3)

E.4.1 Characteristics

Most light metal buildings existing today were built after 1950 (Figure E-17).They are used for agricultural structures, industrial factories, and warehouses. They are typically one story in height, sometimes without interior columns, and often enclose a large floor area. Construction is typically of steel frames spanning the short dimension of the building, resisting lateral forces as moment frames. Forces in the long direction are usually resisted by diagonal steel rod bracing. These buildings are usually clad with lightweight metal or asbestos-reinforced concrete siding, often corrugated.

To identify this construction type, the screener should look for the following characteristics:

Figure E-16 Use of a braced frame to rehabilitate an unreinforced masonry building.

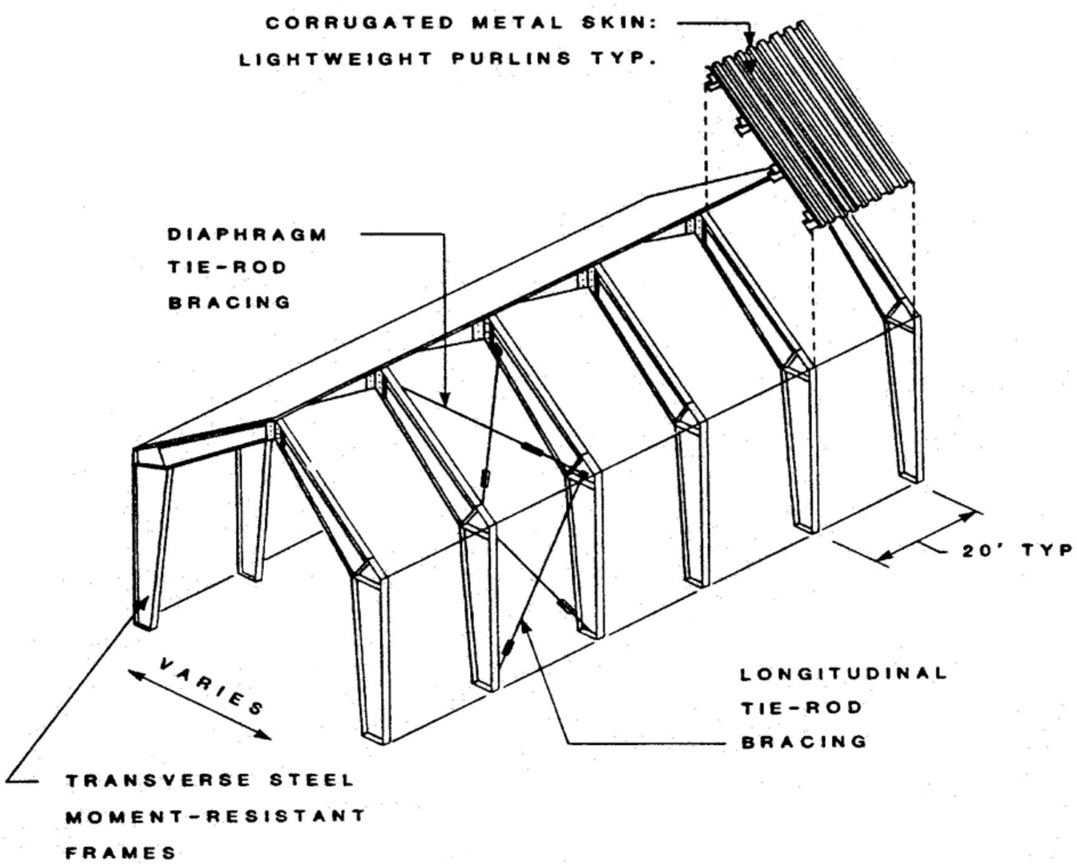


Figure E-17 Drawing of light metal construction.

1. Light metal buildings are typically characterized by industrial corrugated sheet metal or asbestos-reinforced cement siding. The term, “metal building panels” should not be confused with “corrugated sheet metal siding.” The former are prefabricated cladding units usually used for large office buildings. Corrugated sheet metal siding is thin sheet material usually fastened to purlins, which in turn span between columns. If this sheet cladding is present, the screener should examine closely the fasteners used. If the heads of sheet metal screws can be seen in horizontal rows, the building is most likely a light metal structure (Figure E-18).

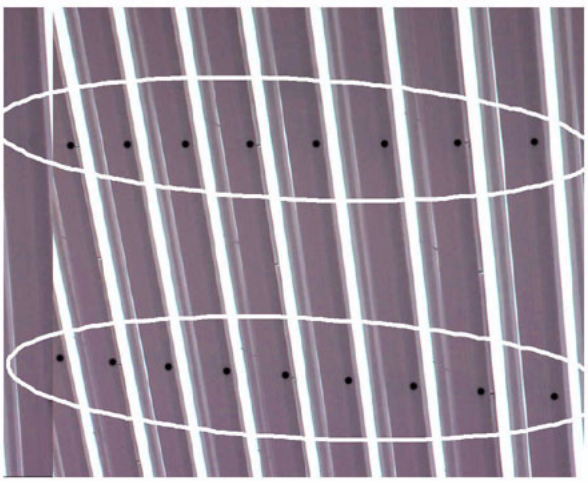


Figure E-18 Connection of metal siding to light metal frame with rows of screws (encircled).

2. Because the typical structural system consists of moment frames in the transverse direction and frames braced with diagonal steel rods in the longitudinal direction, light metal buildings often have low-pitched roofs without parapets or overhangs (Figure E-19). Most of these buildings are prefabricated, so the buildings tend to be rectangular in plan, without many corners.
3. These buildings generally have only a few windows, as it is difficult to detail a window in the sheet metal system.
4. The screener should look for signs of a metal building, and should knock on the siding to see if it sounds hollow. Door openings should be inspected for exposed steel members. If a gap, or light, can be seen where the siding meets the ground, it is certainly light metal or wood frame. For the best indication, an interior inspection will confirm the structural skeleton, because most of these buildings do not have interior finishes.

Figure E-19 Prefabricated metal building (S3, light metal building).

E.4.2 Typical Earthquake Damage

Because these building are low-rise, lightweight, and constructed of steel members, they usually perform relatively well in earthquakes. Collapses do not usually occur. Some typical problems are listed below:

1. Insufficient capacity of tension braces can lead to their elongation or failure, and, in turn, building damage.
2. Inadequate connection to the foundation can allow the building columns to slide.
3. Loss of the cladding can occur.

E.5 Steel Frame with Concrete Shear Wall (S4)

E.5.1 Characteristics

The construction of this structural type (Figure E-20) is similar to that of the steel moment-resisting frame in that a matrix of steel columns and girders is distributed throughout the structure. The joints, however, are not designed for moment resistance, and the lateral forces are resisted by concrete shear walls.

It is often difficult to differentiate visually between a steel frame with concrete shear walls and one without, because interior shear walls will often be covered by interior finishes and will look like interior nonstructural partitions. For the purposes of an RVS, unless the shear wall is identifiable from the exterior (i.e., a raw concrete finish was part of the architectural aesthetic of the building, and was left exposed), this building cannot be identified accurately. Figure E-21shows a structure with such an exposed shear wall. Figure E-22 is a close-up of shear wall damage.

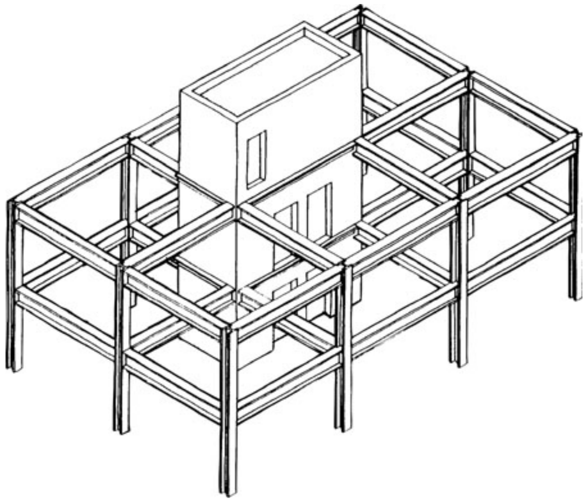


Figure E-20 Drawing of steel frame with interior concrete shear-walls.

Figure E-21 Concrete shear wall on building exterior.

E.5.2 Typical Earthquake Damage

The shear walls can be part of the elevator and service core, or part of the exterior or interior walls. This type of structure performs as well in earthquakes as other steel buildings. Some typical types of damage, other than nonstructural damage and pounding, are:

1. Shear cracking and distress can occur around openings in concrete shear walls.

Figure E-22 Close-up of exterior shear wall damage during a major earthquake.

2. Wall construction joints can be weak planes, resulting in wall shear failure at stresses below expected capacity.
3. Insufficient chord steel lap lengths can lead to wall bending failures.

E.6 Steel Frame with Unreinforced Masonry Infill (S5)

E.6.1 Characteristics

This construction type (Figures E-23 and E-24) consists of a steel structural frame and walls "infilled" with unreinforced masonry (URM). In older buildings, the floor diaphragms are often wood. Later buildings have reinforced concrete floors. Because of the masonry infill, the structure tends to be stiff. Because the steel frame in an older building is covered by unreinforced masonry for fire protection, it is easy to confuse this type of building with URM bearing-wall structures. Further, because the steel columns are relatively thin, they may be hidden in walls. An apparently solid masonry wall may enclose a series of steel columns and girders. These infill walls are usually two or three wythes thick. Therefore, header bricks will sometimes be present and thus mislead the screener into thinking the building is a URM bearing-wall structure, rather than infill. Often in these structures the infill and veneer masonry is exposed. Otherwise, masonry may be obscured by cladding in buildings, especially those that have undergone renovation.

When a masonry building is encountered, the screener should first attempt to determine if the masonry is reinforced, by checking the date of construction, although this is only a rough guide. A

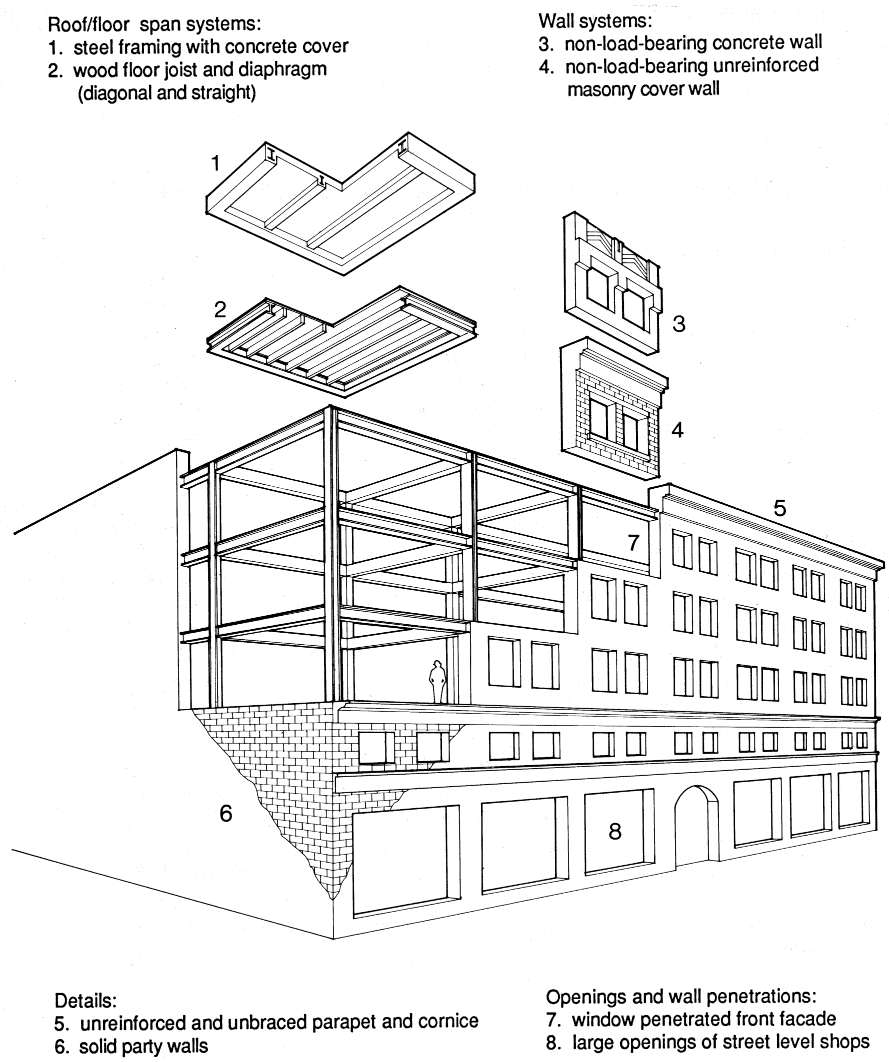


Figure E-23 Drawing of steel frame with URM infill.

clearer indication of a steel frame structure with URM infill is when the building exhibits the characteristics of a frame structure of type S1 or S2. One can assume all frame buildings clad in brick and constructed prior to about 1940 are of this type.

Older frame buildings may be of several types—steel frame encased with URM, steel frame encased with concrete, and concrete frame. Sometimes older buildings have decorative cladding such as terra cotta or stone veneer. Veneers may obscure all evidence of URM. In that case, the structural type cannot be determined. However, if there is evidence that a large amount of concrete is used in the building (for example, a rear wall constructed of concrete), then it is unlikely that the building has URM infill.

When the screener cannot be sure if the building is a frame or has bearing walls, two clues may help—the thickness of the walls and the height. Because infill walls are constructed of two or three wythes of bricks, they should be approximately 9 inches thick (2 wythes). Furthermore, the thickness of the wall will not increase in the lower stories, because the structural frame is carrying the load. For buildings over six stories tall, URM is infill or veneer, because URM bearing-wall structures are seldom this tall and, if so, they will have extremely thick walls in the lower stories.

E.6.2 Typical Earthquake Damage

In major earthquakes, the infill walls may suffer substantial cracking and deterioration from in-plane or out-of-plane deformation, thus reducing the in-plane wall stiffness. This in turn puts additional demand on the frame. Some of the walls may fail while others remain intact, which may result in torsion or soft story problems.

The hazard from falling masonry is significant as these buildings can be taller than 20 stories. As

Figure E-24 Example of steel frame with URM infill walls (S5).

described below, typical damage results from a variety of factors.

1. Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral forces. Because infill walls are non-load-bearing, they tend to be thin (around 9") and cannot rely on the additional shear strength that accompanies vertical compressive loads.
2. Veneer masonry around columns or beams is usually poorly anchored to the structural members and can disengage and fall.
3. Interior infill partitions and other nonstructural elements can be severely damaged and collapse.
4. If stories above the first are infilled, but the first is not (a soft story), the difference in stiffness creates a large demand at the ground floor columns, causing structural damage.
5. When the earthquake forces are sufficiently high, the steel frame itself can fail locally. Connections between members are usually not designed for high lateral loads (except in tall buildings) and this can lead to damage of these connections. Complete collapse has seldom occurred, but cannot be ruled out.

E.6.3 Common Rehabilitation Techniques

Rehabilitation techniques for this structural type have focused on the expected damage. By far the most significant problem, and that which is addressed in most rehabilitation schemes, is failure of the infill wall out of its plane. This failure presents a significant life safety hazard to individuals on the exterior of the building, especially those who manage to exit the building during the earthquake. To remedy this problem, anchorage connections are developed to tie the masonry infill to the floors and roof of the structure.

Another significant problem is the inherent lack of shear strength throughout the building. Some of the rehabilitation techniques employed include the following.

1. Gunite (with pneumatically placed concrete) the interior faces of the masonry wall, creating reinforced concrete shear elements.
2. Rehabilitate the steel frames by providing cross bracing or by fully strengthening the connections to create moment frames. In this latter case, the frames are still not sufficient to resist all the lateral forces, and reliance on the infill walls is necessary to provide adequate strength.

For concrete moment frames the rehabilitation techniques have been to provide ductile detailing. This is usually done by removing the outside cover of concrete (a couple of inches) exposing the reinforcing ties. Additional ties are added with their ends embedded into the core of the column. The exterior concrete is then replaced. This process results in a detail that provides a reasonable amount of ductility but not as much as there would have been had the ductility been provided in the original design.

E.7 Concrete Moment-Resisting Frame (C1)

E.7.1 Characteristics

Concrete moment-resisting frame construction consists of concrete beams and columns that resist both lateral and vertical loads (see Figure E-25). A fundamental factor in the seismic performance of concrete moment-resisting frames is the presence or absence of ductile detailing. Hence, several construction subtypes fall under this category:

a. non-ductile reinforced-concrete frames with unreinforced infill walls,
b. non-ductile reinforced-concrete frames with reinforced infill walls,
c. non-ductile reinforced-concrete frames, and

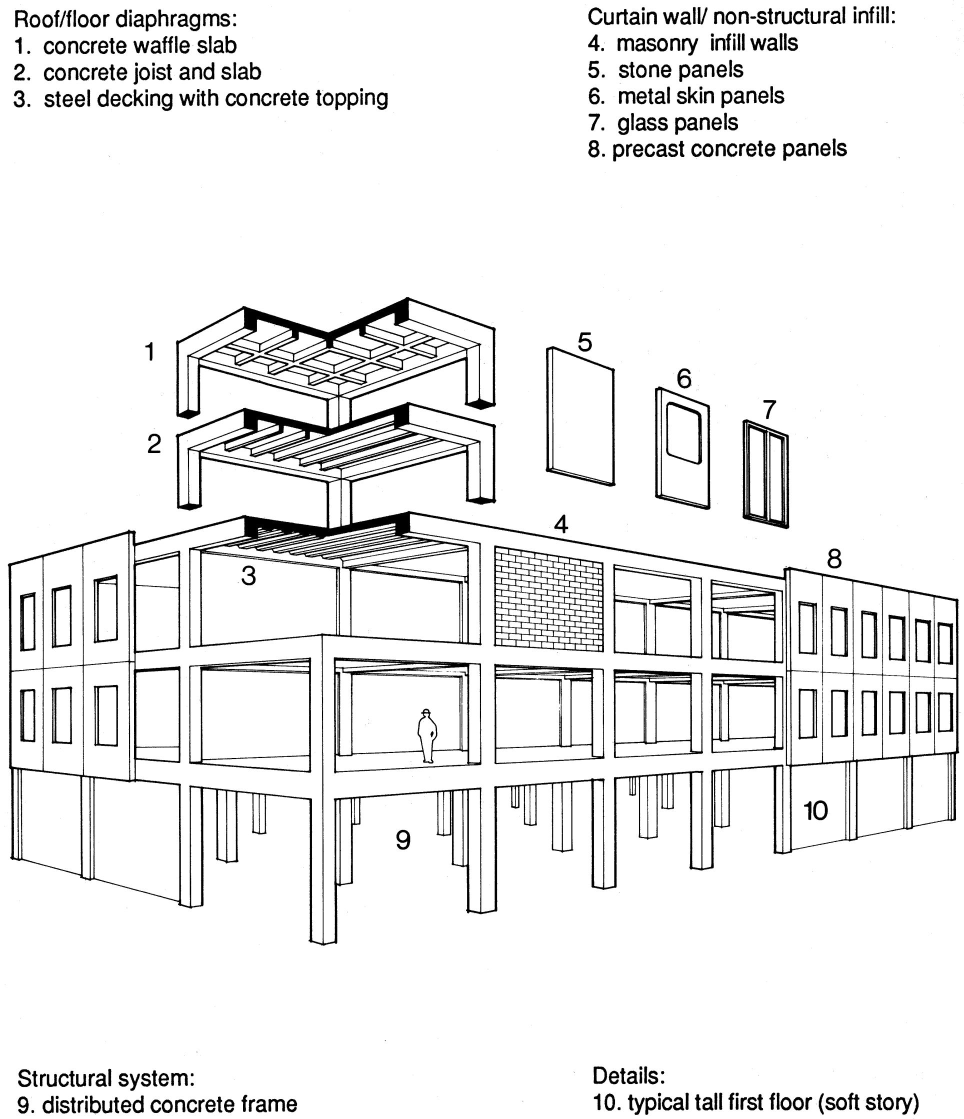


Figure E-25 Drawing of concrete moment-resisting frame building.

d. ductile reinforced-concrete frames.

Ductile detailing refers to the presence of special steel reinforcing within concrete beams and columns. The special reinforcement provides confinement of the concrete, permitting good performance in the members beyond the elastic capacity, primarily in bending. Due to this confinement, disintegration of the concrete is delayed, and the concrete retains its strength for more cycles of loading (i.e., the ductility is increased). See Figure E-26 for a dramatic example of ductility in concrete.

Ductile detailing (Figure E-27) has been practiced in high-seismicity areas since 1967, when ductility requirements were first introduced into the *Uniform Building Code* (the adoption and enforcement of ductility requirements in a given jurisdiction

Figure E-26 Extreme example of ductility in concrete, 1994 Northridge earthquake.

Figure E-27 Example of ductile reinforced concrete column, 1994 Northridge earthquake; horizontal ties would need to be closer for greater demands.

may be later, however). Prior to that time, nonductile or ordinary concrete moment-resisting frames were the norm (and still are, for moderate seismic areas). In high-seismicity areas additional tie reinforcing was required following the 1971 San Fernando earthquake and appeared in the *Uniform Building Code* in 1976.

In many low-seismicity areas of the United States, non-ductile concrete frames of type (a), (b), and (c) continue to be built. This group includes large multistory commercial, institutional, and residential buildings constructed using flat slab frames, waffle slab frames, and the standard beam-and-column frames. These structures generally are more massive than steel-frame buildings, are under-reinforced (i.e., have insufficient reinforcing steel embedded in the concrete) and display low ductility.

This building type is difficult to differentiate from steel moment-resisting frames unless the structural concrete has been left relatively exposed (see Figure E-28). Although a steel frame may be encased in concrete and appear to be a concrete frame, this is seldom the case for modern buildings (post 1940s). For the purpose of the RVS procedures, it can be assumed that all exposed concrete frames are concrete and not steel frames.

Figure E-28 Concrete moment-resisting frame building (C1) with exposed concrete, deep beams, wide columns (and with architectural window framing).

E.7.2 Typical Earthquake Damage

Under high amplitude cyclic loading, lack of confinement will result in rapid disintegration of nonductile concrete members, with ensuing brittle failure and possible building collapse (see Figure E-29).

Causes and types of damage include:

1. Excessive tie spacing in columns can lead to a lack of concrete confinement and shear failure.
2. Placement of inadequate rebar splices all at the same location in a column can lead to column failure.
3. Insufficient shear strength in columns can lead to shear failure prior to the full development of moment hinge capacity.
4. Insufficient shear tie anchorage can prevent the column from developing its full shear capacity.
5. Lack of continuous beam reinforcement can result in unexpected hinge formation during load reversal.

Figure E-29 Locations of failures at beam-to-column joints in nonductile frames, 1994 Northridge earthquake.

6. Inadequate reinforcing of beam-column joints or the positioning of beam bar splices at columns can lead to failures.
7. The relatively low stiffness of the frame can lead to substantial nonstructural damage.
8. Pounding damage with adjacent buildings can occur.

E.7.3 Common Rehabilitation Techniques

Rehabilitation techniques for reinforced concrete frame buildings depend on the extent to which the frame meets ductility requirements. The costs associated with the upgrading an existing, conventional beam-column framing system to meet the minimum standards for ductility are high and this approach is usually not cost-effective. The most practical and cost-effective solution is to add a system of shear walls or braced frames to provide the required seismic resistance (ATC, 1992).

E.8 Concrete Shear Wall (C2)

E.8.1 Characteristics

This category consists of buildings with a perimeter concrete bearing-wall structural system or frame structures with shear walls (Figure E-30). The structure, including the usual concrete floor diaphragms, is typically cast in place. Before the 1940s, bearing-wall systems were used in schools, churches, and industrial buildings. Concrete shear-wall buildings constructed since the early 1950s are institutional, commercial, and residential buildings, ranging from one to more than thirty stories. Frame buildings with shear walls tend to be commercial and industrial. A common example of the latter type is a warehouse with interior frames and perimeter concrete walls. Residential buildings of this type are often mid-rise towers. The shear walls in these newer buildings can be located along the perimeter, as interior partitions, or around the service core.

Frame structures with interior shear walls are difficult to identify positively. Where the building is clearly a box-like bearing-wall structure it is probably a shear-wall structure. Concrete shear wall buildings are usually cast in place. The screener should look for signs of cast-in-place concrete. In concrete bearing-wall structures, the wall thickness ranges from 6 to 10 inches and is thin in comparison to that of masonry bearing-wall structures.

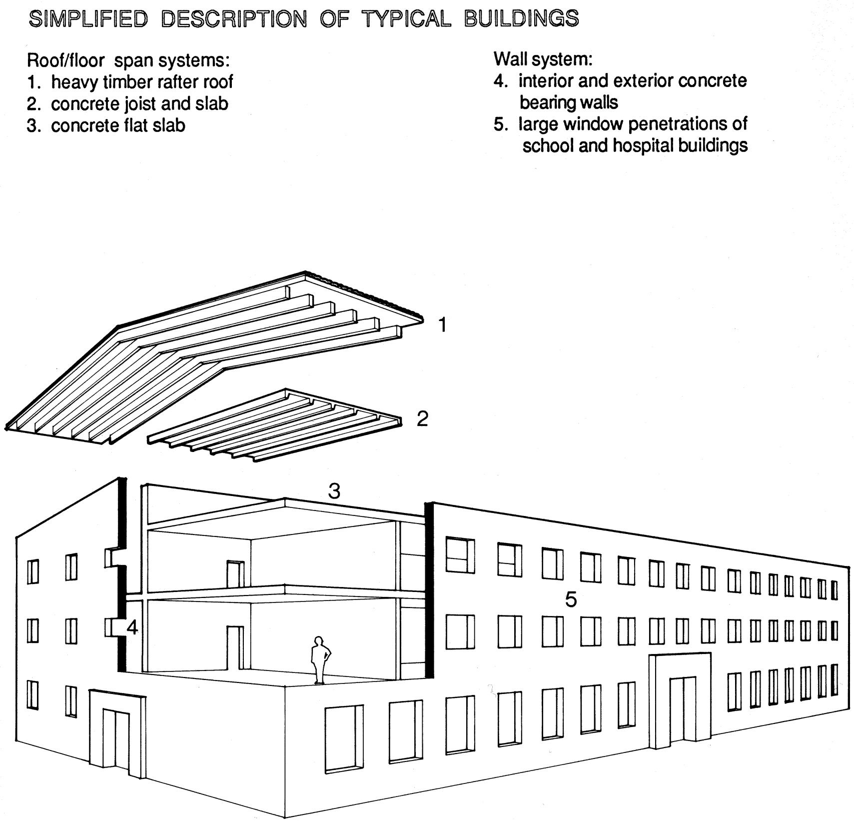


Figure E-30 Drawing of concrete shear-wall building.

E.8.2 Typical Types of Earthquake Damage

This building type generally performs better than concrete frame buildings. The buildings are heavy compared with steel frame buildings, but they are also stiff due to the presence of the shear walls. Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration. Other damage specific to this building type includes the following.

1. During large seismic events, shear cracking and distress can occur around openings in concrete shear walls and in spandrel beams and link beams between shear walls (See Figures E-31 and E-32.)
2. Shear failure can occur at wall construction joints usually at a load level below the expected capacity.
3. Bending failures can result from insufficient vertical chord steel and insufficient lap lengths at the ends of the walls.

E.8.3 Common Rehabilitation

Reinforced concrete shear-wall buildings can be rehabilitated in a variety of ways. Techniques include: (1) reinforcing existing walls in shear by applying a layer of shotcrete or poured concrete; (2) where feasible, filling existing window or door openings with concrete to add shear strength and eliminate critical bending stresses at the edge of openings; and (3) reinforcing narrow overstressed shear panels in in-plane bending by adding reinforced boundary elements (ATC, 1992).

E.9 Concrete Frame with Unreinforced Masonry Infill (C3)

E.9.1 Characteristics

These buildings (Figures E-33 and E-34) have been, and continue to be, built in regions where unreinforced masonry (URM) has not been eliminated by code. These buildings were generally built before 1940 in high-seismicity regions and may continue to be built in other regions.

The first step in identification is to determine if the structure is old enough to contain URM. In contrast to steel frames with URM infill, concrete frames with URM infill usually show clear evidence of the concrete frames. This is particularly true for industrial buildings and can usually be observed at the side or rear of commercial buildings. The concrete col-

Figure E-31 Tall concrete shear-wall building: walls connected by damaged spandrel beams.

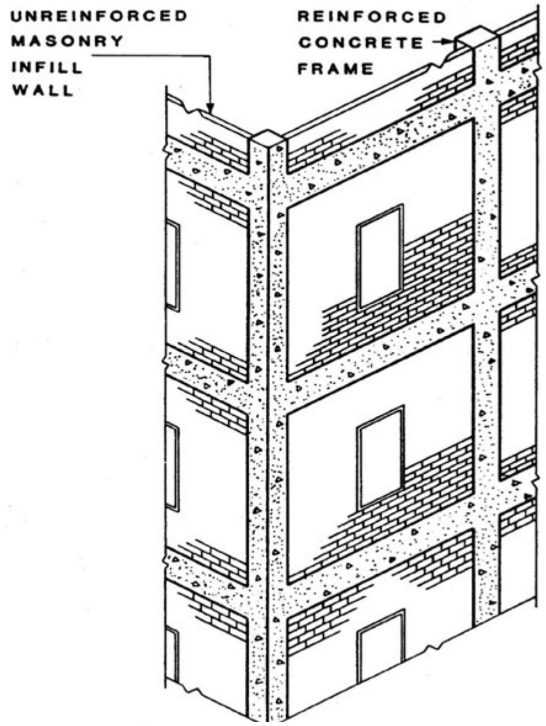


Figure E-33 Concrete frame with URM infill.

Figure E-32 Shear-wall damage, 1989 Loma Prieta earthquake.

Figure E-34 Blow-up (lower photo) of distant view of C3 building (upper photo) showing concrete frame with URM infill (left wall), and face brick (right wall).

umns and beams are relatively large and are usually not covered by masonry but left exposed.

A case in which URM infill cannot be readily identified is the commercial building with large windows on all sides; these buildings may have interior URM partitions. Another difficult case occurs when the exterior walls are covered by decorative tile or stone veneer. The infill material can be URM or a thin concrete infill.

E.9.2 Typical Earthquake Damage

The hazards of these buildings, which in the western United States are often older, are similar to and perhaps more severe than those of the newer concrete frames. Where URM infill is present, a falling hazard exists. The failure mechanisms of URM infill in a concrete frame are generally the same as URM infill in a steel frame.

E.9.3 Common Rehabilitation Techniques

Rehabilitation of unreinforced masonry infill in a concrete frame is identical to that of the URM infill in a steel frame. See Section E.6.3. Anchorage of the wall panels for out-of-plane forces is the key component, followed by providing sufficient shear strength in the building.

E.10 Tilt-up Structures (PC1)

E.10.1 Characteristics

In traditional tilt-up buildings (Figures E-35 through E-37), concrete wall panels are cast on the ground

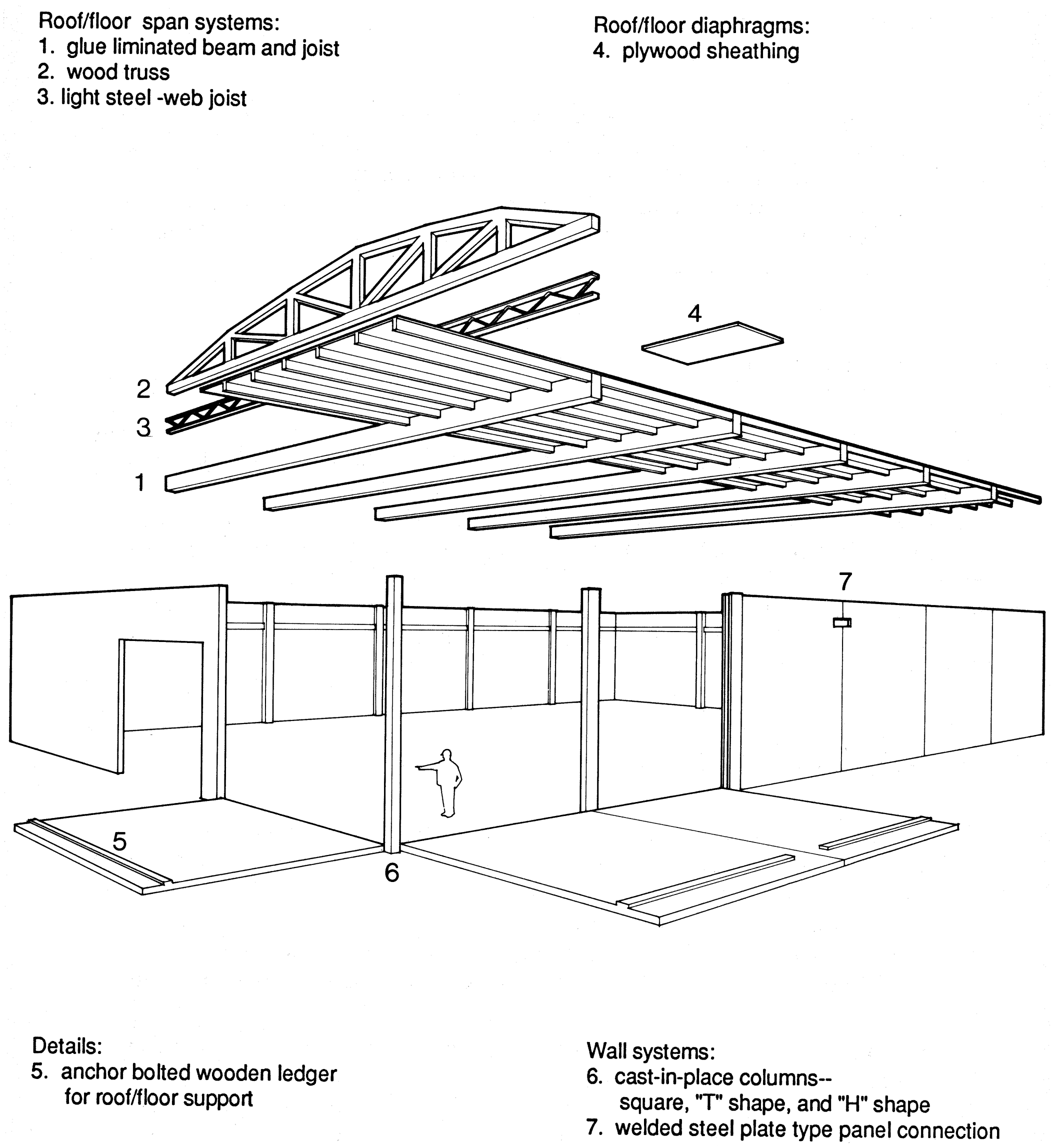


Figure E-35 Drawing of tilt-up construction typical of the western United States. Tilt-up construction in the eastern United States may incorporate a steel frame.

Figure E-36 Tilt-up industrial building, 1970s.

Figure E-37 Tilt-up industrial building, mid- to late 1980s.

and then tilted upward into their final positions. More recently, wall panels are fabricated off-site and trucked to the site.

Tilt-up buildings are an inexpensive form of light industrial and commercial construction and have become increasingly popular in the western and central United States since the 1940s. They are typically one and sometimes two stories high and basically have a simple rectangular plan. The walls are the lateral-force-resisting system. The roof can be a plywood diaphragm carried on wood purlins and glue-laminated (glulam) wood beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. The wall panels are attached to concrete cast-in-place pilasters or to steel columns, or the joint is simply closed with a later concrete pour. These joints are typically spaced about 20 feet apart.

The major defect in existing tilt-ups is a lack of positive anchorage between wall and diaphragm, which has been corrected since about 1973 in the western United States.

In the western United States, it can be assumed that all one-story concrete industrial warehouses with flat roofs built after 1950 are tilt-ups unless supplementary information indicates otherwise.

E.10.2 Typical Earthquake Damage

Before 1973 in the western United States, many tilt-up buildings did not have sufficiently strong connections or anchors between the walls and the roof and floor diaphragms. The anchorage typically was nothing more than the nailing of the plywood roof sheathing to the wood ledgers supporting the framing.

During an earthquake, the weak anchorage broke the ledgers, resulting in the panels falling and the supported framing to collapse. When mechanical anchors were used they pulled out of the walls or split the wood members to which they were attached, causing the floors or roofs to collapse. See Figures E-38 and E-39. The connections between the concrete panels are also vulnerable to failure. Without these connections, the building loses much of its lateral-force-resisting capacity. For these reasons, many tilt-up buildings were damaged in the 1971 San

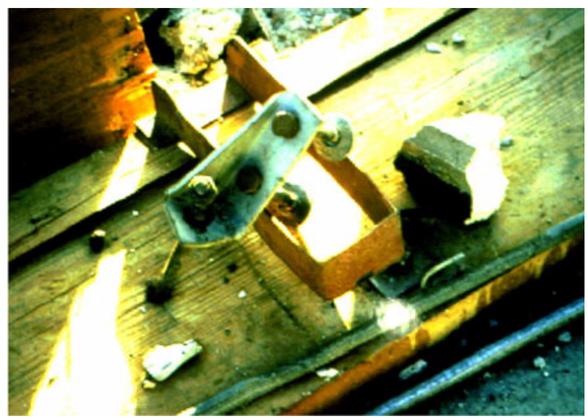


Figure E-38 Tilt-up construction anchorage failure.

Figure E-39 Result of failure of the roof beam anchorage to the wall in tilt-up building.

Fernando, California, earthquake. Since 1973, tilt-up construction practices have changed in California and other high-seismicity regions, requiring positive wall-diaphragm connection. (Such requirements may not have yet been made in other regions of the country.) However, a large number of these older, pre-1970s-vintage tilt-up buildings still exist and have not been rehabilitated to correct this wall-anchor defect. Damage to these buildings was observed again in the 1987 Whittier, California, earthquake, 1989 Loma Prieta, California earthquake, and the 1994 Northridge, California, earthquake. These buildings are a prime source of seismic hazard.

In areas of low or moderate seismicity, inadequate wall anchor details continue to be used. Severe ground shaking in such an area may produce major damage in tilt-up buildings.

E.10.3 Common Rehabilitation Techniques

The rehabilitation of tilt-up buildings is relatively easy and inexpensive. The most common form of rehabilitation is to provide a positive anchorage connection at the roof and wall intersection. This is usually done by using pre-fabricated metal hardware attached to the framing member and to a bolt that is installed through the wall. On the outside of the wall a large washer plate is used. See Figure E-40 for examples of new anchors.

Accompanying the anchorage rehabilitation is the addition of ties across the building to develop the anchorage forces from the wall panels fully into the diaphragm. This is accomplished by interconnecting framing members from one side of the building to the other, and then increasing the connections of the diaphragm (usually wood) to develop the additional forces.

E.11 Precast Concrete Frame (PC2)

E.11.1 Characteristics

Precast concrete frame construction, first developed in the 1930s, was not widely used until the 1960s. The precast frame (Figure E-41) is essentially a post and beam system in concrete where columns, beams and slabs are prefabricated and assembled on site. Various types of members are used. Vertical-load-carrying elements may be Ts, cross shapes, or arches and are often more than one story in height. Beams are often Ts and double Ts, or rectangular sections. Prestressing of the members, including pretensioning and post-tensioning, is often employed. The identification of this structure type cannot rely solely on construction date, although most precast concrete

Figure E-40 Newly installed anchorage of roof beam to wall in tilt-up building.

frame structures were constructed after 1960. Some typical characteristics are the following.

1. Precast concrete, in general, is of a higher quality and precision compared to cast-in-place concrete. It is also available in a greater range of textures and finishes. Many newer concrete and steel buildings have precast concrete panels and column covers as an exterior finish (See Figure E-42). Thus, the presence of precast concrete does not necessarily mean that it is a precast concrete frame.
2. Precast concrete frames are, in essence, post and beam construction in concrete. Therefore, when a concrete structure displays the features of a post-and-beam system, it is most likely that it is a precast concrete frame. It is usually not economical for a conventional cast-in-place concrete frame to look like a post-and-beam system. Features of a precast concrete post-and-beam system include:

a. exposed ends of beams and girders that project beyond their supports or project away from the building surface,

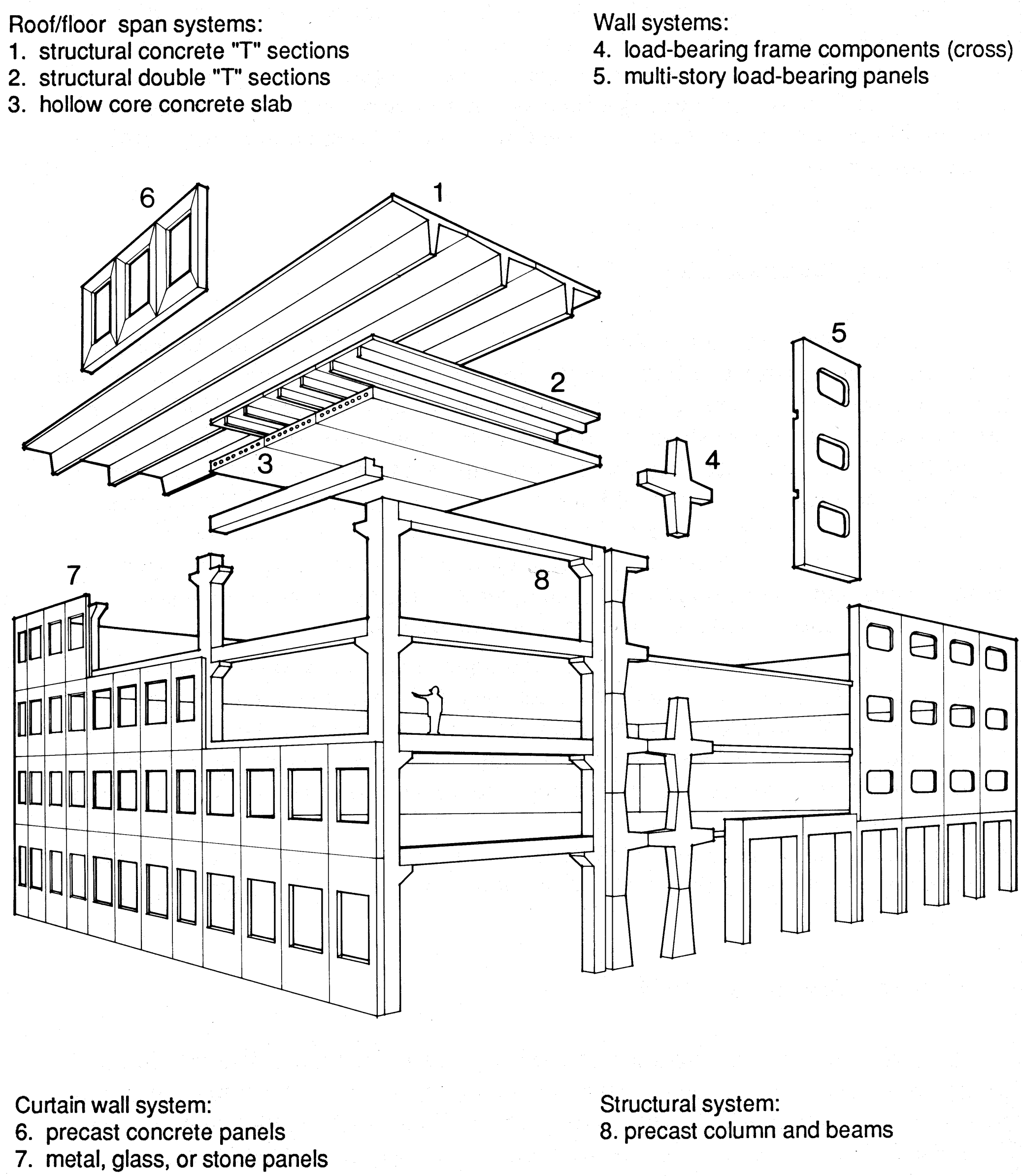


Figure E-41 Drawing of precast concrete frame building.

b. the absence of small joists, and

c. beams sitting on top of girders rather than meeting at a monolithic joint (see Figure E-43)

The presence of precast structural components is usually a good indication of this system, although these components are also used in mixed construction. Precast structural components come in a variety of shapes and sizes. The most common types are sometimes difficult to detect from the street. Less common but more obvious examples include the following.

a. Ts or double Ts—These are deep beams with thin webs and flanges and with large span capacities. (Figure E-44 shows one end of a double-T beam as it is lowered onto its seat.)

b. Cross or T-shaped units of partial columns and beams — These are structural units for constructing moment-resisting frames. They are usually joined together by field welding of steel connectors cast into the concrete. Joints should be clearly visible at the mid-span of the beams or the mid-height of the columns. See Figure E-45.

c. Precast arches—Precast arches and pedestals are popular in the architecture of these buildings.

d. Column—When a column displays a precast finish without an indication that it has a cover (i.e.,

Figure E-42 Typical precast column cover on a steel or concrete moment frame.

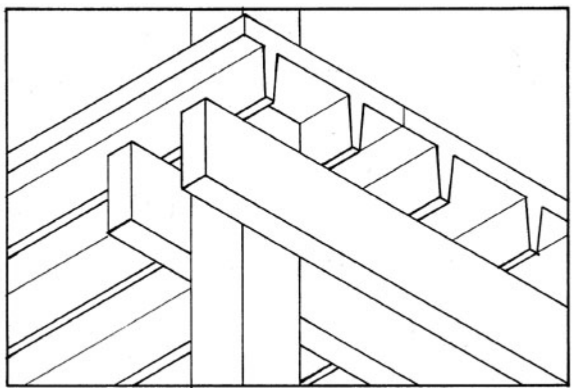


Figure E-43 Exposed precast double-T sections and overlapping beams are indicative of precast frames.

Figure E-44 Example of precast double-T section during installation.

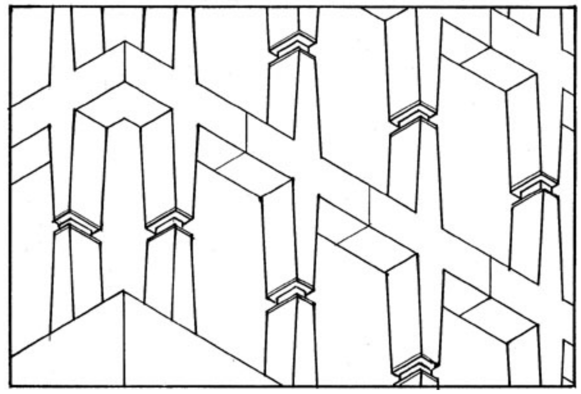


Figure E-45 Precast structural cross; installation joints are at sections where bending is minimum during high seismic demand.

no vertical seam can be found), the column is likely to be a precast structural column.

It is possible that a precast concrete frame may not show any of the above features, however.

E.11.2 Typical Earthquake Damage

The earthquake performance of this structural type varies widely and is sometimes poor. This type of building can perform well if the detailing used to connect the structural elements have sufficient strength and ductility (toughness). Because structures of this type often employ cast-in-place concrete or reinforced masonry (brick or block) shear walls for lateral-load resistance, they experience the same types of damage as other shear-wall building types. Some of the problem areas specific to precast frames are listed below.

1. Poorly designed connections between prefabricated elements can fail.
2. Accumulated stresses can result due to shrinkage and creep and due to stresses incurred in transportation.
3. Loss of vertical support can occur due to inadequate bearing area and insufficient connection between floor elements and columns.
4. Corrosion of the metal connectors between prefabricated elements can occur.

E.11.3 Common Rehabilitation Techniques

Seismic rehabilitation techniques for precast concrete frame buildings are varied, depending on the elements being strengthened. Inadequate shear capacity of floor diaphragms can be addressed by adding reinforced concrete topping to an untopped system when possible, or adding new shear walls to reduce the seismic shear forces in the diaphragm. Corbels with inadequate vertical shear or bending strength can be strengthened by adding epoxied horizontal shear dowels through the corbel and into the column. Alternatively, vertical shear capacity can be increased by adding a structural steel bolster under the corbel, bolted to the column, or a new steel column or reinforced concrete column can be added (ATC, 1992).

E.12 Reinforced Masonry (RM1 and RM2)

E.12.1 Characteristics

Reinforced masonry buildings are mostly low-rise structures with perimeter bearing walls, often with wood diaphragms (RM1 buildings) although precast concrete is sometimes used (RM2 buildings). Floor and roof assemblies usually consist of timber joists and beams, glued-laminated beams, or light steel joists. The bearing walls consist of grouted and reinforced hollow or solid masonry units. Interior supports, if any, are often wood or steel columns, wood stud frames, or masonry walls. Occupancy varies from small commercial buildings to residential and industrial buildings. Generally, they are less than five stories in height although many taller masonry buildings exist. Reinforced masonry structures are usually basically rectangular structures (See Figure E-46).

Figure E-46 Modern reinforced brick masonry.

To identify reinforced masonry, one must determine separately if the building is masonry and if it is reinforced. To obtain information on how to recognize a masonry structure, see Appendix D, which describes the characteristics of construction materials. The best way of assessing the reinforcement condition is to compare the date of construction with the date of code requirement for the reinforcement of masonry in the local jurisdiction.

The screener also needs to determine if the building is veneered with masonry or is a masonry building. Wood siding is seldom applied over masonry. If the front facade appears to be reinforced masonry whereas the side has wood siding, it is probably a wood frame that has undergone facade renovation. The back of the building should be checked for signs of the original construction type.

If it can be determined that the bearing walls are constructed of concrete blocks, they may be reinforced. Load-bearing structures using these blocks are probably reinforced if the local code required it. Concrete blocks come in a variety of sizes and textures. The most common size is 8 inches wide by 16 inches long by 8 inches high. Their presence is obvious if the concrete blocks are left as the finish surface.

E.12.2 Typical Earthquake Damage

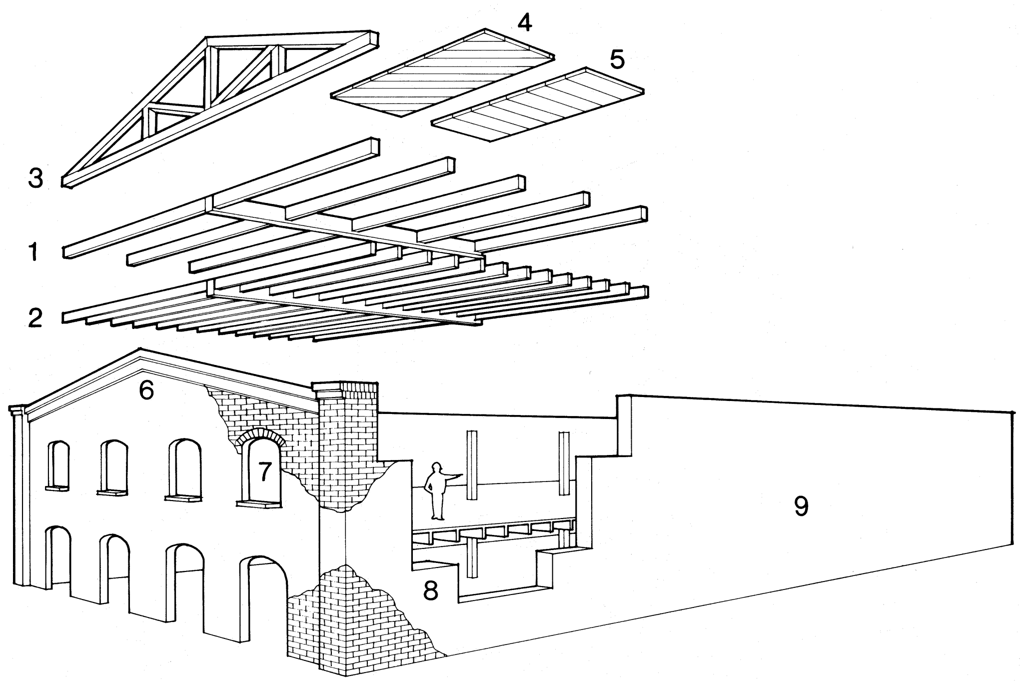
Reinforced masonry buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, and if sufficient diaphragm anchorage exists. A major problem is control of the workmanship during construction.   Poor construction practice can result in ungrouted and unreinforced walls. Even where construction practice is adequate, insufficient reinforcement in the design can be responsible for heavy damage of the walls. The lack of positive connection of the floor and roof diaphragms to the wall is also a problem.

E.12.3 Common Rehabilitation Techniques

Techniques for seismic rehabilitation of reinforced masonry bearing wall buildings are varied, depending on the element being rehabilitated. Techniques for rehabilitating masonry walls include: (1) applying a layer of concrete or shotcrete to the existing walls; (2) adding vertical reinforcing and grouting into ungrouted block walls; and (3) filling in large or critical openings with reinforced concrete or masonry dowelled to the surrounding wall. Wood or steel deck diaphragms in RM1 buildings can be rehabilitated by adding an additional layer of plywood to strengthen and stiffen an existing wood diaphragm, by shear welding between sections of an existing steel deck or adding flat sheet steel reinforcement, or by adding additional vertical elements (for example, shear walls or braced frames) to decrease diaphragm spans and stresses. Precast floor diaphragms in RM2 buildings can be strengthen by adding a layer of concrete topping reinforced with mesh (if the supporting structure has the capacity to carry the additional vertical dead load), or by adding new shear walls to reduce the diaphragm span (ATC, 1992).

Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)
3. wood truss-- pitch and curve

Roof/floor diaphragms:
4. diagonal sheathing
5. straight sheathing



Details:
6. typical unbraced parapet and cornice
7. flat arch window opennings

Wall systems:
8. bearing wall-- four or more wythes of brick
9. typical long solid party wall

Figure E-47 Drawing of unreinforced masonry bearing-wall building, 2-story.

E.13 Unreinforced Masonry (URM)

E.13.1 Characteristics

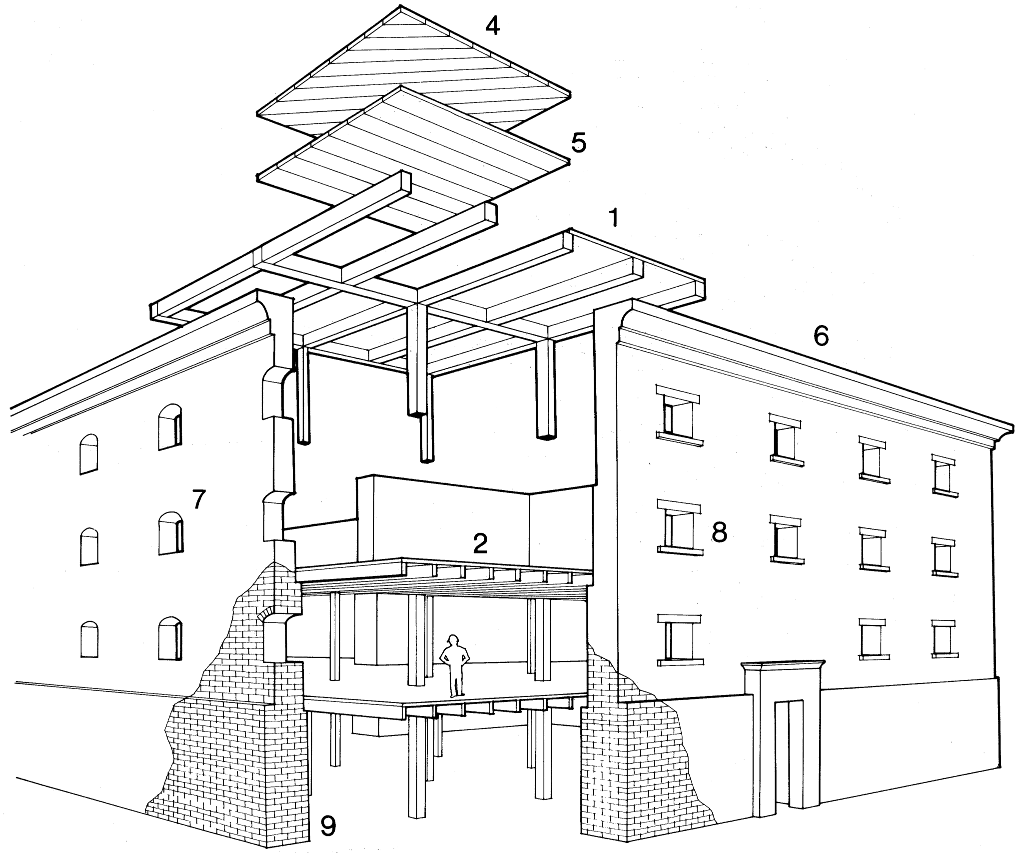
Most unreinforced masonry (URM) bearing-wall structures in the western United States (Figures E-47 through E-51) were built before 1934, although this construction type was permitted in some jurisdictions having moderate or high seismicity until the late 1940s or early 1950s (in some jurisdictions URM may still be a common type of construction, even today). These buildings usually range from one to six stories in height and function as commercial, residential, or industrial buildings. The construction varies according to the type of use, although wood floor and roof diaphragms are common. Smaller commercial and residential buildings usually have light wood floor joists and roof joists supported on the typical perimeter URM wall and interior, wood, load-bearing partitions. Larger buildings, such as industrial warehouses, have heavier floors and interior columns, usually of wood. The bearing walls of these industrial buildings tend to be thick, often as much as 24 inches or more at the base. Wall thickness of residential, commercial, and office buildings range from 9 inches at upper floors to 18 inches a lower floors.

The first step in identifying buildings of this type is to determine if the structure has bearing walls. Second, the screener should determine the approximate age of the building. Some indications of unreinforced masonry are listed below.

1. Weak mortar was used to bond the masonry units together in much of the early unreinforced

Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)
3. wood truss-- pitch and curve

Roof/floor diaphragms:
4. diagonal sheathing
5. straight sheathing



Details:
6. typical unbraced parapet and cornice
7. flat arch window opennings
8. small window penetrations (if bldg is originally a warehouse)

Wall systems:
9. bearing wall-- four to eight wythes of brick

Figure E-48 Drawing of unreinforced masonry bearing-wall building, 4-story.

masonry construction in the United States. As the poor earthquake performance of this mortar type became known in the 1930s, and as cement mortar became available, this weaker mortar was not used and thus is not found in more recent masonry buildings. If this soft mortar is present, it is probably URM. Soft mortar can be scratched with a hard instrument such as a penknife, screwdriver, or a coin. This scratch testing, if permitted, should be done in a wall area where the original structural material is exposed, such as the sides or back of a building. Newer masonry may be used in renovations and it may look very much like the old. Older mortar joints can also be repointed (i.e., regular maintenance of the masonry mortar), or repaired with newer mortar during renovation. The original construction may also have used a high-quality mortar. Thus, even if the existence of soft mortar cannot be detected, it may still be URM.

2. An architectural characteristic of older brick bearing-wall structures is the arch and flat arch

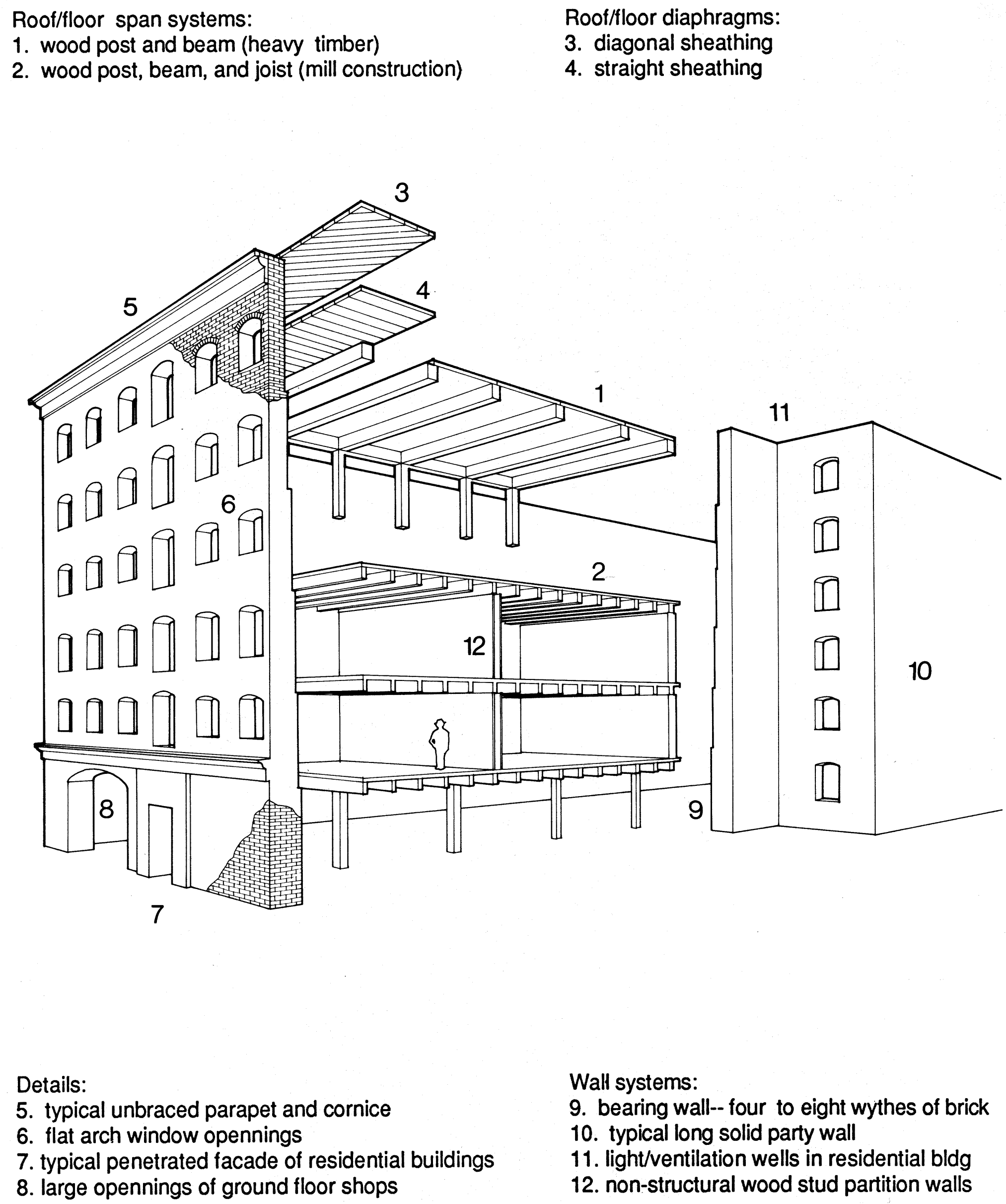


Figure E-49 Drawing of unreinforced masonry bearing-wall building, 6-story.

Figure E-50 East coast URM bearing-wall building.

Figure E-51 West coast URM bearing-wall building.

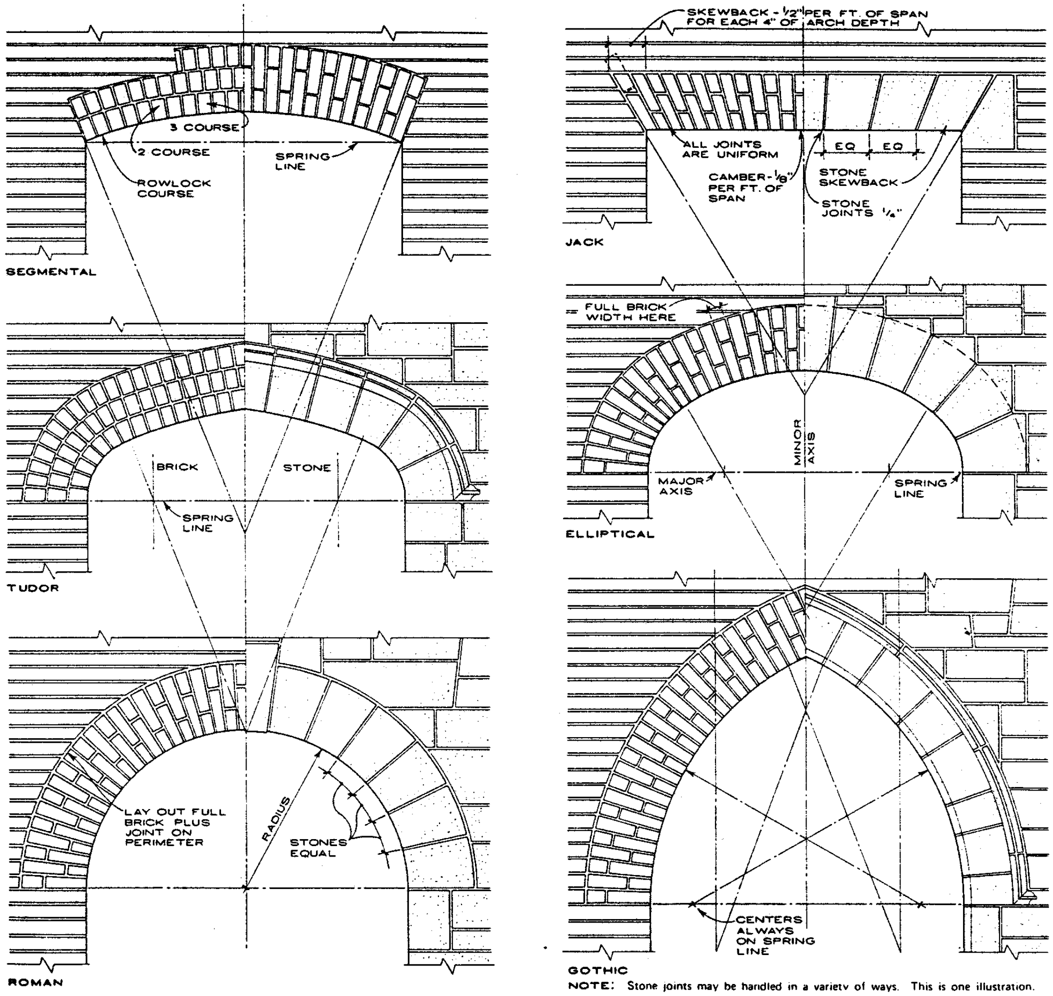


Figure E-52 Drawings of typical window head features in URM bearing-wall buildings.

window heads (see Figure E-52). These arrangements of masonry units function as a header to carry the load above the opening to either side. Although masonry-veneered wood-frame structures may have these features, they are much more widely used in URM bearing-wall structures, as they were the most economical method of spanning over a window opening at the time of construction. Other methods of spanning are also used, including steel and stone lintels, but these methods are generally more costly and usually employed in the front facade only.

3. Some structures of this type will have anchor plates visible at the floor and roof lines, approximately 6-10 feet on center around the perimeter of the building. Anchor plates are usually square or diamond-shaped steel plates approximately 6 inches by 6 inches, with a bolt and nut at the center. Their presence indicates anchor ties have been placed to tie the walls to the floors and roof. These are either from the original construction or from rehabilitation under local ordinances. Unless the anchors are 6 feet on center or less, they are not considered effective in earthquakes. If they are closely spaced, and appear to be recently installed, it indicates that the building has been rehabilitated. In either case, when these anchors are present all around the building, the original construction is URM bearing wall.

4. When a building has many exterior solid walls constructed from hollow clay tile, and no columns of another material can be detected, it is probably not a URM bearing wall but probably a wood or metal frame structure with URM infill.

5. One way to distinguish a reinforced masonry building from an unreinforced masonry building is to examine the brick pattern closely. Reinforced masonry usually does not show header bricks in the wall surface.

If a building does not display the above features, or if the exterior is covered by other finish material, the building may still be URM.

E.13.2 Typical Earthquake Damage

Unreinforced masonry structures are recognized as the most hazardous structural type. They have been observed to fail in many modes during past earthquakes. Typical problems include the following.

1. Insufficient Anchorage—Because the walls, parapets, and cornices are not positively anchored to the floors, they tend to fall out. The collapse of bearing walls can lead to major building collapses. Some of these buildings have anchors as a part of the original construction or as a rehabilitation. These older anchors exhibit questionable performance. (See Figure E-53 for parapet damage.)

Figure E-53 Parapet failure leaving an uneven roof line, due to inadequate anchorage, 1989 Loma Prieta earthquake.

2. Excessive Diaphragm Deflection—Because most of the floor diaphragms are constructed of finished wood flooring placed over ¾”-thick wood sheathing, they tend to be stiff compared with other types of wood diaphragms. This stiffness results in rotations about a vertical axis, accompanying translations in the direction of the open front walls of buildings, due to a lack of in-plane stiffness in these open fronts. Because there is little resistance in the masonry walls for out-of-plane loading, the walls allow large diaphragm displacements and cause the failure of the walls out of their plane. Large drifts occurring at the roof line can cause a masonry wall to overturn and collapse under its own weight.
3. Low Shear Resistance—The mortar used in these older buildings was often made of lime and sand, with little or no cement, and had very little shear strength. The bearing walls will be heavily damaged and collapse under large loads. (See Figure E-54)

Figure E-54 Damaged URM building, 1992 Big Bear earthquake.

4. Slender Walls —Some of these buildings have tall story heights and thin walls. This condition, especially in non-load-bearing walls, will result in buckling out-of-plane under severe lateral load. Failure of a non-load-bearing wall represents a falling hazard, whereas the collapse of a load-bearing wall will lead to partial or total collapse of the structure.

E.13.3 Common Rehabilitation Techniques

Over the last 10 years or more, jurisdictions in California have required that unreinforced masonry bearing-wall buildings be rehabilitated or demolished. To minimize the economical impact on owners of having to rehabilitate their buildings, many jurisdictions implemented phased programs such that the critical items were dealt with first. The following are the key elements included in a typical rehabilitation program.

1. Roof and floor diaphragms are connected to the walls for both anchorage forces (out of the plane of the wall) and shear forces (in the plane of the

wall). Anchorage connections are placed at 6 feet spacing or less, depending on the force requirements. Shear connections are usually placed at around 2 feet center to center. Anchors consist of bolts installed through the wall, with 6-inch-square washer plates, and connected to hardware attached to the wood framing. Shear connections usually are bolts embedded in the masonry walls in oversized holes filled with either a non-shrink grout or an epoxy adhesive. See Figure E-55.

2. In cases when the height to thickness ratio of the walls exceeds the limits of stability, rehabilitation consists of reducing the spans of the wall to a level that their thickness can support. Parapet rehabilitation consists of reducing the parapet to what is required for fire safety and then bracing from the top to the roof.
3. If the building has an open storefront in the first story, resulting in a soft story, part of the storefront is enclosed with new masonry or a steel frame is provided there, with new foundations.
4. Walls are rehabilitated by either closing openings with reinforced masonry or with reinforced gunite.

Figure E-55 Upper: Two existing anchors above three new wall anchors at floor line using decorative washer plates. Lower: Rehabilitation techniques include closely spaced anchors at floor and roof levels.

Appendix F

Earthquakes and How Buildings Resist Them

F.1 The Nature of Earthquakes

In a global sense, earthquakes result from motion between plates comprising the earth's crust (see Figure F-1). These plates are driven by the convective motion of the material in the earth's mantle between the core and the crust, which in turn is driven by heat generated at the earth's core. Just as in a heated pot of water, heat from the earth's core causes material to rise to the earth's surface. Forces between the rising material and the earth's crustal plates cause the plates to move. The resulting relative motions of the plates are associated with the generation of earthquakes. Where the plates spread apart, molten material fills the void. An example is the ridge on the ocean floor, at the middle of the Atlantic Ocean. This material quickly cools and, over millions of years, is driven by newer, viscous, fluid material across the ocean floor.

These large pieces of the earth's surface, termed tectonic plates, move very slowly and irregularly. Forces build up for decades, centuries, or millennia at the interfaces (or faults) between plates, until a large releasing movement suddenly occurs. This sudden, violent motion produces the nearby shaking that is felt as an earthquake. Strong shaking produces strong horizontal forces on structures, which can cause direct damage to buildings, bridges, and other man-made structures as well as triggering fires, landslides, road damage, tidal waves (tsunamis) and other damaging phenomena.

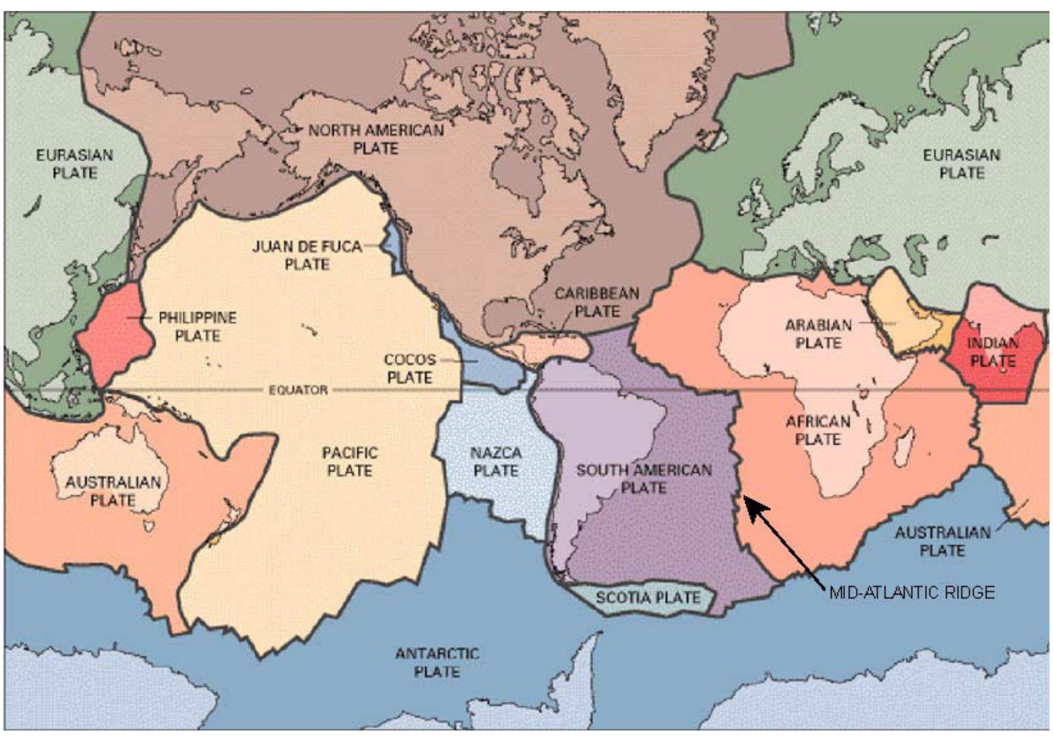


Figure F-1 The separate tectonic plates comprising the earth's crust superimposed on a map of the world.

A fault is like a “tear” in the earth’s crust and its fault surface may be from one to over one hundred miles deep. In some cases, faults are the physical expression of the boundary between adjacent tectonic plates and thus are hundreds of miles long. In addition, there are shorter faults, parallel to, or branching out from, a main fault zone. Generally, the longer a fault, the larger magnitude earthquake it can generate. Beyond the main tectonic plates, there are many smaller sub-plates, “platelets” and simple blocks of crust which can move or shift due to the “jostling” of their neighbors and the major plates. The known existence of these many sub-plates implies that smaller but still damaging earthquakes are possible almost anywhere.

With the present understanding of the earthquake generating mechanism, the times, sizes and locations of earthquakes cannot be reliably predicted. Generally, earthquakes will be concentrated in the vicinity of faults, and certain faults are more likely than others to produce a large event, but the earthquake generating process is not understood well enough to predict the exact time of earthquake occurrence. Therefore, communities must be prepared for an earthquake to occur at any time.

Four major factors can affect the severity of ground shaking and thus potential damage at a site. These are the magnitude of the earthquake, the type of earthquake, the distance from the source of the earthquake to the site, and the hardness or softness of the rock or soil at the site. Larger earthquakes will shake longer and harder, and thus cause more damage. Experience has shown that the ground motion can be felt for several seconds to a minute or longer. In preparing for earthquakes, both horizontal (side to side) and vertical shaking must be considered.

There are many ways to describe the size and severity of an earthquake and associated ground shaking. Perhaps the most familiar are earthquake magnitude and Modified Mercalli Intensity (MMI, often simply termed “intensity”). Earthquake magnitude is technically known as the Richter magnitude, a numerical description of the maximum amplitude of ground movement measured by a seismograph (adjusted to a standard setting). On the Richter scale, the largest recorded earthquakes have had magnitudes of about 8.5. It is a logarithmic scale, and a unit increase in magnitude corresponds to a ten-fold increase in the adjusted ground displacement amplitude, and to approximately a thirty-fold increase in total potential strain energy released by the earthquake.

Modified Mercalli Intensity (MMI) is a subjective scale defining the level of shaking at specific sites on a scale of I to XII. (MMI is expressed in Roman numerals, to connote its approximate nature.) For example, slight shaking that causes few instances of fallen plaster or cracks in chimneys constitutes MMI VI. It is difficult to find a reliable precise relationship between magnitude, which is a description of the earthquake’s total energy level, and intensity, which is a subjective description of the level of shaking of the earthquake at specific sites, because shaking intensity can vary with earthquake magnitude, soil type, and distance from the event.

The following analogy may be worth remembering: earthquake magnitude and intensity are similar to a light bulb and the light it emits. A particular light bulb has only one energy level, or wattage (e.g., 100 watts, analogous to an earthquake’s magnitude). Near the light bulb, the light intensity is very bright (perhaps 100 foot-candles, analogous to MMI IX), while farther away the intensity decreases (e.g., 10 foot-candles, MMI V). A particular earthquake has only one magnitude value, whereas it has intensity values that differ throughout the surrounding land.

MMI is a subjective measure of seismic intensity at a site, and cannot be measured using a scientific instrument. Rather, MMI is estimated by scientists and engineers based on observations, such as the degree of disturbance to the ground, the degree of damage to typical buildings and the behavior of people. A more objective measure of seismic shaking at a site, which can be measured by instruments, is a simple structure’s acceleration in response to the ground motion. In this *Handbook*, the level of ground shaking is described by the spectral response acceleration.

F.2 Seismicity of the United States

Maps showing the locations of earthquake epicenters over a specified time period are often used to characterize the seismicity of given regions. Figures F-2, F-3, and F-4 show the locations of earthquake epicenters[4] in the conterminous United States, Alaska, and Hawaii, respectively, recorded during the time period, 1977-1997. It is evident from Figures F-2 through F-4 that some parts of the country have experienced more earthquakes than others. The boundary between the North American and Pacific tectonic plates lies along the west coast of the United States and south of Alaska. The San Andreas fault in California and the Aleutian Trench off the coast of Alaska are part of this boundary. These active seismic zones have generated earthquakes with Richter

[4]An epicenter is defined as the point on the earth’s surface beneath which the rupture process for a given earthquake commenced.

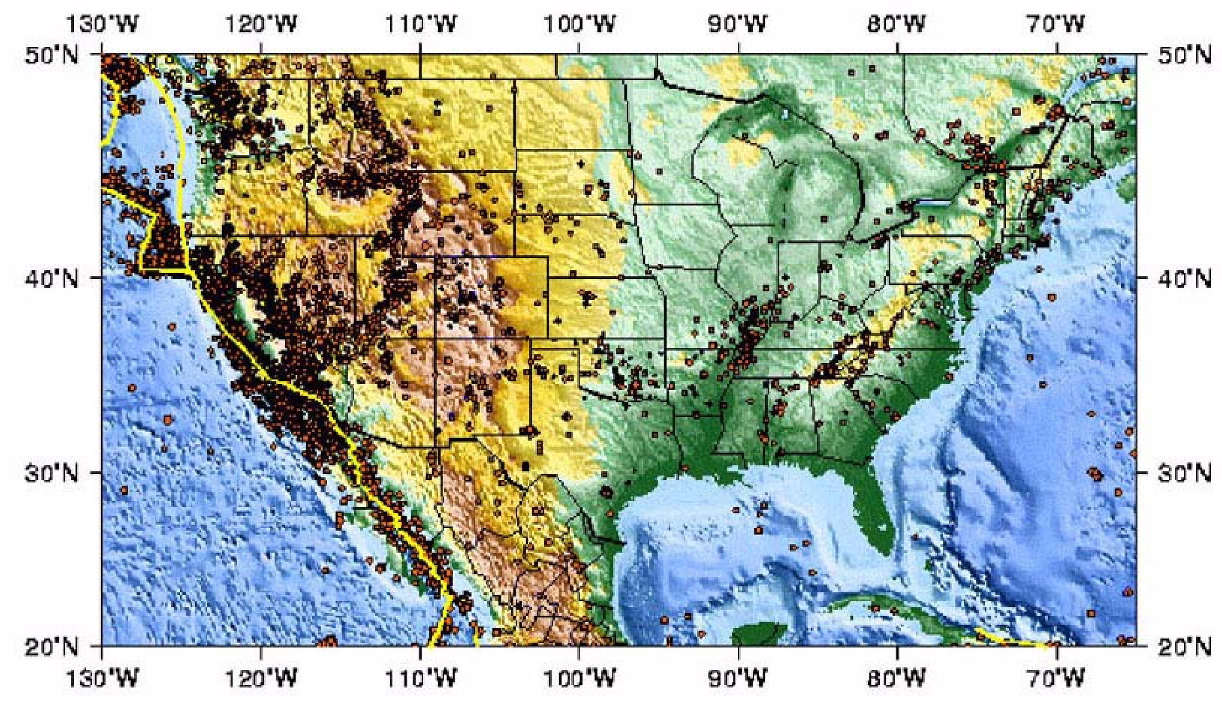


Figure F-2 Seismicity of the conterminous United States 1977 – 1997 (from the website at http://neic.usgs.gov/neis/general/seismicity/us.html). This reproduction shows earthquake locations without regard to magnitude or depth. The San Andreas fault and other plate boundaries are indicated with white lines.

magnitudes greater than 8. There are many other smaller fault zones throughout the western United States that are also participating intermittently in releasing the stresses and strains that are built up as the tectonic plates try to move past one another. Because earthquakes always occur along faults, the seismic hazard will be greater for those population centers close to active fault zones.

In California the earthquake hazard is so significant that special study zones have been created by the legislature, and named Alquist-Priola Special Study Zones. These zones cover the larger known faults and require special geotechnical studies to be performed in order to establish design parameters.

On the east coast of the United States, the sources of earthquakes are less understood. There is no plate boundary and few locations of faults are known. Therefore, it is difficult to make statements about where earthquakes are most likely to occur. Several significant historical earthquakes have occurred, such as in Charleston, South Carolina, in 1886 and New Madrid, Missouri, in 1811 and 1812, indicating that there is potential for large earthquakes. However, most earthquakes in the eastern United States are smaller magnitude events. Because of regional geologic differences, specifically, the hardness of the crustal rock, eastern and central U.S. earthquakes are felt at much greater distances from their sources than those in the western United States, sometimes at distances up to a thousand miles.

F.3 Earthquake Effects

Many different types of damage can occur in buildings. Damage can be divided into two categories: structural and nonstructural, both of which can be hazardous to building occupants. Structural damage means degradation of the building's structural support systems (i.e., vertical- and lateral-force-resisting systems), such as the building frames and walls. Nonstructural damage refers to any damage that does not affect the integrity of the structural support systems. Examples of nonstructural damage are chimneys collapsing, windows breaking, or ceilings falling. The type of damage to be expected is a complex issue that depends on the structural type and age of the building, its configuration, construction materials, the site conditions, the proximity of the building to neighboring buildings, and the type of nonstructural elements.

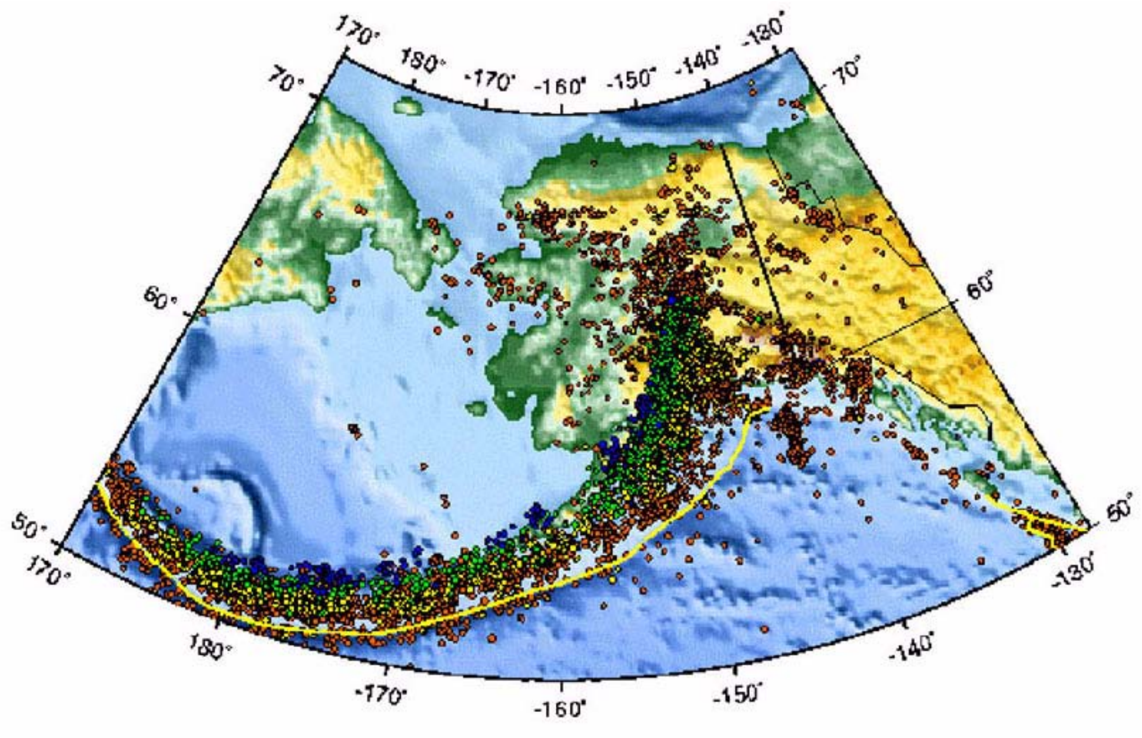


Figure F-3 Seismicity of Alaska 1977 – 1997. The white line close to most of the earthquakes is the plate boundary, on the ocean floor, between the Pacific and North America plates.

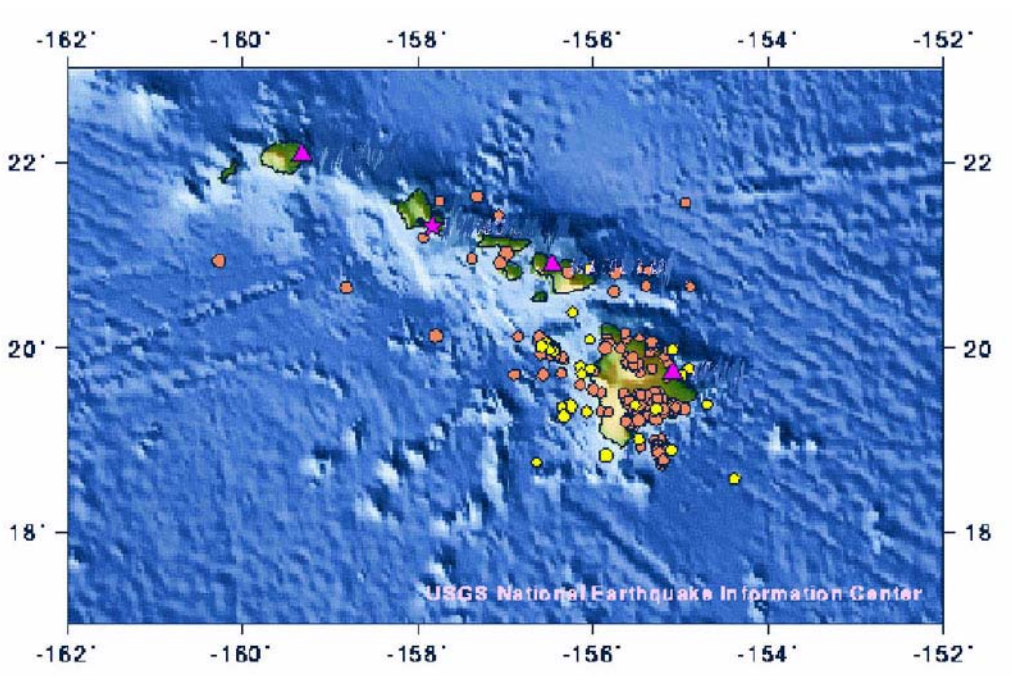


Figure F-4 Seismicity of Hawaii 1977 – 1997. See Figure F-2 caption.

When strong earthquake shaking occurs, a building is thrown mostly from side to side, and also up and down. That is, while the ground is violently moving from side to side, taking the building foundation with it, the building structure tends to stay at rest, similar to a passenger standing on a bus that accelerates quickly. Once the building starts moving, it tends to continue in the same direction, but the ground moves back in the opposite direction (as if the bus driver first accelerated quickly, then suddenly braked). Thus the building gets thrown back and forth by the motion of the ground, with some parts of the building lagging behind the foundation movement, and then moving in the opposite direction. The force F that an upper floor level or roof level of the building should successfully resist is related to its mass m and its acceleration a, according to Newton's law, $F = ma$. The heavier the building the more the force is exerted. Therefore, a tall, heavy, reinforced-concrete building will be subject to more force than a lightweight, one-story, wood-frame house, given the same acceleration.

Damage can be due either to structural members (beams and columns) being overloaded or differential movements between different parts of the structure. If the structure is sufficiently strong to resist these forces or differential movements, little damage will result. If the structure cannot resist these forces or differential movements, structural members will be damaged, and collapse may occur.

Building damage is related to the duration and the severity of the ground shaking. Larger earthquakes tend to shake longer and harder and therefore cause more damage to structures. Earthquakes with Richter magnitudes less than 5 rarely cause significant damage to buildings, since acceleration levels (except when the site is on the fault) and duration of shaking for these earthquakes are relatively small.

In addition to damage caused by ground shaking, damage can be caused by buildings pounding against one another, ground failure that causes the degradation of the building foundation, landslides, fires and tidal waves (tsunamis). Most of these "indirect" forms of damage are not addressed in this *Handbook*.

Generally, the farther from the source of an earthquake, the less severe the motion. The rate at which motion decreases with distance is a function of the regional geology, inherent characteristics and details of the earthquake, and its source location. The underlying geology of the site can also have a significant effect on the amplitude of the ground motion there. Soft, loose soils tend to amplify the ground motion and in many cases a resonance effect can make it last longer. In such circumstances, building damage can be accentuated. In the San Francisco earthquake of 1906, damage was greater in the areas where buildings were constructed on loose, man-made fill and less at the tops of the rocky hills. Even more dramatic was the 1985 Mexico City earthquake. This earthquake occurred 250 miles from the city, but very soft soils beneath the city amplified the ground shaking enough to cause weak mid-rise buildings to collapse (see Figure F-5). Resonance of the building frequency with the amplified ground shaking frequency played a significant role. Sites with rock close to or at the surface will be less likely to amplify motion. The type of motion felt also changes with distance from the earthquake. Close to the source the motion tends to be violent rapid shaking, whereas farther away the motion is normally more of a swaying nature. Buildings will respond differently to the rapid shaking than to the swaying motion.

Each building has its own vibrational characteristics that depend on building height and structural type. Similarly, each earthquake has its own vibrational characteristics that depend on the geology of the site, distance from the source, and the type and site of the earthquake source mechanism. Sometimes a natural resonant frequency of the building and a prominent frequency of the earthquake motion are similar and cause a sympathetic response, termed resonance. This causes an increase in the amplitude of the building's vibration and consequently increases the potential for damage.

Resonance was a major problem in the 1985 Mexico City earthquake, in which the total collapse of many mid-rise buildings (Figure F-5) caused many fatalities. Tall buildings at large distances from the earthquake source have a small, but finite, probability of being subjected to ground motions containing frequencies that can cause resonance.

Where taller, more flexible, buildings are susceptible to distant earthquakes (swaying motion) shorter

Figure F-5 Mid-rise building collapse, 1985 Mexico City earthquake.

Figure F-6 Near-field effects, 1992 Landers earthquake, showing house (white arrow) close to surface faulting (black arrow); the insert shows a house interior.

and stiffer buildings are more susceptible to nearby earthquakes (rapid shaking). Figure F-6 shows the effects on shorter, stiffer structures that are close to the source. The inset picture shows the interior of the house. Accompanying the near field effects is surface faulting also shown in Figure F-6.

The level of damage that results from a major earthquake depends on how well a building has been designed and constructed. The exact type of damage cannot be predicted because no two buildings undergo identical motion. However, there are some general trends that have been observed in many earthquakes.

- Newer buildings generally sustain less damage than older buildings designed to earlier codes.
- Common problems in wood-frame construction are the collapse of unreinforced chimneys (Figure F-7) houses sliding off their foundations (Figure F-8),collapse of cripple walls (Figure F-9), or collapse of post and pier foundations (Figure F-10). Although such damage may be costly to repair, it is not usually life threatening.
- The collapse of load bearing walls that support an entire structure is a common form of damage in unreinforced masonry structures (Figure F-11).

Figure F-7 Collapsed chimney with damaged roof, 1987 Whittier Narrows earthquake.

- Similar types of damage have occurred in many older tilt-up buildings (Figure F-12).

From a life-safety perspective, vulnerable buildings need to be clearly identified, and then strengthened or demolished.

F.4 How Buildings Resist Earthquakes

As described above, buildings experience horizontal distortion when subjected to earthquake motion. When these distortions get large, the damage can be catastrophic. Therefore, most buildings are designed

Figure F-8 House that slid off foundation, 1994 Northridge earthquake.

Figure F-9 Collapsed cripple stud walls dropped this house to the ground, 1992 Landers and Big Bear earthquakes.

Figure F-10 This house has settled to the ground due to collapse of its post and pier foundation.

Figure F-11 Collapse of unreinforced masonry bearing wall, 1933 Long Beach earthquake.

Figure F-12 Collapse of a tilt-up bearing wall.

with lateral-force-resisting systems (or seismic systems), to resist the effects of earthquake forces. In many cases seismic systems make a building stiffer against horizontal forces, and thus minimize the amount of relative lateral movement and consequently the damage. Seismic systems are usually designed to resist only forces that result from horizontal ground motion, as distinct from vertical ground motion.

The combined action of seismic systems along the width and length of a building can typically resist earthquake motion from any direction. Seismic systems differ from building to building because the type of system is controlled to some extent by the basic layout and structural elements of the building. Basically, seismic systems consist of axial-, shear- and bending-resistant elements.

In wood-frame, stud-wall buildings, plywood siding is typically used to prevent excessive lateral deflection in the plane of the wall. Without the extra strength provided by the plywood, walls would distort excessively or "rack," resulting in broken windows and stuck doors. In older wood frame houses, this resistance to lateral loads is provided by either wood or steel diagonal bracing.

The earthquake-resisting systems in modern steel buildings take many forms. In moment-resisting steel frames, the connections between the beams and the columns are designed to resist the rotation of the column relative to the beam. Thus, the beam and the column work together and resist lateral movement and lateral displacement by bending. Steel frames sometimes include diagonal bracing configurations, such as single diagonal braces, cross-bracing and "K-bracing." In braced frames, horizontal loads are resisted through tension and compression forces in the braces with resulting changed forces in the beams and columns. Steel buildings are sometimes constructed with moment-resistant frames in one direction and braced frames in the other.

In concrete structures, shear walls are sometimes used to provide lateral resistance in the plane of the wall, in addition to moment-resisting frames. Ideally, these shear walls are continuous reinforced-concrete walls extending from the foundation to the roof of the building. They can be exterior walls or interior walls. They are interconnected with the rest of the concrete frame, and thus resist the horizontal motion of one floor relative to another. Shear walls can also be constructed of reinforced masonry, using bricks or concrete blocks.

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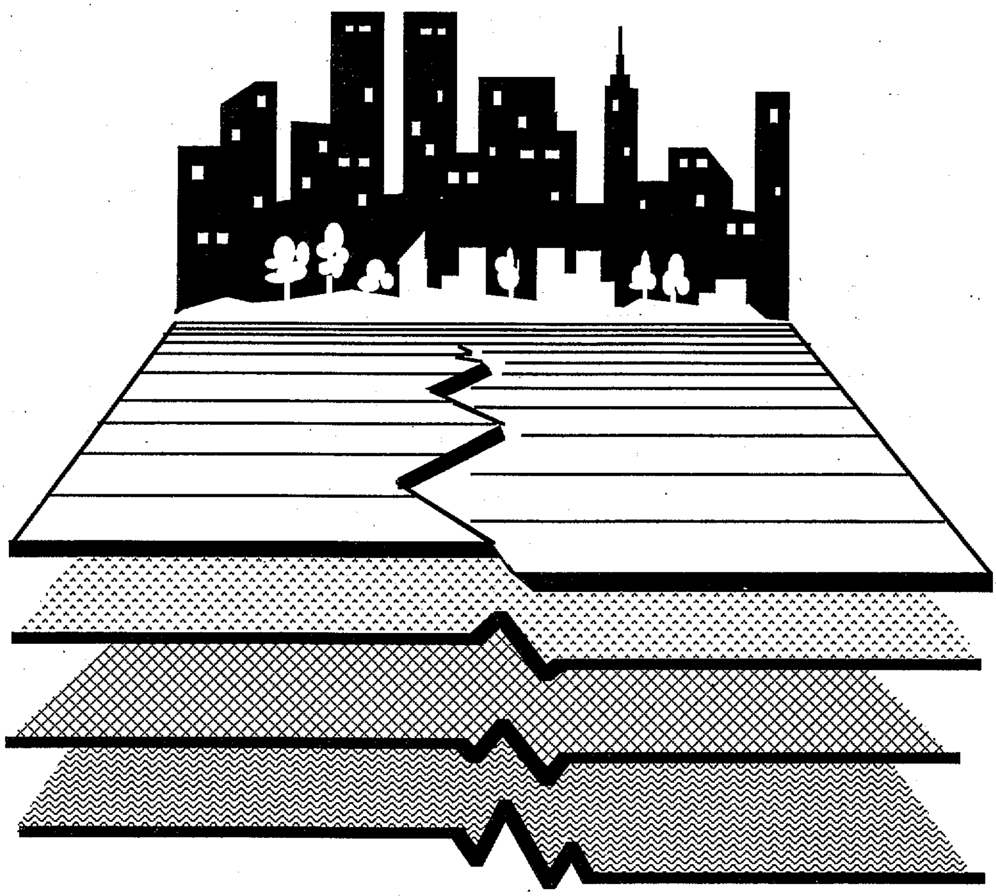
Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation



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RAPID VISUAL SCREENING OF BUILDINGS FOR POTENTIAL SEISMIC HAZARDS: SUPPORTING DOCUMENTATION

ATC

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The Applied Technology Council (ATC) is a non-profit, tax-exempt corporation established in 1971 through the efforts of the Structural Engineers Association of California. The purpose of ATC is to assist the design practitioner in structural engineering (and related design speciality fields such as soils, wind, and earthquake) in the task of keeping abreast of and effectively utilizing technological developments. To this end, ATC also identifies and encourages needed research and develops consensus opinions on structural engineering issues in a non-proprietary format. ATC thereby fulfills a unique role in funded information transfer.

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FEMA FOREWORD

The Federal Emergency Management Agency (FEMA) is pleased to have sponsored the preparation of this publication on rapid visual screening of seismically hazardous buildings. The publication is one of a series that FEMA is sponsoring to encourage local decision makers, the design professions, and other interested groups to undertake a program of mitigating the risks that would be posed by existing hazardous buildings in case of an earthquake. Publications in this series examine both engineering and architectural aspects as well as societal impacts of such an undertaking. They are prepared under the National Earthquake Hazards Reduction Program.

FEMA's program to mitigate the hazards posed by existing buildings was started in 1984 after resources appeared adequate to ensure the completion of a set of practical materials on the seismic safety of new buildings. The first project undertaken was the preparation of a *Plan of Action* and companion *Workshop Proceedings* by a joint venture consisting of Applied Technology Council (ATC), the Building Seismic Safety Council (BSSC), and the Earthquake Engineering Research Institute (EERI). The *Plan* included 23 priority items with a cost of about $40M and is being used as a "road map" by FEMA to chart activities and interpret, regroup, and expand projects in this area.

These activities will result in a coherent, cohesive, carefully selected and planned reinforcing set of documents enjoying a broad consensus and designed for national applicability. The resultant publications (descriptive reports, handbooks, and supporting documentation) will provide guidance primarily to local elected and appointed officials and design professions on how to deal not only with engineering problems, but also with public policy issues and societal dislocations. It is a truly interdisciplinary set of documents, even more so in concept and scope than the set related to new buildings.

Completed in the spring of 1988 were:

- The first collection of costs incurred in seismic rehabilitation of existing buildings of different occupancies, construction, and other characteristics, based on a sample of about 600 projects;

- A handbook (and supporting documentation) on how to conduct a rapid, visual screening of buildings potentially hazardous in an earthquake (ATC-21 and ATC-21-1 reports); and

- A report on the state-of-the-art of heavy urban rescue and victim extrication (ATC-21-2 report).

In preparation are:

- A handbook (and supporting documentation) on consensus-backed and nationally applicable methodologies to evaluate in detail the seismic risk posed by existing buildings of different characteristics (ATC-22 and ATC-22-1 reports);

- An identification of consensus-backed and nationally applicable techniques for the seismic-strengthening of existing buildings of different characteristics and a methodology to estimate their costs, with supporting documentation; and

- A handbook on how to set priorities for the seismic retrofitting of existing buildings—a truly interdisciplinary examination of the complex public policy-societal impacts of retrofitting activities at the local level.

In competitive procurement is:

- An identification of existing and realistically achievable financial incentives in the public and private sectors derived with the assistance of a user group and disseminated in selected localities cooperating in the effort.

Additionally recommended actions are:

- Cost benefit analyses to determine the costs and benefits resulting from rehabilitating selected types of buildings with selected occupancies in a number of cities in different seismic zones. They will build on all the engineering and societal information developed or being developed by the ongoing projects relating to existing buildings. Output will provide findings and recommendations in both strictly economic terms and also in societal and public-policy-related terms.

- A set of nationally applicable and consensus-approved guidelines for the seismic rehabilitation of existing buildings based on acceptable performance and other overarching criteria for strengthening buildings, and on the information developed in the other handbooks and supporting engineering reports described earlier. Reflected in the guidelines will also be the latest research results and technical lessons learned from recent earthquakes.

- Complementary materials to encourage the use of the recommended guidelines similar to those developed for new buildings.

- Information dissemination for existing hazardous buildings, to be modeled after and grafted onto the existing BSSC project of information dissemination on new buildings.

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PREFACE

In April 1987 the Federal Emergency Management Agency (FEMA) awarded the Applied Technology Council (ATC) a 1-year contract to develop a handbook on rapid visual screening of seismically hazardous buildings. The intent of the handbook is to provide a standard rapid visual screening procedure to identify those buildings that might pose potentially serious risk of loss of life and injury, or of severe curtailment of community services, in case of a damaging earthquake.

As the initial step in the development of this handbook, ATC evaluated existing procedures and identified a recommended rapid screening procedure. Included in this report are the results of this initial effort: (1) a review and evaluation of existing procedures; (2) a listing of attributes considered ideal for a rapid visual screening procedure; and (3) a technical discussion of the recommended rapid visual screening procedure. Also included as appendices are sample data entry forms for existing procedures and other supporting information.

Dames & Moore, San Francisco, California, a consulting firm with experience in the seismic evaluation of existing buildings, served as the project subcontractor. Charles Scawthorn, formerly with Dames & Moore and currently with EQE, Inc. San Francisco, served as Principal Author. He was assisted by Thalia Anagnos of San Jose State University. Members of the Project Engineering Panel who provided overall review and guidance for the project were: Christopher Arnold, Maurice R. Harlan, Fred Herman, William T. Holmes, H. S. Lew, Bruce C. Olsen, Chris D. Poland (Co-Principal Investigator), Lawrence D. Reaveley, Christopher Rojahn (Principal Investigator), Claire B. Rubin, Howard Simpson, Ted Winstead, and Domenic A. Zigant. Members of the Technical Advisory Committee, who reviewed the handbook from the user perspective near the close of the project, were: John L. Aho, Brent Ballif, Richard V. Bettinger, Patricia A. Bolton, Don Campi, Laurie Friedman, Terry Hughes, Donald K. Jephcott, Bill R. Manning, Guy J. P. Nordenson, Richard A. Parmelee, Earl Schwartz, William Sommers, Delbert Ward and Dot Y. Yee. Joann T. Dennett served as Technical Communication Consultant. The affiliations of these individuals are provided in Appendix D.

ATC also gratefully acknowledges the participation of the following individuals: Ugo Morelli, FEMA Project Officer, for his valuable assistance, support, and cooperation; Allan R. Porush, William E. Gates, Mike Mehrain and Ronald T. Eguchi of Dames & Moore for their review comments; Sandra Rush of RDD Consultants and Michele Todd of ATC for preparing the final manuscript; and Tom Sabol of Englekirk & Hart, for checking scores presented in Appendix B.

Christopher Rojahn
ATC Executive Director

SUMMARY

This is the second of a two-volume publication on a methodology for rapid visual screening of buildings for potential seismic hazard. A detailed description of the recommended procedure for identifying potentially hazardous buildings, including information to aid the field surveyor in identifying structural framing systems, is contained in the companion ATC-21 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (ATC, 1988).

A literature review of existing procedures for rapid visual screening of buildings for potential seismic hazards showed that few rapid screening methods exist in the literature, and that none has widespread application. A survey of practice indicated that present earthquake structural engineering practice may often involve an engineer conducting a "walk-through" survey of a building, but engineering practitioners appear to rely on extensive experience and judgment rather than any formal procedure. Although some rapid visual studies have been performed, mainly in California to identify unreinforced masonry (URM), these are not well documented in the literature.

The literature search and a review of surveys conducted by communities indicated that a satisfactory rapid visual screening procedure does not presently exist. A satisfactory rapid visual screening procedure would include the following attributes: (i) explicit definition of the expected ground motion (i.e., the "earthquake loading"); (ii) consideration of all major building types, not just one or two; (iii) a procedure whereby the degree of seismic hazard is quantitatively determined, thus permitting priorities to be set with regard to mitigation planning and detailed investigations of the most potentially hazardous buildings; (iv) a rational, analytically based framework for this quantitative procedure (in which weights or factors are not arbitrary), whereby the quantitative results relate to physical quantities and have a physical interpretation; (v) ability to be used nationwide and to account for local variations in building practice, loading levels, and site conditions; (vi) recognition and incorporation of probabilistic concepts, to permit treatment of the inherent uncertainties in attempting to identify building types and characteristics; (vii) incorporation of such factors as building age and condition; and (viii) background reference material illustrating building types, various structural hazards and related information.

This report presents a recommended procedure incorporating these attributes. It is based on a Basic Structural Hazard score, which equals the negative logarithm of the probability of major damage, with major damage defined as 60% or greater of the building's replacement value. Values of the Basic Structural Hazard score for 12 building types are determined for the National Earthquake Hazards Reduction Program (NEHRP) (BSSC, 1985) Map Areas 1 to 7, using data from ATC-13 (ATC, 1985). Modifiers on this score are also presented, based on the collective opinion of the Project Engineering Panel and other engineers nationwide for important seismic performance-related factors such as age, poor condition, and soft story. The procedure can be implemented in the field by use of a standard clipboard form, including a field photo and sketch of the building. Information to aid the field surveyor in identifying the appropriate building type and assigning a Basic Structural Hazard score and modifiers, are provided in the associated handbook, (ATC, 1988).

GLOSSARY

AF	Assessor Files
ABAG	Association of Bay Area Governments
ATC	Applied Technology Council
BF	Braced frame
BSSC	Building Seismic Safety Council
BW	Bearing wall
CF	Concrete frame
CSW	Concrete shear wall
CSWF	Combined shear wall, moment resisting frame
EERC	Earthquake Engineering Research Center
EQ	Earthquake
FEMA	Federal Emergency Management Agency
GNDT	Gruppo Nazionale per la Difesa dai Terremoti
HOG	House over garage
LB	Long Beach
LM	Light metal
MH	Mobile home
MMI	Modified Mercalli intensity
MSW	Masonry shear wall
N/A	Not applicable
ND-RC	Non-ductile reinforced concrete
NEHRP	National Earthquake Hazards Reduction Program
NISEE	National Information Service for Earthquake Engineering
NSF	National Science Foundation
PEP	Project Engineering Panel
P/F	Pass/fail
RC	Reinforced concrete
RM	Reinforced masonry
RSP	Rapid visual screening procedure
S	Structural Score
Sbn	Sanborn maps
SMRF	Steel moment resisting frame
SF	Steel frame
SW	Shear wall
TU	Tilt-up construction
UBC	Uniform Building Code
URM	Unreinforced masonry
W	Wood building, any type
WF	Wood frame

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1
INTRODUCTION

This report, sponsored by the Federal Emergency Management Agency (FEMA), reviews the literature and existing procedures on rapid visual screening in order to determine a recommended procedure as a first step toward the development of a handbook on the rapid visual screening of buildings for potential seismic hazards. The intent of the Handbook, which will be referred to as the *ATC-21 Handbook* (ATC, 1988), is to provide the target audience with a standard rapid visual screening procedure to identify those buildings that might pose potentially serious risk of loss and life and injury, or of severe curtailment of community services, in case of a damaging earthquake.

A rapid visual screening procedure (Rapid Screening Procedure, abbreviated RSP) is a methodology that, with associated background information, would permit an individual to visually inspect a building and, by obtaining selected data, to arrive at a decision as to which buildings should be further studied by an experienced professional engineer who would conduct a more in-depth review of the seismic capacity using structural drawings, design calculations, and perhaps inspecting the structure itself. The RSP inspection and decision-making process typically would occur on the spot, with perhaps two to four "average" buildings being reviewed per person-hour (i.e., 15 to 30 person-minutes per building). The personnel doing the rapid screening would typically not be experts in earthquake performance of buildings, but rather building inspectors, technicians or junior engineers.

Visual inspection would be a "sidewalk survey" done from the street, without benefit of entry to the building and without access to the structural drawings or most other supplementary information. In some cases, general structural general structural system-related information may be available to the inspector via building department or tax assessor files. (Note, however, that experience has shown the latter often to be unreliable with regard to structure information.) In effect, the inspector would note the dimensions of the building, its occupancy, structural materials and systems, condition, and other information. This information would be entered onto a form (on a clipboard or electronically), and employed in algorithms to determine a seismic hazard ranking for that building.

The RSP would be the first step of a two or more step process, in which ideally the RSP would permit (i) identification of those buildings that require additional, more detailed investigation by qualified engineers, and (ii) prioritization of the buildings to be further investigated, so that technical and other resources could be most effectively utilized.

It should be emphasized that any RSP is by definition a very approximate procedure, which will almost certainly fail to identify some potentially seismically hazardous buildings. The goal is to broadly identify *most* of the potentially seismically hazardous buildings, at a relatively modest expenditure of time and effort, and to eliminate *most* of the relatively adequate buildings from further review. Lastly, an RSP is a methodology intended for rapidly evaluating the hundreds or thousands of buildings in a community. It is *definitely not* intended for the full determination of the seismic safety of individual buildings.

The target audience for the *ATC-21 Handbook* includes:

- local building officials
- professional engineers

- registered architects
- building owners
- emergency managers
- interested citizens

Any or all of these people might be involved in efforts to identify a community's seismically hazardous buildings and mitigate the hazard. It is recognized, however, that building inspectors are the most likely group to implement an RSP, and this group is considered the primary target audience.

This report identifies, reviews, and critiques those RSP's currently or previously used to evaluate seismically hazardous buildings. For each method the following is provided:

- a description and discussion of technical advantages and disadvantages, including suitability of scope and format, and costs of implementation
- impacts and implications of regional variations in construction practices and seismic loading levels
- suitability for use by each segment of the target audience
- the general level of uncertainty inherent in its use

Three main sources for identifying existing procedures were used:

- the technical literature
- discussions with jurisdictions and communities that have performed or attempted a survey of their seismically hazardous buildings
- practicing professional engineers who are called upon to provide opinions as to the seismic hazard of a building or other structures. (Prominent engineering firms have performed rapid screenings of hundreds of buildings.)

Technical literature was identified by electronic data retrieval (i.e., the Engineering Index, accessed via Dialog); citations furnished by the ATC-21 Project Engineering Panel; review of the National Information Service for Earthquake Engineering (NISEE) holdings at the Earthquake Engineering Research Center in Richmond, California; and information and references in the author's files.

There exists an extensive body of literature on methods of seismic analysis and/or review of existing buildings. However, most of these methods are simplified or more or less detailed engineering analysis procedures, involving computations of seismic demand and capacity, often with the benefit of the structural plans or similar detailed privy information. Although some of these methods contain an initial rapid visual screening element, most do not. Therefore, only those methods that explicitly have a rapid visual screening element have been reviewed herein, and no attempt has been made to review the much larger literature of seismic evaluation of existing buildings.

Following this first section, the remainder of this report consists of the following chapters:

Chapter 2: Definition of an ideal rapid visual screening procedure, against which existing methods are judged

Chapter 3: Summary of each of the RSP's identified

Chapter 4: Presentation of the evaluation criteria used in this project and a detailed evaluation of the following aspects of the RSPs reviewed herein:

- Organizational
- Structural
- Configuration
- Site and Non-structural
- Personnel

Chapter 5: Recommended procedure for rapid visual screening of buildings for potential seismic hazards

Lastly, the appendices include typical data sheets employed in several of the surveys reviewed; an explanation of the determination of the Basic Structural Hazard scores and modifiers; the criteria for selection of a cut-off Structural Score; and a list of the ATC-21 project participants.

2

ATTRIBUTES OF AN IDEAL RAPID VISUAL SCREENING PROCEDURE

In order to evaluate existing RSP's, a set of criteria is required against which present RSP's can be judged. In this chapter, the attributes of such an "ideal rapid visual screening procedure" are presented. These ideal attributes have been determined based on a review of rapid visual screening procedures, as presented in the following sections, as well as the general experience of the project participants in conducting numerous field surveys and analyses of existing buildings. No single, currently available RSP satisfactorily incorporates all of the attributes indicated below.

Applicability to All Building Types: A rapid visual screening procedure for identifying seismically hazardous buildings should provide an initial assessment of the seismic hazard of individual buildings and therefore it should not be limited to one type of building structure. Rather it should be capable of identifying hazardous buildings of all construction types. For example, many rapid visual surveys have been limited to identifying unreinforced masonry (URM) structures, based on the assumption that these are the most hazardous buildings in the community. Although URM hazards have thus been identified, other (sometimes greater) hazards, for example, related to older tilt-up or non-ductile concrete buildings, have gone uncounted. Should the need arise, an RSP could be applied to only one structural category. However, all building groups should receive at least an initial limited-sample test screening in a portion of the community, to verify assumptions of which building type is the most hazardous. If these assumptions are verified, then selected building groups/areas may be targeted, for reasons of economy. The situation of, for example, identifying all unreinforced masonry buildings and having no idea of the seismic hazards in the non-ductile reinforced concrete building group, or the house-over-garage building group, should be avoided.

Quantitative Assessment: Assessment of the hazard should be quantitative as it not only permits pass/fail decisions, but also provides a ranking system that may be used to set priorities within the "failed" category. A quantitative scheme also has the advantage of assuring a more uniform interpretation of the weights of "structural penalties" by survey personnel.

Nonarbitrary Ranking System: Although several of the studies reviewed do include quantitative approaches, these scoring systems are arbitrary and provide relative hazard assessments rather than an estimate of actual hazard based on physical parameters. A quantitative ranking system, which is useful for ranking structures for hazard abatement, should be nonarbitrary to avoid misleading results. The scores should be rationally based, and include uncertainty when possible. Their development should be clear so that new data can be incorporated as they become available and so that the scores can be modified for local building conditions.

Supplemental Information: As much as possible, supplemental information from building department and assessor's files, insurance (Sanborn) maps, previous studies and other sources should be collated and taken into the field in a usable format, for verification as well as to aid field personnel. Ideally, these data should be in a form so that information can be easily attached to each survey form as it is completed (e.g., a peel-off label or a computer-generated form, with part identifying the building and containing pre-field data, and part to be filled out in the field).

Earthquake Definition: An important attribute is that the earthquake loading against which the capacity of the building is being judged be defined explicitly, preferably in physically based units such as acceleration. Otherwise it is unclear what "earthquake" loading the structures are being judged against and, further, the RSP is limited in its application to the region for which it was developed. Structures will have different damage potential in regions with different seismicity; thus a clear definition of the seismic demand should be included. Although a few of the available methods do include some explicit earthquake definitions, in most of these it is in the form of Modified Mercalli Intensity or Uniform Building Code zone. The complex questions of what earthquake loading a building should withstand and what the "acceptable risk" should be often require iterative solutions; therefore, it is possible that a re-screening could occur at a later time. Thus sufficient building-specific data should be recorded to permit adjustments should the input earthquake data be modified.

Data Collection: Organization of the data is an important part of an RSP. Specific details of structural type and configuration, site conditions, and non-structural aspects should be in a checklist format to avoid omissions. The data collection form should provide space for sketches, photos, and comments and should systematically guide personnel through the data recording procedure. Sketches and photos are invaluable for later reference. Both should be an integral part of the field data recording, because they are complementary. (A photo is data intensive, whereas a sketch emphasizes selected features, such as cracks, that may not be easily discernible on a photo of an entire building. In addition, requiring a sketch forces the surveyor to observe the building in a systematic fashion.)

Systematic and Clear Criteria: It is essential that an RSP, and the decisions deriving therefrom, be based on well-documented criteria and that "judgment" decisions be minimized. Although it is anticipated that survey personnel will have some interest in the elements of earthquake behavior of buildings and be capable of making subjective decisions when necessary, they should be provided with extensive written guidelines to avoid differing interpretations of the criteria for identifying hazardous buildings. Documentation should include many sketches as well as "inferences," or rules, to assist personnel in making decisions when information is uncertain.

Age: Age should be explicitly recorded. Often unavailable, age can be estimated, usually within a decade or two, on the basis of architectural style. Age can indicate whether a building is pre- or post- a specific "benchmark" year in the development of seismic codes for that building type. For example, in San Francisco, wood-frame buildings were required to be bolted to their foundations only since 1948. If a wood-frame building was built before 1948, it is likely that it is unbolted. These benchmark years differ by jurisdiction, but usually are locally known or can be determined.

Condition: State of repair is an important factor in seismic performance, and should be required to be noted, as it forces the survey personnel to look for problems such as cracks, rot, and bad mortar. Where relevant, this would include previous earthquake damage. Additionally, renovation should be noted, where possible. Renovation can be positive, because it indicates increased investment (which may have led to improvements in the structure), and/or negative, when it masks the true age of the structure. Additionally, renovation may have resulted in the removal and/or alteration of important structural members and thus may affect seismic performance. A common example is the "addition" of loading doors by saw-cutting of walls in tilt-up buildings, which actually removes seismic resistance.

Occupancy: Occupancy should be noted, as it is a factor in overall risk and may be required for subsequent decision making. How it will be factored into seismic hazard decision making is sometimes a difficult question. In some of the surveys reviewed, buildings were classified into high, medium, and low risk categories depending on the occupancy. This information was then used to rank the hazardous structures.

Configuration: Configuration issues should be noted and their contribution to the hazard quantified. It is clear from past experience that structural irregularities can be significant in the performance of a building during an earthquake. Many of these issues have been identified by Arnold and Reitherman (1981), and include items such as soft story, vertical and/or horizontal discontinuities, and irregularities of plan.

Site Aspects: Site aspects such as potential pounding between buildings, adjacent potentially hazardous buildings, corner buildings, and soil conditions need to be noted and quantified. By quantifying poor site conditions as "penalties," the survey personnel will have a uniform interpretation of the importance of each of the issues in the performance of the building.

Non-structural Architectural Hazards: Earthquake damage to building ornamentation or exteriors can lead to significant damage and/or life-safety hazard. Common examples include the fall of parapets, chimneys, and other overhanging projections.

Personnel Qualifications: Personnel background and training may prove critical to the results of an RSP. An ideal RSP should rely as little as possible on the need for extensive technical education or experience on the part of the personnel involved. Ideally, technician-level individuals (high school plus one to two years equivalent education/experience) should be able to perform the RSP, after one or two days of specialized training.

Hazard Analysis Scheme: Finally, for an ideal RSP the scheme for combining scores to identify the degree of seismic hazard for a building structure should be simple and fast, involving little or no field calculations beyond simple arithmetic.

The following chapters first present a summary of each of the RSP's identified, then evaluate them against the above "ideal" attributes, and finally, present a recommended procedure.

3
SUMMARY OF EXISTING RAPID SCREENING PROCEDURES

A large number of methods for rapid analysis of seismically hazardous buildings can be found in the literature; however, these are generally abbreviated engineering analyses, requiring a trained engineer and access to the structural drawings. Only a few rapid visual screening methods have been found to exist, and none has had widespread practical application. Some of the available methods have been tested in limited areas for the purpose of refining the survey techniques but never have been applied to an entire community. In many cases the survey method that was chosen depended upon the ultimate use of the data that were gathered—for example, property loss estimation or life-safety estimation versus hazardous building identification. Thus, the different survey formats are in many cases a result of different goals, budgets, and personnel requirements.

This section presents citations and a summary of each RSP identified during the review of the literature, present practice, and community surveys. Each RSP has a brief acronym or other identifier (e.g., NBS 61 refers to the methodology developed at the National Bureau of Standards by Culver et al., 1975; OAKLAND study refers to a survey of buildings in the City of Oakland published in 1984), a bibliographic citation, and typically a one-paragraph summary overview of the methodology or study. The rapid screening procedures have been divided into two groups, surveys and methods, and are presented in reverse chronological order within each of these groups. Surveys are defined as those RSPs that have actually been applied to a real community. Methods are defined as those RSPs that are found in the literature, but as far as could be ascertained have not been applied to any community. Comparisons of certain aspects of the methods are presented in tables in Chapter 4.

SURVEYS

City of Redlands Study. Seismic Strengthening, Final Report and Handbook (1987). Report published by the Department of Economic and Community Development, County of San Bernardino, California. Also M. Green, personal communication.

> This handbook develops an RSP and presents a case study in the City of Redlands, California. The study was sponsored by the County of San Bernardino and the Southern California Earthquake Preparedness Project to identify potentially hazardous unreinforced masonry bearing wall buildings and to encourage voluntary seismic strengthening. The visual survey is designed to be conducted by inspector level personnel, with data being entered on forms (provided herein in Appendix A). Initial survey target areas were chosen based on the density of suspect unreinforced masonry buildings. Design level, building configuration, non-structural hazards, and adjacencies were used to identify the hazardous buildings. The survey resulted in maps showing the distribution and location of hazardous buildings in the city. Buildings were then ranked using a chart of tolerability of failure versus probability of failure for each building. The ranking included occupancy information. In its present

form, the method is limited to URM bearing wall structures and is therefore too limited for an ideal RSP.

San Francisco Study. A Survey of Unreinforced Masonry Buildings in San Francisco (1987). Report by Seismic Investigation & Hazards Survey Advisory Committee, and Department of Public Works. F. Lew, personal communication.

This survey was conducted by the San Francisco Building Department (1985-1986) to identify all unreinforced masonry buildings in the city. An office phase employed Assessor's files, Sanborn maps and Parapet Safety Program files to identify pre-1950 non-wood construction (approx. 6000). Every street in the city was then visually screened by building inspectors to determine and confirm which buildings were unreinforced masonry. The result of the survey is a list of approximately 2100 unreinforced masonry buildings that will be used with a future ordinance specifying mitigation procedures and timetables. Factors such as building configuration, occupancy, age and size were noted, but this information was not used. Costs and level of effort are as follows: two inspectors full time for one year surveyed this city of 700,000 population for a total reported cost of $120,000 (including clerical support).

ABAG. Perkins et al. (1986). Building Stock and Earthquake Losses - The San Francisco Bay Area Example Report by the Association of Bay Area Governments (ABAG), Oakland, California.

This is a survey conducted to estimate the building inventory for nine San Francisco Bay Area counties for estimation of earthquake losses. Specific hazardous buildings were not identified; only estimates of the number and geographic distribution of buildings of each type were provided. Hence, there is no well-defined methodology for identifying specific seismically hazardous buildings. Many of the data were collected from land use maps, interviews with local building officials, Sanborn maps, and previous studies. "Windshield" surveys were conducted by ABAG project staff and a graduate student in architecture to supplement data on building types and to identify seismically suspicious unreinforced masonry buildings in older downtown, commercial, and industrial areas.

Stanford Project. Thurston, H. M., Dong, W., Boissonnade, A. C., Neghabat, F., Gere, J. M., and H. C. Shah (1986). Risk Analysis and Seismic Safety of Existing Buildings. John A. Blume Earthquake Engineering Center, TR-81, Stanford University, Stanford, CA.

This expert-system based method has two steps: (1) Using a computer program, Insight 2 (termed an expert shell), a pre-field screening is performed on the basis of geology, ground motion (MMI), building importance, and vulnerability (furnished from building department and other sources). (2) If the pre-field screening warrants it, an inspection of the building including drawings and building access is performed. A numerical value for risk is assigned using an expert system built from the Deciding Factor shell. (Loosely defined, an expert-system is a computerized data base or "knowledge base" containing logic and rules that process input information to arrive at some conclusion. Ideally its logic is similar to the thought process of a human expert.) Palo Alto was used as a case study to validate the expert system by comparing its risk evaluations with those of experts. Sample data sheets are included herein in Appendix A. The use of an expert system to supplement visually obtained survey data should make this method suitable for a larger target audience; however, in its present form the field survey is too detailed for a rapid visual procedure. In addition, the weighting scheme used to rank building hazard is subjective and not based specifically on damage-related data. This is an extension of earlier work by Miyasato et al. (1986).

Low-Rise Study. Wiggins, J. H., and C. Taylor (1986). Damageability of Low-Rise Construction, Vol. II & IV. Report by NTS Engineering for National Science Foundation, Long Beach, California.

This is an NSF-supported project to develop a methodology to estimate earthquake losses in low-rise buildings. A rating scheme based on a maximum value of 180 points is used. This study is an extension of the method developed for the 1971 Long Beach study. The insurance industry is the primary user of this method. Data gathering, however, is not done by field inspectors. Instead a short questionnaire about relevant aspects of the structure is completed by the building owner and decisions are made from the responses. As such, this is not an RSP.

U.S.-Italy Workshop. Angeletti, P., and V. Petrini (1985). Vulnerability Assessment, Case Studies. US-Italy Workshop on Seismic Hazard and Risk Analysis (Damage Assessment Methodologies), Varenna, Italy, 73-100.

Two methods are presented. The first, a subjective side walk survey, can be performed quickly (12–16 buildings/day per team), and the second is a more in-depth survey with quantitative vulnerability assessments (4–8 buildings/day per team). Both methods were tested on 490 buildings (379 masonry, 111 reinforced concrete) in Forli, Italy, in 1984, using 100 public technicians and 15 earthquake engineering experts and on 293 buildings (279 masonry, 14 reinforced concrete) in Campi Bisenzio. The results are in the form of histograms and maps of vulnerability classes.

Charleston Survey. Survey of Critical Facilities for the City of Charleston, South Carolina (1984-1985). M. Harlan, personal communication.

This study, funded by FEMA, was conducted for the purpose of estimating structural vulnerability and loss of function for the Charleston area in the event of a large earthquake. The study was not used to identify buildings for seismic rehabilitation. Probable Maximum Loss (PML), was used as the measure of damage. (PML was defined by Steinbrugge (1982) as the "expected maximum percentage monetary loss that will not be exceeded for 9 out of 10 buildings.") All critical facilities were evaluated, totaling about 350 buildings. No non-critical facilities were reviewed. Copies of the survey forms and rating forms are included in Appendix A. The advantage of these forms is that they are in a check-off format, thus minimizing omissions. The disadvantage is that they are too long for a rapid visual procedure. This survey was much more detailed than an RSP. Building entrance and plan review were often necessary to determine the PML modifiers needed for Steinbrugge's method. The vulnerability report has not yet been published. Third or fourth year university engineering students performed the survey. Students were given one to two weeks of training before going into the field. Each student reviewed an average of 3 buildings per day. Cost data were not available.

Palo Alto Survey. Survey of Buildings for the City of Palo Alto (1984-85), F. Herman, personal communication.

In 1984-1985, a local jurisdiction (Palo Alto, California) developed an ordinance and a survey method to identify and cite seismically hazardous unreinforced masonry and other specified buildings. The survey focused on three types of structures: (1) unreinforced masonry, (2) pre-1935 construction with more than 100 occupants, and (3) pre-1976 construction with more than 300 occupants. Seismically hazardous buildings were identified, primarily based on age and type of construction, number of occupants, and present condition. A sidewalk survey conducted by civil engineering graduate students under the supervision of a building department official was supplemented with Sanborn maps, building department files, and information from a previous survey conducted in 1936. Hazardous buildings were cited and owners were given one to two years to submit a detailed structural analysis of the building for city review. Examination of the several sample data sheets (included in Appendix A) shows that very little site or structure-specific information was requested in the sidewalk survey. All information about configuration problems, nonstructural hazards, and building dimensions would be included in the remarks area at the discretion of the inspector. This is because the method was essentially pass/fail based on whether a building could be classified into one of the three categories described above.

Oakland Study. Arnold, C. A. and R.K. Eisner (1984). Planning Information for Earthquake Hazard Response and Reduction. Building Systems Development Inc., San Mateo, California.

This is an NSF-sponsored investigation by Building Systems Development and the University of California, Berkeley, of urban planning for seismic risk mitigation, using Oakland as a case study. The procedure was mainly a sidewalk survey of building exteriors following an initial screening using information from Sanborn maps, assessor's files, and building permits. The survey was conducted by graduate students in architecture with guidance from a registered architect. The final product was the identification of "seismically suspicious" buildings, determined mostly on the basis of structural system and configuration factors and, to some extent, occupancy. Some factors, such as non-structural hazards, were noted, but it is not clear that they were used in identifying the seismically suspicious buildings. The report does not specify how the collected data were combined to determine the hazard of a building and thus the method requires a great deal of technical judgment. An example of the data collection sheet used in the sidewalk survey is included in Appendix A. Although building types and occupancy classes are well defined, other information is loosely defined, possibly leading to a lack of consistency among different data collectors. The level of effort expended involved 2 graduate students in architecture, a total of approximately 350 hours for 2500 buildings, and an approximate cost of $20,000.

Multihazard Survey. Reitherman, R., Cuzner, G., and R. W. Hubenette (1984). Multihazard Survey Procedures. Report by Scientific Service, Inc., Redwood City, California, for FEMA. (R. Hubenette, personal communication).

This method, developed for FEMA and

adopted in FEMA technical report TR-84, is designed to apply to essential facilities necessary for disaster operations. The method identifies and quantifies, on a scale of 1 to 5, a building's vulnerabiliy to radiation, fire, earthquake, high wind, tornado, hurricane, and flood hazards. The vulnerability is determined from a combination of the resistance of the construction and the exposure of the building to the particular hazard, but this calculation is not done by the surveyor. All data are processed by computer at the national level (FEMA). The method has been adopted and implemented since 1985 in many states, including California, Florida, North Carolina and Arizona. However, the priority for the multi-hazard surveys is civil defense related, and in many cases the earthquake portion of the survey is not performed. All survey data are collected on a standardized form (included in Appendix A) and are entered in a national database. The data collection form is organized to facilitate the computerized data processing, but it is difficult to follow. Rather than a checkoff format, the form requires the use of numerical codes that are not easily memorized. One of the promising and unique features of this method is that inference rules are provided for cases when visual inspections, drawings, and other supplemental information are not adequate to positively answer survey questions. The method is more detailed than an RSP, as building entrance is necessary and sometimes plans are reviewed. The survey can take from one hour to three days per building. Survey personnel need a minimum of two years undergraduate technical background. Cost information was not available.

New Madrid Study. An Assessment of Damage and Casualties for Six Cities in the Central United States Resulting from Two Earthquakes, M=7.6 and M=8.6, in the New Madrid Seismic Zone (1983). Report by Allen & Hoshall, Inc., Memphis, Tennessee, for FEMA.

This study, also known as the Six Cities Study, assesses damage due to earthquakes on the New Madrid fault zone. An extensive inventory of buildings was supplied by FEMA for the six project cities. These data were checked and in some cases supplemented by visits to the sites by a structural engineer and an engineering technician. In other cases, the data were verified by telephone contact with facility managers. The inventory was limited to a few representative structures of well-defined classes such as hospitals, critical structures, transportation systems, public utilities, and schools, and was primarily to assess the type of construction for each of the classes. Three different survey forms were available depending on the class of the structure and information required (see Appendix A). This is not a rapid visual screening procedure, but a sampling procedure to infer the properties of the larger building inventory for use with fragility curves to estimate damage. Cost information was not available.

OSA Hospital Survey. Earthquake Survivability Potential for General Acute Care Hospitals in the Southern California Uplift Area (1982). Report by Office of the State Architect for Office of Statewide Health Planning and Development, California. J. Meehan, personal communication.

This inventory and evaluation of hospitals in the Palmdale Bulge area were done by structural engineers from the Office of the State Architect. Hospitals were classified into six "survivability index" categories from A (low risk) to F (high risk) based on the date of construction and structural information. The criteria used in this survey require extensive engineering judgment and are specific to hospitals as they are based on adherence to Titles 17 and 24 of the California Administrative Code. Data were gathered by extensive interior and exterior visual inspections along with an in-depth review of construction drawings when possible. Level of effort was probably one to two engineer-days per hospital, depending on the complexity. This was not a rapid procedure, but rather a detailed inventory of hospital resources, such as beds and rooms, as well as anchorage of equipment and availability of emergency services.

Los Angeles Study. Survey of Unreinforced Masonry Bearing Wall Buildings (1978-1979) for the City of Los Angeles. E. Schwartz, personal communication.

This study in the City of Los Angeles was performed by city building inspectors during 1978-1979 for the purpose of identifying bearing wall unreinforced masonry buildings, but not infill or other types of URM. Preliminary identification of pre-1934 URM was performed using assessor's files, Sanborn maps, and records from a previous parapet stabilization program, resulting in identifying about 20,000 potentially hazardous buildings. A block-by-block visual survey of building exteriors (and interiors when possible) reduced this to a final count of about 8,000 hazardous buildings. Although configuration and state of repair were noted, the primary criterion used to identify the hazardous buildings was the existence of unreinforced masonry bearing walls. An average of 40 minutes was spent at each building. After the data were collected, hazardous buildings were placed in one of four classes: (1) essential buildings, which were mostly state- or city-owned; (2) high-risk buildings, with more than 100 occupants and/or few interior walls; (3) medium-risk buildings, defined as having 20 to 100 occupants and/or many interior partitions; and (4) low-risk buildings, those buildings with less than 20 occupants. These categories were used to prioritize the mitigation procedures. The level of effort expended involved 6 inspectors, 1 senior inspector, 1 structural engineer, 2 clericals, all for 2 years, at a cost of approximately $400,000.

University of California Study. McClure, F. E. (1984). "Development and Implementation of the University of California Seismic Safety Policy." Proceedings, Eighth World Conference on Earthquake Engineering, San Francisco, 859-865. F. McClure and L. Wyllie, personal communication.

In response to the 1975 seismic safety policy implemented by the University of California, a survey of buildings with area greater than 4,000 sq ft and with human occupancy was conducted by experienced structural engineers (Degenkolb Associates were consultants on this project). Based on structural, non-structural and life-safety judgments, a seismic rating of good, fair, poor, or very poor was assigned by observations of building exteriors and a review of design drawings and previous engineering reports. Two to four days were spent on each of 9 campuses, for a total review of 44 million sq ft, of which 21% rated poor or very poor. The effort was split between reviewing drawings and on-site inspection. There were no formal criteria in this study, as decisions were made on a building by building basis. A considerable amount of judgment and engineering experience was required to perform this survey.

Santa Rosa Study. Identification of Seismically Hazardous Buildings in Santa Rosa, 1971-present. W. E. Myers. personal communication. Also, Myers, W. E. (1981). "Identification and Abatement of Earthquake Hazards in Existing Buildings in the City of Santa Rosa." Proceedings, 50th Annual SEAOC Convention, Coronado, CA, 55-66.

This study arose from an ordinance adopted by the Santa Rosa City Council in 1971 to review all buildings constructed before December 31, 1957 (one and two-story wood frame, single family dwellings were exempt from the review process). A preliminary review is performed by a city official (experienced structural engineer) to determine if further review is necessary, based on whether the building complies with the 1955 UBC. Any further review is the responsibility of the building owner and must be prepared by a structural or civil engineer. The initial screening consists of a half day (on average) detailed site inspection involving entry into the building, including the basement, attic, and other portions of the building, noting such features as wall ties, openings, and diaphragms. Fire as well as earthquake-related hazards are usually identified. Data are collected using a handheld tape recorder, and later transcribed. Where possible, plans are examined, although in many cases they are unavailable. In a few cases rough calculations are performed. Subsequently a report is written (2 to 20 pages depending on the complexity of the structure) and submitted to the owner with a timeline for mitigation. The established priority of review was based on the number of occupants, buildings with the most occupants being reviewed first. Reviews began in 1972 on churches and other buildings with assembly occupancy greater than 100 persons, and in 1987 the city was reviewing buildings with smaller occupancy such as office buildings and retail stores. Between 1972 and 1987, approximately 400 buildings were initially reviewed (out of approximately 600 in the city) with about 90 percent requiring further review. Due to the detailed nature of the visual inspection and the level of engineering expertise required, this does not fulfill the definition of an RSP. The level of effort expended was: 1 full-time engineer employed by the city for 15 years, and a cost of approximately $500 per building.

Long Beach Study. Wiggins, J. H., and D. F. Moran (1971). Earthquake Safety in the City of Long Beach Based on the Concept of Balanced Risk. Report by J. H. Wiggins Co., Redondo Beach, California. Also E. O'Connor, personal communication.

This study was developed as part of a model ordinance (Subdivision 80) for the City of Long Beach. It was a significant advancement in the techniques of rapid identification of seismically hazardous buildings. In the original methodology, five factors were scored and combined to form a hazard index: (a) framing system/walls, (b) diaphragm/bracing, (c) partitions, (d) special hazards, and (e) physical condition. A score of 0–50 indicated rehabilitation was not required; 51–100 indicated some strengthening was required; and 101–180 indicated a serious life hazard existed. This widely known method was not directly employed by Long Beach but was modified in the ordinance to score the following five structural resistance factors for unreinforced masonry: (a) wall stability, (b) wall anchorage, (c) diaphragm capacity, (d) shear connection capacity, and (e) shear or moment resisting element capacity. Occupancy, importance and occupancy potential factors were also included. A survey of 928 pre-1934, type 1, 2 or 3 buildings was conducted by city building inspectors over several years. Deadlines for hazard mitigation depend on the ranking provided by the hazard index.

METHODS

Seismic Design Guidelines for Upgrading Existing Buildings (A Supplement to "Seismic Design Guidelines for Buildings") (1986). Dept. of the Army.

> This is a methodology developed for the Army that contains both a rapid visual component and a detailed structural analysis. The result of the visual survey is a list of buildings that should be further reviewed. The first step is to eliminate buildings from the survey inventory using eight prescribed criteria. The remaining buildings are then classified as (1) essential, (2) high risk or (3) all others. All available design criteria such as drawings, calculations, and specifications are compiled and pertinent information is transferred to the screening form (Appendix A). A field survey is then performed, allocating 10 to 30 minutes per building. Buildings are eliminated from the list if it would not be feasible or cost effective to upgrade them, or if they are identical to other structures that will be reviewed.

ATC-14, (ATC, 1987). Evaluating the Seismic Resistance of Existing Buildings. Applied Technology Council, Redwood City, California.

> Although this extensive methodology contains no rapid visual screening aspect, it is included in this review because Section 4.2.2 and Appendix C of ATC-14 contain checklists of features that, if elaborated, could form the basis for an RSP. Moreover, buildings identified by the ATC-21 methodology as seismically hazardous should be reviewed in detail with the methodology presented in the ATC-22 Handbook (in preparation), which is based on the ATC-14 methodology.

A Methodology for Seismic Evaluation of Existing Multistory Residential Buildings. U.S. Department of Housing & Urban Development, 3 volumes. Pinkham, C. W., and G. C. Hart (1977).

> This method is based on NBS 61 (described below); however in this case only Masonry B (UBC 73, sections 2414, 2415 and 2418) and Masonry A (all other concrete or brick masonry) are targeted. This is essentially a rapid analysis procedure with a preliminary visual screening component. The data collection forms are the same as those for NBS 61. However, the criteria for preliminary screening are not well defined and therefore require a good deal of judgment.

NBS 61. Culver, C. G, Lew, H. S., Hart, G. C., and C. W. Pinkham (1975). Natural Hazards Evaluation of Existing Buildings, BSS 61, National Bureau of Standards, Washington, D.C.

> This is an extensively developed methodology, designed for building officials and engineers, to evaluate existing buildings for major natural hazards: earthquake, high wind, tornado, and hurricane. Evaluation of existing buildings is performed in three levels, the first of which is a simple visual procedure, providing input to several simple equations that result in a Capacity Rating (CR). This method has been widely referenced but not directly or explicitly applied to any region, as far as could be determined. Data collection forms and field evaluation forms are

included in Appendix A. It can be seen that the data collection forms are quite extensive and assume that the inspector will have access to the interior of the building and to soils and geologic reports; thus, this is not a true sidewalk survey. Bresler et al. (1975) point out that the weights employed and the algorithms or equations for determining the capacity ratio (see field evaluation forms) are arbitrary and gave misleading results for a trial building they examined.

Not included in this list are earthquake loss estimation studies such as those prepared by the federal government for the Los Angeles area (NOAA, 1973), Salt Lake City area (USGS, 1976), San Francisco Bay area (NOAA, 1972), and Puget Sound, Washington, area (USGS, 1975).

4
EVALUATION OF EXISTING RAPID SCREENING PROCEDURES

This section evaluates the previously discussed RSPs and studies according to several broad categories. Because each method/study reviewed was unique in some aspects, the following broad categories within which to compare and comment on the detailed aspects were defined:

- Organizational
- Structural
- Configuration
- Site and Non-structural
- Personnel

These five broad categories were selected as being of greatest interest to one or several segments of the target audience. To facilitate comparison, a tabular format has been used. Within each category specific items were noted, as were whether a specific RSP method or study addressed this issue, employed this data item, or simply noted this item. Where an entry is blank, no information was available.

Organizational—Refers to the general aspects of an RSP method or study that would be of interest to a person or organization implementing and managing a survey of a community. These include items such as the size of the survey defined by number of buildings, population and/or area; the types of buildings that were targeted; and whether graphic methods (sketches or photos) were used to record data.

Structural—Refers to structure-specific data items that would be of most interest and use to a structural engineer (e.g., age, structural material).

Configuration —Includes items such as whether an RSP method or study specifically noted soft stories or irregular building configuration. This would be of interest and use to architects and engineers.

Site and Non-Structural—Includes items related to the site (e.g., soil conditions, potential for pounding), and to the non-structural aspects of a building that may either pose a hazard (e.g., parapets) or may affect structural behavior (e.g., infill walls).

Personnel—Addresses two aspects regarding the qualifications of the personnel who would employ the specific RSP or study being evaluated: (1) What were the backgrounds or qualifications of the personnel who conducted the study or for whom the method was intended? (2) Could the method be applied by each or any segment of the target audience?

After reviewing all the existing surveys and available data, it becomes clear that there is currently relatively little statistical information relating damage to all types of structures under different levels of earthquake loading. Although general statements about the behavior of buildings in earthquakes can be made, it is difficult to quantify the damage. Even general statements about vulnerability based on building type are subject to question because so many other aspects such as configuration, connection detailing or local site conditions can contribute to poor structural performance. Reitherman (1985) noted that architectural configuration can be quite different from structural configuration and thus can be very misleading without access to structural drawings. Structural detailing, which can be so critical to good performance, is difficult to "score" from purely visual inspections. For these reasons, the results of an RSP cannot be regarded as definitive, and structural adequacy or lack thereof can only be determined on the basis of detailed examination by a registered professional engineer.

4.1 Organizational Aspects

Table 1 presents the evaluation of the organizational aspects of the various methods/studies. Specific items considered are discussed below.

Building Groups Targeted: Most methods or studies begin by eliminating some building types as non-hazardous (e.g., wood-frame construction), and limiting themselves to simply identifying that building type considered "most hazardous" (e.g., URM), or they have a well-defined list of structural types in their evaluation methodology. This report identifies those building types that were addressed.

Survey Area: In the case of studies where buildings in a community were actually screened, some measure of the size of the project, such as number of buildings, area, population, or other measure, is indicated.

Number of Hazardous Buildings Identified: As above, where available, the number of hazardous buildings actually identified for the particular study is indicated.

Method: A brief description of whether the method/study (i) simply employed a pass/fail measure (e.g., is or is not URM), or (ii) employed subjective measures and techniques (e.g., has a soft story, is irregular) without quantifying these items, or (iii) employed numerical scoring schemes and algorithms for combining information to arrive at a quantified measure (e.g., tension-only bracing or long-span diaphragms are given weights and these are "scored" in some fashion).

Supplemental Information Employed: Was non-visual off-site information employed, such as from building department, assessor files, Sanborn maps, or previous studies?

Explicit Earthquake Definition: Was the "earthquake loading" explicitly defined? Many times a method/study determined that buildings were seismically hazardous without clearly defining what ground motions the building was being compared against. Admittedly, for a specific jurisdiction this might be implicitly clear (e.g., a repeat of the 1906 event for San Francisco), but this aspect would need clear definition for any general RSP.

Sketch or Photo: Sketches or photos as an integral part of the data recording are invaluable for later reference. Requiring sketches assures that the survey personnel methodically observe the building.

4.2 Structural Aspects

Table 2 presents an evaluation of the methods/studies for the structural aspects. Specific items considered are discussed below.

Age/Design Level/Building Practice: Building age is usually an explicit indicator of the design level or the code under which the building was designed, and the building practices prevalent at the time of construction.

State of Repair: Maintenance and general conditions are important aspects of structural adequacy since corrosion and deterioration decreases structural capacity.

Occupancy Factor Definition: Occupancy is not an explicit factor in structural adequacy, but is important in setting priorities.

Material Groups: Broad structural material groupings can be noted in a variety of ways, and are a basic measure of seismic capacity.

Number of Stories/Dimensions: Number of stories and/or the plan or other dimensions are a broad indicator of structural dynamic properties, as well as of value.

Symmetrical Lateral Force Resisting System: The degree of symmetry of the lateral force resisting systems (LFRS) is an important clue as to adequacy of load path. If this was an item of interest to the survey team, what guidelines were they given for identifying the LFRS? If noted, how was the degree of symmetry employed?

Member Proportions: Were these noted in any way? Relatively thin member proportions are a general indication of potential problems in connections and/or member stability and, for concrete members, usually indicate non-ductile detailing.

Sudden Changes in Member Dimensions: Drastic changes in column dimensions can sometimes be observed through windows, and would indicate upper story "softness." Were these noted?

Tension-only Bracing: Was this relatively non-ductile behaving system identified as an item to note if observed?

Connections Noted: Was any attention paid to connections, as for example whether special wall/diaphragm ties were present in bearing-wall systems (e.g., tilt-up, URM)?

Previous Earthquake Damage: In areas where previous earthquakes might have weakened a building, was any attempt made to look for indications of this damage?

Renovated: Was there any indication that the building had been renovated, either with regard to architectural (thus obscuring the age) or structural details?

4.3 Configuration Aspects

Table 3 presents an evaluation of the methods/studies for the configuration aspects. Specific items considered are discussed below.

Soft Story: Abrupt changes and/or decrease in stiffness in lower stories of a building lead to large story drifts that cannot be accommodated. Was this consideration incorporated into the determination of seismic hazard, or was it noted by survey personnel but not used? Similarly, were plan irregularity, vertical irregularity, excessive openings and aspect ratio of the building or its components (vertical or horizontal) considered?

Corner Building: Buildings on corners typically have potential torsional problems due to adjacency of two relatively infilled back walls, and two relatively open street facades.

4.4 Site and Non-structural Aspects

Table 4 presents an evaluation of the methods/studies for the site and non-structural aspects. Specific items considered are discussed below.

Site-Related: So-called "adjacency" problems of pounding and/or the potential for a neighboring building to collapse onto the subject building are important structural hazards. These are two aspects that can be easily observed from the street and that the 1985 Mexico City experience again emphasized as critical. These were placed under site-related rather than structural or configuration because they involve aspects that are more related to the site and adjacent buildings than to the subject building per se.

Soil conditions or potential for seismic hazards other than shaking, such as landslide or liquefaction, are also very significant factors related as much to the site as to the structure. Admittedly, these non-shaking hazards may more easily be defined on the basis of reference maps than in the field, but in the methods reviewed were these given any consideration at all? Were soft soil/tall building or stiff site/stiff building correlations attempted as a crude measure of resonance/long period potential?

Non-Structural: Were major infill walls and/or interior partitions and their potential effects on structural behavior, especially in light buildings, noted? Were the special and relatively obvious seismic hazards of cornices, parapets, chimneys and other overhanging projections noted?

4.5 Personnel Aspects

Table 5 presents an evaluation of the methods/studies for the personnel aspects. For most projects, cost information was difficult to obtain and was usually based on criteria that are not easily compared. Some data provided included clerical and report production costs, others only the costs of survey personnel. This report provides personnel time per building reported for a particular RSP. By multiplying by labor cost, and including other expenses such as transportation and report production costs, the reader can estimate what a particular RSP would cost if applied to a particular community. Whether or not the particular RSP is appropriate for use by each segment of our target audience is indicated (by Y or N).

4.6 State of the Practice

Information provided by about a dozen practicing structural engineering firms, mostly in California, indicates that no rapid visual screening procedure is currently being used by practitioners. Typically, structural engineers have used visual screening procedures as a preliminary phase of a more detailed analysis. However, because most of the procedures involved entrance into buildings and detailed inventories of structural elements and non-structural elements, these procedures do not fit the definition of "rapid visual screening" utilized herein.

"Subjective judgment" is the type of criteria used most extensively to classify seismically hazardous buildings; in only a few cases have quantitative criteria been developed. However, in most cases, studies have been for planning purposes, and engineers have tried to include some qualitative indicator of the degree of hazard of the building to assist in setting priorities for mitigation procedures. In general, the surveys have been performed by experienced engineers or by entry-level engineers accompanied by a more experienced engineer. Most often, junior personnel have been given brief training as to what to look for and a checklist or data collection form, usually without detailed written guidelines. In some cases, a trial run through a building with the data collection forms was performed under the supervision of an experienced engineer. Usually there were no structured guidelines for identifying a building as one structural type or another, nor was there any consistent way to incorporate the uncertainty in the judgments that were made. Consequently, the variability in backgrounds and experience of the personnel and the lack of detailed guidelines can result in widely differing interpretations of the criteria for identifying hazardous buildings and hence produce inconsistent results.

4.7 Conclusions

The foregoing review indicates that no currently available RSP method or study addresses all of the major aspects fundamental to seismic hazard, and further that no really satisfactory RSP method or procedure exists. Most omit many of the described aspects, and/or are very subjective in their treatment of the data recorded. In many cases, too much reliance is placed on the experience of the survey personnel, with little attention paid to consistency among different personnel. Further, although the personnel may have been given some coaching or training in what to look for, this was usually unsystematic and omitted major aspects.

Most of the rapid visual screening procedures that were reviewed were developed for a particular municipality and thus were applied in only one geographic region. None addresses the issues of regional differences in construction practices and building code regulations. The multihazard study (Reitherman et al., 1984), NBS 61 (Culver et al., 1975) and the Navy Rapid Seismic Analysis Procedure are designed for nationwide application, but these procedures do not specifically discuss differences in building performance that might result from regional engineering and construction practices. In addition, they involve entrance into the building or calculations and thus are too detailed for an RSP.

From the studies that were reviewed and from experience with earthquake-related damage, a set of attributes of a satisfactory RSP method was developed:

1. The earthquake loading against which the building's capacity is being judged should be explicitly defined, preferably in physically based units (e.g., acceleration). The anticipated earthquake loading is defined in several of the studies such as NBS 61, the Stanford Project, the University of California Study, the OSA Hospital Survey, the New Madrid Study and the Multihazard Survey; however, non-physical units such as UBC zone or MMI are used. Only in Wiggins and Moran (1971), and Wiggins and Taylor (1986) is the use of maximum expected bedrock acceleration discussed. Because the decision of what ground motion a building should satisfactorily withstand involves not only geotechnical and seismological issues but also difficult questions of acceptable risk, the "acceptable earthquake" may often be decided in an iterative fashion. Thus, sufficient building-specific data should be clearly recorded to permit later calculations for the purposes of re-screening, given a different "earthquake loading."

2. As much as possible, supplemental information compiled from building department and assessor's files, Sanborn maps and other sources should be collated and taken into the field in a usable format, such as computer listings or peel-off labels that can be affixed to the survey form, for verification as well as aiding the field personnel. Most of the methods that were reviewed use other sources of information to supplement the visually obtained data.

3. An RSP should have the capability to survey and identify hazardous buildings of all types. In some cases, jurisdictions may wish to use the RSP in a limited form for certain "high hazard" target buildings or areas. However, all building groups should receive at least an initial limited-sample-area test screening to verify assumptions of which building type is the most hazardous within the local building stock. If these assumptions are verified, then selected building groups/areas may be targeted for reasons of economy. However, the situation of having identified all URM buildings, and having no idea of the seismic hazards in the older non-ductile reinforced concrete building group, for example, or the older unbolted house-over-garage (HOG) building group, should be avoided.

4. A quantitative approach, as exemplified in the Long Beach study (Wiggins and Moran, 1971) or NBS61 (Culver et al., 1975), appears preferable, as it not only permits pass/fail decisions, but also allows prioritization within the "failed" category. However, the quantitative "scoring" should not be arbitrary but rather should be rationally based, as far as possible.

5. Sketches should be an integral part of the data recording to assure that the survey personnel methodically observe the building. Sketches and photos are invaluable for later reference, and ideally both should be part of the field data

recording because they are complementary. Several of the reviewed methods omitted a sketch or photo.

6. Age should be explicitly recorded. Although often unavailable, age can be estimated, usually to within a decade or two, on the basis of architectural style, and thus can indicate whether a building is pre or post a specific "benchmark" year in the development of that building type. For example, in San Francisco, wood-frame buildings were required to be bolted to their foundations only since 1948. If a wood-frame building is pre-1948, it is likely to be unbolted. Similarly, unreinforced masonry was not permitted after the adoption of the 1948 building code. Thus, in a survey of hazardous buildings in San Francisco, only pre-1950 buildings were considered. These benchmark years differ by jurisdiction, but are usually locally known or can be determined and should be included in training material for survey personnel.

7. State of repair should be explicitly noted, as it forces the survey personnel to look for cracks, rot, corrosion and lack of maintenance. Although the state of repair was noted in many of the methods reviewed, it was not formally used in identifying the seismically hazardous buildings.

8. Occupancy (use) and number of occupants should be noted, using standardized occupancy categories. In the Los Angeles and Long Beach studies, occupancy was used to prioritize buildings for hazard abatement.

9. Specific observable details of structural members, structural hazards and foundation and site conditions should be itemized in a check-off format, to avoid omission.

10. Configuration issues should similarly be considered, but their contribution to seismic hazard must be quantified, at least on a weighting basis. Although some of the methods, such as NBS 61, have addressed configuration problems the scoring systems are subjective and are not based on actual damage-related data.

11. Site aspects of pounding, corner building and adjacencies, and non-structural aspects, need to be similarly noted. Few of the methods have used pounding, corner buildings, or adjacencies as criteria for identifying hazardous buildings, although these problems were noted. Several studies (e.g., City of Redlands, Multihazard Survey, NBS 61) consider non-structural hazards explicitly as part of their criteria.

12. Personnel should have adequate background and training to understand the earthquake behavior of buildings because many of the data they will be called upon to record will involve subjective decisions. In addition, the survey should be accompanied by detailed guidelines as to what to look for and how to interpret and indicate uncertain data to avoid inconsistencies in the data collection. The guidelines presented in the Multihazard Survey are useful examples.

13. Data recording should be complete and systematic. A field remote-entry electronic format (i.e., a "laptop" computer) should be considered, although for economic reasons a clipboard has many advantages.

14. Because information is often lacking, uncertainty considerations must be incorporated into the methodology, although it can be relatively "invisible." For example, building type may be

indicated as (circle as appropriate):

RCMRF* :	definite	likely	possible	unlikely
RCSW:	definite	likely	possible	unlikely
URM:	definite	likely	possible	unlikely

with weights assigned to each, on the basis of their "contribution" to seismic hazard. If it is likely that the building is an RCSW but possible that it is a URM, then the weighting would result in a higher seismic hazard than if the survey personnel were called upon to provide only one typing. The weighting and arithmetic do not need to be performed in the field, although it may be advantageous to have the weighting known to the field personnel.

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*RCMRF:	Reinforced concrete moment-resisting frame
RCSW:	Reinforced concrete shear wall
URM:	Unreinforced masonry

Table 1
ORGANIZATIONAL ASPECTS

PROCEDURE/ Source	Building Groups Targeted	Survey Area (Size, number of buildings, population)	Number of Hazardous Buildings Identified	Method: Pass/Fail, Subjective, Quantitative?	Supplemental Information Employed?	Explicit Earthquake Definition	Sketch or Photo?
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Bearing wall URM	Test survey approximately 200 buildings	Appoximately 160 buildings	Quantitative	Aerial photo Sanborn maps	N	Y
SAN FRANCISO/ Frank Lew	URM pre-1950 construction	Entire city, population 700,000	2100 from initial 6000	Pass/Fail	Assessors' files, Sanborn maps, Parapet Safety Program files, owner feedback	N	N
ABAG/ J. Perkins et al. (1986)	WF, URM, RM, LM, TU, MH	6,000 square miles, population 5.5 million	4700-5700	Subjective	Sanborn maps, Land use maps, interviews with local building office, previous studies	N	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	All 27 defined classes	Phase I Entire city population 50,000	Phase I 4 sub-areas of city identified as most hazardous	Subjective and Quantitative	Palo Alto Comprehensive Plan Building Department input	MMI	Y, sketch
LOW-RISE/ Wiggins and Taylor (1986)	low rise	N/A	N/A	Quantitative	N	Maximum expected bedrock acceleration	Y
PALO ALTO/ F. Herman	URM, pre-1976, pre-1936, TU	2000 focus on older commercial	325	Pass/Fail	Sanborn maps building permits, previous study, owners	N	N

Table 1
(continued)

PROCEDURE/ Source	Building Groups Targeted	Survey Area (Size, number of buildings, population)	Number of Hazardous Buildings Identified	Method: Pass/Fail, Subjective, Quantitative?	Supplemental Information Employed?	Explicit Earthquake Definition	Sketch or Photo?
OAKLAND/ Arnold, Eisner (1980, 1984)	URM, WF ND-RC	Approximately 2000, Oakland Central Business District	377 approximately	Subjective, no clear definition of seismically suspicious	Y Sanborn maps, building permit, previous study, assessors' files	N	Photo, building plan, sketch
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	Essential facilities, definition left to local jurisidiction All types	About 10,000 buildings since 1975	Unknown	Quantitative	Maps, construction drawings	UBC zone	Y
NEW MADRID/ Allen & Hoshall (1983)	All	Six couties population 1 million, approximately 2,400 buildings	N/A	Subjective, damage states	FEMA data	Y M = 7.6 & M = 8.6 MMI used for damage estimate	N
OSA HOSPITAL/ (1982)	Hospitals, all types of construction	1077	100 in classes E & F "low survive index"	Subjective	Building plans	UBC zone	Unknown
LOS ANGELES/ (1978-79)	URM	Entire city population 3 million, 490 square miles	8,000 approximately	Pass/Fail	Y Sanborn maps assessors' files, previous studies	Not explicit (large Ep.)	2 photos per building, sketch

Table 1
(continued)

PROCEDURE/ Source	Building Groups Targeted	Survey Area (Size, number of buildings, population)	Number of Hazardous Buildings Identified	Method: Pass/Fail, Subjective, Quantitative?	Supplemental Information Employed?	Explicit Earthquake Definition	Sketch or Photo?
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Area greater than 4,000 square feet, human occupancy	44,000 square feet, approximately 800 buildings	9,000 square feet of Poor or Very Poor	Subjective	Previous studies, design drawings	MMI > IX	Y
SANTA ROSA/ Myers (1981)	All types built before 1958	About 400 buildings since 1972	About 90% for further review	Subjective	Plans	N	Photos and sketches
LONG BEACH/ Wiggins and Moran (1971)	Pre-1934 type 1, 2, 3	Entire city, population 500,000	938	Quantitative	Y Sanborn	N for LB study Y for Wiggins method (maximum expected bedrock acceleration)	Y
NBS 61/ Culver et al. (1975)	SB, DF, SW, CSF, RF, CSW, MSW, WF, 11 building frame types	N/A	N/A	Subjective and Quantitative (Capacity Ratio Rating) Structure Structure rating vs. MMI's	Suggest use of original drawings or soil reports, Sanborn maps	UBC zone, MMI levels > V	Building elevations and site plan with adjacencies, Photo suggested

Table 2
STRUCTURAL ASPECTS

PROCEDURE/ Source	Age/Design Level/ Building Practice	State of Repair	Occupancy Factor Definition	Material Groups	Number of Stories/ Dimensions	Symmetrical LFRS	Member Proportions	Sudden Changes in Member Dimensions	Tension-only Bracing	Connections	Previous Earthquake Damage	Renovated
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Y	Y	Y	URM	Y	N	N	N	N	Y	N	Y
SAN FRANCISCO/ Frank Lew	Y	N	N	URM	Noted, from assessor file	N	N	N	N	N	N	N
ABAG/ J. Perkins et al. (1986)	N	N	Y noted for some	Concrete Steel Wood Masonry	Y	N	N	N	N	N	N	If available
STANFORD PROJECT/ JABEEC TR 81, Thurston et al (1986)	Y	Y	Y essential facility or large number of occupants, residential, commercial or industrial	Steel Concerete Masonry Wood	Y noted number and dimensions	Y	N	Y	Y	Y	Y	Y
LOW-RISE/ Wiggins and Taylor (1986)	Noted, implicit in some of rating criteria	Y	Noted	Concrete Steel Wood Masonry	Y	Y	N	N	Not explicit, noted inadequate or in-complete bracing	Y	Y noted unrepaired earthquake damage	N

Table 2
(continued)

PROCEDURE/ Source	Age/Design Level/ Building Practice	State of Repair	Occupancy Factor Definition	Material Groups	Number of Stories/ Dimensions	Symmetrical LFRS	Member Propor- tions	Sudden Changes in Member Dimensions	Tension- only Bracing	Connections	Previous Earthquake Damage	Renovated
PALO ALTO/ F. Herman	Y	Noted but not formally employed	Y (number persons)	URM, TU	Noted but not formally employed	N	N	N	N	N	N	N
OAKLAND/ Lagorio, Arnold Eisner (BSD, 1984)	Y	Noted but not formally employed	Noted importance of structure 17 use codes	URM, TU ND-RC, mixed	Noted	N	N	Noted	N	N	N	Noted
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	Y	Y	Noted use	Many classes	Y	Strong beam, weak columns	N	N	Y	Roof/wall and anchor bolts	N	Y
NEW MADRID/ Allan & Hoshall (1983)	Y	N	Y	Steel Concrete Masonry Wood	Y	N	N	N	N	N	N	N
OSA HOSPITAL/ (1982)	Y Building code jurisdiction	Y	Y Noted building use, Not included in ranking	Concrete Steel Masonry Wood	Y	Y	N	Y	Y	N accessed from plans	Not sure	Y
LOS ANGELES/ (1978-1979)	Y	Noted cracks & mortar condition	Y Table 33A UBC	URM	Y	Noted	N	N	Noted from parapet program	N	Noted	Noted from parapet program

Table 2
(continued)

PROCEDURE/ Source	Age/Design Level/ Building Practice	State of Repair	Occupancy Factor Definition	Material Groups	Number of Stories/ Dimensions	Symmetrical LFRS	Member Propor- tiosn	Sudden Changes in Member Dimensions	Tension- only Bracing	Connections	Previous Earthquake Damage	Renovated
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Y	Noted but not significant in ranking	N	Concrete Steel Wood Masonry	Number stories dimensions from plans	Y	Y	Y	Y, not much found	Sometimes	At a few campuses	Y
SANTA ROSA/ Myers (1981)	Y	Y	Noted but not included in decision	No formal groups defined All types examined	Y	Y	N	Y	Y	Y	Y	Y
LONG BEACH/ Wiggins and Moran (1971)	N	Y	N, noted but not formally employed	RC, S, W, URM, RM	Y	Y	N	N	N	N	Y i.e., state of repair noted	N
NBS 61/ Culver et al. (1975)	Y noted but not formally employed employed	Y evidence of past damage repair noted	N noted but not formally employed	Concrete Masonry Steel Wood	Noted	Y	N	N	N	Y, if possible	N	Date noted

Table 3
CONFIGURATION ASPECTS

PROCEDURE/ Source	Soft Story	Plan Irregularity	Vertical Irregularity and Variation in Stiffness	Excessive Openings	Aspect (Vertical or Horizontal)	Corner Building
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	N	N	N	N	N	Y can be inferred from site location sketch
SAN FRANCISCO/ Frank Lew	Noted	Noted	Noted	N	N	N
ABAG/ J. Perkins et. al. (1986)	Y	Y	Y	Y	Y	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	Y	Y	Y	Noted	Y	N
LOW-RISE/ Wiggins and Taylor (1986)	Y	Y	Y	Y	Y	N
PALO ALTO/ F. Herman	N	N	N	N	N	N
OAKLAND/ Arnold, Eisner (1984)	Y	Y	Y	Y	N	N

Table 3
(continued)

PROCEDURE/ Source	Soft Story	Plan Irregularity	Vertical Irregularity and Variation in Stiffness	Excessive Openings	Aspect (Vertical or Horizontal)	Corner Building
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	Y	Y	Y	Y large door width open side	N	N
NEW MADRID/ Allen & Hoshall (1983)	N	N	N	N	N	N
OSA HOSPITAL/ (1982)	Y	Y	Y	Y percent openings noted	Y	N
LOS ANGELES/ (1978-79)	Not specific percent openings	Y	Y	Y percent openings noted	N	N
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Y	Y	Y	Y	Y	N/A
SANTA ROSA/ Myers (1981)	Y	Y	Y	Y	Y	Y
LONG BEACH/ Wiggins and Moran (1971)	N	Y	Y	Y	Y	N
NBS 61/ Culver et al. (1975)	Y, noted	N	Y, Noted	Y, noted	N	Street sides noted

Table 4
SITE AND NON-STRUCTURAL ASPECTS

PROCEDURE/ Source	SITE RELATED: Pounding	SITE RELATED: Neighboring Building Collapse	SITE RELATED: Soil Conditions	SITE RELATED: Potential for Other Geohazards	NON-STRUCTURAL: Infill Walls	NON-STRUCTURAL: Interior Partitions	NON-STRUCTURAL: Cornices, Overhang Parapets, Chimneys
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Noted abutting buildings	Noted abutting buildings	N	N	N	Noted type	Y cornice parapet chimney signs ornament
SAN FRANCISCO/ Frank Lew	N	N	N	N	N	N	Noted
ABAG/ J. Perkins et al. (1986)	N	N	Not explicit, used map overlay	Not explicit, used map overlay	N	N	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	Y	Y, noted	Y, noted	Y	Y	Y	Y
LOW-RISE/ Wiggins and Taylor (1986)	N	Y Neighboring overhang collapse	Y	N	Y	Y	Y
PALO ALTO/ F. Herman	N	N	N	N	N	N	N

Table 4
(continued)

PROCEDURE/ Source	SITE RELATED: Pounding	SITE RELATED: Neighboring Building Collapse	SITE RELATED: Soil Conditions	SITE RELATED: Potential for Other Geohazards	NON-STRUCTURAL: Infill Walls	NON-STRUCTURAL: Interior Partitions	NON-STRUCTURAL: Cornices, Overhang Parapets, Chimneys
OAKLAND/ Arnold, Eisner (1980, 1984)	N	N	N	N	Noted	N	Noted
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	N	N	Y Soft or hard	Landslide liquefaction Settlement Surface faulting	Y noted	N	Braced or unbraced or not present
NEW MADRID/ Allen & Hoshall (1983)	N	N	Y	Liquefaction	N	N	Y
OSA HOSPITAL/ (1982)	Noted distance to nearest building	Noted distance to nearest building	N	Liquefaction Landslide Alquist-Priolo seismic zone	N	Y noted URM partitions	N
LOS ANGELES/ (1978-79)	N	N	N	N	N	Y	Y, also from previous parapet program
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Not a problem	N	N	Y Surface faulting in a few locations	N	Y	Y, noted but not significant in ranking

Table 4
(continued)

PROCEDURE/ Source	SITE RELATED: Pounding	SITE RELATED: Neighboring Building Collapse	SITE RELATED: Soil Conditions	SITE RELATED: Potential for Other Geohazards	NON-STRUCTURAL: Infill Walls	NON-STRUCTURAL: Interior Partitions	NON-STRUCTURAL: Cornices, Overhang Parapets, Chimneys
SANTA ROSA/ Myers (1981)	Y	N	Not explicit, all on alluvial fill	Not explicit, no potential for liquefaction or surface faulting	Y	Y	Y
LONG BEACH/ Wiggins and Moran (1971)	Y	Y	Y	N	Y	Y	Y
NBS 61/ Culver et al. (1975)	Y, noted	Proximity to adjacent buildings noted, separation joints noted	Proximity to adjacent buildings noted	Y Fault rupture liquefaction (implicit fault location noted)	Y, noted and rated	Y, noted and rated	Y, noted and rated

Table 5
PERSONNEL ASPECTS

PROCEDURE/ Source	Survey personnel Approximate person-hours per building	Local Building Officials	Professional Engineers	Registered Architects	Building Owners	Emergency Managers	Interested Citizens
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Not available	Y	Y	Y	N	N	N
SAN FRANCISCO/ Frank Lew	15 min per building	Y	Y	Y	N	N	N
ABAG/ J. Perkins	5 min per building, Very little information noted	Y	Y	Y	Y	Y	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	Experienced structural engineer	Y	Y	Y	N	N	N
LOW-RISE/ Wiggins and Taylor (1986)		Y	Y	Y	N	N	N
PALO ALTO/ F. Herman	15 min per building	Y	Y	Y	Y	Y	N

Table 5
(continued)

PROCEDURE/ Source	Survey personnel Approximate person-hours per building	Local Building Officials	Professional Engineers	Registered Architects	Building Owners	Emergency Managers	Interested Citizens
OAKLAND/ Arnold, Eisner (1980, 1984)	20 min per building	Y	Y	Y	N	N	N
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	1 hour to 3 days per building	Y	Y	Y	N	Y	N
NEW MADRID/ Allen & Hoshall (1983)		N	Y	N	N	N	N
OSA HOSPITAL/ (1982)	1-2 days per building	N	Y	Y	N	N	N
LOS ANGELES (1978-79)	40 min per building	Y	Y	Y	N	Y	N
UNIVERSITY OF CALIFORNIA/ McClure (1984)	20 min per building	N	Y	N	N	N	N
SANTA ROSA/ Myers (1981)	1/2 day ($500) per building	Y	Y	Y	N	N	N
LONG BEACH/ Wiggins and Moran (1971)	Professional engineer	N	Y	N	N	N	N

Table 5
(continued)

PROCEDURE/ Source	Survey personnel Approximate person-hours per building	Local Building Officials	Professional Engineers	Registered Architects	Building Owners	Emergency Managers	Interested Citizens
NBS 61/ Culver et al. (1975)	1 hour per building	Y	Y	Y	N	N	N

5

RECOMMENDED RAPID VISUAL SCREENING PROCEDURE

This section presents and discusses the elements of a recommended RSP, based on the results of the survey discussed above.

5.1 Elements of the Recommended RSP

In response to the conclusions (Section 4.7) reached from the survey of RSPs, an RSP employing the following elements is recommended:

- The Effective Peak Acceleration (EPA) values contained in the National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC, 1985), defined by Map Area, as an explicit measure of the ground motion.
- The building types contained in ATC-14 (i.e., wood frame, 5 steel types, 3 reinforced concrete, 2 pre-cast, 2 reinforced masonry, and 1 unreinforced masonry types).
- A systematic, simple structural hazard analysis scheme, based on a non-arbitrary measure of building performance for the specific building given the occurrence of the EPA. This scheme consists of a Basic Structural Hazard score, modified by penalties and bonuses to account for perceived deficiencies or strengths because of such factors as design level (inferred from age), condition, and configuration. The scheme involves only simple arithmetic, the score and penalties being added, to arrive at a final Structural Score S (A high score corresponds to a low structural hazard, or is "good," and vice-versa.) The resulting S will relate back to the physical performance of the building, in terms of damage. (The basis for S is discussed further below).
- A simple clipboard data collection form, with space for:
  - a photograph of the building
  - a field sketch of the building
  - data from pre-field visit information (e.g., a summary from the Assessor's or other files, giving address, age, value, or owner's name, perhaps printed on a peel-off label that can be affixed directly to the data collection form)
  - a checklist of items (so that significant items are not omitted), with almost all input to be noted by circling of the appropriate item (so that standard notation is employed)
  - the simple calculation for S

This form and process is to be accompanied by a handbook (ATC-21) explaining its use and providing

- information on how to determine which of the building types is most appropriate for the particular building being surveyed
- explanations and guidance as to the recognition of various significant factors, such as pounding, poor configuration, or soft stories

- a summary sheet of basic information, for quick reference in the field

5.2 Basis for Structural Hazard Scores

It has been emphasized in the above that the Structural Hazard score should be rationally based and physically meaningful. It is recommended that it should be *a measure of the probability of major seismic damage to the building*. Major damage is taken to be direct physical damage being 60% or greater of the building value. (Note: definitions of building value, and related terms are similar to those in report ATC-13, (ATC, 1985), "*Earthquake Damage Evaluation Data for California*").

Sixty percent as heavy damage is selected because (i) it is the lower end of the Major Damage State in ATC-13, (ii) if 60 percent of a building's value is damaged, experience has shown that demolition rather than repair often ensues, and (iii) if 60 percent damage is selected, then most buildings likely to collapse will be included in this category, so that life-safety-related hazardous buildings (due to shaking) are probably all captured.

By employing NEHRP EPA values as the measure of ground motion, ATC-13 relations can be used to determine the probability of occurrence of 60 percent or greater damage, given that input ground motion (see Appendix B for details). The determination of the Basic Structural Hazard score then is:

Basic Structural Hazard score =
–log (probability of damage >= 60%) (1)

If the probability of the damage exceeding 60%, given the NEHRP EPA value for the building's site, is, for example, .001, then the Basic Structural Hazard score is 3. If the probability is .01, then it is 2, and so on.

- Although quite simple, the Basic Structural Hazard score is thus intuitively satisfying. A relatively "safe" building would have values of 3 to 5 in California, whereas the identical building would score approximately 7 to 10 in NEHRP Map Area 3, corresponding to New England or the South Carolina regions, as it is likely to experience less severe ground motion. Note, however, that because many buildings in less seismic areas are not designed for earthquake on the same basis as in California, when this is taken into account the resulting score is more consistent for the same building type in different NEHRP map areas (e.g., in the range of 3 to 5). Values of the Basic Structural Hazard score are provided in Table B1, Appendix B.
- The Basic Structural Hazard score can be easily and directly related back to the probability of major physical damage (i.e., damage exceeding 60 percent of building value).
- The Basic Structural Hazard score will likely prove of value in community cost-benefit decision making because it can be directly related to physical damage.
- The ability to relate Basic Structural Hazard score to physical damage has the further virtue of providing a rational analytical basis for quantifying structural penalties for factors such as age, and configuration. If the impact of these factors on the likelihood (or probability) of major damage can be quantified, then the logarithm of this quantity is the modifier. Although lack of data and the present state of the art may preclude general quantification of the effect of a factor such as "soft story" at present, as new data emerge on the effect of this factor, its quantification can be directly related to a penalty on the Basic Structural Hazard score. In the interim, discussion and expert opinion/elicitation regarding the effect of this factor can take place within the framework of

trying to quantify the impact of this factor on the probability of major damage.

5.3 Data Collection Form

This section discusses the layout and use of data collection form, which is shown in Figure 1. The form would be carried in the field in a binder or clipboard.

Basic Information

Space is provided in the upper right of the form for basic information, much of which might be collated and printed out prior to the field visit. Information desired includes address, zip code (although often lacking from the studies reviewed, this is a useful item), the date of the survey, and identity of the surveyor. Additional useful information about the building such as age, construction type, soil type, and value is also desirable. Preferably, such information should either be computer-printed out directly onto the form, or onto a peel-off label applied by the field surveyor. This information would be quickly entered or affixed as the first item upon coming to the building.

Photograph

A general photo of the building should be taken, showing two sides of the building, if possible. (This would preferably be an "instant" type photo, to avoid the task of later collating photos with forms.)

Sketch

The surveyor would then sketch the building (plan and elevation, or oblique view) indicating dimensions, facade and structural materials, and observed special features such as cracks, lack of seismic separation between buildings, roof tanks, cornices, and other features. This sketch is important, as it requires the surveyor to carefully observe the building.

Building Information

Following this, the surveyor would fill in additional basic information specific to the building such as number of stories; an estimate of the building age (e.g., 1930's or late 1960's), the occupancy (e.g., residential, office, retail, wholesale/warehouse, light industrial, heavy industrial, public assembly such as auditoria or theaters, governmental); and an estimate of the number of persons typically in the building under normal occupancy. For example, for a residence, this would be the number of persons living there (not the daytime population); for an office this would be the daytime population; for a theater this would be the seating capacity.

Basic Structural Hazard Score

Next, based on observation, the surveyor would make a determination of the primary structural material (wood, steel, concrete, pre-cast, reinforced masonry or unreinforced masonry) and circle the appropriate Basic Structural Hazard score. The basis for determination of Basic Structural Hazard scores are given in Appendix B. The building types follow the building category scheme of ATC-14 (ATC, 1987).

Wood

W = wood (low-rise (LR) only, W1 and W2 treated together)

Steel

S1 = moment resisting frame
S2 = steel frame with steel bracing
S3 = light metal (LR only)
S4 = steel frame with concrete shear walls
S5 = steel frame with unreinforced masonry infill walls

Concrete

C1 = moment resisting frame
C2 = shear wall
C3 = concrete frame with unreinforced masonry infill walls

Precast

PC1 = tilt-up (LR only)
PC2 = precast concrete frames

Reinforced Masonry

RM = reinforced masonry buildings of all types, differentiated only by height

Unreinforced Masonry

URM = unreinforced masonry bearing wall (LR and mid-rise (MR) only).

Any specific jurisdiction corresponds to one NEHRP Map Area, and the form used in the field for that jurisdiction would have Structural Scores corresponding only to that Map Area/jurisdiction. All NEHRP Map Areas and corresponding Structural Scores would be furnished in the Handbook.

Confidence

If in doubt as to which category is most appropriate for a particular building, the surveyor should record the possible categories and mark them with an asterisk (*) to indicate the subjective evaluation.

If the surveyor cannot narrow the estimate to two alternates, DNK = Do Not Know should be indicated, signifying that the basic structural material or system cannot be identified from the street. DNK would also apply for a building of mixed construction, where no one category predominates. DNK constitutes a default, indicating that the building and drawings should be reviewed in detail.

Modifiers

Negative modifiers corresponding generally to deficiencies such as poor configuration, pounding, and potential for a neighboring building collapsing onto this building (this penalty would depend on the Basic Structural Hazard score for the neighboring building being sufficiently low as to indicate a potential for collapse, and the height and proximity of the neighboring building being such as to indicate that collapse might affect the subject building).

Soil Profile

Modifiers assigned for adverse soil conditions when the soil profile can be identified with some confidence. Soil profiles have been defined according to the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC, 1985):

SL1: Rock or stiff soils less than 200 feet deep overlying rock

SL2: Deep, cohesionless soil or stiff clay conditions exceeding 200 feet depth

SL3: Soft- to medium-stiff clays and sands, exceeding 30 feet in thickness

Structural Score S

Lastly, the Structural Score S is computed by simple addition of the modifiers to the Basic Structural Hazard score. The final Structural Score S is recorded.

5.4 Use of the Results

For any building, the final Structural Score S will typically be a number between 0 and 5 or more, depending on NEHRP Map Area. All buildings surveyed can thus be ranked according to S, and a decision made as to a "cut-off" S. Buildings that score below the cut-off would be subjected to more detailed review. Scoring above the cut-off does not signify a "safe" building, but instead indicates that for the particular community the building is assumed sufficiently safe, and no further review is required.

An appropriate value for the cut-off S is a complex decision, involving financial and ethical questions. Appendix C provides recommendations for a cut-off S. This recommendation should be reviewed and, if necessary, modified by a jurisdiction, as the decision has cost implications. (That is, a relatively high cut-off involves detailed review of a large number of buildings, with increased costs and presumably eventual increased seismic safety, assuming buildings determined to be unsafe are cited and abated. A lower cut-off has lower costs for building review, but may involve lower resulting seismic safety.)

ATC-21/ (NEHRP Map Areas 5,6,7 High)

Rapid Visual Screening of Seismically Hazardous Buildings

Scale:

Address ______________________

______________________ Zip ________

Other Identifiers ______________________

No. Stories ____________ Year Built ________

Inspector ______________________ Date ________

Total Floor Area (sq. ft) ______________________

Building Name ______________________

Use ______________________

(Peel-off label)

INSTANT PHOTO

OCCUPANCY	
Residential	No. Persons
Commercial	0–10
Office	11–100
Industrial	100+
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

☆ = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	4.5	4.5	3.0	5.5	3.5	2.0	3.0	1.5	2.0	1.5	3.0	1.0
High Rise	N/A	−2.0	−1.0	N/A	−1.0	−1.0	−1.0	−0.5	N/A	−0.5	−1.0	−0.5
Poor Condition	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5
Vert. Irregularity	−0.5	−0.5	−0.5	−0.5	−0.5	−1.0	−0.5	−0.5	−1.0	−1.0	−0.5	−0.5
Soft Story	−1.0	−2.5	−2.0	−1.0	−2.0	−2.0	−2.0	−1.0	−1.0	−2.0	−2.0	−1.0
Torsion	−1.0	−2.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0
Plan Irregularity	−1.0	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−1.0	−1.0	−1.0	−1.0
Pounding	N/A	−0.5	−0.5	N/A	−0.5	−0.5	N/A	N/A	N/A	−0.5	N/A	N/A
Large Heavy Cladding	N/A	−2.0	N/A	N/A	N/A	−1.0	N/A	N/A	N/A	−1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	−1.0	−1.0	−1.0	N/A	−1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	−0.3	−0.3	−0.3	−0.3	−0.3	−0.3	−0.3	−0.3	−0.3	−0.3	−0.3	−0.3
SL3	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6
SL3 & 8 to 20 stories	N/A	−0.8	−0.8	N/A	−0.8	−0.8	−0.8	−0.8	N/A	−0.8	−0.8	−0.8

FINAL SCORE

COMMENTS

Detailed Evaluation Required?

YES NO

ATC0794
20039.01

Figure 1. Data Collection Form

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Rehabilitating Hazardous Masonry Buildings: A Draft Model Ordinance (1985). California Seismic Safety Commission, SSC 85-06. (A model ordinance developed as a guideline for local governments planning seismic rehabilitation programs. Based on ordinance and survey performed in the City of Los Angeles.)

Reitherman, R. (1985). *A Review of Earthquake Damage Estimation Methods*. Earthquake Spectra, Vol 1. No. 4, 805-847.

Richter, C.F. (1958). *Elementary Seismology*. W.H. Freeman and Co., Inc., San Francisco, CA.

SCEPP (1983). *San Bernardino County Pilot Project for Earthquake Hazard Assessment*. Final Draft, Van Nuys, CA. (Pilot project to estimate damage - did not involve site visit.)

Scholl, R. (1979). *Seismic Damage Assessment for High-Rise Buildings*. Annual Technical Report to USGS. (The data collection in this report refers to building damage in past earthquakes for the purpose of developing damage functions for different types of structures.) Seismic Design for Buildings (1982). Depts. of Army, Navy, and Air Force, Tech. Man. 5-809-10. (Contains only discussions of design procedures for buildings. No discussion of existing buildings.)

Seismic Design Guidelines for Essential Buildings (1984). Depts. of Army, Navy, and Air Force, Tech. Man. 5-809-10.1. (Contains only discussions of analysis and design of essential facilities. No discussion of existing buildings. No RSP.)

Tandowsky, S., Hanson, C., and C. Beauvoir (1986). "Seismic Vulnerability Studies of Buildings at Military Facilities in the Southeastern United States." Proceedings, Third U.S. Conf. on Earthquake Engineering, Charleston, SC, pp. 1851-1861. (This is a three-phase evaluation of approximately 200 buildings at four Navy and Marine Corps facilities. The first phase involves a review of existing construction documents and a physical inspection resulting in a four class vulnerability rating varying from "likely to incur severe damage" to "unlikely to receive observable damage to structure." The higher two classes were recommended for further review. The second phase is the Navy rapid seismic evaluation procedure, and the third a detailed analysis. After the first two phases, more than 80 percent had been recommended for phase three.)

Tyrrell, J.V. and B. Curry (1986). "The U.S. Navy's Earthquake Safety Program." Proceedings, Third U.S. Conf. on Earthquake Engineering, Charleston, SC, pp. 1863-1872. (This is similar to the method described in Tandowsky et al. using an initial screening procedure, followed by the Navy rapid seismic analysis procedure. Before the visual screening, computer data were used to eliminate seven classes of structures, primarily smaller and less expensive structures, and structures scheduled to be replaced in the next five years.)

UNESCO (1982). *Earthquake Risk Reduction in the Balkans.* Reports of Working Groups A-E, UNDP Proj. RER/79/014. (Basically, these reports deal with seismic hazard analysis, vulnerability and recent damage experience, model code development, dynamic behavior of soils, and of structures. No effort for rapid visual screening of hazardous buildings.)

Werner, S. D. (1987). *Rapid Analysis Procedure for Water Supply System Structures.* Memorandum, Wiss, Janney, Elstner Assoc., Emeryville, CA. (A two-phase procedure, the first being a walk-through of all structures to document structural information, building importance, and present condition to determine which structures need further evaluation. A second, more detailed survey is carried out for those buildings selected in the first previous step. The Navy rapid analysis procedure is used to estimate damage for the building.)

Yao, J.T.P. (1985). *Safety and Reliability of Existing Structures.* Pitman, Boston, 130 pp. (SPERIL is a computer-based damage assessment system for evaluating the damage a building has sustained after an earthquake. It is a rule-based (i.e., expert) system incorporating data from loading tests pre- and post-earthquake, visual data, and accelerometer records during the strong motion, in a fuzzy set formulation. Not directly relevant but included herein because of its use of fuzzy sets and related aspects.)

APPENDIX A

SAMPLE DATA SHEETS

DC-1

DATA COLLECTION FORM
NATURAL HAZARDS EFFECTS
(Extreme Winds, Earthquakes)

A. GENERAL DATA

*1. Facility No. ________ 2. Building Name ________________________________

3. Address ____________________________________ 4. City ____________________

5. State ____________________ 6. Zip Code ________ 7. Year Built ________

8. Date of Major Modifications or Additions, if any _________________________

9. Building Code Jurisdiction: City ☐ County ☐ State ☐ Federal ☐

*10. Latitude ________________________ *11. Longitude _________________________

12. Current Bldg. Use _____________ Orig. Bldg. Use ____________________

13. Basement Yes ____ No ____ Number of Basements ___________________

No. of Stories Above Basement ________________ (See also Item A23)

14. Height of First Story ___________________ ft.

15. Upper Story Height _____________ ft. Special Story Height _________ ft.

16. Is the exterior of first story different from upper stories?

Street Front Side Yes ____ No ____ Other Sides Yes ____ No _____

17. Approximate Roof Overhang Distance ____________ Side ___________________

18. Proximity to Adjacent Buildings: Sketch Below with North Arrow

North Side _______ South Side _______ East Side _______ West Side ______

Note Street or Alley Sides ____

*To be filled in by Field Supervisor.

Sketch

DC-2

19. Are plans available? ______ If so, where obtainable ____________________

____________________ Are original calculations available? ______ If so,

where obtainable ____

Name of: Architect ____________________ Engineer ____________________

Contractor ____

Regulatory Agency ____

20. Basic Building Plan

a. Sketch overall plan.
b. Locate shear walls, if any.
c. Locate main frames.
d. Locate expansion joints, if any.
e. Give approximate north arrow and label sides "A", "B", "C", "D", etc. Show street or alley sides.
f. Note any common or party walls.
g. If plan changes in upper floors, sketch this plan and note level of change.

(Use additional sheet if necessary)

DC-3

21. Elevation of Exterior Walls.

Sketch:
- a. All openings or note pattern of openings.
- b. Note exterior finish and appendages.
- c. Note material of walls.
- d. Major cracks or other damage. (Note if cracks are larger at one end.)
- e. Note previously repaired damage.
- f. Note any evidence of damage to cladding or appendages.

(Use additional sheet if necessary)

DC-4

22. Elevation of Interior Shear Walls.

Sketch: a. All openings.
b. Major cracks or other damage. (Note if cracks are larger at one end.)
c. Note any previously repaired damage.

DC-5

23. Adaptability of Basement to Storm Shelter.

a. Floor Over Basement - Concrete ☐ Other ☐

b. If concrete, give thickness ________

c. Available Space (approximate) ______________ sq. ft.

d. Dangerous Contents. Storage of Flammable Liquids ☐

Presence of Transformers or Other Dangerous Equipment ☐

Other Hazards ____

None ☐

24. Is this a Vault-like Structure? Yes ☐ No ☐

DC-6

25. EXTERIOR WALL SUMMARY SHEET

Exterior Characteristics	Side A	Side B	Side C	Side D
Extensive Architectural Ornaments or Veneer				
WALLS Metal Curtain Wall				
Precast Concrete Curtain Wall				
Stone				
Brick				
Concrete Block				
Concrete				
Other				
For Concrete Block and Brick, indicate R for Running Bond S for Stacked Bond				
Condition of Wall*				
OPENINGS Percent of Open Area per Story				

*1. No cracks, good mortar.
2. Few visible cracks.
3. Many cracks
4. Evidence of minor repairs.
5. Evidence of many repairs.

DC-7

B. <u>SITE RELATED INFORMATION</u>

1. Exposure

   a. Centers of large city [ ] b. Very rough hilly terrain [ ]

   c. Suburban areas, towns, city outskirts, wood areas, or rolling terrain [ ] d. Flat, open country [ ]

   e. Flat coastal belts [ ] f. Other [ ]

2. Topography

   a. Building on level ground [ ] b. Building on sloping ground [ ]

   c. Building located adjacent to embankment [ ]

*3. Geologic formation ____________________

*4. Location of known faults: Name ____________________ Miles ______

____________________ Miles ______

*5. Depth of water table ________ ft. When measured: ____________________
(Month) (Year)

*6. Depth of bedrock __________ ft.

*7. Soil type ____________________

*8. Bearing capacity __________ p.s.f., or __________ blows per inch

9. Proximity to potential wind-blown debris - Type ____________________

Location ____________________ Distance __________

*To be filled in by Field Supervisor.

DC-8

C. STRUCTURAL SYSTEMS

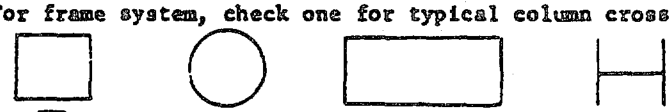
1. Material

   Concrete ☐ Masonry ☐ Steel ☐ Wood ☐

2. Vertical Load Resisting System

   Frame ☐ Bearing Wall ☐ Wall and Pilasters ☐

   For frame system, check one for typical column cross-section



   ☐ ☐ ☐ ☐ Other ☐

3. Lateral Load Resisting System

   Masonry Shear Wall ☐ Braced Frame ☐

   Concrete Shear Wall ☐ Moment Resisting Frame ☐

   Plywood Shear Wall ☐ Are resisting systems symmetrically located? ☐ Yes ☐ No

4. Floor System

   Frame

   Concrete Beams ☐ Wood Beams ☐

   Steel Beams ☐ No Framing Members ☐

   Steel Bar Joist ☐ Precast Concrete Beams ☐

   Deck

   Concrete Flat Plate ☐ Straight Sheathing ☐

   Concrete Flat Slab ☐ Plywood Sheathing ☐

   Concrete Waffle Slab ☐ Diagonal Sheathing ☐

   Steel Deck ☐ Precast Concrete Deck ☐

   Wood Joists ☐ Concrete Joists ☐

   Wood Plank ☐ Concrete Plank ☐

   Note if concrete topping slab is used over metal decks or concrete plank.

BC-9

Connection Details

	Framing	Decking To Framing
Bolted	☐	☐
Welded	☐	☐
Metal Clips	☐	☐
Wire Fastener	☐	☐
No Connection	☐	☐
Nailed	☐	☐
Metal Hangers	☐	☐

Anchorage Floor to Walls

Type ______________________________

Spacing ______________________________

5. Roof System

Frame

Concrete Beams	☐	Steel Truss	☐
Steel Beams	☐	Wood Truss	☐
Steel Bar Joist	☐	No Framing Members	☐
Wood Beams	☐	Precast Concrete Beams or Tees	☐
Wood Rafters	☐		

Deck

Concrete Flat Slab	☐	Concrete Waffle Slab	☐
Metal Decking	☐	Plywood Sheathing	☐
Concrete Slab	☐	Diagonal Sheathing	☐
Concrete Joists	☐	Straight Sheathing	☐
Precast Decking	☐	Concrete Fill	Yes ☐ No ☐

DC-10

Connection Details

	Framing	Decking to Framing
Bolted	☐	☐
Welded	☐	☐
Metal Clips	☐	☐
Wire Fastener	☐	☐
No Connection	☐	☐
Nailed	☐	☐
Metal Hangers	☐	☐

Anchorage Roof to Walls

Type ______________________________

Spacing ______________________________

D. NONSTRUCTURAL ELEMENTS

1. Partitions

Type

	Typical	Corridor
Partial Height	☐	☐
Full Height Floor-To-Ceiling	☐	☐
Floor To Floor	☐	☐
Movable	☐	☐

Composition

Lath and Plaster ☐

Gypsum Wallboard ☐

Concrete Block ☐

Clay Tile ☐

Metal Partitions ☐

DC-11

2. Ceiling

Typical Room

Material

Acoustical Tile ☐ Gypsum Board ☐ Plaster ☐

Method of Attachment

Suspended ☐ Metal Channels ☐ Tee Bar Grid ☐

Attached Directly to Structural Elements ☐

Typical Corridor

Material

Acoustical Tile ☐ Gypsum Board ☐ Plaster ☐

Method of Attachment

Suspended ☐ Metal Channels ☐ Tee Bar Grid ☐

Attached Directly to Structural Elements ☐

3. Light Fixtures

Typical Room

Recessed ☐ Surface Mounted ☐ Pendant (Suspended) ☐

Typical Corridor

Recessed ☐ Surface Mounted ☐ Pendant (Suspended) ☐

4. Mechanical Equipment

Location of Mechanical Equipment Room

Basement ☐ Other Floor ☐ Which Floor ________

Roof ☐

Is Equipment Anchored to Floor? No ☐ Yes ☐

Location of The Following Units

Liquid Storage Tank ________________________________

Cooling Tower ________________________________

Air Conditioning Unit ________________________________

DC-12

5. Roofing

Description

Flat ☐ Arched ☐ Gabled ☐ If arched or gabled, sketch section.

Pitched ☐ Slope (:12)

Parapet No ☐ Yes ☐ Height (______ ft. ______in.) Thickness (_____in.)

Material ______________ Special Anchorage or Bracing Yes ☐ No ☐

Type

Built-up gravel ☐ Gravel ☐ Asphalt or Wood Shingles ☐

Clay Tile ☐ Other ☐

6. Windows

Type

Fixed ☐ Movable ☐

Frame Material:

Aluminum ☐ Steel ☐ Stainless Steel ☐ Wood ☐

Size: Average Size of Casing (____ ft. x _____ ft.)

Average Size of Glazing (____ ft. ____ in. x ____ ft. ____ in.)

How Casing is Attached to Structure

Bolted ☐ Screwed ☐ Clipped ☐ Welded ☐ Nailed ☐

Glazing Attachment to Casing

Elastomeric Gasket ☐ Glazing Bead ☐ Aluminum or Steel Retainer ☐

Other ☐

7. Gas Connection

Flexible Connection to Building ☐ Rigid Connection to Building ☐

Automatic Shut-off ☐ None ☐ Unknown ☐

INSPECTED BY ______________________________

DATE ______________________________

FIELD SUPERVISOR ______________________________

FORM FMA-1

FACILITY NO. ________________ EXPECTED SITE MODIFIED MERCALLI INTENSITY ________

FIELD EVALUATION METHOD

STRUCTURAL SYSTEMS - EARTHQUAKE AND WIND RATING

VERTICAL RESISTING ELEMENTS							
Type	General Rating (GR)		Symmetry (S)	Quantity (Q)	Symmetry Quantity Rating (SQR) [1]	Present Condition (PC)	Sub-Rating (SR1) [2]
	E	W					
TRANSVERSE LOADING							
LONGITUDINAL LOADING							

FOOTNOTES:

1. Symmetry-Quantity Rating (SQR) = $\frac{S + Q}{2}$.

2. Sub-rating SR-1 = $\frac{SQR + 2PC}{3}$.

	TYPE	GENERAL RATING (GR) Earthquake	Wind
A	Steel Moment Resistant Frames	1	1
B	Steel Frames - Moment Resistance Capability Unknown	2	2
C	Concrete Moment Resistant Frames	1	1
D	Concrete Frames - Moment Resistance Capability Unknown	2	2
E	Masonry Shear Walls - Unreinforced	4	2 or 3
F	Masonry or Concrete Shear Walls - Reinforced	1	1
G	Combination - Unreinforced Shear Walls and Moment Resistant Frames	2	2
H	Combination - Reinforced Shear Walls and Moment Resistant Frames	1	1
J	Braced Frames	1	1
K	Wood Frame Buildings, Walls Sheathed or Plastered	1 or 2	2 or 3
L	Wood Frame Buildings, Walls Without Wood Sheathing or Plaster	4	4

SYMMETRY (of Resisting Elements)

1	Symmetrical
2	Fairly Symmetrical
2 or 3	Symmetry Poor
3 or 4	Very Unsymmetrical

NOTE: Add 1 (not to exceed 4) to each rating if a high degree of vertical non-uniformity in stiffness occurs.

QUANTITY (of Resisting Elements)

1	Many Resisting Elements
2	Medium Amount of Resisting Elements
3	Few Resisting Elements
4	Very Few Resisting Elements

NOTE: If exterior shear walls are at least 75% of building length, this rating will be 1.

PRESENT CONDITION (of Resisting Elements)

1	No Cracks, No Damage
2	Few Minor Cracks
3	Many Minor Cracks or Damage
4	Major Cracks or Damage.

NOTE: If masonry walls, note quality of mortar - good or poor. If lime mortar is poor, use next higher rating.

FACILITY NO. ____________

FORM FMA-2

FIELD EVALUATION METHOD

STRUCTURAL SYSTEMS - EARTHQUAKE AND WIND RATING

HORIZONTAL RESISTING ELEMENTS							
Type		Rigidity (R)	Anchorage & Connections (A)	Chords (C)		Sub-Rating (SR2)
				Longitudinal	Transverse	
Roof						
Floors						

Note: Sub-rating SR2 = Largest of R, A or C.

Type

A Diaphragm
B Steel Horizontal Bracing

Rigidity - Ratings

1. Rigid
1.5 Semi-rigid
2.0 Semi-flexible
2.5 Flexible

Anchorage and Connections - Ratings

1 Anchorage confirmed - capacity not computed, but probably adequate.
2 Anchorage confirmed - capacity not computed, but probably inadequate.
3 Anchorage unknown.
4 Anchorage absent.

Chords - Ratings

1 Chords confirmed, but capacity not computed.
2 Chords unknown, but probably present.
3 Chords unknown, but probably not present.
4 Chords absent.

FACILITY NO. ____________ FORM FMB-1

FIELD EVALUATION METHOD

EXIT CORRIDOR AND STAIR ENCLOSURE WALLS - EARTHQUAKE RATING

TYPE OF WALL	REINFORCEMENT			ANCHORAGE					WALL RATING
	Present	Not Present	Not Known	Mortar Only	Dowels	Screws or Bolts	Other	Not Known	
Brick									
Brick									
Concrete Block									
Concrete Block									
Reinforced Concrete									
Tilt-up or Precast Concrete									
Steel Studs & Plaster									
Wood Studs & Plaster									
Hollow Tile									
Hollow Tile & Plaster									

NOTE: Wall Rating on Basis of A, B, C, and X.

FORM FMB-1

FACILITY NO. ______________ FORM FMB-2

FIELD EVALUATION METHOD

OTHER LIFE HAZARDS - EARTHQUAKE RATING

TYPE OF RISK	RATING
Partitions Other Than on Corridors or Stair Enclosures	
Glass Breakage	
Ceiling	
Light Fixtures	
Exterior Appendages and Wall Cladding*	

Ratings
A = Good
B = Fair
C = Poor
X = Unknown

*A description of some of the ratings for Exterior Appendages and Wall Cladding are:

Description	Rating
Spacing of anchors appears satisfactory	A
Size and embedment of anchors satisfactory	A
Spacing of anchors appears to be too great	B
Size and embedment of anchors appears unsatisfactory	C
Anchorage unknown	X
Anchorage corroded or obviously loose	C
No anchorage	C

EARTHQUAKE GAS CONNECTION		
Present	Not Present	Not Known

FACILITY NO ________________ FORM FME

FIELD EVALUATION METHOD

CAPACITY RATIOS - EARTHQUAKE AND WIND RATING

	General Rating (GR)	Sub-Rating SR1	Sub-Rating SR2	Basic Structural Rating*	Capacity Ratio**
EARTHQUAKE					
WIND					

*Basic Structural Rating = $\frac{\text{GR + 2 (Largest of SR1 or SR2)}}{3}$.

**Capacity Ratio for wind shall be obtained from Form FMC-1. For earthquake, the ratio is obtained from the Basic Structural Rating divided by the Intensity Level Factor at the site as determined from the table below.

Modified Mercalli Scale	Intensity Level Factor
VIII or Greater	1
VII	2
VI	3
V or Less	4

A description of Modified Mercalli Scale is included on table 3.3.

Capacity Ratio Rating	
Capacity Ratio	**Rating (In Terms of Risk)**
Less than 1.0	Good
1 through 1.4	Fair
1.5 through 2.0	Poor
Over 2.0	Very Poor

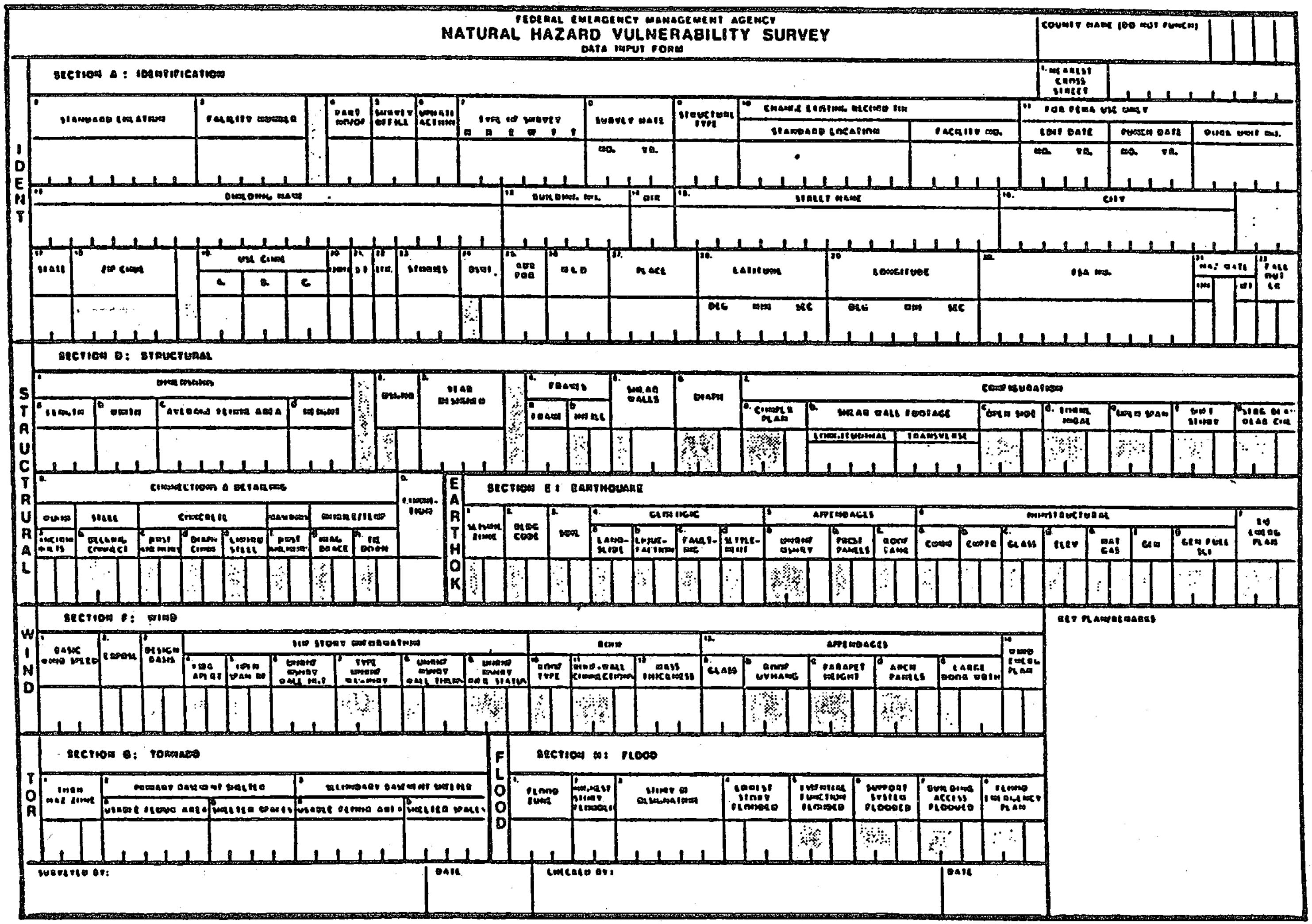


Fig. 1-2. Multi-Hazard DIF.

A. IDENTIFICATION

9. STRUCTURE TYPE (Enter Number)

1. Quonset, steel frame
2. Wood frame
3. Wall bearing
4. Steel frame
5. Reinforced-concrete frame
6. Steel/concrete frame
7. Tunnels
8. Mines

Type floor & roof

1. Wood joist
2. Wood/steel joist, shallow truss
3. Glulam
4. Precast concrete
5. Reinforced concrete slab
6. Flat plate
7. Metal deck/steel frame
8. Metal deck/open-web bar joist
9. Lightweight tension structure

Type walls

1. Masonry, unreinforced
2. Masonry, reinforced
3. Reinforced concrete
4. Precast concrete
5. Infill masonry
6. Corrugated-metal
7. Arch cladding
8. Wood sheathing
9. Stucco
0. Glass

24. BASEMENT
0. No basement

Wood
1. Wood joists
2. Plywood I-joist
3. Glulam
4. Heavy timber

Concrete
5. One-way joists or slab
6. Flat plate
7. Flat slab
8. Two-way slab
9. Waffle slab
10. Precast

Combination
11. Steel joist/concrete slab
12. Steel frame/concrete slab
13. Wood/steel joists

D. STRUCTURAL

4. FRAMES (Enter Number)

a. Frame class

Wood
1. Timber/pole
2. Braced frame

Steel
3. All metal
4. Pinned
5. Moment-resistant
6. Ductile moment-resistant
7. Braced frame

Concrete
8. Pinned
9. Slab/plate
10. Moment-resistant
11. Ductile moment-resistant
12. Braced frame

Lightweight tension structure
13. Tension structure

b. Infill class
0. Not infilled
1. Infill/partial infill unreinforced or partially reinforced masonry
2. Infill/partial infill reinforced masonry

5. SHEAR WALLS (Enter Number)

Wood
1. Plywood
2. Non-plywood

Steel
3. Plate

Masonry
4. Ordinary unreinforced
5. Monumental unreinforced
6. Partially reinforced
7. Reinforced

Concrete
8. Poured-in-place
9. Precast

Mobile/Temporary
10. Mobile/Temp Module

6. DIAPHRAGMS (Enter Number)

Wood
1. Plywood
2. Non-plywood

Steel
3. Metal decking or diagonally braced

Concrete
4. Reinforced
5. Precast
6. Unreinforced
7. Lightweight tension structure

7. CONFIGURATION
(Yes/No/0 = does not apply)

8. CONNECTIONS AND DETAILING
(Yes/No/0 = does not apply)

9. CONDITION (Enter Number)

1 = good
2 = slight deterioration
3 = major deterioration

E. EARTHQUAKE

2. BUILDING CODE (Enter Number)

1. No seismic design
2. Some seismic design
3. UBC 1949-1970
4. UBC 1973+
5. Above average criteria

3. SOIL
(S = soft, H = hard)

4. GEOLOGIC
0 = no data
1 = low hazard
2 = intermediate
3 = high

5. APPENDAGES
(Yes/No/0 = no data)

6. NONSTRUCTURAL
X = not present
0 = no data
B = braced
U = unbraced

7. EARTHQUAKE PLAN
(Yes/No/0 = no data)

F. WIND

2. EXPOSURE
(A or B)
A. Protected
B. Open

3. DESIGN BASIS
(Enter Number)
1. No wind design
2. Some wind design
3. Code, 1961-1975
4. Code, 1976+

7. MASONRY TYPE
(Enter Letter)
a. Clay brick
b. Clay tile
c. Concrete block
d. Concrete brick
e. Adobe
f. Stone

9. INFILL
(Enter Number)

0 = no infill
1 = partial
2 = infill

10. ROOF
(Enter Number)

1. Plywood
2. Non-plywood
3. Metal decking
4. Reinforced concrete
5. Precast
6. Unreinforced concrete
7. Lightweight tension structure

11. ROOF/WALL CONNECTION
(Enter Number)

0. No data
X. No connection
1. Plywood
2. Non-plywood
3. Metal decking
4. Reinforced
5. Precast concrete
6. Unreinforced concrete

13. APPENDAGES
(Enter Letter)

a. Glass (%)
b. Overhang (ft)
c. Parapet height (ft)
d. Arch panels (Yes/No)
e. Large door width (ft)

14. WIND EMERGENCY PLAN
(Yes/No/0 = no data)

G. TORNADO SHELTER

1. TORNADO ZONE (Enter Number)

1 = lower risk
2 = higher risk

CONSTRUCTION:
F-RC-H1 TYPE
___PRE 1939
___PRE 1973
1920 DATE
___RENOVATED
________DATE

OCCUPANCY:
03/15 USE CODE
___VITAL
___HIGH DENSITY
___VULNERABLE
X 8AM-6PM
___6PM-MDNT
___MDNT-8AM

CONFIGURATION:
4 # STORIES
65 x 200 SIZE
___CMPLX PLAN
___CMPLX ELEV
___SOFT STORY
___OPEN FRONT
H = 45'

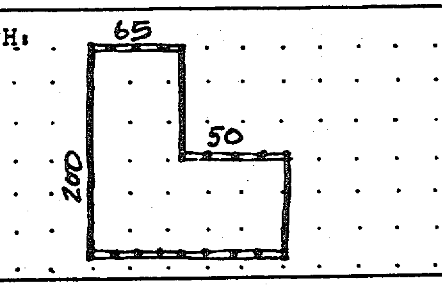
CONTENTS:
X HAZARDOUS
___IMPORTANT

DECORATION:
___HEAVY
___OVERHANGING PUBLIC WAY

CONSTRUCTION
EXT. WALLS: FACADE________ SIDES 6" RC
INT. WALLS: BEARING________ PARTITIONS________
DIAPHRAGMS: FLOOR________ ROOF________
FRAME: ___BRACED; ___MOMENT RESISTING; OTHER:________
MISC. FIRE PROOF CONST

CONFIGURATION
STIFFNESS DISTRIBUTION:
PLAN L- SHAPE
ELEVATION IRREGULAR
MISC.________

PLAN SKETCH:



FUNCTION AND OCCUPANCY
FLOORS:___-___ USES: WAREHOUSE/OFFICE
FLOORS:___-___ USES:________
FLOORS:___-___ USES:________

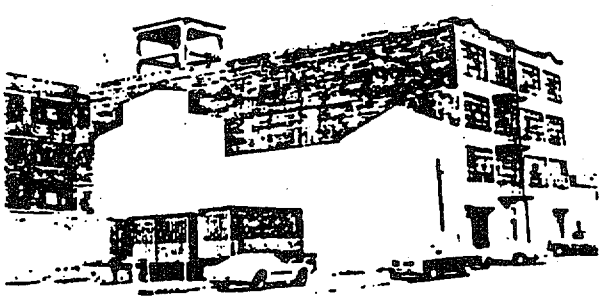


FIGURE A1-2.
Sample Building Information Sheet.

Construction Types Code:

Bearing Wall:

B-UM Unreinforced Masonry
B-RM Reinforced Masonry
B-RC Reinforced Concrete
B-PC Pre-cast Concrete
B-WD Wood (stud wall)

Frame:

F-ST-(HI, LI, HC, LC) Steel
F-RC-( ) Reinforced Concrete
F-WD-( ) Wood (glu-lam, heavy timber)

Exterior skin (heavy infill, light infill, heavy curtain, light curtain)

Frame material

Use Codes:

01 Apartment
02 Hotel
03 Office
04 Retail
05 Restaurant
06 Theatre
07 Auditorium
08 Gymnasium
09 Church
10 School
11 Hospital
12 Parking
13 Car Servicing
14 Manufacturing
15 Warehouse
16 Public facility
17 Public utility

FIGURE A1-3. Key to sample Building Information Sheet.

CRITICAL FACILITIES
FIELD INSPECTION BUILDING DATA SHEET

1. NAME OF BUILDING________________________________CENSUS TRACT__________
2. BLDG. ADDRESS____________________________CITY_______________COUNTY______
3. NO. OF OCCUPANTS__________________________DAY__________NIGHT____________
4. YEAR BUILT____________________ 5. BLDG. SIZE (SQUARE FEET)__________
6. NO. OF STORIES/FLOOR______________ 7. BASEMENT? YES________ NO_______
8. PRIMARY STRUCTURAL SYSTEM

_________ A. STEEL FRAME
_________ B. STEEL FRAME (REINFORCED CONCRETE SHEAR WALL AROUND CENTRAL CORE)
_________ C. WALL BEARING
_________ D. PRECAST COLUMN AND BEAM
_________ E. REINFORCED CONCRETE FRAME
_________ F. REINFORCED CONCRETE FRAME (REINFORCED CONCRETE SHEAR WALL AROUND CENTRAL CORE)
_________ G. FLAT PLATE CONCRETE SLAB
_________ H. WOOD FRAME
_________ I. PLANK AND BEAM FRAME
_________ J. PRE-ENGINEERED METAL BUILDING
_________ K. OTHER STRUCTURAL TYPES DESCRIBE
____
____

9. FOUNDATION TYPE

_________ A. SPREAD
_________ B. STRIP
_________ C. PILES
_________ D. CAISSONS
_________ E. SLAB ON GROUND
_________ F. OTHER

10. WALL TYPE ____
11. FLOOR/ROOF TYPE ____
12. SPECIAL FEATURES ____
____
13. SPECIAL SOIL CONDITIONS ____
____

SINGLE AND MULTI-FAMILY HOUSING DATA SHEET

CENSUS TRACT (DISTRICT) ______________________________

ITY ____________________ COUNTY ____________________

A. SINGLE FAMILY RESIDENCES

1) PREDOMINATE FOUNDATION TYPES
   - A. __________ SLAB ON GROUND
   - B. __________ POURED CONCRETE OR MASONRY BLOCK FOUNDATION WALL
   - C. __________ STONE FOUNDATION WALLS
   - D. __________ OTHER

2) PREDOMINATE EXTERIOR WALL, VENEER OR FINISH
   - A. __________ BRICK/MASONRY
   - B. __________ STONE
   - C. __________ WOOD-SIDING OR SHINGLES
   - D. __________ STUCCO
   - E. __________ OTHER

3) CHIMNEYS, PARAPETS, ORNAMENTATION OR OTHER FALLING HAZARDS __________

4) AGE __________ 5) HEIGHT __________

5) NO. OF OCCUPANTS DAY __________ NIGHT __________

B. MULTI-FAMILY RESIDENCES

1) PREDOMINANT STRUCTURAL TYPE
   - A. __________ STEEL FRAME
   - B. __________ WALL BEARING
   - C. __________ CONCRETE FRAME
   - D. __________ FLAT PLATE
   - E. __________ WOOD FRAME
   - F. __________ PLANK AND BEAM

2) NO. OF OCCUPANTS DAY __________ NIGHT __________

3) AGE __________ 4) HEIGHT __________

5) STORIES/FLOORS __________

CENSUS TRACT ________

NO. OF BLDGS.	COMMERCIAL	PUBLIC NON-EDUCATIONAL	UTILITIES	INDUSTRIAL	EDUCATIONAL
STEEL FRAME					
WALL-BEARING					
CONCRETE FRAME					
FLAT PLATE					
WOOD FRAME					
PLANK AND BEAM					
PRE-ENGINEERED METAL					
1 STORY/FLOOR					
2-5 STORIES/FLOORS					
6-10 STORIES/FLOORS					
OVER 10 STORIES/FLOORS					
AGE PRIOR 1900					
1900-1929					
1930-1949					
1950-1969					
1970-PRESENT					

BUILDING ADDRESS:

BUILDING LOCATION(APN):

NAME OF BUSINESS TENANTS:

OWNERS NAME & ADDRESS:

TYPE OF USE:

NO. OF STORIES: ______

BASEMENT: ______

TYPE OF STRUCTURAL SYSTEM:

BUILDING SIZE:
Square Footage per floor: ______
Total: ______

OCCUPANT LOAD:
(UBC-Table 33-A) ______

DATE OF ORIGINAL CONSTRUCTION: ______
DATE OF SUBSEQUENT REMOD./REPAIR AFFECTING THE STRUCTURAL SYSTEM: ______

NAME OF ORIGINAL DESIGNER: ______

NAME OF ORIGINAL CONTRACTOR: ______

COMPANY RESPONSIBLE FOR SUBSEQUENT STRUCTURAL MODIFICATION: ______

HISTORIC BUILDING CATEGORY: ☐ YES ☐ NO

REMARKS:

BUILDING ADDRESS: 550 Example * 552	BUILDING LOCATION (APN): 120-15-084
NAME OF BUSINESS TENANTS: 550 * 552 *	OWNERS NAME & ADDRESS: *
TYPE OF USE: 550 Coffee House 3274 552 Retail Store 3274	NO. OF STORIES: 1 BASEMENT: No
TYPE OF STRUCTURAL SYSTEM: C.B. & R.C. Beams & Cols. Flat Roof	
BUILDING SIZE: Square Footage per floor: 5475 2250 MEZ. Total: 7725	OCCUPANT LOAD: (UBC-Table 33-A) ≈ 100 $\frac{1/2(5475)}{15} + \frac{1/2(5475)}{30} + \frac{2250}{100}$
DATE OF ORIGINAL CONSTRUCTION: 1951 DATE OF SUBSEQUENT REMOD./REPAIR AFFECTING THE STRUCTURAL SYSTEM:	
NAME OF ORIGINAL DESIGNER: N/A NAME OF ORIGINAL CONTRACTOR: — COMPANY RESPONSIBLE FOR SUBSEQUENT STRUCTURAL MODIFICATION: —	
HISTORIC BUILDING CATEGORY: ☐ YES ☒ NO	
REMARKS: *Names omitted in this publication	

BUILDING INSPECTION QUESTIONNAIRE
(Damage Estimation)

INSPECTORS NAME: ______ DATE: 5/9/85

IDENTIFICATION OF STRUCTURE: Bldg. #4

LOCATION: ______ ZONE: UBC 4

SPECIFIED INTENSITY (MMI): IX

Adjacency Factor:
The structure endangers another structure: yes
The structure is endangered by another structure: yes
The structure may be a support for another sturcture: yes
The structure may be supported by another structure: yes

STRUCTURES USE: Residential ______ Commercial ✓ Industrial ______
Special Facility no
Lifelines no

Importance Factor:
Impact of structures' use in the regions' economy in the event of an earthquake. negligible

MISC. DATA: Year Structure Built 1890-1900 No. of Stories 1
Floor area per story 4950 (Square Feet)(w/penthouse)
No. of Occupants: Day 15 Night 0
Potential no. of victims 15
Is there a basement? no
Is there a SANITARY crawl space? no

BUILDING CONFIGURATION: REGULAR ______ Elevation Regularity yes
Plan Symmetry yes
IRREGULAR ✓ Offset center of rigidity maybe
Discontinuity yes

SETBACKS yes
GEOMETRY OF BUILDING (Attach sketches showing overall dimensions, layout, window spacings and sizes): Elevation View ______
Plan View 45' x 110'
Exterior Wall View ______
Typical Shear Wall (core of corner) URM

NO. OF SEPARATION JOINTS:
In Elevation none
In Plan of Superstructure none

EVALUATION	Transverse Direction	Longitudinal Direction
-Plan Symmetry	good average poor	good average poor
-Elevation Regularity	good average poor	good average poor
-Redundancy of Bracing Elements	good average poor	good average poor

SPECIAL CHARACTERISTICS:

BUILDING CLASSIFICATION SYSTEM 2.1.1.a

STRUCTURAL REDUNDANCIES: Frame Line no
Plan no

QUALITY OF CONSTRUCTION:

		Good	Avg.	Poor
Workmanship:	Visual Observation	✓	-	-
	Review of Documentation	-	-	-
	Analytical Studies	-	-	-
Overload History Weakening Structural Resistance:				
	* Due to Earthquake	-	-	-
	Due to Fire	-	-	-
	Due to Extreme Environmental Conditions	-	-	-

*masonry cracks @ mortar joints

QUALITY OF DESIGN:

Is design regular or special? regular
Proper consideration of soil condition? unknown
Is it designed for earthquake loading? no
Structural ductility? none
Does as-built structure conform to design? n/a
Original designed base shear (kips)? n/a
Computed existing base shear (kips)? n/a
Ratio of existing to original? unknown

CONSTRUCTION MATERIALS:

Quality of materials used? average
Comparison with original material specs? n/a
Masonry or non-masonry? URM
Reinforced or non-reinforced?

SUPERSTRUCTURE

Continuous concrete wall? no
Concrete columns with infill? no
Large heavy pre-cast structural elements? no
Others masonry pilaster and infill
Any signs of distress?

FOUNDATION:

Type? spread
Is soil strength adequate? unknown - probably
(Identify loose sands, sensitive clays, or highly cemented sands clay
Possibility of landslide? no
Possibility of settlement? no - has already occurred
Possibility of sliding? no
Possibility of overturning? no
Possibility of liquefaction? no
Possibility of uplift? no

PRIMARY STRUCTURAL SYSTEM OR ELEMENTS:

Vertical load carrying elements? masonry pilasters
Lateral load carrying elements? URM shear walls

INTERIOR ENVELOPE:	VERTICAL	NON-VERTICAL
	Walls gypsum	Floors concrete slab on grade
	Doors/Windows wood/ald	Ceilings gypsum
	Others —	Others —

EXTERIOR ENVELOPE:	VERTICAL	NON-VERTICAL
	Walls masonry	Roofs tin built-up
	Doors/Windows wood/ald	Slabs concrete on grade

EVALUATION:

Some columns added to lower truss chord. A second floor (attic) was then placed on the truss chord.

Possibility of buckling of x-bracings? no
Excessive deflections of long span floors and roofs, etc.? no
Presence of cracks? yes - masonry walls
Excessive compressive force (Possibility of crushing)? no
Additional openings and/or penetrations? no
Possibility of weak column strong beam? no
Additional closures (partitions)? no
Shear wall type and thickness? 8" URM
Is suspended ceiling braced? no

SECONDARY NON-STRUCTURAL SYSTEM OR COMPONENTS:

ARCHITECTURAL:

INTERIOR ELEMENTS	EXTERIOR ELEMENTS
Lights hanging fluorescent	Parapets yes
Ornamentations much	Ornamentations no
Finishes no	Marquees —
Partitions gypsum	Overhangs no
Stairways timber/old	Balconies no
Shaftway —	Chimneys no
Ceilings gypsum	Railings no
Others —	Roofing tin w/ built-up over
	Siding no
	Cladding no
	Fire Escape no
	Canopies no
	Veneers no
	Others —

Possibility of collapse of infill materials? yes

SERVICE SYSTEMS:

ELEVATORS: no
Possibility of cage falling? ___
Adequacy of cage guides and motor mountings ___
MECHANICAL forced air gas
ELECTRICAL old
SPRINKLER none
FIRE CONTROL SYSTEM none
FUEL (HVC) natural gas

Are service systems adequate? yes
Are service systems adequately mounted? no
Will they provide service after an earthquake? no
Possibility of failure in fuel system causing fire? slight
Adequacy of fire control system? no
Possibility of explosion? no
Possibility of release of toxic chemicals? no

CONNECTIONS:

Adequacy of connections between primary structural elements to develop shear resistance? poor
Adequacy of connections between secondary non-structural elements to develop shear resistance? poor
Adequacy of connections between primary structural elements and secondary non-structural components to develop shear resistance? poor
Adequacy of foundations connections? unknown

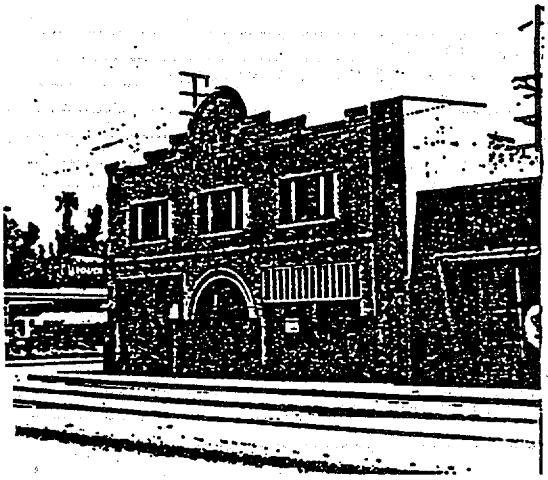
General Remarks:

a. Old URM building with timber roof trusses and sheet metal roof.

b. Reasonably open interior from floor to roof trusses with a few wood stud/gypsum partitions.

c. Trusses poorly attached to masonry pilasters!

BUILDING DATA FORM



ADDRESS:
AREA: TARGET AREA V
BUILDING NAME:
OWNER:
OCCUPANCY TYPE: B-2 AND R-3
TYPE OF CONSTRUCTION: URM, STUCCO
NUMBER OF STORIES: 2
BUILDING HEIGHT: 24 FEET
CONSTRUCTION: 1912
PLANS AVAILABLE: NONE

SUMMARIZE FINDINGS AND RECOMMENDATIONS HERE:

PRESENTLY VACANT. OWNER IS PRESENTLY IN PROCESS OF GUTTING THE BUILDING IN ORDER TO DO SEISMIC RETROFIT AND REMODELING TO OFFICE/COMMERCIAL USESES. INTERIOR WALLS ON SECOND FLOOR REMOVED SHOWING STRUCTURAL LUMBER AND INTERIOR SIDE OF WALLS. OLD WOOD IN GOOD SHAPE. SECOND STORY FLOOR IS DIAGONALLY SHEATHED. NO MAJOR CRACKS OR OTHER STRUCTURAL WEAKNESSES NOTED.

SAMPLE

FIELD DATA

ROOF: FLAT

COVERING HOT-MOPPED TAR

PARAPETS:FRONT - MATERIAL: BRICK QUALITY GOOD MORTAR QUAL. GOOD
THICKNESS 8" HEIGHT 2'-3', 7' AT FRONT BRACED OR BOND BEAM: —
OTHER REINF: NONE

ARCHITECTURAL IMPORTANCE: POTENTIAL - UNIQUE STYLE

SIDE AND REAR WALLS: URM, STUCCO COVERED

CORNICES: MATERIAL: NONE
PROJECTION: —
OTHER OBSERVATIONS: ROOF TILE —
COPING —
TOWERS/CHIMNEYS —
SIGNS 3'x 7' PROJECTED OVER SIDEWALK
TANKS —

ATTIC:HEIGHT: — MATERIAL: —
ANCHORS/BOND BEAMS: —

INTERIOR:
FLOORS: WOOD
INTERIOR WALLS: LATH & PLASTER
FRAMING: 2"x 6"

EXTERIOR:
ABUTTING BUILDINGS: SOUTH SIDE ONLY; TIRE STORE

STREET FRONT CONSTRUCTION: 4 LANE BOULEVARD

ARCHITECTURAL SIGNIFICANCE: POTENTIAL

LINTELS: ARCHED FRONT

THIN FACING OVER FRAMING:

SIGNS OR OTHER HAZARDS: ONE SIGN CANTILEVERED OVER FRONT SIDEWALK

OTHER OBSERVATIONS: EXPOSED BRICK ALONG BACK SIDE

SAMPLE

SUMMARY OF CONSTRUCTION

Exterior Walls:

N STUCCO OVER BRICK E EXPOSED BRICK S ABUTS OTHER BUILDING W 2 LARGE WINDOWS

Notes:

Roof: FLAT

Floor(s): WOOD AND CONCRETE

Interior Walls BEING REMODELED FROM LATH AND PLASTER

Frame

Lintels ARCHED

Other: MEZZANENE, 2 STORE FRONT WINDOWS

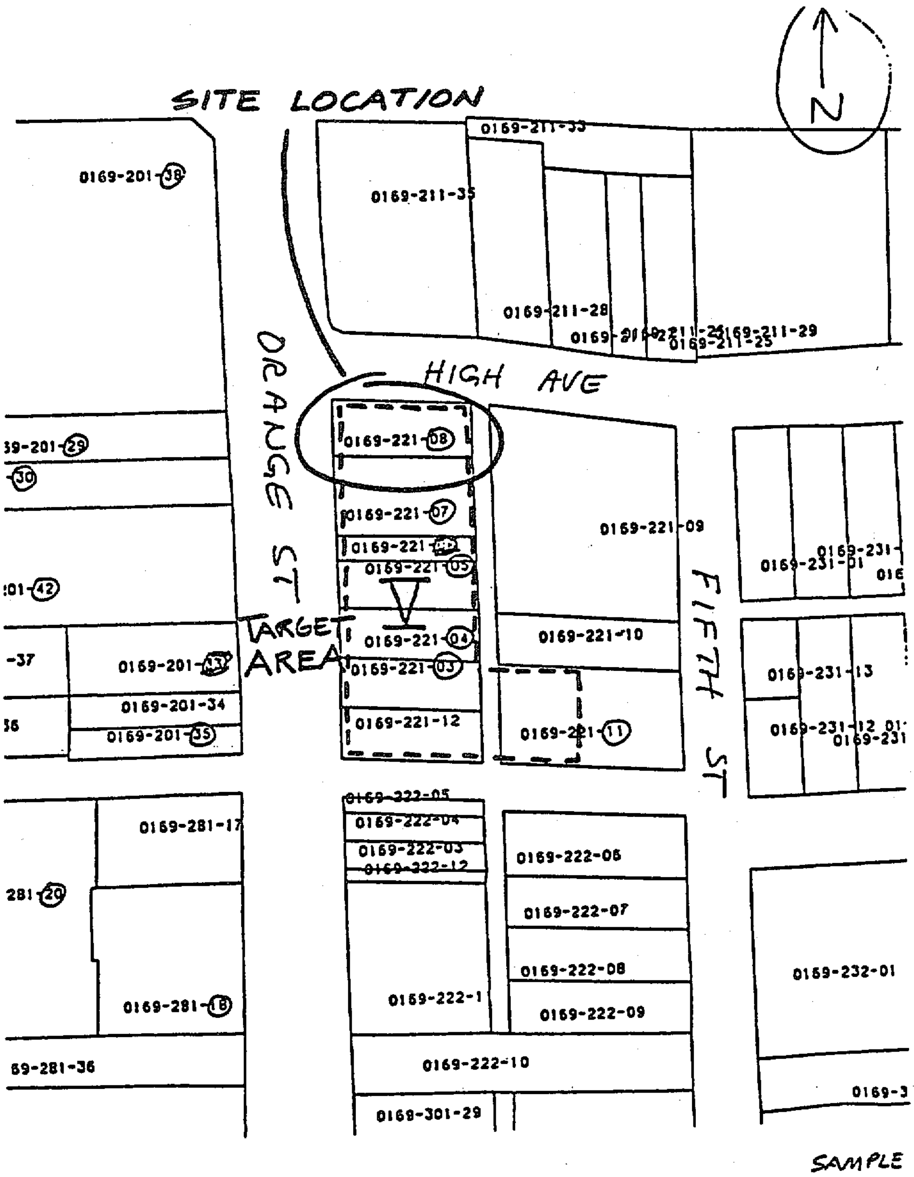
POSSIBLE HAZARDS

X Parapets
Walls
Gables
X Signs
Roof Tile
Coping
Facing
Towers
Marquees
Cornices
Ornamentation
Chimneys Tanks

OTHER NOTES OR REMARKS:

SAMPLE

SKETCHES AND NOTES



CRITICAL FACILITIES
BUILDING STRUCTURE CLASSIFICATION FORM

Name of building ____
Address ____
____
Census tract _________

Primary function of building ________________________________

Year built _____ Year remodeled or rehabilited _____

Plan sketch and dimensions:

Building length (parallel to street) L = ________ feet
Building depth (perpendicular to street) D = ________ feet
Building height (ground level to roof) H = ________ feet
Building size (L*D) A = ________ sq ft
Aspect ratio MAX(H/L,H/D) R = ________

Number of floors (ground floor and above) N = ________
Number of basements B = ________

1984 Replacement value $ ____________

Amount of earthquake insurance $ ____________

Underwriter's building classification _________
[ ] ISO
[ ] Other System: ____________

SURVEY BUILDING CLASSIFICATION: ____________

STRUCTURAL SYSTEM

GENERAL TYPE:

[ ] (1) Mobile Home
[ ] (1) Wood frame

[ ] (2) All metal

[ ] (3) Steel frame
- [ ] Simple
- [ ] Moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Ductile moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Poured-in-place concrete fire-proofing
- [ ] Shear walls

[ ] (4) Concrete frame
- [ ] Precast elements
- [ ] Moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Ductile moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Shear walls

[ ] (5) Mixed construction
- [ ] Unreinforced masonry
- [ ] Reinforced masonry
- [ ] Tilt-up

[ ] (6) Special earthquake resistant
(Requires written justification)

EMERGENCY SYSTEMS:

[ ] Fire alarms

[ ] Heat and/or smoke detectors

[ ] Fire doors
- [ ] Self closing
- [ ] Automatic closing (Fusable link)

EXTERIOR WALLS:

Location: ___________ story

Type: [ ] Bearing
[ ] Non-bearing
[ ] Curtain
[ ] Panel
[ ] In-filled

Material: [ ] Adobe
[ ] Wood
[ ] Cripple studs
[ ] Unbraced
[ ] Braced
[ ] Brick veneer
[ ] Stucco
[ ] Other Type: ____________________
[ ] Masonry
[ ] Hollow
[ ] Solid
[ ] Unreinforced
[ ] Reinforced
[ ] Brick
[ ] Tile
[ ] CMU
[ ] Concrete
[ ] Glass
[ ] Steel panels
[ ] Precast concrete panels
[ ] Other Type: ____________________

Percent of exterior wall openings: North __________
East __________
South __________
West __________

Thickness: ______ in

Through-wall ties: ____

INTERIOR WALLS:

Location: ___________ story

Shear Walls:

Type: [ ] None
[ ] Isolated
[ ] Core

Material: [ ] Masonry
[ ] Hollow

```
                [ ] Solid
                [ ] Unreinforced
                [ ] Reinforced
                [ ] Brick
                [ ] Tile
                [ ] CMU
            [ ] Concrete
            [ ] Other      Type: _________________

   Thickness: ______ in


  Partitions:

        Type: [ ] Non-moveable
              [ ] Moveable

    Material: [ ] Wood studs
                  [ ] Plaster
                  [ ] Gypsum board
                  [ ] Plywood panel
                  [ ] Other          Type: _________________
              [ ] Metal studs
                  [ ] Plaster
                  [ ] Gypsum board
                  [ ] Plywood panel
                  [ ] Other          Type: _________________
              [ ] Plaster
              [ ] Masonry
                  [ ] Brick
                  [ ] Tile
                  [ ] CMU
                  [ ] Non-reinforced
                  [ ] Reinforced

         Top: [ ] Below ceiling
              [ ] At ceiling
              [ ] At underside of upper floor/roof
                  Anchorage: [ ] None
                             [ ] Poor
                             [ ] Good
                             [ ] Excellent
   Thickness: ______ in
```

FLOOR FRAMING:

Location: ____________ story

Type: [ ] Concrete slab on grade
[ ] Joists
  [ ] Wood
  [ ] Steel
  [ ] Concrete
  [ ] Not anchored
  [ ] Anchored
[ ] Beam/girder
  [ ] Timber
  [ ] Steel
  [ ] Concrete
[ ] Wood trussed joists
[ ] Concrete slab
  [ ] Poured-in-place
  [ ] Precast
  [ ] Reinforced
  [ ] Prestressed
  [ ] Solid
  [ ] Hollow
  [ ] Ribbed
  [ ] Waffel
  [ ] Flat slab
  [ ] Slab w/drops
  [ ] Slab w/capitals
  [ ] Slab w/drops and capitals
  [ ] Precast elements   Type: ______________

Deck: [ ] Wood
[ ] Steel
[ ] Concrete planks
[ ] Light concrete deck slab (LEQ 3")
[ ] Heavy concrete deck slab (GTR 3")
[ ] Other   Type: ______________________

Diaphragm: [ ] No
[ ] Poor
[ ] Good
[ ] Excellent

Diaphragm shear transfer connection: [ ] None
[ ] Poor
[ ] Good
[ ] Excellent

ROOF FRAMING:

```
     Surface: [ ] Flat
              [ ] Sloped
              [ ] Curved

        Type: [ ] Joists
                  [ ] Wood
                  [ ] Steel
                  [ ] Concrete
                  [ ] Not anchored
                  [ ] Anchored
              [ ] Beam/girder
                  [ ] Timber
                  [ ] Steel
                  [ ] Concrete
              [ ] Wood trussed rafters
              [ ] Truss/purlin
                  [ ] Timber
                  [ ] Steel
              [ ] Concrete slab
                  [ ] Poured-in-place
                  [ ] Precast
                  [ ] Reinforced
                  [ ] Prestressed
                  [ ] Solid
                  [ ] Hollow
                  [ ] Ribbed
                  [ ] Waffel
                  [ ] Flat slab
                  [ ] Slab w/drops
                  [ ] Slab w/capitals
                  [ ] Slab w/drops and capitals
                  [ ] Precast elements   Type: ______________

        Deck: [ ] Wood
              [ ] Steel
              [ ] Concrete planks
              [ ] Light concrete deck slab (LEQ 3")
              [ ] Heavy concrete deck slab (GTR 3")
              [ ] Other     Type: _______________________

   Diaphragm: [ ] No
              [ ] Poor
              [ ] Good
              [ ] Excellent

   Diaphragm shear transfer connection: [ ] None
                                        [ ] Poor
                                        [ ] Good
                                        [ ] Excellent
```

ORNAMENTATION:

Exterior: Inadequately anchored ornamentation and/or veneer above the first story ____________
____
____

Stone coping on parapets, stone or pre-cast ledges, or sculptered sills and key-stones ________________________________
____
____

Interior: [ ] Suspended ceilings
- [ ] Tie wires
  - [ ] Not looped
  - [ ] Looped
- [ ] Lateral bracing
  - [ ] None
  - [ ] Wires
  - [ ] Metal channels

[ ] Suspended light fixtures
- [ ] Wire
- [ ] Chain
- [ ] Pendant (pipe / conduit)

[ ] Poorly anchored chandeliers and/or other ceiling appurtanacies

[ ] Drop-in fluorescent light fixtures

[ ] Bracket-mounted television sets _____
____

[ ] Floor coverings ____________________
____
____

MECHANICAL/ELECTRICAL:

Heating Equipment: ______________
Air Conditioning Equipment: ______________
Electrical Generation and Distribution Equipment: ______________
Elevators: ______________
Escalators: ______________
Miscellaneous Equipment: ______________

Anchorage: (All equipment) ________________________

UNUSUAL CONDITIONS:

Previous EQ damage: ____

Settlement: (Differential settlement, cracking, bowing, leaning of walls) ______________________
____
____

Shear walls: (Symmetric or non-symmetric) ____________

Lateral bracing: (Type) ____________________________________
(Symmetric or non-symmetric) ____________

Building shape: [ ] Rectangular
[ ] Triangular/L-shape/T-shape/H-shape
[ ] "Open front" (U-shape)

Columns: (Continuous, non-continuous) ____________
____

Foundation: [ ] Above grade concrete piers or pedestals
  [ ] Unreinforced
  [ ] Reinforced
[ ] Above grade masonry piers or pedestals
  [ ] Unreinforced
  [ ] Reinforced
[ ] Tiedowns
[ ] Cross-bracing

Floors: (Cracking or sagging) ____________________

Swimming Pools: (On roofs) ____________________________

Aspect ratio: R = _______

Other: ____
____
____
____

HAZARDOUS EXPOSURES:

Roof tanks: Number: ______________________
Purpose: ______________________
Size: ______________________
Bracing/anchorage: ______________________

Roof signs: ____

Parapet walls: [ ] None
[ ] Unreinforced masonry
[ ] Reinforced masonry
[ ] Other Type: ______________________

```
                      [ ] Unbraced
                      [ ] Braced

   Overhanging walls: ______________________________________

           Chimneys:  Height above roof: ____________________
                               Material: ____________________
                      Anchorage/bracing: ____________________

           Pounding:  ______________________________________

         FOUNDATION:

               Type:  [ ] Strip footings
                      [ ] Isolated footings
                      [ ] Mat foundation
                      [ ] Piles
                          [ ] Wood
                          [ ] Steel
                          [ ] Concrete
                      [ ] Caissons
                      [ ] Other   Type: _____________________


SOIL TYPE/CONDITION:  [ ] Rock or firm alluvium or well-
                          engineered man-made fill
                      [ ] Soft alluvium
                      [ ] Poor (natural or man-made)
                          Remarks: __________________________
                                   __________________________
```

CRITICAL FACILITIES
BUILDING STRUCTURE EARTHQUAKE VULNERABILITY RATING FORM

BUILDING: ________________________________ CLASS PML = ______

MODIFICATION FACTOR = [1.0 + (SUM OF MODIFIERS)/100] . . . ______

BUILDING PML = (CLASS PML)*(MODIFICATION FACTOR) . . . . . ______

MODIFIERS:

1. Occupancy type . . . . ______

(1) Office, Habitational, Hospital, Laboratory, School
[ ] (-5) Low damageability
[ ] (0) Average damageability
[ ] (+5) High damageability

(2) Mercantile, Restaurant, Church
[ ] (-10)
[ ] (-5)
[ ] (0)

(3) Manufacturing, Warehousing, Parking structure, Stadium
[ ] (-15)
[ ] (-10)
[ ] (0)

2. Walls. . . . . ______

A. Exterior walls

(1) Concrete, poured or precast
(2) Masonry, reinforced solid or hollow
(3) Metal
(4) Glass
(5) Stucco on studs
[ ] (-5)
[ ] (0)
[ ] (+5)
(6) Masonry, unreinforced solid
[ ] (0)
[ ] (+5)
[ ] (+10)
(7) Masonry, unreinforced hollow
[ ] (0)
[ ] (+10)
[ ] (+20)

B. Interior walls and partitions

(1) Concrete, poured or precast
(2) Masonry, reinforced solid or hollow
(3) Plaster or gypsumboard on metal or wood studs
[ ] (-5)
[ ] (0)
[ ] (+5)
(4) Masonry, unreinforced solid or hollow
(5) Tile, hollow clay
[ ] (0)
[ ] (+5)
[ ] (+10)

3. Diaphragms . . . . ______

A. Floors

(1) Concrete, poured
(2) Metal deck with concrete fill
(3) Metal
[ ] (-5)
[ ] (0)
[ ] (+5)
(4) Concrete, precast
(5) Wood: maximum ratio LEQ 2:1 w/ length LEQ 150'
[ ] (0)
[ ] (+5)
[ ] (+10)
(6) Wood: maximum ratio GTR 2:1
[ ] (0)
[ ] (+10)
[ ] (+20)

B. Roof (Null modifier when building GTR 5 stories)

(1) Concrete, poured
(2) Metal deck with concrete fill
(3) Metal
[ ] (-5)
[ ] (0)
[ ] (+5)
(4) Concrete, precast
(5) Wood or gypsum: maximum ratio LEQ 2:1 w/ length LEQ 150'
[ ] (0)
[ ] (+5)
[ ] (+10)
(6) Wood or gypsum: maximum ratio GTR 2:1
[ ] (0)
[ ] (+10)
[ ] (+20)

C. Purlin anchors lacking (+10)

```
4. Ornamentation. . . . . . . . . . . . . . . . . ______

   A. Exterior
         [ ] (      -5)
         [ ] (       0)
         [ ] ( +5,+10)

   B. Interior (includes ceilings and floor covers)
         [ ] (      -5)
         [ ] (       0)
         [ ] ( +5,+10)

5. Mechanical and Electrical Systems. . . . . . . ______

         [ ] (-10, -5)
         [ ] (       0)
         [ ] ( +5,+10)

6. Unusual Conditions . . . . . . . . . . . . . . ______

         Include previous earthquake damage and repairs

         [ ] (-10, -5)
         [ ] (      +5)
         [ ] (+10,+25)

7. Hazardous exposures  . . . . . . . . . . . . . ______

      "Average" means "No exposure"

   A. Roof tanks
         [ ] Null
         [ ] (       0)
         [ ] (     +25)

   B. Roof signs and overhanging walls
         [ ] Null
         [ ] (       0)
         [ ] ( +5,+10)

   C. Founding of adjacent buildings
         [ ] Null
         [ ] (       0)
         [ ] (      +5)

8. Site dependent hazards . . . . . . . . . . . . ______

   A. Foundation materials
         [ ] (  0)  Rock or firm alluvium or
                    well-engineered man-made
                    fill
         [ ] (+10)  Soft alluvium
         [ ] (+25)  Poor (natural or man-made)

                               SUM OF MODIFIERS: ______
```

PRELIMINARY SCREENING
(PRE INSPECTION DATA)

BUILDING NO. 55 INSPECTED BY SAF DATE 1/15/86

DESCRIPTIVE TITLE (Current Use) HOSPITAL BUILDING

CLASSIFICATION ESSENTIAL

AVAILABILITY OF DESIGN DATA DRAWINGS AND CALCULATIONS ARE AVAILABLE

BUILDING DATA:

Number of Stories 3

Height 35' Plan (Show Dimensions) 48' x 192'

CONSTRUCTION:

Structural System Structural Steel Frame

Roof METAL DECK WITH LIGHTWEIGHT FILL

Intermediate Floors METAL DECK WITH CONC. FILL

Ground Floors SLAB ON GRADE

Foundations

Interior Walls

Exterior Walls

LATERAL FORCE RESISTING SYSTEM DMRSF TRANSV. BRACED FRAME LONGIT.

EVALUATION:

General Condition

Earthquake Damage Potential

DAMAGE OBSERVED:

COMMENTS:

APPENDIX B

DETERMINATION OF BASIC STRUCTURAL HAZARD SCORES AND MODIFIERS

This Appendix presents the derivation of the Basic Structural Hazard score and discusses modifications to account for building specific problems and to extend this score to areas outside of California. Sample calculations of probabilities of damage and resulting Basic Structural Hazard scores are included for several building types. A summary of Basic Structural Hazard scores for all structural types and for all regions is found in Table B1.

B.1 Determination of Structural Score S

The Basic Structural Hazard (BSH) is defined for a type or class of building as the negative of the logarithm (base 10) of the probability of damage (D) exceeding 60 percent of building value for a specified NEHRP Effective Peak Acceleration (EPA) loading (reflecting seismic hazard) as:

$$\mathrm{BSH} = -\log_{10}[\Pr(D \geq 60\%)] \qquad \text{(B1a)}$$

The BSH is a generic score for a type or class of building, and is modified for a specific building by Performance Modification Factors (PMFs) specific to that building, to arrive at a Structural Score, S. That is,

$$\mathrm{BSH} \pm \mathrm{PMF} = \mathrm{S} \qquad \text{(B1b)}$$

where the

$$\text{Structural Score } S = \log_{10}[\Pr(D \geq 60\%)] \qquad \text{(B1c)}$$

is the measure of the probability or likelihood of damage being greater than 60 percent of building value for the *specific* building.

Sixty percent damage was selected as the generally accepted threshold of major damage, the point at about which many structures are demolished rather than repaired (i.e., structures damaged to 60 percent of their value are often a "total loss"), and the approximate lower bound at which there begins to be a significant potential for building collapse (and hence a significant life safety threat). Value is used as defined in ATC-13 (ATC, 1985), which may be taken to mean replacement value for the building.

The determination of the probability of damage exceeding 60 percent for a class of buildings or structures for a given ground motion defined in terms of Modified Mercalli Intensity (MMI), Peak Ground Acceleration (PGA) or Effective Peak Ground Acceleration is a difficult task for which insufficient data or methods presently exist. In order to fill this gap, earthquake engineering expert opinion was elicited in a structured manner in the ATC-13 project, as to the likelihood of various levels of damage given a specified level of ground motion (ATC, 1985).

The Basic Structural Hazard scores herein were developed from earthquake damage related information, using damage factors (DF) from ATC-13 (ATC, 1985), wherein damage factor is defined as the ratio of dollar loss to replacement value. It is assumed in ATC-13 that, depending on the building class, both modern code and older non-code buildings may be included, and that the damage data are applicable to buildings throughout the state of California. Inasmuch as ATC-13 was intended for large scale economic studies and not for studies of individual structures, damage factors apply to "average" buildings in each class. ATC-13 damage factors were chosen as the

Table B1: Basic Structural Hazard Scores for all Building Classes and NEHRP Areas

	Building Identifier	Seismic Area (NEHRP MAP AREAS) low (1,2)	moderate (3,4)	high (5,6,7)
W	WOOD FRAME	8.5	6.0	4.5
S1	STEEL MRF	3.5	4.0	4.5
S2	BRACED STEEL FRAME	2.5	3.0	3.0
S3	LIGHT METAL	6.5	6.0	5.5
S4	STEEL FRAME W/CONCRETE SW	4.5	4.0	3.5
C1	RC MRF	4.0	3.0	2.0
C2	RCSW NO MRF	4.0	3.5	3.0
C3/S5	URM INFILL	3.0	2.0	1.5
PC1	TILT-UP	3.5	3.5	2.0
PC2	PC FRAME	2.5	2.0	1.5
RM	REINFORCED MASONRY	4.0	3.5	3.0
URM	UNREINFORCED MASONRY	2.5	2.0	1.0

basis for the handbook scores because, at the present time, this is the most complete and systematically compiled source of earthquake damage related information available. Appendix G of ATC-13 contains summaries of experts' opinions of DFs for 78 facility classes (designed in California) due to 6 different levels of input motion. Each ATC-13 expert was asked to provide a low, best and high estimate of the damage factor at Modified Mercalli Intensities VI through XII. The low and high estimates were defined to be the 90% probability bounds of the damage factor distribution. The best estimate was defined for the experts as the DF most likely to be observed for a given MMI and facility class (Appendix E and equation 7.10, ATC-13). This relationship is illustrated in Figure B1.

To incorporate the inherent variability in structural response due to earthquake input and variations in building design and construction, the DF is treated as a random variable—that is, it is recognized that there is uncertainty in the DF, for a given ground motion. This uncertainty is due to a number of factors including variation of structural properties within the category of structure under consideration and variation in ground motion. In ATC-13, DF uncertainty about the mean was examined and found to be acceptably modeled by a Beta distribution although differences between the Beta, lognormal and normal probabilities were very small (see for example ATC-13, Fig. 7.9). For convenience herein, the lognormal rather than Beta distribution was chosen to represent the DF. The lognormal distribution offers the advantage of easier calculation using well-known polynomial approximations. Ideally a truncated lognormal distribution should be used to account for the fact that the DF can be no larger than 100. In the worst case this would have only changed the resulting hazard score by 5%. It should be noted that the lognormal distribution was the ATC-21 subcontractor's preference, and the Beta or other probability distributions could be used in developing structural scores.

For specified building classes (as defined in ATC-13) and for load levels ranging from MMI VI to XII, parameters of damage probability distributions were estimated from the "weighted statistics of the damage factor" given in Appendix G of ATC-13. Weights based on experience level and confidence of the experts were factored into the mean values of the low, best and high estimates (ML, MB, MH) found in that Appendix. For the development of hazard scores, the mean low and mean high estimates of the DF were taken as the 90% probability bounds on the damage factor distribution. The mean best estimate was interpreted as the median DF. Major damage was defined as a DF > .60 (greater than 60 percent damage).

For any lognormally distributed random variable, X, a related random variable, Y=ln(X), is normally distributed. The normal distribution is characterized by two parameters, its mean and standard deviation. The mean value of the normal distribution, m, can be equated to the median value of the lognormal distribution, x_m, by

$$m = \ln(x_m) \tag{B2}$$

(Ang and Tang, 1975). Thus if it is assumed that the DF is lognormally distributed with the median = MB, the ln(DF) is normally distributed with mean m=ln(MB). The additional information needed to find the standard deviation, s, is provided by knowing that 90% of the probability distribution lies between ML and MH. Thus approximately 95% of the distribution is below the MH damage factor. From tables of the cumulative standard normal distribution, F(x), where x is the standard normal variate defined by $x=(y-m)/s$, it can be seen that F(x=1.64)=0.95. Therefore $(y-m)/s = 1.64$, where in this case y=ln(MH). The standard deviation may then be calculated from $s= (\ln(MH)-m)/1.64$. A similar calculation could be performed using the ML and the 5% cutoff. An average of these two values results in the following equation:

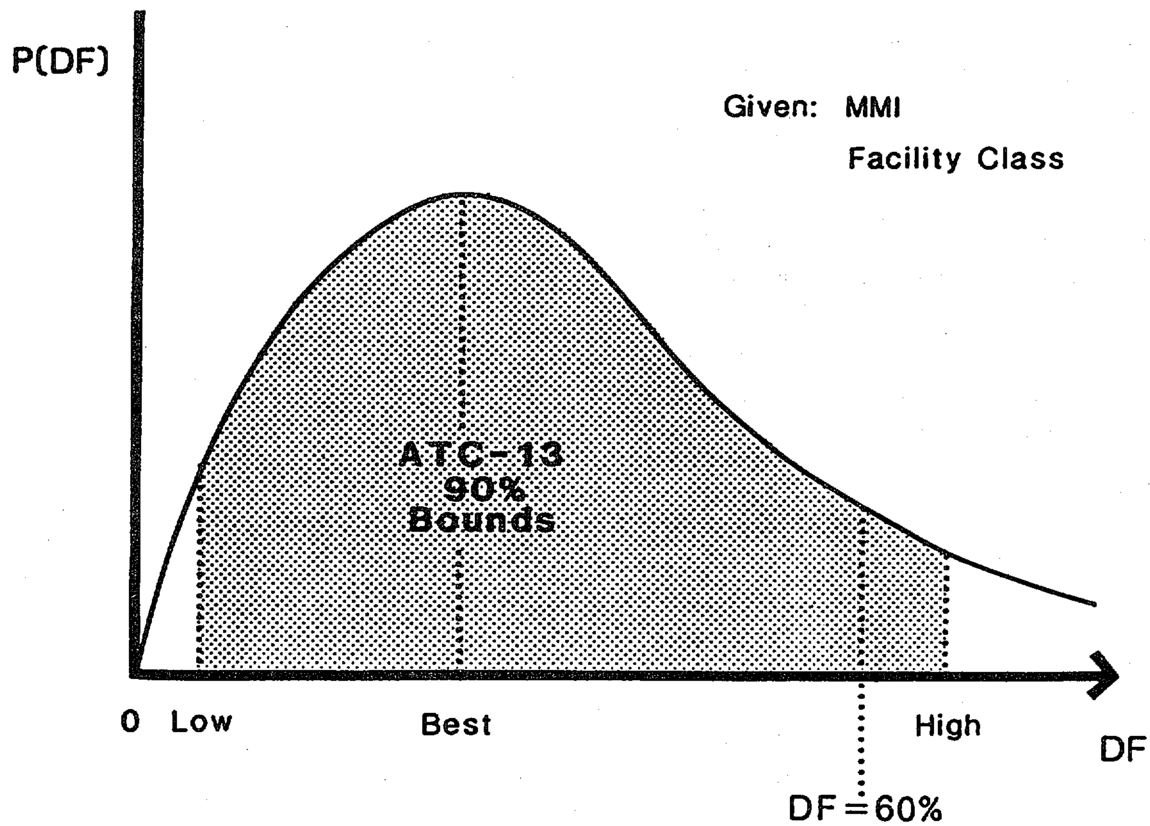

P(DF)
Given: MMI
Facility Class
ATC-13
90%
Bounds
0
Low
Best
High
DF
DF = 60%

Figure B1

$$s = (\ln(MH)-\ln(ML))/3.28 \qquad \text{(B3)}$$

A FORTRAN program was used to calculate the parameters *m* and *s* for various ATC-13 facility classes and all MMI levels.

To estimate probabilities of exceeding a 60% DF for various NEHRP areas, MMI was converted to EPA according to:

$$PGA = 10^{(MMI-1)/3} \qquad \text{(B4)}$$

where PGA is in gals (cm/sec^2), and

$$EPA = .75\ PGA \qquad \text{(B5)}$$

Equation B4 is a modification of the standard conversion given in Richter (1958) to arrive at PGA at the mid-point of the MMI value (rather than at the threshold, as given by Richter). Equation B5 is an approximate conversion (N. C. Donovan, personal communication). Only MMI VI to IX were considered, as this is the equivalent range of EPA under consideration in NEHRP Areas 1 to 7.

It was found that large uncertainty in DF for MMI VI and sometimes VII could lead to inconsistencies in the calculated probabilities of damage. To smooth these inconsistencies, $\log_{10}(s)$ was regressed against $\log_{10}$(EPA). The standard deviations of the damage probability distributions for various EPA levels were calculated from the resulting regression.

Once the parameters of the normal distribution were found, the probability of the DF being greater than 60%, Q, was calculated from the following polynomial approximation of the normal distribution (NBS 55, 1964). For the derivation of structural hazard scores, the standard variate $x = (\ln(60)-m)/s$:

$$Q(x) = Z(x)[b_1t+b_2t^2+b_3t^3+b_4t^4+b_5t^5] \qquad \text{(B6)}$$

where

$$Z(x) = (2\pi)^{-.5}*\exp(-x^2/2) \quad \text{and} \quad t = 1/(1+px)$$

and the constants are

$$b_1 = .319381530 \qquad b_2 = -.356563782$$
$$b_3 = 1.781477937 \qquad b_4 = -1.821255978$$
$$b_5 = 1.330274429 \qquad p = .2316419$$

The resulting values of $\log_{10}(Q)$ (i.e. $\log_{10}[Pr(D >= 60\%)]$) corresponded to initial values of the Basic Structural Hazard score defined in Equation B1. These Structural Hazard scores are presented in Table B2 under NEHRP Map Area 7. These scores for the ATC-13 building classification were then used to determine the scores for the building classifications of ATC-14 (ATC, 1987), which are also employed here in ATC-21 (see left column, Table B1). In many cases, the correspondence of ATC-13 and ATC-14 is one-to-one (e.g., light metal). In some cases, several building types of ATC-13 correspond to one in ATC-14, and were therefore averaged to determine the ATC-21 score. In a few instances, due to inconsistencies still remaining despite the smoothing discussed above, these initial Basic Structural Hazard scores were adjusted on the basis of judgment, by consensus of the Project Engineering Panel. In order to extend the Structural Hazard scores for buildings constructed according to California building practices (which was all that ATC-13 considered) to other NEHRP Map Areas, two factors must be incorporated in the determination of the Structural Hazard score:

1. The seismic environment (i.e., lower EPA values) for NEHRP Map Areas 1 through 6 must be considered.
2. Buildings constructed in places other than the high seismicity portions of California, which probably have not been designed for the same seismic loadings and with the same seismic detailing as in California, must be considered. This latter aspect is termed the "non-California building" factor.

Table B2: Structural Hazard Score Values After Modification for Non-California Buildings (prior to rounding)
(Follows ATC-13 (ATC, 1985) building classifications)

EPA (g)	.05	.05	.10	.15	.20	.30	.40	LOW	MOD	HIGH
NEHRP Area	1	2	3	4	5	6	7	1,2	3,4	5,6,7
WOOD FRAME -LR	8.3	8.3	6.5	5.6	5.3	4.7	4.0	8.5	6.0	4.5
LIGHT METAL	6.6	6.6	6.4	5.8	5.5	5.3	5.7	6.5	6.0	5.5
URM - LR	3.1	3.1	2.0	2.0	1.7	1.4	1.2	3.0	2.0	1.5
URM - MR	2.5	2.5	1.9	1.5	1.3	1.1	1.0	2.5	1.5	1.0
TILT UP	4.8	4.8	4.9	3.1	2.9	1.9	2.4	5.0	3.5	2.0
BR STL FRAME - LR	3.2	3.2	3.7	3.1	3.4	3.0	3.1	3.0	3.5	3.0
BR STL FRAME - MR	2.1	2.1	2.7	2.3	2.8	2.6	2.9	2.0	2.5	3.0
BR STL FRAME - HR	2.3	2.3	2.6	1.9	2.3	1.9	2.0	2.5	2.5	2.0
STL PERIM. MRF - LR	4.3	4.3	5.4	4.7	4.9	5.5	5.4	4.5	5.0	5.5
STL PERIM. MRF - MR	3.7	3.7	4.5	3.7	3.8	4.1	3.9	3.5	4.0	4.0
STL PERIM. MRF - HR	3.6	3.6	3.5	2.7	2.6	2.7	2.4	3.5	3.0	2.5
STL DISTRIB MRF - LR	3.1	3.1	3.8	3.5	3.8	4.4	4.5	3.0	3.5	4.5
STL DISTRIB MRF - MR	3.0	3.0	3.8	3.3	3.5	3.8	3.7	3.0	3.5	4.0
STL DISTRIB MRF - HR	3.0	3.0	3.4	2.8	2.8	2.8	2.5	3.0	3.0	2.5
RCSW NO MRF - LR	5.4	5.4	5.4	3.9	4.6	4.0	3.5	5.5	4.5	4.0
RCSW NO MRF - MR	4.6	4.6	4.1	2.7	3.4	2.9	2.5	4.5	3.5	2.5
RCSW NO MRF - HR	3.5	3.5	3.2	2.1	2.5	2.1	1.8	3.5	2.5	2.0
URM INFILL - LR	2.8	2.8	2.1	1.6	1.3	1.2	1.1	3.0	1.5	1.0
URM INFILL - MR	2.5	2.5	1.7	1.2	1.1	1.1	1.1	2.5	1.5	1.0
URM INFILL - HR	2.3	2.3	1.5	1.1	1.0	1.0	1.1	2.5	1.0	1.0
ND RC MRF - LR	4.2	4.2	4.2	2.4	2.9	2.7	2.2	4.0	3.0	2.5
ND RC MRF - MR	3.9	3.9	3.7	2.3	2.2	2.0	1.7	4.0	2.5	2.0
ND RC MRF - HR	3.4	3.4	3.5	2.1	2.2	2.1	1.8	3.5	2.5	2.0
D RC MRF - LR	7.6	7.6	8.7	6.6	7.0	6.5	5.7	7.5	7.5	6.0
D RC MRF - MR	5.0	5.0	6.3	4.8	5.4	5.4	4.9	5.0	5.5	5.0
D RC MRF - HR	5.7	5.7	5.9	4.0	4.3	3.8	3.2	5.5	4.5	3.5
PC FRAME - LR	3.0	3.0	3.8	2.3	2.0	1.4	1.6	3.0	2.5	1.5
PC FRAME - MR	1.8	1.8	2.2	1.7	2.2	1.8	1.2	2.0	2.0	1.5
PC FRAME - HR	1.6	1.6	2.3	1.4	1.7	1.4	1.0	1.5	2.0	1.0
RM SW W/O MRF - LR	3.9	3.9	5.4	4.5	4.1	3.5	2.9	4.0	4.5	3.0
RM SW W/O MRF - MR	3.4	3.4	4.3	3.4	3.1	2.6	2.2	3.5	3.5	2.5
RM SW W/O MRF - HR	2.7	2.7	3.4	2.6	2.3	1.9	1.7	2.5	3.0	2.0
RM SW W/ MRF - LR	4.0	4.0	5.8	5.0	4.7	4.1	3.6	4.0	5.0	4.0
RM SW W/ MRF - MR	5.7	5.7	7.6	5.8	5.1	3.9	3.1	5.5	6.0	3.5
RM SW W/ MRF - HR	5.9	5.9	8.1	6.2	5.5	4.3	3.4	6.0	6.5	4.0
LONG SPAN	4.2	4.2	3.9	3.2	3.3	3.5	3.2	4.0	3.5	3.5

With regard to the first of these factors, to facilitate calculating the final Structural Hazard scores for the EPA loadings in NEHRP Areas 1 through 6, $\log_{10}[\log_{10}$(Structural Hazard Score)] was regressed against EPA and scores were calculated from the resulting regression. These values represent the values for a "California building" (i.e., designed and built according to standard California seismic practices) in a different NEHRP Map Area. The extension of the scoring system to structures outside of California (i.e., "non-California buildings") is discussed below.

B.2 Extension to Non-California Building Construction

Due to the nature of data compiled in ATC-13, the above Structural Hazard scores are appropriate for "average" buildings designed and built in California, subjected to seismic loadings appropriate for NEHRP Map Area 7. In regions where building practices differ significantly from California (i.e., NEHRP Map Area 7) building practices, the Structural Hazard score should be modified. It would be expected that in regions where seismic loading does not control the design, this would lead to an increase in the value of the Structural Hazard score.

An example of this "non-California building" effect might be a reinforced masonry (RM) building in NEHRP Map Area 3, where local building codes typically may not have required any design for seismic loading until recently, if at all. This is not to say that buildings in NEHRP Map Area have no lateral load (and hence seismic) capacity. Design for wind loads would provide some lateral load capacity, although lack of special details might result in relatively little ductility. However, interior masonry partitions (e.g., interior walls built of concrete masonry units, CMU) might typically be unreinforced, with ungrouted cells, for example. Although the building structure could thus be fairly classified as RM, failure and probable collapse of most of the interior walls would be a major life-safety hazard, as well as resulting in major property damage. Although the exterior walls are reinforced, they will likely lack details required in UBC Seismic Zones 3 and 4, and thus will likely have less ductility. Therefore, the Structural Hazard score in NEHRP Map Area 3 for this building type should be lower than it would be for a "California" building, if the seismic loading were the same. Given that the seismic loading in NEHRP Map Area 3 is less than in most of California, the actual resulting score may be higher or lower, depending on the seismic capacity/demand ratio.

Some building types, on the other hand, such as older unreinforced masonry (URM) may be no different in California than in most other parts of the United States, so that the seismic capacity is the same in many NEHRP areas. Since the seismic loading is less for most non-California map areas (e.g., NEHRP Map Areas 1, 2, 3), the seismic capacity/demand ratio increases for these type of buildings for NEHRP Map Areas 1, 2, 3. Similarly, building types whose seismic capacity is the same will have higher Basic Structural Hazard scores in the lower seismicity NEHRP Map Areas.

Quantification of the change in Structural Hazard score due to variations in regional seismicity can be treated in a rather straightforward manner, as outlined above. Changes in the Structural Hazard score due to variations in local design or building practices, as discussed above, however, is difficult because seismic experience for these regions is less, and expert opinion data similar to ATC-13 did not exist for non-California buildings. In the course of the development of the *ATC-21 Handbook* therefore, expert opinion was sought in order to extend the ATC-13 information to non-California building construction. Information was sought in a structured manner from experienced engineers in NEHRP Areas 1 to 6, asking them to compare the performance of specific building types in their regions to

California-designed buildings of the same type. After reviewing and comparing the responses, a composite of all responses for a region was sent to the experts, who were then asked, based on these composite results, for their final estimate of the seismic performance for each building type for their region.

Generally, for the same level of loading, the experts expected higher damage for buildings in their regions than for similar structures built in California, as might be expected. For a given NEHRP Map Area, although there was substantial scatter in these experts' responses, in most cases the responses could be interpreted such that the non-California building DF could be considered to differ by a constant multiple from the corresponding "California building" DF. That is, responses from all experts in each region were averaged and used to estimate the modification constant for each building type.

These modification constants (MC), presented in Table B3, were used to change the value of the mean best estimate from ATC-13 (MB) to a best estimate for each NEHRP Map Area (BENA) according to the following equation:

$$BENA = MC*MB \tag{B7}$$

Keeping the standard deviation constant (as calculated in equation B3) and using the best estimate of the DF (BENA) from equation B7, Structural Hazard scores were calculated for each region using the methodology described in Section B.1. These structural scores are presented in Table B2, for each NEHRP Map Area.

Because the derived scores were based on expert opinion, and involved several approximations as discussed above, it was felt that the precision inherent in the Structural Hazard scores only warranted expressing these values to the nearest 0.5 (i.e., all were rounded to the nearest one half: .3 rounded to .5, 1.2 to 1.0 and so on). A comparison of scores for low rise (1 to 3 stories) and medium rise (4 to 7 stories) structures after rounding showed little or no difference for most building classes. Therefore, these values (before rounding) were averaged for low- and medium-rise buildings. This value, appropriate for low- and medium-rise buildings, is designated as the Basic Structural Hazard score. For high-rise construction (8+ stories), this is modified by a high-rise Performance Modification Factor (PMF). This high-rise PMF is a function of building class and was calculated by subtracting the Basic Structural Hazard score for low- and mid-rise buildings from that determined for high-rise buildings.

Lastly, a comparison of scores for different NEHRP Map Areas revealed very little difference of Structural Hazard scores for certain levels of seismicity. The scoring process was therefore simplified by grouping high, moderate, and low seismicity NEHRP areas together as follows:

Seismicity	NEHRP Areas
High	5, 6, 7
Moderate	3, 4
Low	1, 2

B.3 Sample Calculation of Basic Structural Hazard Scores

A sample calculation is presented here for ATC-13 facility class 1 (wood frame), based on data taken from Appendix G in ATC-13 (ATC, 1985), shown in Table B4. Although ATC-13 provided data for MMI VI to XII, the data for MMI greater than X do not correspond to the NEHRP Map effective peak accelerations. Therefore they were not included in developing the scores for this Rapid Screening Procedure (RSP).

Table B3: ATC-21 Round 2 Damage Factor Modification Constants

Structure Type	NEHRP Map Area 1,2	3	4	5	6
Wood Frame	1.0	1.3	1.3	1.2	1.0
Steel Moment Resisting Frame (S1)	1.9	1.2	1.4	1.3	1.0
Steel Frame with Steel Bracing or Concrete Shear Walls	1.9	1.2	1.4	1.1	1.1
Light Metal	1.1	1.1	1.3	1.3	1.2
Steel Frame or Concrete Frame with Unreinforced Masonry Infill Walls	1.2	1.2	1.3	1.3	1.2
Concrete Moment Resisting Frame	2.2	1.3	1.5	1.2	1.0
Concrete Shear Wall	1.7	1.3	1.5	1.1	1.0
Tilt-up (PC1)	2.0	1.2	1.5	1.3	1.4
Precast Concrete Frames	2.9	1.1	1.8	1.2	1.3
Reinforced Masonry (RM)	2.9	1.1	1.3	1.1	1.0
Unreinforced Masonry	1.1	1.2	1.0	1.0	1.0

The mean and standard deviation of the Normal distribution are calculated from equations B2 and B3 with the results shown in Table B5.

A regression of $\log_{10}(s)$ versus $\log_{10}(\text{EPA})$ yields the following equation:

$$\log_{10}(s) = -0.409 - 0.192*\log_{10}(\text{EPA})$$

Using values of s obtained from the above equation and the polynomial approximation of the normal distribution given in Equation B6, probabilities of exceeding 60 percent damage were calculated for EPA values of .35 and lower. The resulting probabilities and hazard scores are shown in Table B6.

Finally $\log_{10}[\log_{10}(\text{BSH})]$ was regressed against EPA resulting in the following equation:

$$\log_{10}[\log_{10}(\text{BSH})] = -0.0101 - 0.532*\text{EPA}$$

Values of the Basic Structural Hazard score for California buildings calculated from the above equation for specified EPA are shown below:

EPA(g)	BSH
0.05	8.30
0.10	7.32
0.15	6.50
0.20	5.82
0.30	4.75
0.40	3.97

BSH = 3.97 corresponding to an EPA of 0.4g is the score for NEHRP Map Area 7. To calculate BSH for other NEHRP Map Areas the same process must be used with the modified mean damage factor described in Section B.2. For wood-frame structures the modification constants developed from the questionnaires are:

NEHRP Map Area	1	2	3	4	5	6
Modification Constant	1	1	1.3	1.3	1.2	1

Using these constants, the modified median damage factors for NEHRP Map Area 3, for example, are (see Equation B7):

MMI	VI	VII	VIII	IX
Median DF	1.0	1.9	5.9	11.5

Repeating the same procedure using the natural log of these median DF to calculate the mean of the normal distribution and the same standard deviations shown above, the Structural Hazard score is calculated for each NEHRP Map Area. The final values for the example given here (wood-frame buildings), before and after rounding to the nearest half, are shown in Table B7 for this example of wood buildings and in Table B2 for all building types.

Finally, because there appeared to be little variation between some NEHRP Map Areas, these were grouped together into three areas, with corresponding BSH values (see Table B1). For the example of wood-frame buildings, resulting values are:

	NEHRP Map Areas	BSH
LOW	1, 2	8.5
MODERATE	3, 4	6.0
HIGH	5, 6, 7	4.5

Table B4

MMI	PGA (g)	EPA (g)	Damage Factor (%) Mean Low (ML)	Mean Best (MB)	Mean High (MH)
VI	0.05	0.04	0.2	0.8	2.6
VII	0.10	0.08	0.7	1.5	4.8
VIII	0.22	0.16	1.8	4.7	11.0
IX	0.47	0.35	4.5	9.2	19.7

Table B5

EPA (g)	ln (ML)	ln (MH)	*s* (std. dev.)	*m* (mean=ln{MB})
0.04	-1.609	0.956	0.782	-0.223
0.08	-0.356	1.569	0.587	0.405
0.16	0.588	2.398	0.552	1.548
0.35	1.504	2.981	0.450	2.219

Table B6

EPA	$Pr(D \geq 60)$	BSH
0.04	2.69×10^{-9}	8.57
0.08	3.80×10^{-9}	8.42
0.16	1.91×10^{-6}	5.72
0.35	4.07×10^{-5}	4.39

Table B7

NEHRP	EPA (g)	Final Values	BSH
1	0.05	8.3	8.5
2	0.05	8.3	8.5
3	0.10	6.45	6.50
4	0.15	5.6	5.5
5	0.20	5.26	5.5
6	0.30	4.75	5.0
7	0.40	3.97	4.0

The final resulting values of Basic Structural Hazard score presented in Table B1 are intended for use nationwide. However, local building officials may feel that building practice in their community differs significantly from the conditions typified by the Modification Constants (MCs) in Table B3. The computer source code and data employed for this study is therefore furnished (Figure B2) so that alternative MCs may be employed to generate BSH scores based on an alternative set of MCs. An alternative computation might be conducted, for example, if a community in NEHRP Map Area 5 (e.g., Memphis, TN) felt that the MCs for Map Area 4 were more appropriate. Example resulting BSH scores would then be:

Wood	5.0
Light Metal	5.5
URM	1.5
Tilt-up	2.5

Note that if non-standard BSH scores are thus computed, PMFs should be reevaluated. In most cases, however, the BSH scores in Table B1 should be appropriate.

The interpretation of these values is rather straightforward—a value of 8.5 in Low seismicity areas indicates that on average wood-frame buildings, when subjected to EPA of 0.05g, have a probability of sustaining major damage (i.e., damage greater than 60 percent of their replacement value) of $10^{-8.5}$. In High seismicity areas, where the EPA is 0.3g to 0.4g, the probability of sustaining major damage is $10^{-4.5}$.

Thus, BSH has a straightforward interpretation: if BSH is 1, the probability of major damage is 1 in 10, if BSH is 2, the probability of major damage is 1 in 100, if BSH is 3, the probability of major damage is 1 in 1000, and so on.

It should be noted that BSH as defined and used here is similar to the structural reliability index, Beta (Hasofer and Lind, 1974), which can be thought of as the standard variate of the probability of failure (if the basic variables are normally distributed, which is often a good approximation). For values of BSH between about 0 and 5 (typically the range of interest herein), Beta and BSH are approximately equal. Further, it should be noted that research into the Beta values inherent in present building codes (NBS 577, 1980) indicates that Beta (or BSH) values of 3 for gravity loads and about 1.75 for earthquake loads are typical.

B.4 Performance Modification Factors

There are a number of factors that can modify the seismic performance of a structure causing the performance of an individual building to differ from the average. These factors basically are related to significant deviations from the normal structural practice or conditions, or have to do with the effects of soil amplification on the expected ground motion.

Deviations from the normal structural practice or conditions, in the case of wood frame buildings for example, can include deterioration of the basic wood material, due to pests (e.g., termites) or rot, or basic structural layout, such as unbraced cripple walls or lack of bolting of the wood structure to the foundation. The number and variety of such performance modification factors, for all types of buildings, is very large, and many of these cannot be detected from the street on the basis of a rapid visual inspection. Because of this, based on querying of experts and checklists from ATC-14, a limited number of the most significant factors were identified. Factors considered for this RSP were limited to those having an especially severe impact on seismic performance. Those that could not be readily observed from the street were eliminated. The performance modification factors were assigned values, based on judgment, such that when

```
C THIS PROGRAM FINDS THE STRUCTURAL SCORES FOR THE ATC21 HANDBOOK
C USING DATA FROM ATC13
C A LOGNORMAL DISTRIBUTION FOR DAMAGE IS ASSUMED
C T. Anagnos and C. Scawthorn 1987,1988
C----------------------------------------------------
C
C
     dimension x(10),y(10),epa(7)
     open(5,file='atcs.dat',status='old')
     open(6,file='outputcs',status='old')
     data epa /.05,.05,.1,.15,.2,.3,.4/
     write(6,200) (epa(i),i=1,7)
     write(6,210) (i,i=1,7)
200  format('EPA',17x,7(f5.2),'    LOW  MOD  HIGH       M2
H2')
 210  format('NEHRP Area            ',7(i5))
 202     FORMAT (' ')
         WRITE (6,202)
      read(5,*) ntype
      do 1 i=1,ntype
         call dfread
 1    continue
      end
c----------------------------------------------------
subroutine dfread
dimension pga(7),s(7),p(7),stvar(7),sigma(7),x(7),y(7)
DIMENSION dmodfy(7),dbest(7),sfinal(7), bldg(10)
      real lnlow(7),lnbest(7),lnhigh(7),epa(10)
      read(5,100) (bldg(i),i=1,6)
100   format(6a4)
c READ MODIFICATION FACTORS FOR EACH NEHRP AREA
      read(5,*) (dmodfy(j),j=1,7)
C CONVERT MMI TO PGA
      do 2 i=1,7
        read(5,*) xmmi,dlow,dbest(i),dhigh
        pga(i)=10**(((xmmi+0.5)/3.)-0.5)/981.
        lnlow(i)=alog(dlow)
      lnhigh(i)=alog(dhigh)
 2    continue
      do 50 nehrp=1,7
      do 7 i=1,7
      temp=dbest(i)/dmodfy(nehrp)
      if (temp.gt.100.) temp=100.
        lnbest(i)=alog(temp)
        x(i)=alog10(pga(i))
 7    continue
      do 3 i=1,7
 3    continue
 201  format(' ',4(f10.5,1x))
C COMPUTE STANDARD DEVIATION OF THE LOGNORMAL DISTRIBUTION
      do 4 i=1,7
        sigma(i)=(lnhigh(i)-lnlow(i))/3.28
        y(i)=alog10(sigma(i))
 4    continue
```

Figure B2

```
     FORTRAN PROGRAM NEHRP.FOR
     PAGE 2

C REGRESS LOG(SIGMA) AGAINST LOG(PGA)
      n=7
      call regres(x,y,n,a,b)
 202  format(' a=',f8.3,'b= ',f8.3)
C COMPUTE PROBABILITIES OF EXCEEDANCE USING AN APPROXIMATION
C OF THE LOGNORMAL DISTRIBUTION
C STVAR = STANDARD VARIATE
      c1=.31938153
      c2=-.356563782
      c3=1.781477937
      c4=-1.821255978
      c5=1.330274429
      do 5 i=1,7
      stvar(i)=(alog(60.)-lnbest(i))/10**(a+b*x(i))
      t=1./(1.+stvar(i)*0.2316419)
c Approximation is invalid for large negative standard
c variates
      if(stvar(i).lt.-3.) p(i)=1.0
      if(stvar(i).lt.-3.) goto 8
      ctot=c1*t+c2*t**2+c3*t**3+c4*t**4+c5*t**5
      p(i)=exp(-.5*stvar(i)**2)/sqrt(6.283185308)*ctot
C ACCOUNT FOR ROUND OFF ERROR IN THE APPROXIMATION
 8     continue
      if(p(i).gt.1.0) p(i)=1.0
      if(p(i).lt.0.0) p(i)=0.0
C CALCULATE THE STRUCTURAL SCORE "S"
       s(i)=-1.*alog10(p(i))
 5    continue
C FIND WHERE STRUCTURAL SCORE BECOMES NEGATIVE
        marker=0
      do 6 j=1,4
      temp=alog10(s(j))
       if(temp.le.0.0) marker=j
       if (temp.le.0.0) goto 10
       y(j)=alog10(temp)
 6     continue
       goto 11
 10    continue
 11    continue
       n=4
       if(marker.ne.0) n=marker-1
C REGRESS LOG(S) AGAINST PGA
      call regress(pga,y,n,ascor,bscor)
       call finscr(ascor,bscor,nehrp,score)
       sfinal(nehrp)=score
 510   format(' a=',f10.3,'b= ',f10.3)
 204   format(' x=',f8.5,'p=',f8.5,'s=',f8.5)
 50    continue
       xl=.5*nint((sfinal(1)+sfinal(2))/(2*.5))
       xm=.5*nint((sfinal(3)+sfinal(4)+sfinal(5))/(3*.5))
       xh=.5*nint((sfinal(6)+sfinal(7))/(2*.5))
       xm2=.5*nint((sfinal(3)+sfinal(4))/(2*.5))
       xh2=.5*nint((sfinal(5)+sfinal(6)+sfinal(7))/(3*.5))
200   format(' ',10a4)
```

Figure B2

```
     FORTRAN PROGRAM NEHRP.FOR
     PAGE 3

210  format(' ',5A4,7(f5.1),3x,3f5.1,3x,2f5.1)
     write(6,210)
     (bldg(i),i=1,5),(sfinal(i),i=1,7),xl,xm,xh,xm2,xh2
     return
     end
c------------------------------------------------------------
c SUBROUTINE TO CALCULATE THE FINAL SCORE FOR EA NEHRP AREA
c------------------------------------------------------------
      subroutine finscr(a,b,narea,score)
      dimension epa(7),s(7)
      data epa/.05,.05,.1,.15,.2,.3,.4/
      do 1 i=1,7
       s(i)=10**(10**(a+b*epa(i)*4/3))
   1  continue
      score=s(narea)
 200  format(' nehrp area',7(i5,1x))
 210  format(' score     ',7(f5.2,1x))
      return
       end
c-----------------------------------------------
C SUBROUTINE TO PERFORM LINEAR REGRESSION AND PROVIDE THE
C RESULTING CONSTANTS
C-----------------------------------------------
      subroutine regres(x,y,n,a,b)
      dimension x(10),y(10)
 500 format(' x',10f10.6)
 501 format(' y',10f10.6)
      sumx=0.0
      sumxy=0.0
      sumy=0.0
      sumx2=0.0
      do 1 i=1,n
      sumx=sumx+x(i)
      sumx2=sumx2+x(i)**2
      sumy=sumy+y(i)
      sumxy=sumxy+x(i)*y(i)
 1    continue
      b=(sumxy-sumx*sumy/n)/(sumx2-sumx*sumx/n)
      a=(sumy-b*sumx)/n
      return
      end
```

Figure B2

```
36
WOOD FRAME - LR
1 1 .8 .8 .87 1 1
 6  0.20  0.80  2.60
 7  0.70  1.50  4.80
 8  1.80  4.70 11.00
 9  4.50  9.20 19.70
10  8.80 19.80 39.70
11 14.40 24.40 47.30
12 23.70 37.30 61.30
LIGHT METAL
.9 .9 .9 .8 .77 .83 1
 6  0.01  0.40  1.60
 7  0.50  1.10  2.70
 8  0.90  2.10  5.70
 9  2.10  5.60 10.50
10  6.00 12.90 23.50
11  9.80 22.30 34.40
12 17.60 31.30 44.00
URM - LR
.9 .9 .82 1 1 1 1
 6  0.90  3.10  7.50
 7  3.30 10.10 26.40
 8  8.90 22.50 48.50
 9 22.10 41.60 74.90
10 41.90 64.60 93.60
11 57.20 78.30 97.30
12 72.70 89.60 100.0
URM - MR
.9 .9 .82 1 1 1 1
 6  1.20  4.60 10.90
 7  2.60 11.40 31.30
 8 12.70 28.80 55.00
 9 28.80 51.40 77.30
10 45.80 71.70 94.80
11 62.00 83.00 98.30
12 74.90 91.10 100.0
TILT UP
.5 .5 .85 .68 .77 .7 1
 6  0.40  1.50  4.20
 7  1.80  4.20  9.60
 8  4.00 10.60 18.20
 9  9.10 18.50 31.60
10 15.20 28.70 49.20
11 25.60 45.00 69.40
12 35.60 62.50 80.20
BR STL FRAME -LR
.53 .53 .85 .7 .91 .87 1
 6  0.01  0.60  2.40
 7  0.40  1.80  5.00
 8  1.20  5.10 10.30
 9  4.60 10.10 18.70
10  7.90 15.80 27.40
11 13.90 27.00 43.40
12 19.60 38.80 53.90

BR STL FRAME -MR
.53 .53 .85 .7 .91 .87 1
 6  0.01  0.80  2.90
 7  0.40  5.80  6.50
 8  2.20  7.00 13.50
 9  6.20 11.90 22.10
10 10.50 20.40 32.80
11 17.00 30.10 49.60
12 23.00 41.80 62.40
BR STL FRAME -HR
.53 .53 .85 .7 .91 .87 1
 6  0.01  0.90  4.90
 7  0.70  5.40 10.20
 8  3.90 10.20 21.80
 9 10.00 17.70 26.10
10 14.40 22.80 40.30
11 20.60 37.80 61.20
12 27.60 50.50 77.50
STL PERIM. MRF -LR
.5 .5 .85 .7 .8 1 1
 6  0.01  0.70  2.20
 7  0.50  1.70  3.90
 8  2.00  3.80  7.90
 9  3.70  7.20 11.50
10  6.90 13.90 20.90
11 10.10 22.20 32.20
12 16.80 31.40 44.10
STL PERIM. MRF -MR
.5 .5 .85 .7 .8 1 1
 6  0.01  0.70  2.50
 7  0.70  2.10  5.10
 8  1.60  4.40  9.80
 9  4.30  8.90 15.80
10  8.00 15.70 24.60
11 12.00 28.20 40.30
12 17.10 36.40 51.10
STL PERIM. MRF -HR
.5 .5 .85 .7 .8 1 1
 6  0.01  0.70  3.50
 7  0.90  2.40  7.30
 8  2.30  6.20 14.20
 9  5.30 14.50 24.50
10  9.60 19.80 31.50
11 17.00 36.70 50.50
12 23.40 44.50 59.10
STL DISTRIB MRF-LR
.5 .5 .85 .7 .8 1 1
 6  0.01  0.40  1.90
 7  0.10  1.40  4.20
 8  1.10  2.90  7.60
 9  2.80  5.80 12.10
10  4.70 10.80 20.10
11  7.10 19.70 31.00
12 18.60 32.50 44.10

STL DISTRIB MRF-MR
.5 .5 .85 .7 .8 1 1
 6  0.01  0.80  2.70
 7  0.30  1.70  4.80
 8  1.50  4.30  9.60
 9  3.20  7.10 14.80
10  5.50 12.60 19.30
11  8.40 19.60 33.70
12 11.50 30.30 42.10
STL DISTRIB MRF-HR
.5 .5 .85 .7 .8 1 1
 6  0.01  0.50  2.70
 7  0.40  2.40  6.50
 8  1.70  4.90 12.70
 9  3.30  9.60 18.60
10  6.60 16.30 26.40
11  8.40 24.20 41.40
12 11.80 32.30 50.20
RCSW NO MRF - LR
.6 .6 .8 .65 .91 .97 1
 6  0.10  0.50  1.90
 7  0.80  2.80  6.30
 8  2.60  6.60 12.50
 9  5.60 13.00 22.00
10 11.50 23.60 34.10
11 20.20 35.50 51.20
12 31.30 47.60 61.90
RCSW NO MRF - MR
.6 .6 .8 .65 .91 .97 1
 6  0.20  1.00  2.80
 7  0.60  3.70  7.80
 8  3.30  8.80 16.10
 9  8.00 17.50 29.50
10 16.40 28.90 44.70
11 22.60 39.50 57.90
12 33.10 49.80 70.40
RCSW NO MRF - HR
.6 .6 .8 .65 .91 .97 1
 6  0.20  1.20  3.00
 7  1.00  5.60 10.90
 8  4.10 11.80 21.40
 9 10.50 24.80 39.00
10 26.10 37.70 57.70
11 36.90 54.00 75.00
12 48.30 67.10 88.20
URM INFILL - LR
.83 .83 .82 .78 .77 .85 1
 6  0.20  1.70  6.80
 7  1.70  5.80 18.90
 8  3.60 14.10 36.60
 9 11.60 28.50 58.40
10 21.50 44.00 79.40
11 32.60 60.20 95.40
12 47.20 76.10 99.99

URM INFILL - MR
.83 .83 .82 .78 .77 .85 1
 6  0.60  3.40 10.30
 7  1.80  8.20 23.20
 8  7.20 20.60 40.30
 9 14.50 33.60 58.80
10 25.60 47.30 80.40
11 41.60 68.00 94.80
12 60.30 80.70 99.20
URM INFILL - HR
.83 .83 .82 .78 .77 .85 1
 6  1.30  4.80 14.70
 7  2.30 11.00 28.00
 8  8.70 23.50 48.40
 9 18.70 43.90 67.40
10 33.60 56.20 89.80
11 44.80 68.90 99.99
12 60.40 76.90 99.99
ND RC MRF - LR
.45 .45 .8 .65 .83 .97 1
 6  0.20  1.30  3.60
 7  1.90  4.20 10.10
 8  5.40 12.10 21.80
 9 12.80 21.10 38.20
10 17.50 31.80 50.80
11 27.20 47.50 65.60
12 42.40 62.00 81.40
ND RC MRF - MR
.45 .45 .8 .65 .83 .97 1
 6  0.40  1.70  3.90
 7  2.50  5.10 14.80
 8  5.70 13.00 25.70
 9 13.70 26.50 45.50
10 21.40 35.70 58.00
11 33.50 51.90 74.20
12 47.80 67.40 92.60
ND RC MRF - HR
.45 .45 .8 .65 .83 .97 1
 6  0.40  1.70  3.50
 7  1.70  5.40 13.40
 8  6.00 13.30 28.00
 9 12.60 25.30 44.90
10 23.70 40.50 65.20
11 33.70 55.30 80.30
12 54.00 75.80 94.90
D RC MRF - LR
.45 .45 .8 .65 .83 .97 1
 6  0.20  0.40  1.50
 7  0.70  1.70  4.70
 8  2.10  4.10 10.40
 9  4.00  9.20 16.90
10  8.70 17.50 26.60
11 15.30 25.90 36.30
12 28.30 41.90 51.70

D RC MRF - MR
.45 .45 .8 .65 .83 .97 1
 6  0.40  1.30  3.30
 7  1.30  3.40  6.90
 8  2.30  5.80 12.60
 9  5.40 10.80 20.10
10  8.60 16.90 26.30
11 16.80 28.40 40.40
12 24.10 37.10 51.50
D RC MRF - HR
.45 .45 .8 .65 .83 .97 1
 6  0.50  1.80  3.90
 7  1.50  3.20  7.80
 8  3.10  6.90 17.50
 9  6.10 13.70 24.70
10 10.90 21.50 33.60
11 14.80 31.80 47.20
12 19.50 38.60 56.80
PC FRAME -LR
.35 .35 .9 .57 .83 .8 1
 6  0.10  1.10  4.20
 7  0.80  2.80  8.40
 8  3.20  8.00 18.90
 9 10.00 23.20 33.90
10 18.90 37.60 56.90
11 24.20 48.70 68.60
12 32.10 60.00 83.90
PC FRAME -MR
.35 .35 .9 .57 .83 .8 1
 6  .001  1.10  4.90
 7  1.10  3.40 10.10
 8  3.30  8.40 21.60
 9 10.50 27.20 34.50
10 24.20 43.10 62.90
11 29.30 53.70 78.30
12 35.70 68.70 93.70
PC FRAME - HR
.35 .35 .9 .57 .83 .8 1
 6  .001  1.10  5.00
 7  1.00  4.10  9.80
 8  3.30 10.10 24.60
 9 11.90 29.60 39.70
10 24.70 44.30 63.90
11 29.90 54.60 79.60
12 35.00 69.70 99.50
RM SW W/O MRF - LR
.35 .35 .9 .85 .91 .97 1
 6  0.20  0.80  2.30
 7  0.90  2.90  7.10
 8  2.20  6.00 14.20
 9  4.60 13.50 27.20
10 11.90 23.20 40.50
11 21.50 41.90 62.20
12 31.80 52.30 72.90

RM SW W/O MRF - MR
.35 .35 .9 .85 .91 .97 1
 6  0.20  1.20  3.20
 7  1.50  3.50  8.90
 8  2.90  9.90 20.20
 9  6.60 17.90 32.70
10 15.80 30.50 51.60
11 26.90 46.10 73.60
12 38.50 59.70 89.50
RM SW W/O MRF - HR
.35 .35 .9 .85 .91 .97 1
 6  0.30  1.20  4.00
 7  1.60  5.10 12.50
 8  3.40 13.30 25.90
 9 11.10 22.50 44.10
10 19.20 36.80 65.40
11 31.30 55.00 82.80
12 44.00 70.50 97.20
RM SW W/ MRF - LR
.35 .35 .9 .85 .91 .97 1
 6  0.10  1.00  2.40
 7  0.80  2.40  7.60
 8  3.10  5.90 12.40
 9  6.50 11.90 20.10
10 10.70 18.40 33.40
11 19.80 30.90 59.00
12 29.40 51.30 79.20
RM SW W/ MRF - MR
.35 .35 .9 .85 .91 .97 1
 6  0.60  1.40  2.90
 7  1.60  3.50  8.00
 8  3.70  8.80 16.80
 9  8.10 15.20 27.20
10 13.00 23.70 45.00
11 22.80 39.40 69.40
12 37.00 57.80 87.50
RM SW W/ MRF - HR
.35 .35 .9 .85 .91 .97 1
 6  0.80  1.60  3.20
 7  1.20  2.90  7.10
 8  3.10  7.10 14.80
 9  6.80 13.20 25.20
10 11.20 24.30 47.40
11 19.40 40.10 69.70
12 36.00 66.50 89.90
LONG SPAN
1 1 .9 .7 .83 1 1
 6  0.01  0.30  1.60
 7  0.20  1.10  5.50
 8  1.00  4.00 10.60
 9  3.60  9.00 17.20
10  7.60 16.10 33.00
11 16.00 29.70 45.90
12 27.50 45.70 62.50
```

Figure B2

added to the Basic Structural Hazard scores above, (or subtracted, depending on whether their effect was to decrease or increase the probability of major damage) the resulting modified score would approximate the probability of major damage given the presence of that factor.

The final list of performance modification factors applicable to the rapid visual screening methodology is:

Poor condition: deterioration of structural materials

Plan irregularities: buildings with reentrant corners and long narrow wings such as L, H, or E-shaped buildings

Vertical irregularities: buildings with major cantilevers, major setbacks, or other structural features that would cause a significant change in stiffness in the upper stories of the building

Soft story: structural features that would result in a major decrease in the lateral load resisting system's stiffness at one floor - typically at the ground floor due to large openings or tall stories for commercial purposes

Pounding: inadequate seismic clearance between adjacent buildings - to be applied only when adjacent building floor heights differ so that building A's floors will impact building B's columns at locations away from B's floor levels and thus weaken the columns..

Large heavy cladding: precast concrete or stone panels that might be inadequately anchored to the outside of a building and thus cause a falling hazard (only applies to buildings designed prior to the adoption of the local ordinances requiring improved seismic anchorage).

Short columns: columns designed as having a full story height but which because of wall sections or deep spandrel beams between the columns have an effective height much less than the full story height. This causes brittle failure of the columns and potential collapse.

Torsion: corner or wedge buildings or any type of building in which the lateral load resisting system is highly non-symmetric or concentrated at some distance from the center of gravity of the building.

Soil profile: soil effects were treated by employing the UBC and NEHRP classification of "standard" soil profiles SL1, SL2 and SL3, where SL1 is rock, or stable soil deposits of sands, gravels or stiff clays less than 200 ft. in thickness; SL2 is deep cohesionless or stiff clay conditions exceeding 200 ft. in thickness; and SL3 is soft to medium stiff clays or sands, greater than 30 ft. in thickness. Present building code practice is to apply an increase in lateral load of 20% for SL2 profiles and 50% for SL3 profiles, over the basic design lateral load. This approach was used herein, and these factors were applied to the EPA for each NEHRP Map Area to determine the impact on the Basic Structural Hazard score. It was determined that this impact could generally be accounted for by a PMF of 0.3 for SL2 profiles, and 0.6 for SL3 profiles. Further, to account for resonance type effects, based on judgment the 0.6 PMF for SL3 profiles was increased to 0.8 if the building in questions was 8 to 20 stories in height.

Benchmark Year: year in which modern seismic design revisions were enforced by the local jurisdiction. Buildings built after this year are assumed to be seismically adequate unless exhibiting a major defect as discussed above.

Unbraced parapets, overhangs, chimneys and other non-structural falling hazards, while potentially posing life safety problems, do not cause structural collapse and therefore have not been assigned performance modifiers. Similarly, weak masonry foundations, unbraced cripple walls and houses not bolted to their foundations will cause significant structural damage but will probably not lead to structural collapse. Therefore the data collection form contains a section where this type of information may be noted, and the owner notified.

It was also determined that certain building types were not significantly affected by some of the factors. Therefore the modifiers do not apply to all building types. The actual values of the PMFs, specific to each NEHRP Map Area, may be seen on the data collection forms, Figures B3a,b,c.

ATC-21/ (NEHRP Map Areas 1,2 Low)

Rapid Visual Screening of Seismically Hazardous Buildings

Scale:

Address ______________________________

______________________ Zip __________

Other Identifiers ______________________

No. Stories ____________ Year Built ________

Inspector ______________ Date ________

Total Floor Area (sq. ft) ________________

Building Name __________________________

Use ____________________________________

(Peel-off label)

INSTANT PHOTO

OCCUPANCY

	No. Persons
Residential	0–10
Commercial	11–100
Office	100+
Industrial	
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

* = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	**8.5**	**3.5**	**2.5**	**6.5**	**4.5**	**4.0**	**4.0**	**3.0**	**3.5**	**2.5**	**4.0**	**2.5**
High Rise	N/A	0	0	N/A	-0.5	-0.5	-0.5	-0.5	N/A	-1.0	-1.5	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-1.0	-0.5	-1.0
Soft Story	-1.0	-2.0	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-1.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8

FINAL SCORE

COMMENTS

ATC15LOW
30032.01

Detailed Evaluation Required?

YES NO

Figure B3a

ATC-21/ (NEHRP Map Areas 3,4, Moderate)

Rapid Visual Screening of Seismically Hazardous Buildings

Scale:

Address ______________________ Zip______

Other Identifiers______________________

No. Stories ____________ Year Built ________

Inspector ______________ Date ________

Total Floor Area (sq. ft)______________________

Building Name______________________

Use______________________

(Peel-off label)

INSTANT PHOTO

OCCUPANCY	
Residential	No. Persons
Commercial	0–10
Office	11–100
Industrial	100+
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

* = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	**6.0**	**4.0**	**3.0**	**6.0**	**4.0**	**3.0**	**3.5**	**2.0**	**3.5**	**2.0**	**3.5**	**2.0**
High Rise	N/A	-1.0	-0.5	N/A	-1.0	-0.5	-1.0	-1.0	N/A	0	-0.5	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-1.0	-0.5	-1.0
Soft Story	-1.0	-2.0	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-1.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8

FINAL SCORE

COMMENTS

ATC21MOD
30003.01

Detailed Evaluation Required?

YES NO

Figure B3b

ATC-21/ (NEHRP Map Areas 5,6,7 High)

Rapid Visual Screening of Seismically Hazardous Buildings

Scale:

Address ______________________

______________________ Zip ______

Other Identifiers ______________________

No. Stories ____________ Year Built ____________

Inspector ____________ Date ____________

Total Floor Area (sq. ft) ______________________

Building Name ______________________

Use ______________________

(Peel-off label)

INSTANT PHOTO

OCCUPANCY

	No. Persons
Residential	0–10
Commercial	11–100
Office	100+
Industrial	
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

* = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	**4.5**	**4.5**	**3.0**	**5.5**	**3.5**	**2.0**	**3.0**	**1.5**	**2.0**	**1.5**	**3.0**	**1.0**
High Rise	N/A	-2.0	-1.0	N/A	-1.0	-1.0	-1.0	-0.5	N/A	-0.5	-1.0	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5
Soft Story	-1.0	-2.5	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-2.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8
FINAL SCORE												

COMMENTS

ATC87H
30092.01

Detailed Evaluation Required?

YES NO

Figure B3c

REFERENCES

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APPENDIX C

CRITERIA FOR SELECTION OF A CUT-OFF SCORE

Because the final Structural Score S can be directly related to the probability of major damage, the field survey building S scores can be employed in an approximate cost-benefit analysis of costs of detailed review versus benefits of increased seismic safety, as a guide for selection of a cut-off S appropriate for a particular jurisdiction.

As a preliminary guide to an appropriate cut-off value of S, note that an S of 1 indicates a probability of major damage of 1 in 10, given the occurrence of ground motions equivalent to the Effective Peak Acceleration (EPA) for the particular NEHRP Map Area. S =2 corresponds to a probability of 1 in 100, S =3 is 1 in 1000, and so on.

As a simple example, take a jurisdiction with a population of 10,000 and a corresponding building inventory of 3,000 wood frame houses and 100 tilt-up, 100 LR URM, and 10 mid-rise steel-framed buildings. Assume the jurisdiction is in NEHRP Map Area 6, and the Basic Structural Hazard scores of Appendix B, High seismic area, apply. Assume for the example that no penalties apply (in actuality, the penalties of course would discriminate the good structures from the bad). The building inventories, probabilities of major damage and corresponding mean number of buildings sustaining major damage are shown in Table C1.

Table C1

Type	No. Bldgs.	S	Prob. Major Damage	Expected No. Bldgs. With Major Damage
Wood	3,000	4.5	1/31,600	Approx. 0
Tilt-up	100	2.0	1/100	Approx. 1
URM	100	1.0	1/10	Approx. 10
Br. Steel Fr.	100	3.0	1/1000	Approx. 0

Given these results, this example jurisdiction might decide that a cut-off S of between 1 and 2 is appropriate. A jurisdiction ten times larger (i.e., 100,000 population, everything else in proportion) in the same Map Area might decide that the potential life loss in a steel-framed mid-rise (1,000 mid-rise buildings instead of 10) warrants the cut-off S being between 2 and 3. Different cut-off S values for different building or occupancy types might be warranted.

Ideally, each community should engage in some consideration of the costs and benefits of seismic safety, and decide what S is an appropriate "cut-off" for their situation. Because this is not always possible, the observation that research has indicated (NBS, 1980; see references in Appendix B) that:

> "In selecting the target reliability it was decided, after carefully examining the resulting reliability indices for the many design situations, that β = 3 is a

representative average value for many frequently used structural elements when they are subjected to gravity loading, while $\beta = 2.5$ and $\beta = 1.75$ are representative values for loads which include wind and earthquake, respectively".

(where β, the structural reliability index, as used in the National Bureau of Standards study, is approximately equivalent to S as used herein) is provided.

That is, present design practice is such that an S of about 3 is appropriate for day-to-day loadings, and a value of about 2 or somewhat less is appropriate for infrequent but possible earthquake loadings.

It is possible that communities may decide to assign a higher cut-off score for more important structures such as hospitals, fire and police stations and other buildings housing emergency services. However, social function has not been discussed in the development of the scoring system for this RSP. This will be addressed in a future FEMA publication tentatively entitled "Handbook for Establishing Priorities for Seismic Retrofit of Buildings." Until and unless a community considers the cost-benefit aspects of seismic safety for itself, a preliminary value to use in an RSP, would be an S of about 2.0.

APPENDIX D

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APPENDIX E

ATC PROJECT AND REPORT INFORMATION

One of the primary purposes of Applied Technology Council is to develop resource documents that translate and summarize research information into forms useful to practicing engineers. This includes the development of guidelines and manuals, as well as the development of research recommendations for specific areas determined by the profession. ATC is not a code development organization, although several of the ATC project reports serve as resource documents for the development of codes, standards and specifications.

A brief description of several major completed and ongoing projects is given in the following section. Funding for projects is obtained from government agencies and tax-deductible contributions from the private sector.

ATC-1: This project resulted in five papers which were published as part of *Building Practices for Disaster Mitigation*, Building Science Series 46, proceedings of a workshop sponsored by the National Science Foundation (NSF) and the National Bureau of Standards (NBS). Available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22151, as NTIS report No. COM-73-50188.

ATC-2: The report, *An Evaluation of a Response Spectrum Approach to Seismic Design of Buildings*, was funded by NSF and NBS and was conducted as part of the Cooperative Federal Program in Building Practices for Disaster Mitigation. Available through the ATC office. (270 pages)

> *Abstract*: This study evaluated the applicability and cost of the response spectrum approach to seismic analysis and design that was proposed by various segments of the engineering profession. Specific building designs, design procedures and parameter values were evaluated for future application. Eleven existing buildings of varying dimensions were redesigned according to the procedures.

ATC-3: The report, *Tentative Provisions for the Development of Seismic Regulations for Buildings* (ATC-3-06), was funded by NSF and NBS. The second printing of this report, which included proposed amendments, is available through the ATC office. (505 pages plus proposed amendments)

> *Abstract*: The tentative provisions in this document represent the result of a concerted effort by a multidisciplinary team of 85 nationally recognized experts in earthquake engineering. The project involved representation from all sections of the United States and had wide review by affected building industry and regulatory groups. The provisions embodied several new concepts that were significant departures from existing seismic design provisions. The second printing of this document contains proposed amendments prepared by a joint committee of the Building Seismic Safety Council (BSSC) and the NBS; the proposed amendments were published separately by BSSC and NBS in 1982.

ATC-3-2: The project, *Comparative Test Designs of Buildings Using ATC-3-06 Tentative Provisions*, was funded by NSF. The project consisted of a study to develop and plan a program for making comparative test designs of the ATC-3-06 Tentative Provisions. The project report was written to be used by the Building Seismic Safety Council in its refinement of the ATC-3-06 Tentative Provisions.

ATC-3-4: The report, *Redesign of Three Multistory Buildings: A Comparison Using ATC-3-06 and 1982 Uniform Building Code Design Provisions*, was published under a grant from NSF. Available through the ATC office (112 pages)

Abstract: This report evaluates the cost and technical impact of using the 1978 ATC-3-06 report, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, as amended by a joint committee of the Building Seismic Safety Council and the National Bureau of Standards in 1982. The evaluations are based on studies of three existing California buildings redesigned in accordance with the ATC-3-06 Tentative Provisions and the 1982 Uniform Building Code. Included in the report are recommendations to code implementing bodies.

ATC-3-5: This project, *Assistance for First Phase of ATC-3-06 Trail Design Program Being Conducted by the Building Seismic Safety Council*, was funded by the Building Seismic Safety Council and provided the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the first phase of its Trial Design Program. The first phase provided for trial designs conducted for buildings in Los Angeles, Seattle, Phoenix, and Memphis.

ATC-3-6: This project, *Assistance for Second Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council*, was funded by the Building Seismic Safety Council and provided the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the second phase of its Trial Design Program. The second phase provided for trial designs conducted for buildings in New York, Chicago, St. Louis, Charleston, and Fort Worth.

ATC-4: The report, *A Methodology for Seismic Design and Construction of Single-Family Dwellings*, was published under a contract with the Department of Housing and Urban Development (HUD). Available through HUD. 451 7th Street S.W., Washington, DC 20410, as Report No. HUD-PDR-248-1. (576 pages)

Abstract: This report presents the results of an in-depth effort to develop design and construction details for single-family residences that minimize the potential economic loss and life-loss risk associated with earthquakes. The report: (1) discusses the ways structures behave when subjected to seismic forces, (2) sets forth suggested design criteria for conventional layouts of dwellings constructed with conventional materials, (3) presents construction details that do not require the designer to perform analytical calculations, (4) suggests procedures for efficient plan-checking, and (5) presents recommendations including details and schedules for use in the field by construction personnel and building inspectors.

ATC-4-1: The report, *The Home Builders Guide for Earthquake Design* (June 1980), was published under a contract with HUD. Available through the ATC office. (57 pages)

Abstract: This report is a 57-page abridged version of the ATC-4 report. The concise, easily understood text of the Guide is supplemented with illustrations and 46 construction details. The details are provided to ensure that houses contain structural features which are properly positioned, dimensioned and constructed to resist earthquake forces. A brief description is included on how earthquake forces impact on houses and some precautionary constraints are given with respect to site selection and architectural designs.

ATC-5: The report, *Guidelines for Seismic*

Design and Construction of Single-Story Masonry Dwellings in Seismic Zone 2, was developed under a contract with HUD. Available through the ATC office.

Abstract: The report offers a concise methodology for the earthquake design and construction of single-story masonry dwellings in Seismic Zone 2 of the United States, as defined by the 1973 Uniform Building Code. The guidelines are based in part on shaking table tests of masonry construction conducted at the University of California at Berkeley Earthquake Engineering Research Center. The report is written in simple language and includes basic house plans, wall evaluations, detail drawings, and material specifications.

ATC-6: The report, *Seismic Design Guidelines for Highway Bridges*, was published under a contract with the Federal Highway Administration (FHWA). Available through the ATC office. (210 pages)

Abstract: The Guidelines are the recommendations of a team of sixteen nationally recognized experts that included consulting engineers, academics, state and federal agency representatives from throughout the United States. The Guidelines embody several new concepts that are significant departures from existing design provisions. An extensive commentary and an example demonstrating the use of the Guidelines are included. A draft of the Guidelines was used to seismically redesign 21 bridges and a summary of the redesigns is also included.

ATC-6-1: The report, *Proceedings of a Workshop on Earthquake Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (625 pages)

Abstract: The report includes 23 state-of-the-art and state-of-practice papers on earthquake resistance of highway bridges. Seven of the twenty-three papers were authored by participants from Japan, New Zealand and Portugal. The Proceedings also contain recommendations for future research that were developed by the 45 workshop participants.

ATC-6-2: The report, *Seismic Retrofitting Guidelines for Highway Bridges*, was published under a contract with FHWA. Available through the ATC office. (220 pages)

Abstract: The Guidelines are the recommendations of a team of thirteen nationally recognized experts that included consulting engineers, academics, state highway engineers, and federal agency representatives. The Guidelines, applicable for use in all parts of the U.S., include a preliminary screening procedure, methods for evaluating an existing bridge in detail, and potential retrofitting measures for the most common seismic deficiencies. Also included are special design requirements for various retrofitting measures.

ATC-7: The report, *Guidelines for the Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (190 pages)

Abstract: Guidelines are presented for designing roof and floor systems so these can function as horizontal diaphragms in a lateral force resisting system. Analytical procedures, connection details and design examples are included in the Guidelines.

ATC-7-1: The report, *Proceedings of a Workshop on Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (302 pages)

Abstract: The report includes seven papers on state-of-the practice and two papers on recent research. Also included are recommendations for future research that were developed by the 35 participants.

ATC-8: This project, *Workshop on the Design of Prefabricated Concrete Buildings for Earthquake Loads*, was funded by NSF. Project report available through the ATC office. (400 pages)

Abstract: The report includes eighteen state-of-the-art papers and six summary papers. Also included are recommendations for future research that were developed by the 43 workshop participants.

ATC-9: The report, *An Evaluation of the Imperial County Services Building Earthquake Response and Associated Damage*, was published under a grant from NSF. Available through the ATC Office. (231 pages)

Abstract: The report presents the results of an in-depth evaluation of the Imperial County Services Building, a 6-story reinforced concrete frame and shear wall building severely damaged by the October 15, 1979 Imperial Valley, California, earthquake. The report contains a review and evaluation of earthquake damage to the building; a review and evaluation of the seismic design; a comparison of the requirements of various building codes as they relate to the building; and conclusions and recommendations pertaining to future building code provisions and future research needs.

ATC-10: This report, *An Investigation of the Correlation Between Earthquake Ground Motion and Building Performance*, was funded by the U.S. Geological Survey. Available through the ATC office. (114 pages)

Abstract: The report contains an in-depth analytical evaluation of the ultimate or limit capacity of selected representative building framing types, a discussion of the factors affecting the seismic performance of buildings, and a summary and comparison of seismic design and seismic risk parameters currently in widespread use.

ATC-10-1: This report, *Critical Aspects of Earthquake Ground Motion and Building Damage Potential*, was co-funded by the USGS and the NSF. Available through the ATC office. (259 pages)

Abstract: This document contains 19 state-of-the-art papers on ground motion, structural response, and structural design issues presented by prominent engineers and earth scientists in an ATC seminar. The main theme of the papers is to identify the critical aspects of ground motion and building performance that should be considered in building design but currently are not. The report also contains conclusions and recommendations of working groups convened after the Seminar.

ATC-11: The report, *Seismic Resistance of Reinforced Concrete Shear Walls and Frame Joints: Implications of Recent Research for Design Engineers*, was published under a grant from NSF. Available through the ATC office. (184 pages)

Abstract: This document presents the results of an in-depth review and synthesis of research reports pertaining to cyclic loading of reinforced concrete shear walls and cyclic loading of joints in reinforced concrete frames. More than 125 research reports published since 1971 are reviewed and evaluated in this report, which was prepared via a consensus process that involved numerous experienced design professionals from throughout the U.S. The report contains reviews of current and past design practices, summaries of research developments, and in-depth discussions of design implications of recent research results.

ATC-12: This report, *Comparison of United States and New Zealand Seismic Design Practices for Highway Bridges*, was published under a grant from NSF. Available through the ATC office (270 pages).

Abstract: The report contains summaries of all aspects and innovative design procedures used in New Zealand as well as comparisons of United States and New Zealand design practice. Also included are research recommendations developed at a 3-day workshop in New Zealand attended by 16 U.S. and 35 New Zealand bridge design engineers and researchers.

ATC-12-1: This report, *Proceedings of Second Joint U.S.-New Zealand Workshop on Seismic Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office (272 pages).

Abstract: This report contains written versions of the papers presented at this 1985 Workshop as well as a list and prioritization of workshop recommendations. Included are summaries of research projects currently being conducted in both countries as well as state-of-the-practice papers on various aspects of design practice. Topics discussed include bridge design philosophy and loadings, design of columns, footings, piles, abutments and retaining structures, geotechnical aspects of foundation design, seismic analysis techniques, seismic retrofitting, case studies using base isolation, strong-motion data acquisition and interpretation, and testing of bridge components and bridge systems.

ATC-13: The report, *Earthquake Damage Evaluation Data for California*, was developed under a contract with the Federal Emergency Management Agency (FEMA). Available through the ATC office (492 pages).

Abstract: This report presents expert-opinion earthquake damage and loss estimates for existing industrial, commercial, residential, utility and transportation facilities in California. Included are damage probability matrices for 78 classes of structures and estimates of time required to restore damaged facilities to pre-earthquake usability. The report also describes the inventory information essential for estimating economic losses and the methodology used to develop the required data.

ATC-14: The report, *Evaluating the Seismic Resistance of Existing Buildings*, was developed under a grant from the National Science Foundation. Available through the ATC office (370 pages).

Abstract: This report, written for practicing structural engineers, describes a methodology for performing preliminary and detailed building seismic evaluations. The report contains a state-of-practice review; seismic loading criteria; data collection procedures; a detailed description of the building classification system; preliminary and detailed analysis procedures; and example case studies, including non-structural considerations.

ATC-15: This report, *Comparison of Seismic Design Practices in the United States and Japan*, was published under a grant from NSF. Available through the ATC office (317 pages).

Abstract: The report contains detailed technical papers describing current design practices in the United States and Japan as well as recommendations emanating from a joint U.S.-Japan workshop held in Hawaii in March, 1984. Included are detailed descriptions of new seismic design methods for buildings in Japan and case studies of the design of specific buildings (in both countries). The report also contains an overview of the history and objectives of the Japan Structural Consultants Association.

ATC-15-1: The report, *Proceedings of Second U.S.-Japan Workshop on Improvement of Building Seismic Design and Construction Practices*, was published under a grant from NSF. Available through ATC office (412 pages).

Abstract: This report contains 23 technical papers presented at this San Francisco workshop in August of 1986 by practitioners and researchers from the U.S. and Japan. Included are state-of-the-practice papers and case studies of actual building designs and information on regulatory, contractual, and licensing issues.

ATC-16: This project, *Development of a 5-Year Plan for Reducing the Earthquake Hazards Posed by Existing Nonfederal Buildings*, was funded by FEMA and was conducted by a joint venture of ATC, the Building Seismic Safety Council and the Earthquake Engineering Research Institute. The project involved a workshop in Phoenix, Arizona, where approximately 50 earthquake specialists met to identify the major tasks and goals for a 5-year plan for reducing the earthquake hazards posed by existing nonfederal buildings nationwide. The plan was developed on the basis of nine issue papers presented at the workshop and workshop working group discussions. The Workshop Proceedings and Five-Year Plan are available through the Federal Emergency Management Agency, 500 "C" Street, S. W., Washington, D.C. 20472.

ATC-17: This report, *Proceedings of a Seminar and Workshop on Base Isolation and Passive Energy Dissipation*, was published under a grant from NSF. Available through the ATC office (478 pages).

Abstract: The report contains 42 papers describing the state-of-the-art and state-of-the-practice in base-isolation and passive energy-dissipation technology. Included are papers describing case studies in the Untied States, applications and developments worldwide, recent innovations in technology development, and structural and ground motion design issues. Also included is a proposed 5-year research agenda that addresses the following specific issues: (1) strong ground motion; (2) design criteria; (3) materials, quality control, and long-term reliability; (4) life cycle cost methodology; and (5) system response.

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