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SEISMIC DAMAGE ASSESSMENT FOR HIGH-RISE BUILDINGS

ANNUAL TECHNICAL REPORT

August 1980

sponsored by the
U.S. Geological Survey
Contract No. 14-08-0001-16814

prepared by
URS/John A. Blume & Associates, Engineers
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

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130 Jessie Street (at New Montgomery)
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Project Direction	Roger E. Scholl
Internal Consultation	John A. Blume
Building Categorization	Kenneth K. Honda
Data Collection	Peter I. Yanev Cynthia L. Perry
Seismology	Jack M. Zanetti

EXECUTIVE SUMMARY

The problem considered in this project, conducted by URS/John A. Blume & Associates, Engineers (URS/Blume), for the U.S. Geological Survey, is the identification, evaluation, and correlation of ground-motion and structural parameters in order to improve procedures for predicting dollar losses for high-rise structures damaged by earthquakes. Ground-motion data bases, analytical techniques, and known motion-damage relationships already developed for high-rise buildings and for other classes of structures will be refined and extended so that reliable quantitative seismic risk evaluations can be made.

The research effort consists of three one-year phases composed of five major tasks, as follows:

Task I	Data collection
Task II	Building categorization and calculation of theoretical motion-damage relationships
Task III	Estimation of engineering intensity from seismological intensity data
Task IV	Evaluation of empirical motion-damage relationships
Task V	Correlations between theoretical and empirical motion-damage relationships

Task I was largely completed during the first year. Tasks II and III were initiated during the first year and are scheduled to be completed during the third year. Task IV was initiated in the second year and is scheduled for completion in the third year. Task V will be initiated and completed during the third year.

The objective of Task I was to establish a data base of worldwide seismic response and damage data for high-rise buildings. Only earthquakes that affected high-rise structures were selected for study. For convenience, the data collection effort was divided into the following regions: North America; Latin America; Europe and the Mediterranean; and the western Pacific, which includes Japan and New Zealand.

Five different forms were developed to systematically collect the pertinent data. Form 1 provides general earthquake data; Form 2, motion and damage data; Form 3, site information; Form 4, building categorization; and Form 5, detailed site and building information, such as test boring logs or design calculations. The collected data that are essential for the completion of the project include strong ground-motion parameters, soil characteristics, estimated damage, design parameters, building categorization, and geographical location. In addition, seismological data, construction practices, and other general information has been collected for selected areas.

A data-base system, called data base HIRISE, has been established using the information collected in the forms and computerized. The data base facilitates the access and retrieval of data in any order or arrangement desired, thus simplifying the correlation studies.

The building categorization included in Task II has been completed. Structural systems considered in this categorization are foundation systems, vertical-load-support systems, lateral-load-resisting systems, and floor systems. The most important of these are the lateral-load-resisting systems. The structural and architectural materials used in the construction of buildings are also considered. Architectural materials, although not designed specifically to resist the lateral loads, contribute in varying degrees to this resistance and are important for damage evaluation. The degree of contribution depends not only on the type of architectural material used but also on the framing characteristics of the building system. Building configuration is important because irregularity in building plan and elevation may result in torsional response. Torsional response may also occur because of eccentric location of either the building masses or the lateral-load-resisting elements. Data collection Form 4 was developed to appropriately record each of these items for the categorization of buildings.

Another facet of Task II is the establishment of theoretical motion-damage relationships. Individual buildings damaged by the San Fernando earthquake are being analyzed in detail, and damage estimation procedures based on interstory drift and ductility are being developed and tested. The Bank of California Building and two Holiday Inn buildings are currently under study. Significant progress has been realized in the analytical identification of damage threshold and in the values of various response parameters at this level of response for the buildings. High correlation has been obtained between interstory displacement and threshold damage.

The basic concepts for prescribing theoretically based motion-damage relationships have been established and are being implemented. The major work remaining is that of extracting structure component test data from the literature and documentation.

In Task III, substantial progress has been made toward relating seismological intensity to engineering intensity.* Initial results based on published data from the 1971 San Fernando, California, earthquake have been compiled, and some conclusions have been drawn. It is evident, for example, that further consideration should be given to seismological and geological factors such as distance, magnitude, and local geology; as the investigation continues, more data will be used to check the relationships among these factors. URS/Blume has acquired an extensive data base of 281 (3-channel) strong-motion records from earthquakes throughout the world; these will be used to extend the conclusions concerning relationships between engineering intensity and seismological intensity.

In Task IV, various empirically derived motion-damage relationships will be developed from data base HIRISE. The principal indicators of damage to be calculated will be the Damage Factor (DF), defined as the ratio of dollar damage to replacement value, and the Damage Ratio (DR), defined as the ratio of the number of buildings damaged to the total number of buildings in a given area. These damage parameters will be correlated with motion identified in terms of Engineering Intensity Scale (EIS) level. Finally, these empirical motion-damage relationships will be calculated for various building categorizations -- including subclasses for various types of structural and nonstructural components -- as the available data permit.

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*Engineering intensity implies a measure of ground shaking that is useful for performing engineering analyses and is readily interpretable for designing structures. A detailed description of the Engineering Intensity Scale that is used to characterize ground motion is given in Appendix D.

1. INTRODUCTION

1.1 Purpose

The problem considered in this project, which is being conducted by URS/John A. Blume & Associates, Engineers (URS/Blume), for the U.S. Geological Survey (USGS), is the identification, evaluation, and correlation of ground motion and structural parameters in order to improve procedures for predicting dollar losses in high-rise structures damaged by earthquakes. Ground motion data bases, analytical techniques, and known motion-damage relationships already developed for high-rise buildings and for other classes of structures are being refined and extended so that reliable quantitative seismic risk evaluations can be made.

1.2 Background

Several methods for predicting damage to structures due to ground vibrations have been developed and described by various investigators for such purposes as seismic design optimization, earthquake insurance considerations, predicting the effects of underground nuclear explosions on man-made structures, and earthquake hazard reduction.

One such method for estimating earthquake-induced economic losses to wood-frame dwellings in California, described by Steinbrugge et al. (1969), was developed to aid in analyzing the feasibility and effectiveness of earthquake insurance.

This method uses the modified Mercalli intensity (MMI) scale to describe the intensity of ground motion. For a given earthquake, such as the maximum credible earthquake, empirical isoseismal maps are developed. These maps consider the rupture of the fault (hence, the ellipticity of the isoseismals) and the empirical relationship between magnitude and MMI. The area enclosed within a given MMI isoseismal line is also determined from empirical data, as a function of magnitude. Because MMI is used to represent the ground motion intensity, and MMI is directly related to damage, no structural response calculation is done.

Damage to wood-frame dwellings is estimated by four components: structure, interior finish, exterior finish, and chimney. These are further subdivided to account for major variations within a component. One possible way of subdividing is by age. For each damage component, the degree of damage is described by such terms as slight, moderate, severe, and total loss.

The relationship of MMI to degree of component damage is estimated by earthquake professionals from limited available data. These MMI-damage relationships are converted into relationships of MMI to repair cost, again by estimates made by professionals.

In order to predict losses to wood-frame dwellings within a region, the region under consideration is divided into standard location areas (SLAs). For a given earthquake, MMI intensities are estimated for each SLA. Then, losses for each SLA are calculated by using the intensity-loss relationships. Characteristics of the structure population within each SLA (inventory data) are derived mainly from data from the United States Bureau of the Census.

The method is a good one for the type of building for which it is intended. The sources of information identified are of great value for similar future studies. However, the method requires a great deal of expertise that can only be provided by professionals from such diverse fields as engineering, statistics, and insurance. Also, the method cannot be applied to high-rise structures without modifications that are so extensive that they should lead to the development of a completely independent method.

Studies have been performed to improve Steinbrugge's method and to apply it to other types of structures. Rinehart et al. (1976) have performed a sensitivity analysis to determine the relative significance of various parameters with respect to losses. This analysis has led to improvements in the method.

Algermissen et al. (1978a) extended the previous work to cover buildings other than a single-family dwellings. In this study, a building inventory methodology was formally introduced. A building classification, not necessarily related to engineering design parameters, was adopted from the Insurance Services Office (ISO) system, and used in the method.

Based on their previous work, Algermissen et al. (1978b) developed a technique for rapid estimation of earthquake losses. This method entails the development of a series of maps showing contours of percent losses to specific building types for each MMI level. The method could be valuable for quick postearthquake loss estimates; however, the necessary data must be collected and processed before such an earthquake, and experts with specific understanding of the method must be available.

Another method is described by Culver et al. (1975) for survey and evaluation of existing buildings, to determine the risk to life, and to estimate the amount of expected damage. In this method, damage to both structural and nonstructural building components resulting from the extreme natural environments encountered in earthquakes, hurricanes, and tornadoes is considered. The method can treat a large class of structural types, including braced and unbraced steel frames, concrete frames with and without shear walls, bearing wall structures, and long-span roof structures. Three independent but related sets of procedures for estimating damage for each of the natural hazards are included. The first set of procedures (called the Field Evaluation Method) provides a means for qualitatively determining the damage level on the basis of data collected in field surveys. The second set (the Approximate Analytical Evaluation Method) uses a structural analysis of the building to determine the damage level as a function of the behavior of critical elements. The third set (the Detailed Analytical Evaluation Method) is based on a computer analysis of the entire structure. The procedures are presented in a format that allows updating and refining.

The Field Evaluation Method and the Approximate Analytical Evaluation Method do not estimate the extent of damage quantitatively. In the Detailed Analytical Evaluation Method, the ground motion at a site is expressed in terms of a site particle velocity spectrum, which is obtained by multiplying a hard-rock velocity spectrum by an appropriate soil amplification factor. Alternative procedures are described for obtaining the hard-rock velocity spectrum and the soil amplification factor for a given site.

A response spectrum approach with provisions for amplitude-dependent damping and stiffness characteristics is suggested for calculating the structure's response to the prescribed ground motion. The response parameters used in predicting damage are maximum floor accelerations, floor velocities, and interstory displacements. Three types of damage, namely, structural, nonstructural partition, and nonstructural window damage are related to these parameters. Structural damage and window damage are assumed to be a functions of interstory drift, whereas nonstructural partition damage is assumed to be related to the maximum floor velocity and acceleration.

The relationship between the percentage of structural damage at a given story level and the maximum drift at that level is assumed to be a normally distributed curve defined by a mean ductility to failure and an associated coefficient of variation. Ductility to failure is determined empirically, and professional judgement is exercised in selecting the proper coefficient of variation.

Nonstructural damage at a floor level is estimated by treating that level as a site on the ground subjected to an effective floor modified Mercalli intensity, I_i. I_i is empirically related to maximum floor acceleration and velocity. The relationship between I_i and the percentage of nonstructural damage to the floor is also given by an empirical formula, which includes a parameter called Quality Factor, reflecting the damageability of the specific construction type.

The relationship of story drift to glass damage is treated in a similar manner to structural damage, with a defined drift-to-failure value, an associated coefficient of variation, and assumed normal distribution.

The method attempts to relate engineering parameters to the extent of damage suffered by the components of a given structure. However, damage is expressed in percentage only and is not related to monetary loss.

An extensive program has been undertaken at Massachusetts Institute of Technology, led by R. V. Whitman, J. M. Biggs, C. A. Cornell, and E. H. Vanmarcke, to develop a method named Optimum Seismic Protection and Building Damage Statistics. The title was later changed (Whitman, 1973) to Seismic Design Decision Analysis (SDDA). To select the level of seismic resistance to be required for an individual structure or a group of structures, the SDDA considers the cost of providing increased seismic resistance, the damage that may occur during future earthquakes, and the human and social consequences of such damage.

Many studies have been performed and reports published as part of the SDDA program. A description of the program as originally conceived is given in Report No. 1 (Whitman et al., 1972). Theoretical structure response studies are reported in Reports No. 3 and No. 4 (Anagnostopoulos, 1972; Biggs and Grace, 1973). Damage data and statistics obtained from the 1971 San Fernando, California, earthquake are reported in Report No. 7 (Whitman et al., 1973). Report No. 8, by Whitman (1973), gives damage probability matrices for multistory buildings. Two reports attempt to correlate earthquake damage to tall buildings with strong ground motion parameters (Wong, 1975; Whitman et al., 1977). And in Report No. 30, Schumacker and Whitman apply the methods developed to the estimation of losses to cities and regions.

Czarnecki (1973) has developed a damage-prediction method, as part of MIT's SDDA program, that is based on engineering principles and is oriented toward high-rise building structures. In this method, the damage is related to the structural response parameters. The building can be analyzed for a given earthquake using any acceptable dynamic analysis technique, such as response spectrum analysis or linear or nonlinear time-history analysis. Total damage to a given building is classified into components. Components suggested for high-rise buildings are structural damage (damage to steel frames, concrete frames, braced frames, shear walls), nonstructural damage (damage to drywall partitions, exterior glazing, brick masonry walls, concrete block walls), and other damage. Structural damage is fully attributed to the vertical structural elements, i.e., columns, shear walls, etc., and is assumed to be proportional to the inelastic energy absorbed by that element. Nonstructural damage is associated with maximum interstory drift. Drift-damage curves are developed based on actual data and engineering design practices. No attempt is made to consider the variabilities of the parameters used in the damage prediction or of the final results.

Three distinct methods for predicting damage to structures due to large underground nuclear explosions, that are equally applicable to predicting damage due to earthquakes, have been developed and described by Blume. These three methods -- the Engineering Intensity Scale, the Spectral Matrix Method, and the Threshold Evaluation Method -- provide a means for making progressively more detailed predictions of structural effects due to seismic motions.

The Engineering Intensity Scale (EIS) method (Blume, 1970) is used to estimate the extent of the area in which structures might be damaged and to make a general evaluation of the incidence and degree of damage to structures within that area.

In the formulation of the Engineering Intensity Scale, ground motion is characterized by 5%-damped spectral velocity (S_v), and structures are characterized by their fundamental-mode vibration properties. Neglecting mode shape considerations, the important correlation variables for relating motion and damage are S_v amplitude and building period. The 5%-damping value is used because damping in many real structures varies from about 2% to 10%, and 5% has been made a standard reference level in the nuclear event structural response program conducted by URS/Blume for the Nevada Operations Office of the U.S. Department of Energy.

Engineering intensity (EI) numbers are assigned to various spectral velocity bands. The applicable range of spectral velocities (S_v) and periods (T) applicable to civil engineering structures is divided into a 10 by 9 matrix with ten intensity levels, from 0 through 9, and nine period bands, I through IX, in the period range from 0.01 sec to 10 sec.

A significant amount of data on ground motion caused by underground nuclear explosions and corresponding damage data have been available for establishing the incidence and degree of damage for various EI ranges for low-rise buildings (Hafen and Kintzer, 1977; URS/Blume, 1975). In addition, motion and damage data from the 1971 San Fernando earthquake for low-rise (Hafen and Kintzer, 1977; Scholl, 1974) and high-rise (Hafen and Kintzer, 1977; Wong, 1975) buildings are available. Motion-damage relationship information for high-rise buildings from Whitman et al. (1977) and the additional correlation work currently in process at URS/Blume will provide sufficient information for this class of buildings.

The Spectral Matrix Method (SMM) has been in continuous development and use by URS/Blume since 1966. The earliest version was presented in January 1967 (Blume, 1967). The method has subsequently been simplified and further developed (Blume, 1968; Blume and Monroe, 1971; URS/Blume, 1975).

The method is a generalized, statistical, computer-based procedure developed for the purpose of quantitatively predicting damage on a large scale. That is, the procedure is applicable to predictions involving a large number of structures, including structures of several different classes and types. A fundamental philosophy of the procedure is that both structure resistance (capacity) and ground motion (demand) are random variables, and damage prediction therefore becomes a problem of joint probabilities.

The most important element in the SMM procedure is the evaluation of the damage factor (called damage ratio by some investigators) as a function of motion amplitude. The damage factor is defined as the ratio of dollar damage for a building to the building's replacement value. Appropriate damage factor models can be obtained directly from experimental motion-damage relationship investigations or indirectly from theoretical considerations. The damage factor model in the SMM is theoretically derived. Five fundamental structure-based parameters are included in the theoretical damage factor model in order to take best advantage of available structure-element test data and thus to facilitate application of the procedure to predictions involving structures for which no empirical motion-damage relationship data exist. Specifically, for predicting building damage caused by ground motion, the method considers the following factors:

- Amplitude and frequency distribution of ground motion
- Foundation conditions
- Elastic strength, capacity, and damping of structures
- Inelastic reserve strength of structures for dissipating excess demand of communicated energy
- Probabilistic evaluation of the random variables inherent in the prediction problem

While the SMM procedure is theoretically based, it is essential that the procedure be calibrated. Substantial low-rise building motion and damage data from underground nuclear explosions (URS/Blume, 1975) and some data from earthquakes (URS/Blume, 1975; Scholl, 1974) have been used for this purpose.

The Threshold Evaluation Method (TEM, Blume, 1969) for predicting the effects of dynamic ground motion on structures involves a systematic and detailed dynamic structural analysis of individual structures. This method is used to identify both the potential risk from a structure's failure and modifications that might improve the resistance of that structure to structural failure caused by ground motion. Basically, the TEM is an extension of conventional structural analysis procedures used in design. It requires the identification of various capacity thresholds and the evaluation of the probability of exceeding these thresholds for a given seismic event. It is intended to provide detailed insight into the structural behavior of an individual building under lateral loading and to take advantage of several mitigating factors that are normally ignored in structural design practice in the interests of providing additional margins of safety.

A fundamental step in conducting a threshold evaluation analysis is to develop a mathematical model of the building. Because the TEM considers both elastic and inelastic response, it is usually desirable to develop at least two mathematical models. The frequencies and mode shapes obtained from the mathematical model are used to estimate the response spectrum demand amplitude.

A capacity threshold is defined as the total lateral load that would be required to cause a building to reach a specified level of behavior. For example, a code-required threshold is the base shear coefficient required by an applicable building code. Similarly, a yield limit threshold is the smallest base shear coefficient causing a significant structural member to reach yield stress.

With this information, the probability of exceeding the various capacity thresholds for a particular seismic response spectrum can be evaluated. The significance of a high probability of exceedance depends on the threshold and the severity of the demand spectra being considered. For example, a high probability of exceeding the yield limit or observable damage threshold for a seismic event that is likely to occur several times during the building's useful life may be an unacceptably high risk. However, for the maximum credible seismic event, it may be acceptable to exceed all thresholds except story failure.

1.3 Scope

To improve quantitative reliability and to refine earthquake damage prediction procedures for high-rise buildings, URS/Blume is conducting in this project an extensive collection and correlation analysis of worldwide seismic response and damage data for high-rise buildings, related earthquake ground motion data, intensity estimates, and structural response information. Pertinent experimental building response and damage data are being investigated as well. Empirical motion-damage relationships will be calculated, and theoretical analyses will be conducted to establish motion-damage relationships for various types of high-rise buildings. The theoretical analyses will be based on engineering fundamentals of dynamic response prediction and on available structure component damage criteria and will be used to assess and to aid in substantiating the empirically derived relationships. Finally, studies will be undertaken to correlate the assembled empirical data with the theoretically derived models of structure damage. These correlation studies will aid in establishing damage prediction reliability and in identifying future research needs.

Specifically, the research consists of three one-year phases made up of five major tasks, as follows:

Task I	Data collection.
Task II	Building categorization and calculation of theoretical motion-damage relationships.
Task III	Estimation of engineering intensity from seismological intensity data.
Task IV	Evaluation of empirical motion-damage relationships.
Task V	Correlations between theoretical and empirical motion-damage relationships.

Task I was largely completed during the first year, but data collection is continuing to make the data base more complete. Tasks II and III were initiated during the first year and are scheduled to be completed during the third year. Task IV was initiated during the second year and is scheduled to be completed during the third year. Task V will be initiated and completed during the third year. This report summarizes progress made in the first and second years.

2. BUILDING CATEGORIZATION

2.1 Introduction

As a part of the data collection effort, information about earthquake effects on buildings and the relevant characteristics of affected buildings has been collected. Once this information is evaluated, empirical motion-damage relationships can be developed.

Four major building features considered in the categorization are: structural system, structural material, architectural material, and building configuration. Each of these categories is subcategorized to identify unique features of each building. This categorization scheme is the basis for Data Collection Form 4, which is discussed in Chapter 3.

2.2 Structural System

The structural system comprises the basic elements of the building. These elements include the foundation that supports the building against the action of the vertical (gravity) load and transmits the inertial forces generated in the building by seismic action to the foundation material, the vertical-load-support system that is designed to support the vertical load of the building and to transmit the load to the foundation, the lateral-load-resisting system that transmits lateral loads such as earthquake-generated inertial forces to the foundation, and the floor system (including the roof system) that transmits both vertical and horizontal loads to the adjoining framing system.

2.2.1 Foundation. The function of the foundation is to transmit vertical and horizontal loads from the building to the soil foundation material. The type of foundation depends on the structural system and the foundation material. Wall footings distribute the wall loads to the soil foundation and are continuous along the wall. Spread footings distribute the load from individual columns. Often, as a result of space limitations or column spacing, more than one column is supported by a footing. This is referred to as a combined footing. When more than one spread footing is combined or connected by a beam, it is referred to as a strap footing. A raft or mat foundation is essentially a large combined footing: the entire foundation below the building consists of a single footing. Depending on the quality of the foundation material, it is sometimes necessary to provide additional means to support the building load. This is provided by piles or caissons. The piles are driven into the ground, and the load is transferred from a column to the piles by footings. Caissons perform functions similar to those of piles. It is possible for a building to have a combination of the foundation types described above.

2.2.2 Vertical and Horizontal Load-Support Systems. In the design of most buildings, the elements that support the vertical and horizontal loads are treated independently. For some buildings, certain elements are designed specifically to support only the gravity load or to support only the seismic load. Some elements, however, are designed to support both loads. For this reason, these two systems are discussed under one heading.

Buildings are composed of vertical and horizontal structural elements that resist internal and applied forces. The forces originating from the mass of vertical elements are transferred either directly to the ground, as in the case of vertical cantilevers, or to horizontal resisting elements other than the ground through vertical beam action of the vertical elements. The forces originating from the mass tributary to the horizontal elements are distributed by these horizontal elements to vertical elements that, in turn, transmit the forces to the ground. Vertical elements used to transfer lateral forces to the ground are moment-resisting space frames, shear walls, and braced frames.

A space frame is a three-dimensional structural system, without bearing walls, composed of interconnected members laterally supported so as to function as a complete, self-contained unit with or without the aid of horizontal diaphragms or floor-bracing systems. Horizontal forces at any floor or roof level are transmitted to the soil foundation by the strength, rigidity, and ductility of the space frame. A space frame depends on its own bending stiffness for the lateral stability of the structure. A moment-resisting space frame is a vertical-load-carrying space frame in which the members and joints are capable of resisting design lateral forces by bending moments at beam-column connections.

Walls may be subjected to both vertical and horizontal forces. A wall carrying a vertical load other than its own weight is called a bearing wall. The horizontal forces acting on a wall may be either normal to the wall or parallel to the wall. A shear wall resists horizontal forces parallel to the wall. Any wall or partition that carries a vertical load other than its own weight or that resists a horizontal force parallel to the wall is classified as a structural wall. Sometimes these walls are arranged around stairs and elevators to form a box. This system is called a shear core, and it acts to resist the seismic load not only parallel to the walls, but perpendicular to the walls as well. It can be visualized as a huge box cantilevered out of the ground.

Braced frames are sometimes used in place of shear walls to resist lateral forces. The material may be reinforced concrete, structural steel, or wood. Vertical bracing systems are used to transfer the horizontal forces at the floor or roof levels to the foundation. The function of the bracing is to resist forces that tend to deform the building in the direction parallel to the plane of that bracing and to transmit these lateral loads to the foundation.

Buildings may use both shear walls and moment-resisting space frames to resist lateral forces. The contribution of the frame to the resistance of lateral forces is that it will provide redundancy and a reserve strength against complete collapse if the shear walls should fail.

Similar to using a shear core in place of shear walls, an entire building can be constructed to act as a cantilever beam. Lateral load is resisted not only by frames or walls parallel to the load but also by the frames and walls perpendicular to the load through the interaction of these elements.

2.2.3 Floor System. Horizontal forces produced by seismic motion are proportional to the masses of building elements involved and originate at the centroid of mass of these elements. The forces originating at masses tributary to the horizontal elements are distributed by these horizontal elements to vertical elements that, in turn, transmit the forces to the ground.

Forces may also be transmitted from vertical elements to horizontal elements and then be redistributed to other vertical elements. Horizontal forces at any floor or roof level are distributed to the vertical resisting elements by mobilizing the strength and ridigity of the floor or roof deck as a diaphragm. Horizontal bracing may be used in place of diaphragms. A diaphragm may be considered analogous to a plate girder or shear wall in the horizontal (or inclined, in the case of the roof) plane; the floor or roof deck performs the function of the plate girder web, the joints or beams function as web stiffeners, and the peripheral beams or integral reinforcement functions as flanges. A diaphragm may be constructed of materials such as concrete, wood, or metal. Combinations of materials are possible.

2.3 Structural Material

The structural materials considered in building categorization are those used in the construction of the structural system. Materials used in the construction of buildings are an important part of the total evaluation since the response characteristics of the buildings are influenced not only by the structural framing systems but also by the strength and deformation characteristics of the material. Different materials also influence the possibility and the amount of damage to the buildings.

2.4 Architectural Components

Architectural components in a building include all elements of a building that are not explicitly considered in the design of the building as either vertical- or lateral-load-carrying members. These include such elements as interior partitions and exterior cladding. Although not designed specifically to resist the lateral loads, architectural components contribute in varying degrees to this resistance and are important for evaluations of damage. Their contribution depends not only on the type of architectural component used, but also on the framing characteristics of the building systems.

The damage to architectural components on a stiff shear-wall building would normally be less than the damage to these components on a flexible frame building if both buildings were subjected to an equal lateral force level. Thus, architectural component damage factors for a frame building and a shear-wall building would also differ. Regardless of the level of ground motion, the frame building would have a higher proportion of architectural damage than would the shear-wall building.

2.5 Building Configuration

Any irregularity in building response or torsional response may result in localized damage. Irregularity in response may be caused by discontinuity or a major shift in the load distribution path, construction variabilities, or nonsymmetry in configuration. Torsional response may result from marked asymmetry in stiffnesses and masses. Most building codes reflect recognition of irregularities in design configuration and require corrective action for design.

3. DATA COLLECTION AND DATA BASE MANAGEMENT

3.1 Introduction

Task I involves the collection of information about earthquakes and building damage caused by earthquakes. This information will be used as a basis for the analyses to be performed in the second and third phases of the project. Specifically, this information will be used for calculating empirical motion-damage relationships for high-rise buildings.

The principal information to be collected for developing empirical motion-damage relationships includes descriptions of: the earthquake shaking, the structure involved, and the damage incurred. This information can be collected with varying degrees of detail. Since the ultimate objective of this study is to develop both empirical and theoretical motion-damage relationships for high-rise buildings and because it is intended that the information collected be useful for any of the contemporary damage prediction procedures (see Chapter 1), it was decided that the data collection should be as comprehensive as possible. Accordingly, five data collection forms were developed to record the pertinent data. These are discussed below in Section 3.2. The earthquakes and urban areas included in the data collection effort are described in Section 3.3. To manipulate, and thus facilitate analyzing, the substantial volume of data collected, a data-base-management system has been used; this system is described in Section 3.5.

A list of the references searched thus far in collecting the data is given in Appendix A.

3.2 Data Collection Forms

Five data collection forms were designed to separate earthquake-dependent data from a general description of each high-rise building and its site. These forms are:

- Form 1: General Earthquake Data
- Form 2: Motion and Damage Data
- Form 3: Site Information
- Form 4: Building Categorization

- Form 5: Detailed Site and Building Information

The blank forms are reproduced in Figures 3.1 through 3.5.

The identification numbers placed on each form are described in Figure 3.6. The "Earthquake ID" includes an abbreviated name, the month and year of occurrence, plus a letter to indicate aftershocks. For example, ROM-03-77 identifies the main shock of the Romanian earthquake on March 4, 1977. The "Site ID" includes both a country and city designation plus four additional characters to indicate whether there is a building or ground station at the site. An uninstrumented building in Anchorage, Alaska, would have a site ID of USA-ANC-B501.

General earthquake data, such as magnitude, maximum intensity, epicentral location, and estimated damage, are given on Form 1. A separate form is used to give basic information about significant aftershocks, but generally the earthquake effects and damage estimates are combined and given for the main shock only.

Form 2 lists motion and damage data at each site for a particular earthquake. In an area of high seismicity, a given building may have sustained damage in several earthquakes, requiring a separate form for each. Only Section 2.1 of the form on motion data is relevant to ground motion stations, but all the items apply to building sites. The damage summary is divided between primary and secondary damage. Structural and architectural damage are considered primary effects; secondary effects include casualties and mechanical failure. When a detailed damage description is available, it is attached using Form 5.

General site information is given on Forms 3 and 4. For ground motion stations, only the site geology on Form 3 is required. For building sites, the geology data, as well as building design and construction data, are given on Form 3. Each building is classified according to its structural system, materials, configuration, and foundation type on Form 4. The building categorization scheme was described in Chapter 2.

Two columns are provided at the right margin of Forms 1 through 4. A check mark in the column headed "Details Attached" indicates that further details are available and are labeled with the same ID numbers and attached using Form 5. A separate reference list is used for each of the four regions discussed in Section 3.3.

3.3 Earthquakes and Urban Areas Considered

Earthquakes occur most frequently along several belts that form the interfaces between major tectonic plates. The areas of highest seismicity are along the Circum-Pacific Belt, which encircles the Pacific Ocean, and along the Alpide Belt in the Mediterranean and trans-Asiatic zone. These belts can be seen in the world seismicity map in Figure 3.7.

This investigation considered only those earthquakes that affected high-rise buildings in urban areas. Using this criterion, all the earthquakes selected were grouped into one of the following regions: North America; Latin America; the Mediterranean section of the Alpide Belt; and the western branch of the Circum-Pacific Belt, which includes Japan and New Zealand. These regions were chosen more for convenience than because of any earthquake engineering considerations.

Among the criteria used to select the earthquakes were peak ground acceleration, maximum intensity, number of high-rise buildings affected, extent of damage, and availability of information. It is difficult to quantify these criteria and establish an overall standard because the characteristics of damaging earthquakes are different in each region. The extent of damage depends on many parameters, including the design, construction, age, and condition of the affected buildings; the geological and foundation conditions; and the magnitude and duration of motion. For example, a magnitude 6.0 shock might cause extensive damage in a poorly constructed city but little or no damage in an area where the lateral force requirements are very stringent. A description of the salient features of the earthquakes selected and the specific criteria used for each region are included in the sections that follow. Table 3.1 provides a list of the earthquakes initially considered for all the regions.

3.3.1 North America. The earthquakes selected in North America all occurred in the western United States, including Hawaii. Each earthquake affected high-rise buildings in one of the following urban areas: Southern California; San Francisco Bay Area, California; Puget Sound, Washington; or Anchorage, Alaska. These regions are only loosely defined. Each may include several major cities and take in a large land area.

All of the earthquakes chosen had a Richter magnitude greater than 4.0 and an MMI of V or greater. Because of the lack of instrumental data near the epicenters or fault breaks, no specific cutoff was used for peak ground acceleration. Other criteria, such as the availability of ground motion and building response records and damage descriptions, were also used. In addition, the proximity of an earthquake to one of the four urban areas mentioned was considered. Several low-magnitude earthquakes were chosen to establish a damage threshold, while others were chosen to provide information on cumulative damage to buildings in a particular area. Each one of the earthquakes chosen adds something to the data base on high-rise building performance.

3.3.2 Latin America. Selection of Latin American earthquakes, which was based on the extent of damage and the availability of data, was largely subjective. Form 1 was completed only when sufficient information was available. No specific cutoffs were used in the selection process, but generally both the Richter magnitudes and the MMI ratings were five or greater. Lack of instrumental data and the wide variation of ground-motion periods made it impossible to establish a cutoff for peak ground acceleration. A number of the earthquakes were included just to indicate the extent of seismic activity at each site and to allow a damage comparison to be made. The quality of available data and the possibility of gathering future seismic data from existing instrumentation were also considered in the selection process.

3.3.3 Europe and the Mediterranean. The most destructive of the recent earthquakes in this region are listed in Table 3.1. Although none of these are considered great earthquakes, they have caused extensive damage and loss of life. Magnitudes are typically 6.0 or 7.0 on the Richter scale, with MMI ratings ranging from VIII to X. The shallow focus of these shocks, the extensive use of unreinforced masonry, and the poor quality of construction all contributed to the high level of damage.

3.3.4 Western Pacific Region. The earthquakes selected in the western Pacific region all occurred in either Japan or the Philippines. Most of these earthquakes were centered in the portion of the Circum-Pacific Belt that borders Japan.

The fault system near Japan is well defined because many earthquakes occur in this region. Off the coast of Honshu, the largest of the Japanese islands, the Circum-Pacific Belt branches into two distinct faults, as shown in Figure 3.8. One section branches southward toward the Marianas, and the other section stretches to the southwest through Kiushiu to Taiwan (Gutenberg and Richter, 1965). These faults outline the subduction zone where the Pacific Plate is moving under the Eurasian and Philippine plates. The fault slopes westward underneath mainland Japan at approximately 30°. Epicenters under Japan, therefore, are typically at a considerable depth. There are also two belts of deep-focus shocks. One crosses Japan transversely, and the other extends from Manchuria across southern Sakhalin into the Sea of Okhotsk.

The National Research Center for Disaster Prevention started publishing *Strong-Motion Earthquake Records in Japan* in 1960. These extensive publications provide data for a large number of earthquakes in the western Pacific region. Criteria were established to limit the earthquakes considered in this region to a workable number. Japanese earthquakes were considered if they incurred a Japanese (JMA) intensity of 5.0 or greater, with a recorded peak ground acceleration greater than or equal to 0.1g. Earthquakes in New Zealand, Taiwan, and the Philippines were considered if there was some reported damage to high-rise structures. Because of lack of published data, earthquakes in China were not considered.

3.4 Damage States

The prediction of dollar losses in high-rise structures damaged by earthquakes requires information about damage sustained by buildings that have been exposed to seismic ground motion. Normally, in the articles that deal with damage to buildings, the failure mechanisms and description of damage are reported, but seldom is the dollar value of loss or the damage ratio explicitly given. Because of this lack of information and also because of the different backgrounds and motives of those who report the damage value in buildings after an earthquake, it was considered necessary to use a simple measure of damage. Given the statistical nature of the studies, reported damage to buildings was classified according to discrete damage states.

A nonlinear scale based on previous experience was employed (Whitman, 1973). Table 3.2 shows the state, the description of damage, the central value, and the intervals covered. A graphic representation of this scale is shown in Figure 3.9.

3.5 Data Base Management

The large volume of data collected during the course of this project necessitated the use of a data-base-management system to handle the information. We chose a general-purpose data-management system (MRI SYSTEM 2000), available at the Lawrence Berkeley Laboratory. This system allows the user to define data elements and repeating groups at many different levels and to specify the hierarchical relationship of each element to the others. The data base may be readily updated and manipulated to generate statistics and summary tables or to prepare reports.

The flexibility of the MRI SYSTEM 2000 increases user efficiency and facilitates cross correlation between the many motion and damage parameters stored in the data base. The information contained in the data base can thus be applied to motion-damage relationships, seismological theories, and seismicity forecasts. As more data are obtained, the data base can be augmented and expanded as needed.

3.5.1 Data Base HIRISE: Organization and Structure. Data Base HIRISE consists of three levels. At the top of the hierarchy is a city, or more appropriately, an urban area. At the second level are three independent repeating groups describing each earthquake, each ground station or building site, and each element in the grid system used to discretize the area. additional level is used to describe the effects of each earthquake at a specific site or grid location. The basic structure of the data base is shown schematically in Figure 3.10.

Most motion and damage information appears in reports that describe the effects of one particular earthquake; we have organized this information according to the urban areas affected. The data base is thus able to indicate the seismicity of each area; to show readily the effects of cumulative damage to buildings; and to provide a historical survey of design requirements, construction practices, and structural systems, as well as the character of earthquake damage, in a given area. At present, the data base, which includes selected earthquakes from 1906 to 1979, documents damage to high-rise buildings in 26 urban centers of 12 countries. Each metropolis appears in the data base as a separate entry with the structure shown in Figure 3.10.

The most significant and reliable information on the data collection forms was selected for input to the data base. A pattern emerged indicating those parameters that were both widely reported and statistically significant for correlation studies. Some unreported items could be reasonably estimated and were added to the data base; other items were unavailable or too difficult to obtain.

The HIRISE data-base definition, shown in Figure 3.11, includes 118 elements used for storing data values. Six types of data may be stored: NAME, TEXT, INTEGER, DECIMAL, DATA, and MONEY. Where there are multiple occurrences of data values, repeating groups are used. To save memory, a NON-KEY option is available for elements that do not require frequent retrieval. Elements to be used as access criteria for retrieval are defined as KEY elements. For example, a list of rock sites can be readily generated because SITE GEOLOGY is a KEY element. A "padding" option leaves space in the data file directories for future additions. (Further details are presented in Control Data Corporation, 1976.)

The data-base system is quite versatile and can be used to perform a wide variety of operations. Examples of simple sorting operations include the the following: listing all sites for which we have tripartite response spectra that can be used directly to generate EI values; listing all buildings that suffered greater than 50% damage; listing the height, number of stories, plan dimensions, design period, and measured period for all steel, moment-resisting frame buildings. Several such sample listings are given in Appendix B.

3.5.2 Creating the Data Base. Once the structure and elements of the data base were defined, data could be transferred from the data collection forms to the data base. To simplify the coding process, many items were assigned a number or a short two- or three-letter code. For example, a collapsed building is assigned a DAMAGE STATE of 8, a rock site is specified as RK, and an unreinforced masonry building is denoted by the code UM. The link between the data collection forms and the data-base elements is shown by the codes that appear on the forms in Figures 3.12 through 3.15. To reflect the hierarchy of elements in HIRISE and to show the sequence of data entry, the forms are reordered as follows: Form 1, Form 3, Form 4, Form 2.

Several elements require explanation. The MAJOR CITY CODE was created in order to avoid repetition of the earthquake data on Form 1 in cases where more than one city or area were affected. One city is designated as the MAJOR city (CODE = 1) and all other areas are MINOR (CODE = Ø). The data on Form 1, including the summary table at the bottom, are then entered only for the major city. To avoid duplication, this information is then referenced under each minor city. If foreshocks or aftershocks have occurred, the damage is generally lumped together and attributed to the primary shock. Thus, related shocks are given a FORE/AFTERSHOCK CODE, and only the information at the top of Form 1 (Section 1.1) is entered. All damage data are included in the summary of effects for the major city and primary shock.

After HIRISE was established and the data entered, a number of lists, summaries, and tables were generated to check the data and insure their accuracy.

3.6 Summary of Data Collected

Table 3.3 summarizes the data collected. Included in the table are comments regarding additional data that will be sought. Augmenting the empirical data base will be a continuing effort throughout the project.

Appendix B gives examples of more detailed lists of the information collected. These lists are provided to show the extent of the data collected as well as the versatility of the data-base-management system.

TABLE 3.1

LIST OF EARTHQUAKES CONSIDERED

79/04/01

COUNTRY	URBAN AREA	EARTHQUAKE ID	M	DATE
***				
* GREECE	SALONICA	GRE-06-78-F1	5.75	05/24/1978
* GREECE	SALONICA	GRE-06-78	6.50	06/20/1978
* GUATEMALA	GUATEMALA	GUA-02-76	7.50	02/04/1976
* ITALY	FRUILI	ITA-05-76	6.50	05/06/1976
* JAPAN	HACHINOHE	JPN-05-68	7.90	05/16/1968
* JAPAN	HACHINOHE	JPN-05-68-A1	7.50	05/16/1968
* JAPAN	HACHINOHE	JPN-06-78		06/12/1978
* JAPAN	IZU PENINSULA	JPN-05-74	6.80	05/08/1974
* JAPAN	NIIGATA	JPN-06-64	7.50	06/06/1964
* JAPAN	SENDAI	JPN-06-78	7.40	06/12/1978
* JAPAN	TOKYO	JPN-09-23	8.30	09/01/1923
* MEXICO	MEXICO	MEX-06-11		06/07/1911
* MEXICO	MEXICO	MEX-12-37		12/23/1937
* MEXICO	MEXICO	MEX-02-43		02/22/1943
* MEXICO	MEXICO	MEX-04-44		04/15/1944
* MEXICO	MEXICO	MEX-01-51		01/05/1951
* MEXICO	MEXICO	MEX-07-57	7.50	07/28/1957
* MEXICO	MEXICO	MEX-07-57-A1	6.25	08/04/1957
* MEXICO	MEXICO	MEX-08-59	6.50	08/26/1959
* MEXICO	MEXICO	MEX-12-61	5.25	12/10/1961
* MEXICO	MEXICO	MEX-05-62	6.70	05/11/1962
* MEXICO	MEXICO	MEX-05-62-A1	6.50	05/19/1962
* MEXICO	MEXICO	MEX-07-64		07/06/1964
* MEXICO	MEXICO	MEX-12-65	6.80	12/09/1964
* MEXICO	MEXICO	MEX-08-68	6.50	08/02/1968
* MEXICO	MEXICO	MEX-08-73	7.00	08/28/1973
* MEXICO	MEXICO	MEX-11-78	7.00	11/29/1978
* MEXICO	MEXICO	MEX-14-79	7.50	03/14/1979
* MOROCCO	AGADIR	MOR-02-60	5.75	02/29/1960
* NICARAGUA	MANAGUA	MNG-01-68	4.50	01/04/1968
* NICARAGUA	MANAGUA	MNG-01-68-A1		01/18/1968
* NICARAGUA	MANAGUA	MNG-01-68-A2		01/22/1968
* NICARAGUA	MANAGUA	MNG-01-72		01/02/1972
* NICARAGUA	MANAGUA	MNG-01-72-A1		01/04/1972
* NICARAGUA	MANAGUA	MNG-01-72-A2		01/05/1972
* NICARAGUA	MANAGUA	MNG-12-72-A1	5.00	12/23/1972
* NICARAGUA	MANAGUA	MNG-12-72-A2	5.20	12/23/1972
* NICARAGUA	MANAGUA	MNG-12-72	5.60	12/23/1972
* PHILIPPINES	COTABATO	PHL-08-76	7.90	08/16/1976
* PHILIPPINES	COTABATO	PHL-08-76-A1	6.80	08/17/1976
* ROMANIA	BUCHAREST	ROM-03-77	7.20	03/04/1977
* UNITED STATES	ANCHORAGE	ALA-10-54	6.75	10/03/1954
* UNITED STATES	ANCHORAGE	ALA-03-64	8.40	03/28/1964

COUNTRY	URBAN AREA	EARTHQUAKE ID	M	DATE
***				
* UNITED STATES	BAKERSFIELD	KRN-07-52		07/21/1952
* UNITED STATES	BAKERSFIELD	KRN-08-52	5.80	08/22/1952
* UNITED STATES	BAKERSFIELD	SFD-02-71		02/09/1971
* UNITED STATES	LOS ANGELES	LBH-03-33	6.30	03/11/1933
* UNITED STATES	LOS ANGELES	TOR-11-41	5.40	11/14/1941
* UNITED STATES	LOS ANGELES	KRN-07-52	7.70	07/21/1952
* UNITED STATES	LOS ANGELES	KRN-08-52		08/22/1952
* UNITED STATES	LOS ANGELES	BOR-04-68	6.40	04/09/1968
* UNITED STATES	LOS ANGELES	LYT-09-70	5.40	09/12/1970
* UNITED STATES	LOS ANGELES	SFD-02-71	6.40	02/09/1971
* UNITED STATES	LOS ANGELES	PMG-02-73	5.90	02/21/1973
* UNITED STATES	OAKLAND	SFR-04-06		04/18/1906
* UNITED STATES	OAKLAND	JOS-09-55		09/05/1955
* UNITED STATES	OAKLAND	OAK-10-55	5.50	10/24/1955
* UNITED STATES	OAKLAND	SFR-03-57		03/22/1957
* UNITED STATES	OAKLAND	ROS-10-69		10/02/1969
* UNITED STATES	OLYMPIA	OLY-04-49	7.10	04/13/1949
* UNITED STATES	OLYMPIA	SEA-04-65		04/29/1965
* UNITED STATES	SAN FRANCISCO	SFR-04-06	8.25	04/18/1906
* UNITED STATES	SAN FRANCISCO	JOS-09-55		09/05/1955
* UNITED STATES	SAN FRANCISCO	OAK-10-55		10/24/1955
* UNITED STATES	SAN FRANCISCO	SFR-03-57	5.30	03/22/1957
* UNITED STATES	SAN FRANCISCO	ROS-10-69	5.70	10/02/1969
* UNITED STATES	SAN JOSE	SFR-04-06		04/18/1906
* UNITED STATES	SAN JOSE	JOS-09-55	5.80	09/05/1955
* UNITED STATES	SAN JOSE	OAK-10-55		10/24/1955
* UNITED STATES	SAN JOSE	SFR-03-57		03/22/1957
* UNITED STATES	SANTA BARBARA	SBA-06-25	6.30	06/29/1925
* UNITED STATES	SANTA BARBARA	SBA-06-41	5.90	07/01/1941
* UNITED STATES	SANTA BARBARA	KRN-07-52		07/21/1952
* UNITED STATES	SANTA BARBARA	KRN-08-52		08/22/1952
* UNITED STATES	SANTA BARBARA	BOR-04-68		04/09/1968
* UNITED STATES	SANTA BARBARA	SFD-02-71		02/09/1971
* UNITED STATES	SANTA BARBARA	PMG-02-73		02/21/1973
* UNITED STATES	SANTA BARBARA	SBA-08-78	5.10	08/13/1978
* UNITED STATES	SEATTLE	OLY-04-49		04/13/1949
* UNITED STATES	SEATTLE	SEA-04-65	6.50	04/29/1965
* UNITED STATES	TACOMA	OLY-04-49		04/13/1949
* UNITED STATES	TACOMA	SEA-04-65		04/29/1965
* UNITED STATES	WHITTIER	ALA-03-64		03/28/1964
* VENEZUELA	CARABELLEDA	VNZ-07-67		07/29/1967
* VENEZUELA	CARACAS	VNZ-07-67	6.50	07/29/1967
* YUGOSLAVIA	SKOPJE	YUG-07-63	6.00	07/26/1963

TABLE 3.2

EARTHQUAKE DAMAGE STATE

Damage State	Level of Damage	Damage Ratio* (%)	
		Central Value	Range
0	No damage	0.03	0 - 0.05
1	Negligible damage	0.08	0.05 - 0.14
2	Minor nonstructural damage -- a few walls and partitions cracked, incidental mechanical and electrical damage	0.24	0.14 - 0.40
3	Substantial nonstructural damage -- more extensive cracking (but still not widespread); possibly damage to elevators and other mechanical/electrical components	0.67	0.40 - 1.1
4	Major nonstructural damage (widespread) -- possibly a few beams and columns cracked, although not noticeable	2	1.1 - 3.2
5	Minor structural damage -- obvious cracking or yielding in a few structural members; substantial nonstructural damage with widespread cracking	5	3.2 - 9
6	Substantial structural damage requiring repair or replacement of some structural members; associated extensive nonstructural damage	15	9 - 25
7	Major structural damage requiring repair or replacement of many structural members; associated nonstructural damage requiring repairs to major portion of interior	45	25 - 70
8	Collapse or condemnation	100	70 -

Source: Whitman (1973)

*Ratio of cost of loss to replacement cost (called Damage Factor in this report)

TABLE 3.3

SUMMARY OF DATA COLLECTED

Country	Earthquake ID	M	Urban Area	MMI	Expected Totals		Current Data Base		Work Remaining	
					Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings
United States	SBA-06-25	6.30	Santa Barbara	IX	2	2	2	2	0	0
	LBH-03-33	6.30	Los Angeles	IX			14	12		
	SBA-06-41	5.90	Santa Barbara	VIII	2	2	2	2	0	0
	TOR-11-41	5.40	Los Angeles	VII		0	2	0		
	KRN-07-52	7.70	Bakersfield	VIII	1	1	1	1	0	0
			Los Angeles	VII			26	24		
			Santa Barbara	VII	2	2	2	2	0	0
	KRN-08-52	5.80	Bakersfield	VIII	1	1	1	1	0	0
			Los Angeles	V		0	26	0		0
			Santa Barbara	V	2	0	2	0	0	0
	BOR-04-68	6.40	Los Angeles	VI	1220	3	27	3		0
	LYT-09-70	5.40	Los Angeles		~1240	0	5	0		0
	SFD-02-71	6.30	Los Angeles	XI	~1250	256	877	256	~373	0
			Santa Barbara	VI	7	0	7	0	0	0
	PMG-02-73	5.90	Los Angeles	VII	~1270	1	2	1		0
			Santa Barbara	VII	7	0	7	0	0	0
	SBA-08-78	5.10	Santa Barbara		7	7	7	7	0	0
	SFR-04-06	8.25	San Francisco	X	~50	~50	38	38	12	12
	JOS-09-55	5.80	San Francisco	VI	856	0	856	0	0	0
	OAK-10-55	5.50	San Francisco	VI	856	2	856	2	0	0
	SFR-03-57	5.80	San Francisco	VII	865	21	865	21	0	0

TABLE 3.3 (Continued)

Country	Earthquake ID	M	Urban Area	MMI	Expected Totals		Current Data Base		Work Remaining	
					Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings
United States	OLY-04-49	7.10	Olympia	VIII	4		4	0	0	
			Seattle	VIII	191		191	0	0	
			Tacoma	VII	38		38	0	0	
	SEA-04-65	6.50	Olympia	VII	4		4	0		
			Seattle	VIII	217		217	21		
			Tacoma	VII	43		43	1		
	ALA-10-54	6.75	Anchorage	VIII	3	2	3	2	0	0
	ALA-03-64	8.40	Anchorage	XI	12	11	12	11	0	0
			Whittier		1	1	1	1	0	0

TABLE 3.3 (Continued)

Country	Earthquake ID	M	Urban Area	MMI	Expected Totals		Current Data Base		Work Remaining	
					Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings
Guatemala	GUA-02-76	7.50	Guatemala	IX	3	3	3	3	0	0
Mexico	MEX-07-57	7.50	Mexico	VIII			39	28	0	0
	MEX-08-68	6.50	Mexico	VII			8	7	0	0
	MEX-11-78	7.90	Mexico*	VII	101	46	48	22	53	24
Nicaragua	MNG-01-68	4.50	Managua	VIII	5	5	5	5	0	0
	MNG-01-72		Managua	VI	12	12	12	12	0	0
	MNG-12-72	5.60	Managua	IX	12	12	12	12	0	0
Venezuela	VNZ-07-67	6.50	Caracas†	VII	~200		24	24	~176	0
			Caraballeda	VII	5	5	5	5	0	0

*4 zones only (Appendix A, Reference MEX 13)

†Palos Grandes area only (Appendix A, Reference VNZ 6)

TABLE 3.3 (Continued)

Country	Earthquake ID	M	Urban Area	MMI	Expected Totals		Current Data Base		Work Remaining	
					Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings
Greece	GRE-06-78	6.50	Salonica	VI			5	5		
Italy	ITA-05-76	6.50	Friuli	IX	6	6	6	6	0	0
	ITA-09-76	6.10	Friuli	VIII	4	4	0	0	0	0
Morocco	MOR-02-60	5.75	Agadir	X	1	1	1	1	0	0
Romania	ROM-03-77	7.20	Bucharest	VIII (MSK)			17	17		
Yugoslavia	YUG-07-63	6.0	Skopje	IX	17	17	17	17	0	0

TABLE 3.3 (Continued)

Country	Earthquake ID	M	Urban Area	MMI	Expected Totals		Current Data Base		Work Remaining	
					Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings	Number of Buildings	Number of Damaged Buildings
Japan	JPN-09-23	8.30	Tokyo	IX (RF)			9	9		
	JPN-06-64	7.50	Niigata	VIII			11	7		
	JPN-06-78	7.40	Sendai	5.5 (JMA)	141	135	3	2	138	133

Earthquake ID: ____________ By: ______ Date ______

FORM 1: GENERAL EARTHQUAKE DATA

	DETAILS ATTACHED	REFERENCE

1.1 EARTHQUAKE

1.1.1 Earthquake Name: ____________

1.1.2 Date: ____________

1.1.3 Origin Time: Local ____________ GMT ____________

1.1.4 Latitude: ____________ Longitude: ____________

1.1.5 Depth (km): ____________

1.1.6 Magnitude: M_L ________ M_s ________ M_b ________

1.1.7 Type of Faulting: ____________

1.1.8 Length of Surface Faulting (km): ____________

1.1.9 ID of Significant Aftershocks (see separate form for each):

____

____

1.2 EFFECTS

1.2.1 Estimated Total Damage (U.S. $ for Year of Earthquake):

____

1.2.2 Number of Deaths: ____________ Injuries: ____________

1.2.3 Maximum Intensity: MMI ____________ RFI ____________

Other (specify)____________

1.2.4 Land Area (km^2): For MMI $\geq$ 4 ________ MMI $\geq$ 6 ________

1.2.5 Population in MMI $\geq$ 6 Zone: ____________

1.2.6 Number of Ground Motion Stations with Records: ____________

1.2.7 Principal Communities Involved: ☐ City Maps ☐ Aerial Photos

Name of Town, City, or Urban Area	Number of High-Rise Buildings Affected MMI $\geq$ 4	Number of High-Rise Buildings Damaged	Number of High-Rise Buildings w/Recorded Response	Maximum Intensity (see 1.2.3)	Peak Ground Accel. (g)
All Other					
Total					

FIGURE 3.1 GENERAL EARTHQUAKE DATA (FORM 1)

Site ID: ____________ By: _____ Date: _____

Earthquake ID: ____________

FORM 2: MOTION AND DAMAGE DATA

(Right-hand columns: DETAILS ATTACHED | REFERENCE)

2.1 MOTION AT SITE

2.1.1 Distance from Site to (km):

Epicenter ________ Hypocenter ________ Rupture ________

2.1.2 Site Intensity: MMI _____ FRI _____ Other (specify) ________

2.1.3 Peak Acceleration at Site (g): Estimated ______ Recorded ______

Recording Instruments		Component ______	Component ______	Vertical Component ______
Type	Location			

2.1.4 Duration of Motion Reported: ____________

Estimated: ☐ 15 Sec ☐ 30 Sec ☐ 60 Sec ☐ 120 Sec

2.1.5 Available Data: ____________

Response Spectrum: ☐ 5% Damping, Tripartite ☐ Other ________

Time History: ☐ Digitized ☐ Corrected ☐ Other ________

2.1.6 ID of Nearest Recording Stations: ____________

2.1.7 Maximum Interstory Displacement (cm): ____________

2.2 PRIMARY DAMAGE

2.2.1 Primary Cause of Damage: ☐ Foundation Soil Failure

☐ Shaking ☐ Settlement ☐ Slope Failure

2.2.2 Replacement Cost ($/Year): ____________

2.2.3 Damage Repair Cost ($/Year): ____________

2.2. Structural ______ % Architectural ______ % Mech. & Elec. ______ %

2.2.4 Damage Factor (%): ____________

2.2.5 Damage State: ☐ No Damage

☐ Negligible ☐ Minor Structural

☐ Minor Nonstructural ☐ Substantial Structural

☐ Substantial Nonstructural ☐ Major Structural

☐ Major Nonstructural ☐ Collapse or Condemnation

2.3 SECONDARY DAMAGE

2.3.1 Number of Deaths: ________ Injuries: ________

2.3.2 Loss of Building Function ($/Year): ____________

Cause: ☐ Structural ☐ Architectural ☐ Mech. & Elec.

FIGURE 3.2 MOTION AND DAMAGE DATA (FORM 2)

Site ID: ________ By: _____ Date: _____

FORM 3: SITE INFORMATION

	DETAILS ATTACHED	REFERENCE

3.1 GENERAL SITE INFORMATION

3.1.1 Instrumentation at Site:

Ground Station: ☐ Free Field ☐ Basement of Lowrise Building

High-rise Building: ☐ Basement ☐ Upper Story ☐ None

3.1.2 Latitude: ________ Longitude: ________

3.1.3 Address: ________

3.2 SITE GEOLOGY

3.2.1 Site Category:

☐ Rock ☐ <10 m Alluvium Underlain by Rock

☐ Alluvium ☐ 10-60 m of Alluvium Underlain by Rock

3.2.2 Average Specific Gravity: ________

3.2.3 Average Shear Wave Velocity: ________ m/s, ________ ft/sec

3.2.4 Depth of Water Table: ________ m

3.3 GENERAL BUILDING INFORMATION

3.3.1 Building Name: ________

3.3.2 Function/Occupation: ________

3.3.3 Building Orientation: ________

3.3.4 Number of Stories (above/below grade): ________

3.3.5 Height (m) (above/below grade): ________

3.3.6 Total Floor Area (m^2): ________

3.3.7 Year of Construction: ________

3.3.8 Construction Cost (U.S. $): ________

3.4 BUILDING DESIGN AND CONSTRUCTION

3.4.1 Lateral Force Design Analysis Type: ☐ None

Static Equivalent: ☐ Seismic ☐ Wind

Dynamic Analysis: ☐ Response Spectrum ☐ Time History

Other: ________

3.4.2 Lateral Force Design Parameters:

L-Axis: C_b = ________ S_a = ________ T_L = ________

T-Axis: C_b = ________ S_a = ________ T_L = ________

3.4.3 Building Period:

	Measured	Date
L-Axis		
T-Axis		
Torsion		

FIGURE 3.3 SITE INFORMATION (FORM 3)

Site ID: ______________ By: ____ Date: ____

FORM 4: BUILDING CATEGORIZATION

	DETAILS ATTACHED	REFERENCE
4.1 Foundation: ☐ Wall Footing ☐ Spread Footing ☐ Combine Footing ☐ Strap Footing ☐ Mat or Raft Foundation ☐ Pile Foundation ☐ Caissons ☐ Other ______		
4.2 Vertical Load-Support System: ☐ Space Frame ☐ Bearing Wall ☐ Truss ☐ Other ______		
4.3 Lateral Load-Resisting System (L T Directions): ☐ ☐ Moment-Resisting Frame ☐ ☐ Shear Wall ☐ ☐ Shear Core ☐ ☐ Braced Frame ☐ ☐ Truss Frame ☐ ☐ Tube ☐ ☐ Other ______		
4.4 Floor System (describe): ______		
4.5 Structural Material: ☐ Steel ☐ Reinforced Concrete ☐ Prestressed Concrete ☐ Reinforced Masonry ☐ Unreinforced Masonry ☐ Wood ☐ Other ______		
4.6 Architectural Material (☐ ☐ Exterior/Interior): ☐ ☐ Concrete ☐ ☐ Concrete Block ☐ ☐ Hollow Clay Tile ☐ ☐ Lath and Plaster ☐ ☐ Drywall on Metal Studs ☐ ☐ Drywall on Wood Studs ☐ ☐ Glass ☐ ☐ Metal ☐ ☐ Other ______		
4.7 Configuration: ☐ Regular ☐ Irregular (Discuss): ______		

FIGURE 3.4 BUILDING CATEGORIZATION (FORM 4)

Site ID: ______________ By: ____ Date: ____

Earthquake ID: ________________

FORM 5: DETAILED SITE AND BUILDING INFORMATION

5.0 REMARKS (Specify Item Number of Discussion and Reference Number in Front of Each Discussion):

FIGURE 3.5 DETAILED SITE AND BUILDING INFORMATION (FORM 5)

Earthquake ID:

```
EQN - MM - YY - A
 |     |    |   └── Aftershock
 |     |    └── Year
 |     └── Month
 └── Earthquake
```

Examples:

```
KRN - 07 - 52, KRN - 07 - 52 - A
 └── Kern County, July 21, 1952, and Aftershock
```

Site ID:

```
USA - SBA - G001
 |     |     └── Ground Station or Building ID
 |     └── City
 └── Country
```

G001 - G220: Ground Station Only

B201 - B500: Building with Instrumentation

B501 - B999: Building without Instrumentation

Example:

```
NIC - MNG - B501
 └── Nicaragua, Managua, Uninstrumented Building
```

FIGURE 3.6 EARTHQUAKE AND SITE IDENTIFICATION

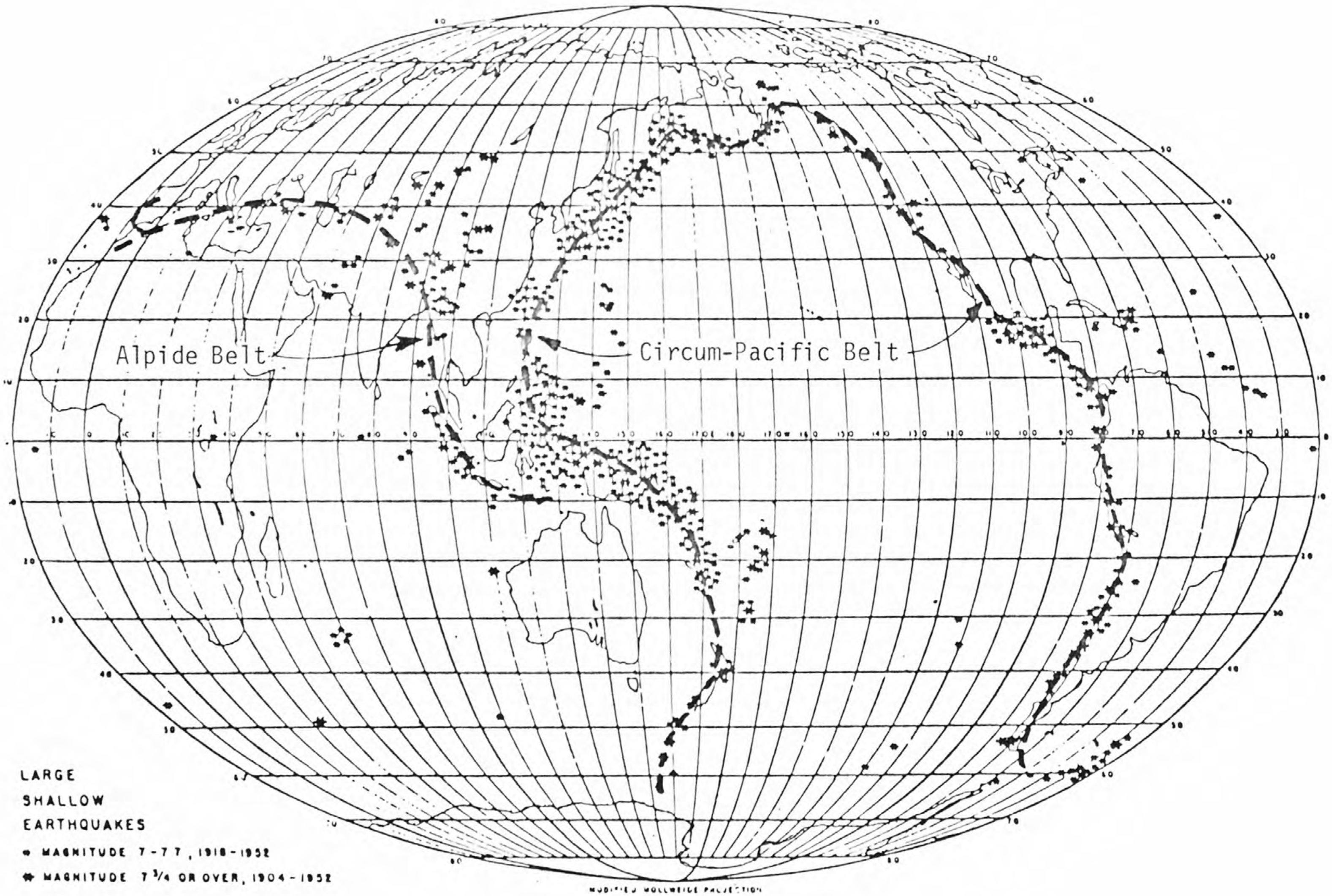


FIGURE 3.7 PRINCIPAL EARTHQUAKE BELTS OF THE WORLD
(Adapted from Gutenberg and Richter, 1965)

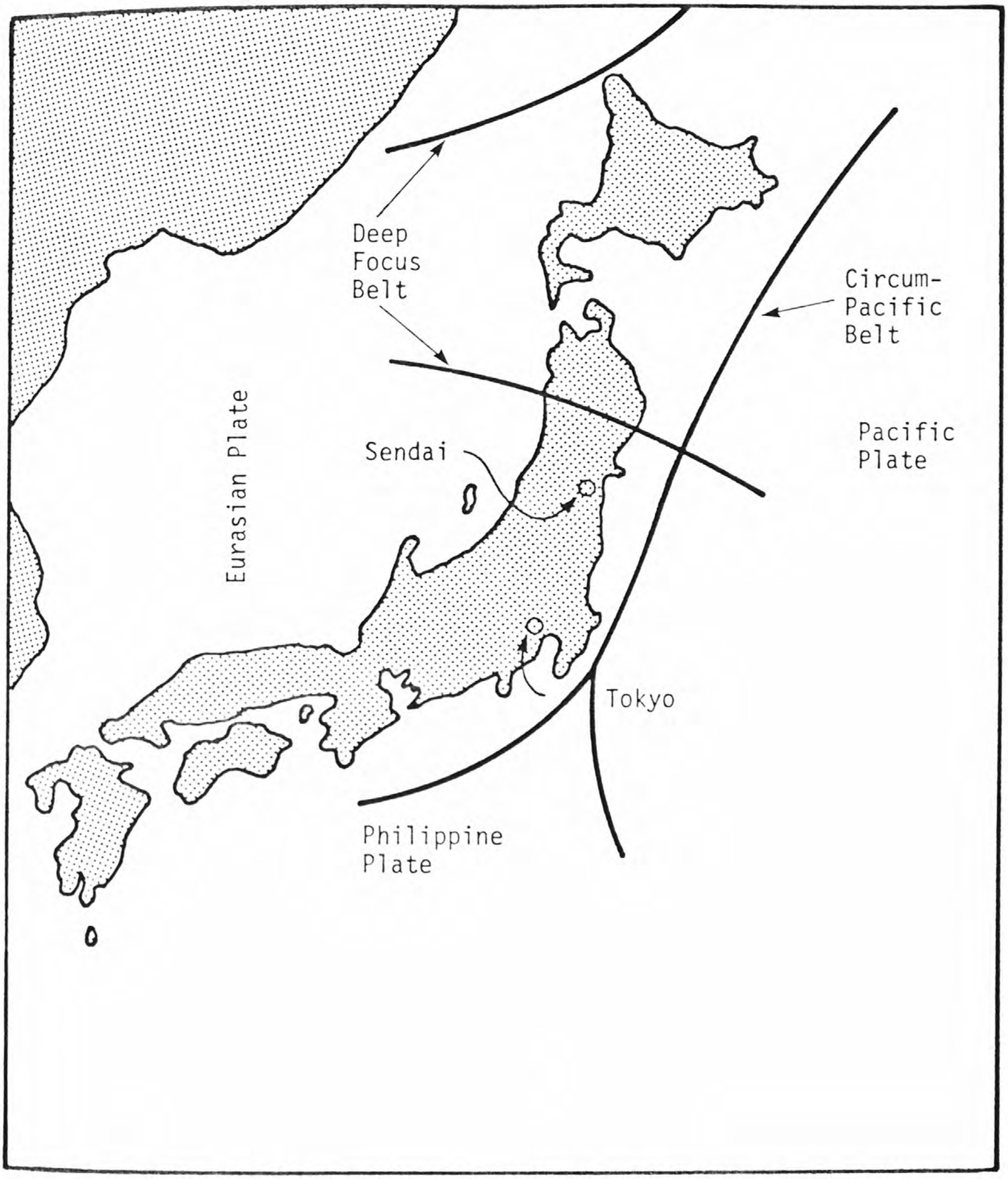


FIGURE 3.8 SEISMIC/GEOLOGIC STRUCTURE OF THE JAPANESE REGION

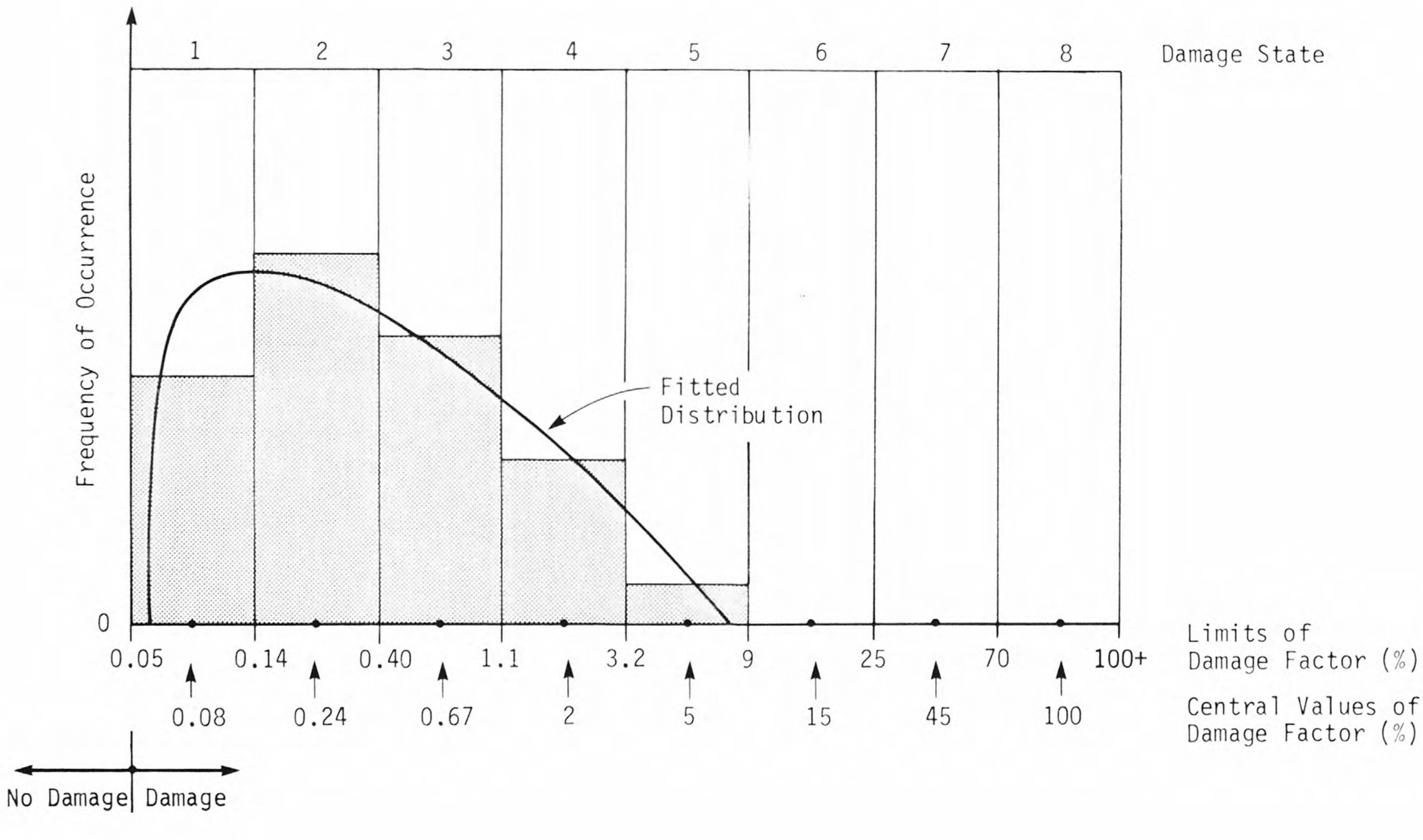


FIGURE 3.9 SAMPLE DAMAGE-STATE HISTOGRAM

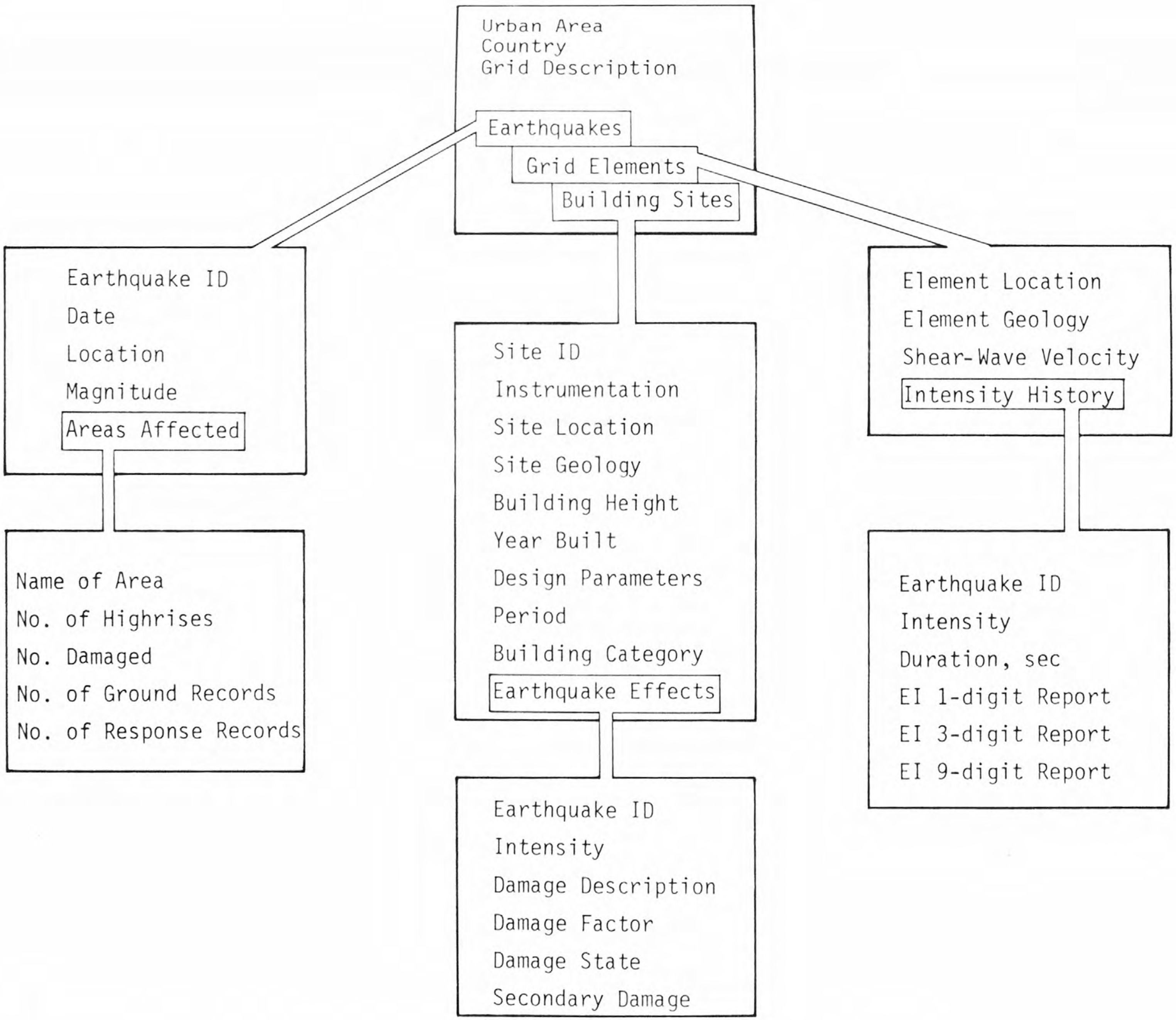


FIGURE 3.10 SCHEMATIC STRUCTURE OF DATA BASE HIRISE

```
DESCRIBE;
 SYSTEM RELEASE NUMBER         2.6)C
 DATA BASE NAME IS HIRISE
 DEFINITION NUMBER        2
 DATA BASE CYCLE          1
    1*  CITY (NAME X(20) WITH SOME FUTURE ADDITIONS)
    2*  COUNTRY (NAME X(15) WITH SOME FUTURE ADDITIONS)
    3*  GRID ORIGIN LATITUDE (NON-KEY DECIMAL NUMBER 999.9999)
    4*  LATITUDE /N/S/ (NON-KEY NAME X)
    5*  N/S INCREMENT (NON-KEY DECIMAL NUMBER 9.9999)
    6*  N/S DIMENSION (NON-KEY INTEGER NUMBER 99)
    7*  GRID ORIGIN LONGITUDE (NON-KEY DECIMAL NUMBER 999.9999)
    8*  LONGITUDE /E/W/ (NON-KEY NAME X)
    9*  E/W INCREMENT (NON-KEY DECIMAL NUMBER 9.9999)
   10*  E/W DIMENSION (NON-KEY INTEGER NUMBER 99)
   11*  EARTHQUAKES (RG)
     12*  EARTHQUAKE ID/1 (NAME X(12) IN 11 WITH SOME FUTURE ADDITIONS)
     13*  FORE/AFTERSHOCK ID /F1/A1/ (NAME XX IN 11 WITH SOME FUTURE AD
          DITIONS)
     14*  MAJOR CITY CODE /0/1/ (INTEGER NUMBER 9 IN 11 WITH SOME FUTUR
          E ADDITIONS)
     15*  EARTHQUAKE NAME (NON-KEY NAME X(20) IN 11)
     16*  DATE /MM/DD/YY/ (DATE IN 11 WITH SOME FUTURE ADDITIONS)
     17*  GREENWICH MEAN TIME (NON-KEY DECIMAL NUMBER 99.999 IN 11)
     18*  EPICENTRAL LATITUDE (NON-KEY DECIMAL NUMBER 999.9999 IN 11)
     19*  LAT /N/S/ (NON-KEY NAME  ) IN 11)
     20*  EPICENTRAL LONGITUDE (NON-KEY DECIMAL NUMBER 999.9999 IN 11)
     21*  LONG /E/W/ (NON-KEY NAME X IN 11)
     22*  FOCAL DEPTH KM (DECIMAL NUMBER 999.9 IN 11 WITH SOME FUTURE A
          DDITIONS)
     23*  MAGNITUDE (DECIMAL NUMBER 9.99 IN 11 WITH SOME FUTURE ADDITIO
          NS)
     24*  FAULT TYPE /SS/NR/RT/ (NAME XX IN 11 WITH SOME FUTURE ADDITIO
          NS)
     25*  FAULT LENGTH KM (DECIMAL NUMBER 999.99 IN 11 WITH SOME FUTURE
           ADDITIONS)
     26*  FAULT AREA KM2 (DECIMAL NUMBER 9(5).9 IN 11 WITH SOME FUTURE
          ADDITIONS)
     27*  RELATED SHOCKS (RG IN 11)
       28*  EARTHQUAKE ID/2 (NON-KEY NAME X(12) IN 27)
     29*  AFFECTED AREA (RG IN 11)
       30*  NAME OF AREA (NAME X(20) IN 29 WITH SOME FUTURE ADDITIONS)
       31*  AFFECTED HIGHRISES (INTEGER NUMBER 9(5) IN 29 WITH SOME FUT
            URE ADDITIONS)
       32*  DAMAGED HIGHRISES (INTEGER NUMBER 9(5) IN 29 WITH SOME FUTU
            RE ADDITIONS)
```

FIGURE 3.11 HIRISE DATA-BASE DEFINITION

```
   33*  GROUND MOTION RECORDS (INTEGER NUMBER 9999 IN 29 WITH SOME
        FUTURE ADDITIONS)
   34*  RESPONSE RECORDS (INTEGER NUMBER 9999 IN 29 WITH SOME FUTUR
        E ADDITIONS)
35*  SITE INFORMATION (RG)
  36*  SITE ID (INTEGER NUMBER 9(5) IN 35 WITH SOME FUTURE ADDITIONS
       )
  37*  INSTRUMENTATION /FF/LB/HB/HU/BU/HN/ (NAME XX IN 35 WITH SOME
       FUTURE ADDITIONS)
  38*  SITE LOCATION CODE /A22/H83/ (NAME XXX IN 35 WITH SOME FUTURE
        ADDITIONS)
  39*  SITE LATITUDE (NON-KEY DECIMAL NUMBER 999.9999 IN 35)
  40*  SITE LONGITUDE (NON-KEY DECIMAL NUMBER 999.9999 IN 35)
  41*  SITE GEOLOGY /RK/LA/MA/DA/ (NAME XX IN 35 WITH SOME FUTURE AD
       DITIONS)
  42*  BUILDING ORIENTATION /N52W/ (NON-KEY NAME XXXX IN 35)
  43*  STORIES ABOVE GRADE (INTEGER NUMBER 999 IN 35 WITH SOME FUTUR
       E ADDITIONS)
  44*  STORIES BELOW GRADE (NON-KEY INTEGER NUMBER 9 IN 35)
  45*  HEIGHT ABOVE GRADE M (DECIMAL NUMBER 999.9 IN 35 WITH SOME FU
       TURE ADDITIONS)
  46*  HEIGHT BELOW GRADE M (NON-KEY DECIMAL NUMBER 99.9 IN 35)
  47*  HEIGHT CODE /N/ (INTEGER NUMBER 9 IN 35 WITH SOME FUTURE ADDI
       TIONS)
  48*  WIDTH M (NON-KEY DECIMAL NUMBER 999.9 IN 35)
  49*  LENGTH M (NON-KEY DECIMAL NUMBER 999.9 IN 35)
  50*  TOTAL FLOOR AREA M2 (NON-KEY INTEGER NUMBER 9(7) IN 35)
  51*  YEAR OF CONSTRUCTION (INTEGER NUMBER 9999 IN 35 WITH SOME FUT
       URE ADDITIONS)
  52*  DESIGN CODE /UBC46/OTHER/ (NON-KEY NAME X(5) IN 35)
  53*  LATERAL DESIGN /SS/SW/RS/TH/CT/NO/ (NAME XX IN 35 WITH SOME F
       UTURE ADDITIONS)
  54*  BASE SHEAR L-G (DECIMAL NUMBER 9.999 IN 35)
  55*  BASE SHEAR T-G (DECIMAL NUMBER 9.999 IN 35)
  56*  MAXDESIGN SPECTRAL ACCL L-G (DECIMAL NUMBER 9.999 IN 35 WITH
       SOME FUTURE ADDITIONS)
  57*  MAXDESIGN SPECTRAL ACCL T-G (DECIMAL NUMBER 9.999 IN 35 WITH
       SOME FUTURE ADDITIONS)
  58*  DESIGN PERIOD L (DECIMAL NUMBER 99.99 IN 35 WITH SOME FUTURE
       ADDITIONS)
  59*  DESIGN PERIOD T (DECIMAL NUMBER 99.99 IN 35 WITH SOME FUTURE
       ADDITIONS)
  60*  MEASURED PERIOD L (NON-KEY DECIMAL NUMBER 99.99 IN 35)
  61*  MEASURED PERIOD T (NON-KEY DECIMAL NUMBER 99.99 IN 35)
  62*  MEASURED PERIOD TOR (NON-KEY DECIMAL NUMBER 99.99 IN 35)
  63*  DATE MEASURED (NON-KEY INTEGER NUMBER 9999 IN 35)
```

FIGURE 3.11 (Continued)

64* QUALITY FACTOR /N/ (INTEGER NUMBER 9 IN 35 WITH SOME FUTURE ADDITIONS)
65* VERTICAL LOAD /SF/TR/BW/OT/ (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
66* LATERAL LOAD L /MF/SW/SC/TF/BF/TB/OT/ (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
67* LATERAL LOAD T /MF/SW/SC/TF/BF/TB/OT/ (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
68* STRUCTURAL MATERIAL /ST/RC/PC/RM/UM/WD/OT/SR/ (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
69* ARCHITECTURAL EXTERIOR /CO/CB/CT/LP/DM/DW/GL/MT/OT/ (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
70* ARCHITECTURAL INTERIOR /CO/CB/CT/LP/DM/DW/GL/MT/OT/ (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
71* CONFIGURATION /RG/IR/ (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
72* STRUCTURAL RIGIDITY /N/ (INTEGER NUMBER 9 IN 35 WITH SOME FUTURE ADDITIONS)
73* ARCHITECTURAL RIGIDITY /N/ (INTEGER NUMBER 9 IN 35 WITH SOME FUTURE ADDITIONS)
74* BUILDING CATEGORY (NAME XX IN 35 WITH SOME FUTURE ADDITIONS)
75* EARTHQUAKE EFFECTS (RG IN 35)
  76* EARTHQUAKE ID/3 (NAME X(12) IN 75 WITH SOME FUTURE ADDITIONS)
  77* INTENSITY MMI (DECIMAL NUMBER 99.9 IN 75 WITH SOME FUTURE ADDITIONS)
  78* INTENSITY OTHER (NON-KEY DECIMAL NUMBER 99.9 IN 75)
  79* INTENSITY SCALE /RFI/MKS/GEO/JMA/WD/ (NON-KEY NAME XXX IN 75)
  80* REPORTED DURATION SEC (INTEGER NUMBER 999 IN 75 WITH SOME FUTURE ADDITIONS)
  81* ESTIMATED DURATION SEC (INTEGER NUMBER 999 IN 75 WITH SOME FUTURE ADDITIONS)
  82* AVAILABLE RECORDS /RS5/RSO/THR/THC/THO/OTH/ (NAME XXX IN 75 WITH SOME FUTURE ADDITIONS)
  83* MAXINTERSTORY DRIFT CM (DECIMAL NUMBER 99.9 IN 75 WITH SOME FUTURE ADDITIONS)
  84* CAUSE OF DAMAGE /SHK/FND/STL/SLP/FIR/ (NAME XXX IN 75 WITH SOME FUTURE ADDITIONS)
  85* REPLACEMENT COST $ (NON-KEY INTEGER NUMBER 9(8) IN 75)
  86* DAMAGE REPAIR COST $ (NON-KEY INTEGER NUMBER 9(8) IN 75)
  87* PERCENT STRUCTURAL (DECIMAL NUMBER 9.999 IN 75 WITH SOME FUTURE ADDITIONS)

FIGURE 3.11 (Continued)

```
    88*  PERCENT ARCHITECTURAL (DECIMAL NUMBER 9.999 IN 75 WITH SOME
          FUTURE ADDITIONS)
    89*  PERCENT MECH/ELEC (DECIMAL NUMBER 9.999 IN 75 WITH SOME FUT
         URE ADDITIONS)
    90*  DAMAGE FACTOR (DECIMAL NUMBER 9.9(5) IN 75 WITH SOME FUTURE
          ADDITIONS)
    91*  DAMAGE STATE /N/ (INTEGER NUMBER 9 IN 75 WITH SOME FUTURE A
         DDITIONS)
    92*  DEATHS (NON-KEY INTEGER NUMBER 999 IN 75)
    93*  INJURIES (NON-KEY INTEGER NUMBER 9999 IN 75)
    94*  LOSS OF FUNCTION % (INTEGER NUMBER 9(9) IN 75 WITH SOME FUT
         URE ADDITIONS)
    95*  CAUSE OF LOSS /ST/AR/ME/FR/ (NON-KEY NAME XX IN 75)
    96*  SITE EI 9-DIGIT (NON-KEY INTEGER NUMBER 9(9) IN 75)
97*  CITY GRID ELEMENTS (RG)
  98*  LOCATION CODE (NAME XXX IN 97 WITH SOME FUTURE ADDITIONS)
  99*  ELEMENT LATITUDE (NON-KEY DECIMAL NUMBER 999.9999 IN 97)
 100*  ELEMENT LONGITUDE (NON-KEY DECIMAL NUMBER 999.9999 IN 97)
 101*  SOIL TYPE /RK/LA/MA/DA/ (NAME XX IN 97 WITH SOME FUTURE ADDIT
       IONS)
 102*  SHEAR WAVE VELOCITY M/SEC (NON-KEY INTEGER NUMBER 9(5) IN 97)

 103*  INTENSITY HISTORY (RG IN 97)
   104*  EARTHQUAKE ID/4 (NAME X(12) IN 103 WITH SOME FUTURE ADDITIO
         NS)
   105*  ELEMENT INTENSITY MMI (DECIMAL NUMBER 99.9 IN 103 WITH SOME
          FUTURE ADDITIONS)
   106*  AVERAGE DURATION SEC (INTEGER NUMBER 999 IN 103 WITH SOME F
         UTURE ADDITIONS)
   107*  EI 1-DIGIT REPORT (NON-KEY NAME XX IN 103)
   108*  EI 3-DIGIT REPORT (NON-KEY NAME X(8) IN 103)
   109*  EI 9-DIGIT REPORT (NON-KEY NAME X(11) IN 103)
   110*  EI1 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   111*  EI2 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   112*  EI3 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   113*  EI4 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   114*  EI5 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   115*  EI6 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   116*  EI7 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   117*  EI8 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
   118*  EI9 (INTEGER NUMBER 9 IN 103 WITH SOME FUTURE ADDITIONS)
```

FIGURE 3.11 (Continued)

Earthquake ID: *11*12* By: ______ Date: ______

FORM 1: GENERAL EARTHQUAKE DATA

	DETAILS ATTACHED	REFERENCE
1.1 EARTHQUAKE		
1.1.1 Earthquake Name: *15*		
1.1.2 Date: *16*		
1.1.3 Origin Time: Local ______ GMT *17*		
1.1.4 Latitude: *18* *19* (N/S) Longitude: *20* *21* (E/W)		
1.1.5 Depth (km): *22*		
1.1.6 Magnitude: M_L *23* M_s ______ M_b ______		
1.1.7 Type of Faulting: *24* (SS) *Strike Slip* (NR) *Normal* (RT) *Reverse, Thrust*		
1.1.8 Length of Surface Faulting (km): *25*		
1.1.9 ID of Significant Aftershocks (see separate form for each): *27 * 28*		
*27 * 28*		
1.2 EFFECTS		
1.2.1 Estimated Total Damage (U.S. $ for Year of Earthquake): ______		
1.2.2 Number of Deaths: ______ Injuries: ______		
1.2.3 Maximum Intensity: MMI ______ RFI ______ Other (specify) ______		
1.2.4 Land Area (km^2): For MMI $\geq$ 4 ______ MMI $\geq$ 6 ______		
1.2.5 Population in MMI $\geq$ 6 Zone: ______		
1.2.6 Number of Ground Motion Stations with Records: *33*		
1.2.7 Principal Communities Involved: ☐ City Maps ☐ Aerial Photos		

Name of Town, City, or Urban Area	Number of High-Rise Buildings Affected MMI $\geq$ 4	Number of High-Rise Buildings Damaged	Number of High-Rise Buildings w/Recorded Response	Maximum Intensity (see 1.2.3)	Peak Ground Accel. (g)	DETAILS ATTACHED	REFERENCE
*29 * 30*	*31*	*32*	*34*				
*29 * 30*	*31*	*32*	*34*				
All Other							
Total*29 * 30*	*31*	*32*	*34*				

FIGURE 3.12 GENERAL EARTHQUAKE DATA (FORM 1)

Site ID: *35*36* By: ____ Date: ____

FORM 3: SITE INFORMATION

	DETAILS ATTACHED	REFERENCE

3.1 GENERAL SITE INFORMATION

37 3.1.1 Instrumentation at Site: (BU) *High-Rise Basement and Upper Story*

Ground Station: [FF] Free Field [LB] Basement of Lowrise Building

High-rise Building: [HB] Basement [HU] Upper Story [HN] None

3.1.2 Latitude: *39* Longitude: *40*

3.1.3 Address: ____

3.2 SITE GEOLOGY

41 3.2.1 Site Category:

[RK] Rock [LA] < 10 m Alluvium Underlain by Rock

[DA] Alluvium [MA] 10-60 m of Alluvium Underlain by Rock

3.2.2 Average Specific Gravity: ____

3.2.3 Average Shear Wave Velocity: ____ m/s, ____ ft/sec

3.2.4 Depth of Water Table: ____ m

3.3 GENERAL BUILDING INFORMATION

3.3.1 Building Name: ____

3.3.2 Function/Occupation: ____

3.3.3 Building Orientation: *42*

3.3.4 Number of Stories (above/below grade): *43*/*44*

3.3.5 Height (m) (above/below grade): *45*/*46*

3.3.6 Total Floor Area (m^2): *50*

3.3.7 Year of Construction: *51*

3.3.8 Construction Cost (U.S. $): ____

3.4 BUILDING DESIGN AND CONSTRUCTION *Code:* *52*

53 3.4.1 Lateral Force Design Analysis Type: [NO] None

Static Equivalent: [SS] Seismic [SW] Wind

Dynamic Analysis: [RS] Response Spectrum [TH] Time History

Other: (OT) ____

3.4.2 Lateral Force Design Parameters:

L-Axis: C_b = *54* S_a = *56* T_L = *58*

T-Axis: C_b = *55* S_a = *57* T_L = *59*

3.4.3 Building Period:

	Measured	Date
L-Axis	*60*	*63*
T-Axis	*61*	
Torsion	*62*	

Plan Width (m): *48*

Plan Length (m): *49*

FIGURE 3.13 SITE INFORMATION (FORM 3)

Site ID: ______________ By: ____ Date: ____

FORM 4: BUILDING CATEGORIZATION

DETAILS ATTACHED	REFERENCE

4.1 Foundation:

- [ ] Wall Footing
- [ ] Combine Footing
- [ ] Mat or Raft Foundation
- [ ] Caissons
- [ ] Spread Footing
- [ ] Strap Footing
- [ ] Pile Foundation
- [ ] Other ______________

65 4.2 Vertical Load-Support System:

- [SF] Space Frame
- [TR] Truss
- [BW] Bearing Wall
- [OT] Other______________

4.3 Lateral Load-Resisting System ([L] [T] Directions):

66 *L*

67 *T*

- [MF] [MF] Moment-Resisting Frame
- [SC] [SC] Shear Core
- [TF] [TF] Truss Frame
- [SW] [SW] Shear Wall
- [BF] [BF] Braced Frame
- [TB] [TB] Tube
- [OT] [OT] Other ______________

4.4 Floor System (describe): ______________

*68*4.5 Structural Material:

- [ST] Steel
- [PC] Prestressed Concrete
- [UM] Unreinforced Masonry
- [RC] Reinforced Concrete
- [RM] Reinforced Masonry
- [WD] Wood
- [OT] Other ______________
- (SR) *Steel Reinforced Concrete (Japan)*

4.6 Architectural Material ([ ] [ ] Exterior/Interior):

69 *Ext.*

60 *Int.*

- [CO] [CO] Concrete
- [CT] [CT] Hollow Clay Tile
- [DM] [DM] Drywall on Metal Studs
- [GL] [GL] Glass
- [CB] [CB] Concrete Block
- [LP] [LP] Lath and Plaster
- [DW] [DW] Drywall on Wood Studs
- [MT] [MT] Metal
- [OT] [OT] Other______________

71 4.7 Configuration: [R] Regular [I] Irregular

(Discuss): ______________

FIGURE 3.14 BUILDING CATEGORIZATION (FORM 4)

Site ID: ____________ By: _____ Date: _____

Earthquake ID: *75 * 76*

FORM 2: MOTION AND DAMAGE DATA

(Right-hand columns: DETAILS ATTACHED | REFERENCE)

2.1 MOTION AT SITE

2.1.1 Distance from Site to (km):

Epicenter ________ Hypocenter ________ Rupture ________

2.1.2 Site Intensity: MMI *77* FRI _____ Other (specify) *78*,*79*

2.1.3 Peak Acceleration at Site (g): Estimated ______ Recorded ______

Recording Instruments		Component	Component	Vertical Component
Type	Location			

2.1.4 Duration of Motion Reported: *80*

81 Estimated: ☐ 15 Sec ☐ 30 Sec ☐ 60 Sec ☐ 120 Sec

2.1.5 Available Data: (OTH) *Other* (NO) *None*

82 Response Spectrum: [RSS] 5% Damping, Tripartite [RSO] Other ________

Time History: [THR] Digitized [THC] Corrected [THO] Other ________

2.1.6 ID of Nearest Recording Stations: ________

2.1.7 Maximum Interstory Displacement (cm): *83*

2.2 PRIMARY DAMAGE

2.2.1 Primary Cause of Damage: [FND] Foundation Soil Failure (FIR) *Fire*

84 [SHK] Shaking [STL] Settlement [SLP] Slope Failure

2.2.2 Replacement Cost ($/Year): *85*

2.2.3 Damage Repair Cost ($/Year): *86*

2.2. Structural *87* % Architectural *88* % Mech. & Elec. *89* %

2.2.4 Damage Factor (%): *90*

2.2.5 Damage State: [0] No Damage

91

[1] Negligible

[2] Minor Nonstructural

[3] Substantial Nonstructural

[4] Major Nonstructural

[5] Minor Structural

[6] Substantial Structural

[7] Major Structural

[8] Collapse or Condemnation

2.3 SECONDARY DAMAGE

2.3.1 Number of Deaths: *92* Injuries: *93*

2.3.2 Loss of Building Function ($/Year): *94*

95 Cause: [ST] Structural [AR] Architectural [ME] Mech. & Elec.

EI: *96*

FIGURE 3.15 MOTION AND DAMAGE DATA (FORM 2)

4. ESTIMATION OF ENGINEERING INTENSITY FROM SEISMOLOGICAL INTENSITY DATA

4.1 Introduction

This chapter describes work performed in relating seismological intensity to engineering intensity -- Task III of the overall study. Included are sections on purpose and general background, a description of the method used for correlating engineering intensity with seismological intensity, a discussion of work completed thus far, and a description of the work to be performed to complete this task.

4.2 Purpose

Records of strong ground motion have not been obtained for many important earthquakes; only seismological intensity data were available. Thus, there are numerous reports of damage for which no quantitative measure of ground motion exists. By developing general relationships between seismological intensity and engineering intensity, additional quantitative ground motion information can be developed for establishing motion-damage relationships for high-rise buildings.

4.3 Background

To engineers, it is obvious that damage must be related to a quantitative measure of ground motion to be of most use in reducing earthquake hazards. To others, it is not so obvious. This section is provided to elucidate the need for this correlation.

4.3.1 Seismological Intensity (SI). Many scales have been developed throughout the world over the past 200 years that are useful for communicating the effects of earthquakes. Because the development of these scales for rating seismological intensity preceded the development of ground motion instrumentation, the rating scales are inherently qualitative. All these scales indicate ground shaking intensity at a site and associate varying degrees of observable damage with arbitrary numerical values.

The most common of the various seismological intensity scales are the modified Mercalli (MM), Rossi-Forel (RF), Medvedev-Sponheuer-Karnik (MSK), Japan Meteorological Agency (JMA), and GEOFIAN scales. Each of these is reproduced in Appendix C along with a discussion comparing them.

4.3.2 Engineering Intensity (EI). The Engineering Intensity Scale (EIS) was developed by Blume (1970) to serve as a systematic and orderly means of reporting the intensity of ground shaking at a site in a form useful to engineers.

In the formulation of the scale, ground shaking is characterized by 5%-damped response spectrum velocity (S_v), and structures are characterized by their fundamental-mode vibration properties. Disregarding mode shape considerations, the variables important for correlating ground motion with damage are S_v amplitude and structure period (T). A damping value of 5% is used because damping in many real structures varies from about 2% to 10%, and 5% has become a standard reference level in investigations analyzing the response of structures to ground motion.

A comprehensive description of the EIS is given in Appendix D.

4.3.3 EI vis-a-vis SI for Damage Prediction. SI scales are defined in terms of damage observed at a site. The EIS defines ground motion response spectrum amplitude at a site. Whereas SI provides a qualitative estimate of ground motion, EI provides a quantitative measure of ground motion at a site. The most important advantage the EIS has over any of the SI scales is that the EIS reveals ground motion characteristics commonly used in the design of structures; thus, EI values can be used to perform engineering analyses of structures.

Seismological intensity scales have provided important information concerning ground shaking for past earthquakes, and it is likely that they will continue to be used in the future. Their principal shortcoming for purposes of damage prediction is that their basis is strictly qualitative. Any future changes in the design of structures to reduce earthquake hazards will undoubtedly result from engineering analyses. Because the damage scenarios associated with SI scales are based on empirical observations, it will take a long time of observing how structures perform during future earthquakes to change the scenarios to comply with engineering design changes. Earthquake engineering technology would thus be hindered if damage estimation and earthquake hazard reduction were constrained to function with only SI measures of ground shaking.

Currently, earthquake engineers are aware that different structures respond to the same ground motion in different ways. Similarly, it is most likely that the same structure will respond differently to different earthquakes. These variations are all accounted for within the context of dynamic response and associated amplification phenomena. The single most theoretically justifiable and intuitively palatable simple measure of dynamic response for engineering purposes that has been put forth thus far is the response spectrum. The important characteristics of earthquake ground motion, as it affects structure response and damage, are:

- Amplitude
- Frequency content
- Duration
- Periodicity

All these characteristics except for duration are reflected in standard response spectrum plots. Duration can be included using three-dimensional response spectrum plots (Schopp and Scholl, 1972), but, because the importance of duration has not been rigorously established, it is currently not done. These ground motion characteristics are also included in SI scales but are not independently distinguishable.

Most importantly, response spectrum plots facilitate distinguishing amplitude as a function of frequency. This is important in engineering because different structures have different natural frequencies and thus dynamic amplification for various structures depends on the amplitudes of ground motion at various frequencies. It is well known (Richter, 1958; McGuire, 1977) that the frequency content of earthquake motion depends on the magnitude of the earthquake, with earthquakes of larger magnitude producing more long-period effects. This trend is shown in Figure 4.1, which is the result of a statistical analysis of the effects of magnitude (M) and distance (R) on spectral response. Because the SI scales combine both long- and short-period structure damage at a given intensity level, they are inherently biased toward a specified magnitude. The SI ratings assigned to damage to long-period structures (i.e., high-rises) would thus be lower for earthquakes of larger magnitude. It is therefore desirable when considering long-period structures to use the EIS because it facilitates accounting for the intensities at various period ranges.

Similar arguments can be put forth regarding the effects of site geology, fault type, etc., on the variation of ground motion amplitude as a function of frequency.

The EIS facilitates distinguishing ground motion amplitude as a function of frequency; the SI scales do not.

4.4 Procedure for Correlating EI with SI

Various approaches could be adopted for establishing relationships between SI and EI. The method adopted for this project consists of collecting ground motion time-history records for which MMI reports are also available, calculating 5%-damped response spectrum values, and performing correlation analyses. Details of the statistical procedures used in performing the correlation analysis are given in Appendix E.

As previously stated, shapes of ground motion spectra are functions (to varying degrees) of many seismological and geological factors (Trifunac and Brady, 1975). For example, Agbabian Associates (1977) have described spectra shapes accounting for various MMIs and several soil conditions, and McGuire (1977) has described variations in spectral shape considering the effects of magnitude and distance. One of the most difficult aspects of this task is to identify the important seismological and geological factors affecting ground motion.

The factors influencing the ground motion at any site begin with the faulting process and the associated stress regime. Parameters such as those from the source mechanism model -- stress drop, focal depth, source time history, and rupture length -- all affect the ground motion representation. The relative effect of each of these parameters is not yet fully known; research is currently being conducted to delineate the relative influence of each parameter.

The next factor is the transmission path of the energy from the rupture surface to the recording site. Except for near-field sources, the transmission path of the energy is primarily through basement rock, with the effect being mainly one of attenuation of energy with distance. By contrast, in the near field, complexities in the geologic structure (e.g., nonhorizontal layering or high-contrast impedance boundaries) will affect the ground motion and its calculated response spectra. Focusing of energy by a particular orientation of fault plane with the site location may also affect the amount of seismic motion recorded at a site.

The final influencing factor is the geologic structure at the site. The site classification must consider the large-scale geologic structure down to the crystalline basement.

Because building damage is a nonlinear phenomenon, the duration of the ground motion will have an effect on the amount of damage, particularly for reinforced concrete, where there is degradation of stiffness with repetition and reversal of loads. An attempt will be made to address the effect of the duration of strong ground motion on the MMI-EIS correlation.

In accordance with the factors discussed above, the following is a list of information compiled or calculated for each ground motion record to be used in the correlation analysis:

- Earthquake identification
- Earthquake description
  - -- Magnitude
  - -- Seismic moment
  - -- Fault type
  - -- Permanent fault dislocation
  - -- Focal depth
  - -- Stress drop
  - -- Rupture velocity
  - -- Rise time
- Component of motion identification
- Epicentral distance
- Site peak ground acceleration (PGA)

- Site MMI
- Site geologic description
  - -- Rock site outcrop
  - -- Rock site with thin alluvium: $t < 10$ m
  - -- Alluvium: $10 \text{ m} < t < 60$ m
  - -- Deep alluvium: $t > 60$ m
- Bracketed duration: acceleration > 0.05g
- Calculated S_v and $S_v + 1\sigma$ values for 91 discrete periods in the range $0.04 \text{ sec} \leq t \leq 14.78$ sec
- 9-digit EI values
- 3-digit EI values
- 1-digit EI value

Although this information can be used to sort in a multitude of ways, the principal correlations are MMI and EI values for various magnitudes and various site soil conditions.

4.5 Work Completed

The 1977 Agbabian Associates report summarizes the results of a correlation of MMI and response spectra for records of 372 horizontal components and 186 vertical components from the 1971 San Fernando, California, earthquake. Results of their investigation, without consideration of different site geology classifications, are reproduced in Figures 4.2 through 4.5. The statistical correlation procedure used by Agbabian is the same as that described in Appendix E.

Tables 4.1 and 4.2 show correlations between EI and MMI as calculated from the Agbabian results.

4.6 Additional Studies for Project Completion

The spectra in Figures 4.2 through 4.5 are limited to MMI values of V, VI, and VII. The data base described in Chapter 2 indicates that damage data are available for MMI values as high as XI. Accordingly, more data are required to perform statistical analyses for the higher intensities.

Table 4.3 lists various strong-motion records that URS/Blume has acquired for use in this task. The final product of the task will be plots similar to those in Figures 4.2 through 4.5 and a tabulation of EI versus MMI values similar to those in Tables 4.1 and 4.2.

Finally, an attempt will be made to develop damage scenarios for various EI values for high-rise buildings similar to those now available for SI scales. The EIS currently lacks any such scenarios.

TABLE 4.1

CORRELATION OF MMI AND EI USING DATA FROM THE 1971 SAN FERNANDO EARTHQUAKE - 5% DAMPING, LOGNORMAL MEAN S_v

Direction of Motion	MMI	EI
Vertical	V	233,333,333 3-,3,3 3
Vertical	VI	233,344,443 3-,4-,4- 3+
Vertical	VII	334,455,554 3+,5-,5- 4+
Horizontal	V	234,444,443 3,4,4- 4-
Horizontal	VI	344,455,454 4-,5-,4+ 4+
Horizontal	VII	345,555,665 4,5,6- 5

TABLE 4.2

CORRELATION OF MMI AND EI USING DATA FROM THE 1971 SAN FERNANDO EARTHQUAKE - 5% DAMPING, LOGNORMAL 84TH-PERCENTILE S_v

Direction of Motion	MMI	EI
Vertical	V	233,333,443 3-,3,4- 3
Vertical	VI	334,444,444 3+,4,4 4-
Vertical	VII	345,555,554 4,5,5- 5-
Horizontal	V	234,444,444 3,4,4 4-
Horizontal	VI	345,555,555 4,5,5 5-
Horizontal	VII	345,666,665 4,6,6- 5+

TABLE 4.3

STRONG-MOTION RECORDS AVAILABLE ON MAGNETIC TAPE FOR USE IN CORRELATING MMI AND EI

Earthquake Identification		Epicentral MMI	Number of Records
Location	Date		
Long Beach, California	3/10/33	IX	3
Southern California	10/2/33	VI	2
Eureka, California	7/6/34	V	1
Helena, Montana	10/31/35	VIII	3
Lower California	12/30/34	IX	1
Humboldt Bay, California	2/6/37	--	1
Northwest California	9/11/38	VI	1
Imperial Valley, California	5/18/40	X	1
Northwest California	2/9/41	--	1
Santa Barbara, California	6/30/41	VIII	1
Northern California	10/3/41	VII	1
Torrance-Gardena, California	11/14/41	VIII	2
Borrego Valley, California	10/21/42	VII	1
Northern California	3/9/49	VII	1
Western Washington	4/13/49	VIII	2
Imperial Valley, California	1/23/51	VII	1
Northwest California	10/7/51	VII	1
Kern County, California	7/21/52	XI	5
Northern California	9/22/52	VII	1
Southern California	11/21/52	VII	1
Imperial Valley, California	6/13/53	VII	1
Wheeler Ridge, California	1/12/54	VIII	1
Central California	4/25/54	VII	1
Lower California	11/12/54	V	1
Eureka, California	12/21/54	VII	2
San Jose, California	9/4/55	VII	1
Imperial County, California	12/16/55	VII	1
El Alamo, Baja California	2/9/56	--	2
Southern California	3/18/57	VI	1

TABLE 4.3 (Continued)

Earthquake Identification		Epicentral MMI	Number of Records
Location	Date		
San Francisco, California	3/22/57	VII	5 (3-aftershock)
Central California	1/19/60	VI	1
Northern California	6/5/60	VI	1
Hollister, California	4/8/61	VII	2
Northern California	9/4/62	VI	1
Puget Sound, Washington	4/29/65	VIII	2
Southern California	7/15/65	VI	1
Parkfield, California	6/27/66	VII	7
Gulf of California	8/7/66	VI	1
Northern California	9/12/66	VII	1
Northern California	12/10/67	VI	2
Northern California	12/18/67	VI	1
Borrego Mountain, California	4/8/68	VII	13
Lytle Creek, California	9/12/70	VII	7
San Fernando, California	2/9/71	XI	101
Central California	3/8/71	V	1
Andreanof Islands, Alaska	5/1/71	VI	1
Central Chile	7/8/71	X	1 (1 component)
Northern California	9/12/71	V	1
Southeast Alaska	7/30/72	VII	1
Central California	9/4/72	VI	3
Managua, Nicaragua	1/3/72	--	3
Managua, Nicaragua	12/23/72	IX	3
Gazli, USSR	5/17/76	--	1
Rumania	3/4/77	IX	1
Oroville, California	8/11/75	VII	14
Friuli, Italy	5/76	IX	26
Coyote Lake, California	8/6/79	VII	6
Imperial Valley, California	10/15/79	IX	22
Oaxaca, Mexico	11/29/78	VIII	4

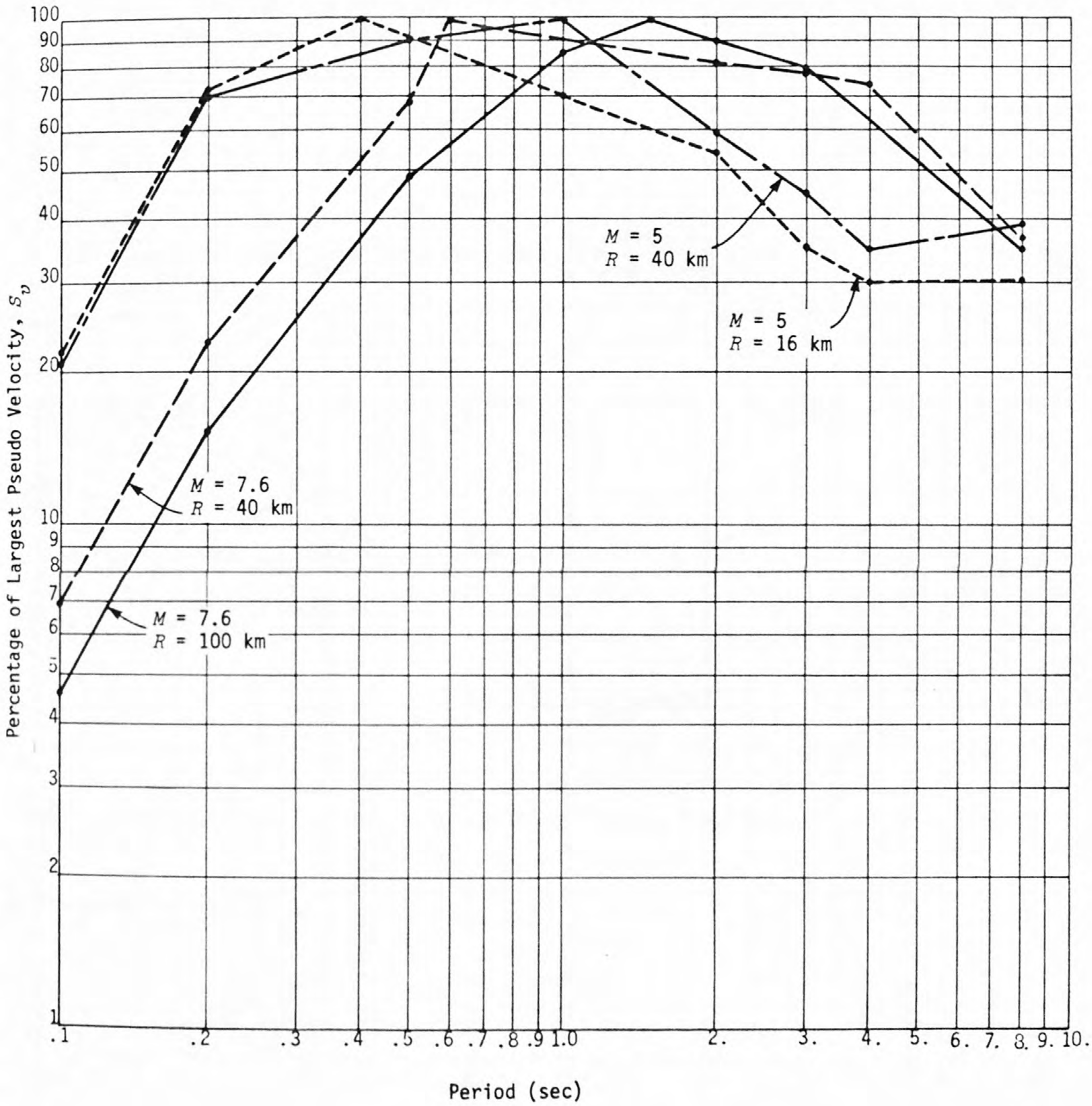


FIGURE 4.1 PREDICTED SPECTRAL PSEUDO VELOCITIES FOR EARTHQUAKES OF SEVERAL MAGNITUDES AND DISTANCES (AFTER MCGUIRE, 1977)

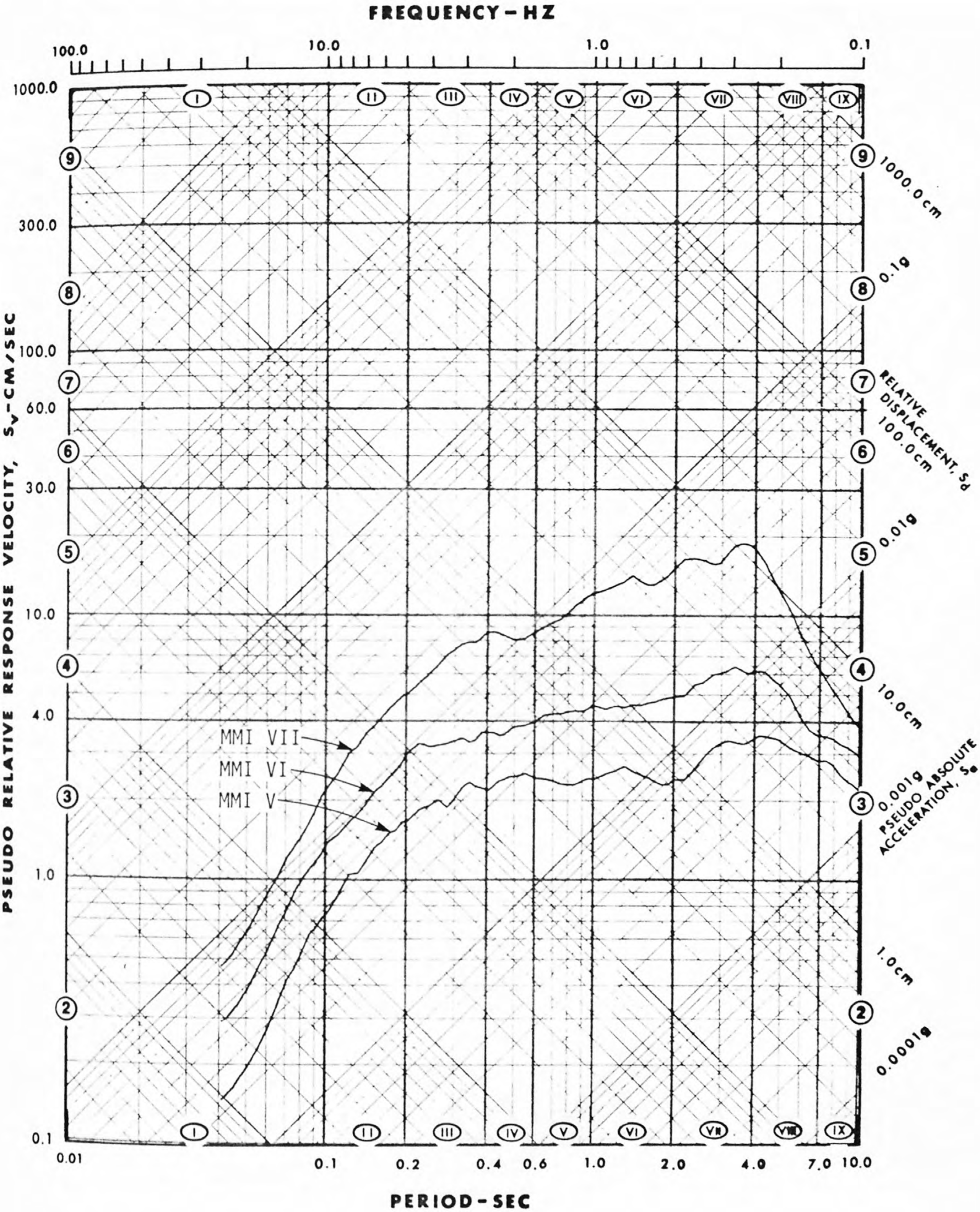


FIGURE 4.2 LOGNORMAL MEAN VERTICAL SPECTRA FOR MMI V, VI, AND VII - 5% DAMPING

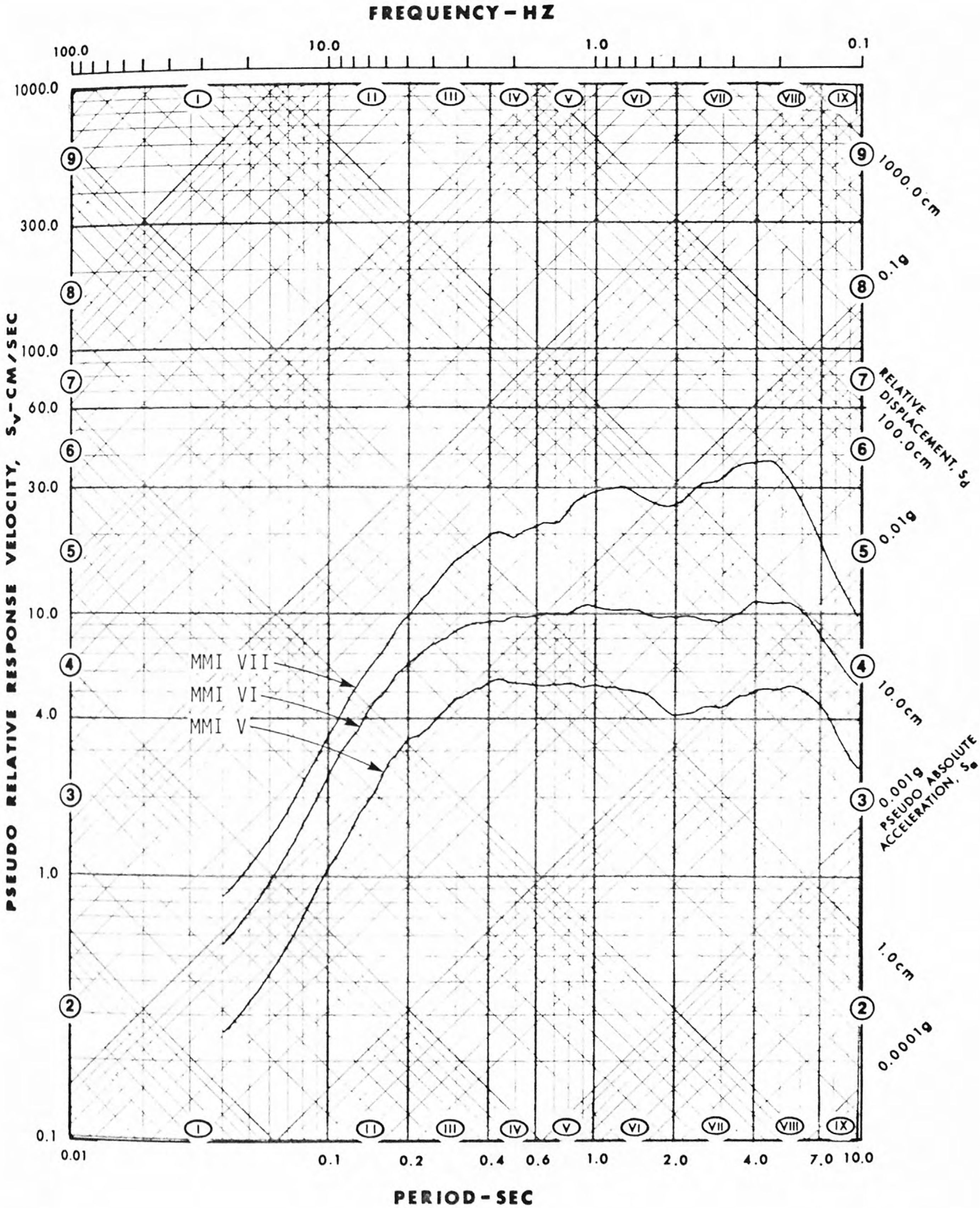


FIGURE 4.3 LOGNORMAL MEAN HORIZONTAL SPECTRA FOR MMI V, VI, AND VII - 5% DAMPING

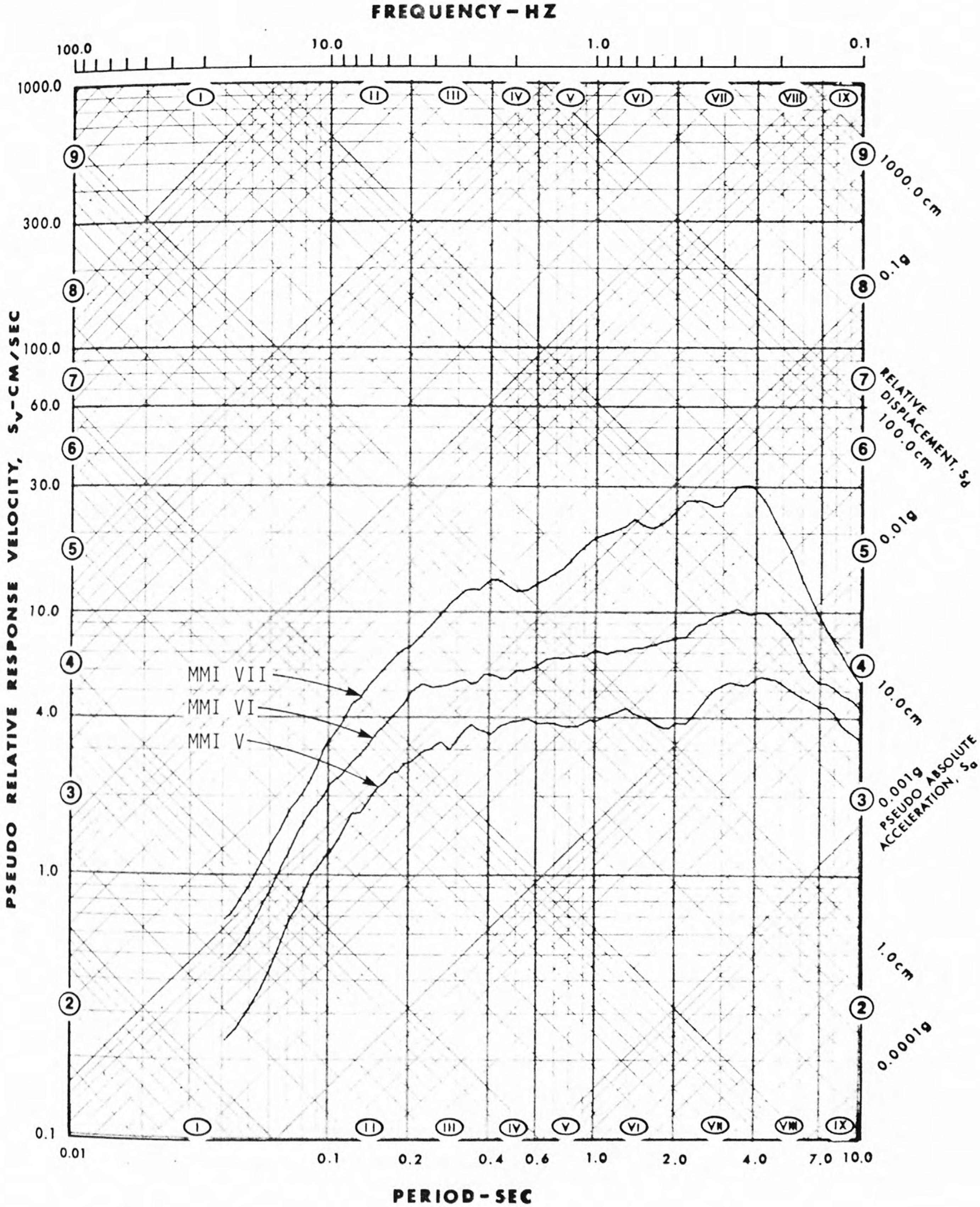


FIGURE 4.4 LOGNORMAL 84TH-PERCENTILE VERTICAL SPECTRA FOR MMI V, VI, AND VII - 5% DAMPING

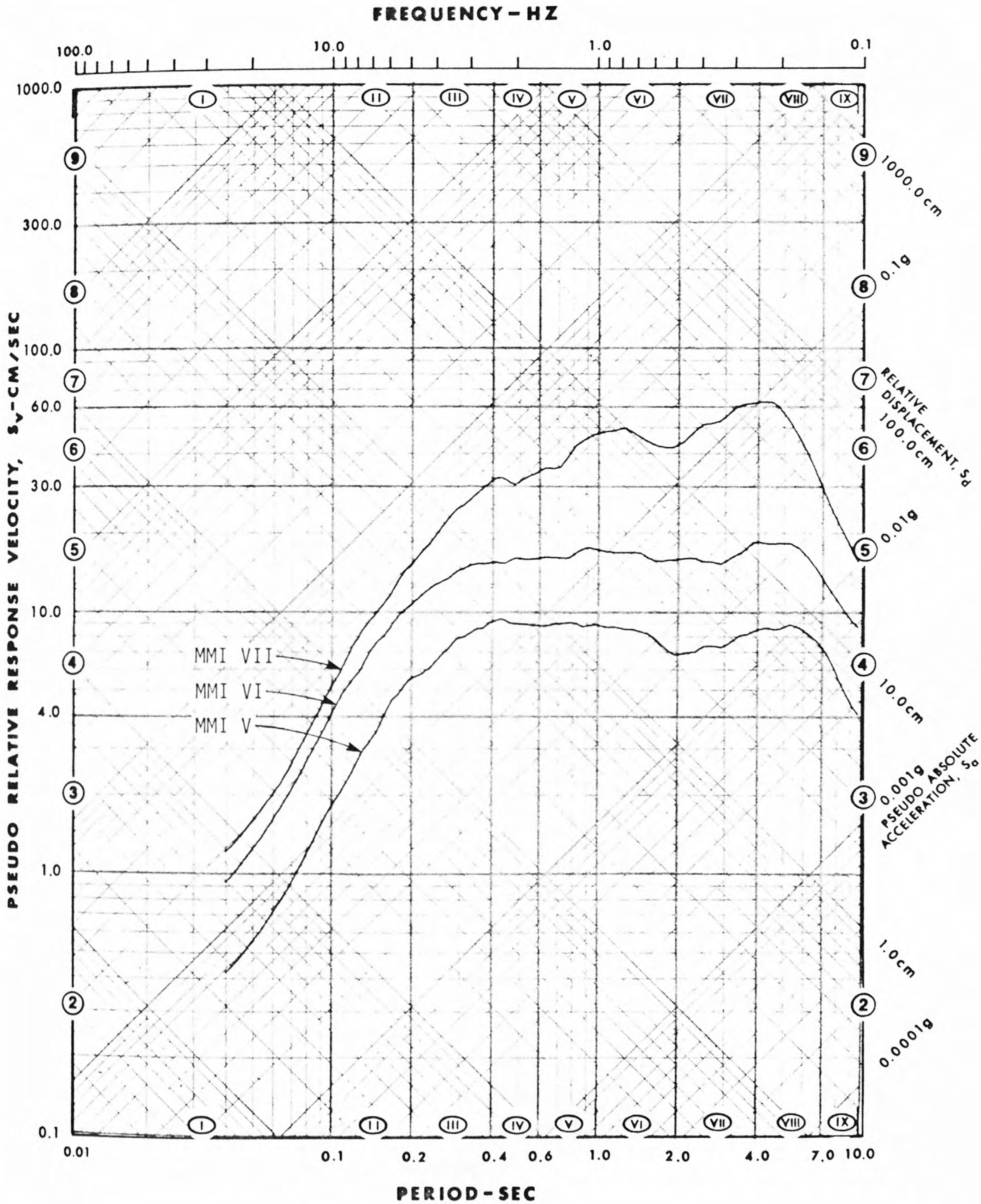


FIGURE 4.5 LOGNORMAL 84TH-PERCENTILE HORIZONTAL SPECTRA FOR MMI V, VI, AND VII - 5% DAMPING

5. THEORETICAL MOTION-DAMAGE RELATIONSHIPS

5.1 Introduction

Structural analysis technology for prediction of earthquake response has advanced significantly in the past 15 years. Linear dynamic response analyses are commonplace today, and nonlinear dynamic response analyses are feasible for simple structures. These procedures are used for calculating structure member stresses and strains and are correspondingly used in design (i.e., structure members are sized by comparing calculated stresses and strains with those allowed by codes).

Unfortunately, the codes do not specify the degree of damage associated with various prescribed stresses and strains. In addition, the stated philosophy of contemporary earthquake design procedures (Structural Engineers Association of California, 1979) is that structures are expected to be damaged during major earthquakes but that collapse is to be precluded by using the recommendations prescribed. Finally, because structures are expected to be damaged during major earthquakes, they will respond nonlinearly. Therefore, nonlinear response considerations must be included in any attempt to relate response and damage.

As indicated in Chapter 1, various researchers have begun developing methods for estimating damage to structures. A few have used structural response analysis concepts, but much work is still needed to develop a comprehensive methodology. Task IV of this project is directed toward furthering earthquake engineering technology by developing methods for predicting damage using fundamental structural response analysis concepts. Only through such developments will structural designers come to understand what amplitude of response causes a particular degree of damage.

The work of this task is divided into two major activities: (1) detailed analysis of high-rise buildings damaged by earthquakes and (2) approximate theoretical motion-damage relationships.

The first activity was conducted to facilitate a detailed understanding of the manner in which a structure responds while experiencing damage. Nonlinear response is particularly important in this regard. The second activity is an attempt at consolidating various types of information currently available from various sources in order to establish a theoretical basis for predicting damage.

5.2 Detailed Response Analysis of Damaged Buildings

The overall objective of this study is to predict and evaluate the correlation of ground motion and damage to high-rise buildings. To help accomplish this goal, detailed structure response and damage data from high-rise buildings that were instrumented at the time of damaging earthquakes is being used to relate building damage and seismic motion.

The first buildings to be analyzed were the Bank of California Building and two Holiday Inn buildings, all of which experienced both structural and nonstructural damage during the San Fernando earthquake of February 9, 1971 (John A. Blume & Associates, 1973). The roof, an intermediate floor, and the ground floor of the buildings were equipped with SMA-1 strong-motion accelerographs.

The first step of this study was to match the response time histories recorded on an intermediate floor and the roof of the building with response time histories calculated using the recorded first-floor ground acceleration. Because damage may have significantly changed structural behavior, record analyses were necessary to detect nonlinearities in the structural responses. In order to reasonably match the recorded and calculated response time histories, certain changes in the analysis models had to be made and justified.

5.3 Detailed Response Analysis of the Bank of California Building

5.3.1 Building Description. The Bank of California Building is a 12-story reinforced concrete structure located in the Sherman Oaks district of Los Angeles, California. The site is approximately 17 miles south of the epicenter of the San Fernando earthquake.

Typical plan dimensions of the floors are 60 ft by 161 ft, except at the first floor, where plan dimensions are 90 ft by 161 ft. Typical story height is 13 ft, with the exception of a 16-ft height for the first story. A mechanical penthouse covers 30% of the main roof area, which stands 159 ft above the ground floor. Typical plans and sections are shown in Figures 5.1 through 5.4.

The structure was designed in 1969, under the requirements of the 1968 Los Angeles city building code, and was completed in 1970 at a cost of $4 million. Except at the lower levels, where some shear walls are located, lateral forces in both directions are resisted by moment-resisting reinforced concrete frames consisting of columns and girders. All the moment-resisting frames on the exterior extend to the full height of the structure. However, interior frames in both directions were designed to be moment-resisting only from the ground to the third floor. Above the third floor, interior columns continue to the roof and are considered to be non-moment-resisting because beams framing into these columns are merely wide joists, with reinforcement designed to carry only vertical loads.

Two shear walls, each two stories high, rise along column line 1, A 1-story-high separation wall rises along column line 4, adjacent to the property line. This wall serves as a shear wall. Locations of these shear walls may be found on the ground-floor plan (Figure 5.1).

Spandrel beams are set back above the third floor 16-1/2 in. from the column lines of the longitudinal frame along column line 1 and from the column lines of the transverse frames along column lines A and I. This offset is 43 in. at the typical second-floor girders. In addition, along column line 3 between the ground floor and the second floor, alternate columns have been omitted between lines C and H.

Typical floor construction consists of a 4-1/2-in. slab on a 17-in.-deep pan-joist system spanning from girder to girder. Lightweight concrete was used for all floor and girder construction. Rectangular tied columns, built with regular-weight stone-aggregate concrete, support the girders. The properties of the materials used in the construction are given in Tables 5.1 and 5.2.

Soil at the site is primarily silt and silty sand, with lesser deposits of clay and sand. A typical soil boring log is shown in Figure 5.5. The shear wave velocities of the subsurface materials were investigated to a depth of 320 ft by conventional downhole geophysical methods (Figure 5.6). Inhole testing was accomplished by measuring the travel time of polarized shear waves from a source at the surface to three multiple-component geophones coupled inside the casing. The testing methods are presented in the report by Shannon & Wilson (1978).

Since silt and silty sand, the upper soils at the site, are only moderately firm and would tend to become weaker and more compressible when wet, pile foundations were provided. Column footings and pile foundations are shown on the foundation plan in John A. Blume & Associates (1973). Piles shown on the foundation plan are drilled and cast-in-place concrete piles 35 to 50 ft long.

Earthquake Damage. The San Fernando earthquake caused both structural and nonstructural damage to the Bank of California Building. All the damage was repairable. Structural damage consisted of both concrete cracking and spalling of columns, spandrel beams, girders, and a parapet wall at the first story. Nonstructural damage to partitions, ceilings, stairwells, stairs, mechanical equipment, and to some furnishings resulted. Repair costs were approximately $44,000.

Visible structural damage, generally, was slight and consisted almost entirely of minor cracking and spalling of concrete. Nevertheless, extensive cracking occurred in some areas, particularly at the exposed parts of girders between the spandrel beams and exterior columns along the second-floor level, where torsional effects were induced. At the penthouse level, slight spalling of patched concrete was observed where the exterior penthouse walls joined the penthouse columns. Between the sixth and eleventh floors, there was minor spalling on some east and west columns at the floor line on the inside face of the building.

Exterior columns typically spalled at the floor levels of the third, fourth, and fifth floors. Spalling also occurred on the interior face at the top of the columns on the east and west sides of the building. Some slight spalling of spandrel beams showed up near these columns. Although interior columns, at the same levels, experienced no damage, a series of cracks occurred in the slab around the columns.

The typical spandrel-beam-column detail, which facilitated construction from the fourth floor to the roof, provided the main bottom reinforcing for the spandrel without confining stirrups within the column zone. Major joint rotation and column or spandrel-beam spalling occurred in areas where this detail was used.

At the second floor, the typical floor plan changes. Some of the exterior columns along column line 3 do not extend to the first floor below, and a 1-story low-roof structure is attached at the east side by means of a parapet. At the juncture of the parapet and office building columns, cracking occurred because the seismic separation joint was poured monolithically during construction. Girders projecting beyond the spandrel line were damaged at the second-floor level. The torsion induced in girders between spandrel beams and columns on the north and south sides caused major cracking in these zones. Girders on the west side showed some bending cracks in the same zones.

The east wall of the 1-story structure showed horizontal cracks at construction joints, but no other damage or shear cracks were observed. The drilled and cast-in-place pile foundation seemed to perform satisfactorily. No noticeable foundation distress, settlement, or overturning effects were observed.

Nonstructural damage was widespread between the sixth and eleventh floors. The east-west gypsum wallboard on steel stud partitions was fastened to both the floor and the suspended ceiling. As the partitions pulled away from the east and west exterior columns, ceiling tiles fell out.

In the mechanical penthouse, a compressor mounted on an inertia block came off its spring support. Other equipment, such as the cooling tower and chiller units, were little affected.

5.3.2 Instrumentation. Three SMA-1 triaxial accelerographs, serial No. 185, manufactured by Kinemetrics, Inc., were the strong-motion instruments used in this building. The station was established on February 1, 1971, by the Seismological Field Survey Unit of NOAA's National Ocean Survey. It is listed by Perez and Schwartz (1973) as USGS Station No. 466. The accelerometers have the following specifications:

Component	Orientation	Sensitivity (cm/g)	Period (sec)
Longitudinal	N 11° E	1.98	0.041
Vertical	Down	1.70	0.038
Transverse	N 79° W	1.78	0.039

The locations of the three SMA-1 triaxial accelerographs in the building--on the roof, the seventh floor, and the ground floor--can be found on the floor plans in Figures 5.1 to 5.4.

Approximately 28 sec of motion of the San Fernando earthquake were recorded. The recorded time histories and associated response spectra are presented in Figures 5.7 to 5.9. These time histories and response spectra have been digitized by the California Institute of Technology.

5.3.3 Record Analysis. The recorded time histories at the three different floor levels of the Bank of California Building were used as original data for extracting the building's natural frequencies, damping ratios, and mode shapes in the elastic range. While the structure was being damaged during the earthquake, the structural response became nonlinear. In other words, during the earthquake, the structural frequencies and damping ratios changed. The relationship between the ground time histories and the response time histories can be represented by instantaneous transfer functions of the structural response.

The transfer function TF_j at node j can be written as:

$$TF_j(i\omega) = \frac{X_j(i\omega)}{F(i\omega)} \tag{5.1}$$

where:

ω = circular frequency

$X_j(i\omega)$ = Fourier transform of the recorded relative response at node j

$F(i\omega)$ = Fourier transform of the forcing function, i.e., the recorded ground motion

i = imaginary constant, $i^2 = -1$

The response time history at the seventh floor in the transverse direction was selected for transfer function calculation because the mass and the rigidity centers are approximately coincident, which eliminates, or at least minimizes, the torsional effects during the earthquake.

Two different approaches were used for the calculation of transfer functions. In the first approach, 10-sec segments of the time histories were used to generate the transfer function. If the structure stays within the elastic range, the dominant structural frequencies should be steady for all segments. To eliminate the instability in numerical analysis, time-history segments were overlapped. The plots of the variation of fundamental period shown in Figures 5.10 (cases 1 through 7) and 5.11 show that the structural fundamental period was approximately 1.8 sec and shifted to around 3.5 sec at about 22 sec. This indicates that the structural members were damaged at about this time.

In the second approach, the transfer function was calculated for the time interval from the beginning of the earthquake up to certain chosen times in the time history. Again, it is possible to conclude from the results (Figure 5.10, cases A through G) that nonlinearity occurred after the first 22 sec of the earthquake.

Figure 5.12 shows plots of the transfer functions for each case in Figure 5.10. A smoothing technique was employed in the generation of the transfer functions to eliminate possible noises recorded in the time histories.

5.3.4 Detailed Structural Analysis. Several mathematical models were used in determining the dynamic properties of the structure. Mode shapes, periods, and participation factors were calculated for each model using the TABS

(Wilson and Dovey, 1972) computer progrem. Two of these models are described below.

The first structural model attempts to duplicate the structure's response in its initial stage of vibration, which is considered to be within the range of linear elastic material properties. Therefore, all frames, including those designed to carry only vertical forces, were modeled.

In the longitudinal direction, three 12-story frames, one large shear wall, and two small pieces of 2-story shear walls contribute to the lateral stiffness of the structure. The frames stand on column lines 1, 2, and 3. The interior frame on line 2 has an interior bay width twice as large as those of the exterior frames on lines 1 and 3. A 1-story single-piece shear wall runs along column line 4, while the other two 2-story shear walls, each with the width of a bay, stand on line 1.

In the transverse direction, there are nine 12-story frames on column lines A to I. With the exception of the exterior frames on lines A and I, which have five typical bays 12 ft in width, each frame has two bays 36 ft and 24 ft in width. These frames contribute to the lateral stiffness of the structure. The principal axes of the central columns of the frames on lines D, E, and F are different from those of the exterior columns.

The stiffness of the pan-joist floor systems spanning from girder to girder was not taken into account in either direction. However, because TABS assumes rigid diaphragms, the in-plane stiffness of the floor system was treated as infinite.

The resultant dynamic properties were, in turn, used as input to another computer program for generating response time histories and graphic plots. These theoretical plots are shown in Figure 5.13 along with the time histories actually recorded during the earthquake. Structural mode shapes and periods are shown in Figure 5.14.

The second model includes only those structural systems that were designed specifically for resisting lateral forces. It was developed in an effort to reconcile structural responses with actual recordings in the last stage of vibration, when the building was already damaged.

In this model, two frames, one shear wall, and two small 2-story shear walls constitute the whole lateral-load-resisting system in the longitudinal direction. The frames are on lines 1 and 3, and the frame on line 1 contains two 2-story shear walls 11-1/2 ft in width. The 1-story-high shear wall on line 4 remains the same as in model 1.

In the transverse direction, only two exterior frames, those on column lines A and I, were considered as a lateral-load-resisting system.

Elevation views of the four main frames are shown in Figures 5.15 through 5.17. Frames 1 and 3 were used to represent moment-resisting frames in the longitudinal direction for both Model 1 and Model 2, while frames A and I were used in the transverse direction.

Analysis of Model 2 showed a fundamental period of 3.0 sec, which closely approximates the 3.3 sec measured in the building. Figure 5.18 shows the analytical results and recorded time histories for both the longitudinal and the transverse directions.

5.3.5 Study of Interstory Drifts. Dynamic analyses of the two computer models were performed using TABS. The results of these analyses, such as structural frequencies, mode shapes, and participation factors, were used in calculating interstory drifts due to the earthquake.

For Model 1, which simulates linear response of this structure, damping ratios of 3% and 5% of critical damping were used for the fundamental mode and higher modes, respectively. Because it was concluded that the structure frequencies shifted at about 22 sec into the earthquake, information shown on plots after 22 sec for Model 1 is inconsequential.

For Model 2, a damping ratio of 5% of critical damping was used for the fundamental mode, and 7% was used for higher modes in order to reconcile the theoretical response with the recorded nonlinear response time histories. To avoid interference of the linear response with the nonlinear response, ground motion from 0 to 18 sec was truncated: Model 2 was subjected to 40 sec of ground acceleration motion with 18 sec of zero motion.

Figure 5.19 shows the maximum interstory drifts throughout the height of the building for both Model 1 and Model 2.

Average interstory drifts between all floors, for both models, were also calculated as follows:

$$\overline{\Delta u} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} \Delta u_i^2} \qquad (5.2)$$

where:

N = number of stories

Δu_i = interstory drift at ith floor level

$\overline{\Delta u}$ = quantity describing average interstory drift

Figures 5.20 and 5.21 show plots of average interstory drifts calculated using Equation (5.2) along the building height for Models 1 and 2, respectively.

5.4 Detailed Response Analysis of the Holiday Inn Building

5.4.1 Building Description. The Holiday Inn on Orion Avenue is a 7-story reinforced concrete structure with typical plan dimensions of about 62 ft by 160 ft. The structure is located about 13 miles south of the epicenter of the San Fernando earthquake. It was designed in 1965 and constructed in 1966 at a cost of roughly $1.3 million. It is essentially identical to the Holiday Inn on Marengo Street, for which the dynamic analysis is in progress.

Except for two small areas of the ground floor, which are covered by one-story canopies, the plan configurations of each floor, including the roof, are the same. The typical framing consists of columns spaced at 20-ft centers in the transverse direction and 19-ft centers in the longitudinal direction. Spandrel beams surround the perimeter of the structure. The floor system is a reinforced concrete flat slab, 10 in. thick at the second floor, 8-1/2 in. thick at the third to seventh floors, and 8 in. thick at the roof. A penthouse with mechanical equipment covers approximately 10% of the roof area.

Interior partitions, in general, are gypsum wallboard on metal studs. The north side of the building has four bays of brick masonry walls located between the ground floor and the second floor at the east end of the structure. Nominal 1-in. expansion joints separate these walls from the exterior columns, and nominal 1/2-in. expansion joints separate them from the underside of the second-floor spandrels.

5.4.2 Earthquake Damage. Costs for repairing the damage caused by the earthquake were approximately $145,000. Structural repair amounted to less than $2,000; the remainder was for nonstructural damage.

Nonstructural damage was observed in almost every guest room. About 80% of the repair cost was spent on drywall partitions, bathroom tiles, and plumbing fixtures. The damage was most severe on the second and third floors and least severe on the sixth and seventh floors.

5.4.3 Record Analysis. The recorded acceleration time histories at three different floor levels of the building were used as original data for extracting the dynamic properties of the structure, such as vibration frequencies, damping ratios, and mode shapes, in the linear elastic range. However, since the structure was damaged during the earthquake, the structural response became nonlinear, which means that the structural frequencies and damping ratios changed within the duration of motion.

The instantaneous transfer function technique described for the Bank of California Building study was employed to estimate the time when the structure went into the nonlinear response stage by using successive windows along the entire length of the records. Variations in the dominant periods in the longitudinal and transverse directions can be seen in Figures 5.22 and 5.23, respectively.

For both the longitudinal and the transverse directions, the first peak of the transfer function plots shifted toward a lower period after about 15 to 20 sec, which implies that the structural responses stayed in the linear elastic range up to about 15 sec.

5.4.4 Study of Interstory Drift. Figures 5.24 through 5.27 are average interstory-drift plots for Models 1 and 2. The drift in the transverse direction reached its maximum value at about 12 sec; in the longitudinal direction, the maximum occurred at about 13 sec. Figures 5.28 and 5.29 show the maximum interstory drifts for each floor of the building.

The nonstructural damage reported for almost all guest rooms was most severe on the second and third floors and least severe on the sixth and seventh floors. The interstory drift plots reveal this phenomenon consistently. Lower floors experienced larger interstory displacement than upper floors did, reflecting the pattern of distribution of nonstructural damage caused by the earthquake.

5.4.5 Additional Studies. At the time of this report, work was continuing on a detailed nonlinear analysis of this Holiday Inn building; the other Holiday Inn building was in the stage of system identification.

5.5 Approximate Theoretical Motion-Damage Relationships

Any theoretically based damage prediction will have certain simplifying assumptions. Observations of damage from severe earthquakes commonly reveal that design inadequacies (e.g., inadequately tied structure members) are common causes of catastrophic failures. At the outset, it will be assumed that these inadequacies do not exist. After the basic development has been put forth, which puts high-rise damage into perspective, it will be seen that these types of inadequacies can be taken into account through statistical variability.

5.5.1 General Considerations for Predicting Damage. A comprehensive damage-prediction methodology should satisfy the following criteria:

- It should be based on sound theory and engineering principles, and it should relate to and use commonly known engineering analysis and design methods and parameters. This would allow improvements to be made easily in the damage-prediction methodology as the state of the art in engineering design and analysis advances. It would also facilitate the use of the methodology by most practicing professionals without requiring extensive experience with damage-prediction technology.

- The methodology should be easily adaptable to all engineering structures. This criterion will be satisfied if the methodology is based on engineering principles and uses commonly known design and analysis methods and parameters.
- The methodology should have provisions for using the data from actual earthquakes and from laboratory experiments as they become available.
- Uncertainties in the ground motion demand, the structural capacity, and the analytical methods and assumptions should be accounted for. This requires the methodology to adopt a probabilistic approach.
- The methodology should be able to be conveniently automated for use of computers in real-world applications. This requires a modular structuring of the methodology. Basic modules, for example, can be ground motion prediction, structure response prediction, structure (or component) inventory, basic damage prediction, and economic factors. In addition, a decision analysis module can also be incorporated. The structure response - damage relationships or data can be stored as a separate module or as a damage data library.

Existing methodologies that attempt to correlate directly a subjective ground motion intensity, such as MMI, with overall damage or loss do not satisfy most of these criteria. They basically provide an expanded definition of the subjective intensity scale they use, and, therefore, the predictions are as good as the experience and judgment of the person making the prediction.

Classification of structures presents another serious problem for some of the existing methodologies. Structures are usually classified as high-rise, low-rise, concrete, steel, etc. This type of classification is made necessary partly because these methodologies try to estimate the total damage to the structures under consideration without any regard to the components of the damage, i.e., damage to plaster, walls, columns, foundation, glass, or contents. No consensus exists among various investigators regarding how best to classify structures for damage prediction.

One possible way of resolving the structure classification problem is to estimate damage to components of structures rather than trying to estimate total damage. The number of components, such as beams, walls, and windows, used in constructing engineering structures are finite compared to the infinite number of combinations (i.e., independent structures) that can be built using these components. Also, extensive theoretical and experimental work has been done to study the behavior of components. If needed, further component data can easily and inexpensively be obtained from laboratory experiments. If such an approach is adopted, and the basic methodology is developed, the remaining task would be systematically to develop component damage behavior data and form a data base or library.

Considering the advantages and disadvantages of the various existing damage-prediction methodologies, the following methodology has been synthesized and is being further developed as part of the current study.

The damage to a structure will be obtained by adding the damage to its modules or pieces. For a high-rise building, the most convenient module is a story or floor level. For each module, the damage will consist of the summation of the damage to its components.

The suggested damage components for high-rise buildings are:

- Structural damage
  - -- Steel frame
  - -- Concrete frame
  - -- Concrete shear wall
  - -- Masonry shear wall
  - -- Braced frames
  - -- Foundations
- Nonstructural damage
  - -- Drywall partitions
  - -- Brick infill walls
  - -- Concrete block infill walls
  - -- Glazing
  - -- Cladding
  - -- Other (ceilings, mechanical and electrical equipment)
- Damage to contents

For each one of these damage components, motion-damage relationships will be developed. For all structural damage (except foundations), dry wall partitions, brick and concrete block walls, and glazing, the motion parameter should be the maximum interstory drift. For cladding and other nonstructural damage, maximum floor acceleration or velocity could be the motion parameter. Damage to contents should most likely be related to maximum floor accelerations.

The motion-damage relationships for brittle elements, such as glazing, can be derived from typical geometry and from design practices. Test results can be used to verify these calculations. For ductile components, the various threshold values can be calculated analytically or derived from experiments, or certain assumptions can be made for the motion-damage relationships. Eventually the objective would be to develop and improve a library of component motion-damage relationships. Information from the data base will be used to verify and improve these relationships.

All components at a floor level will have the same maximum response (or demand), which will be either the interstory drift at that level or the maximum velocity or acceleration. The response parameters will be obtained from a dynamic analysis of the structure for the given ground motion. It should be noted that the prediction of the floor response parameters through a dynamic analysis of the structure is quite independent of the damage-prediction methodology and can be accomplished by any qualified professional using various available structural analysis techniques, such as response spectrum analysis or time-history analysis. The analytical model and the analysis method used can be as sophisticated as judged to be necessary for the problem under consideration.

If the approach described is taken, statistics for the replacement values of building components, as precentages of the total value, must be collected for various types of buildings. Of course, for the study of an individual building, this information can be obtained from the contract documents or can be estimated by contractors.

A step-by-step application of this methodology would follow the flow chart shown in Figure 5.30.

5.5.2 Theoretical Motion-Damage Relationships for Various Types of Buildings. Using the concepts described in the preceding section, motion-damage relationships are presented here for various types of buildings. The specific methodology used is tentative and is subject to change during the third year of this project. The basic concepts are firm, however.

As stated in the preceding section, damage to most structural and nonstructural components of a building can be related to interstory drift, and component test data are available or can be estimated for many types of structure configurations. Accordingly, information such as that indicated in Table 5.3 can be determined.

The interstory drift information can then be used to calculate response spectrum amplitudes for the various drift limits as follows. From fundamental considerations of dynamic response analysis, and considering only the fundamental mode response:

$$\delta_{roof} = S_d \gamma \qquad (5.3)$$

where:

δ_{roof} = displacement of the roof relative to the ground

S_d = response spectrum displacement

γ = modal participation factor for fundamental mode with roof displacement normalized to unity

Then, assuming:

1. building period $T = 0.1N$, where N is the number of stories
2. straight-line mode shape

it follows that:

$$\Delta u = \frac{\delta_{roof}}{N} = \frac{\gamma S_d}{N} \qquad (5.4)$$

where:

Δu = average interstory drift

Finally:

$$S_d = \frac{N\Delta u}{\gamma} \tag{5.5}$$

Equation (5.5) facilitates plotting various interstory drift limits onto a response spectrum plot. In that form, damage can be crudely estimated by comparing a demand ground motion response spectrum with various structure component capacities developed from interstory drift limits. The calculated S_d values for the example assumed drift limits in Table 5.3 are given in Table 5.4. These S_d values are plotted in Figure 5.31, which also shows a plot of the 5%-damped response spectrum for the 1940 El Centro earthquake record.

5.6 Additional Studies for Project Completion

The following additional work will be performed in connection with this task during Phase III.

- More succinct conclusions relating to nonlinear response will be derived from the detailed response analyses (e.g., changes in frequency and damping).
- Structure component test data will be reviewed to complete response spectrum plots of damage for various types of structure framing and nonstructural elements. Plots for equipment damage will be attempted. Variability of damage will be established where possible.

TABLE 5.1

BANK OF CALIFORNIA BUILDING - PROPERTIES OF CONCRETE

Member Type	Aggregates	Unit Weight (pcf)	f'_c (psi)	E (psi)
Columns	regular weight	150	4,000	3.9×10^6
Beams, Joists, and Slabs	lightweight	110	3,000	2.1×10^6
Foundation	regular weight	150	3,000	3.3×10^6

TABLE 5.2

BANK OF CALIFORNIA BUILDING -

PROPERTIES OF REINFORCING BARS

Location	Grade	f_y (ksi)	E (psi)
Walls, Slabs, Ties, and Stirrups	40	40	29×10^6
All Other	60	60	29×10^6

TABLE 5.3

INTERSTORY DRIFT LIMITS FOR VARIOUS STRUCTURE TYPES

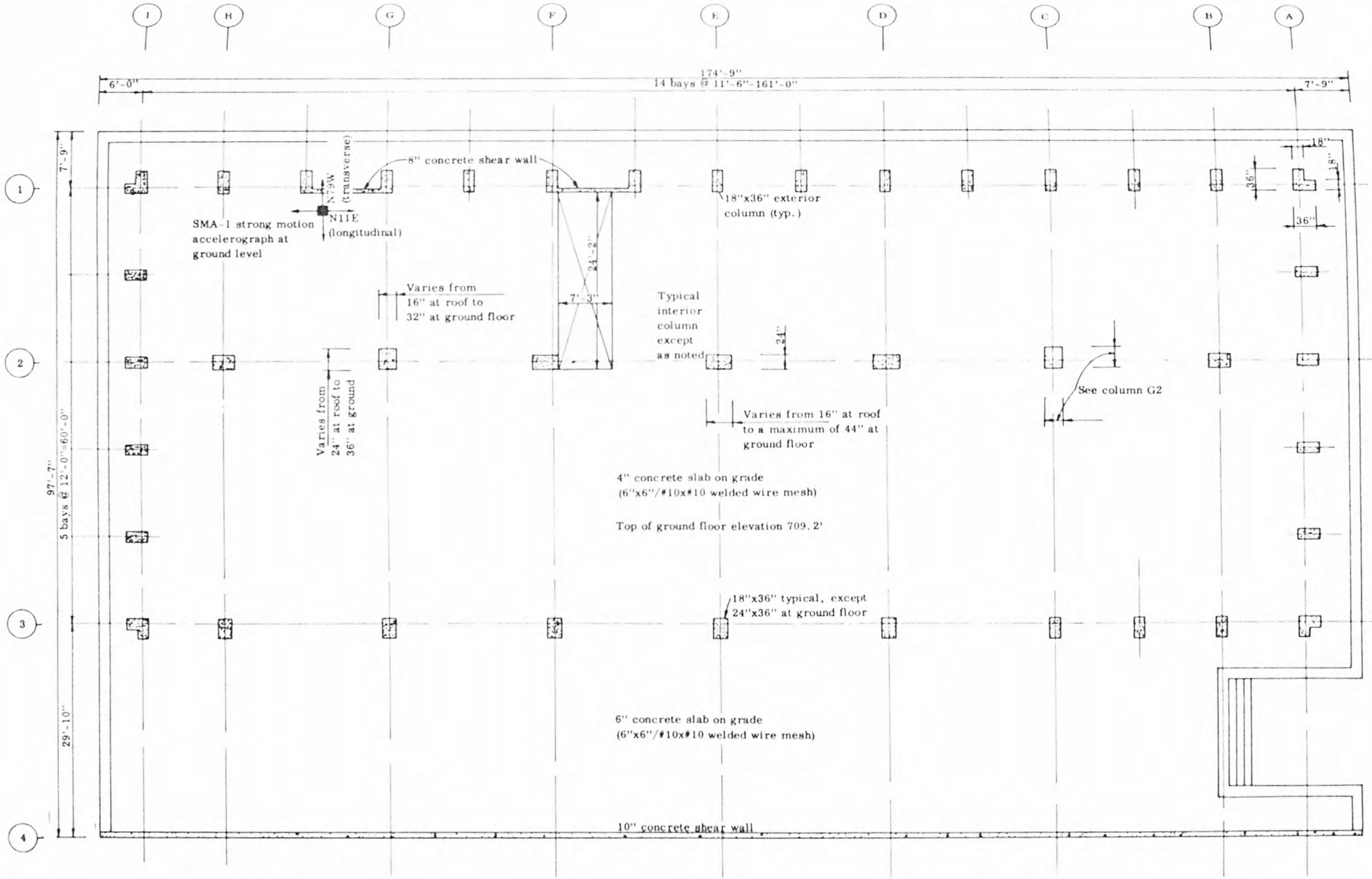
Lateral-Force-Resisting System	Interstory Drift (cm)		
	Observable Damage, Δu_1	Yield Capacity, Δu_2	Ultimate Capacity, Δu_3
Wood Frame			
Unreinforced Masonry			
Reinforced Masonry			
Reinforced Concrete Frame	.25*	1.0*	5.0*
Reinforced Concrete Shear Wall			
Steel Frame			
Steel Braced Frame			
Steel Eccentrically Braced Frame			

*Values assumed for this example. As further data are obtained, appropriate values can be filled in for each structure type.

TABLE 5.4

RESPONSE SPECTRUM DISPLACEMENTS FOR VARIOUS DAMAGE THRESHOLDS AND BUILDING HEIGHTS

Number of Stories, N	T (sec)	γ	$S_d = \frac{N\Delta u}{\gamma}$		
			Observable Damage	Yield Capacity	Ultimate Capacity
1	0.1	1.0	0.25	1.0	5.0
2	0.2	1.2	0.42	1.67	8.3
3	0.3	1.29	0.58	2.33	11.6
4	0.4	1.33	0.75	3.01	15.0
5	0.5	1.36	0.92	3.68	18.4
10	1.0	1.43	1.75	6.99	35.0
20	2.0	1.46	3.42	13.70	68.5
30	3.0	1.48	5.06	20.27	101.4
40	4.0	≈1.5	6.67	26.67	133.3



Source: John A. Blume & Associates (1973)

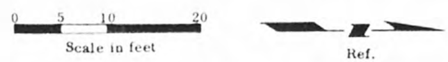
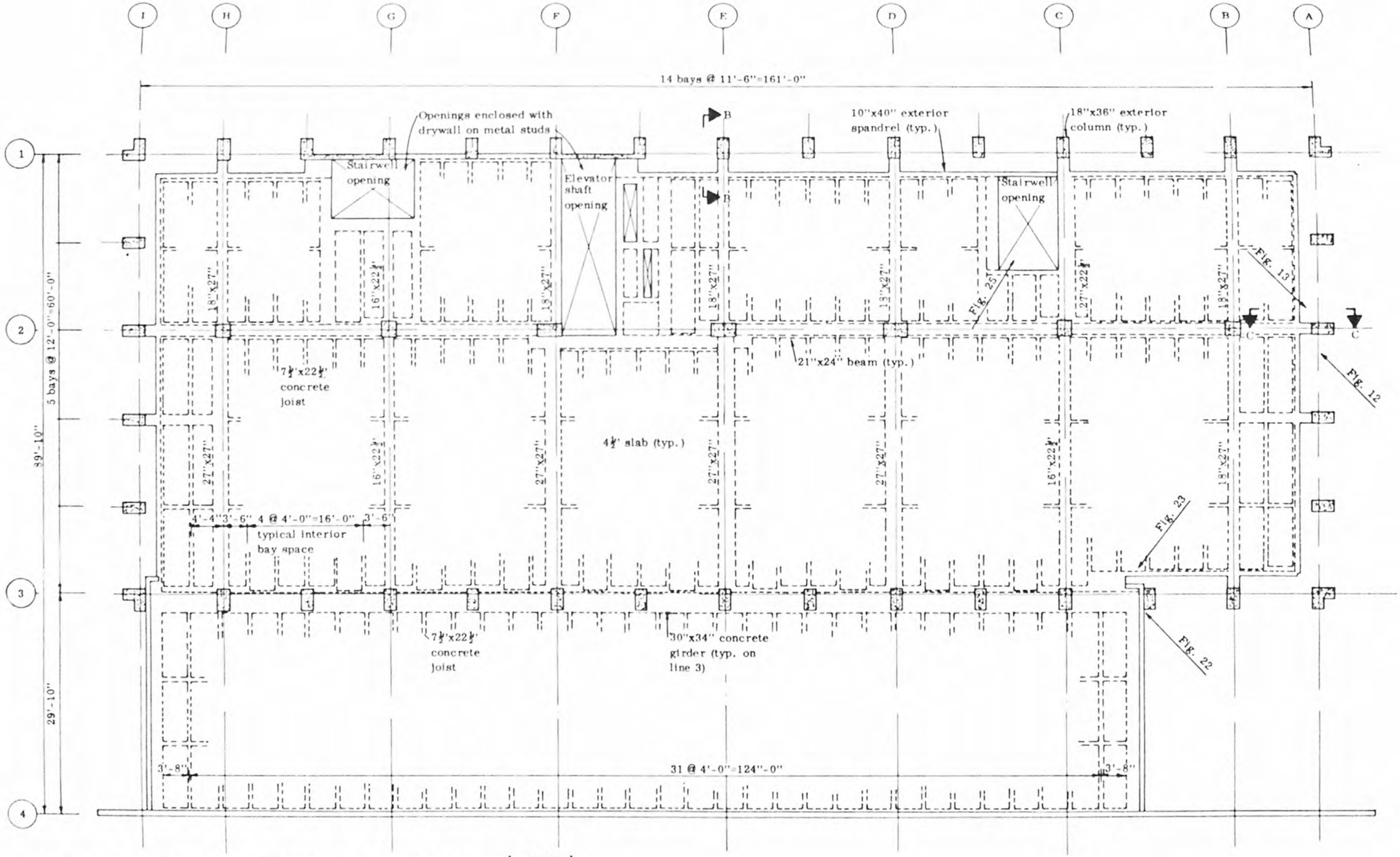
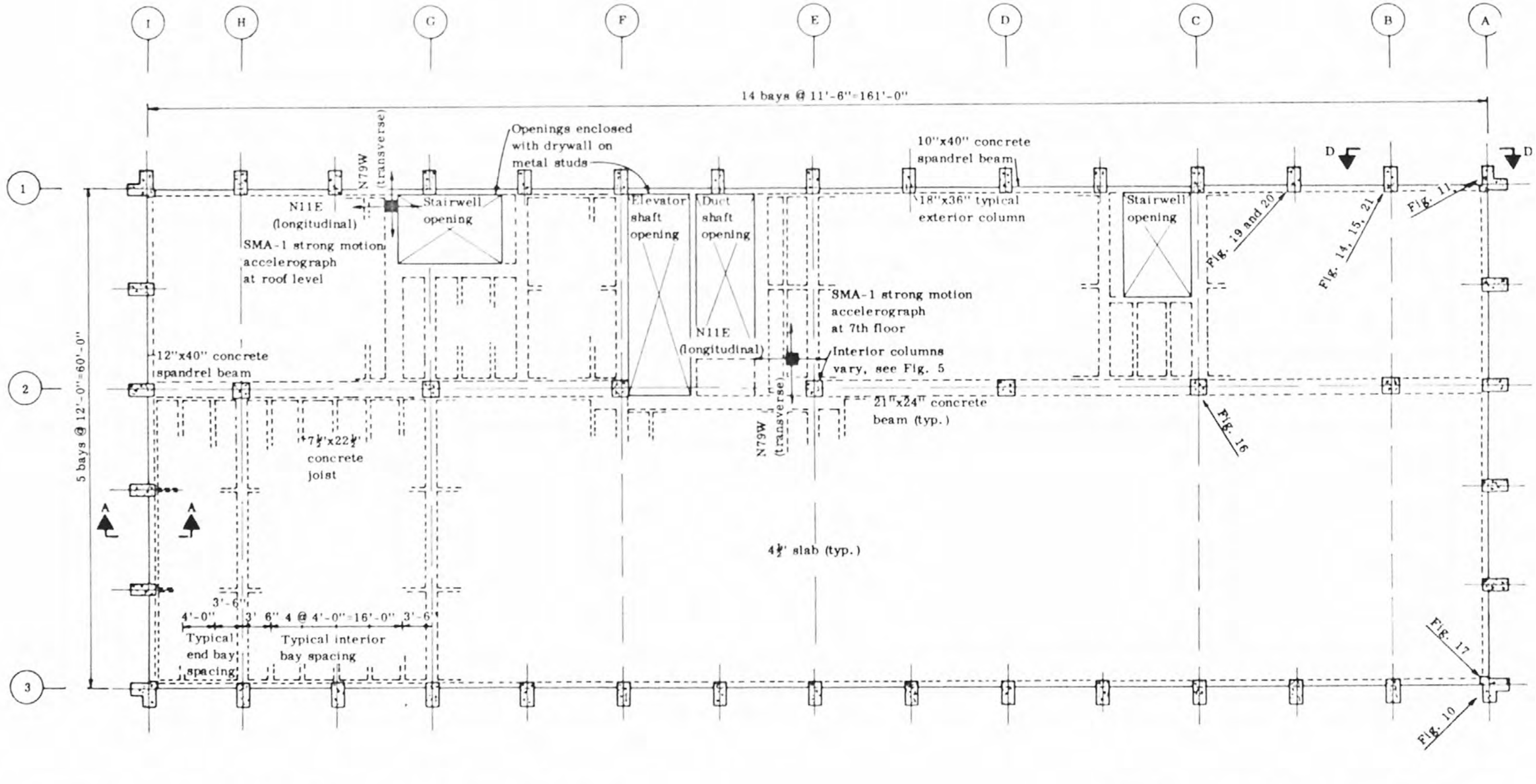


FIGURE 5.1 BANK OF CALIFORNIA BUILDING: GROUND-FLOOR PLAN



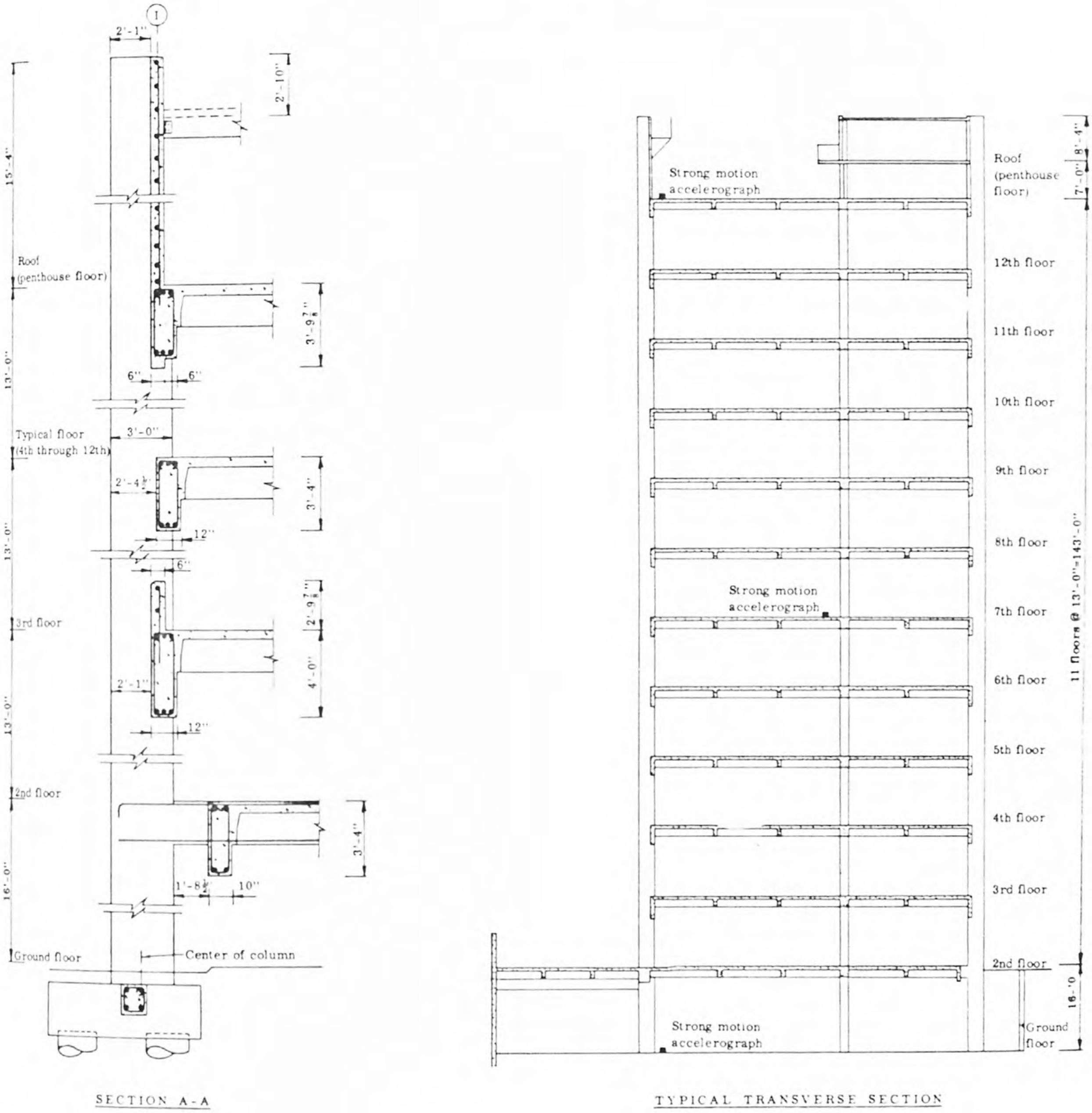
Source: John A. Blume & Associates (1973)

FIGURE 5.2 BANK OF CALIFORNIA BUILDING: SECOND-FLOOR PLAN



Source: John A. Blume & Associates (1973)

FIGURE 5.3 BANK OF CALIFORNIA BUILDING: TYPICAL FLOOR PLAN, THIRD THROUGH TWELFTH FLOORS



Source: John A. Blume & Associates (1973)

FIGURE 5.4 BANK OF CALIFORNIA BUILDING: TYPICAL TRANSVERSE SECTION AND STRUCTURAL DETAILS

LOG OF BORING

BORING NO. A-11 (THIS REPORT)

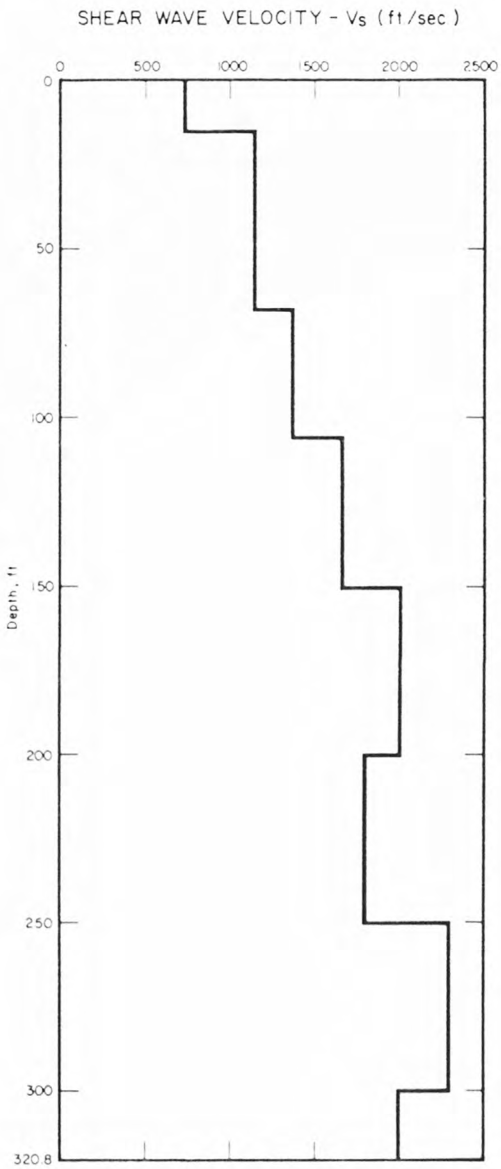
Source of Data* LeRoy Crandall & Assoc.		Sheet 1 of 1	
Building Address 15250 Ventura Blvd., Los Angeles		Boring No. Unknown	
Boring Location approx. 265' S. of Ventura Blvd. & 380' W. of Columbus Ave.			
Equipment Used 18" diameter bucket			
Elevation 709.3'	Total Depth 57.5'	Date Drilled January 18, 1969	

Depth in Feet	Log	United Soil Class.	Classification of Materials (Description)	Moisture Content %	Dry Density lbs./cu.ft.	Shear Strength kips/sq.ft.
		SM	Dark brown, silty, fine SAND	8.6	85	
		ML	Light brown to brown, sandy SILT; some roots, few shale gravel, clayey	13.9	89	
				11.0	88	
				11.1	90	
10				10.9	92	
				15.9	92	
		ML	Brown, clayey SILT; alkali streaks	16.3	95	
			Light brown, layer of sandy SILT; few shale gravel	12.8	96	
				12.5	90	
20				12.8	97	
		ML	Light brown, sandy SILT			
		ML	Brown, clayey SILT	17.4	88	
30				13.9	98	
			Light brown, layer of sandy SILT; few shale gravel, some alkali	13.3	96	
40		CL	Light brown, silty CLAY	16.8	114	
50		ML	Brown, sandy SILT	18.6	108	
			Layers of sand	22.4	104	
60			Bottom of hole 57.5"			
			NOTE: Water encountered at a depth of 56"; water level at a depth of 53.5'. No caving.			

Note: *Original foundation engineering data has been modified for use in this report. Modifications include rewording of descriptions, omission of data, and format changes.	BORING NO. (THIS REPORT) A-11

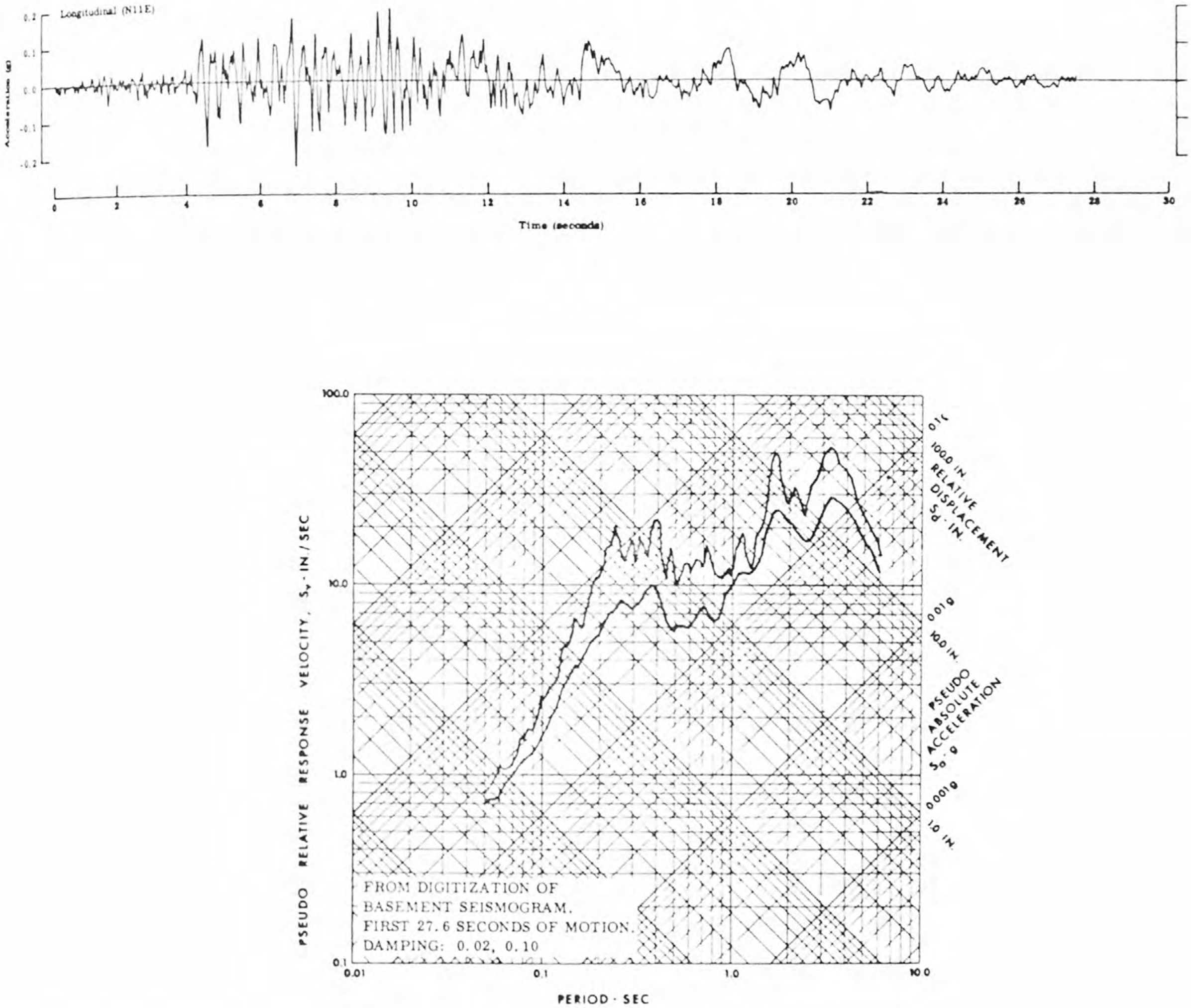
Source: Shannon & Wilson (1978)

FIGURE 5.5 TYPICAL SOIL BORING LOG AT THE SITE OF THE BANK OF CALIFORNIA BUILDING



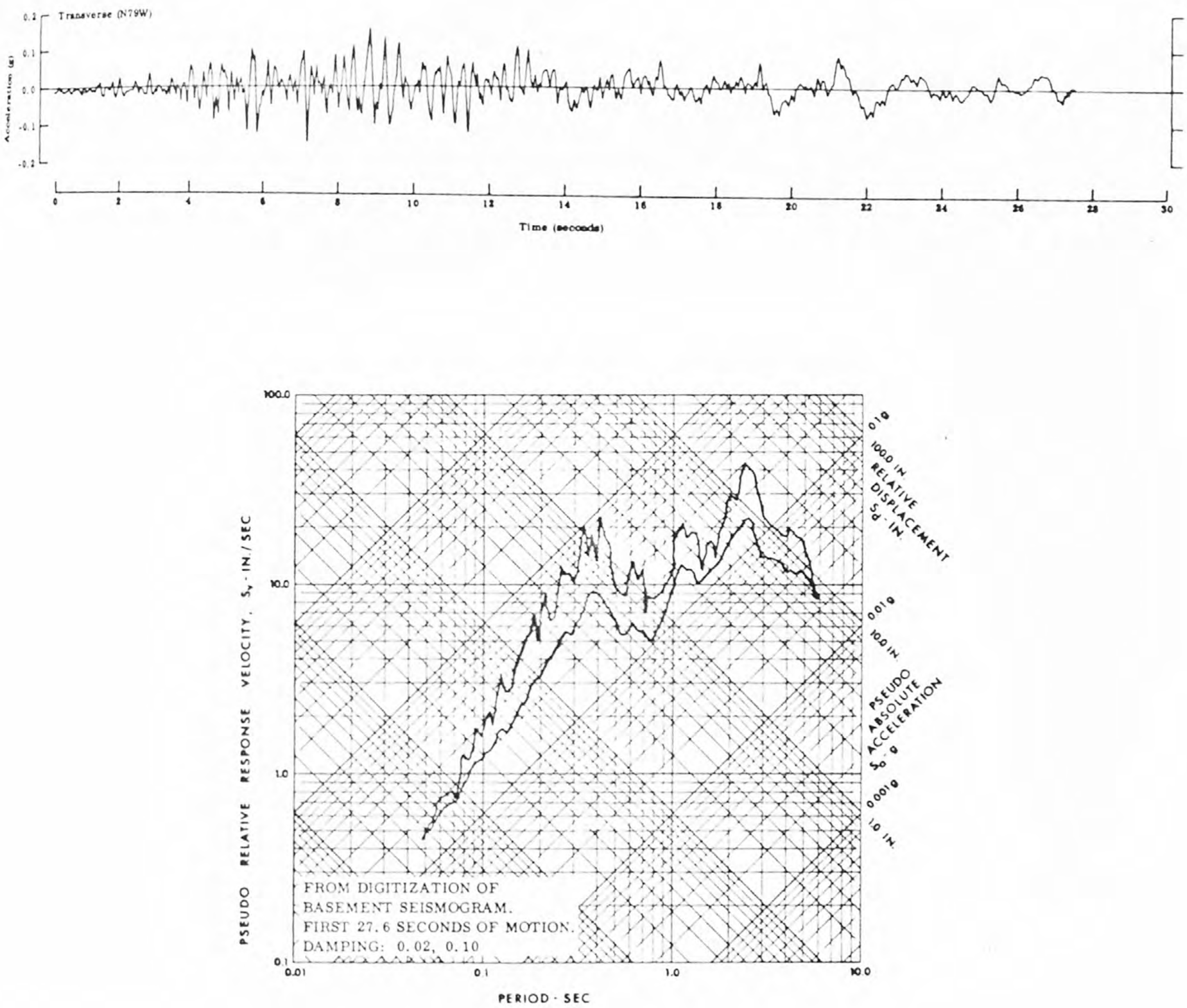
Source: Shannon & Wilson (1978)

FIGURE 5.6 SHEAR WAVE VELOCITY AT THE SITE OF THE BANK OF CALIFORNIA BUILDING



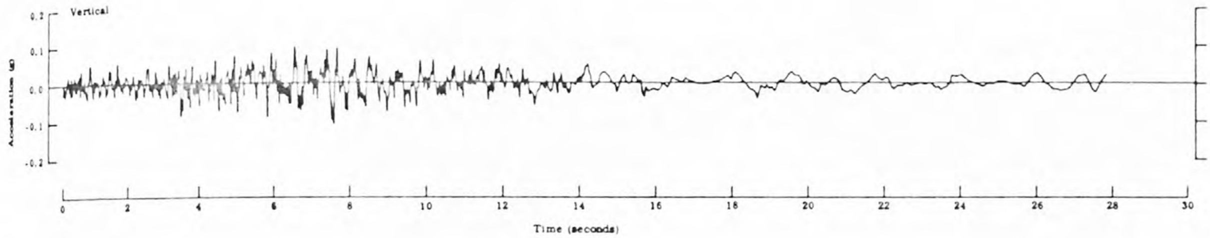
Source: John A. Blume & Associates (1973)

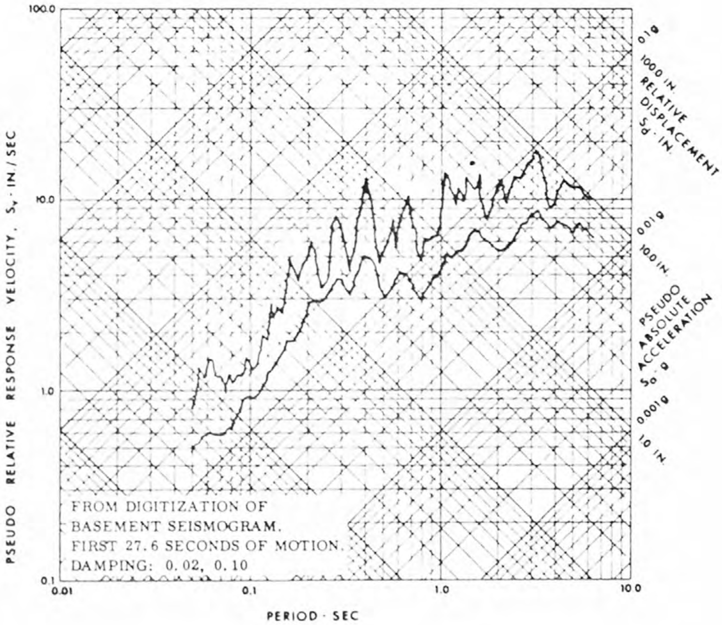
FIGURE 5.7 BANK OF CALIFORNIA BUILDING, GROUND FLOOR: RECORDED LONGITUDINAL ACCELERATION TIME HISTORY AND ASSOCIATED RESPONSE SPECTRA



Source: John A. Blume & Associates (1973)

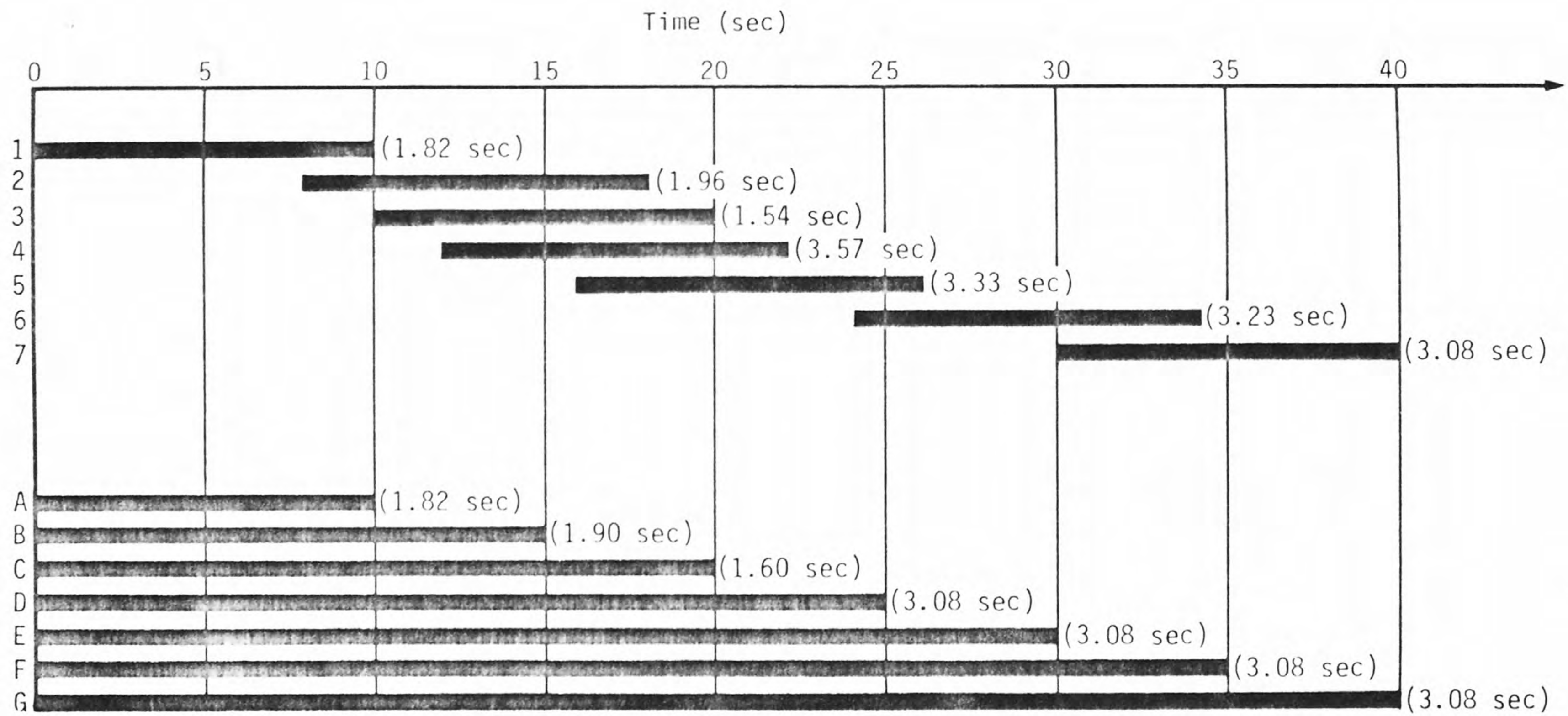
FIGURE 5.8 BANK OF CALIFORNIA BUILDING, GROUND FLOOR: RECORDED TRANSVERSE ACCELERATION TIME HISTORY AND ASSOCIATED RESPONSE SPECTRA





Source: John A. Blume & Associates (1973)

FIGURE 5.9 BANK OF CALIFORNIA BUILDING, GROUND FLOOR: RECORDED VERTICAL ACCELERATION TIME HISTORY AND ASSOCIATED RESPONSE SPECTRA



Note: Fundamental periods are shown in parentheses. Instantaneous transfer functions for cases 1 through 7 and A through G are given in Figure 5.12.

FIGURE 5.10 BANK OF CALIFORNIA BUILDING: FUNDAMENTAL PERIODS OBTAINED FROM INSTANTANEOUS TRANSFER FUNCTIONS

7th Floor, Transverse Direction

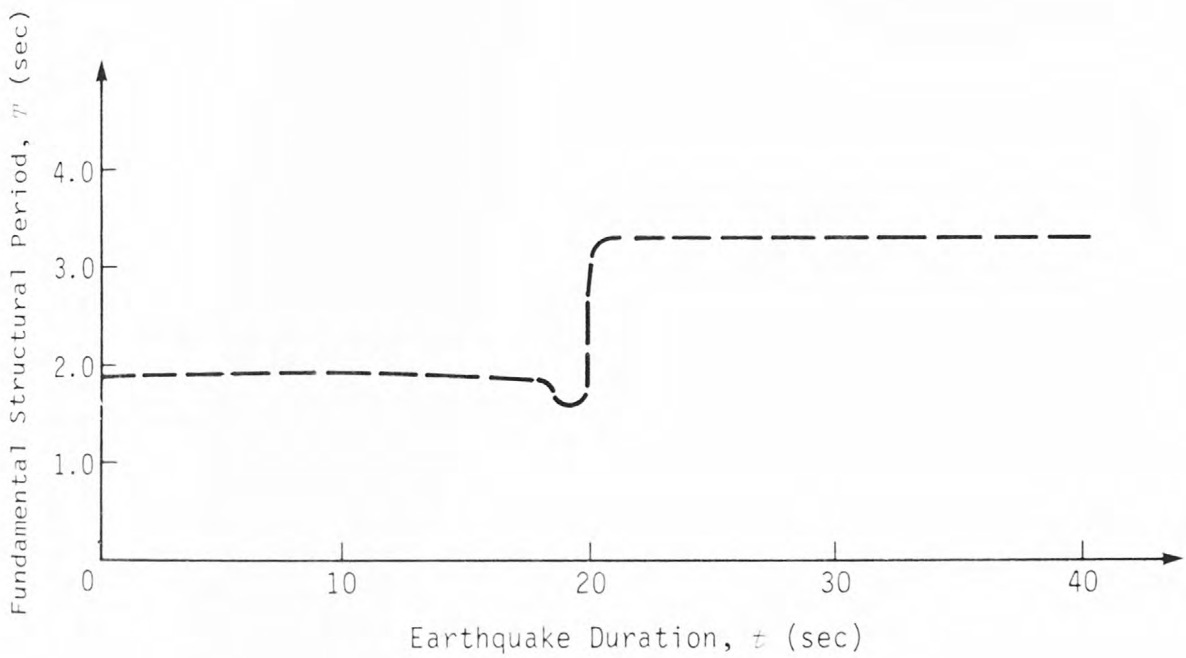


FIGURE 5.11 BANK OF CALIFORNIA BUILDING: CHANGE OF FUNDAMENTAL PERIODS DURING EARTHQUAKE EXCITATION

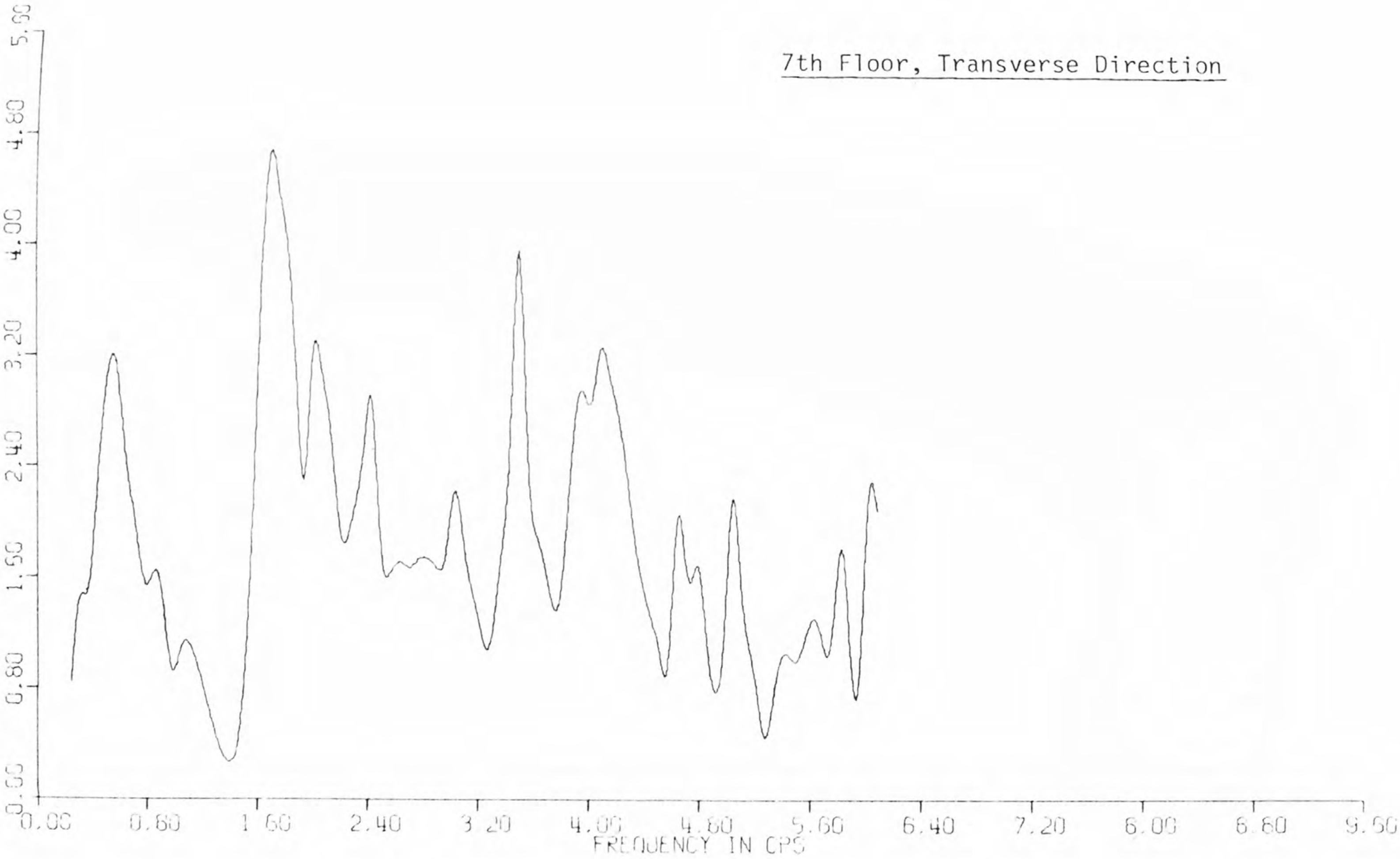


FIGURE 5.12a BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASES 1 and A

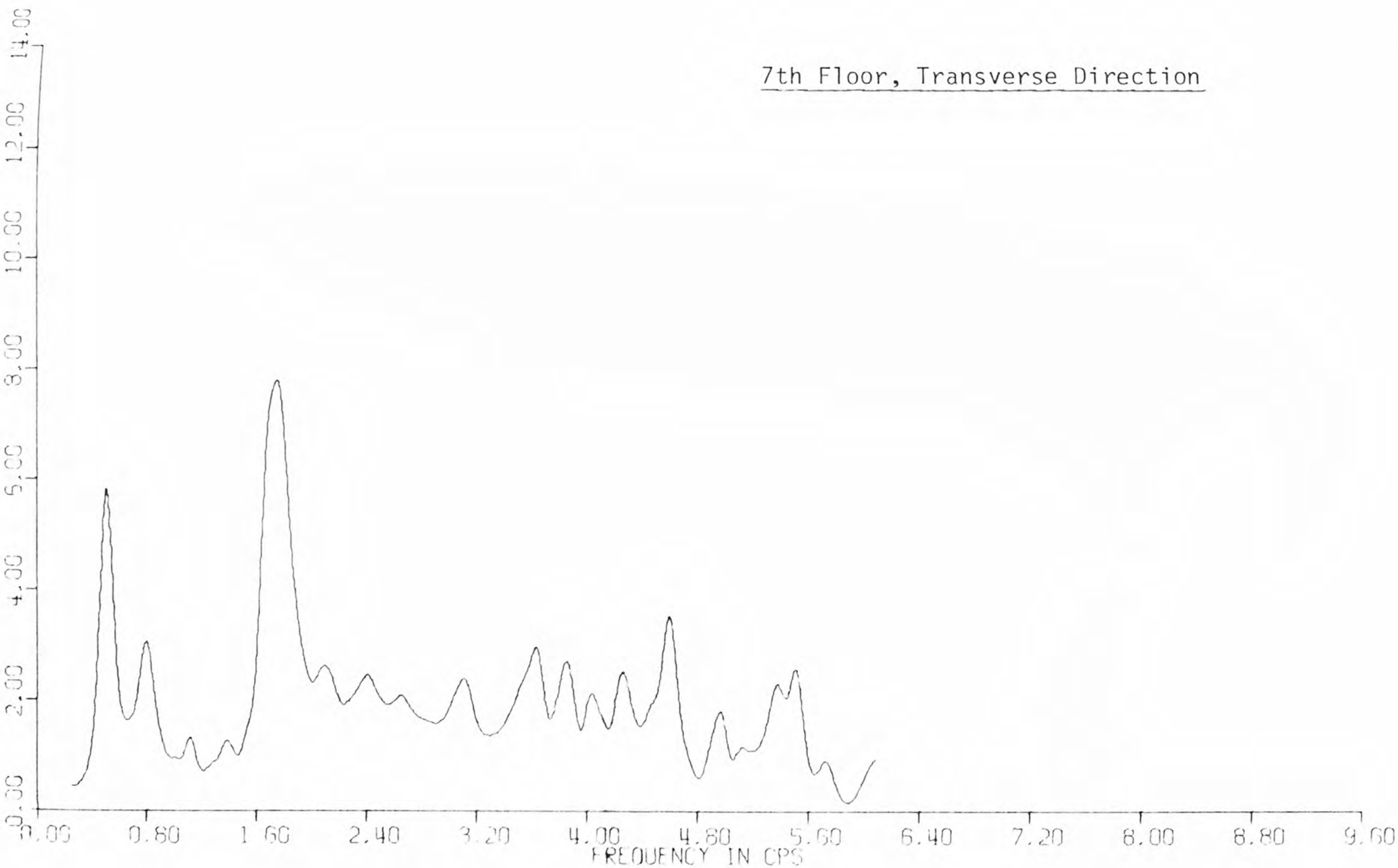


FIGURE 5.12b BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE 2

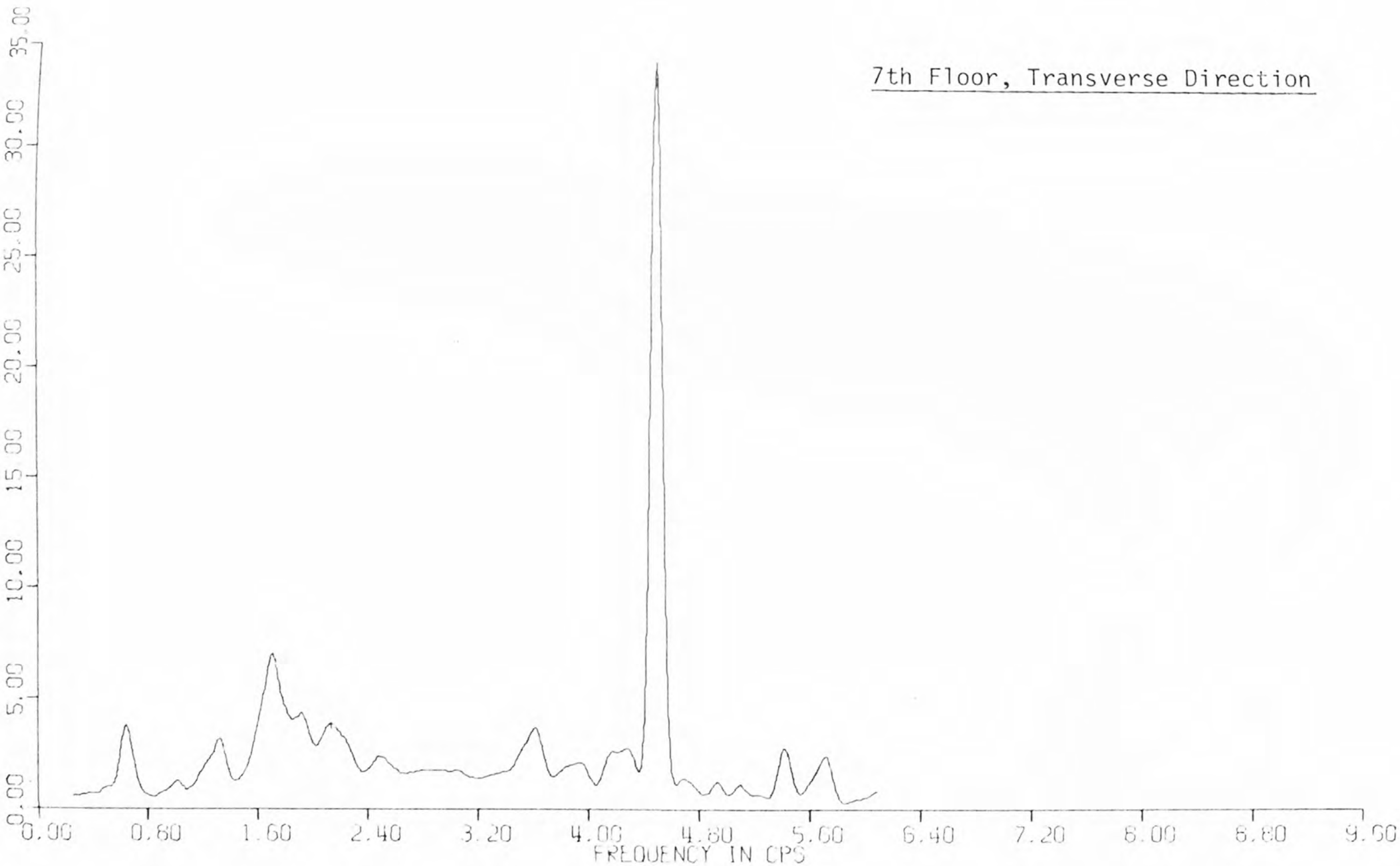


FIGURE 5.12c BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE 3

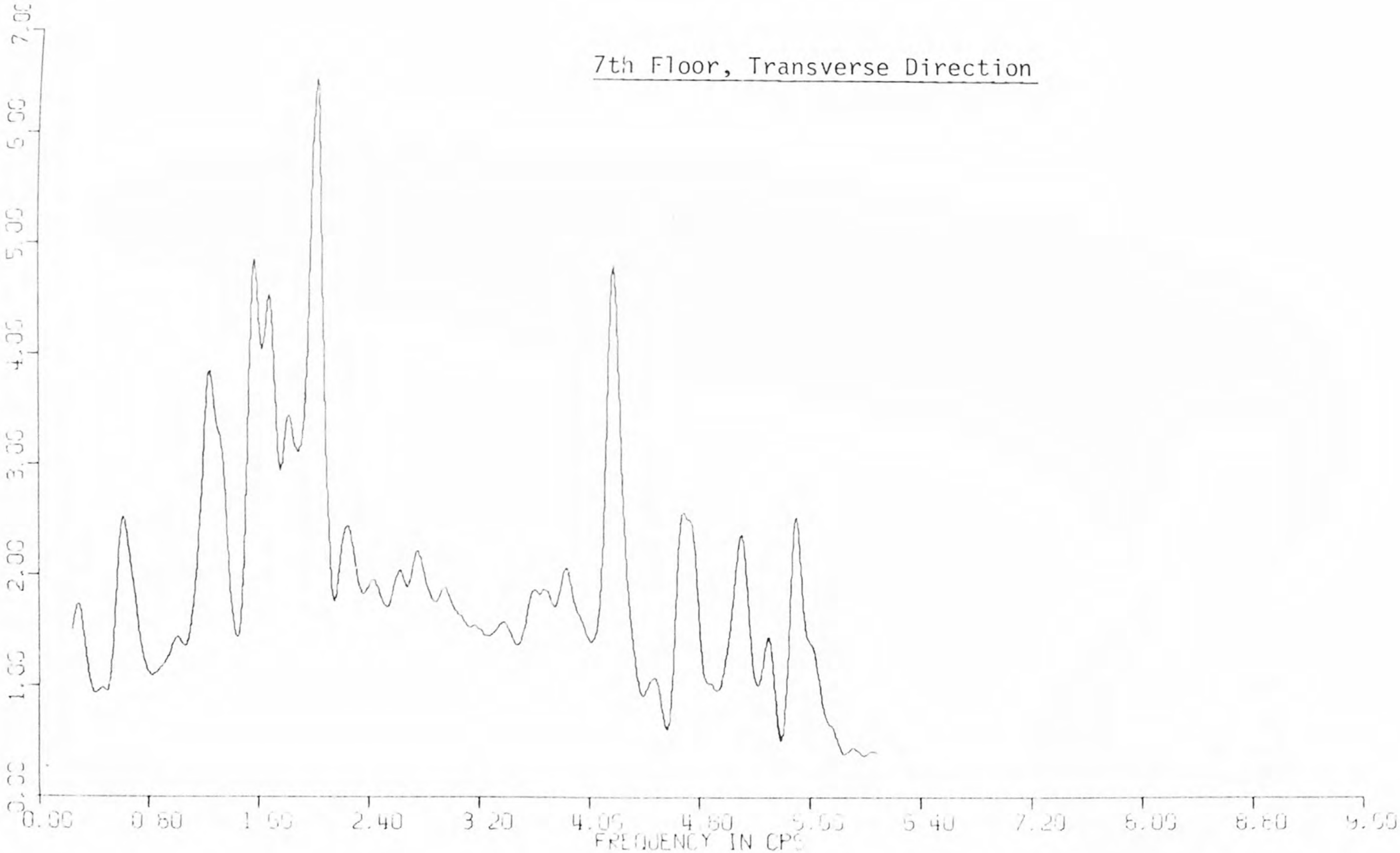


FIGURE 5.12d BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE 4

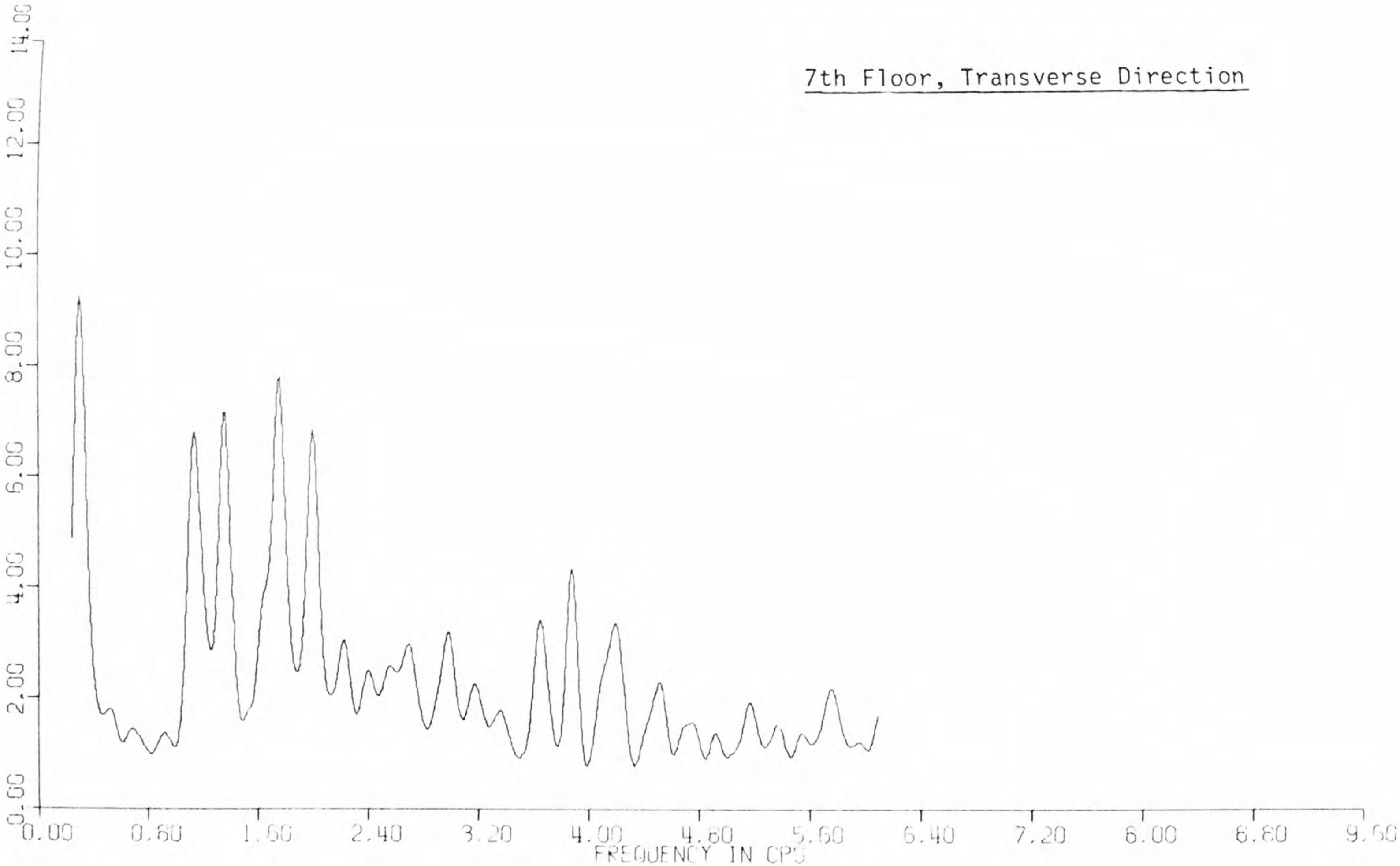


FIGURE 5.12e BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE 5

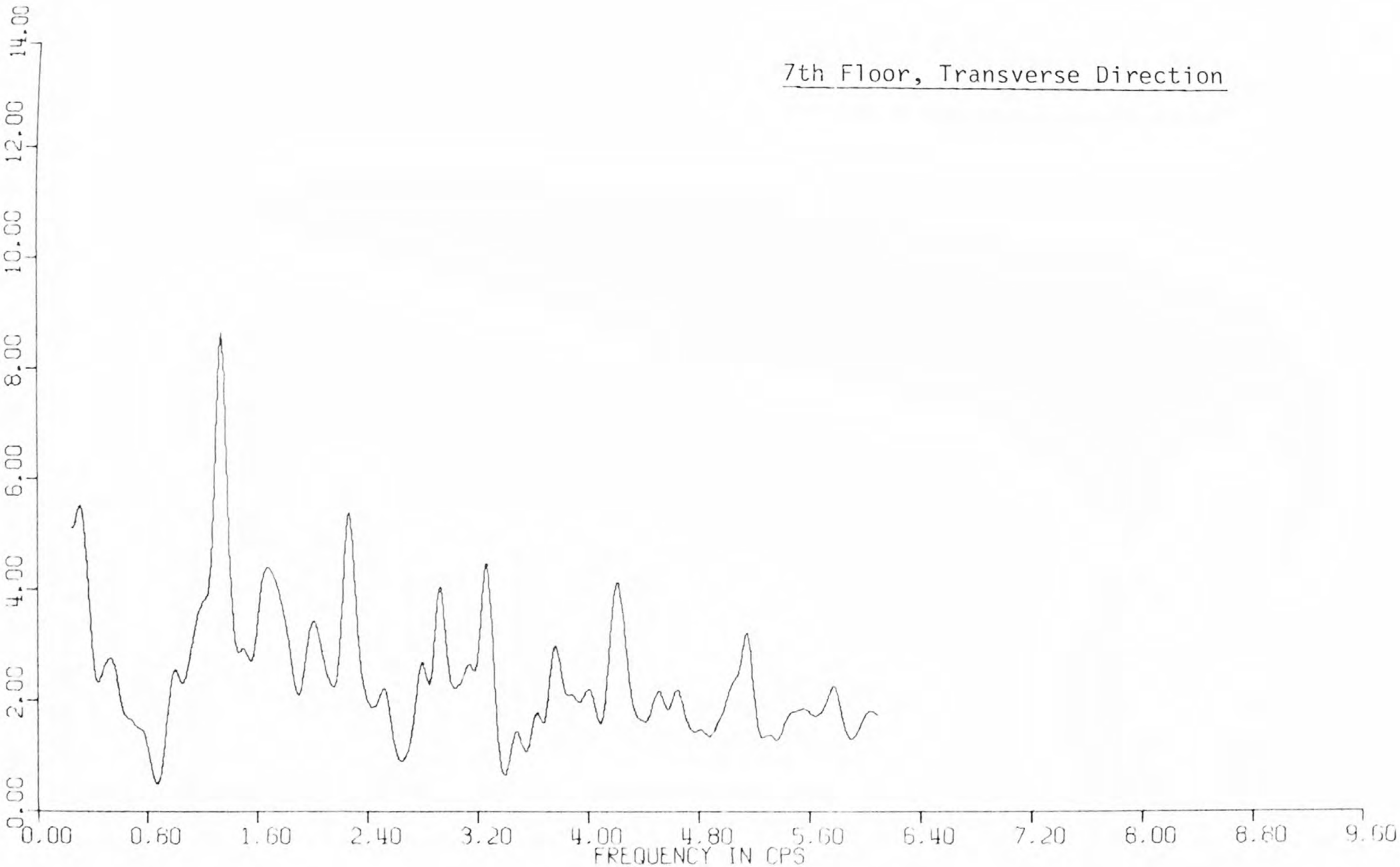


FIGURE 5.12f BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE 6

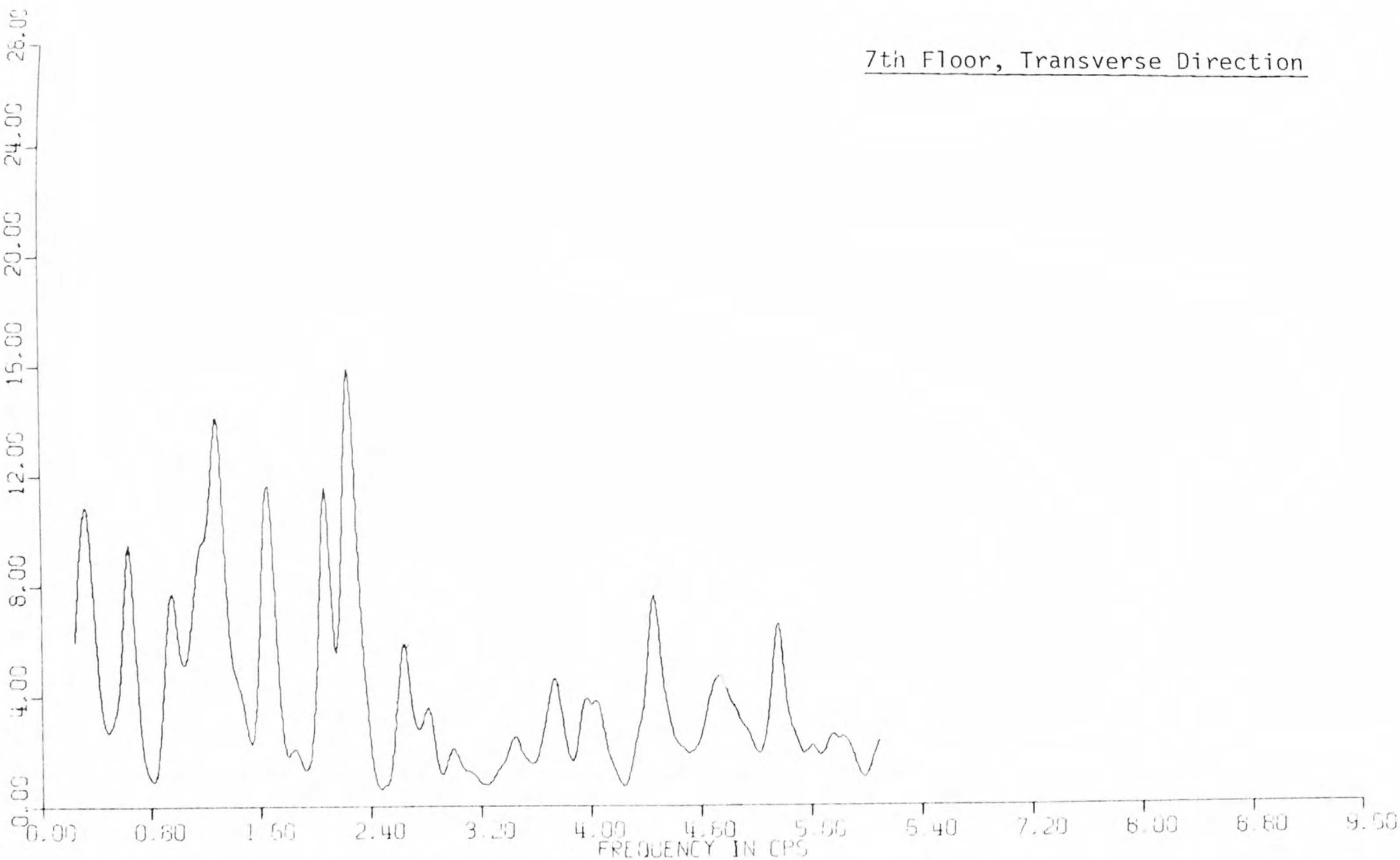


FIGURE 5.12g BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE 7

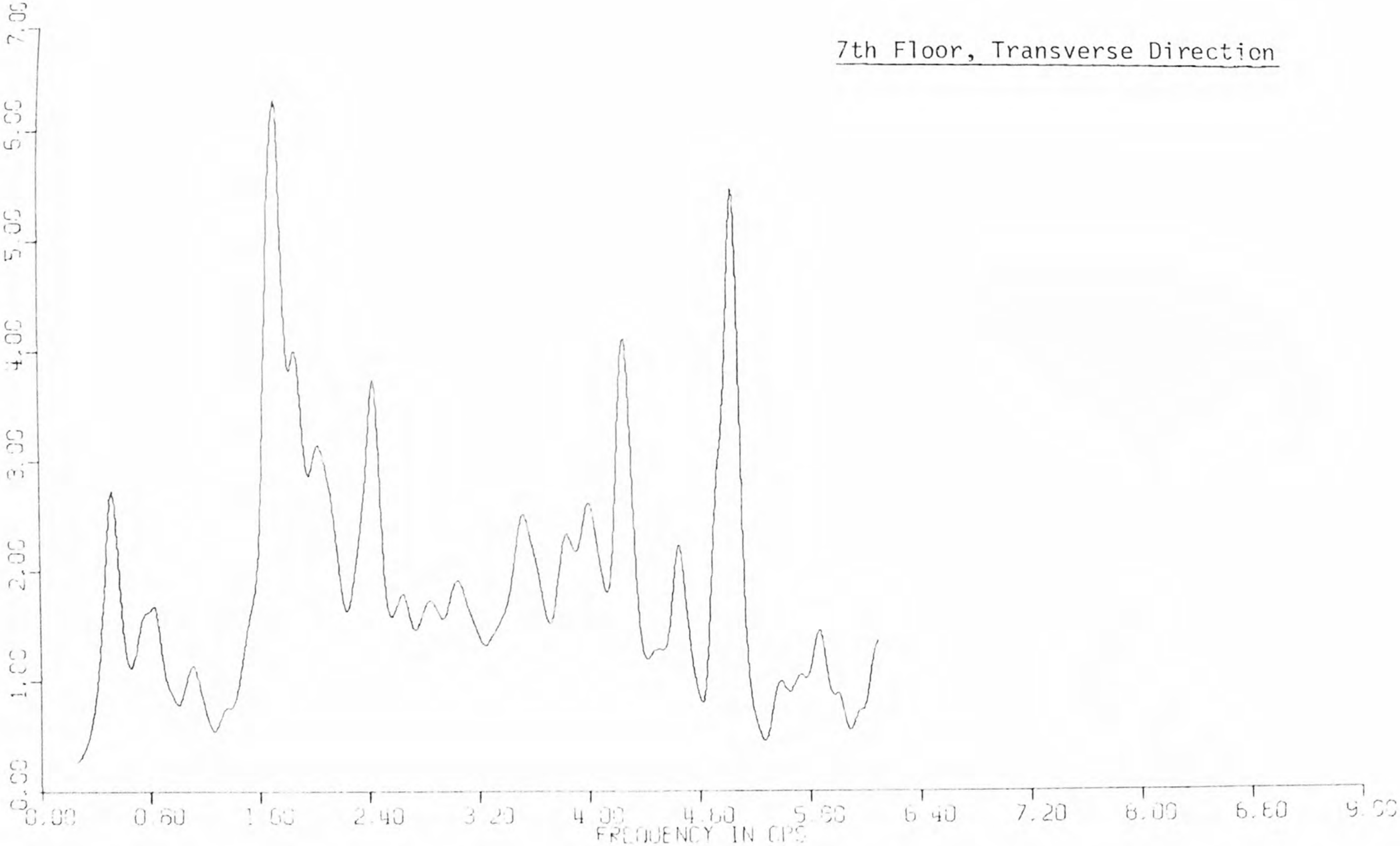


FIGURE 5.12h BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE B

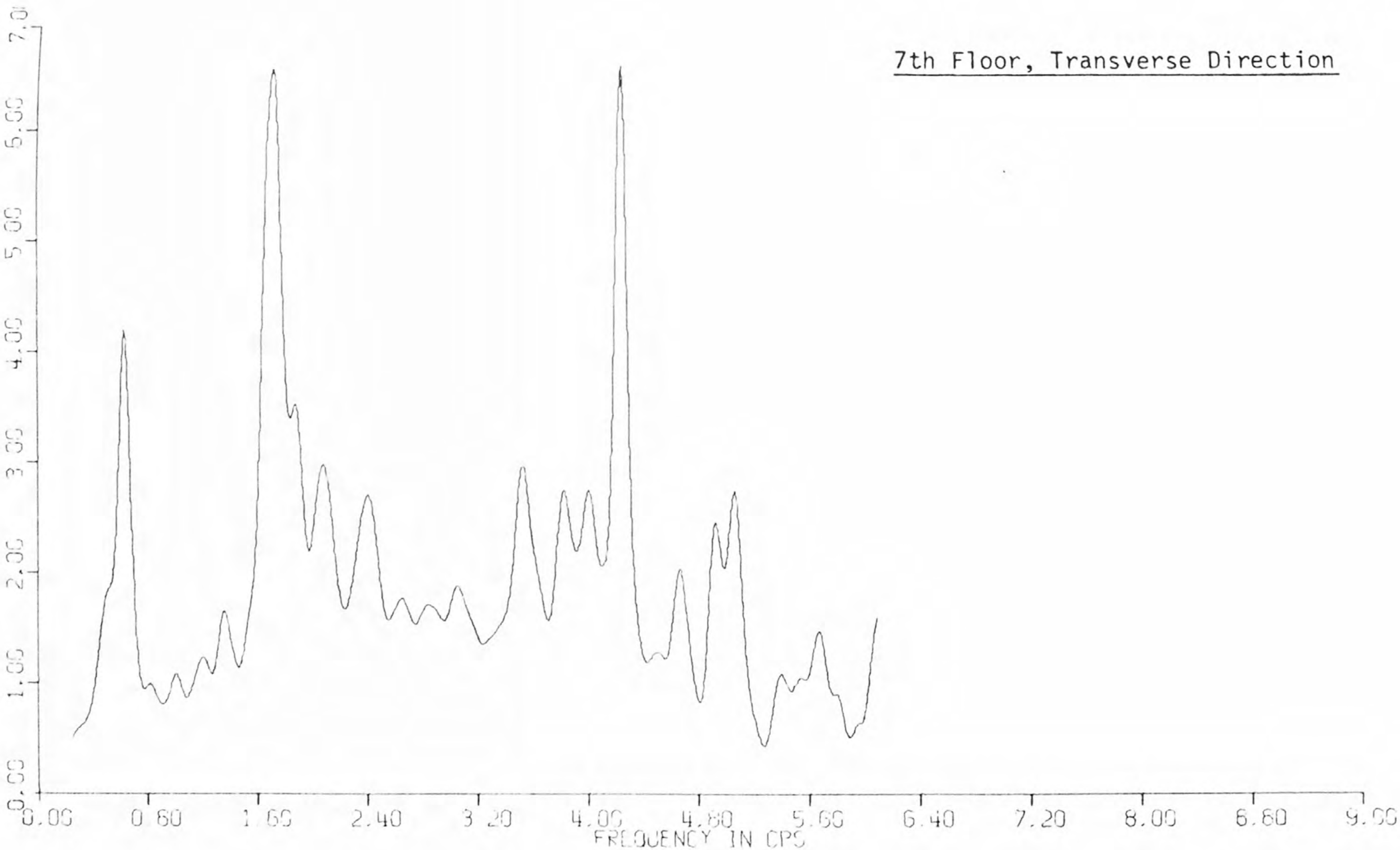


FIGURE 5.12i BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE C

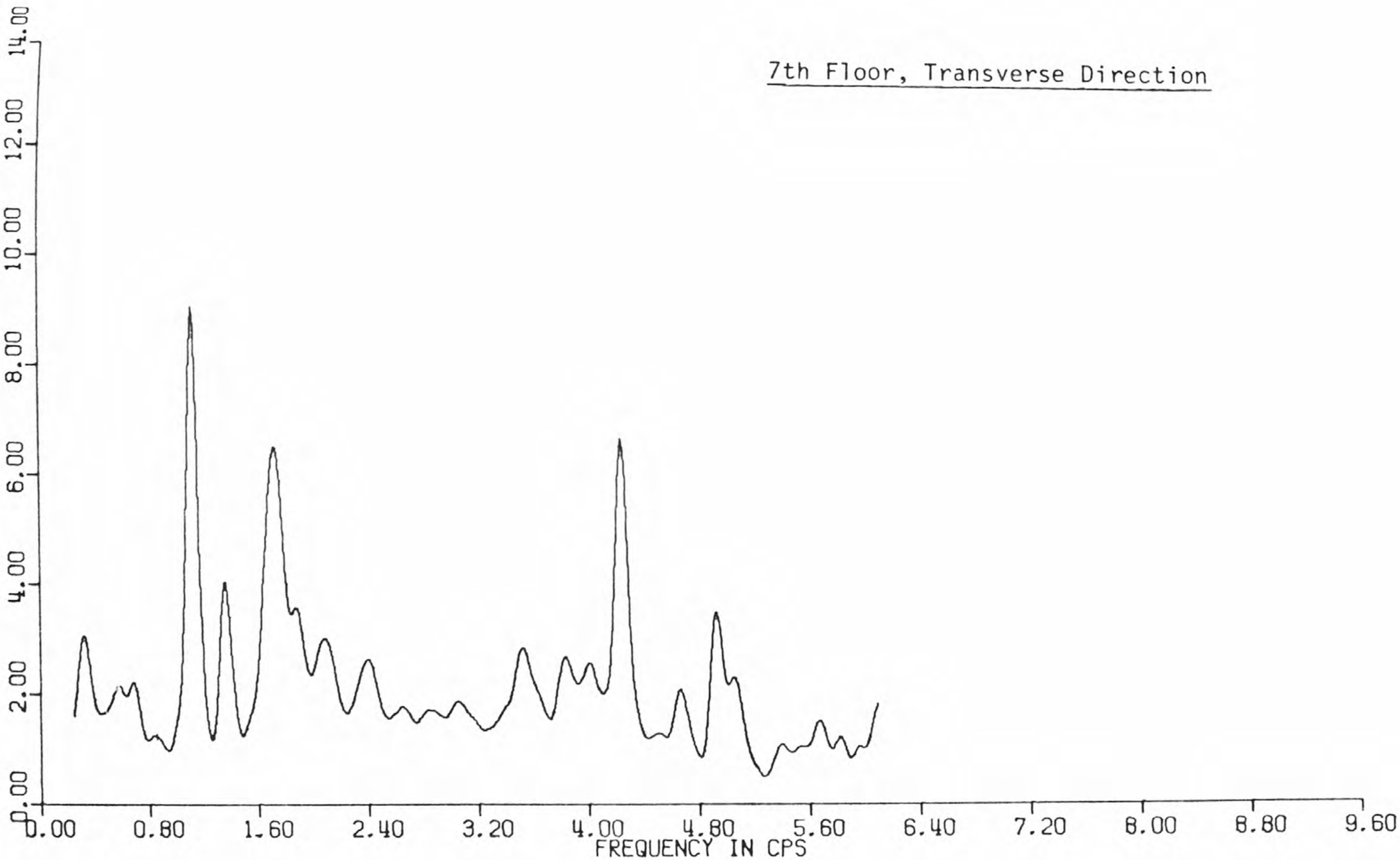


FIGURE 5.12j BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE D

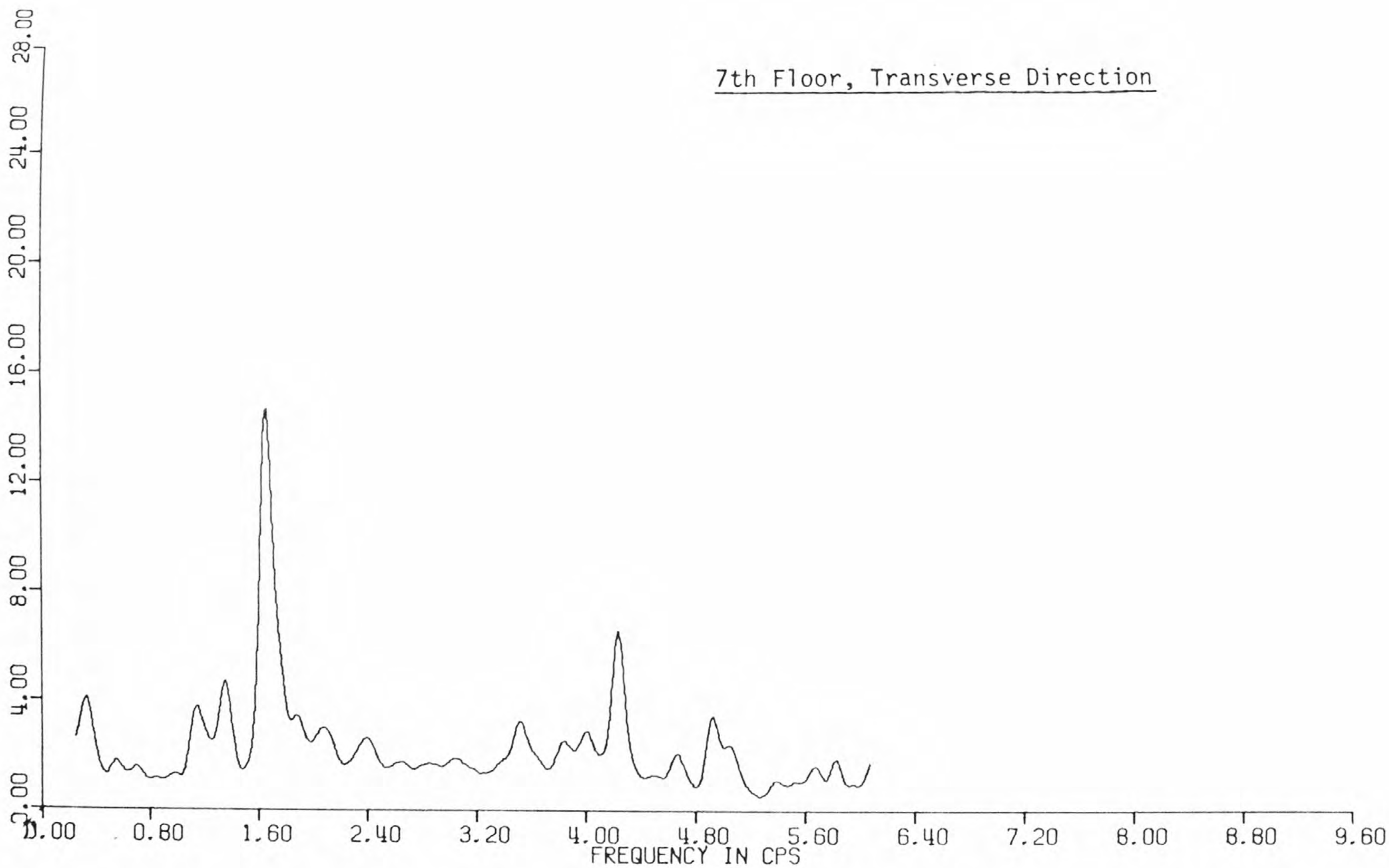


FIGURE 5.12k BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE E

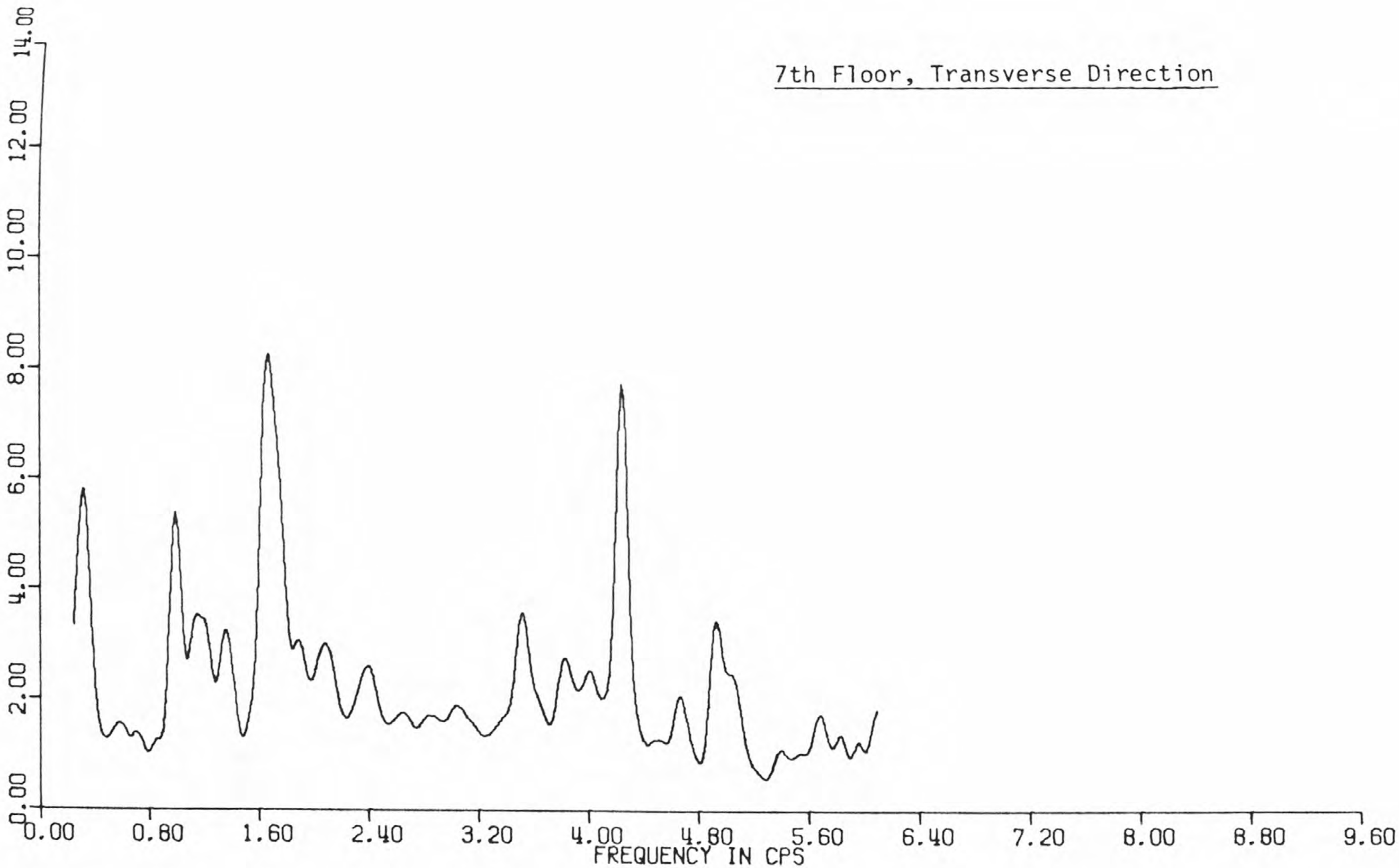


FIGURE 5.121 BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE F

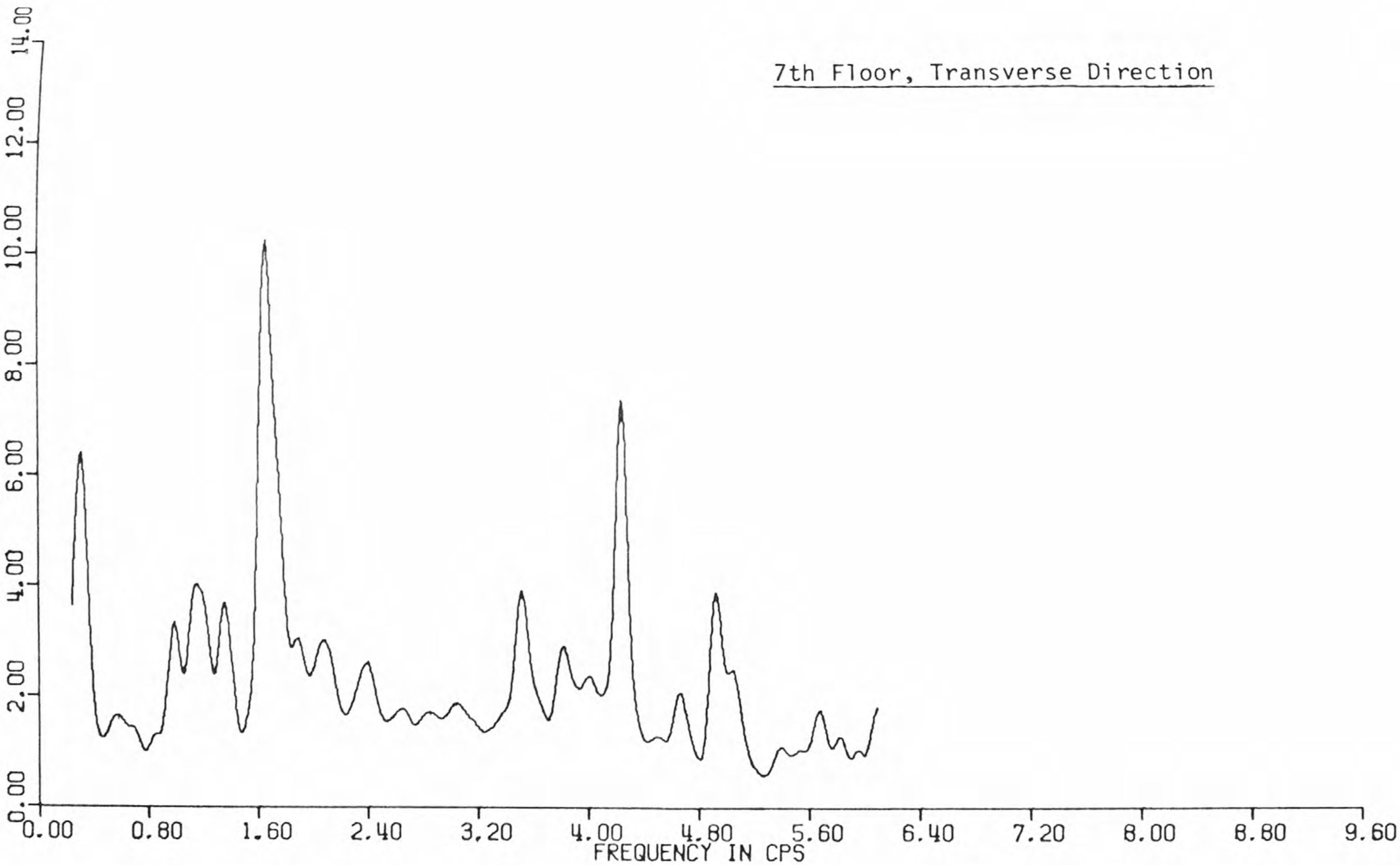
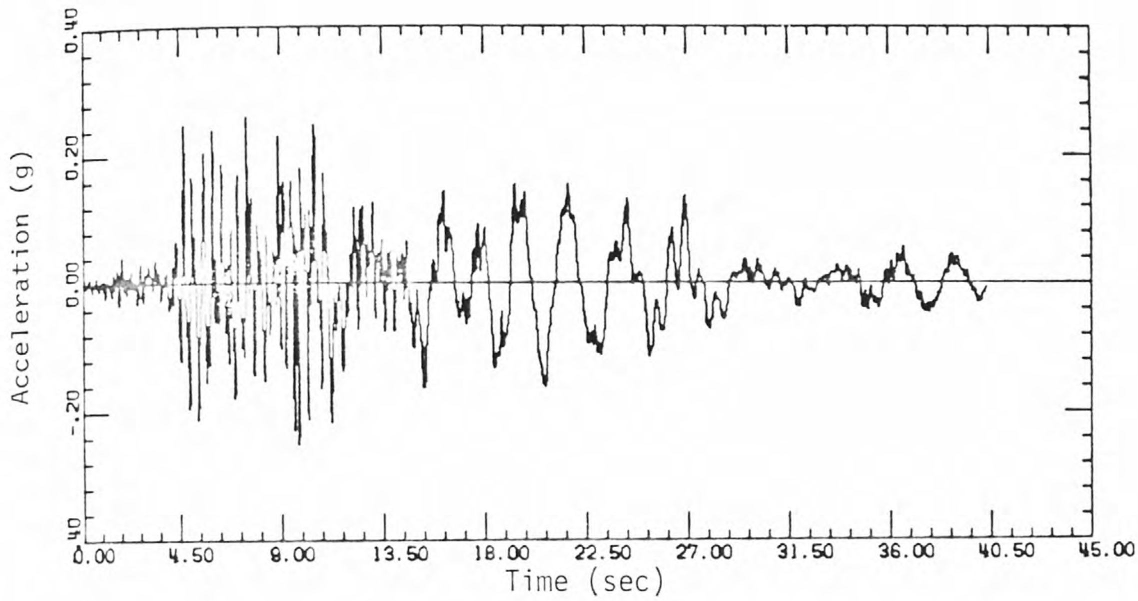
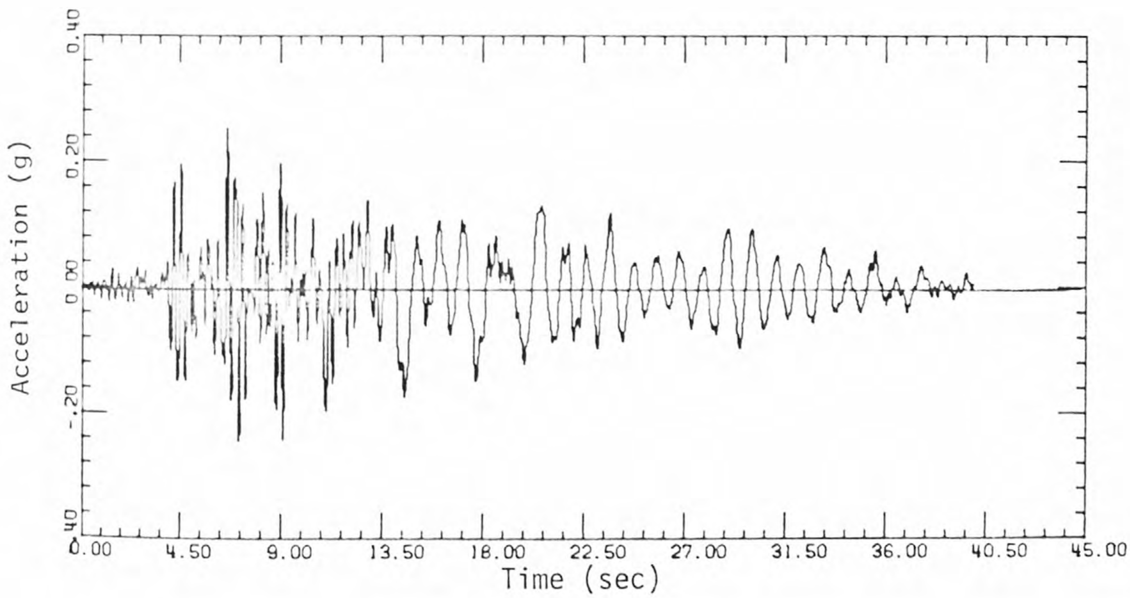


FIGURE 5.12m BANK OF CALIFORNIA BUILDING: INSTANTANEOUS TRANSFER FUNCTION: CASE G

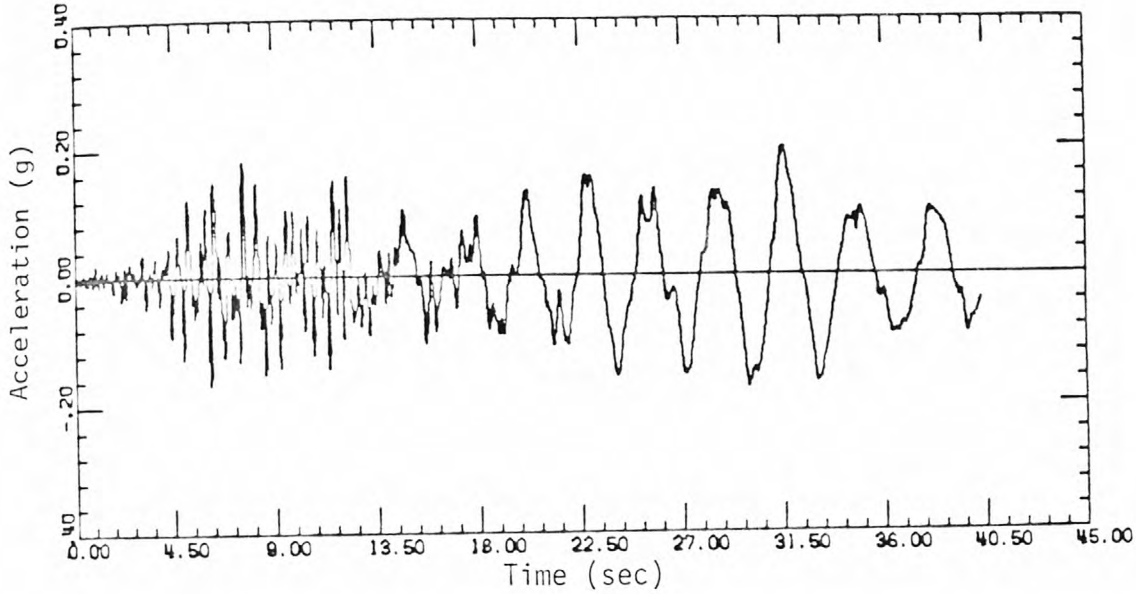


Recorded Time History



Theoretical Time History

FIGURE 5.13a MODEL 1, RECORDED AND THEORETICAL TIME HISTORIES: BANK OF CALIFORNIA BUILDING, SEVENTH FLOOR, LONGITUDINAL DIRECTION



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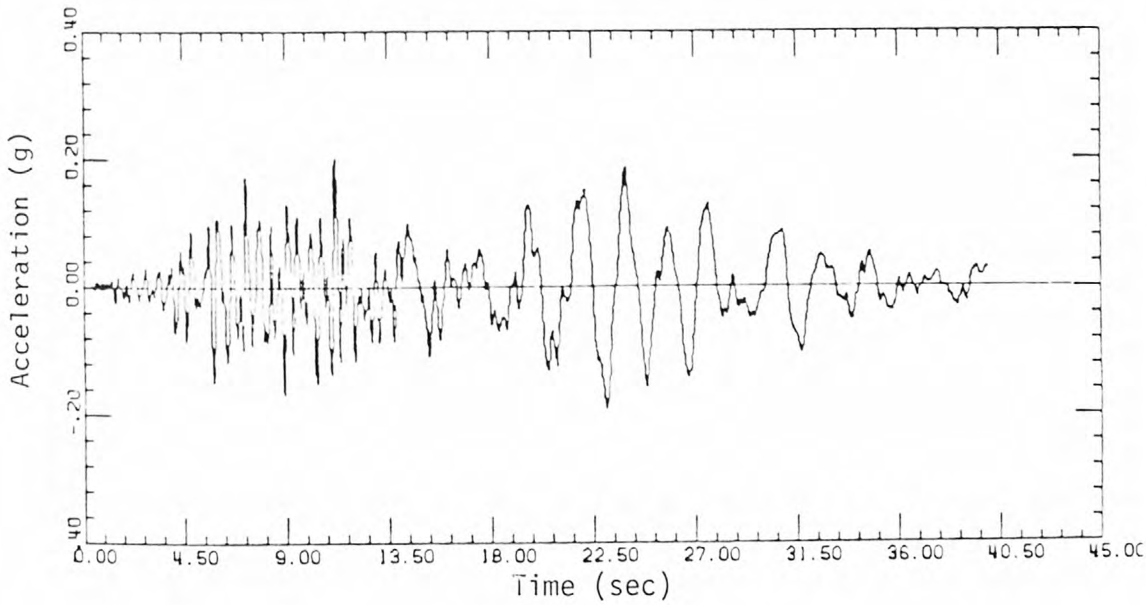
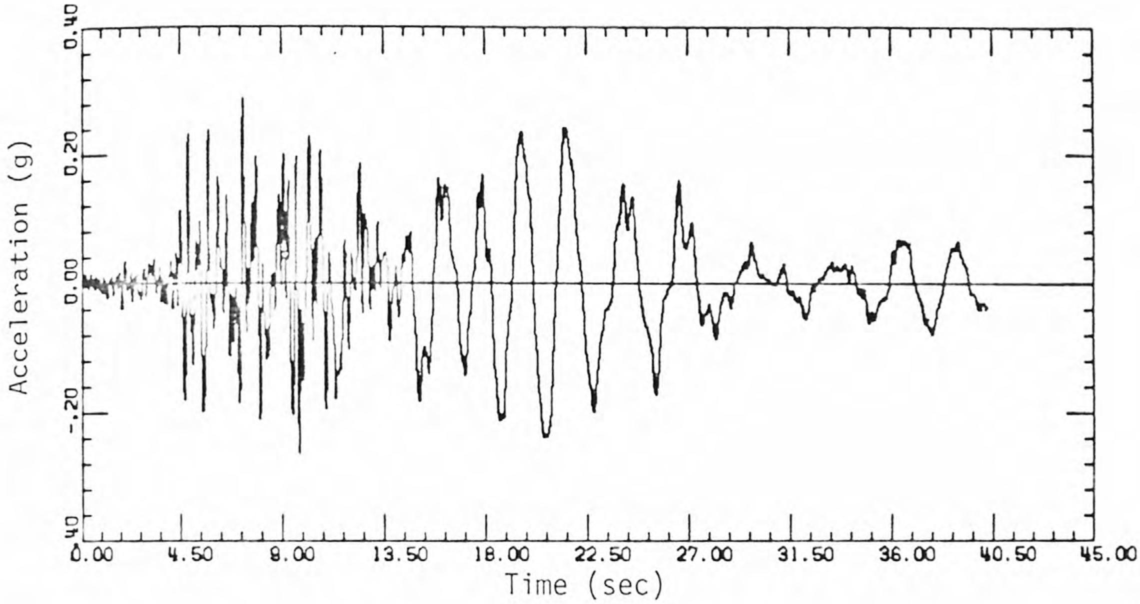
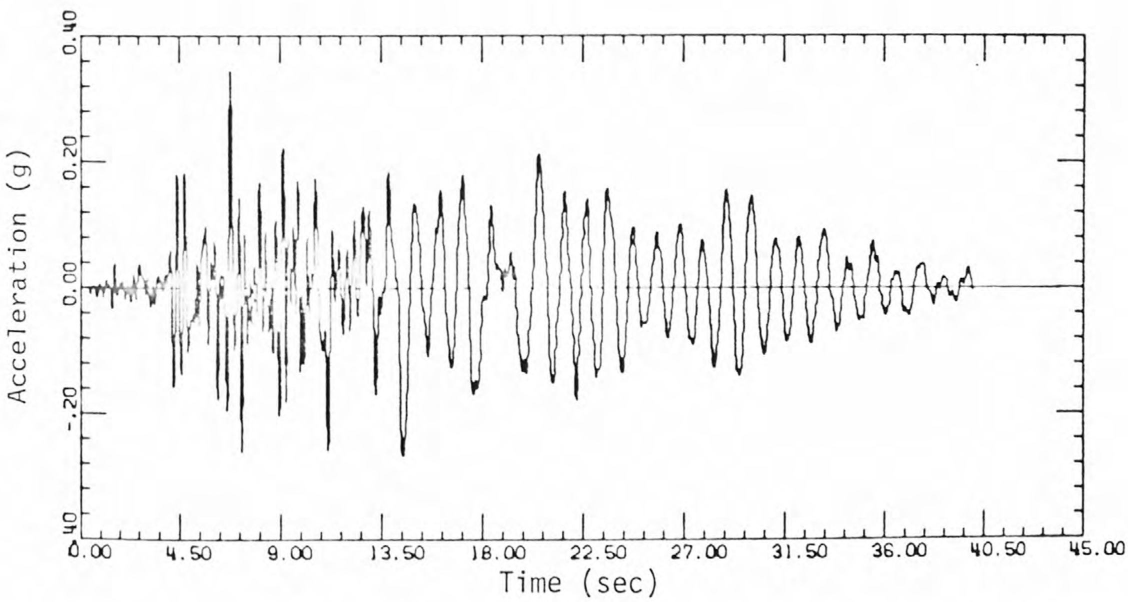


Theoretical Time History

FIGURE 5.13b MODEL 1, RECORDED AND THEORETICAL TIME HISTORIES: BANK OF CALIFORNIA BUILDING, ROOF, TRANSVERSE DIRECTION

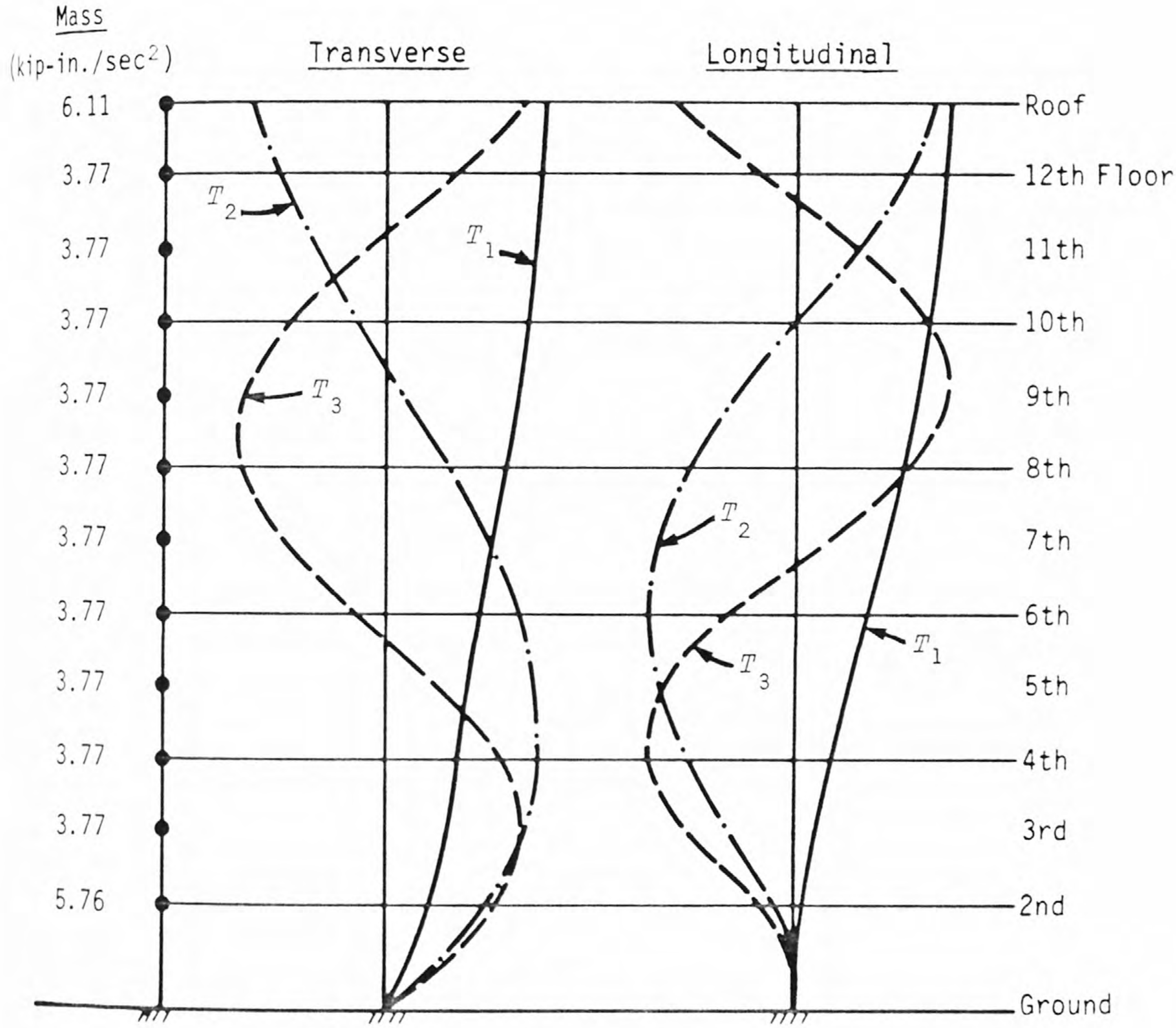


Recorded Time History



Theoretical Time History

FIGURE 5.13c MODEL 1, RECORDED AND THEORETICAL TIME HISTORIES: BANK OF CALIFORNIA BUILDING, ROOF, LONGITUDINAL DIRECTION



Period

T_1 = 2.18 sec
T_2 = 0.72 sec
T_3 = 0.38 sec

Period

T_1 = 1.07 sec
T_2 = 0.35 sec
T_3 = 0.20 sec

FIGURE 5.14 BANK OF CALIFORNIA BUILDING, MODEL 1: STRUCTURAL MODE SHAPES AND PERIODS

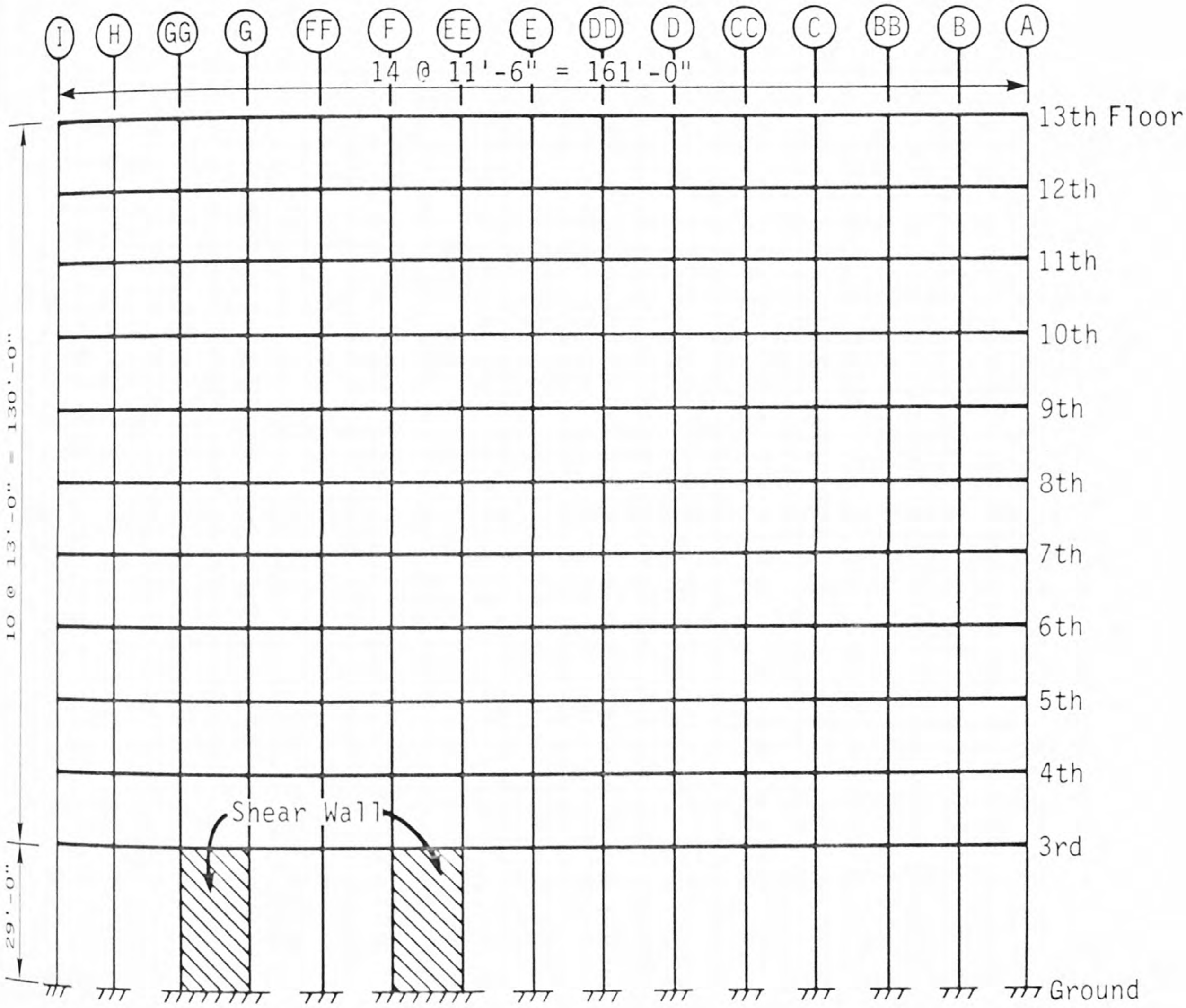


FIGURE 5.15 BANK OF CALIFORNIA BUILDING: LONGITUDINAL FRAME ON COLUMN LINE 1

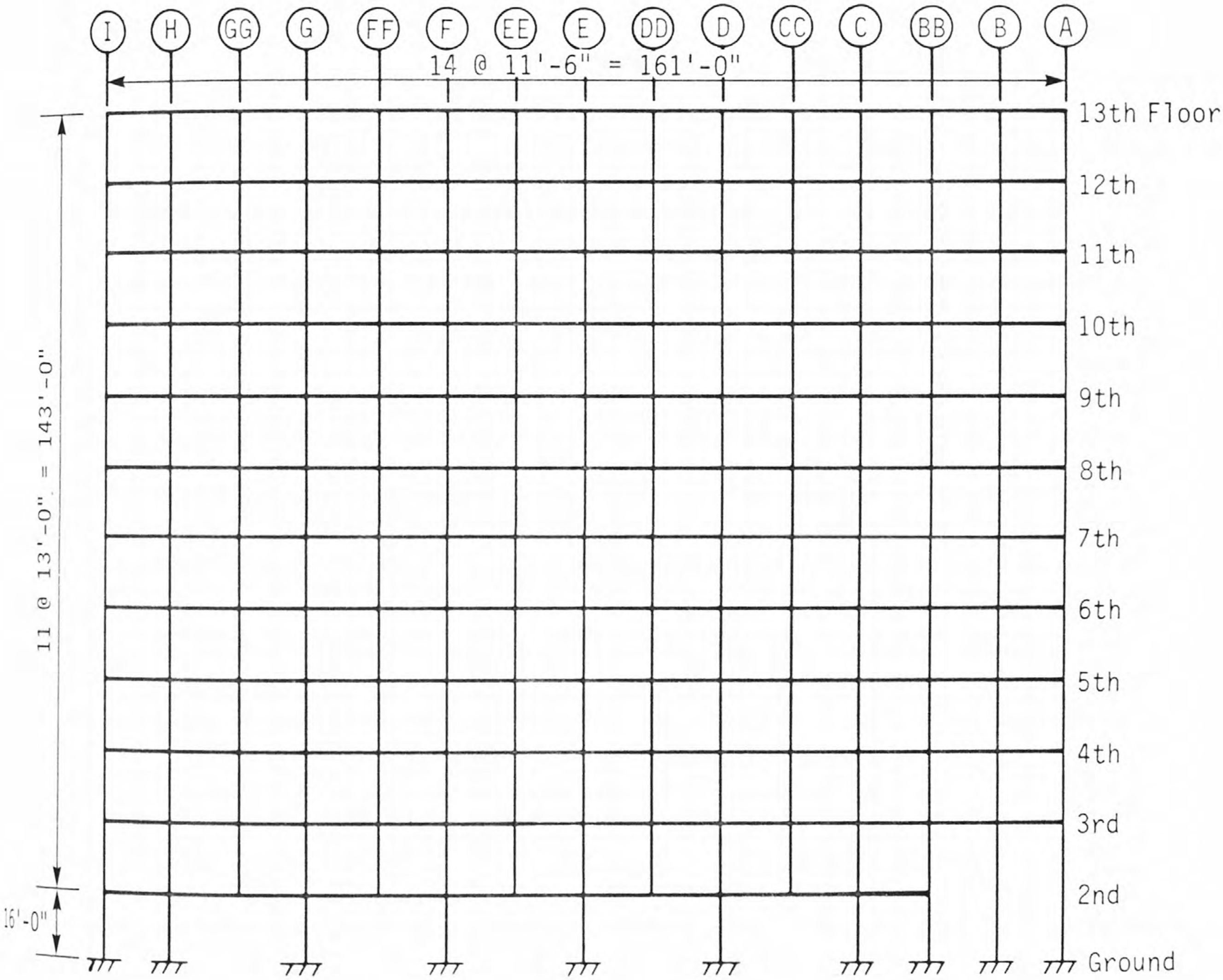


FIGURE 5.16 BANK OF CALIFORNIA BUILDING: LONGITUDINAL FRAME ON COLUMN LINE 3

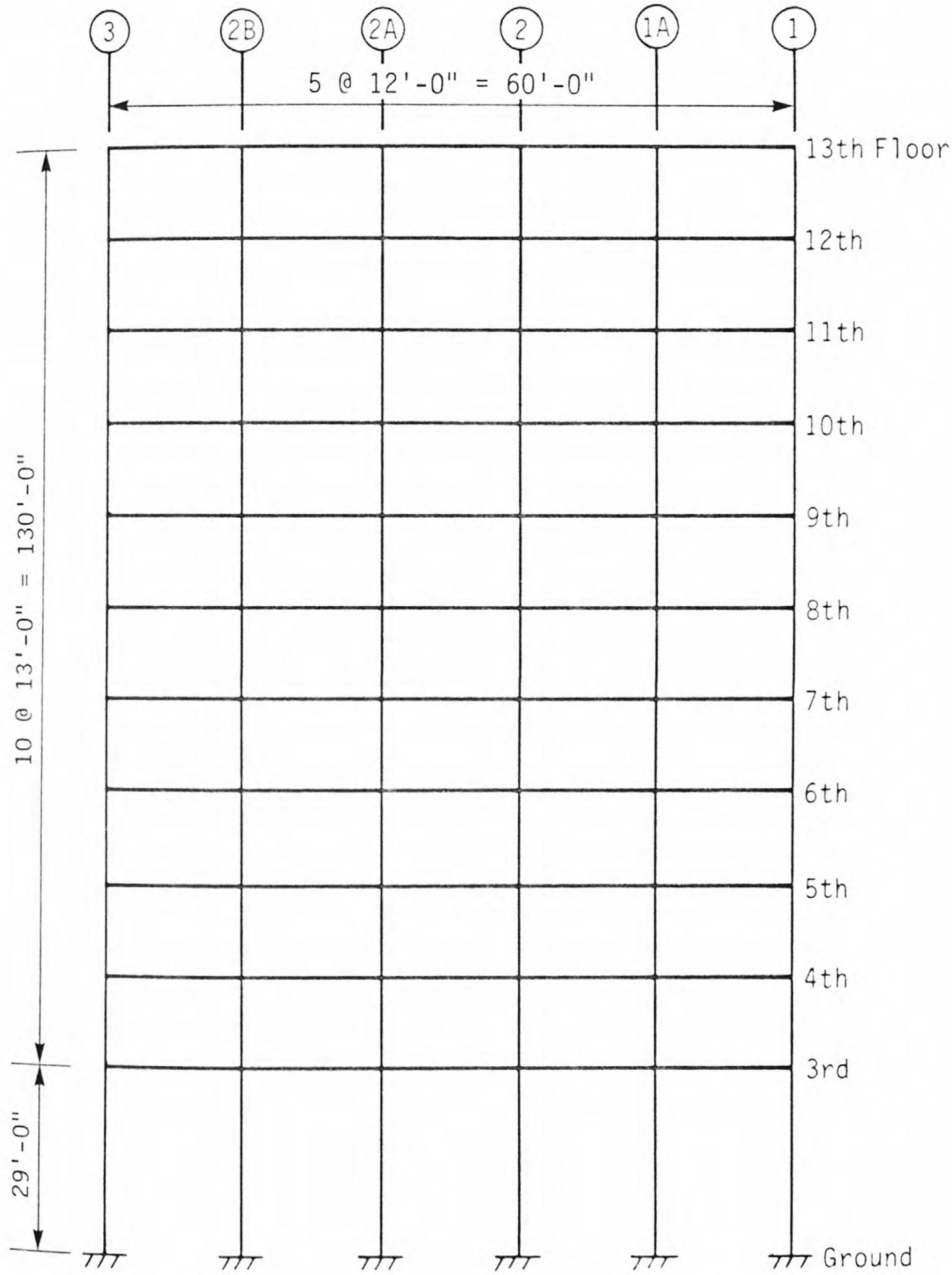
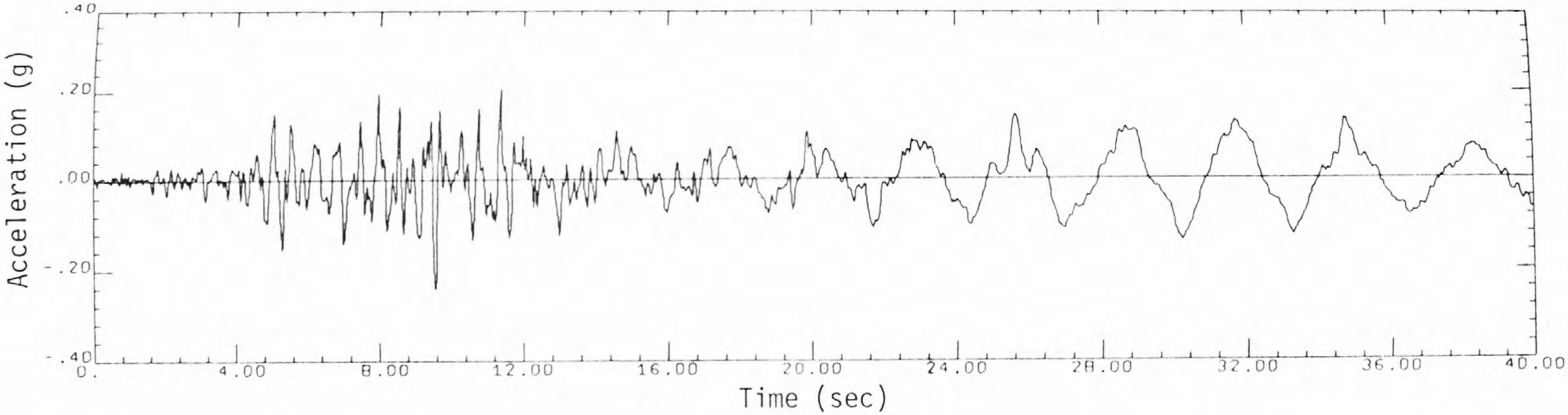
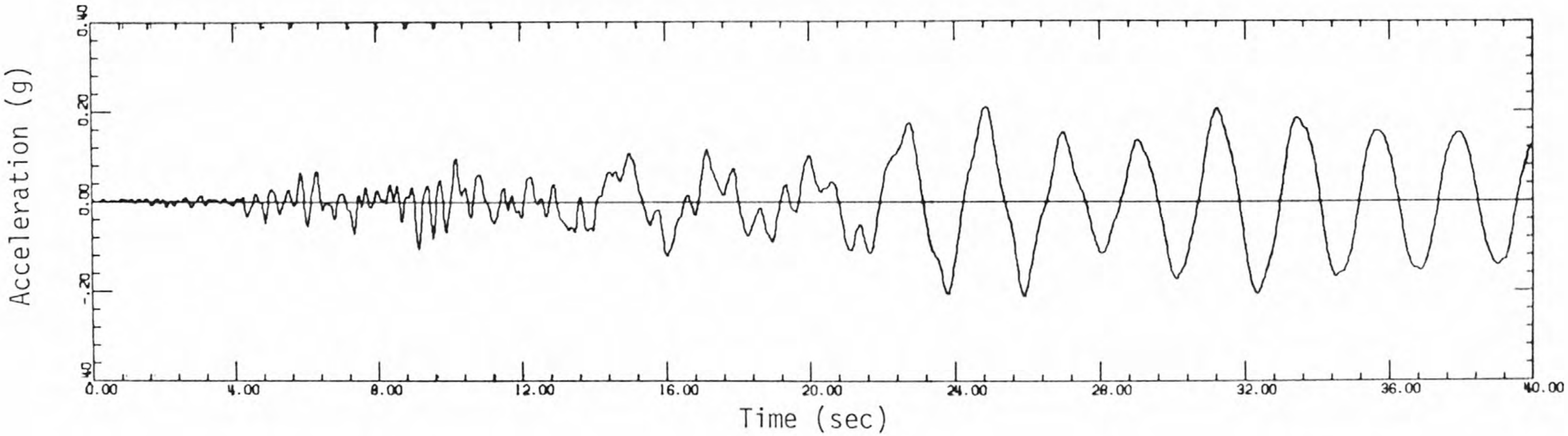


FIGURE 5.17 BANK OF CALIFORNIA BUILDING: TRANSVERSE FRAMES ON COLUMN LINES A AND I

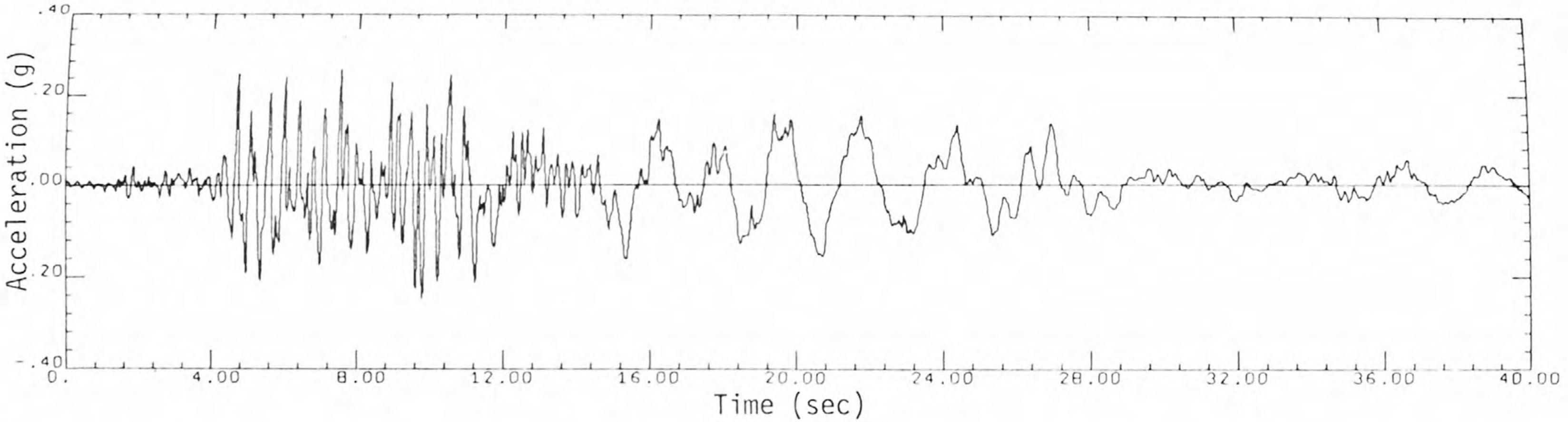


Recorded Time History

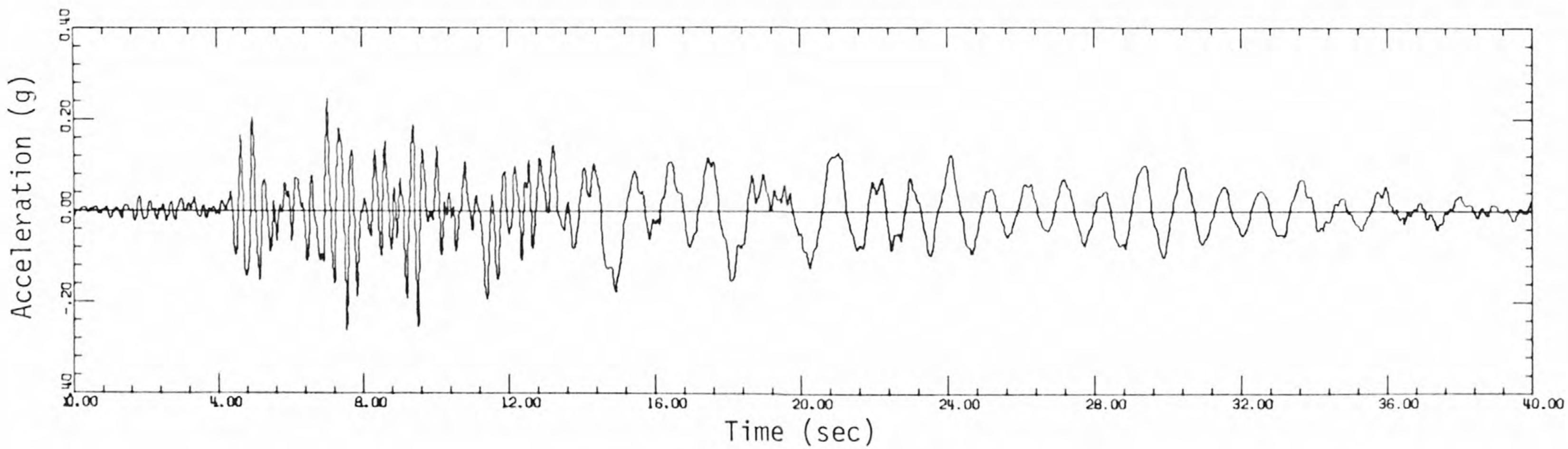


Theoretical Time History

FIGURE 5.18a MODEL 2: RECORDED AND THEORETICAL TIME HISTORIES: BANK OF CALIFORNIA BUILDING, SEVENTH FLOOR, TRANSVERSE DIRECTION

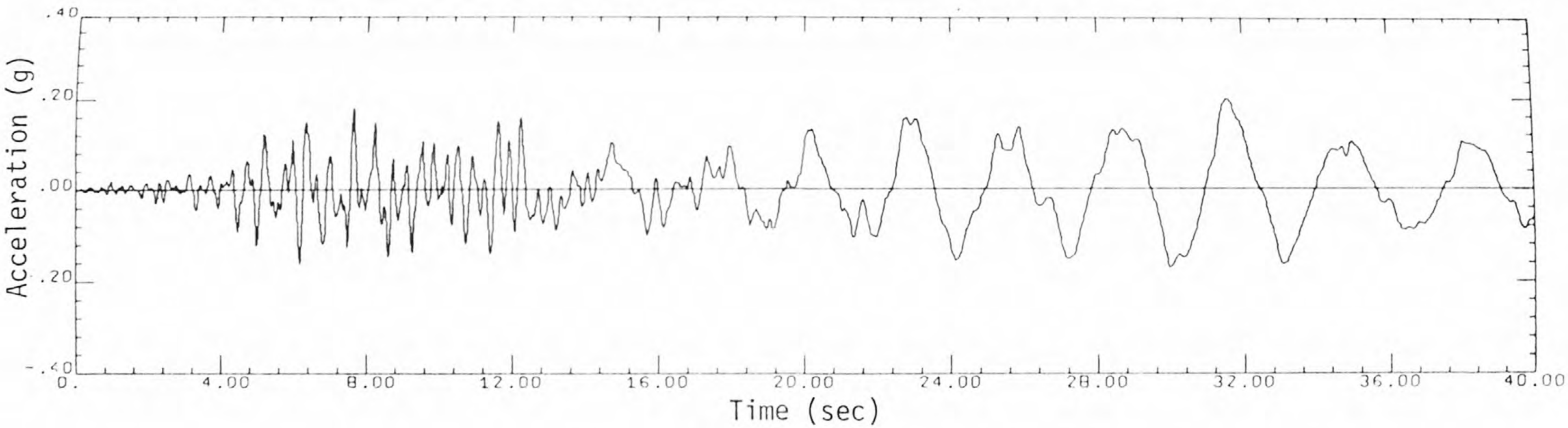


Recorded Time History

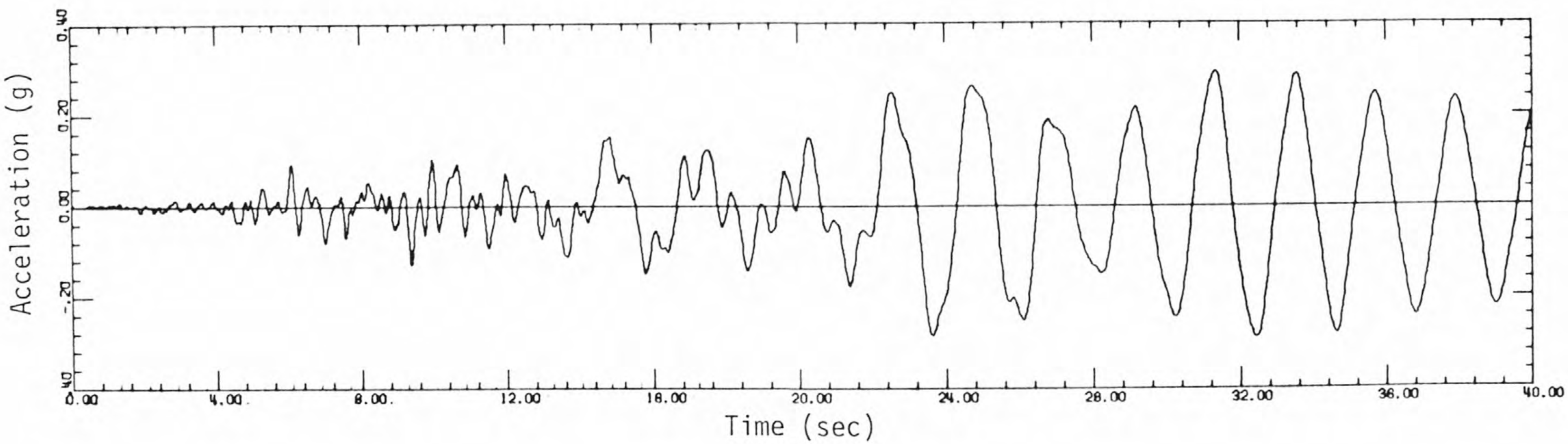


Theoretical Time History

FIGURE 5.18b MODEL 2: RECORDED AND THEORETICAL TIME HISTORIES: BANK OF CALIFORNIA BUILDING, SEVENTH FLOOR, LONGITUDINAL DIRECTION

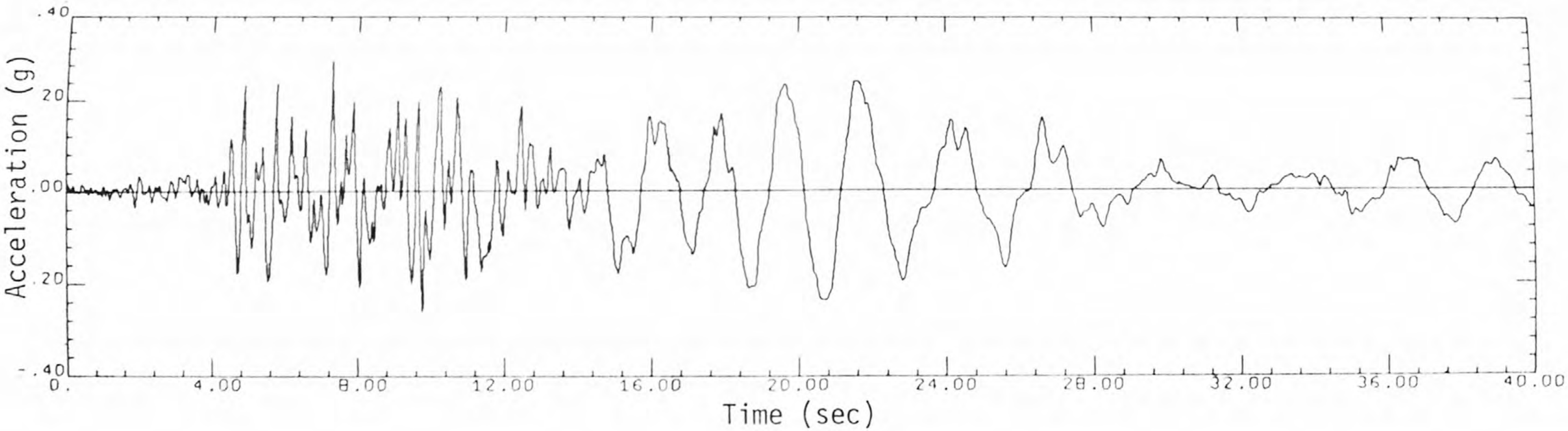


Recorded Time History

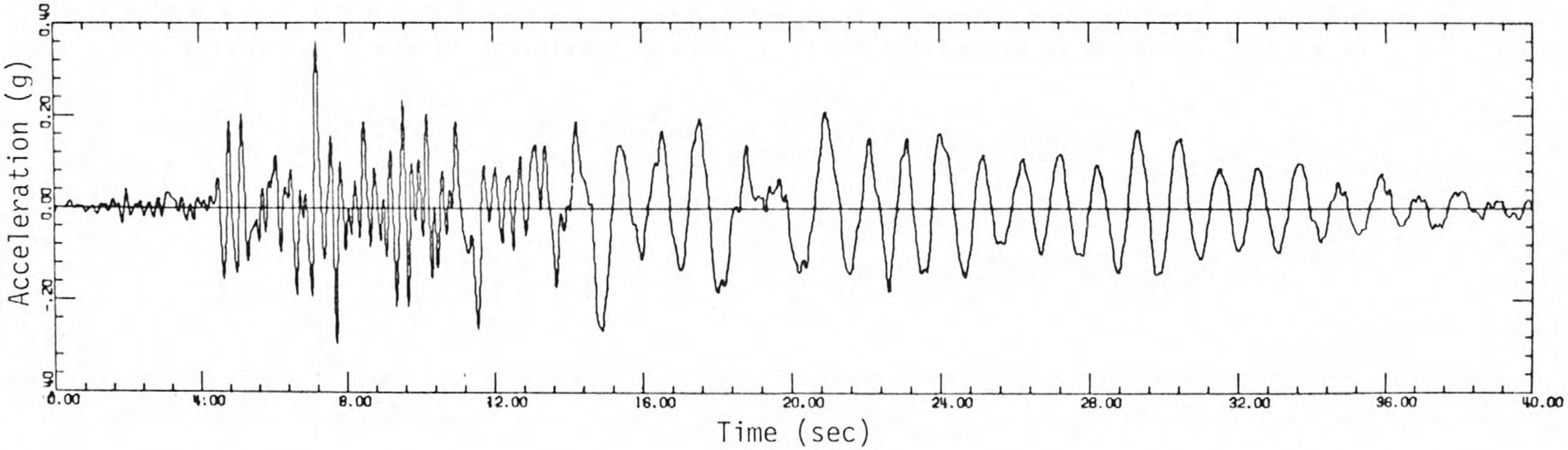


Theoretical Time History

FIGURE 5.18c MODEL 2: RECORDED AND THEORETICAL TIME HISTORIES: BANK OF CALIFORNIA BUILDING, ROOF, TRANSVERSE DIRECTION



Recorded Time History



Theoretical Time History

FIGURE 5.18d MODEL 2: RECORDED AND THEORETICAL TIME HISTORIES: BANK OF CALIFORNIA BUILDING, ROOF, LONGITUDINAL DIRECTION

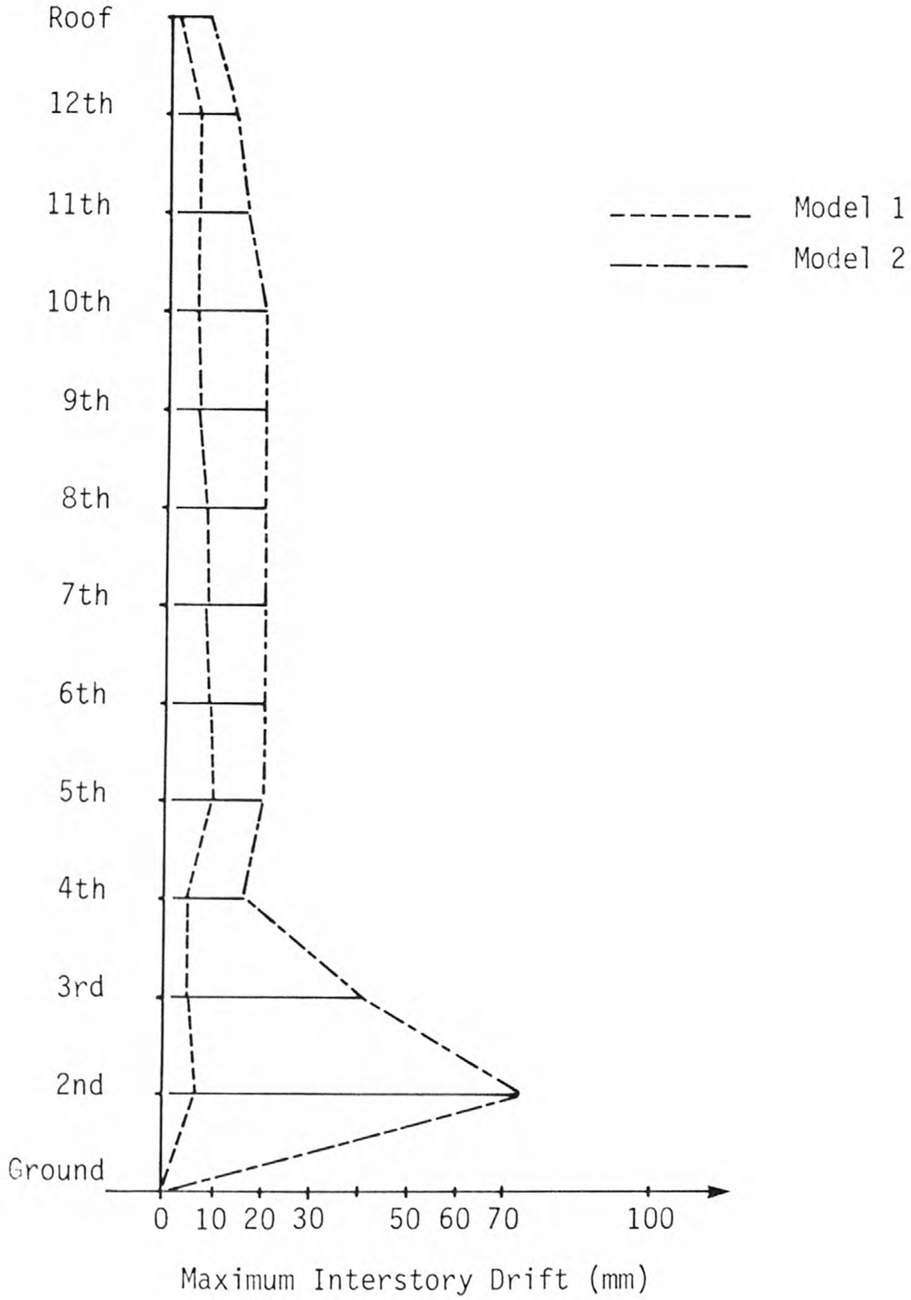


FIGURE 5.19 MAXIMUM CALCULATED INTERSTORY DRIFTS FOR THE BANK OF CALIFORNIA BUILDING, TRANSVERSE DIRECTION

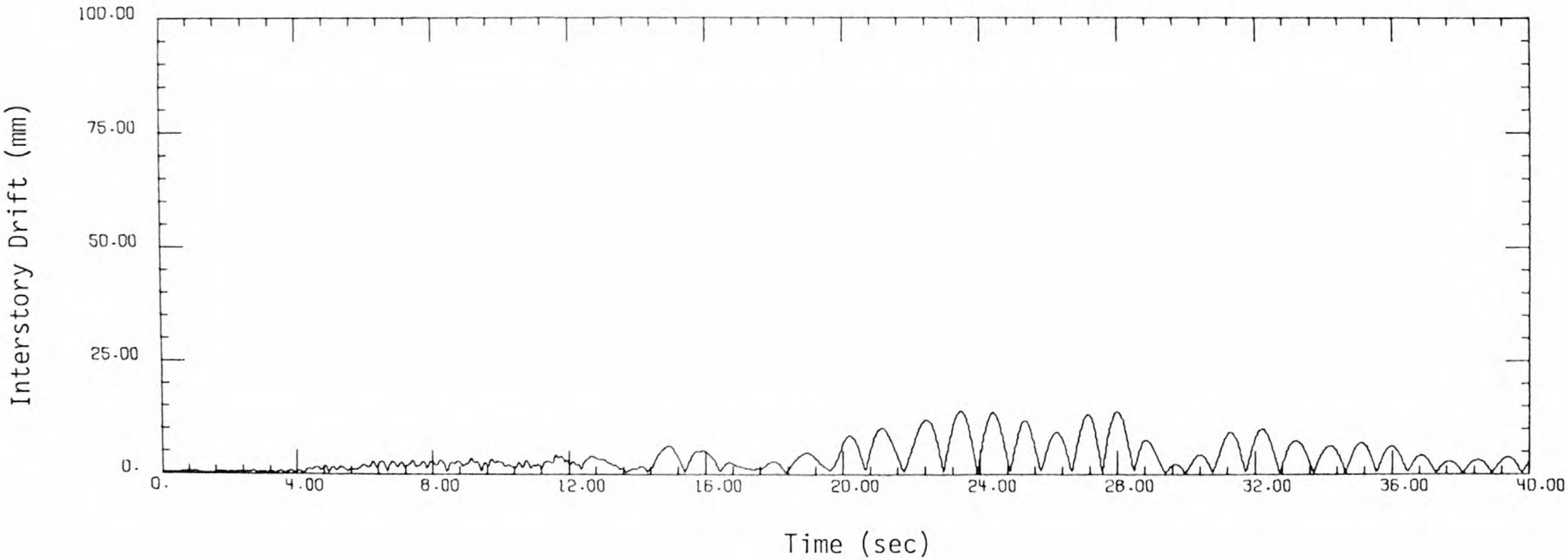


FIGURE 5.20 AVERAGE INTERSTORY DRIFT: BANK OF CALIFORNIA BUILDING, TRANSVERSE DIRECTION, MODEL 1

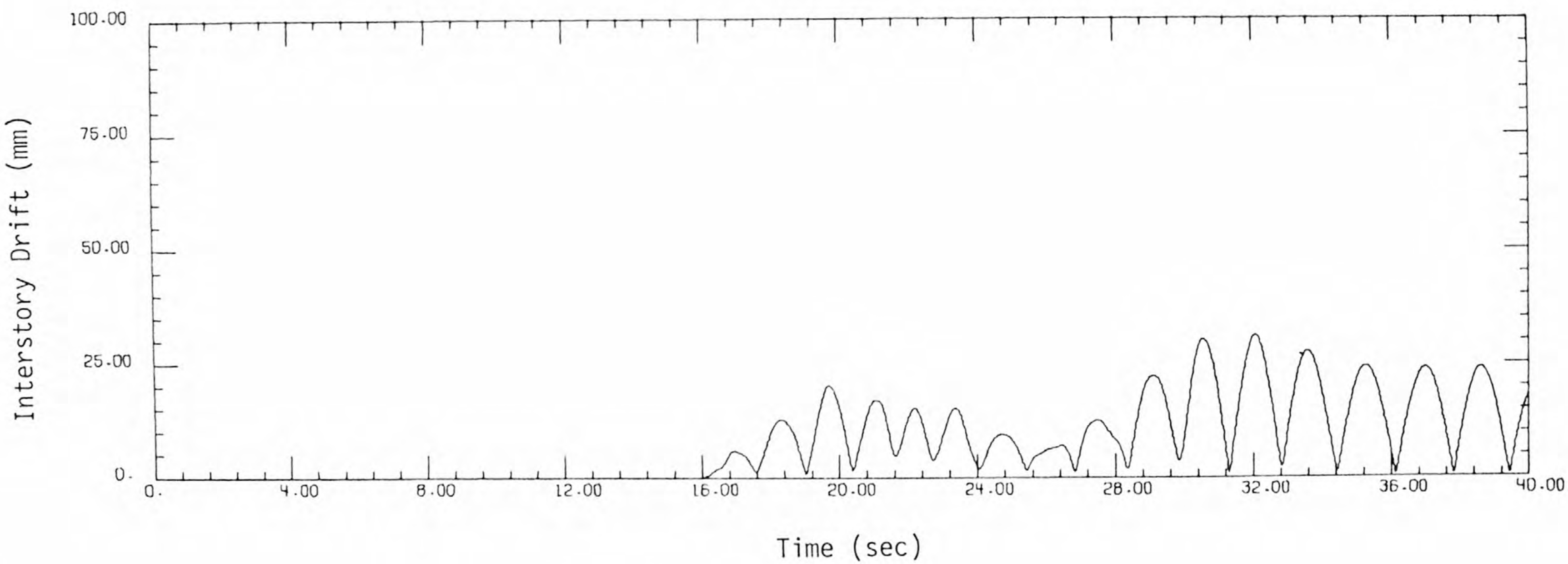
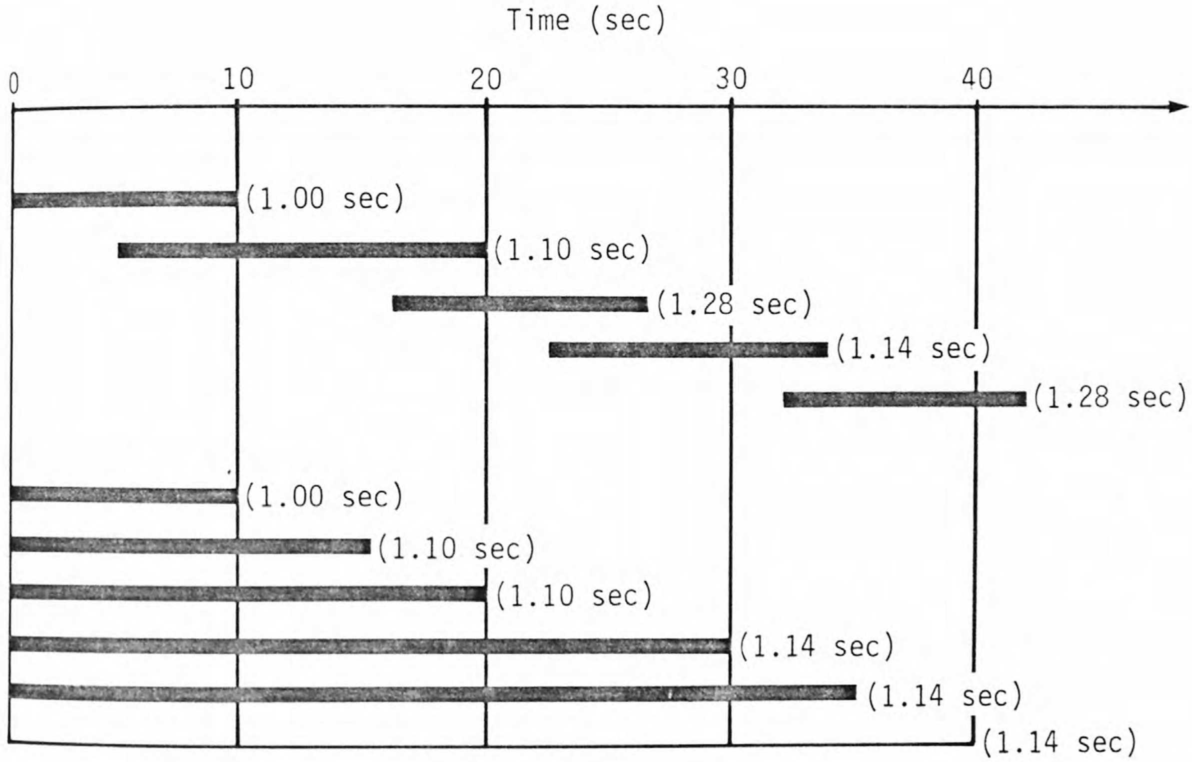
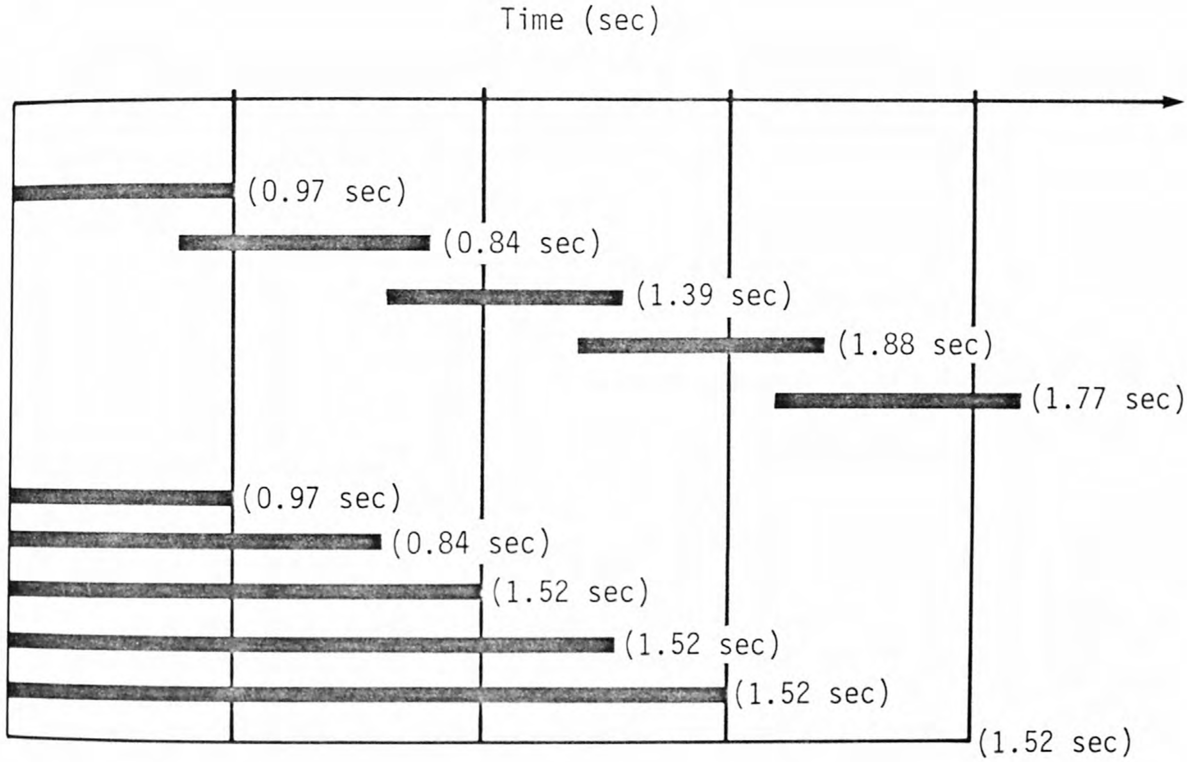


FIGURE 5.21 AVERAGE INTERSTORY DRIFT: BANK OF CALIFORNIA BUILDING, TRANSVERSE DIRECTION, MODEL 2



Note: Fundamental periods are shown in parentheses.

FIGURE 5.22 ORION AVENUE HOLIDAY INN: FUNDAMENTAL PERIODS OBTAINED FROM INSTANTANEOUS TRANSFER FUNCTIONS, LONGITUDINAL DIRECTION



Note: Fundamental periods are shown in parentheses.

FIGURE 5.23 ORION AVENUE HOLIDAY INN: FUNDAMENTAL PERIODS OBTAINED FROM INSTANTANEOUS TRANSFER FUNCTIONS, TRANSVERSE DIRECTION

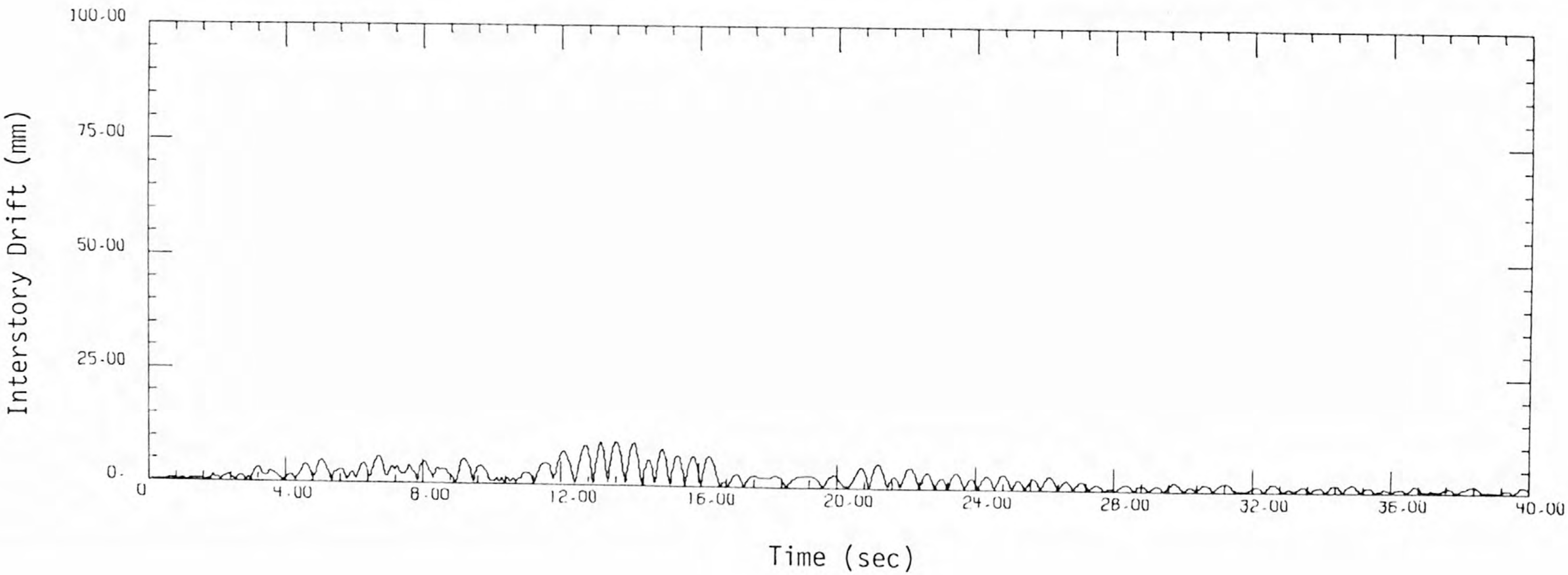


FIGURE 5.24 AVERAGE INTERSTORY DRIFT: ORION AVENUE HOLIDAY INN, LONGITUDINAL DIRECTION, MODEL 1

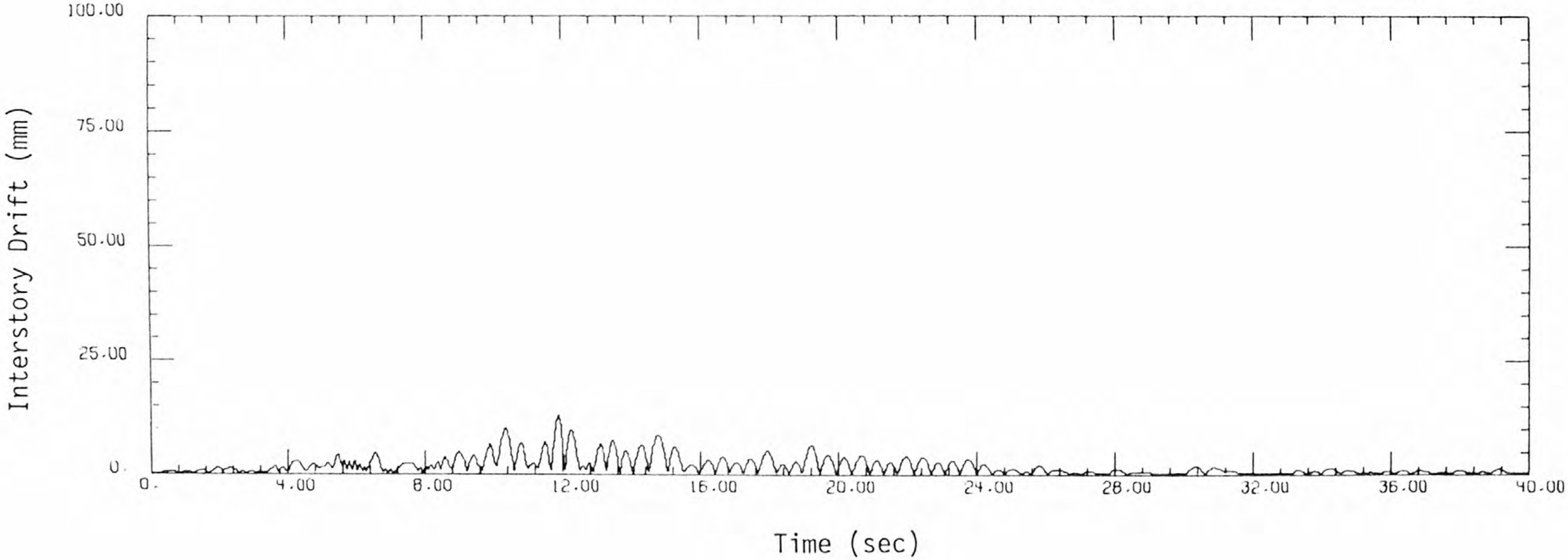


FIGURE 5.25 AVERAGE INTERSTORY DRIFT: ORION AVENUE HOLIDAY INN, TRANSVERSE DIRECTION, MODEL 1

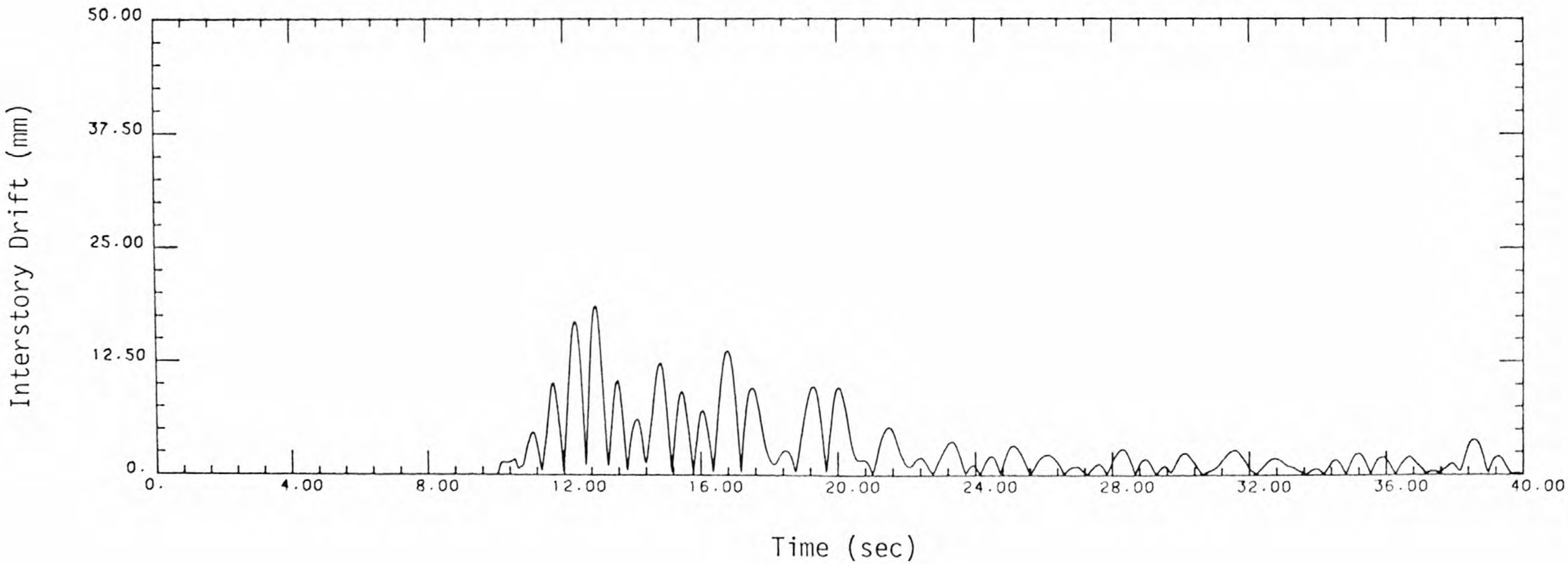


FIGURE 5.26 AVERAGE INTERSTORY DRIFT: ORION AVENUE HOLIDAY INN, LONGITUDINAL DIRECTION, MODEL 2

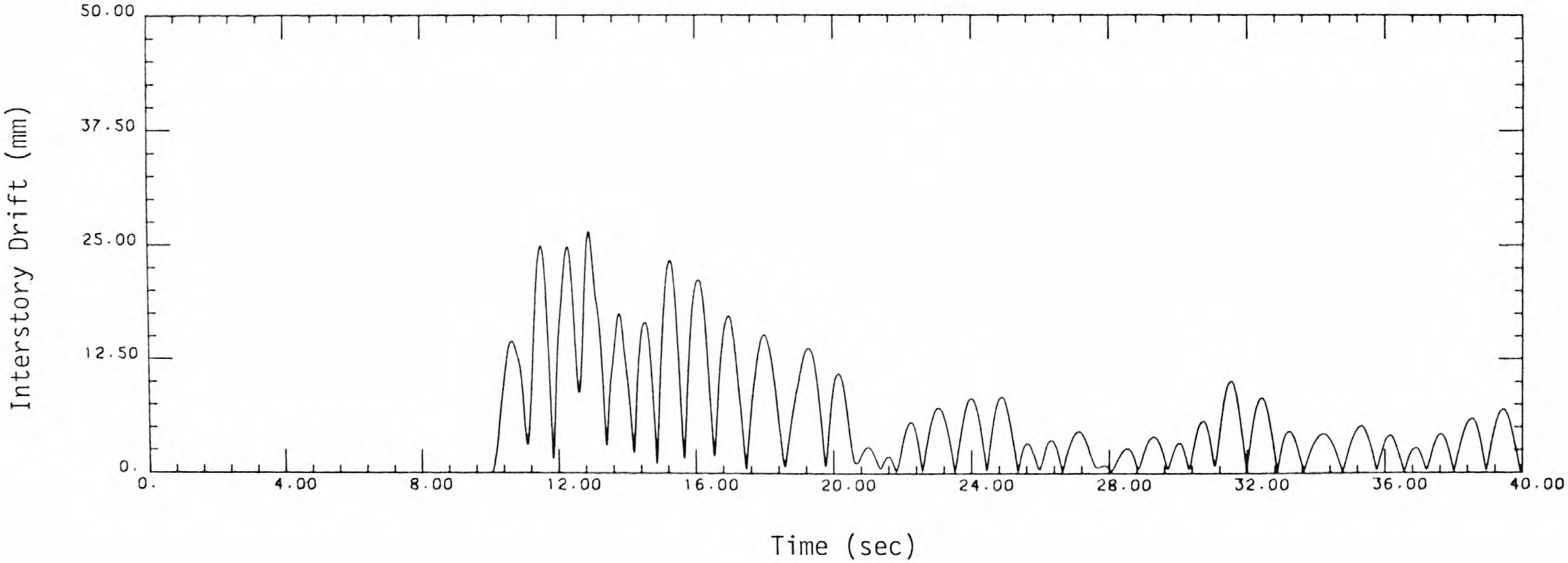


FIGURE 5.27 AVERAGE INTERSTORY DRIFT: ORION AVENUE HOLIDAY INN, TRANSVERSE DIRECTION, MODEL 2

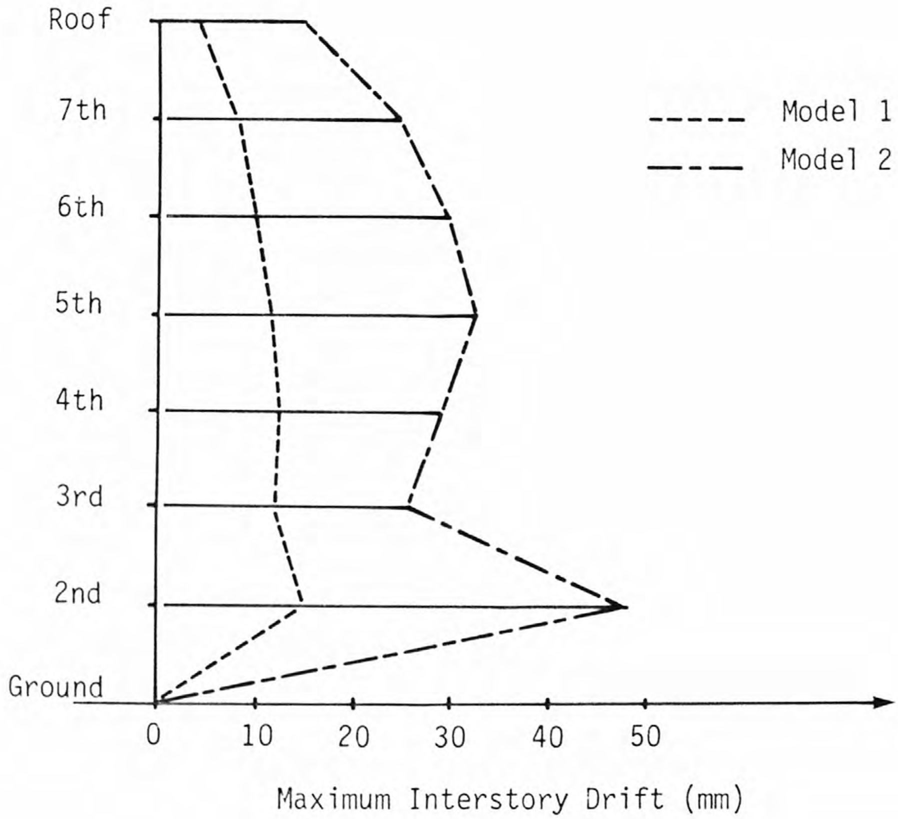


FIGURE 5.28 MAXIMUM CALCULATED INTERSTORY DRIFTS FOR ORION AVENUE HOLIDAY INN, TRANSVERSE DIRECTION

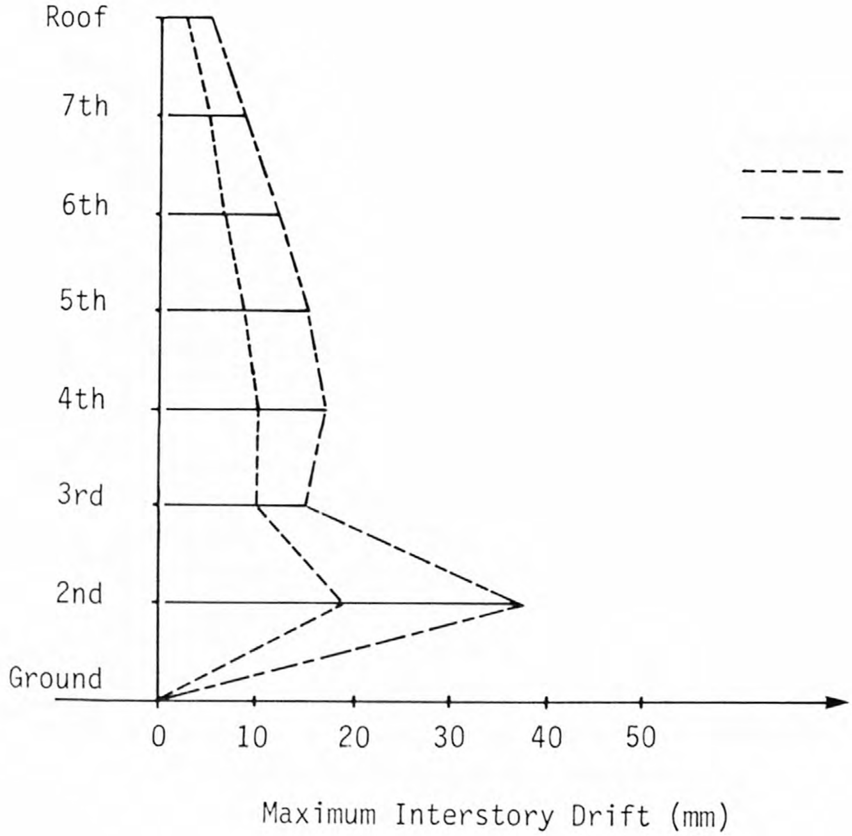


FIGURE 5.29 MAXIMUM CALCULATED INTERSTORY DRIFTS FOR ORION AVENUE HOLIDAY INN, LONGITUDINAL DIRECTION

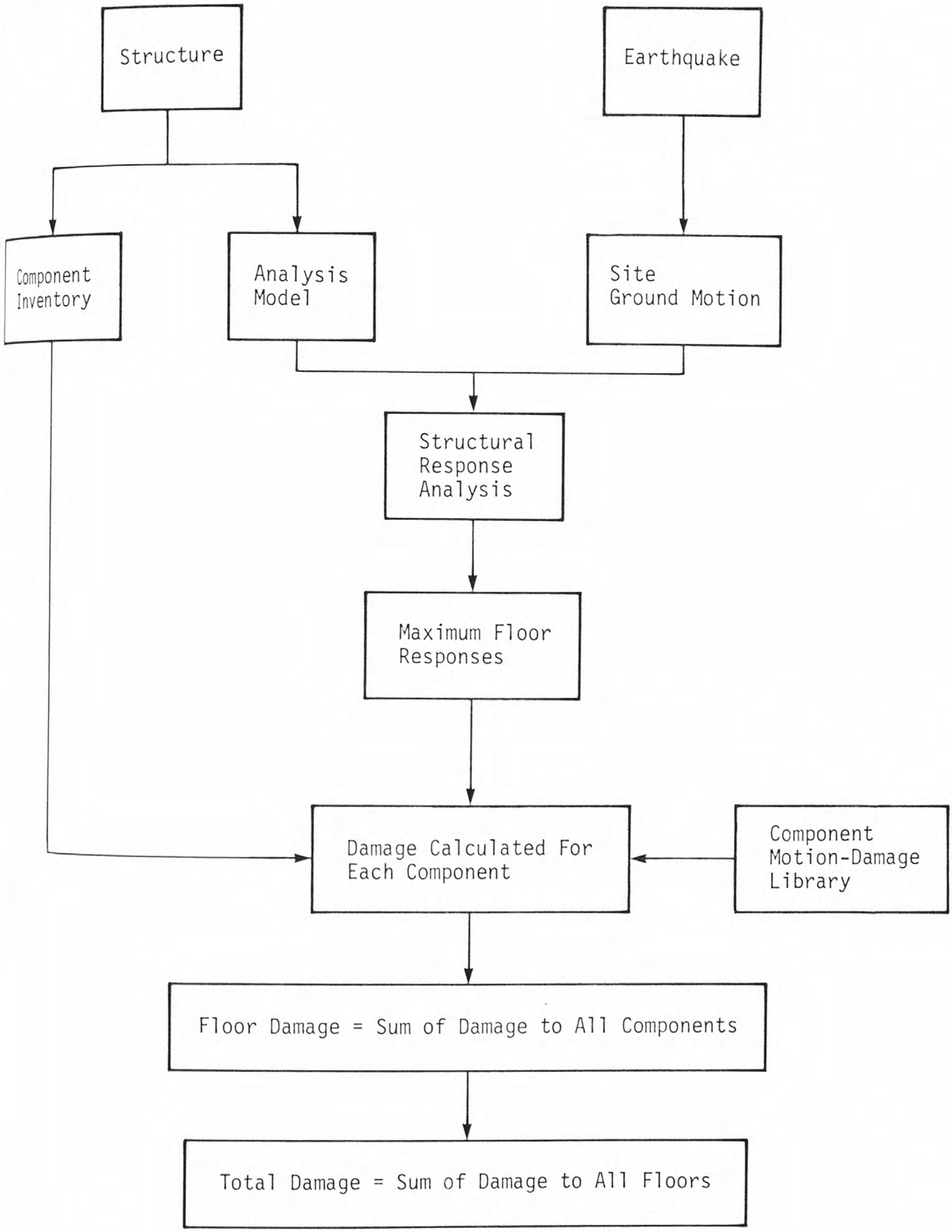


FIGURE 5.30 DAMAGE PREDICTION USING STRUCTURE COMPONENT INFORMATION

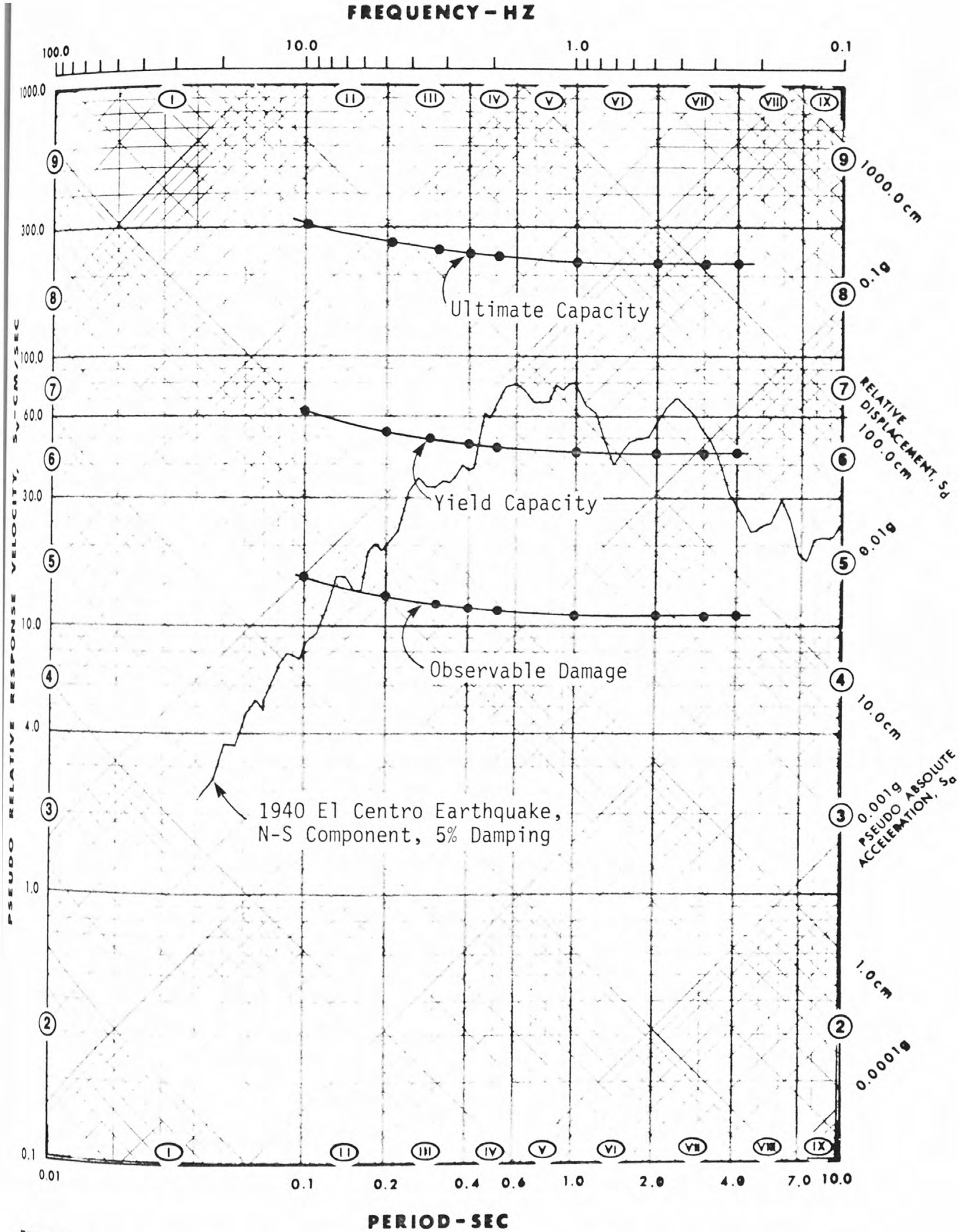


FIGURE 5.31 RESPONSE SPECTRUM AMPLITUDES FOR VARIOUS DAMAGE THRESHOLDS FOR REINFORCED CONCRETE FRAME STRUCTURES

6. EMPIRICAL MOTION-DAMAGE RELATIONSHIPS

6.1 Introduction

Motion-damage correlation analyses can be performed and presented in a variety of ways. The most important parameters are the ground motion, the type of structure, and the damage. Effective correlation of ground motion with damage, therefore, requires careful and precise identification of the damage, idealization of the structure, and characterization of the ground motion. Proper attention to these parameters at the outset reduces scatter in the correlation results and thus minimizes the tedium involved in the work.

Motion-damage correlations that are useful for reducing hazards must be performed using parameters used in engineering design. Empirical motion-damage relationships developed with this in mind can be used to develop theoretically based damage-prediction procedures. If the theoretically based damage-prediction procedures are not too esoterically prescribed, they can be useful to the designer to reduce hazards. Several theoretical damage-prediction procedures have been proposed; these are discussed in Chapter 1. Various considerations germane to theoretically predicting damage are discussed in Chapter 5. Finally, for completeness, details of some other theoretically based damage-prediction formulations that have been proposed are presented in Appendix F.

Variability is another fact that must be considered in correlating motion and damage. Ground motion is highly random, and buildings, considering the substantial variation in design and construction, must similarly be recognized as highly variable. Accordingly, it is expectable that there will be substantial variability in calculated damage. It is important to recognize that, at least currently, the only practicable means for determining the variability of damage as a function of ground motion is from the analysis of empirical data.

6.2 Correlation Parameters

As stated above, the most important parameters of motion-damage correlations are the ground motion, the type of structure, and the damage. Various aspects of these parameters, insofar as they must be considered for fruitful correlations and as they will be considered in this study, are discussed in this section.

6.2.1 Ground Motion Characterization. The ground motion that a structure might be subjected to can be identified in many ways: seismological intensity, peak ground motion parameters (acceleration, velocity, or displacement), response spectrum amplitude, or engineering intensity. The most important ground motion characteristics that affect dynamic structure response and damage are: motion amplitude, frequency content, periodicity, and duration. Insofar as these characteristics influence structure response and damage, they are all included in the response spectrum characterization, except duration. Ground motion duration is included to the extent that peak response is calculated, but structure response duration is not included. Structure response duration is not of significant importance for low levels of damage and for ductile materials (e.g., steel), but it is significant at high damage levels and for brittle materials (e.g., concrete). Another limitation of the response spectrum is that only linear response is depicted. At low levels of damage this is not a serious shortcoming, but at high damage levels it is.

Although response spectrum amplitudes are not a perfect means of characterizing ground motion, it is clear that spectral values are better than either seismological intensities or peak ground motion values. Accordingly, EIS values will be used as the principal ground motion characterization. Approximations to account for duration and for nonlinearity will be made where deemed necessary in the correlation analysis.

6.2.2 Structure Idealization. Structures can be idealized in many ways, for example by material type (e.g., steel, concrete, masonry) or construction system (e.g., frame, shear-wall, braced frame). The most important considerations for idealizing a structure are the dynamic response of the structure and the manner in which the construction materials and type imply that it will be damaged.

A multi-degree-of-freedom model is, of course, the most appropriate means to represent the dynamic response aspect of the problem. For the type of analysis being conducted, this is simply too elaborate, and approximations must be made. The most important aspect of dynamic response that needs to be included in the analysis is the characteristics of the fundamental mode of the building. These include period, mode shape, and damping. Period and damping can be readily included, but to include mode shape would require establishing another subset to the analysis. Accordingly, mode shape will be disregarded and will be recognized as contributing to the scatter in the results of the analysis. Consistent with the EIS, 5% damping will be assumed.

Construction materials and the type of construction system have a significant effect on the manner and degree in which damage is manifested. Accordingly, various classifications of structural systems and nonstructural components will be considered as follows:

- Structural Damage
  - -- Steel frame
  - -- Concrete frame
  - -- Concrete shear wall
  - -- Masonry shear wall
  - -- Braced frames
  - -- Foundations
- Nonstructural Damage
  - -- Drywall partitions
  - -- Brick infill walls
  - -- Concrete block infill walls
  - -- Glazing
  - -- Cladding
  - -- Other (ceilings, mechanical and electrical equipment, etc.)
- Damage to Contents

6.2.3 Damage Identification. The principal consideration in establishing an appropriate means of describing damage is that it satisfy user needs. To that end, two quantities are useful: the incidence of damage and the degree of damage. Quantitatively, these are calculated as follows:

Damage ratio (DR), defined by

$$DR = \frac{\text{number of buildings damaged}}{\text{total number of buildings}} \qquad (6.1)$$

Damage factor (DF), defined by

$$DF = \frac{\text{damage repair cost}}{\text{replacement value of building}} \tag{6.2}$$

These two nondimensional parameters are quite general and can be defined for a geographical area or subarea as well as for various building classifications or types of construction, e.g., steel, concrete, or masonry. They can also be defined for various types of damage, e.g., structural, nonstructural, or glass.

All that is needed for the ultimate development of a damage-prediction procedure is the DF and its variability. Tracking the DR facilitates a more complete understanding of the damage process.

6.3 Correlation Analysis Procedures

The principal correlation analyses will entail relating the two parameters -- DR and DF -- to corresponding EI values.

Three statistics useful for establishing damage probability density functions (shown for DF) are:

The mean of the damage probability density function m_{DF}

$$m_{DF} = \frac{1}{N} \sum_{i=1}^{N} DF_i \tag{6.3}$$

The variance of the damage probability density function, σ^2_{DF}

$$\sigma^2_{DF} = \frac{1}{N} \sum_{i=1}^{N} (DF_i - m_{DF})^2 \tag{6.4}$$

The standard deviation of the damage probability density function, σ_{DF}

$$\sigma_{DF} = \sqrt{\sigma^2_{DF}} \tag{6.5}$$

These statistics can be interpreted as geometric properties of the damage probability function. They are, respectively: the center of gravity, m_{DF}; the moment of inertia about the centroid, σ^2_{DF}; and the radius of gyration, σ_{DF}, of the area under the probability density function, which is considered as a plane curve.

A final statistic is the coefficient of variation, which is defined as:

$$V_{DF} = \sigma_{DF}/m_{DF} \tag{6.6}$$

V_{DF} measures the relative uncertainty or relative spread of the probability density function. Large values of V_{DF} are associated with large relative uncertainties, and vice versa.

Another means of revealing damage information is the damage probability matrix concept proposed by Whitman (1973). (See Tables 3.2 and 6.1.) Because these matrices so clearly reveal the shape of the damage probability density function, this information will also be calculated and presented.

To the extent that the motion-damage information can be linearized, correlation coefficients, r, will be calculated as follows (shown for DF):

$$r_{DF} = \frac{\Sigma\, xy}{\sqrt{(\Sigma\, x^2)(\Sigma\, y^2)}} \tag{6.7}$$

where:

$$x = \text{EI} - \overline{\text{EI}}$$
$$y = \text{DF} - \overline{\text{DF}}$$

6.4 Additional Studies for Completion

The work remaining for this task, Task IV, is that of utilizing the data base to calculate the empirical motion-damage relationships. This work will be executed upon completion of Task III.

TABLE 6.1

GENERAL FORM OF DAMAGE PROBABILITY MATRIX

Damage State	Structural Damage	Nonstructural Damage	Damage Ratio (%)	Intensity of Earthquake				
				V	VI	VII	VIII	IX
0	none	none	0 - 0.05	95	79	33	6	0
1	none	minor	0.05 - 0.3	5	18	34	19	2
2	none	localized	0.3 - 1.25	0	3	20	44	18
3	not noticeable	widespread	1.25 - 3.5	0	0	10	13	30
4	minor	substantial	3.5 - 7.5	0	0	3	6	20
5	substantial	extensive	7.5 - 20	0	0	0	12	10
6	major	nearly total	20 - 65	0	0	0	0	7
7	building condemned		100	0	0	0	0	8
8	collapse		100	0	0	0	0	5

Source: Whitman (1973)

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APPENDIX B

Sample Listings of the HIRISE Data Base

SAMPLE LISTINGS OF THE HIRISE DATA-BASE

B.1 General Listings

The product of this project's data-collection effort is stored at the Lawrence Berkeley Laboratory computer using the MRI SYSTEM 2000 data-base management system. Rather than a large computer output, this appendix includes a number of tables and figures that summarize certain features of the HIRISE data base and indicate the versatility of the data-base system.

Table B.1 lists the total number of sites in each of the 27 urban areas included in the data base. The earthquakes considered in the study are listed chronologically by area in Table B.2. Tables B.3, B.4, and B.5 were generated by scanning the data and extracting a subset of elements meeting stated criteria. Site geology (element C41) was used to select the elements shown in Table B.3, where all buildings listed are located on rock sites. Table B.4 lists selected data for all sites affected by the Kern County earthquake of July 21, 1952. All buildings with a damage factor greater than 0.70 or a damage state equal to 8, indicating collapse or condemnation, are listed in Table B.5 along with the earthquake ID, the number of stories, and the MMI.

The unique occurrences and frequency of occurrence can be tabulated for any KEY element in the data base. This is shown in Table B.6 for data-base elements C43 and C47, the number of stories and height code, respectively, along with the correlation between the two elements. For example, a height code of 3 is assigned to 105 buildings with 12 to 17 stories.

All available information for a specific building can be readily listed using the SYSTEM 2000 PRINT command. Examples of this are shown in Figures B.1, B.2, and B.3 for one building in each of three cities: Los Angeles, Mexico City, and Sendai, Japan. The data values following each asterisk may be interpreted with the help of the codes shown on the data collection forms reproduced in Chapter 3 (Figures 3.12 through 3.15).

B.2 Sample Listings for the San Fernando Earthquake

Data base HIRISE contains a wide variety of information describing the greater Los Angeles area and the effects of the San Fernando earthquake. Figure B.4 is a graphic representation of the grid system showing the location code and soil type for each grid cell as well as the average MMI, the number of affected high-rise buildings, and the availability of ground motion records for the San Fernando earthquake. Many cells did not have any high-rise buildings in 1971; the figure shows that approximately 45% of the buildings were concentrated in downtown Los Angeles in grid cell E06.

The high-rise building inventory for the Los Angeles area is listed in Table B.7, which shows selected data for each building. The most complete documentation was obtained for the buildings numbered 201 to 275, which had strong-motion recording instruments in 1971 as required by the Los Angeles city building code. The majority of buildings were not instrumented, and these are numbered 501 and above. Some data items for these noninstrumented buildings were given assumed values because more complete information was unavailable. For example, design base shear values were calculated assuming a code design based on the date of construction and the number of floors. Buildings constructed prior to 1933 are shown as having no building code and a design base shear coefficient of 0.0. Data for the Los Angeles grid system is shown in Table B.8 including the latitude and longitude at the center of each grid cell and average values for the soil type, epicentral distance, MMI, and the duration of strong motion in seconds.

Two additional listings are included to illustrate the selectivity and sorting capabilities of the data-base system. The first, Table B.9, was generated by a scan of the building list to tally the number of buildings in each grid cell. These subtotals for each cell are also given in Figure B.4. The second example, Table B.10, includes only undamaged, reinforced concrete buildings in grid cell D06 (roughly the area bounded by 3rd Street, Vermont Avenue, Rodeo Boulevard, and Hauser Boulevard). Fourteen of the eighteen 13-story buildings in the Park LaBrea complex were selected using these criteria. The remaining four buildings in this complex are also undamaged, reinforced concrete but are in grid cell C06 and thus were not listed. This sort-and-selection capability is important for use with correlation procedures.

TABLE B.1

NUMBER OF SITES IN EACH AREA 1
79/04/01

COUNTRY	URBAN AREA	NUMBER OF SITES
***		
* UNITED STATES	ANCHORAGE	12
* UNITED STATES	WHITTIER	1
* UNITED STATES	BAKERSFIELD	1
* UNITED STATES	LOS ANGELES	137
* UNITED STATES	OAKLAND	1
* UNITED STATES	SAN FRANCISCO	66
* UNITED STATES	SAN JOSE	1
* UNITED STATES	SANTA BARBARA	19
* UNITED STATES	OLYMPIA	1
* UNITED STATES	SEATTLE	3
* UNITED STATES	TACOMA	2
* GUATEMALA	GUATEMALA	3
* MEXICO	MEXICO	45
* NICARAGUA	MANAGUA	12
* VENEZUELA	CARABELLEDA	5
* VENEZUELA	CARACAS	24
* GREECE	SALONICA	6
* ITALY	FRUILI	7
* MOROCCO	AGADIR	2
* ROMANIA	BUCHAREST	18
* YUGOSLAVIA	SKOPJE	7
* JAPAN	HACHINOHE	5
* JAPAN	IZU PENINSULA	8
* JAPAN	NIIGATA	11
* JAPAN	SENDAI	6
* JAPAN	TOKYO	10
* PHILIPPINES	COTABATO	2

TABLE B.2

LIST OF EARTHQUAKES CONSIDERED

79/04/01

COUNTRY	URBAN AREA	EARTHQUAKE ID	M	DATE
GREECE	SALONICA	GRE-06-78-F1	5.75	05/24/1978
GREECE	SALONICA	GRE-06-78	6.50	06/20/1978
GUATEMALA	GUATEMALA	GUA-02-76	7.50	02/04/1976
ITALY	FRUILI	ITA-05-76	6.50	05/06/1976
JAPAN	HACHINOHE	JPN-05-68	7.90	05/16/1968
JAPAN	HACHINOHE	JPN-05-68-A1	7.50	05/16/1968
JAPAN	HACHINOHE	JPN-06-78		06/12/1978
JAPAN	IZU PENINSULA	JPN-05-74	6.80	05/08/1974
JAPAN	NIIGATA	JPN-06-64	7.50	06/06/1964
JAPAN	SENDAI	JPN-06-78	7.40	06/12/1978
JAPAN	TOKYO	JPN-09-23	8.30	09/01/1923
MEXICO	MEXICO	MEX-06-11		06/07/1911
MEXICO	MEXICO	MEX-12-37		12/23/1937
MEXICO	MEXICO	MEX-02-43		02/22/1943
MEXICO	MEXICO	MEX-04-44		04/15/1944
MEXICO	MEXICO	MEX-01-51		01/05/1951
MEXICO	MEXICO	MEX-07-57	7.50	07/28/1957
MEXICO	MEXICO	MEX-07-57-A1	6.25	08/04/1957
MEXICO	MEXICO	MEX-08-59	6.50	08/26/1959
MEXICO	MEXICO	MEX-12-61	5.25	12/10/1961
MEXICO	MEXICO	MEX-05-62	6.70	05/11/1962
MEXICO	MEXICO	MEX-05-62-A1	6.50	05/19/1962
MEXICO	MEXICO	MEX-07-64		07/06/1964
MEXICO	MEXICO	MEX-12-65	6.80	12/09/1964
MEXICO	MEXICO	MEX-08-68	6.50	08/02/1968
MEXICO	MEXICO	MEX-08-73	7.00	08/28/1973
MEXICO	MEXICO	MEX-11-78	7.00	11/29/1978
MEXICO	MEXICO	MEX-14-79	7.50	03/14/1979
MOROCCO	AGADIR	MOR-02-60	5.75	02/29/1960
NICARAGUA	MANAGUA	MNG-01-68	4.50	01/04/1968
NICARAGUA	MANAGUA	MNG-01-68-A1		01/18/1968
NICARAGUA	MANAGUA	MNG-01-68-A2		01/22/1968
NICARAGUA	MANAGUA	MNG-01-72		01/02/1972
NICARAGUA	MANAGUA	MNG-01-72-A1		01/04/1972
NICARAGUA	MANAGUA	MNG-01-72-A2		01/05/1972
NICARAGUA	MANAGUA	MNG-12-72-A1	5.00	12/23/1972
NICARAGUA	MANAGUA	MNG-12-72-A2	5.20	12/23/1972
NICARAGUA	MANAGUA	MNG-12-72	5.60	12/23/1972
PHILIPPINES	COTABATO	PHL-08-76	7.90	08/16/1976
PHILIPPINES	COTABATO	PHL-08-76-A1	6.80	08/17/1976
ROMANIA	BUCHAREST	ROM-03-77	7.20	03/04/1977
UNITED STATES	ANCHORAGE	ALA-10-54	6.75	10/03/1954
UNITED STATES	ANCHORAGE	ALA-03-64	8.40	03/28/1964

COUNTRY	URBAN AREA	EARTHQUAKE ID	M	DATE
UNITED STATES	BAKERSFIELD	KRN-07-52		07/21/1952
UNITED STATES	BAKERSFIELD	KRN-08-52	5.80	08/22/1952
UNITED STATES	BAKERSFIELD	SFD-02-71		02/09/1971
UNITED STATES	LOS ANGELES	LBH-03-33	6.30	03/11/1933
UNITED STATES	LOS ANGELES	TOR-11-41	5.40	11/14/1941
UNITED STATES	LOS ANGELES	KRN-07-52	7.70	07/21/1952
UNITED STATES	LOS ANGELES	KRN-08-52		08/22/1952
UNITED STATES	LOS ANGELES	BOR-04-68	6.40	04/09/1968
UNITED STATES	LOS ANGELES	LYT-09-70	5.40	09/12/1970
UNITED STATES	LOS ANGELES	SFD-02-71	6.40	02/09/1971
UNITED STATES	LOS ANGELES	PMG-02-73	5.90	02/21/1973
UNITED STATES	OAKLAND	SFR-04-06		04/18/1906
UNITED STATES	OAKLAND	JOS-09-55		09/05/1955
UNITED STATES	OAKLAND	OAK-10-55	5.50	10/24/1955
UNITED STATES	OAKLAND	SFR-03-57		03/22/1957
UNITED STATES	OAKLAND	ROS-10-69		10/02/1969
UNITED STATES	OLYMPIA	OLY-04-49	7.10	04/13/1949
UNITED STATES	OLYMPIA	SEA-04-65		04/29/1965
UNITED STATES	SAN FRANCISCO	SFR-04-06	8.25	04/18/1906
UNITED STATES	SAN FRANCISCO	JOS-09-55		09/05/1955
UNITED STATES	SAN FRANCISCO	OAK-10-55		10/24/1955
UNITED STATES	SAN FRANCISCO	SFR-03-57	5.30	03/22/1957
UNITED STATES	SAN FRANCISCO	ROS-10-69	5.70	10/02/1969
UNITED STATES	SAN JOSE	SFR-04-06		04/18/1906
UNITED STATES	SAN JOSE	JOS-09-55	5.80	09/05/1955
UNITED STATES	SAN JOSE	OAK-10-55		10/24/1955
UNITED STATES	SAN JOSE	SFR-03-57		03/22/1957
UNITED STATES	SANTA BARBARA	SBA-06-25	6.30	06/29/1925
UNITED STATES	SANTA BARBARA	SBA-06-41	5.90	07/01/1941
UNITED STATES	SANTA BARBARA	KRN-07-52		07/21/1952
UNITED STATES	SANTA BARBARA	KRN-08-52		08/22/1952
UNITED STATES	SANTA BARBARA	BOR-04-68		04/09/1968
UNITED STATES	SANTA BARBARA	SFD-02-71		02/09/1971
UNITED STATES	SANTA BARBARA	PMG-02-73		02/21/1973
UNITED STATES	SANTA BARBARA	SBA-08-78	5.10	08/13/1978
UNITED STATES	SEATTLE	OLY-04-49		04/13/1949
UNITED STATES	SEATTLE	SEA-04-65	6.50	04/29/1965
UNITED STATES	TACOMA	OLY-04-49		04/13/1949
UNITED STATES	TACOMA	SEA-04-65		04/29/1965
UNITED STATES	WHITTIER	ALA-03-64		03/28/1964
VENEZUELA	CARABELLEDA	VNZ-07-67		07/29/1967
VENEZUELA	CARACAS	VNZ-07-67	6.50	07/29/1967
YUGOSLAVIA	SKOPJE	YUG-07-63	6.00	07/26/1963

TABLE B.3

SAMPLE LIST OF BUILDINGS ON ROCK SITES

04/29/79

URBAN AREA	SITE ID	INSTRU-MENTS	SOIL TYPE	NO. OF STORIES	YEAR BUILT	STRUCT. MATL.
LOS ANGELES	220	BU	RK	39	1965	ST
LOS ANGELES	222	BU	RK	32	1968	ST
LOS ANGELES	225	BU	RK	17	1966	ST
LOS ANGELES	231	BU	RK	17	1962	ST
LOS ANGELES	232	BU	RK	20	1968	RC
LOS ANGELES	272	HB	RK	13	1930	
LOS ANGELES	273	HB	RK	12	1927	ST
SAN FRANCISCO	204	HB	RK	7	1960	RC

TABLE B.4

SELECTED DATA FOR THE KERN COUNTY EARTHQUAKE OF 21JUL52 1

79/04/01

URBAN AREA	SITE ID	NO. OF STORIES	BLDG MATL	MMI	DAMAGE FACTOR	DAMAGE STATE
***						
* BAKERSFIELD	501	8	RC	8.0	0.01000	3
* LOS ANGELES	7					
* LOS ANGELES	16			6.0		
* LOS ANGELES	23			7.0		
* LOS ANGELES	226	14	RC	7.0		
* LOS ANGELES	273	12	ST	7.0	0.04000	
* LOS ANGELES	505	12	ST	7.0		3
* LOS ANGELES	507	11	ST	7.0	0.06000	3
* LOS ANGELES	508	9	ST	7.0		2
* LOS ANGELES	509	6	ST	7.0		2
* LOS ANGELES	510	9	ST	7.0		5
* LOS ANGELES	511	12	ST	7.0		2
* LOS ANGELES	512	12	ST	7.0		2
* LOS ANGELES	513	13	ST	7.0		2
* LOS ANGELES	514	12	ST	7.0		2
* LOS ANGELES	515	11	ST	7.0		5
* LOS ANGELES	516	12	ST	7.0		5
* LOS ANGELES	517	12	ST	7.0		5
* LOS ANGELES	518	12	ST	7.0	0.02000	3
* LOS ANGELES	519	11	ST	7.0	0.01000	2
* LOS ANGELES	520	15	ST	7.0	0.01000	3
* LOS ANGELES	521	13	ST	7.0	0.02500	3
* LOS ANGELES	522	13	ST	7.0		3
* LOS ANGELES	523	12	RC	7.0		5
* LOS ANGELES	524	11	ST	7.0		5
* LOS ANGELES	525	13	RC	6.0		2
* LOS ANGELES	526	9	ST	6.0		4
* LOS ANGELES	527	10	RC	6.0		
* LOS ANGELES	528	12	RC	6.0		5
* LOS ANGELES	529	12	ST	6.0		4
* SANTA BARBARA	7			7.0		
* SANTA BARBARA	501	8	RC		0.05000	
* SANTA BARBARA	502	6	RC	7.0	0.22000	6

TABLE B.5

LIST OF EXTENSIVELY DAMAGED BUILDINGS

80/08/11

URBAN AREA	SITE ID	EARTHQUAKE ID	NO. OF STORIES	MMI	DAMAGE FACTOR	DAMAGE STATE
***						
* AGADIR	502	MOR-02-60	8	10.0		8
* ANCHORAGE	501	ALA-03-64	6	9.0	1.00000	8
* ANCHORAGE	506	ALA-03-64	6	9.0	1.00000	8
* BUCHAREST	501	ROM-03-77				8
* BUCHAREST	502	ROM-03-77				8
* BUCHAREST	503	ROM-03-77				8
* BUCHAREST	504	ROM-03-77				8
* BUCHAREST	505	ROM-03-77	12			8
* BUCHAREST	506	ROM-03-77	9			8
* BUCHAREST	507	ROM-03-77	8			8
* BUCHAREST	508	ROM-03-77	10			8
* BUCHAREST	510	ROM-03-77	10			8
* BUCHAREST	511	ROM-03-77	8			8
* CARABALLEDA	503	VNZ-07-67	11	8.0		8
* CARACAS	501	VNZ-07-67	10	7.0		8
* CARACAS	502	VNZ-07-67	12	7.0		8
* CARACAS	503	VNZ-07-67	12	7.0		8
* CARACAS	504	VNZ-07-67	11	7.0		8
* FRIULI	501	ITA-05-76	6	9.0		8
* FRIULI	503	ITA-05-76	6	9.0		8
* GUATEMALA	501	GUA-02-76	6	8.0		8
* LOS ANGELES	504	SFD-02-71	6	11.0	1.00000	8
* MANAGUA	509	MNG-12-72		9.0		8
* MEXICO	505	MEX-07-57	16	8.0		8
* MEXICO	510	MEX-07-57	8	8.0		8
* MEXICO	516	MEX-07-57		8.0		8
* MEXICO	517	MEX-07-57	6	8.0		8
* MEXICO	518	MEX-07-57	6	8.0		8
* SALONICA	201	GRE-06-78	7	6.0		8
* SALONICA	501	GRE-06-78	8	6.0	1.00000	8
* SKOPJE	501	YUG-07-63	7	9.0		8
* TOKYO	507	JPN-09-23	7	9.0	1.00000	8

TABLE B.6

HEIGHT DISTRIBUTION FOR 338 BUILDINGS

TALLY/EACH/C43:

ELEMENT- STORIES ABOVE GRADE

FREQUENCY	VALUE
38	6
40	7
30	8
32	9
41	10
24	11
32	12
27	13
18	14
11	15
9	16
8	17
5	18
3	19
6	20
2	21
1	22
1	23
1	26
1	27
1	29
1	30
1	31
1	32
1	35
1	39
1	42
1	43

28 UNIQUE VALUES

338 OCCURRENCES

ELEMENT- HEIGHT CODE /N/

FREQUENCY	VALUE
108	1
97	2
105	3
28	4

4 UNIQUE VALUES

338 OCCURRENCES

Height Code 1: 6 to 8 stories
Height Code 2: 9 to 11 stories
Height Code 3: 12 to 17 stories
Height Code 4: 18 to 43 stories

(As of April 7, 1980)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
201	F05	DA	12	2	345556654	30500	1969	UBC70	0.032	ST	RG			1
202	C05	DA	10	2	334555554		1970	UBC70	0.070	RC				1
203	C06	DA	10	2	355555564		1970	UBC70	0.070	RC				1
204	C06	LA	10	2	345555665	22000	1969	UBC70	0.070	RC	RG	3240000	0.00000	0
205		DA	18	3	233454555		1970	UBC70	0.057	RC				1
206	J09	DA	10	2	234444554	17540	1970	UBC70	0.070	RC	IR			1
207	G11	DA	9	2	234455564		1969	UBC70	0.072					1
208	C08	DA	14	2	234445565	25600	1967	UBC70	0.062	ST		10438350	0.00287	2
209	C06	DA	27	3		51500	1968	UBC70	0.024	ST	RG	21360000	0.00118	1
210	C06	DA	20	3	355555565	46500	1966	UBC67	0.037	ST	RG	19519000	0.00072	1
211	C06	DA	7	1	345555565		1966	UBC70	0.078	RC	IR			1
212	C08	DA	7	1		15000	1967	UBC70	0.038	ST				1
213	C06	DA	16	2	345555565	23000	1970	UBC70	0.043	RC		9120000	0.00033	0
214	C06	DA	15	2	345555565	31500	1968	UBC70	0.029	ST	RG	9944000	0.00051	2
215	C06	DA	20	3		47600	1969	UBC70	0.055	ST		11600000	0.00086	1
216	C06	DA	6	1		24000	1970	UBC70	0.095	RC				1
217	C06	DA	17	2		17400	1969	UBC70	0.058	RC		9390000	0.00021	2
218	E06	LA	17	2	345555665	11300	1968	UBC70	0.083	RC	RG	13853000	0.00000	0
219	E06	LA	17	2		11300	1968	UBC70	0.083	RC	IR	13853000	0.00000	0
220	E06	RK	39	3	345565665	69600	1965	UBC70	0.040	ST	RG	30000000	0.00333	2
221	E06	DA	15	2	345555665	8800	1967	UBC70	0.029	ST	RG	3668000	0.00027	0
222	E06	RK	32	3	345556665	30000	1968		0.030	ST	RG	13267800	0.00007	1
223	E06	DA	10	2		11000	1967	UBC70	0.070	RC				1
224	E06	MA	8	1			1967	UBC70	0.075	RC	IR			1
225	E06	RK	17	2		34000	1966	UBC64	0.058	ST				1
226	D05	DA	14	2	355566665	14000	1930		0.000	RC				
227	B06	DA	15	2		9290	1968	UBC70	0.061	ST	IR	8646000	0.00001	0
228	E06	DA	10	2	344556665	44500	1968	UBC70	0.037	ST				1
229	D05	DA	11	2	345555554	12100	1968	UBC64	0.032	RC	IR	4608000	0.00239	2
231	E06	RK	17	2	345555665	82000	1962	UBC64	0.030	ST	RG	43120000	0.00104	1
232	C04	RK	20	3	345555554	25300	1968	UBC67	0.026	RC	RG	9825000	0.00021	0
233	C08	DA	12	2	234455565	12000	1967	UBC70	0.062	RC	IR			0
234	F06	DA	7	1	345556555	5900	1966	UBC67	0.038	RC	RG	2332800	0.03772	5
235	D06	DA	16	2	345555665	16600	1969	UBC70	0.060	RC		3808100	0.00242	2
236	E06	DA	7	1	355566665	14100	1966	UBC70	0.075	OT	IR			
237	E06	DA	7	1	345566665	24400	1969	UBC70	0.078	RC				
238	E06	DA	10	2	355566665	27800	1969	UBC70	0.070	RC	IR			
239	D05	DA	22	3	345555554	25240	1968	UBC70	0.026	RC		7800000	0.00125	1
240	B03	DA	7	1	355667765	5900	1966	UBC67	0.038	RC	RG	2304000	0.05103	5
241	C06	DA	9	2	345555665	9300	1965	UBC67	0.072	RC	IR	7488000	0.00142	2
242	B06	DA	9	2		9760	1969	UBC70	0.072	RC		3600000	0.00072	2
243	E06	DA	42	3	344555665	72300	1966	UBC67	0.021	ST	IR	35108000	0.00062	1
244	D06	DA	9	2	355565665	10300	1965	UBC67	0.072	ST	IR	3312000	0.00010	0
245	D05	MA	8	1	345566665	47000	1966	UBC67	0.075	RC	IR			
246	D05	DA	14	2		20000	1969	UBC70	0.062	ST				

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
247	D05	DA	11	2		8830	1968	UBC70	0.067	ST		3537000	0.00057	1
248	B06	DA	14	2		9100	1966	UBC67	0.062	RC				1
249	B06	MA	7	1	345455554		1969	UBC70	0.078					
250	E06	MA	12	2	234556665	6270	1966	UBC67	0.066					
251	B03	DA	7	1	345557775	21800	1970	UBC73	0.040	RC	IR	5875000	0.00851	3
252	B04	DA	14	2	356656775	15800	1966	UBC64	0.077	RC	RG	4161600	0.00769	3
253	B04	DA	12	2	355556765	10900	1970	UBC70	0.057	RC	RG	3277000	0.01293	5
254	B04	DA	13	2		11000	1967	UBC70	0.064	RC	IR	4879750	0.00205	2
255	B04	DA	16	2	345566664	17900	1970	UBC70	0.029	ST	RG	5700000	0.01754	2
256	B04		12	2		55000	1969	UBC73	0.066	PC				
257	A04	DA	10	2		10200	1965	UBC70	0.070	RC		4312560	0.00000	0
258	E06	DA	13	2	344556664	21400	1970	UBC70	0.064	RC	IR	6780000	0.00004	0
259	D06	DA	12	2		11800	1966	UBC70	0.053	RC		8803800	0.00002	1
260	D06	DA	31	3		50000	1969	UBC70	0.048	ST		29640000	0.00186	2
261	D06	DA	12	2	345566665	26700	1966	UBC70	0.047	RC				
262	D06	DA	21	3		41300	1969	UBC70	0.054	ST		13000800	0.00232	2
263	D06	DA	11	2	345556665	28000	1965	UBC70	0.048	RC		4454500	0.00786	3
264	D06	DA	7	1	345555665	8082	1966	UBC70	0.078	RC	IR			
265	C06	DA	30	3		40000	1968	UBC70	0.048	ST		18080000	0.00277	2
266	C06	DA	15	2	345555675	19000	1969	UBC70	0.061	RC	IR			
267	F06	LA	9	2	334555555	10100	1966	UBC70	0.079	RC				
268	J11	DA	19	3	234444554	1700	1967	UBC70	0.056	RC			0.00000	0
269	G04	DA	9	2	345555554	4330	1966	UBC70	0.068	RC	IR			
270	F03	DA	9	2	345555554	8180	1966	UBC70	0.072	ST		5167500	0.01935	4
272	E06	RK	13	2		32500	1930		0.000			8750000	0.00286	2
274	E07	DA	6	1			1930		0.000					
275		DA	6	1			1966	UBC70	0.083					0
501	B04	MA	13	2		18600	1965	UBC70	0.064	RC		6103420	0.01597	4
502	B01	DA	7	1		7400	1966	UBC70	0.045	RC	RG	1900000	0.16000	6
503	B01	DA	7	1		13000	1961	UBC60	0.052	RC	IR	9500000	0.48000	7
504	B01	DA	6	1			1965	UBC64	0.045	RC	IR		1.00000	8
530	E06		27	3		55700	1928	NO	0.000	ST	IR	15000000	0.08667	5
531	E06		10	2		13900	1953	UBC	0.041	ST	IR	5420000	0.00000	0
532	E06		7	1		31200	1932	NO	0.000	ST	IR	8400000	0.02524	4
533	E06		10	2		5390	1964	UBC	0.070	ST	RG	3700000	0.00000	0
534	E06		6	1			1930	NO	0.000	RC	IR		0.00000	0
535	E06		13	2			1925	NO	0.000	RC	IR		0.00000	0
536	E06		8	1			1912	NO	0.000	RC	IR		0.00000	0
537	D05		7	1			1928	NO	0.000	RC	IR		0.00000	0
538	D06		6	1			1927	NO	0.000	RC	RG		0.00000	0
539	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
540	E06		6	1			1909	NO	0.000	RC	IR		0.00000	0
541	E06		6	1			1907	NO	0.000	ST	IR		0.00000	0
542	E06		7	1			1920	NO	0.000	ST	IR		0.00000	0
543	E06		13	2			1918	NO	0.000	ST	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
544	E06		7	1			1920	NO	0.000	RC	IR		0.00000	0
545	E06		8	1			1926	NO	0.000	RC	IR		0.00000	0
546	D06		6	1			1928	NO	0.000	ST	IR		0.00000	0
547	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
548	E06		6	1			1904	NO	0.000	RC	IR		0.00000	0
549	E06		6	1			1910	NO	0.000	ST	IR		0.00000	0
550	D06		6	1			1930	NO	0.000	RC	IR		0.00000	0
551	E06		6	1			1905	NO	0.000	RC	IR		0.00000	0
552	E06		7	1		650	1915	NO	0.000	ST	IR	175000	0.02857	4
553	E06		13	2			1915	NO	0.000	ST	IR		0.00000	0
554	E06		12	2		14600	1914	NO	0.000	ST	IR	3915000	0.03814	5
555	E06		12	2			1905	NO	0.000	RC	IR		0.00000	0
556	E06		12	2		10400	1927	NO	0.000	ST	IR	2800000	0.00357	2
557	E06		9	2		7840	1913	NO	0.000	RC	IR	2109500	0.01673	4
558	E12		12	2		13010	1964	UBC	0.066	ST	RG	4770000	0.00000	0
559	E06		13	2			1923	NO	0.000	ST	IR		0.00000	0
560	E06		9	2			1913	NO	0.000	ST	IR		0.00000	0
561	E06		13	2		7150	1930	NO	0.000	ST	IR	1925000	0.00052	1
562	E06		8	1			1906	NO	0.000	RC	IR		0.00000	0
563	E06		6	1			1920	NO	0.000	RC	IR		0.00000	0
564	E06		9	2			1921	NO	0.000	RC	IR		0.00000	0
565	E06		6	1		660	1911	NO	0.000	RC	IR	88750	0.06761	5
566	E06		7	1			1933	UBC	0.010	RC	IR		0.00000	0
567	E06		12	2			1927	NO	0.000	RC	IR		0.00000	0
568	E06		11	2			1908	NO	0.000	ST	IR		0.00000	0
569	E06		8	1			1920	NO	0.000	RC	IR		0.00000	0
570	E06		6	1			1910	NO	0.000	RC	IR		0.00000	0
571	E06		12	2		18600	1923	NO	0.000	RC	IR	5000000	0.02000	4
572	E06		6	1			1924	NO	0.000	RC	IR		0.00000	0
573	E06		11	2		10100	1907	NO	0.000	ST	IR	2715350	0.08309	5
574	E06		10	2			1923	NO	0.000	ST	IR		0.00000	0
575	E06		13	2		20400	1912	NO	0.000	ST	IR	5500000	0.01170	4
576	E06		7	1			1906	NO	0.000	ST	IR		0.00000	0
577	E06		14	2		6380	1914	NO	0.000	ST	IR	1717500	0.00000	0
578	E06		12	2		3900	1921	NO	0.000	ST	IR	524250	0.28612	7
579	E06		12	2		46300	1912	NO	0.000	ST	IR	12469000	0.00642	3
580	E06		13	2		13000	1927	NO	0.000	RC	IR	3500000	0.00583	3
581	E06		6	1			1924	NO	0.000	RC	IR		0.00000	0
582	E06		6	1			1924	NO	0.000	RC	IR		0.00000	0
583	E06		9	2			1912	NO	0.000	RC	IR		0.00000	0
584	E06		10	2		1630	1924	NO	0.000	RC	IR	219250	0.09122	6
585	E06		7	1		11600	1926	NO	0.000	RC	IR	3125000	0.02816	4
586	E06		10	2			1927	NO	0.000	RC	IR		0.00000	0
587	E06		10	2		7900	1924	NO	0.000	RC	IR	2125000	0.00235	2

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
588	E06		8	1		3250	1923	NO	0.000	RC	RG	875000	0.00480	3
589	E06		12	2			1920	NO	0.000	RC	RG		0.00000	0
590	E06		7	1			1916	NO	0.000	RC	IR		0.00000	0
591	E06		8	1			1925	NO	0.000	RC	IR		0.00000	0
592	E06		13	2			1925	NO	0.000	RC	IR		0.00000	0
593	D06		12	2		13900	1961	UBC	0.036	ST	IR	4060000	0.00000	0
594	E06		13	2			1924	NO	0.000	RC	IR		0.00000	0
595	E06		6	1			1919	NO	0.000	UM	IR		0.00000	0
596	E06		6	1			1918	NO	0.000	UM	IR		0.00000	0
597	E06		7	1			1918	NO	0.000	UM	IR		0.00000	0
598	E06		8	1			1921	NO	0.000	RC	IR		0.00000	0
599	E06		13	2		11900	1929	NO	0.000	RC	IR	3205200	0.00434	3
600	E06		12	2			1914	NO	0.000	ST	IR		0.00000	0
601	E06		9	2			1919	NO	0.000	ST	IR		0.00000	0
602	E06		12	2		7780	1926	NO	0.000	ST	IR	2094000	0.04059	5
603	E06		8	1			1923	NO	0.000	RC	IR		0.00000	0
604	E06		13	2			1924	NO	0.000	RC	IR		0.00000	0
605	E06		6	1			1925	NO	0.000	RC	IR		0.00000	0
606	F06		6	1		7720	1963	UBC	0.083	RC	IR	2077000	0.05779	5
607	E06		12	2		8920	1926	NO	0.000	RC	IR	240000	0.04046	5
608	E06		11	2			1912	NO	0.000	ST	IR		0.00000	0
609	E06		9	2			1920	NO	0.000	ST	IR		0.00000	0
610	E06		6	1			1917	NO	0.000	RC	IR		0.00000	0
611	E06		12	2		16700	1912	NO	0.000	ST	IR	4500000	0.01703	4
612	E06		12	2			1913	NO	0.000	ST	IR		0.00000	0
613	E06		13	2			1913	NO	0.000	ST	IR		0.00000	0
614	E06		7	1			1915	NO	0.000	UM	IR		0.00000	0
615	E06		12	2			1923	NO	0.000	ST	IR		0.00000	0
616	E06		12	2			1926	NO	0.000	ST	IR		0.00000	0
617	E06		8	1		6970	1965	UBC	0.075	ST	RG	5254800	0.00000	0
618	E06		15	2		21000	1971	UBC	0.061	ST	RG	5110000	0.00000	0
619	E06		11	2		37200	1926	NO	0.000	ST	IR	10000000	0.11000	6
620	E06		11	2			1922	NO	0.000	RC	IR		0.00000	0
621	E06		13	2			1926	NO	0.000	ST	IR		0.00000	0
622	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
623	D06		13	2		1770	1964	UBC	0.064	ST	RG	785000	0.00000	0
624	E06		9	2			1923	NO	0.000	RC	IR		0.00000	0
625	E06		12	2			1926	NO	0.000	RC	IR		0.00000	0
626	E06		6	1			1914	NO	0.000	RC	IR		0.00000	0
627	E06		8	1			1924	NO	0.000	RC	IR		0.00000	0
628	E06		6	1			1926	NO	0.000	RC	IR		0.00000	0
629	E06		6	1			1946	UBC	0.057	RC	IR		0.00000	0
630	E06		12	2		4980	1922	NO	0.000	RC	IR	670000	0.00403	3
631	E06		9	2			1915	NO	0.000	ST	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
632	E06		11	2		20440	1921	NO	0.000	RC	IR	5500000	0.02255	4
633	E06		13	2		9480	1959	UBC	0.034	ST	RG	4300000	0.00000	0
634	E06		6	1			1931	NO	0.000	RC	IR		0.00000	0
635	E06		13	2			1925	NO	0.000	RC	IR		0.00000	0
636	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
637	E06		12	2		10220	1929	NO	0.000	RC	IR	2750000	0.00036	0
638	E06		13	2			1924	NO	0.000	ST	IR		0.00000	0
639	E06		7	1		3120	1906	NO	0.000	RC	IR	840000	0.00952	3
640	E06		11	2		9290	1927	NO	0.000	ST	IR	2500000	0.00400	3
641	E06		14	2		44600	1963	UBC	0.062	ST	RG	17172000	0.00047	0
642	E06		13	2		44600	1965	UBC	0.064	ST	RG	17172000	0.00000	0
643	E06		12	2			1920	NO	0.000	RC	IR		0.00000	0
644	E06		12	2		16200	1913	NO	0.000	ST	IR	4350000	0.00115	1
645	E06		13	2			1925	NO	0.000	ST	IR		0.00000	0
646	E06		6	1			1927	NO	0.000	ST	IR		0.00000	0
647	E06		12	2		18580	1925	NO	0.000	ST	IR	5000000	0.08800	5
648	E06		12	2			1924	NO	0.000	RC	IR		0.00000	0
649	E06		7	1			1923	NO	0.000	RC	IR		0.00000	0
650	E06		8	1			1963	UBC	0.075	RC	RG		0.00000	0
651	E06		8	1			1962	UBC	0.075	RC	RG		0.00000	0
652	D06		6	1			1962	UBC	0.083	RC	RG		0.00000	0
653	E07		11	2			1925	NO	0.000	RC	IR		0.00000	0
654	B07		12	2		16200	1970	UBC	0.066	RC	RG	3500000	0.00000	0
655	C08		8	1		13800	1963	UBC	0.075	RC	RG	5565000	0.00002	0
656	D06		6	1			1920	NO	0.000	RC	IR		0.00000	0
657	E06		7	1			1913	NO	0.000	RC	IR		0.00000	0
658	D06		6	1			1929	NO	0.000	RC	IR		0.00000	0
659	D05		7	1			1928	NO	0.000	UM	IR		0.00000	0
660	C06		13	2		27900	1964	UBC	0.064	ST	RG	13700000	0.00046	0
661	C06		13	2		27900	1964	UBC	0.064	ST	RG	13700000	0.00039	0
662	C06		16	2		74320	1966	UBC	0.060	ST	IR	32112000	0.00016	0
663	C06		27	3		39300	1965	UBC	0.050	ST	RG	13100000	0.00052	1
664	C06		27	3		39300	1965	UBC	0.050	ST	RG	13100000	0.00000	0
665	E06		6	1			1913	NO	0.000	RC	IR		0.00000	0
666	E06		6	1			1920	NO	0.000	RC	IR		0.00000	0
667	E05		9	2			1932	NO	0.000	ST	IR		0.00000	0
668	D06		6	1			1920	NO	0.000	OT	IR		0.00000	0
669	B06		10	2		17200	1961	UBC	0.041	ST	RG	5080000	0.00000	0
670	C06		12	2			1968	UBC	0.066	RC	IR		0.00000	0
671	B06		10	2		11600	1963	UBC	0.070	RC	RG	2679150	0.00019	0
672	C05		9	2		10220	1955	UBC	0.044	ST	IR	2750000	0.00291	2
673	C05		9	2		12800	1962	UBC	0.072	ST	RG	2450000	0.00000	0
674	E06		6	1			1922	NO	0.000	RC	IR		0.00000	0
675	E06		6	1			1940	UBC	0.010	ST	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
676	E06		14	2		40100	1958	UBC	0.033	ST	IR	28800000	0.00113	1
677	B07		9	2		47700	1958	UBC	0.044	RC	RG	16200000	0.00000	0
678	E06		8	1			1931	NO	0.000	ST	IR		0.00000	0
679	E06		10	2			1911	NO	0.000	RC	IR		0.00000	0
680	E06		7	1			1905	NO	0.000	ST	IR		0.00000	0
681	E06		6	1			1902	NO	0.000	RC	IR		0.00000	0
682	E06		7	1			1920	NO	0.000	UM	IR		0.00000	0
683	E06		7	1			1920	NO	0.000	ST	IR		0.00000	0
684	E06		11	2			1914	NO	0.000	RC	IR		0.00000	0
685	E06		10	2			1907	NO	0.000	RC	IR	45500	0.04916	5
686	E06		6	1			1920	NO	0.000	UM	IR		0.00000	0
687	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
688	E06		6	1			1923	NO	0.000	OT	IR		0.00000	0
689	E06		11	2		10300	1910	NO	0.000	ST	IR	1380000	0.00592	3
690	E06		7	1		22100	1924	NO	0.000	RC	IR	5950925	0.00114	1
691	E06		9	2			1907	NO	0.000	RC	IR		0.00000	0
692	E06		10	2		11900	1913	NO	0.000	ST	IR	3200000	0.01044	3
693	E06		7	1			1906	NO	0.000	ST	IR		0.00000	0
694	E06		12	2			1921	NO	0.000	ST	IR		0.00000	0
695	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
696	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
697	E06		7	1			1920	NO	0.000	ST	IR		0.00000	0
698	E06		7	1			1920	NO	0.000	ST	IR		0.00000	0
699	E06		7	1			1920	NO	0.000	ST	IR		0.00000	0
700	E06		8	1			1914	NO	0.000	RC	IR		0.00000	0
701	E06		11	2			1912	NO	0.000	ST	IR		0.00000	0
702	E06		13	2			1912	NO	0.000	ST	IR		0.00000	0
703	E06		6	1			1924	NO	0.000	ST	IR		0.00000	0
704	E06		8	1			1943	UBC	0.048	RC	IR		0.00000	0
705	E06		12	2			1924	NO	0.000	UM	IR		0.00000	0
706	E06		6	1			1913	NO	0.000	RC	IR		0.00000	0
707	E06		12	2			1928	NO	0.000	ST	IR		0.00000	0
708	E06		12	2			1925	NO	0.000	ST	IR		0.00000	0
709	E06		13	2			1929	NO	0.000	ST	IR		0.00000	0
710	E06		12	2		23200	1930	NO	0.000	ST	IR	6250000	0.00800	3
711	E06		6	1			1917	NO	0.000	ST	IR		0.00000	0
712	E06		8	1			1914	NO	0.000	RC	IR		0.00000	0
713	E06		15	2			1927	NO	0.000	ST	IR		0.00000	0
714	E06		11	2			1924	NO	0.000	RC	IR		0.00000	0
715	E06		7	1			1913	NO	0.000	RC	IR		0.00000	0
716	E06		12	2			1925	NO	0.000	RC	IR		0.00000	0
717	E06		10	2		7520	1921	NO	0.000	RC	IR	2022500	0.02794	4
718	E06		13	2		1250	1925	NO	0.000	RC	IR	336000	0.47619	7
719	E06		12	2		79900	1957	UBC	0.036	ST	IR	15800000	0.00167	2

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
720	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
721	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
722	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
723	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
724	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
725	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
726	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
727	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
728	D05		6	1			1925	NO	0.000	RC	IR		0.00000	0
729	B03		10	2		26400	1960	UBC	0.041	RC	IR	13920000	0.10777	6
730	D06		7	1			1929	NO	0.000	RC	IR		0.00000	0
731	C06		20	3		46200	1966	UBC	0.055	ST	IR	28800000	0.00000	0
732	C06		20	3		46200	1966	UBC	0.055	ST	IR	28800000	0.00004	0
733	C08		7	1		14400	1968	UBC	0.078	RC	RG	3800000	0.00000	0
734	C08		7	1		6970	1969	UBC	0.078	RC	RG	2040000	0.00000	0
735	C06		10	2		33900	1971	UBC	0.070	ST	IR	1700000	0.00000	0
736	C08		13	2		20400	1966	UBC	0.064	RC	IR	7550000	0.00347	2
737	C08		12	2		22800	1964	UBC	0.066	RC	IR	8310000	0.00126	1
738	C08		12	2		62040	1963	UBC	0.066	ST	RG	16700000	0.00002	0
739	E06		19	3		30700	1969	UBC	0.056	ST	RG	12000000	0.00000	0
740	C06		20	3		26900	1961	UBC	0.030	ST	RG	7950000	0.00000	0
741	C06		20	3		26900	1961	UBC	0.030	ST	RG	7950000	0.00000	0
742	C06		7	1			1965	UBC	0.078	RC	RG		0.00000	0
743	C06		13	2			1950	UBC	0.034	RC	IR		0.00000	0
744	C06		13	2			1950	UBC	0.034	RC	IR		0.00000	0
745	C06		13	2			1950	UBC	0.034	RC	IR		0.00000	0
746	C06		13	2			1950	UBC	0.034	RC	IR		0.00000	0
747	D05		8	1			1962	UBC	0.075	RC	IR		0.00000	0
748	E06		14	2		21200	1970	UBC	0.062	RC	RG	11140000	0.00000	0
749	E06		12	2			1924	NO	0.000	ST	IR		0.00000	0
750	E06		7	1			1960	UBC	0.052	ST	RG		0.00000	0
751	E06		7	1			1923	NO	0.000	OT	IR		0.00000	0
752	E06		13	2			1920	NO	0.000	ST	IR		0.00000	0
753	E06		6	1			1920	NO	0.000	RC	IR		0.00000	0
754	E06		9	2			1964	UBC	0.072	ST	RG		0.00000	0
755	E06		52	3		260000	1971	UBC	0.040	ST	RG	99999999	0.00000	0
756	E06		52	3		260000	1971	UBC	0.040	ST	RG	99999999	0.00274	2
757	E06		8	1			1929	NO	0.000	ST	IR		0.00000	0
758	E06		12	2			1929	NO	0.000	ST	IR		0.00000	0
759	E06		12	2		14900	1956	UBC	0.036	RC	RG	7040000	0.00148	2
760	E06		13	2		46800	1949	UBC	0.034	ST	RG	32610000	0.00054	1
761	E06		21	3		28500	1960	UBC	0.030	ST	IR	12900000	0.00592	3
762	E06		6	1			1960	UBC	0.057	ST	RG		0.00000	0
763	E06		8	1		9650	1926	NO	0.000	ST	IR	2597000	0.00366	2
764	E06		7	1			1948	UBC	0.052	RC	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
765	E06		12	2			1924	NO	0.000	ST	IR		0.00000	0
766	E06		13	2			1923	NO	0.000	RC	IR		0.00000	0
767	E06		6	1			1941	UBC	0.010	RC	RG		0.00000	0
768	E06		6	1			1952	UBC	0.057	RC	RG		0.00000	0
769	E06		7	1			1924	NO	0.000	RC	IR		0.00000	0
770	E06		6	1			1958	UBC	0.057	ST	IR		0.00000	0
771	D05		9	2		27400	1951	UBC	0.044	ST	IR	7364000	0.13145	6
772	D05		7	1			1928	NO	0.000	ST	IR		0.00000	0
773	D05		11	2			1931	NO	0.000	ST	IR		0.00000	0
774	D05		13	2		38600	1964	UBC	0.064	RC	IR	10500000	0.00000	0
775	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
776	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
777	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
778	B06		20	3		27900	1962	UBC	0.055	ST	RG	14020000	0.00000	0
779	D06		7	1			1929	NO	0.000	RC	IR		0.00000	0
780	D06		8	1			1931	NO	0.000	RC	IR		0.00000	0
781	D06		8	1			1923	NO	0.000	RC	IR		0.00000	0
782	D06		6	1			1926	NO	0.000	RC	IR		0.00000	0
783	E06		6	1			1963	UBC	0.083	ST	IR		0.00000	0
784	E06		7	1			1961	UBC	0.052	RC	RG		0.00000	0
785	E06		10	2			1947	UBC	0.041	ST	RG		0.00000	0
786	E06		13	2		13000	1927	NO	0.000	RC	IR	3510000	0.00570	3
787	E06		13	2			1924	NO	0.000	RC	IR		0.00000	0
788	E06		30	3		65000	1964	UBC	0.048	ST	RG	32650000	0.00000	0
789	E06		13	2		6500	1926	NO	0.000	ST	IR	1750000	0.00200	2
790	E06		6	1			1963	UBC	0.083	RC	IR		0.00000	0
791	E06		8	1			1924	NO	0.000	RC	IR		0.00000	0
792	E06		10	2			1913	NO	0.000	RC	IR		0.00000	0
793	E06		9	2			1913	NO	0.000	RC	IR		0.00000	0
794	E06		6	1			1945	UBC	0.057	RC	IR		0.00000	0
795	E07		8	1			1922	NO	0.000	UM	IR		0.00000	0
796	E07		9	2			1921	NO	0.000	RC	IR		0.00000	0
797	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
798	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
799	D06		13	2		15700	1950	UBC	0.034	RC	IR	5891000	0.00000	0
800	D05		12	2		9290	1958	UBC	0.036	ST	IR	2500000	0.00069	1
801	D05		9	2		11150	1964	UBC	0.072	RC	IR	3660000	0.00057	1
802	D05		6	1		2800	1928	NO	0.000	RC	IR	750000	0.00000	0
803	B06		14	2		18900	1961	UBC	0.033	RC	IR	6590000	0.00000	0
804	E06		7	1			1926	NO	0.000	ST	IR		0.00000	0
805	C06		8	1			1907	NO	0.000	RC	IR		0.00000	0
806	E06		8	1			1910	NO	0.000	RC	IR		0.00000	0
807	E06		11	2			1920	NO	0.000	RC	IR		0.00000	0
808	E06		10	2			1907	NO	0.000	ST	IR		0.00000	0
809	E06		11	2			1913	NO	0.000	RC	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
810	E06		10	2		2420	1930	NO	0.000	ST	IR	500000	0.00400	3
811	E06		12	2		900	1925	NO	0.000	RC	IR	241250	0.14508	6
812	E06		12	2			1919	NO	0.000	ST	IR		0.00000	0
813	E06		9	2		12500	1909	NO	0.000	RC	IR	3375000	0.00006	0
814	E06		13	2		4650	1928	NO	0.000	ST	IR	1250000	0.01200	4
815	E06		12	2			1930	NO	0.000	RC	IR		0.00000	0
816	E06		8	1		4980	1925	NO	0.000	RC	IR	1341250	0.02610	4
817	E06		8	1			1934	UBC	0.010	ST	IR		0.00000	0
818	E06		8	1			1907	NO	0.000	RC	IR		0.00000	0
819	E06		13	2		13000	1929	NO	0.000	ST	IR	3500000	0.00571	3
820	E06		12	2			1922	NO	0.000	ST	IR		0.00000	0
821	E06		7	1			1922	NO	0.000	RC	IR	30000	0.03333	5
822	E06		7	1			1914	NO	0.000	RC	IR		0.00000	0
823	E06		13	2			1924	NO	0.000	RC	IR		0.00000	0
824	E06		12	2			1924	NO	0.000	RC	IR		0.00000	0
825	E06		6	1			1920	NO	0.000	OT	IR		0.00000	0
826	E06		7	1			1912	NO	0.000	RC	IR		0.00000	0
827	E06		10	2		6970	1923	NO	0.000	RC	IR	1875000	0.02677	4
828	E06		30	3		65000	1965	UBC	0.048	ST	IR	25920000	0.01016	3
829	E06		8	1		61300	1970	UBC	0.075	RC	RG	14400000	0.00000	0
830	D05		7	1			1929	NO	0.000	RC	IR		0.00000	0
831	E06		11	2		26000	1964	UBC	0.067	ST	RG	15160000	0.00000	0
832	D05		6	1			1962	UBC	0.083	ST	IR		0.00000	0
833	D06		7	1			1929	NO	0.000	ST	IR		0.00000	0
834	D06		6	1			1920	NO	0.000	UM	IR		0.00000	0
835	D05		7	1			1927	NO	0.000	RC	IR		0.00000	0
836	D05		12	2			1929	NO	0.000	RC	IR		0.00000	0
837	D05		9	2			1928	NO	0.000	RC	IR		0.00000	0
838	D05		12	2			1924	NO	0.000	RC	IR		0.00000	0
839	D05		7	1		6300	1925	NO	0.000	RC	IR	1695600	0.00590	3
840	D05		6	1		5570	1929	NO	0.000	ST	IR	1500000	0.00233	2
841	D05		9	2		6000	1921	NO	0.000	UM	IR	1600000	0.00031	0
842	D05		7	1		6040	1957	UBC	0.052	ST	IR	1625000	0.06154	5
843	D05		12	2		5090	1927	NO	0.000	ST	IR	1369000	0.00146	2
844	D05		12	2		9480	1959	UBC	0.036	ST	IR	3600000	0.00059	1
845	D05		7	1			1925	NO	0.000	ST	IR		0.00000	0
846	D05		12	2		18600	1965	UBC	0.066	ST	IR	6340000	0.00063	1
847	D05		14	2			1926	NO	0.000	RC	IR		0.00000	0
848	D05		8	1			1926	NO	0.000	RC	IR		0.00000	0
849	D05		12	2		13470	1969	UBC	0.066	RC	RG	4560000	0.00000	0
850	D05		13	2		27600	1965	UBC	0.064	ST	IR	7480000	0.00000	0
851	E06		8	1			1925	NO	0.000	OT	IR		0.00000	0
852	E06		6	1			1921	NO	0.000	RC	IR		0.00000	0
853	E06		13	2			1925	NO	0.000	ST	IR		0.00000	0
854	E06		11	2			1907	NO	0.000	ST	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
855	E06		8	1			1925	NO	0.000	RC	IR		0.00000	0
856	E06		6	1			1937	UBC	0.010	RC	IR		0.00000	0
857	E06		6	1			1929	NO	0.000	RC	IR		0.00000	0
858	E06		9	2			1925	NO	0.000	ST	IR		0.00000	0
859	E06		9	2			1925	NO	0.000	ST	IR		0.00000	0
860	E06		6	1			1924	NO	0.000	RC	IR		0.00000	0
861	D06		8	1			1930	NO	0.000	ST	IR		0.00000	0
862	D06		20	3		38600	1962	UBC	0.055	ST	RG	11500000	0.00377	2
863	D05		12	2			1924	NO	0.000	RC	IR		0.00000	0
864	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
865	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
866	E06		9	2			1913	NO	0.000	RC	IR		0.00000	0
867	E06		7	1			1930	NO	0.000	RC	IR		0.00000	0
868	C04		7	1		6040	1961	UBC	0.052	ST	IR	5853000	0.01025	3
869	D05		11	2		7900	1964	UBC	0.067	RC	IR	2700000	0.00390	2
870	C08		6	1		7800	1964	UBC	0.083	ST	IR	3930000	0.00000	0
871	E06		8	1		25400	1953	UBC	0.048	RC	IR	9420000	0.00000	0
872	E06		6	1		10220	1907	NO	0.000	RC	IR	2750000	0.00000	0
873	E06		8	1		92900	1963	UBC	0.075	RC	RG	30690000	0.00000	0
874	E06		6	1			1916	NO	0.000	RC	IR		0.00000	0
875	E06		6	1			1926	NO	0.000	RC	IR		0.00000	0
876	E06		6	1			1919	NO	0.000	RC	IR		0.00000	0
877	E06		13	2			1925	NO	0.000	RC	IR		0.00000	0
878	E06		12	2			1928	NO	0.000	RC	IR		0.00000	0
879	E06		6	1			1925	NO	0.000	RC	IR		0.00000	0
880	E06		7	1			1913	NO	0.000	RC	IR		0.00000	0
881	E06		11	2			1916	NO	0.000	RC	IR		0.00000	0
882	E06		9	2			1913	NO	0.000	RC	IR		0.00000	0
883	E06		12	2			1948	UBC	0.036	RC	IR		0.00000	0
884	E06		9	2			1946	UBC	0.044	RC	IR		0.00000	0
885	D05		14	2		17400	1963	UBC	0.062	ST	RG	4980000	0.00000	0
886	D05		14	2		17400	1963	UBC	0.062	ST	RG	4980000	0.00000	0
887	E06		7	1		21400	1953	UBC	0.052	RC	IR	6570000	0.02283	4
888	E06		20	3		55700	1968	UBC	0.055	RC	IR	26320000	0.00000	0
889	E06		8	1			1907	NO	0.000	UM	IR		0.00000	0
890	E06		6	1		42300	1906	NO	0.000	UM	IR	11385000	0.00445	3
891	E06		7	1			1929	NO	0.000	RC	IR		0.00000	0
892	E06		6	1			1920	NO	0.000	UM	IR		0.00000	0
893	E06		14	2			1924	NO	0.000	RC	IR		0.00000	0
894	E06		6	1			1922	NO	0.000	RC	IR		0.00000	0
895	E06		6	1			1923	NO	0.000	RC	IR		0.00000	0
896	E06		10	2		13600	1928	NO	0.000	RC	IR	3650000	0.01323	4
897	E06		12	2			1928	NO	0.000	RC	IR		0.00000	0
898	E06		7	1			1925	NO	0.000	ST	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
899	D06		8	1			1963	UBC	0.075	RC	IR		0.00000	0
900	A02		7	1		28800	1962	UBC	0.078	ST	IR	10442000	0.00575	3
901	A02		7	1		13630	1964	UBC	0.078	ST	IR	3668100	0.00545	3
902	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
903	D06		7	1			1928	NO	0.000	RC	IR		0.00000	0
904	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
905	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
906	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
907	E06		10	2		12100	1965	UBC	0.070	ST	IR	3190000	0.00035	0
908	B07		12	2		13800	1964	UBC	0.066	ST	IR	3311000	0.00151	2
909	E06		7	1			1929	NO	0.000	RC	IR		0.00000	0
910	E06		6	1			1920	NO	0.000	RC	IR		0.00000	0
911	E06		7	1			1923	NO	0.000	RC	IR		0.00000	0
912	E06		7	1			1925	NO	0.000	RC	IR		0.00000	0
913	E06		9	2			1924	NO	0.000	ST	IR		0.00000	0
914	E06		13	2			1927	NO	0.000	ST	IR		0.00000	0
915	E06		26	3		27900	1967	UBC	0.051	ST	RG	13440000	0.00000	0
916	E06		13	2			1928	NO	0.000	ST	IR		0.00000	0
917	E06		10	2		6500	1913	NO	0.000	RC	IR	1750000	0.00183	2
918	E06		12	2			1922	NO	0.000	ST	IR		0.00000	0
919	E06		13	2			1922	NO	0.000	RC	IR		0.00000	0
920	E06		6	1			1957	UBC	0.057	RC	IR		0.00000	0
921	E06		6	1			1929	NO	0.000	ST	IR		0.00000	0
922	E06		9	2		12300	1924	NO	0.000	RC	IR	3311500	0.04022	5
923	E06		10	2		23000	1925	NO	0.000	RC	IR	6203400	0.00806	3
924	E06		6	1			1931	NO	0.000	RC	IR		0.00000	0
925	B06		6	1		2680	1965	UBC	0.083	ST	RG	2869000	0.00010	0
926	D05		12	2		11200	1964	UBC	0.066	ST	RG	3080000	0.00000	0
927	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
928	D06		6	1			1929	NO	0.000	RC	IR		0.00000	0
929	D06		6	1			1920	NO	0.000	ST	I		0.00000	0
930	E06		11	2			1925	NO	0.000	RC	I		0.00000	0
931	E06		11	2			1926	NO	0.000	RC	IR		0.00000	0
932	E06		11	2		11150	1927	NO	0.000	RC	IR	3000000	0.00500	3
933	D06		8	1			1915	NO	0.000	RC	IR		0.00000	0
934	D06		8	1			1928	NO	0.000	RC	IR		0.00000	0
935	E06		7	1			1910	NO	0.000	RC	IR		0.00000	0
936	B04		8	1		4180	1965	UBC	0.075	ST	RG	2310000	0.00040	0
937	B07		6	1			1924	NO	0.000	RC	IR	116000	0.00000	0
938	D05		6	1			1940	UBC	0.010	RC	IR		0.00000	0
939	D05		10	2			1928	NO	0.000	RC	IR		0.00000	0
940	D05		7	1			1936	UBC	0.010	RC	IR		0.00000	0
941	D06		6	1			1920	NO	0.000	ST	IR		0.00000	0
942	E06		6	1			1924	NO	0.000	UM	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
943	E06		6	1			1922	NO	0.000	RC	IR		0.00000	0
944	E06		6	1			1928	NO	0.000	RC	IR		0.00000	0
945	E06		6	1			1916	NO	0.000	RC	IR		0.00000	0
946	C06		26	3		55700	1971	UBC	0.051	ST	RG	19780000	0.00000	0
947	E06		10	2			1918	NO	0.000	RC	IR		0.00000	0
948	E06		12	2			1925	NO	0.000	RC	IR		0.00000	0
949	E06		10	2			1926	NO	0.000	RC	IR		0.00000	0
950	E06		6	1			1923	NO	0.000	RC	IR		0.00000	0
951	E06		12	2			1928	NO	0.000	RC	IR		0.00000	0
952	C08		8	1		10200	1964	UBC	0.075	RC	RG	3390000	0.00000	0
953	D06		7	1			1930	NO	0.000	ST	IR		0.00000	0
954	D06		6	1			1920	NO	0.000	UM	IR		0.00000	0
955	D06		6	1			1929	NO	0.000	RC	IR		0.00000	0
956	D06		6	1			1929	NO	0.000	RC	IR		0.00000	0
957	D06		6	1			1928	NO	0.000	RC	IR		0.00000	0
958	D06		7	1			1929	NO	0.000	RC	IR		0.00000	0
959	D06		7	1			1930	NO	0.000	RC	IR		0.00000	0
960	D05		6	1			1930	NO	0.000	RC	IR		0.00000	0
961	E06		12	2		17700	1948	UBC	0.036	ST	IR	8460000	0.02033	4
962	E06		13	2			1913	NO	0.000	ST	IR		0.00000	0
963	E06		8	1		480	1956	UBC	0.048	RM	IR	128000	0.00000	0
964	E06		13	2			1903	NO	0.000	ST	IR		0.00000	0
965	E06		12	2			1914	NO	0.000	RC	IR		0.00000	0
966	E06		13	2		25300	1928	NO	0.000	RC	IR	6798000	0.01150	4
967	E06		7	1		5270	1955	UBC	0.052	RC	IR	1417500	0.00616	3
968	E06		11	2		23800	1929	NO	0.000	ST	IR	6417000	0.00546	3
969	E06		12	2		16300	1913	NO	0.000	RC	IR	4375000	0.05570	5
970	E06		12	2		12700	1913	NO	0.000	RC	IR	3425000	0.07097	5
971	E06		11	2		17700	1907	NO	0.000	RC	IR	4775000	0.04435	5
972	E06		12	2			1910	NO	0.000	ST	IR		0.00000	0
973	E06		6	1			1908	NO	0.000	RC	IR		0.00000	0
974	E06		12	2			1923	NO	0.000	ST	IR		0.00000	0
975	E06		12	2		17500	1913	NO	0.000	RC	IR	4720000	0.04081	5
976	E06		18	3		26000	1959	UBC	0.031	ST	RG	16200000	0.00000	0
977	E06		12	2			1930	NO	0.000	ST	IR		0.00000	0
978	E06		12	2			1923	NO	0.000	ST	IR		0.00000	0
979	E06		6	1			1915	NO	0.000	RC	IR		0.00000	0
980	E06		14	2			1930	NO	0.000	ST	IR		0.00000	0
981	E06		7	1			1918	NO	0.000	RC	IR		0.00000	0
982	E06		12	2			1930	NO	0.000	ST	IR		0.00000	0
983	E06		13	2		12400	1921	NO	0.000	ST	IR	3348000	0.00906	3
984	E06		12	2		23400	1924	NO	0.000	ST	IR	6307500	0.08053	5
985	E06		13	2			1924	NO	0.000	ST	IR		0.00000	0
986	E06		13	2			1914	NO	0.000	ST	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
987	E06		13	2			1923	NO	0.000	ST	IR		0.00000	0
988	E06		12	2		13900	1923	NO	0.000	ST	IR	3750000	0.00667	3
989	E06		8	1			1914	NO	0.000	RC	IR		0.00000	0
990	D05		6	1			1920	NO	0.000	ST	IR		0.00000	0
991	D05		6	1			1920	NO	0.000	ST	IR		0.00000	0
992	D05		6	1			1920	NO	0.000	RC	IR		0.00000	0
993	D06		7	1		5340	1965	UBC	0.078	RC	IR	6206400	0.01611	4
994	E05		12	2		11150	1963	UBC	0.066	ST	RG	4470000	0.00000	0
995	D05		8	1		20700	1967	UBC	0.075	ST	RG	5575000	0.00108	1
996	D05		8	1		9750	1961	UBC	0.048	RC	IR	4900000	0.00000	0
997	D05		7	1			1960	UBC	0.052	RC	IR		0.00000	0
998	D05		19	3		8360	1964	UBC	0.056	ST	RG	4590000	0.00100	1
999	D05		10	2		10200	1964	UBC	0.070	ST	RG	3500000	0.00738	3
1000	D05		10	2			1923	NO	0.000	RC	IR		0.00000	0
1001	C05		6	1			1925	NO	0.000	RC	IR		0.00000	0
1002	A06		10	2		13800	1961	UBC	0.041	RC	RG	2250000	0.00000	0
1003	A06		10	2		13800	1961	UBC	0.041	RC	RG	2250000	0.00000	0
1004	A06		6	1		8400	1961	UBC	0.057	RC	RG	1476000	0.00000	0
1005	A06		6	1		8400	1961	UBC	0.057	RC	RG	1476000	0.00000	0
1006	E06		11	2		3720	1932	NO	0.000	ST	IR	1000000	0.03000	4
1007	E06		9	2		28700	1960	UBC	0.044	RC	IR	10800000	0.00000	0
1008	E06		10	2		67800	1958	UBC	0.041	ST	IR	16740000	0.00454	3
1009	E06		19	3		81400	1970	UBC	0.056	ST	RG	36680000	0.00000	0
1010	E06		6	1			1926	NO	0.000	RC	IR		0.00000	0
1011	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
1012	E06		6	1			1920	NO	0.000	ST	IR		0.00000	0
1013	B03		8	1		9010	1963	UBC	0.075	ST	IR	4930000	0.00507	3
1014	B03		6	1		6690	1967	UBC	0.083	RC	IR	1825600	0.02301	4
1015	B03		13	2		13900	1962	UBC	0.064	RC	IR	4920000	0.08487	5
1016	C06		8	1		5570	1963	UBC	0.075	ST	IR	2450000	0.00042	0
1017	B04		12	2		15600	1970	UBC	0.066	RC	RG	5090000	0.00000	0
1018	B04		7	1		5570	1968	UBC	0.078	RC	RG	2122200	0.00000	0
1019	B04		8	1		6320	1964	UBC	0.075	RC	IR	2620000	0.00770	3
1020	A04		14	2		22500	1970	UBC	0.062	RC	RG	6056800	0.00000	0
1021	A04		10	2		8360	1970	UBC	0.070	RC	RG	1700000	0.00000	0
1022	D06		6	1			1927	NO	0.000	RC	IR		0.00000	0
1023	D06		12	2		12100	1965	UBC	0.066	RC	IR	5390000	0.00000	0
1024	D05		6	1		16300	1925	NO	0.000	RC	IR	4375000	0.01143	4
1025	D05		8	1			1961	UBC	0.048	RC	IR		0.00000	0
1026	D06		7	1			1915	NO	0.000	RC	IR		0.00000	0
1027	D06		13	2		6690	1968	UBC	0.064	RC	IR	2160000	0.00665	3
1028	C03		9	2		1150	1958	UBC	0.044	ST	RG	540000	0.00000	0
1029	D05		10	2			1925	NO	0.000	RC	IR		0.00000	0
1030	D05		16	2		21800	1971	UBC	0.060	ST	RG	7910000	0.00000	0
1031	D05		12	2			1924	NO	0.000	RC	IR		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
1032	D05		13	2		9100	1956	UBC	0.034	ST	IR	2410000	0.00392	2
1033	E06		8	1			1924	NO	0.000	RC	IR		0.00000	0
1034	B07		11	2		10900	1969	UBC	0.067	RC	RG	2022000	0.00000	0
1035	D06		7	1			1926	NO	0.000	RC	IR		0.00000	0
1036	D05		8	1			1925	NO	0.000	RC	IR		0.00000	0
1037	D05		7	1			1928	NO	0.000	RC	IR		0.00000	0
1038	E06		6	1			1924	NO	0.000	RC	RG		0.00000	0
1039	D06		6	1			1960	UBC	0.057	RC	RG		0.00000	0
1040	D05		6	1			1930	NO	0.000	ST	IR		0.00000	0
1041	D05		13	2		5760	1926	NO	0.000	ST	IR	1550000	0.00613	3
1042	B07		11	2		6260	1971	UBC	0.067	ST	RG	1685000	0.00000	0
1043	D05		13	2		31300	1961	UBC	0.034	RC	IR	9020000	0.02055	4
1044	E06		13	2		15800	1953	UBC	0.034	ST	IR	9270000	0.00000	0
1045	E06		11	2		17800	1965	UBC	0.067	RC	RG	6340000	0.00050	1
1046	E06		6	1		6970	1966	UBC	0.083	RC	RG	2362000	0.00106	1
1047	E06		16	2		21100	1970	UBC	0.060	ST	RG	6780000	0.00000	0
1048	E06		15	2		13900	1951	UBC	0.031	ST	IR	7990000	0.00000	0
1049	E06		8	1			1912	NO	0.000	RC	IR		0.00000	0
1050	E06		17	2		17200	1960	UBC	0.031	ST	IR	8112000	0.00105	1
1051	E06		15	2		16400	1964	UBC	0.061	ST	IR	8470000	0.00114	1
1052	E06		6	1			1964	UBC	0.083	RC	IR		0.00000	0
1053	E06		8	1		11400	1959	UBC	0.048	RC	IR	4140000	0.00000	0
1054	E06		8	1		9290	1964	UBC	0.075	RC	RG	4130000	0.00551	3
1055	E06		13	2		10220	1928	NO	0.000	ST	IR	2750000	0.00309	2
1056	E06		9	2			1923	NO	0.000	RC	IR		0.00000	0
1057	E06		10	2			1951	UBC	0.041	ST	RG		0.00000	0
1058	E06		12	2		12100	1961	UBC	0.036	RC	RG	7570000	0.00078	1
1059	E06		8	1			1923	NO	0.000	RC	IR		0.00000	0
1060	E06		6	1			1959	UBC	0.057	ST	IR		0.00000	0
1061	E06		12	2		14100	1926	NO	0.000	RC	IR	3298000	0.21225	6
1062	E06		9	2			1911	NO	0.000	ST	IR		0.00000	0
1063	D06		13	2			1928	NO	0.000	RC	IR		0.00000	0
1064	D06		6	1			1957	UBC	0.057	ST	RG		0.00000	0
1065	D06		9	2		12900	1963	UBC	0.072	RC	IR	4890000	0.00327	2
1066	D06		16	2		21400	1961	UBC	0.032	ST	IR	11180000	0.00235	2
1067	D06		6	1			1956	UBC	0.057	RC	IR		0.00000	0
1068	D06		22	3		38600	1968	UBC	0.054	ST	RG	13560000	0.00000	0
1069	D06		10	2			1924	NO	0.000	RC	IR		0.00000	0
1070	D06		12	2		15800	1971	UBC	0.066	RC	RG	4520000	0.00069	1
1071	D06		13	2		18700	1955	UBC	0.034	RC	RG	5910000	0.00000	0
1072	D06		12	2		16700	1957	UBC	0.036	ST	IR	6140000	0.00000	0
1073	D06		13	2			1924	NO	0.000	RC	IR		0.00000	0
1074	D06		6	1			1920	NO	0.000	RC	IR		0.00000	0
1075	D06		13	2		18600	1958	UBC	0.034	ST	RG	8370000	0.00123	1

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
1076	D06		12	2		15700	1950	UBC	0.036	ST	RG	4200000	0.00000	0
1077	D06		12	2		15700	1950	UBC	0.036	ST	RG	4200000	0.00000	0
1078	D06		12	2		15700	1950	UBC	0.036	ST	RG	4200000	0.01512	4
1079	D06		12	2			1965	UBC	0.066	RC	IR		0.00000	0
1080	D06		13	2		19000	1955	UBC	0.034	ST	IR	5630000	0.00207	2
1081	D06		22	3		42500	1961	UBC	0.029	ST	IR	20800000	0.00381	2
1082	D06		11	2		30700	1966	UBC	0.067	RC	RG	15100000	0.00129	1
1083	D06		11	2		37500	1969	UBC	0.067	RC	RG	20960000	0.00000	0
1084	E06		11	2			1969	UBC	0.067	RC	RG		0.00000	0
1085	D06		12	2			1931	NO	0.000	OT	IR		0.00000	0
1086	D06		12	2		13900	1967	UBC	0.066	RC	RG	5290000	0.00092	1
1087	D06		22	3		33070	1963	UBC	0.054	ST	RG	15910000	0.00650	3
1088	D06		13	2		7430	1929	NO	0.000	ST	RG	2000000	0.00900	3
1089	D06		7	1			1959	UBC	0.052	ST	RG		0.00000	0
1090	D06		6	1			1962	UBC	0.083	ST	RG		0.00000	0
1091	D06		9	2		10870	1963	UBC	0.072	RC	RG	3770000	0.01056	3
1092	D06		6	1		32500	1958	UBC	0.057	ST	RG	10230000	0.00122	1
1093	D06		12	2		11150	1949	UBC	0.036	ST	RG	3220000	0.00031	0
1094	D06		13	2			1930	NO	0.000	RC	RG		0.00000	0
1095	D06		12	2		5500	1929	NO	0.000	RC	RG	1480000	0.00034	0
1096	D06		22	3		19500	1960	UBC	0.029	ST	RG	10320000	0.00197	2
1097	D06		12	2			1929	NO	0.000	RC	RG		0.00000	0
1098	D06		27	3		43600	1963	UBC	0.050	ST	RG	19080000	0.00000	0
1099	D06		11	2		50000	1948	UBC	0.039	RC	RG	13700000	0.01329	4
1100	C06		6	1		39500	1959	UBC	0.057	ST	IR	15100000	0.00000	0
1101	C06		6	1			1939	UBC	0.010	ST	IR		0.00000	0
1102	C06		7	1			1957	UBC	0.052	RC	IR		0.00000	0
1103	C06		21	3		36000	1971	UBC	0.054	ST	RG	14700000	0.00000	0
1104	C06		7	1			1954	UBC	0.052	ST	IR		0.00000	0
1105	C06		6	1			1949	UBC	0.057	RC	IR		0.00000	0
1106	C06		16	2		14900	1964	UBC	0.060	ST	RG	6360000	0.00097	1
1107	C06		11	2		9290	1952	UBC	0.039	RC	IR	3290000	0.00316	2
1108	C06		12	2		6000	1964	UBC	0.066	RC	RG	2770000	0.00050	1
1109	C06		19	3		17900	1970	UBC	0.056	ST	RG	7460000	0.00000	0
1110	C06		12	2		10200	1956	UBC	0.036	ST	IR	4020000	0.00258	2
1111	B06		11	2		18670	1950	UBC	0.039	RC	RG	3024000	0.00000	0
1112	B06		15	2		24160	1962	UBC	0.061	ST	RG	7660000	0.00000	0
1113	B06		13	2		27600	1960	UBC	0.034	RC	RG	7940000	0.00000	0
1114	B06		23	3		37800	1962	UBC	0.053	ST	RG	12500000	0.00000	0
1115	B06		6	1		600	1960	UBC	0.057	RC	IR	161000	0.00150	2
1116	B06		23	3		18500	1963	UBC	0.053	ST	RG	8750000	0.00000	0
1117	B06		12	2		14400	1956	UBC	0.036	RC	IR	3650000	0.00723	3
1118	B06		16	2		16200	1960	UBC	0.032	ST	RG	5410000	0.00000	0
1119	B06		24	3		56200	1970	UBC	0.052	ST	IR	22400000	0.00029	0
1120	B06		15	2		23300	1962	UBC	0.061	ST	RG	14430000	0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m²	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
1121	B06		12	2		22300	1961	UBC	0.036	ST	RG	6000000	0.00000	0
1122	B06		7	1		3250	1958	UBC	0.052	ST	RG	875000	0.00000	0
1123	B06		12	2		11900	1962	UBC	0.066	ST	RG	5070000	0.00016	0
1124	B06		17	2		58100	1969	UBC	0.058	ST	IR	21000000	0.00278	2
1125	B06		17	2		27800	1960	UBC	0.031	ST	RG	7980000	0.00000	0
1126	B06		17	2		27800	1960	UBC	0.031	ST	RG	7980000	0.00000	0
1127	B06		26	3		42300	1960	UBC	0.028	ST	RG	12680000	0.00000	0
1128	B06		23	3		48800	1971	UBC	0.053	ST	RG	17000000	0.00000	0
1129	E06		7	1		3900	1920	NO	0.000	RC	IR	1050000	0.01581	4
1130	D05		8	1		3700	1930	NO	0.000	RC	IR	1000000	0.00000	0
1131	F06		7	1			1968	UBC	0.078	RC	RG		0.00000	0
1132	C06		8	1			1961	UBC	0.048	RC	IR		0.00000	0
1133	C06		6	1			1928	NO	0.000	UM	IR		0.00000	0
1134	C06		7	1		5600	1964	UBC	0.078	ST	IR	2310000	0.00433	3
1135	C06		7	1			1960	UBC	0.052	ST	RG		0.00000	0
1136	C05		9	2			1932	NO	0.000	ST	IR		0.00000	0
1137	C05		13	2		16400	1962	UBC	0.064	ST	RG	5710000	0.00000	0
1138	C06		14	2		21200	1962	UBC	0.062	RC	RG	4890000	0.00000	0
1139	C06		8	1			1930	NO	0.000	RC	IR		0.00000	0
1140	C06		6	1			1956	UBC	0.057	ST	IR		0.00000	0
1141	C06		6	1			1960	UBC	0.057	RC	RG		0.00000	0
1142	C06		8	1		8550	1954	UBC	0.048	ST	IR	2810000	0.00049	0
1143	C06		8	1		5570	1964	UBC	0.075	RC	RG	3080000	0.00000	0
1144	C06		7	1		19400	1962	UBC	0.078	ST	RG	5216000	0.00009	0
1145	C06		10	2		20400	1970	UBC	0.070	RC	RG	12400000	0.00000	0
1146	C06		9	2		9290	1963	UBC	0.072	RC	RG	5090000	0.00000	0
1147	C06		10	2		4270	1970	UBC	0.070	RC	RG	1350000	0.00000	0
1148	C06		8	1		18600	1966	UBC	0.075	RC	IR	5000000	0.00130	1
1149	C06		6	1			1941	UBC	0.010	RC	IR		0.00000	0
1150	C06		10	2		40000	1969	UBC	0.070	RC	RG	12000000	0.00000	0
1151	C06		9	2		7900	1959	UBC	0.044	ST	RG	4300000	0.00030	0
1152	C06		10	2		12100	1969	UBC	0.070	RC	RG	2600000	0.00000	0
1153	C06		7	1			1959	UBC	0.052	RC	IR		0.00000	0
1154	C06		6	1		5850	1964	UBC	0.083	RC	IR	1575000	0.01333	4
1155	C06		8	1			1960	UBC	0.048	RC	IR		0.00000	0
1156	C06		12	2		19900	1971	UBC	0.066	ST	RG	5090000	0.00000	0
1157	C06		6	1			1929	NO	0.000	ST	IR		0.00000	0
1158	C06		10	2		13900	1968	UBC	0.070	RC	RG	6550000	0.00000	0
1159	C06		8	1		7900	1959	UBC	0.048	RC	IR	3960000	0.00000	0
1160	C06		10	2		20400	1960	UBC	0.041	ST	IR	7540000	0.00000	0
1161	C06		9	2			1927	NO	0.000	ST	IR		0.00000	0
1162	C06		6	1			1950	UBC	0.057	RC	IR		0.00000	0
1163	C06		10	2		14900	1970	UBC	0.070	RC	RG	4520000	0.00000	0
1164	C06		6	1			1939	UBC	0.010	RC	IR		0.00000	0
1165	C06		8	1			1947	UBC	0.048	RC	IR		0.00000	0

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
1166	C06		8	1		27900	1961	UBC	0.048	ST	RG	13940000	0.00000	0
1167	C06		8	1		6500	1962	UBC	0.075	RC	IR	2460000	0.00372	2
1168	C06		8	1		11150	1965	UBC	0.075	RC	RG	4770000	0.00066	1
1169	C06		8	1			1955	UBC	0.048	RC	IR		0.00000	0
1170	C08		15	2		31500	1970	UBC	0.061	ST	RG	7460000	0.00000	0
1171	C08		8	1		11300	1963	UBC	0.075	ST	RG	2930000	0.00035	0
1172	C08		12	2		11000	1965	UBC	0.066	ST	RG	4530000	0.00000	0
1173	C08		11	2		23800	1971	UBC	0.067	ST	RG	6600000	0.00107	1
1174	C08		8	1		11150	1961	UBC	0.048	ST	RG	2460000	0.00000	0
1175	D09		6	1		15800	1964	UBC	0.083	ST	RG	1924000	0.00000	0
1176	C08		12	2		22300	1962	UBC	0.066	ST	RG	8150000	0.00000	0
1177	C08		8	1		9750	1961	UBC	0.048	ST	RG	2623000	0.00000	0
1178	C08		8	1		11300	1961	UBC	0.048	RC	RG	2460000	0.00000	0
1179	C05		16	2		32100	1965	UBC	0.060	ST	IR	7550000	0.00000	0
1180	C05		13	2		13100	1960	UBC	0.034	ST	RG	4230000	0.00000	0
1181	C05		30	3		48600	1963	UBC	0.048	ST	RG	9540000	0.00000	0
1182	C05		13	2		33900	1963	UBC	0.064	RC	RG	6840000	0.00000	0
1183	C05		13	2		22300	1963	UBC	0.064	ST	RG	4770000	0.00000	0
1184	C05		12	2			1938	UBC	0.010	RC	IR	155000	0.00226	2
1185	C05		13	2		23400	1961	UBC	0.034	ST	RG	3770000	0.00000	0
1186	C05		10	2		13000	1963	UBC	0.070	RC	RG	2450000	0.00000	0
1187	C05		14	2		13010	1965	UBC	0.062	ST	RG	4290000	0.00000	0
1188	C05		13	2		22900	1970	UBC	0.064	ST	RG	8140000	0.00000	0
1189	C05		9	2		9290	1963	UBC	0.072	RC	RG	3260000	0.00000	0
1190	C05		9	2		9290	1960	UBC	0.044	ST	RG	5920000	0.00000	0
1191	C05		11	2		14800	1961	UBC	0.039	ST	RG	4890000	0.00016	0
1192	C09		10	2		13300	1966	UBC	0.070	RC	RG	5470000	0.00000	0
1193	A06		17	2		16300	1964	UBC	0.058	ST	RG	3390000	0.00000	0
1194	B07		8	1			1928	NO	0.000	RC	RG	98000	0.00000	0
1195	A06		13	2		16800	1962	UBC	0.064	RC	RG	3260000	0.00000	0
1196	A06		13	2		15100	1962	UBC	0.064	RC	RG	2990000	0.00260	2
1197	A06		21	3		24600	1970	UBC	0.054	ST	RG	8400000	0.00000	0
1198	B07		8	1		6020	1932	NO	0.000	ST	IR	1620000	0.00000	0
1199	B07		15	2		28600	1964	UBC	0.061	ST	RG	7050000	0.00027	0
1200	B07		10	2		7150	1961	UBC	0.041	RC	RG	1640000	0.00000	0
1201	B07		13	2		3530	1929	NO	0.000	RC	IR	950000	0.00000	0
1202	B06		7	1		10000	1964	UBC	0.078	ST	RG	2695000	0.00167	2
1203	A06		8	1		6600	1969	UBC	0.075	RC	RG	2160000	0.00000	0
1204	B06		9	2		8260	1961	UBC	0.044	ST	IR	2232000	0.00000	0
1205	B06		6	1		8300	1969	UBC	0.083	RC	RG	2234500	0.00000	0
1206	B07		17	2		39900	1964	UBC	0.058	ST	RG	6930000	0.00000	0
1207	B07		17	2		39900	1964	UBC	0.058	ST	RG	6930000	0.00000	0
1208	B07		8	1		6330	1968	UBC	0.075	ST	RG	1703000	0.00000	0
1209	A06		9	2		17300	1962	UBC	0.072	RC	RG	3990000	0.00000	0
1210	A06		16	2		22300	1970	UBC	0.060	ST	RG	4240000	0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
1211	D10		11	2		18600	1967	UBC	0.067	ST	RG	6190000	0.00000	0
1212	D10		11	2		17400	1967	UBC	0.067	ST	RG	1250000	0.00000	0
1213	D10		7	1		7400	1970	UBC	0.078	ST	RG	2002000	0.00020	0
1214	E04		6	1		1860	1927	NO	0.000	RC	IR	500000	0.22420	6
1215	E04		8	1		6000	1959	UBC	0.048	ST	RG	3780000	0.00000	0
1216	E04		6	1		4180	1968	UBC	0.083	RC	IR	1125000	0.00111	1
1217	E04		12	2		10700	1964	UBC	0.066	RC	IR	2390000	0.03247	5
1218	E04		6	1		2320	1930	NO	0.000	RC	IR	625000	0.01280	4
1219	E04		8	1		4650	1929	NO	0.000	RC	IR	1250000	0.00000	0
1220	G04		9	2		12500	1970	UBC	0.072	ST	RG	2830000	0.00000	0
1221	G04		13	2			1970	UBC	0.064	RM	RG		0.00000	0
1222	G04		8	1		9100	1925	NO	0.000	ST	IR	2450000	0.00900	3
1223	G04		9	2		940	1925	NO	0.000	ST	IR	252500	0.01505	4
1224	G04		9	2		14900	1962	UBC	0.072	RC	IR	6520000	0.00106	1
1225	G04		7	1		8550	1923	NO	0.000	RC	IR	2300000	0.00261	2
1226	G04		13	2		9570	1967	UBC	0.064	ST	IR	2020000	0.00926	3
1227	G04		7	1		1300	1926	NO	0.000	RC	IR	352500	0.00000	0
1228	H04		11	2		10900	1965	UBC	0.067	RC	RG	4680000	0.00000	0
1229	G04		8	1		8000	1926	NO	0.000	RC	IR	2150000	0.00000	0
1230	G04		8	1		6780	1967	UBC	0.075	RC	RG	2240000	0.00000	0
1231	G04		8	1		29500	1966	UBC	0.075	RC	RG	7550000	0.00015	0
1232	G03		8	1		4370	1925	NO	0.000	RC	IR	1175000	0.00102	1
1233	G04		9	2		24200	1970	UBC	0.072	ST	RG	6720000	0.00000	0
1234	G04		7	1		3350	1912	NO	0.000	RC	IR	901500	0.00329	2
1235	G04		8	1		3750	1914	NO	0.000	RC	IR	1000000	0.00000	0
1236	G04		9	2		16800	1970	UBC	0.072	RC	RG	7070000	0.00000	0
1237	F03		6	1		4650	1966	UBC	0.083	RC	RG	1250000	0.04000	5
1238	F03		9	2		9290	1964	UBC	0.072	ST	RG	2500000	0.04000	5
1239	F03		9	2		6130	1964	UBC	0.072	ST	RG	1650000	0.03000	4
1240	G07		10	2		10900	1965	UBC	0.070	RC	RG	4530000	0.00000	0
1241	H04		8	1		3900	1965	UBC	0.075	RC	RG	1360000	0.00000	0
1242	J05		9	2		9380	1965	UBC	0.072	RC	RG	2610000	0.00000	0
1243	F11		11	2			1926	NO	0.000	RC	IR		0.00000	0
1244	F11		7	1			1924	NO	0.000	RC	IR		0.00000	0
1245	F11		8	1			1929	NO	0.000	RC	IR		0.00000	0
1246	F11		7	1			1924	NO	0.000	RC	IR		0.00000	0
1247	F11		8	1			1922	NO	0.000	RC	IR	1250000	0.00032	0
1248	F10		14	2		17300	1962	UBC	0.062	RC	RG	4310000	0.00000	0
1249	F10		6	1		5860	1969	UBC	0.083	RC	RG	2508600	0.00000	0
1250	F11		7	1			1924	NO	0.000	ST	IR		0.00000	0
1251	F11		11	2		2730	1922	NO	0.000	ST	IR	734000	0.00000	0
1252	F11		6	1			1959	UBC	0.057	ST	RG		0.00000	0
1253	F11		12	2		17300	1971	UBC	0.066	ST	RG	6100000	0.00000	0
1254	G10		9	2		7900	1963	UBC	0.072	ST	IR	2770000	0.00702	3

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
1255	F11		10	2		7660	1928	NO	0.000	ST	IR	2062500	0.00000	0
1256	F11		6	1		4430	1929	NO	0.000	RC	IR	1192500	0.00000	0
1257	F11		7	1		2970	1913	NO	0.000	ST	IR	800000	0.00000	0
1258	F11		6	1			1927	NO	0.000	ST	RG		0.00000	0
1259	F11		10	2		11150	1961	UBC	0.041	RC	IR	6930000	0.00000	0
1260	F11		12	2			1923	NO	0.000	RC	IR		0.00000	0
1261	F10		10	2		9290	1968	UBC	0.070	ST	RG	3280000	0.00000	0
1262	F11		10	2			1916	NO	0.000	ST	IR		0.00000	0
1263	F11		11	2		13200	1929	NO	0.000	RC	IR	3550000	0.00000	0
1264	F11		9	2		9890	1969	UBC	0.072	ST	RG	2660000	0.00000	0
1265	F11		14	2			1926	NO	0.000	RC	IR		0.00000	0
1266	F11		8	1		5570	1922	NO	0.000	ST	IR	1500000	0.00000	0
1267	F11		13	2			1923	NO	0.000	RC	IR		0.00000	0
1268	F11		10	2			1959	UBC	0.041	ST	RG		0.00000	0
1269	F11		12	2		11600	1923	NO	0.000	RC	IR	3125000	0.00000	0
1270	F11		7	1			1914	NO	0.000	RC	IR		0.00000	0
1271	F11		10	2		11150	1968	UBC	0.070	ST	RG	3740000	0.00000	0
1272	F11		12	2		18300	1964	UBC	0.066	RC	RG	3960000	0.00000	0
1273	F11		34	3		39200	1966	UBC	0.046	RC	IR	8590000	0.00037	0
1274	F11		15	2			1928	NO	0.000	ST	IR		0.00000	0
1275	F11		8	1			1925	NO	0.000	RC	IR		0.00000	0
1276	F11		7	1		4550	1922	NO	0.000	RC	IR	1225000	0.00000	0
1277	F11		17	2		35600	1962	UBC	0.058	ST	RG	7820000	0.00000	0
1278	F11		12	2			1925	NO	0.000	RC	IR		0.00000	0
1279	F11		14	2		12100	1924	NO	0.000	ST	IR	3250000	0.00262	2
1280	F11		6	1		18580	1926	NO	0.000	ST	IR	5000000	0.00000	0
1281	F11		6	1			1924	NO	0.000	ST	IR		0.00000	0
1282	F11		8	1			1925	NO	0.000	RC	IR		0.00000	0
1283	F11		10	2			1924	NO	0.000	RC	IR		0.00000	0
1284	F11		6	1			1928	NO	0.000	RC	IR		0.00000	0
1285	G11		6	1			1958	UBC	0.057	RC	IR		0.00000	0
1286	G11		6	1		2600	1962	UBC	0.083	RC	RG	1630000	0.00000	0
1287	F11		20	3		19700	1965	UBC	0.055	ST	RG	3820000	0.00000	0
1288	F11		16	2		19300	1968	UBC	0.060	ST	RG	5880000	0.00000	0
1289	G11		8	1		7900	1968	UBC	0.075	RC	RG	1620000	0.00000	0
1290	F11		9	2		10000	1969	UBC	0.072	ST	RG	3920000	0.00000	0
1291	F12		6	1		11370	1969	UBC	0.083	ST	RG	3060000	0.00000	0
1292	A06		13	2		9750	1963	UBC	0.064	RC	RG	1590000	0.00000	0
1293	A06		17	2		14500	1968	UBC	0.058	RC	RG	4050000	0.00170	2
1294	F11		8	1			1922	NO	0.000	ST	IR		0.00000	0
1295	F11		11	2		16170	1958	UBC	0.039	ST	IR	6120000	0.00000	0
1296	E06		6	1		4000	1969	UBC	0.083	ST	RG	1080000	0.00556	3
1297	E06		7	1			1964	UBC	0.078	ST	RG		0.00000	0
1298	B06		8	1			1964	UBC	0.075	RC	RG		0.00000	0

TABLE B.7 (Continued)

Site Identification	Grid Cell	Soil Type	Number of Floors	Height Code	EIS Value	Area, m^2	Year Built	Building Code	Design Base Shear	Building Material	Configuration	Replacement Value	Damage Factor	Damage State
1299	B07		8	1			1968	UBC	0.075	RC	RG		0.00000	0
1300	E06		10	2		5340	1923	NO	0.000	ST	IR	1437500	0.02087	4
1301	E06		10	2		6180	1924	NO	0.000	ST	IR	1662500	0.01341	4
1302	E06		11	2		8180	1928	NO	0.000	ST	IR	2200000	0.01045	3
1303	E06		7	1		3860	1921	NO	0.000	ST	IR	1037500	0.01041	3
1304	E06		7	1		16440	1907	NO	0.000	ST	IR	4425000	0.01051	3
1305	E06		8	1		16200	1906	NO	0.000	RC	IR	4375000	0.01047	3
1306	J12		9	2			1970	UBC	0.072	RC	RG		0.00000	0
1307	E06		8	1		8900	1934	UBC	0.010	ST	IR	2400000	0.01467	4
1308	J10		10	2		12100	1970	UBC	0.070	ST	RG	3010000	0.00000	0
1309	E06		13	2			1910	NO	0.000	ST	IR		0.00000	0
1310	J12		11	2		4090	1960	UBC	0.039	ST	RG	2064000	0.00000	0
1311	J11		12	2		11060	1970	UBC	0.066	ST	RG	2040000	0.00000	0
1312	J12		10	2		13010	1968	UBC	0.070	RC	RG	2800000	0.00000	0
1313	C04		14	2		13900	1962	UBC	0.062	ST	RG	5720000	0.00000	0
1314	J11		10	2		10000	1968	UBC	0.070	RC	RG	2490000	0.00000	0
1315	J12		11	2		49800	1966	UBC	0.067	RC	RG	20020000	0.00000	0
1316	J12		10	2		9290	1964	UBC	0.070	ST	RG	4160000	0.00000	0
1317	J12		11	2		11150	1970	UBC	0.067	ST	RG	3540000	0.00000	0
1318	E06		6	1			1924	NO	0.000	RC	IR	7500	0.40000	7
1319	J11		12	2		11150	1963	UBC	0.066	ST	RG	4920000	0.00000	0
1320	J11		12	2		11150	1967	UBC	0.066	ST	RG	4340000	0.00000	0
1321	D06		13	2		6970	1929	NO	0.000	RC	IR	1875000	0.01333	4
1322	B06		14	2		42100	1957	UBC	0.033	RC	RG	14140000	0.00000	0
1323	B07		17	2		34700	1970	UBC	0.058	RC	IR	9680000	0.00000	0
1324	C05		6	1		1860	1959	UBC	0.057	ST	RG	500000	0.00100	1
1325	E06		13	2		7430	1913	NO	0.000	RC	IR	2000000	0.00400	3
1326	E06		11	2		37900	1928	NO	0.000	ST	IR	10207000	0.01001	3
1327	F11		9	2		21400	1916	NO	0.000	ST	IR	5750000	0.00000	0
1328	D06		12	2		7250	1930	NO	0.000	RC	IR	1950000	0.00359	2
1329	E06		12	2		16160	1916	NO	0.000	ST	IR	4350000	0.00287	2
1330	E06		7	1		5750	1948	UBC	0.052	RC	RG	1550000	0.00000	0

TABLE B.8

LOS ANGELES AREA GRID - SAN FERNANDO EARTHQUAKE 09FEB71

80/04/01

GRID CELL	LATITUDE	LONGITUDE	SOIL TYPE	EPICENTRAL DISTANCE KM	MMI	DURATION
A01	34.2980	118.5260	RK	17	8.0	36
A02	34.2474	118.5260	MA	21	8.0	42
A03	34.1968	118.5260	DA	26	7.0	53
A04	34.1462	118.5260	MA	31	7.0	48
A05	34.0956	118.5260	RK	36	6.0	49
A06	34.0450	118.5260	LA	42	6.0	50
A07	33.9944	118.5260	MA	47	6.0	55
B01	34.2980	118.4574	MA	13	8.0	41
B02	34.2474	118.4574	DA	19	8.0	47
B03	34.1968	118.4574	DA	24	8.0	47
B04	34.1462	118.4574	DA	29	7.0	53
B05	34.0956	118.4574	RK	35	7.0	44
B06	34.0450	118.4574	MA	41	6.0	55
B07	33.9944	118.4574	MA	46	6.0	55
B08	33.9438	118.4574	MA	52	6.0	56
C01	34.2980	118.3888	LA	12	8.0	36
C02	34.2474	118.3888	LA	18	8.0	37
C03	34.1968	118.3888	DA	23	8.0	47
C04	34.1462	118.3888	DA	29	7.0	53
C05	34.0956	118.3888	LA	35	7.0	44
C06	34.0450	118.3888	MA	40	7.0	49
C07	33.9944	118.3888	MA	46	6.0	55
C08	33.9438	118.3888	DA	51	6.0	61
C09	33.8932	118.3888	DA	57	6.0	61
C10	33.8426	118.3888	DA	63	6.0	62
C11	33.7920	118.3888	RK	68	6.0	52
C12	33.7414	118.3888	RK	74	6.0	53
D01	34.2980	118.3202	RK	14	8.0	36
D02	34.2474	118.3202	LA	19	8.0	37
D03	34.1968	118.3202	MA	24	8.0	42
D04	34.1462	118.3202	MA	30	7.0	48
D05	34.0956	118.3202	LA	35	7.0	44
D06	34.0450	118.3202	MA	41	7.0	49
D07	33.9944	118.3202	DA	46	7.0	55
D08	33.9438	118.3202	DA	52	6.0	61
D09	33.8932	118.3202	DA	58	6.0	61
D10	33.8426	118.3202	DA	63	6.0	62
D11	33.7920	118.3202	LA	69	6.0	53
D12	33.7414	118.3202	RK	74	6.0	53
E01	34.2980	118.2516	RK	18	7.0	42
E02	34.2474	118.2516	LA	22	7.0	42
E03	34.1968	118.2516	LA	27	7.0	43
E04	34.1462	118.2516	MA	32	7.0	48
E05	34.0956	118.2516	LA	37	7.0	44
E06	34.0450	118.2516	MA	42	7.0	49
E07	33.9944	118.2516	DA	48	7.0	55
E08	33.9438	118.2516	DA	53	6.0	61
E09	33.8932	118.2516	DA	59	6.0	62
E10	33.8426	118.2516	DA	64	6.0	62
E11	33.7920	118.2516	DS	70	6.0	63
E12	33.7414	118.2516	DS	75	5.0	63
F01	34.2980	118.1830	RK	23	7.0	43
F02	34.2474	118.1830	RK	27	7.0	43
F03	34.1968	118.1830	MA	31	7.0	48
F04	34.1462	118.1830	LA	35	7.0	44
F05	34.0956	118.1830	MA	40	7.0	49
F06	34.0450	118.1830	MA	45	7.0	50
F07	33.9944	118.1830	DA	50	7.0	55
F08	33.9438	118.1830	DA	55	6.0	61
F09	33.8932	118.1830	DA	60	6.0	62
F10	33.8426	118.1830	DA	66	6.0	62
F11	33.7920	118.1830	DS	71	5.0	63

TABLE B.8 (Continued)

GRID CELL	LATITUDE	LONGITUDE	SOIL TYPE	EPICENTRAL DISTANCE KM	MMI	DURATION
F12	33.7414	118.1830	DS	77	6.0	63
G01	34.2980	118.1144	RK	29	6.0	49
G02	34.2474	118.1144	RK	32	6.0	49
G03	34.1968	118.1144	MA	35	7.0	49
G04	34.1462	118.1144	DA	39	7.0	54
G05	34.0956	118.1144	MA	43	7.0	49
G06	34.0450	118.1144	MA	48	7.0	50
G07	33.9944	118.1144	MA	53	5.0	56
G08	33.9438	118.1144	DA	58	6.0	61
G09	33.8932	118.1144	DA	63	6.0	62
G10	33.8426	118.1144	DA	68	6.0	62
G11	33.7920	118.1144	DA	73	6.0	63
G12	33.7414	118.1144	DS	78	6.0	63
H01	34.2980	118.0458	RK	35	6.0	49
H02	34.2474	118.0458	RK	37	6.0	49
H03	34.1968	118.0458	RK	40	6.0	50
H04	34.1462	118.0458	DA	44	6.0	60
H05	34.0956	118.0458	MA	47	6.0	55
H06	34.0450	118.0458	DA	52	6.0	61
H07	33.9944	118.0458	MA	56	6.0	56
H08	33.9438	118.0458	MA	61	6.0	57
H09	33.8932	118.0458	MA	66	6.0	57
H10	33.8426	118.0458	DA	71	6.0	63
H11	33.7920	118.0458	DA	76	6.0	63
H12	33.7414	118.0458	DA	81	6.0	64
I01	34.2980	117.9772	RK	41	5.0	50
I02	34.2474	117.9772	RK	43	6.0	50
I03	34.1968	117.9772	RK	45	6.0	50
I04	34.1462	117.9772	MA	48	6.0	55
I05	34.0956	117.9772	MA	52	6.0	56
I06	34.0450	117.9772	DA	56	6.0	61
I07	33.9944	117.9772	RK	60	6.0	52
I08	33.9438	117.9772	MA	64	6.0	57
I09	33.8932	117.9772	RK	69	6.0	53
I10	33.8426	117.9772	DA	74	6.0	63
I11	33.7920	117.9772	DA	79	6.0	64
I12	33.7414	117.9772	DA	84	6.0	64
J01	34.2980	117.9086	RK	47	6.0	50
J02	34.2474	117.9086	RK	48	6.0	50
J03	34.1968	117.9086	RK	51	6.0	57
J04	34.1462	117.9086	MA	54	6.0	56
J05	34.0956	117.9086	MA	57	6.0	56
J06	34.0450	117.9086	MA	60	6.0	57
J07	33.9944	117.9086	LA	64	6.0	52
J08	33.9438	117.9086	RK	68	6.0	52
J09	33.8932	117.9086	MA	73	6.0	58
J10	33.8426	117.9086	DA	77	6.0	63
J11	33.7920	117.9086	DA	82	6.0	64
J12	33.7414	117.9086	DA	87	6.0	64

TABLE B.9

NUMBER OF BUILDINGS IN EACH CELL OF LOS ANGELES AREA GRID

```
---
TALLY/EACH/C38
************************
 ELEMENT-      SITE LOCATION CODE /A22/H83/
************************
FREQUENCY    VALUE
------------------------
        2       A02
        3       A04
       13       A06
        3       B01
        6       B03
       10       B04
       32       B06
       16       B07
        1       C03
        3       C04
       20       C05
       79       C06
       19       C08
        1       C09
       65       D05
      106       D06
        1       D09
        3       D10
        6       E04
        2       E05
      405       E06
        4       E07
        1       E12
        4       F03
        1       F05
        4       F06
        3       F10
       49       F11
        1       F12
        1       G03
       16       G04
        1       G07
        1       G10
        4       G11
        2       H04
        1       J05
        1       J09
        1       J10
        5       J11
        6       J12
------------------------
       40   UNIQUE VALUES
------------------------
      902   OCCURRENCES
------------------------
```

TABLE B.10

UNDAMAGED CONCRETE BUILDINGS IN GRID CELL D06

80/04/07

SITE ID	NO. OF FLOORS	HEIGHT CODE	AREA SQ.M	YEAR BUILT	BLDG CODE	BASE SHEAR	BLDG MATL	CONFIG	DAMAGE STATE
956	6	1		1929	NO	0.000	RC	IR	0
955	6	1		1929	NO	0.000	RC	IR	0
957	6	1		1928	NO	0.000	RC	IR	0
782	6	1		1926	NO	0.000	RC	IR	0
1022	6	1		1927	NO	0.000	RC	IR	0
928	6	1		1929	NO	0.000	RC	IR	0
1074	6	1		1920	NO	0.000	RC	IR	0
658	6	1		1929	NO	0.000	RC	IR	0
656	6	1		1920	NO	0.000	RC	IR	0
550	6	1		1930	NO	0.000	RC	IR	0
538	6	1		1927	NO	0.000	RC	RG	0
958	7	1		1929	NO	0.000	RC	IR	0
959	7	1		1930	NO	0.000	RC	IR	0
1026	7	1		1915	NO	0.000	RC	IR	0
903	7	1		1928	NO	0.000	RC	IR	0
779	7	1		1929	NO	0.000	RC	IR	0
730	7	1		1929	NO	0.000	RC	IR	0
1035	7	1		1926	NO	0.000	RC	IR	0
781	8	1		1923	NO	0.000	RC	IR	0
780	8	1		1931	NO	0.000	RC	IR	0
934	8	1		1928	NO	0.000	RC	IR	0
933	8	1		1915	NO	0.000	RC	IR	0
1069	10	2		1924	NO	0.000	RC	IR	0
1097	12	2		1929	NO	0.000	RC	RG	0
1063	13	2		1928	NO	0.000	RC	IR	0
1094	13	2		1930	NO	0.000	RC	RG	0
1073	13	2		1924	NO	0.000	RC	IR	0
720	13	2	15700	1950	UBC	0.034	RC	IR	0
721	13	2	15700	1950	UBC	0.034	RC	IR	0
722	13	2	15700	1950	UBC	0.034	RC	IR	0
723	13	2	15700	1950	UBC	0.034	RC	IR	0
724	13	2	15700	1950	UBC	0.034	RC	IR	0
725	13	2	15700	1950	UBC	0.034	RC	IR	0
726	13	2	15700	1950	UBC	0.034	RC	IR	0
775	13	2	15700	1950	UBC	0.034	RC	IR	0
776	13	2	15700	1950	UBC	0.034	RC	IR	0
777	13	2	15700	1950	UBC	0.034	RC	IR	0
1071	13	2	18700	1955	UBC	0.034	RC	RG	0
797	13	2	15700	1950	UBC	0.034	RC	IR	0
798	13	2	15700	1950	UBC	0.034	RC	IR	0
799	13	2	15700	1950	UBC	0.034	RC	IR	0
727	13	2	15700	1950	UBC	0.034	RC	IR	0
1067	6	1		1956	UBC	0.057	RC	IR	0
1039	6	1		1960	UBC	0.057	RC	RG	0
1079	12	2		1965	UBC	0.066	RC	IR	0
1023	12	2	12100	1965	UBC	0.066	RC	IR	0
1083	11	2	37500	1969	UBC	0.067	RC	RG	0
899	8	1		1963	UBC	0.075	RC	IR	0
652	6	1		1962	UBC	0.083	RC	RG	0

```
PRINT C1,C2,C35 WHERE C1 EQ LOS ANGELES AND C36 EQ 220;
CITY* LOS ANGELES
COUNTRY* UNITED STATES

  SITE ID*   220
  INSTRUMENTATION /FF/LB/HB/HU/BJ/HN/* BU
  SITE LATITUDE*  34.0500
  SITE LONGITUDE* 118.2600
  SITE GEOLOGY /RK/LA/MA/DA/* RK
  BUILDING ORIENTATION /N52W/* S38W
  STORIES ABOVE GRADE*  39
  STORIES BELOW GRADE* 4
  HEIGHT ABOVE GRADE M* 151.0
  HEIGHT BELOW GRADE M* 12.2
  HEIGHT CODE /N/* 4
  WIDTH M*  29.9
  LENGTH M*  59.7
  TOTAL FLOOR AREA M2*   69600
  YEAR OF CONSTRUCTION* 1965
  DESIGN CODE /UBC46/OTHER/* UBC70
  LATERAL DESIGN /SS/SW/RS/TH/OT/NO/* TH
  BASE SHEAR L-G* 0.040
  BASE SHEAR T-G* 0.040
  DESIGN PERIOD L*  5.04
  DESIGN PERIOD T*  5.43
  MEASURED PERIOD L*  3.29
  MEASURED PERIOD T*  2.84
  DATE MEASURED* 1968
  VERTICAL LOAD /SF/TR/BW/OT/* SF
  LATERAL LOAD L /MF/SW/SC/TF/BF/TB/OT/* MF
  LATERAL LOAD T /MF/SW/SC/TF/BF/TB/OT/* MF
  STRUCTURAL MATERIAL /ST/RC/PC/RM/UM/WD/OT/SR/* ST
  ARCHITECTURAL EXTERIOR /CO/CB/CT/LF/DM/DW/GL/MT/OT/* GL
  CONFIGURATION /RG/IR/* R

    EARTHQUAKE ID/3* BOR-04-68
    AVAILABLE RECORDS /RS5/RSC/THR/THC/THO/OTH/* OTH
    CAUSE OF DAMAGE /SHK/FND/STL/SLP/FIR/* SHK
    DAMAGE STATE /N/* 1

    EARTHQUAKE ID/3* LYT-09-70
    AVAILABLE RECORDS /RS5/RSO/THR/THC/THO/OTH/* RS5
    CAUSE OF DAMAGE /SHK/FND/STL/SLP/FIR/* SHK
    DAMAGE STATE /N/* 0
```

FIGURE B.1 SAMPLE LISTING FOR A BUILDING IN LOS ANGELES, CALIFORNIA

```
EARTHQUAKE ID/3* SFD-02-71
INTENSITY MMI*  7.0
REPORTED DURATION SEC*  57
AVAILABLE RECORDS /RS5/RSO/THR/THC/THO/OTH/* RS5
CAUSE OF DAMAGE /SHK/FND/STL/SLP/FIR/* SHK
REPLACEMENT COST $* 30000000
DAMAGE REPAIR COST $*    100000
PERCENT STRUCTURAL* 0.000
PERCENT ARCHITECTURAL* 0.700
PERCENT MECH/ELEC* 0.300
DAMAGE FACTOR* 0.00333
DAMAGE STATE /N/* 2
LOSS OF FUNCTION $*          0
CAUSE OF LOSS /ST/AR/ME/FR/* ME
SITE EI 9-DIGIT* 345565665
```

FIGURE B.1 (Continued)

```
PRINT/NAME/C1,C2,C35 WHERE C1 EQ MEXICO AND C36 EQ 501;
CITY* MEXICO
COUNTRY* MEXICO

  SITE ID*   501
  INSTRUMENTATION /FF/LB/HB/HU/BJ/HN/* HN
  SITE GEOLOGY /RK/LA/MA/DA/* DA
  BUILDING ORIENTATION /N52W/* NS
  STORIES ABOVE GRADE*  43
  STORIES BELOW GRADE* 3
  HEIGHT CODE /N/* 4
  YEAR OF CONSTRUCTION* 1955
  LATERAL DESIGN /SS/SW/RS/TH/CT/NO/* RS
  BASE SHEAR L-G* 0.050
  BASE SHEAR T-G* 0.050
  VERTICAL LOAD /SF/TR/BW/OT/* SF
  LATERAL LOAD L /MF/SW/SC/TF/EF/TB/OT/* MF
  LATERAL LOAD T /MF/SW/SC/TF/BF/TB/OT/* MF
  STRUCTURAL MATERIAL /ST/RC/PC/RM/UM/WD/OT/SR/* ST
  ARCHITECTURAL EXTERIOR /CO/CB/CT/LP/DM/DW/GL/MT/OT/* GL
  ARCHITECTURAL INTERIOR /CO/CB/CT/LP/DM/DW/GL/MT/OT/* DM
  CONFIGURATION /RG/IR/* R

    EARTHQUAKE ID/3* MEX-07-57
    INTENSITY MMI*  7.0
    ESTIMATED DURATION SEC*  60
    AVAILABLE RECORDS /RS5/RSO/THR/THC/THO/OTH/* NO
    CAUSE OF DAMAGE /SHK/FND/STL/SLP/FIR/* SHK
    DAMAGE STATE /N/* 0

    EARTHQUAKE ID/3* MEX-08-68
    INTENSITY MMI*  7.0
    ESTIMATED DURATION SEC*  60
    AVAILABLE RECORDS /RS5/RSO/THR/THC/THO/OTH/* RS5
    CAUSE OF DAMAGE /SHK/FND/STL/SLP/FIR/* SHK
    DAMAGE STATE /N/* 0
```

FIGURE B.2 SAMPLE LISTING FOR A BUILDING IN MEXICO CITY

```
PRINT C1,C2,C35 WHERE C1 EQ SENDAI AND C36 EQ 201;
CITY* SENDAI
COUNTRY* JAPAN

  SITE ID*   201
  INSTRUMENTATION /FF/LS/HB/HU/BJ/HN/* BU
  STORIES ABOVE GRADE*   9
  STORIES BELOW GRADE* 0
  HEIGHT CODE /N/* 2
  YEAR OF CONSTRUCTION* 1972
  LATERAL DESIGN /SS/SW/RS/TH/OT/NO/* SS
  BASE SHEAR L-G* 0.200
  BASE SHEAR T-G* 0.200
  VERTICAL LOAD /SF/TR/BW/OT/* SF
  LATERAL LOAD L /MF/SW/SC/TF/BF/TB/OT/* OT
  LATERAL LOAD T /MF/SW/SC/TF/BF/TB/OT/* OT
  STRUCTURAL MATERIAL /ST/RC/PC/RM/UM/WD/OT/SR/* RC

    EARTHQUAKE ID/3* JPN-06-78
    INTENSITY MMI*  6.0
    INTENSITY OTHER*  5.0
    INTENSITY SCALE /RFI/MKS/GEO/JMA/WD/* JMA
    ESTIMATED DURATION SEC*  20
    AVAILABLE RECORDS /RS5/RSC/THR/THC/THO/OTH/* OTH
    CAUSE OF DAMAGE /SHK/FND/STL/SLP/FIR/* SHK
    DAMAGE STATE /N/* 6
---
```

FIGURE B.3 SAMPLE LISTING FOR A BUILDING IN SENDAI, JAPAN

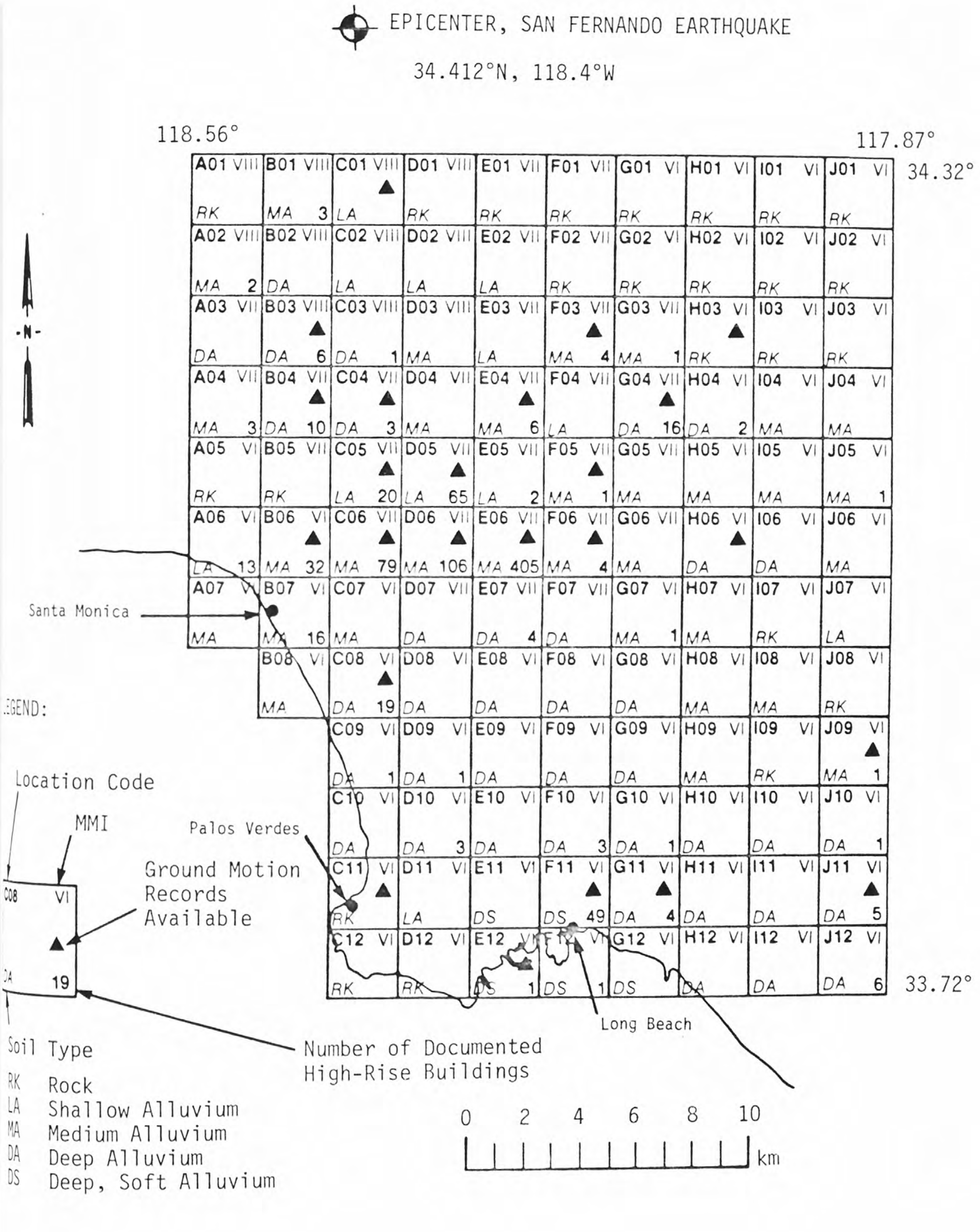

FIGURE B.4 LOS ANGELES AREA GRID AND DATA SUMMARY FOR THE SAN FERNANDO EARTHQUAKE

APPENDIX C

Seismological Intensity Scales

SEISMOLOGICAL INTENSITY SCALES

Various seismological intensity scales have been developed in the past 200 years. Derived purely from empirical observations of damage, they provided the first scale form for communicating the destructive effects of earthquakes.

Because of the purely empirical manner in which the various seismological intensity scales were developed, they have thus far been of only limited value in calculating the response of structures to estimate the effects of a postulated earthquake. Various correlation studies (Gutenberg and Richter, 1942 and 1956; Hershberger, 1956; Ambraseys, 1974; Trifunac and Brady, 1975; and Gupta, 1980) have been conducted to relate seismological intensities with engineering ground-motion parameters (e.g., acceleration, velocity, and displacement), but these have serious limitations and thus far are accepted as only crude estimates. These limitations include wide scatter in the data (Ambraseys, 1974; Trifunac and Brady, 1975) and the inadequacy of a single ground-motion parameter such as peak acceleration for making estimates of nonlinear structure response (Scholl, 1974).

Until an engineering intensity scale is adequately enough developed to render it useful for making estimates of damage on the basis of response analysis, the seismological intensity scales will continue to be of value. In developing a useful engineering intensity scale, the various seismological intensity scales will be useful as a basis for establishing damage scenarios for the engineering intensity scale and for cross correlating various engineering ground motion parameters with seismological intensity values. Currently, damage scenarios are associated with various seismological intensity scales, but the seismological intensity ratings are of questionable value to the engineer for analysis. Similarly, an engineering intensity scale has been defined (Appendix D), but no damage scenarios have been defined for it. The two systems must be integrated. Some work has been done to correlate various seismological intensity scales (Barosh, 1969; Medvedev and Sponheuer, 1964); no work has been done to establish damage scenarios for an engineering intensity scale.

Of the seismological intensity scales in use throughout the world, five are of particular value for developing damage scenarios for an engineering intensity scale. These are:

- Modified Mercalli Scale (MM)
- Japan Meterological Agency Scale (JMA)
- Medvedev-Sponheuer-Karnik Scale (MSK)
- Rossi-Forel Scale (RF)
- GEOFIAN Scale

Figure C.1 gives a graphic correlation showing the relationship between the five scales. These relationships were derived from information presented by Barosh (1969) and Richter (1958). Tables C.1 through C.5 are listings of the scales.

TABLE C.1

MODIFIED MERCALLI (MM) INTENSITY SCALE*

I. Not felt—or, except rarely under especially favorable circumstances. Under certain conditions, at and outside the boundary of the area in which a great shock is felt:
- sometimes birds, animals, reported uneasy or disturbed;
- sometimes dizziness or nausea experienced;
- sometimes trees, structures, liquids, bodies of water, may sway—doors may swing, very slowly.

II. Felt indoors by few, especially on upper floors, or by sensitive or nervous persons.

Also, as in grade I, but often more noticeably:
- sometimes hanging objects may swing, especially when delicately suspended;
- sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly;
- sometimes birds, animals, reported uneasy or disturbed;
- sometimes dizziness or nausea experienced.

III. Felt indoors by several, motion usually rapid vibration.
- Sometimes not recognized to be an earthquake at first.
- Duration estimated in some cases.
- Vibration like that due to passing of light, or lightly loaded trucks, or heavy trucks some distance away.
- Hanging objects may swing slightly.
- Movements may be appreciable on upper levels of tall structures.
- Rocked standing motor cars slightly.

IV. Felt indoors by many, outdoors by few.
- Awakened few, expecially light sleepers.
- Frightened no one, unless apprehensive from previous experience.
- Vibration like that due to passing of heavy, or heavily loaded trucks.
- Sensation like heavy body striking building, or falling of heavy objects inside.
- Rattling of dishes, windows, doors; glassware and crockery clink and clash.
- Creaking of walls, frame, especially in the upper range of this grade.
- Hanging objects swung, in numerous instances.
- Disturbed liquids in open vessels slightly.
- Rocked standing motor cars noticeably.

V. Felt indoors by practically all, outdoors by many or most: outdoors direction estimated.
- Awakened many, or most.
- Frightened few—slight excitement, a few ran outdoors.
- Buildings trembled throughout.
- Broke dishes, glassware, to some extent.
- Cracked windows—in some cases, but not generally.
- Overturned vases, small or unstable objects, in many instances, with occasional fall.
- Hanging objects, doors, swing generally or considerably.
- Knocked pictures against walls, or swung them out of place.
- Opened, or closed, doors, shutters, abruptly.
- Pendulum clocks stopped, started, or ran fast, or slow.
- Moved small objects, furnishings, the latter to slight extent.
- Spilled liquids in small amounts from well-filled open containers.
- Trees, bushes, shaken slightly.

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*Adapted from Sieberg's (1929) Mercalli-Cancani scale, modified and condensed. Quoted from Wood and Neumann (1931).

VI. Felt by all, indoors and outdoors.
- Frightened many, excitement general, some alarm, many ran outdoors.
- Awakened all.
- Persons made to move unsteadily.
- Trees, bushes, shaken slightly to moderately.
- Liquid set in strong motion.
- Small bells rang—church, chapel, school, etc.
- Damage slight in poorly built buildings.
- Fall of plaster in small amount.
- Cracked plaster somewhat, especially fine cracks chimneys in some instances.
- Broke dishes, glassware, in considerable quantity, also some windows.
- Fall of knick-knacks, books, pictures.
- Overturned furniture in many instances.
- Moved furnishings of moderately heavy kind.

VII. Frightened all—general alarm, all ran outdoors.
- Some, or many, found it difficult to stand.
- Noticed by persons driving motor cars.
- Trees and bushes shaken moderately to strongly.
- Waves on ponds, lakes, and running water.
- Water turbid from mud stirred up.
- Incaving to some extent of sand or gravel stream banks.
- Rang large church bells, etc.
- Suspended objects made to quiver.
- Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc.
- Cracked chimneys to considerable extent, walls to some extent.
- Fall of plaster in considerable to large amount, also some stucco.
- Broke numerous windows, furniture to some extent.
- Shook down loosened brickwork and tiles.
- Broke weak chimneys at the roofline (sometimes damaging roofs).
- Fall of cornices from towers and high buildings.
- Dislodged bricks and stones.
- Overturned heavy furniture, with damage from breaking.
- Damage considerable to concrete irrigation ditches.

VIII. Fright general—alarm approaches panic.
- Disturbed persons driving motor cars.
- Trees shaken strongly—branches, trunks, broken off, especially palm trees.
- Ejected sand and mud in small amounts.
- Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters.
- Damage slight in structures (brick) built especially to withstand earthquakes.
- Considerable in ordinary substantial buildings, partial collapse: racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling.
- Fall of walls.
- Cracked, broke, solid stone walls seriously.
- Wet ground to some extent, also ground on steep slopes.
- Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers.
- Moved conspicuously, overturned, very heavy furniture.

IX. Panic general.
Cracked ground conspicuously.
Damage considerable in (masonry) structures built especially to withstand earthquakes:
threw out of plumb some wood-frame houses built especially to withstand earthquakes;
great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames;
serious to reservoirs; underground pipes sometimes broken.

X. Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks.
Landslides considerable from river banks and steep coasts.
Shifted sand and mud horizontally on beaches and flat land.
Changed level of water in wells.
Threw water on banks of canals, lakes, rivers, etc.
Damage serious to dams, dikes, embankments.
Damage severe to well-built wooden structures and bridges, some destroyed.
Developed dangerous cracks in excellent brick walls.
Destroyed most masonry and frame structures, also their foundations.
Bent railroad rails slightly.
Tore apart, or crushed endwise, pipe lines buried in earth.
Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.

XI. Disturbances in ground many and widespread, varying with ground material.
Broad fissures, earth slumps, and land slips in soft, wet ground.
Ejected water in large amount charged with sand and mud.
Caused sea-waves (tidal waves) of significant magnitude.
Damage severe to wood-frame structures, especially near shock centers.
Great to dams, dikes, embankments, often for long distances.
Few, if any (masonry), structures remained standing.
Destroyed large well-built bridges by the wrecking of supporting piers, or pillars.
Affected yielding wooden bridges less.
Bent railroad rails greatly, and thrust them endwise.
Put pipe lines buried in earth completely out of service.

XII. Damage total—practically all works of construction damaged greatly or destroyed.
Disturbances in ground great and varied, numerous shearing cracks.
Landslides, falls of rock of significant character, slumping of river banks, etc., numerous and extensive.
Wrenched loose, tore off, large rock masses.
Fault slips in firm rock, with notable horizontal and vertical offset displacements.
Water channels, surface and underground, disturbed and modified greatly.
Dammed lakes, produced waterfalls, deflected rivers, etc.
Waves seen on ground surfaces (actually seen, probably, in some cases).
Distorted lines of sight and level.
Threw objects upward into the air.

MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

TABLE C.2

ROSSI-FOREL (RF) INTENSITY SCALE*

I. *Microseismic shock.* Recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds: the shock felt by an experienced observer.

II. *Extremely feeble shock.* Recorded by several seismographs of different kinds; felt by a small number of persons at rest.

III. *Very feeble shock.* Felt by several persons at rest; strong enough for the direction or duration to be appreciable.

IV. *Feeble shock.* Felt by persons in motion; disturbance of movable objects, doors, windows, cracking of ceilings.

V. *Shock of moderate intensity.* Felt generally by everyone; disturbance of furniture, beds, etc., ringing of some bells.

VI. *Fairly strong shock.* General awakening of those asleep; general ringing of bells; oscillation of chandeliers; stopping of clocks; visible agitation of trees and shrubs; some startled persons leaving their dwellings.

VII. *Strong shock.* Overthrow of movable objects; fall of plaster; ringing of church bells; general panic, without damage to buildings.

VIII. *Very strong shock.* Fall of chimneys; cracks in the walls of buildings.

IX. *Extremely strong shock.* Partial or total destruction of some buildings.

X. *Shock of extreme intensity.* Great disaster; ruins; disturbance of the strata, fissures in the ground, rock falls from mountains.

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*After Rossi (1883). Quoted from Richter (1958).

TABLE C.3

MEDVEDEV-SPONHEUER-KARNIK (MSK) INTENSITY SCALE*

CLASSIFICATION OF THE SCALE

1. *Types of structures (buildings not antiseismic):*
   - Structure A: Buildings in field-stone, rural structures, adobe houses, clay houses.
   - B: Ordinary brick buildings, buildings of the large block and prefabricated type, half timbered structures, buildings in natural hewn stone.
   - C: Reinforced buildings, well-built wooden structures.
2. *Definition of quantity:*
   - Single, few: about 5 percent
   - Many: about 50 percent
   - Most: about 75 percent
3. *Classification of damage to buildings:*
   - Grade 1—Slight damage: Fine cracks in plaster; fall of small pieces of plaster.
   - Grade 2—Moderate damage: Small cracks in walls; fall of fairly larger pieces of plaster; pantiles slip off; cracks in chimneys; parts of chimneys fall down.
   - Grade 3—Heavy damage: Large and deep cracks in walls; fall of chimneys.
   - Grade 4—Destruction: Gaps in walls; parts of buildings may collapse; separate parts of the building lose their cohesion; inner walls and filled-in walls of the frame collapse.
   - Grade 5—Total damage: Total collapse of buildings.
4. *Arrangement of the Scale:*
   - a. Persons and surroundings.
   - b. Structures of all kinds.
   - c. Nature.

INTENSITY SCALE

I. *Not noticeable:*

a. The intensity of the vibration is below the limit of sensibility; the tremor is detected and recorded by seismographs only.

II. *Scarcely noticeable (very slight):*

a. Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.

III. *Weak, partially observed only:*

a. The earthquake is felt indoors by a few people, outdoors only in favourable circumstances. The vibration is like that due to the passing of a light truck. Attentive observers notice a slight swinging of hanging objects, somewhat more heavily on upper floors.

IV. *Largely observed:*

a. The earthquake is felt indoors by many people, outdoors by few. Here and there people awaken, but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. Windows, doors and dishes rattle. Floors and walls creak. Furniture begins to shake. Hanging objects swing slightly. Liquids in open vessels are slightly disturbed. In standing motor cars the shock is noticeable.

V. *Awakening:*

a. The earthquake is felt indoors by all, outdoors by many. Many sleeping people awake. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Few unstable objects may be overturned or shifted. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The sensation of vibration is like that due to a heavy object falling inside the building.

b. Slight damages of grade 1 in buildings of type A are possible.

c. Sometimes change in flow of springs.

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*After Medvedev, Sponheuer, and Karnik (1965). Quoted from Barosh (1969).

TABLE C.3 (Continued)

VI. *Frightening:*

a. Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In few instances dishes and glassware may break, books fall down. Heavy furniture may possibly move and small steeple bells may ring.

b. Damage of grade 1 is sustained in single buildings of type B and in many of type A. Damage in few buildings of type A is of grade 2.

c. In few cases cracks up to widths of 1 cm possible in wet ground; in mountains occasional landslips; changes in flow of springs and in level of well water are observed.

VII. *Damage to buildings:*

a. Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring.

b. In many buildings of type C damage of grade 1 is caused; in many buildings of type B damage is of grade 2. Many buildings of type A suffer damage of grade 3, few of grade 4. In single instances landslips of roadway on steep slopes; cracks in roads; seams of pipelines damaged; cracks in stone walls.

c. Waves are formed on water, and water is made turbid by mud stirred up. Water levels in wells change, and the flow of springs changes. In few cases dry springs have their flow restored and existing springs stop flowing. In isolated instances parts of sandy or gravelly banks slip off.

VIII. *Destruction of buildings:*

a. Fright and panic; also persons driving motor cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are in part damaged.

b. Many buildings of type C suffer damage of grade 2, few of grade 3. Many buildings of type B suffer damage of grade 3, and many buildings of type A suffer damage of grade 4. Occasional breakage of pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.

c. Small landslips in hollows and on banked roads on steep slopes; cracks in ground up to widths of several centimeters. Water in lakes becomes turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases change in flow and level of water.

IX. *General damage to buildings:*

a. General panic; considerable damage to furniture. Animals run to and fro in confusion and cry.

b. Many buildings of type C suffer damage of grade 3, a few of grade 4. Many buildings of type B show damage of grade 4; a few of grade 5. Many buildings of type A suffer damage of grade 5. Monuments and columns fall. Considerable damage to reservoirs; underground pipes partly broken. In individual cases railway lines are bent and roadways damaged.

c. On flat land overflow of water, sand and mud is often observed. Ground cracks to widths of up to 10 cm, on slopes and river banks more than 10 cm. furthermore a large number of slight cracks in ground; falls of rock, many landslides and earthflows; large waves on water. Dry wells renew their flow and existing wells dry up.

TABLE C.3 (Continued)

X. *General destruction of buildings:*

b. Many buildings of type C suffer damage of grade 4, a few of grade 5. Many buildings of type B show damage of grade 5; most of type A have destruction category 5; critical damage to dams and dykes and severe damage to bridges. Railway lines are bent slightly. Underground pipes are broken or bent. Road paving and asphalt show waves.

c. In ground, cracks up to widths of several decimeters, sometimes up to 1 meter. Parallel to water courses occur broad fissures. Loose ground slides from steep slopes. From river banks and steep coasts considerable landslides are possible. In coastal areas displacement of sand and mud; change of water level in wells; water from canals, lakes, rivers, etc., thrown on land. New lakes occur.

XI. *Catastrophe:*

b. Severe damage even to well-built buildings, bridges, water dams, and railway lines; highways become useless; underground pipes destroyed.

c. Ground considerably distorted by broad cracks and fissures, as well as by movement in horizontal and vertical directions; numerous landslips and falls of rock.

The intensity of the earthquake requires to be investigated specially.

XII. *Landscape changes:*

b. Practically all structures above and below ground are greatly damaged or destroyed.

c. The surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Falls of rock and slumping of river banks over wide areas; lakes are dammed; waterfalls appear, and rivers are deflected.

The intensity of the earthquake requires to be investigated specially.

TABLE C.4

JAPAN METEOROLOGICAL AGENCY (JMA) SCALE*

0. Not felt: too weak to be felt by humans; registered only by seismographs.
I. Slight: felt only feebly by persons at rest or by those who are especially observant of earthquakes.
II. Weak: felt by most persons; slight shaking of windows and Japanese latticed sliding doors (Shōji).
III. Moderately strong: shaking of houses and buildings, heavy rattling of windows and Japanese latticed sliding doors, swinging of hanging objects, stopping of some pendulum clocks, and moving of liquids in vessels; some people are so frightened that they run out of doors.
IV. Strong: strong shaking of houses and buildings, overturning of unstable objects, and spilling of liquids out of vessels.
V. Very strong: cracking brick and plaster walls, overturning stone lanterns and gravestones, and similar objects, damaging chimneys and mud-and-plaster warehouses, and causing landslides in steep mountains.
VI. Disastrous: causing destruction of 1–30 percent of Japanese wooden houses; causing large landslides; fissures in flat ground and some in low fields, accompanied by mud and waterspouts.
VII. Ruinous: causing destruction of more than 30 percent of the houses; causing large landslides, fissures and faults.

*Quoted from Barosh (1969).

TABLE C.5

GEOFIAN SCALE*

Intensity	X_0 (mm)	Brief description of earthquake
1	------------	Oscillations of the ground are detected with instruments.
2	------------	In individual cases felt by very sensitive persons at rest.
3	------------	Oscillations felt by few persons.
4	<0. 5	Noted by many persons. Windows or doors may rattle.
5	0. 5–1. 0	Objects swing, floors squeak, glasses jar, outer plaster crumbles.
6	1. 1–2. 0	Light damage to buildings: thin cracks in plaster, cracks in tile furnaces, etc.
7	2. 1–4. 0	Considerable damage to buildings: thin cracks in plaster and stripping of individual pieces, thin cracks in walls.
8	4. 1–8. 0	Destruction in buildings: large cracks in walls, falling of cornices or chimneys.
9	8. 1–16. 0	Collapse in some buildings; destruction of walls, roofs, floors.
10	16. 1–32. 0	Collapse of many buildings; fissures in ground about 1 meter wide.
11	>32. 0	Numerous fissures on the surface of the earth, large landslides in mountains.
12	------------	Large scale change in the relief.

DESCRIPTION OF AFTEREFFECTS OF EARTHQUAKES

The force of the earthquake at points where there are no seismometers is determined from the aftereffects of the earthquake, as described below for:

1. Buildings and structures.
2. Residual phenomena in ground and change in the state of the ground and surface water.
3. Other symptoms.

The degree of damage and destruction resulting from an earthquake in buildings constructed without the necessary earthquake countermeasures is established in accordance with the following subdivisions:

I. By groups of buildings.

Group A—Single story buildings with walls of unfinished stone, raw brick, adobe, etc.

Group B—Brick and stone houses.

Group C—Frame houses.

II. By degree of damage.

Light damage—Thin cracks in plaster and in tile furnaces, crumbling of outer plaster, etc.

Considerable damage—Cracks in plaster, falling of pieces of plaster, thin cracks in the walls, cracks in partitions, damage to chimneys, furnaces, etc.

Destruction—Large cracks in walls, splitting of masonry, destruction of individual parts of walls, falling of cornices and parapets, collapse of plaster, falling of chimneys, furnaces, etc.

Collapses—Destruction of walls, roofs, and floors of the entire building or of considerable parts of the building and large deformation of the walls.

III. By the number of buildings.

Majority.

Many.

Individual.

Buildings and structures

Intensity:

I. No damage.

II. No damage.

III. No damage.

IV. No damage.

*Quoted from Barosh (1969).

V. Light squeaking of floors and partitions. Jarring of glasses. Crumbling of outer plaster. Movement of unclosed doors and windows. Slight damage in individual buildings.

VI. Light damage in many buildings. In individual buildings of Groups A and B—considerable damage. In rare cases, in the case of wet ground—thin cracks on the roads.

VII. In most buildings of Group A considerable damage and in individual cases destruction. In most buildings of Group B—light damage, and in many, considerable damage. In many buildings of Group C light damage, with considerable damage in individual buildings.

In some cases, landslides on steep slopes of road embankments, cracks in roads, and dislocations in joints of pipelines. Stone walls damaged.

VIII. In many buildings of Group A there is destruction and individual buildings collapse. In most buildings of Group B there is considerable damage, and destruction in individual ones. In most buildings of Group C light damage and in many of them considerable damage.

Small slides on steep banks of cuts or embankments of roads. In individual cases piping joints break. Statues and tombstones shift. Stone walls are destroyed.

IX. In many buildings of Group A—collapse. In many buildings of Group B—destruction and individual ones collapse. Many buildings of Group C are considerably damaged and some are destroyed.

In individual cases, railroad tracks are twisted and embankments damaged. Many cracks in roads. Breaking and damaging of pipelines. Monuments and statues overturned. Most stacks and towers destroyed.

X. In many buildings of Group B—collapse. In many buildings of Group C—destruction and in some cases collapse.

Considerable damage to embankments and dams. Local bending of rails. Breaks in pipelines. Roads crack in many places and are deformed ; smokestacks, towers, and monuments, stone walls collapse.

XI. Total destruction of buildings.

Destruction of embankments over great lengths. Pipelines become completely useless. Railroad tracks bent over great lengths.

XII. Total destruction of buildings and structures.

Residual phenomena in ground with change in status of ground and surface waters

Intensity:

I. No damage.

II. No damage.

III. No damage.

IV. No damage.

V. Small waves in unstable water reservoirs. In some cases the spring flow is changed.

VI. Cracks in wet ground with widths up to 1 cm. In mountainous regions there are sporadic cases of slides and crumbling of ground. Small changes in the spring flow and the water level in wells.

VII. Thin cracks in dry ground. Large numbers of cracks in wet ground. Individual cases of slides on river banks. Small slides in mountainous regions and crumbling of ground. Possible landslides in the mountains.

In individual cases the water becomes muddy in reservoirs and in rivers. The spring flow and the water level are changed. In some cases new springs appear or existing ones are lost.

VIII. Cracks in ground reach several centimeters. Many cracks on slopes of mountains and in wet ground. Extensive crumbling of ground, slides, and mountain landslides. Water in the reservoirs becomes turbid. New water reservoirs are produced. New springs of water appear and existing ones are lost. In many cases the spring flow and the water level in wells change.

IX. Fissures in ground reach widths of 10 cm, and more than 10 cm on slopes and river banks. Large number of thin fissures in ground. Mountain landslides. Many slides and crumbling of ground. Small mud eruptions. Pronounced waves on water reservoirs. New water springs frequently arise or old ones disappear.

X. Fissures in ground with widths of several decimeters and in individual cases reaching 1 m. Rock slides in mountainous regions and at the seashore. Large mudflows of sand and clay. Surf and splashing of water in reservoirs and rivers. New lakes are produced.

XI. Numerous fissures are produced on the surface of the earth. Vertical displacement of strata. Large landslides and earth slips. Water-saturated friable sediments come out of the fissures. The conditions in the springs and water reservoirs change strongly, as well as the ground-water level.

XII. Large scale change in the relief. Tremendous landslides and earth-slides. Considerable vertical and horizontal faulting and displacement. Large changes in the state of the ground and surface waters. Waterfalls are produced. Lakes are produced. River beds change.

Other symptoms

Intensity:

I. Earthquakes not felt by persons. The oscillations of the earth are registered with instruments.

II. Noticed by individual persons who are very sensitive and who are perfectly at rest.

III. Oscillations noted by a few persons who are at rest inside buildings. Careful observers note only a slight swinging of hanging objects.

IV. Light swaying of hanging objects and of standing automobiles. Slight vibration of liquids in vessels. Slight ringing of densely stacked unstable dishes.

Earthquake perceived by most people located indoors. In rare cases sleepers are awakened. Felt by individual people outdoors.

V. Hanging objects swing noticeably. In rare cases pendulums of wall clocks stop. Water splashes sometimes from filled vessels. Unstable dishes and ornaments on shelves sometimes topple over.

Felt by all persons inside buildings and by majority of persons in the outdoors; all wake up. Animals are restless.

VI. Hanging objects swing. Sometimes books fall off shelves and pictures shift. Many pendulums of wall clocks stop. Light furniture shifts. Dishes fall.

Many persons run out of the houses. Movement of persons unstable. Animals run out of shelter.

VII. Chandeliers swing strongly. Light furniture shifts. Books, vessels, and vases fall down.

All persons run out of the buildings and in individual cases jump out of windows. It is difficult to move without support.

VIII. Some hanging lamps are damaged. Furniture shifts and frequently tilts over. Light objects jump and tilt over. Persons can stand on their feet with difficulty. All run out of buildings.

IX. Furniture topples over and breaks. Animals very panicky.

X. Numerous damages to household goods. Animals cry and howl.

XI. Loss of life, animals, and property under fragments from buildings.

XII. Great catastrophe. A considerable part of the population is killed by collapse of the buildings. Vegetation and animals destroyed by avalanches and landslides in mountainous regions.

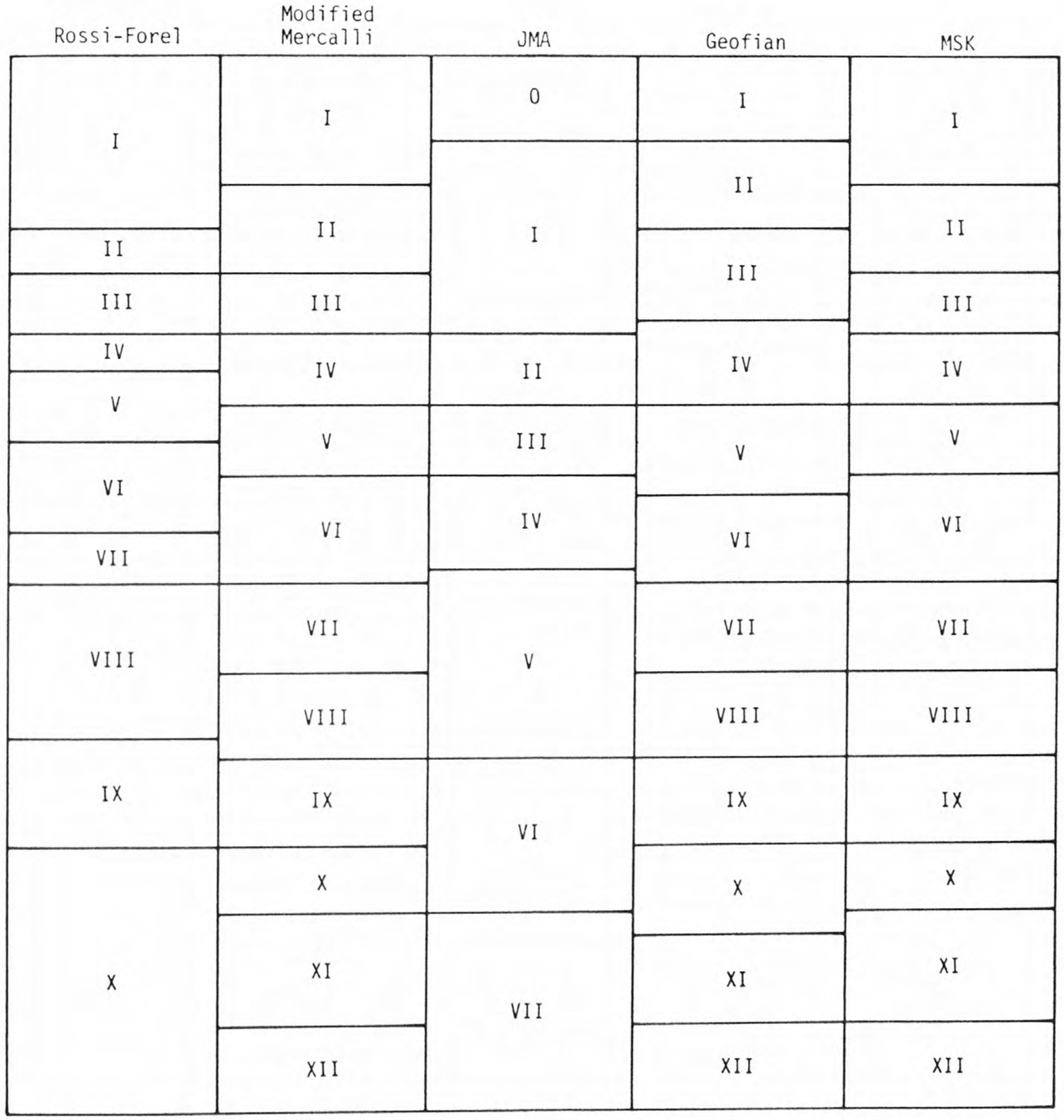

FIGURE C.1 GRAPHIC COMPARISON OF SEISMOLOGICAL INTENSITY SCALES

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APPENDIX D

Engineering Intensity Scale

ENGINEERING INTENSITY SCALE

D.1 Formulation of the Engineering Intensity Scale (EIS)

The EIS was developed by Blume* to serve as a systematic and orderly means for facilitating a rapid and simple reporting of the engineering intensity of ground shaking at a site. Engineering intensity implies a measure of ground shaking that is useful for performing engineering analyses and is readily interpretable for designing structures.

In the formulation of the scale, ground motion is characterized by 5%-damped response spectrum velocity (S_v), and structures are characterized by their fundamental-mode vibration properties. Disregarding mode-shape considerations, the variables important for correlating ground motion with damage are S_v amplitude and building period (T). A damping value of 5% is used because damping in many real structures varies from about 2% to 10%, and 5% has become a standard reference level in investigations analyzing the response of structures to ground motion.

The EIS procedure provides an orderly means for relating ground motion amplitudes for various frequencies with structures having specific frequency characteristics. The range of S_v and T values applicable to civil engineering structures is represented as a 10 x 9 matrix, shown in Figure D.1. The range of S_v values, from 0.001 to 1000.0 cm/sec, is divided into ten levels that are assigned engineering intensity (EI) numbers from 0 to 9. The T range, from 0.01 to 10 sec, is divided into nine period bands from I to IX. Table D.1 lists the 5%-damped S_v amplitude boundary values represented by the intensity levels shown in the figure.

D.2 EIS Reporting

Three ways of reporting earthquakes using the EIS have been found useful. The most accurate is a nine-digit report in which an EI number is reported for each of the period bands shown in Figure D.1. If the response spectrum

*Blume, J. A., "An Engineering Intensity Scale for Earthquakes and Other Ground Motion," *Bulletin of the Seismological Society of America*, Vol. 60, No. 1, February 1970.

does not cross a particular period band, the letter X is substituted for the EI number of that band. To facilitate reading, groups of three digits in the report are separated by a comma. For applications that require somewhat less detailed reporting, an average of each group of three consecutive EI numbers is taken, which results in a three-digit report. Finally, the most abbreviated and least descriptive report consists of a single digit obtained by averaging the intensity numbers of the three-digit report.

The Nine-Digit Report. The response of the north-south component of the 1940 El Centro, California, earthquake will be used as an example of a nine-digit report. In Figure D.1, S_v values for this earthquake, recorded at El Centro, are shown with the EIS diagram superimposed. The nine-digit intensity for this particular response spectrum would read: X56,777,76X.

The first X indicates that the response spectrum does not enter period band I (from 0.01 to 0.1 sec), often the case because of recording-instrument limitations or because of inadequately fine digitization of the spectral response calculation. In period band II, S_v generally falls between 10 and 30 cm/sec; in band III, between 30 and 60 cm/sec; and in bands IV through VIII, between 60 and 100 cm/sec. The final X indicates that the response spectrum fails to enter band IX, again possibly because of instrument limitations. The nine digits represent a rough plot of the response spectrum. They are easily transmitted and stored and provide data useful for correlating the frequency content of ground motion with the characteristic responses of structures of various periods.

Note that a number reported for period band I would represent a general indication of peak ground acceleration because damping and dynamic amplification have little effect in the short period of this band. The spectral response is asymptotic to peak ground acceleration. Likewise, a response reported for period band IX is indicative of maximum ground displacement.

An EIS report with relatively high numbers indicates very strong earthquake motion at the locality under consideration. A report with only a few high numbers may indicate a narrow-band spectrum of response to either a small, local energy release or a large, distant energy release.

The Three-Digit Report. Although it gives less information than the nine-digit report, the three-digit report may be more convenient for many purposes.

Before averaging the values in the three groups of period bands of the nine-digit report, X values must be enumerated. This is done by estimating where the response spectrum would fall if extended through the X column, bearing in mind the asymptotic conditions noted above. The value is usually taken to be one unit less than that reported for the adjoining column. For example, the El Centro response spectrum reported as X56,777,76X would become 456,777,765. The three-digit report, obtained by averaging each group of three digits, would thus read: 5,7,6. The commas are retained in the notation to identify the scale and the source of the rating.

The period bands of the three-digit report, described as short (T < 0.4 sec), intermediate (T = 0.4 to 2.0 sec), and long (T > 2.0 sec), represent typical classes of buildings. This report shows at a glance where the energy would fall in each period group and how buildings in each class would tend to respond.

The One-Digit Report. For limited purposes, a crude report that merely indicates the overall spectral content of ground motion may be sufficient. This is obtained by averaging the EI numbers of the three-digit report to produce a single number. In the case of the El Centro example, that number would be 6.

If reporting purposes are best served by the use of a single digit to rate a seismic event but at the same time would benefit by a finer comparison among events, a scale of 30 ratings can be obtained by subdividing the S_v range represented by each of the ten EI numbers (see Figure D.1) into three parts. For example, a one-digit report of 6, which represents an S_v range of 30 to 60 cm/sec, can be subdivided into ranges of 30 to 40 cm/sec, 40 to 50 cm/sec, and 50 to 60 cm/sec. These narrower ranges are identified in the EI report by the use of a plus sign, a minus sign, or no sign at all with the single digit. Thus a report of 6- indicates the lowest part of the EI-6 range (30 to 40 cm/sec), 6 indicates the middle of the range (40 to 50 cm/sec), and 6+ the highest part (50 to 60 cm/sec). The narrower range thus reported is based on the result obtained when the numbers of the three-digit report are averaged: the average of a 6,7,6 three-digit report is therefore reported as 6+ while the average of 6,6,5 is reported as 6-.

Combined Report. It is possible, of course, to report all three ratings in order to allow the user to select the one most useful for his purposes. On this basis, the 1940 El Centro north-south component would be reported to have an intensity of:

X56,777,76X
5,7,6
6

Experience has shown that, except for special purposes, the three-digit report offers the optimum combination of convenience and usefulness.

Engineering Intensity Maps

Isointensity (iso-EI) maps can be constructed if sufficient spectral data are available. It is possible to prepare a map for each of the nine period bands, but a convenient alternative is to use the short-period, intermediate-period, and long-period bands of the three-digit report ($T < 0.4$ sec; $T =$ 0.4 to 2.0 sec; and $T > 2.0$ sec).

Another alternative is to construct maps for particular narrow-period bands of interest. Figure D.2, an example of such a map, shows iso-EI lines for the period band $T < 0.2$ sec for an underground nuclear detonation that took place on January 18, 1968, in central Nevada. Spectral response curves were calculated for various stations, as shown in the figure.

TABLE D.1

ENGINEERING INTENSITY SCALE BOUNDARY S_v VALUES

EIS Intensity Level	S_v Value		
	(cm/sec)	(in./sec)	(ft/sec)
9	>300	>118	>9.84
8	100 - 300	39.4 - 118	3.28 - 9.84
7	60 - 100	23.6 - 39.4	1.97 - 3.28
6	30 - 60	11.8 - 23.6	0.984 - 1.97
5	10 - 30	3.94 - 11.8	0.328 - 0.984
4	4 - 10	1.57 - 3.94	0.131 - 0.328
3	1 - 4	0.394 - 1.57	0.0328 - 0.131
2	0.1 - 1	0.039 - 0.394	0.0033 - 0.0328
1	0.01 - 0.1	0.0039 - 0.039	0.00033 - 0.0033
0	<0.01	<0.0039	<0.00033

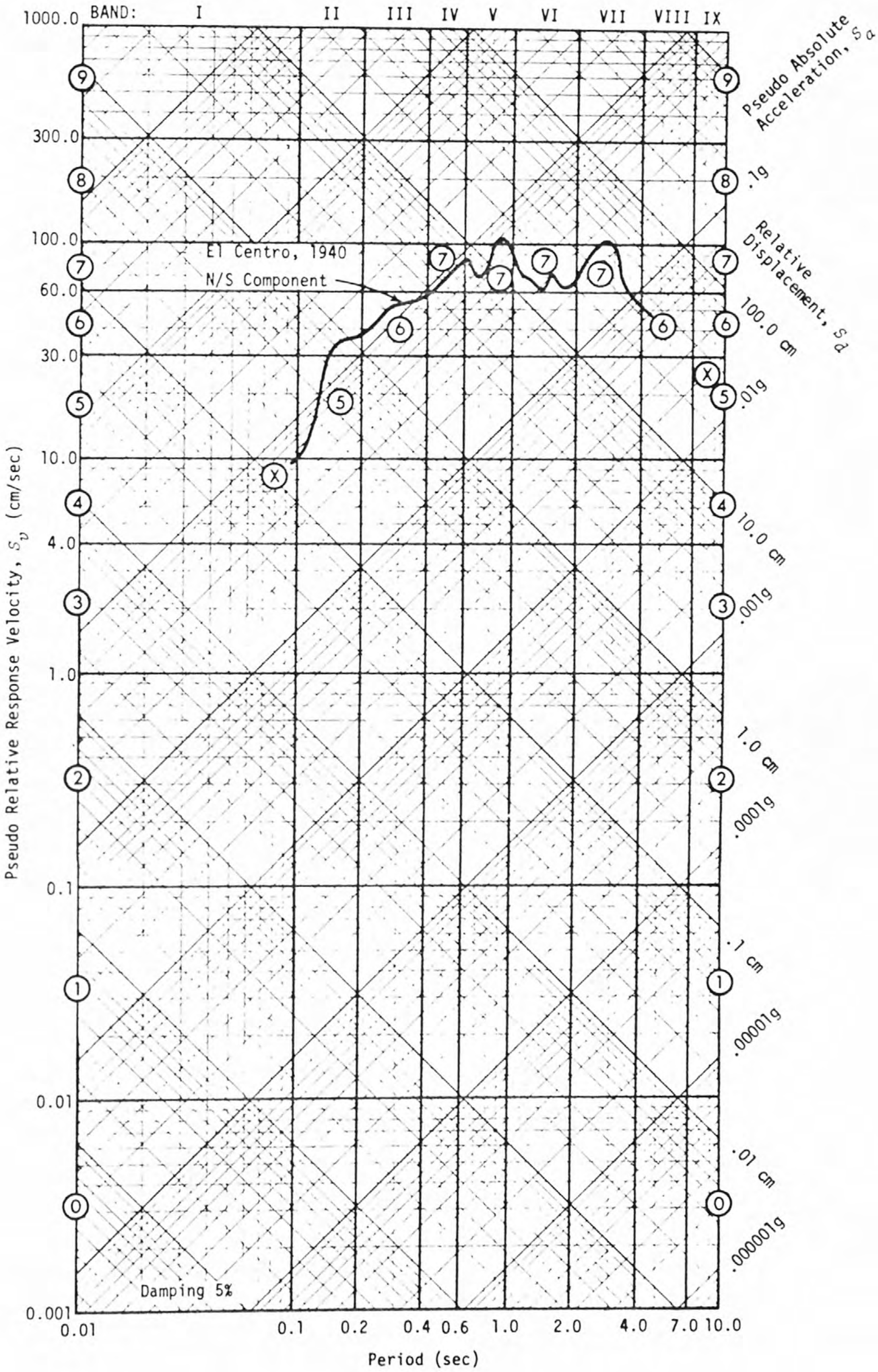


FIGURE D.1 ENGINEERING INTENSITY SCALE MATRIX SUPERIMPOSED WITH EXAMPLE SPECTRUM

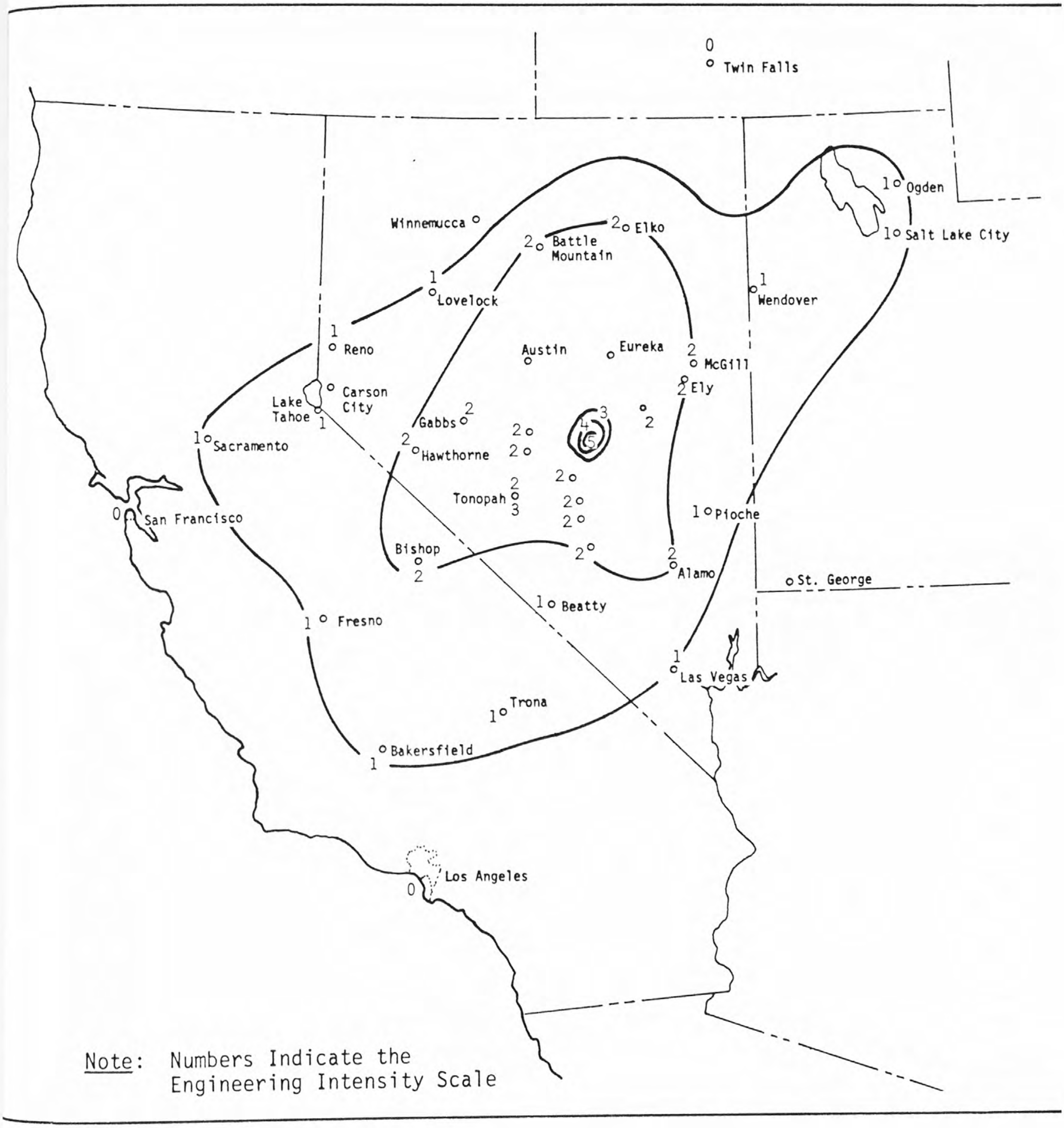


FIGURE D.2 ISO-EI LINES FOR PERIOD BAND OF T < 0.4 SEC, EVENT FAULTLESS

APPENDIX E

Review of Lognormal Distribution Used for Statistical Analysis of Response Spectra

REVIEW OF LOGNORMAL DISTRIBUTION USED FOR STATISTICAL ANALYSIS OF RESPONSE SPECTRA

The purpose of this appendix is to show how Agbabian Associates analyzed their data and used lognormal distribution to perform statistical analysis.

The data used by Agbabian Associates consisted of digitized ground response spectra. California Institute of Technology (CIT) was the source of the data. From each of 372 horizontal records and 186 vertical records, five sets of spectra (damping ratios of 0.0, 0.02, 0.05, 0.10, and 0.20) were computed. Each spectrum was defined in terms of pseudo velocities provided at 91 discrete frequencies between 0.06 Hz and 25 Hz. Table E.1 gives further descriptions of the CIT records.

Three statistical methods were considered in the report by Agbabian Associates titled *Correlation of Ground Response Spectra with Modified Mercalli Intensity* (June 1977). These three methods were (1) counting method, (2) Gaussian distribution, and (3) lognormal distribution. Lognormal distribution was chosen from among these methods. The following is a brief summary of lognormal distribution.

Lognormal Distribution: A random variable, Y, is said to have a lognormal distribution if the natural logarithm of Y follows a Gaussian distribution. The resulting expression for lognormal distribution is

$$f_Y(y) = \frac{1}{\sqrt{2\pi}\,\sigma_X y} \exp\left[-\frac{1}{2}\left(\frac{\ln y - \mu_X}{\sigma_X}\right)^2\right] \qquad y > 0 \qquad \text{(E.1)}$$

or:

$$f_Y(y) = \frac{1}{\sqrt{2\pi}\, y \ln N} \exp\left\{-\frac{1}{2}\left[\frac{1}{\ln N} \ln\left(\frac{y}{\breve{Y}}\right)\right]^2\right\} \qquad y > 0 \qquad \text{(E.2)}$$

where:

$$X = \ln y \qquad \text{(E.3)}$$

$$\mu_X = \frac{\sum_{i=1}^{n} \ln y_i}{n} \tag{E-4}$$

$\breve{Y}$ denotes median of y

$$N = \text{Geometric standard deviation}$$

$$= \exp\left\{\ln\left[\left(\frac{\sigma_Y}{\mu_Y}\right)^2 + 1\right]\right\}^{1/2} \tag{E-5}$$

$$\mu_Y = \exp\left[\mu_X + \frac{1}{2}\sigma_X{}^2\right] \tag{E-6}$$

$$\sigma_Y = \mu_Y\left[\exp\left(\sigma_X{}^2\right) - 1\right]^{1/2} \tag{E-7}$$

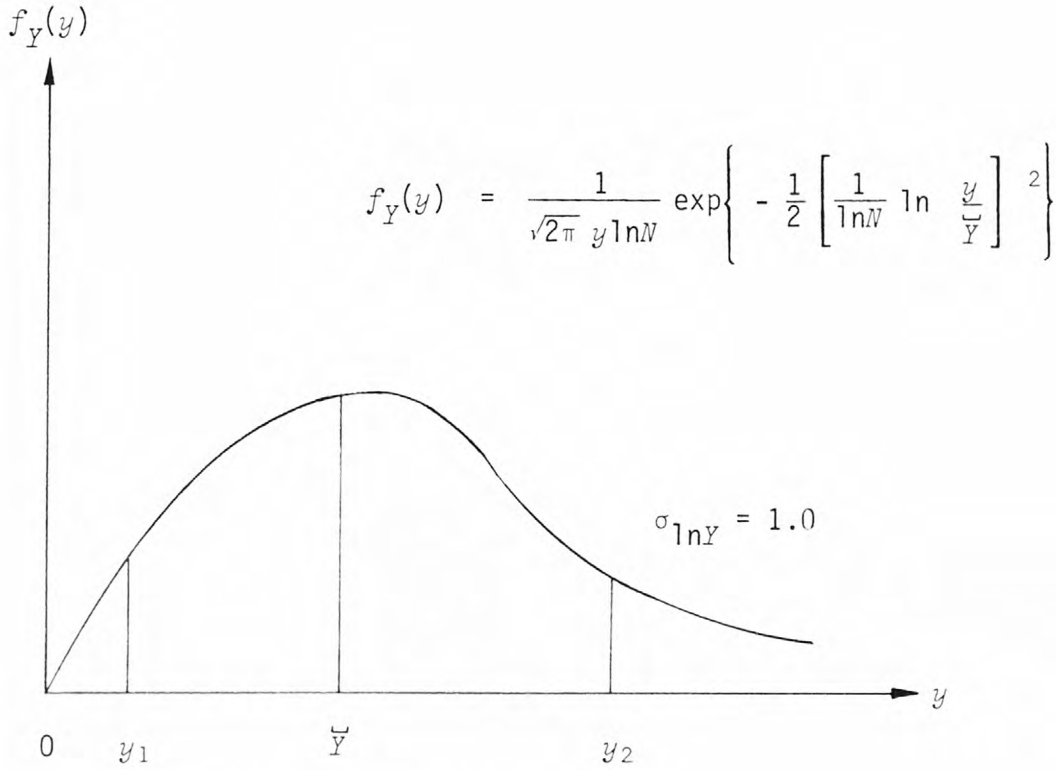
To understand some of the probability terms, inverse distribution is used. Let F be the lognormal distribution as defined in Equation (E-1) or Equation (E-2). Then the inverse distribution function is $F^{-1}(y)$, where $0 < y < 1$. $\breve{Y} = F^{-1}$ (0.5), is called the median of F, and not to be confused with mean of F, μ_X, as defined in Equation (E-4). F^{-1} (k/100) is called the k-percentile. For example, lognormal 16th percentile means that by integrating the lognormal distribution from zero to a certain point of y, 16% of the area is obtained. Likewise, lognormal 84th percentile means that 84% of the area under the curve is obtained. Figure E-1 shows a sample curve of lognormal distribution with $\sigma_{\ln Y} = 1.0$.

The significance of using 16th and 84th percentiles is to allow comparison with results from normal distribution. For standardized normal distribution, $N(0,1)$, $N(1) = 0.84$, and $N(-1) = 0.16$.

TABLE E.1

SUMMARY OF CIT DATA FOR STATISTICAL ANALYSIS

Classification	Spectral Damping Ratio	Direction of Motion	Total Sample Size	Sample Size for Each Site Intensity Level						
				<IV	V	VI	VII	VIII	X	Total
Data classed according to site intensity only; no additional classifications according to site conditions	0.0, 0.02, 0.05, 0.10, 0.20	Horizontal	372	8	68	132	150	12	2	372
		Vertical	186	4	34	66	75	6	1	186



$$\int_0^{y_1} f_Y(y)\, dy = .16 \qquad \text{lognormal 16th percentile}$$

$$\int_0^{y_2} f_Y(y)\, dy = .84 \qquad \text{lognormal 84th percentile}$$

FIGURE E.1 LOGNORMAL DISTRIBUTION OF $\sigma_{\ln Y} = 1.0$

APPENDIX F

Damage Functions

DAMAGE FUNCTIONS

To denote the structural damage, we will adopt a normalized scale ranging from zero to unity, with zero indicating "no damage" and unity indicating "total damage." Some suggested damage functions follow.

In the Spectral Matrix Method (Reference F1), the damage function is defined as a function of ductility μ:

$$DF = \left(\frac{\mu - 1}{\mu_{ult} - 1}\right)^{\kappa} = \frac{\text{repair cost}}{\text{replacement cost}} \qquad (F.1)$$

where κ is an economic scale factor, and μ_{ult} is the ultimate ductility.

Ductility is obtained by equating the energy absorbed by the structure when the response is taken to be elastic to the energy absorbed by an inelastic structural model. This relationship is shown in Figure F.1, where the variables are defined. For the elastic-demand model, the energy is given by:

$$E = \frac{1}{2}\frac{V_e^2}{K} \qquad (F.2)$$

For the inelastic-capacity model, the energy is given by:

$$E = \frac{1}{2}\frac{V_y^2}{K} + \frac{V + V_y}{2}(\Delta - \Delta_y) \qquad (F.3)$$

But:

$$V = K\Delta_y + (\Delta - \Delta_y)\xi K, \text{ and } \mu = \Delta/\Delta_y \qquad (F.4)$$

Therefore:

$$E = \frac{1}{2}\frac{V_y^2}{K}[2(\mu - 1) + (\mu - 1)^2 \xi + 1] \qquad (F.5)$$

By equating Equations (F.1) and (F.3), an expression for ductility, μ, can then be obtained:

$$\mu = 1 - \frac{1}{\xi} + \sqrt{\frac{1}{\xi}\left[\frac{1}{\xi} + \frac{V_e}{V_y}^2 - 1\right]} \tag{F.6}$$

where ξ is a bilinear parameter, as shown in Figure F.2, and $\frac{V_e}{V_y}$ is the ratio of ground motion demand over damage-resisting capacity, D/C.

Substituting Equation (F.6) into Equation (F.1), we have:

$$DF = 0$$

$$\text{if } D/C \leq 1$$

$$DF = \left[\frac{\sqrt{1 + \xi\left[\frac{D}{C}^2 - 1\right]} - 1}{\xi(\mu_{ult} - 1)}\right]^{\kappa} \tag{F.7}$$

$$\text{if } 1 < D/C \leq \sqrt{2\mu_{ult} - 1 + \xi(\mu_{ult} - 1)^2}$$

$$DF = 1$$

$$\text{if } D/C > \sqrt{2\mu_{ult} - 1 + \xi(\mu_{ult} - 1)^2}$$

The ground motion demand, D, imposed on a structure and the damage-resisting capacity, C, of the structure are considered to be random variables with appropriate associated probability functions. The probability of the quotient D/C exceeding a certain value x is given by the probability density function:

$$p_{D/C}(x) = \int_{-\infty}^{\infty} |c| p_{D,C}(xc, c)\,dc \tag{F.8}$$

where $p_{D,C}(xc,c)$ is the joint probability density for demand and capacity, and x is the specified value of D/C.

The standard procedure for computing the moments of a function of a random variable produces the following general expressions for the first and second moments of the damage factor:

$$E(DF) = \int_1^{\lim} p_{D/C}(x)\left[\frac{\sqrt{1 + \xi(x^2 - 1)} - 1}{\xi(\mu_{ult} - 1)}\right]^{\kappa} dx$$

$$+ \int_{\lim}^{\infty} p_{D/C}(x)\,dx \tag{F.9}$$

$$E(DF^2) = \int_1^{\lim} p_{D/C}(x)\left[\frac{\sqrt{1 + \xi(x^2 - 1)} - 1}{\xi(\mu_{ult} - 1)}\right]^{2\kappa} dx$$

$$+ \int_{\lim}^{\infty} p_{D/C}(x)\,dx \tag{F.10}$$

where:

$$\lim = \sqrt{2\mu_{ult} - 1 - \xi(\mu_{ult} - 1)^2}$$

If D and C are taken as following lognormal and Weibull distributions, respectively, then the lognormal probability of demand is given by:

$$p_D(d) = \frac{1}{\sqrt{2\pi}\, d\, \mathrm{Ln}(N)}\, e^{-\frac{1}{2}\left[\frac{1}{\mathrm{Ln}(N)} \mathrm{Ln}\frac{d}{\breve{D}}\right]^2}, \quad d > 0 \tag{F.11}$$

where:

$\breve{D}$ = median demand value

N = geometric standard deviation

d = known value of demand

D = demand (as a random variable)

Ln = log with base e

Figure F.3 shows examples of the lognormal probability density function of demand.

The Weibull probability of C is:

$$p_C(c) = \frac{k}{u}\left(\frac{c - \varepsilon}{u}\right)^{k-1} e^{-\left(\frac{c - \varepsilon}{u}\right)^k}, \quad c > \varepsilon \tag{F.12}$$

where:

$$\overline{C} = \varepsilon + u\Gamma\left(1 + \frac{1}{k}\right)$$

$$V_C = \frac{u}{\overline{C}}\sqrt{\Gamma\left(1 + \frac{2}{k}\right) - \Gamma^2\left(1 + \frac{1}{k}\right)}$$

$\Gamma(\cdot)$ = the gamma function of $\cdot$

c = known value of capacity

C = capacity (as a random variable)

ε = shift in capacity axis

Figure F.4 shows examples of Weibull probability density functions of capacity.

If it is reasonable to assume that demand and capacity are independent, then $p_{D,C}(d,c)$ can be factored as follows:

$$p_{D,C}(d,c) = p_D(d)p_C(c) \tag{F.13}$$

Combining Equations (F.8) and (F.13), and using the definitions for $p_D(d)$ and $p_C(c)$ given by Equations (F.11) and (F.12), $p_{D/C}(x)$ is expressed as follows:

$$p_{D/C}(x) = \frac{k\displaystyle\int_{\varepsilon}^{\infty}\left(\frac{c - \varepsilon}{u}\right)^{k-1} e^{-\left\{\left(\frac{c - \varepsilon}{u}\right)^k + \frac{1}{2}\left[\frac{1}{\mathrm{Ln}(N)}\,\mathrm{Ln}\,\frac{xc}{\overset{\cup}{D}}\right]^2\right\}} dc}{\sqrt{2\pi}\, xu\mathrm{Ln}(N)} \tag{F.14}$$

A similar damage function was defined by Oliveira (Reference F2) as follows:

$$DF = 0, \text{ if } Z < Y_d$$

$$DF = \left(\frac{Z - Y_d}{X - Y_d}\right)^{\alpha}, \text{ if } Y_d \le Z \le X \tag{F.15}$$

$$DF = 1, \text{ if } Z > X$$

where Z = maximum displacement response; Y_d = yield displacement; X = displacement at collapse point; and α = a material and structural parameter. To account for the uncertainty of the building resistance, Z, Y_d, and X are considered to be random variables. The probability density function of DF is then:

$$p_{DF}(u) = \int_{\xi}\int_{\gamma} p_{Z,Y_d,X}\left(\xi, \frac{\xi - u^{1/\alpha}\gamma}{1 - u^{1/\alpha}}, \gamma\right)\left|\frac{1}{\alpha}u^{1/\alpha - 1}\left[\frac{\xi - \gamma}{(1 - u^{1/\alpha})^2}\right]\right| d\xi d\gamma \tag{F.16}$$

Another damage function, applicable to structures subjected to low-cycle, high-amplitude reversed plastic deformation, was suggested by Yao and Munse (Reference F3):

$$DF = \sum_{i=1}^{n}\left[\left(\frac{\Delta q}{\Delta q_1}\right)^{1/m}\right]_i \tag{F.17}$$

where $1/m$ = a parameter depending upon the ratio of cyclic-compressive change in plastic strain to the subsequent tensile change in plastic strain; Δq = percentage of cyclic-tensile change in plastic true strain; Δq_1 = percentage cyclic-tensile change in plastic true strain at $n = 1$; and n = number of applications of tensile load prior to fracture. In terms of the notation of Equations (F.1 and (F.15), which may be treated as special cases of Equation (F.17), the following correspondences can be made:

$$\Delta q = \mu - 1; \; \Delta q_1 = \mu_{ult} - 1; \; \frac{1}{m} = k \qquad (F.18)$$

$$\Delta q = Z - Y_d; \; \Delta q_1 = C - Y_d; \; \frac{1}{m} = \alpha \qquad (F.19)$$

The validation of these damage functions, as well as the estimation of their parameters, requires further trials to correlate with data obtained from surveys of damage due to seismic motion and from the response of mathematical models to given disturbances.

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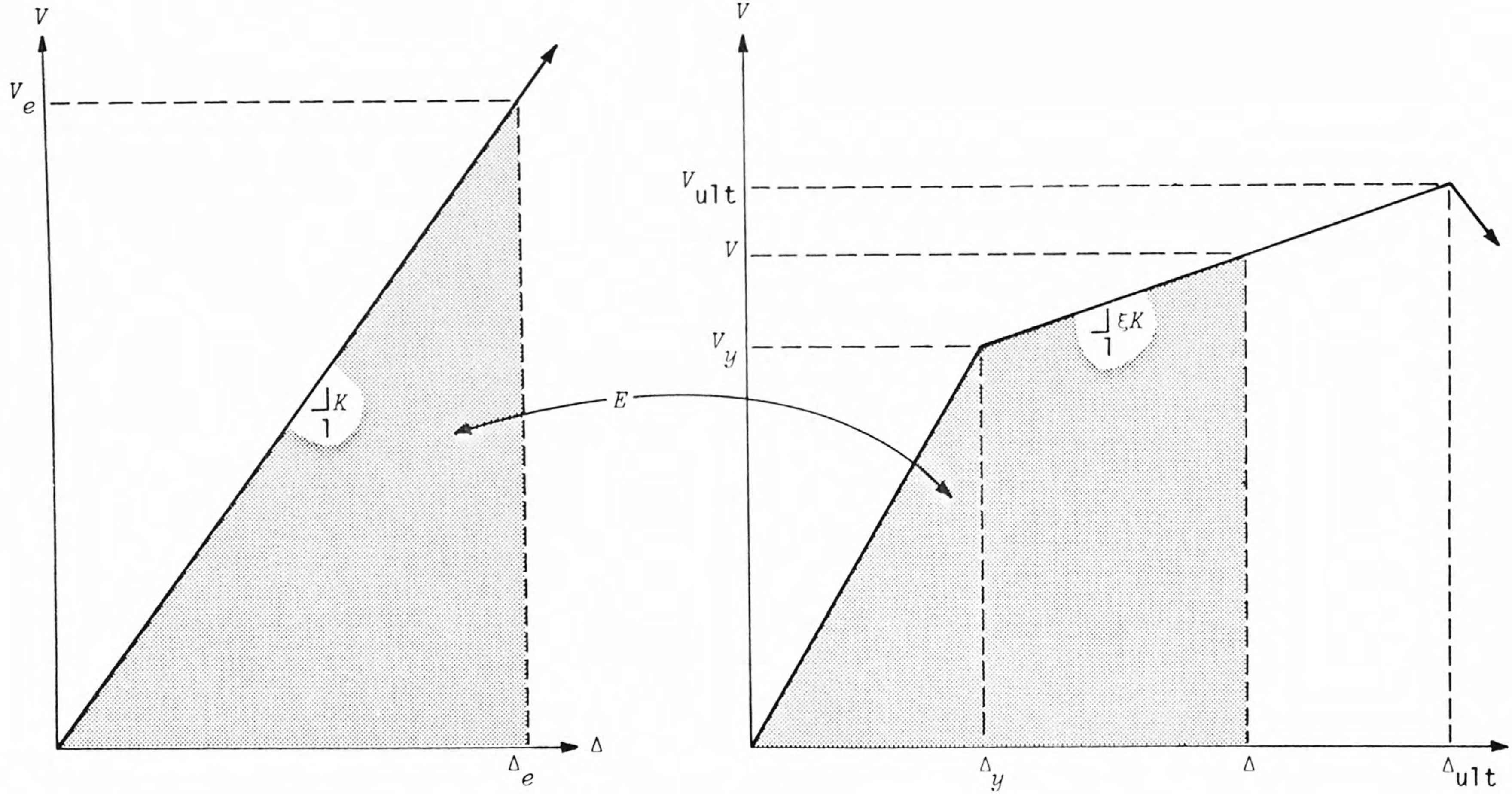
F2. Oliveira, C. S., *Seismic Risk Analysis for a Site and a Metropolitan Area*, Report No. EERC-75-3, Earthquake Engineering Research Center, University of California, Berkeley, August 1975.

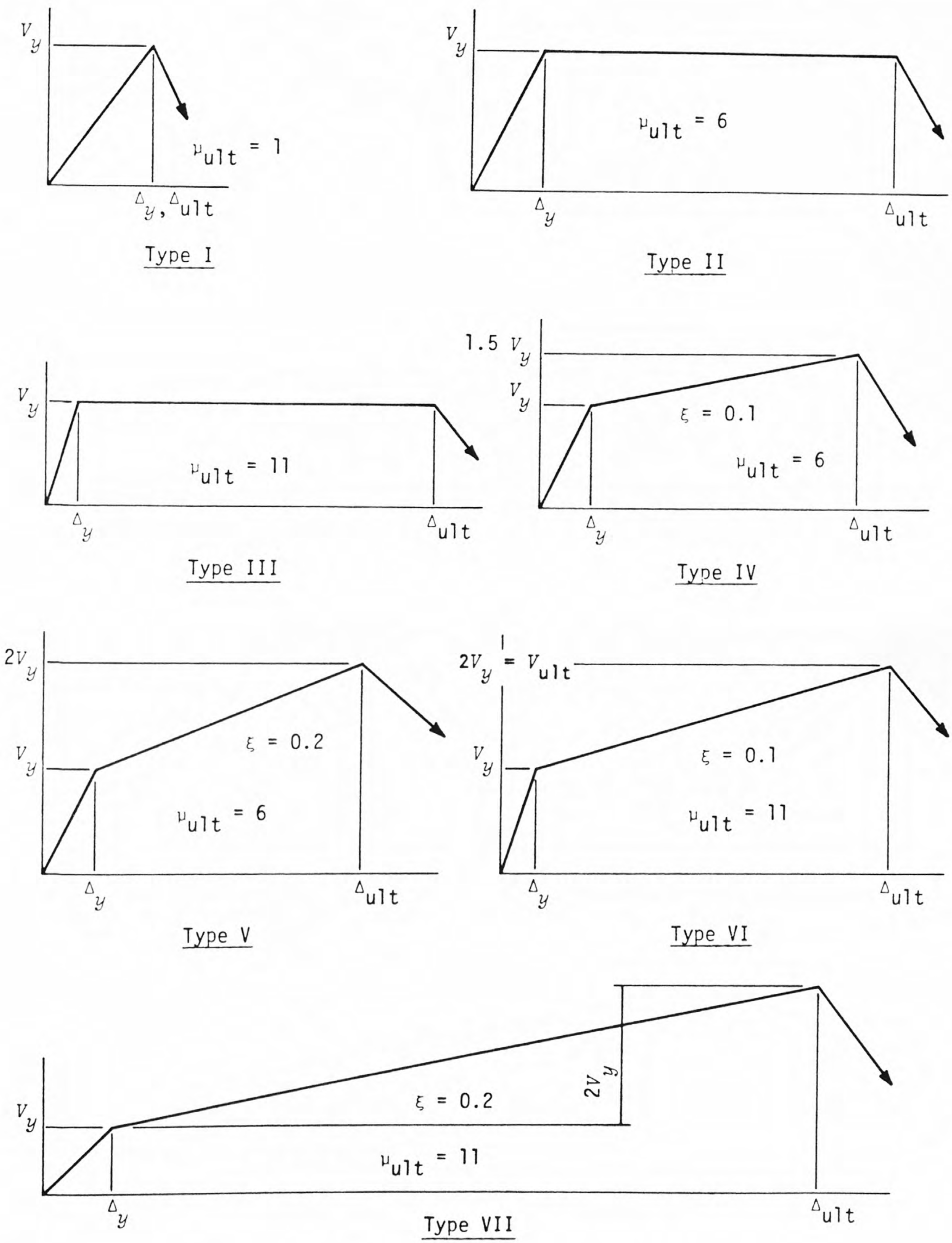
F3. Yao, J. T. P., and W. H. Munse, "Low-Cycle Axial Fatigue Behavior of Mild Steel," *ASTM Special Technical Publication* No. 338, 1962.



Elastic Demand Model

Inelastic Capacity Model

FIGURE F.1 DEMAND AND CAPACITY ENERGY MODELS



Note: Scale and values vary from model to model.

FIGURE F.2 INELASTIC MODELS OF ASSUMED ONE-MASSED SYSTEMS

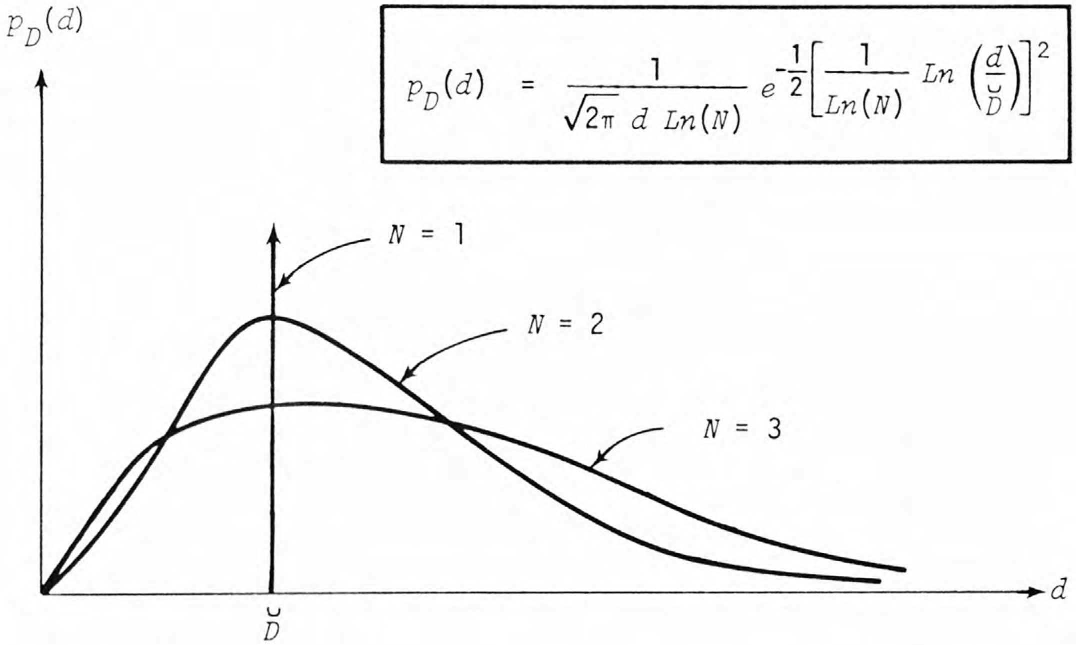


FIGURE F.3 EXAMPLES OF LOGNORMAL PROBABILITY DENSITY FUNCTIONS OF DEMAND

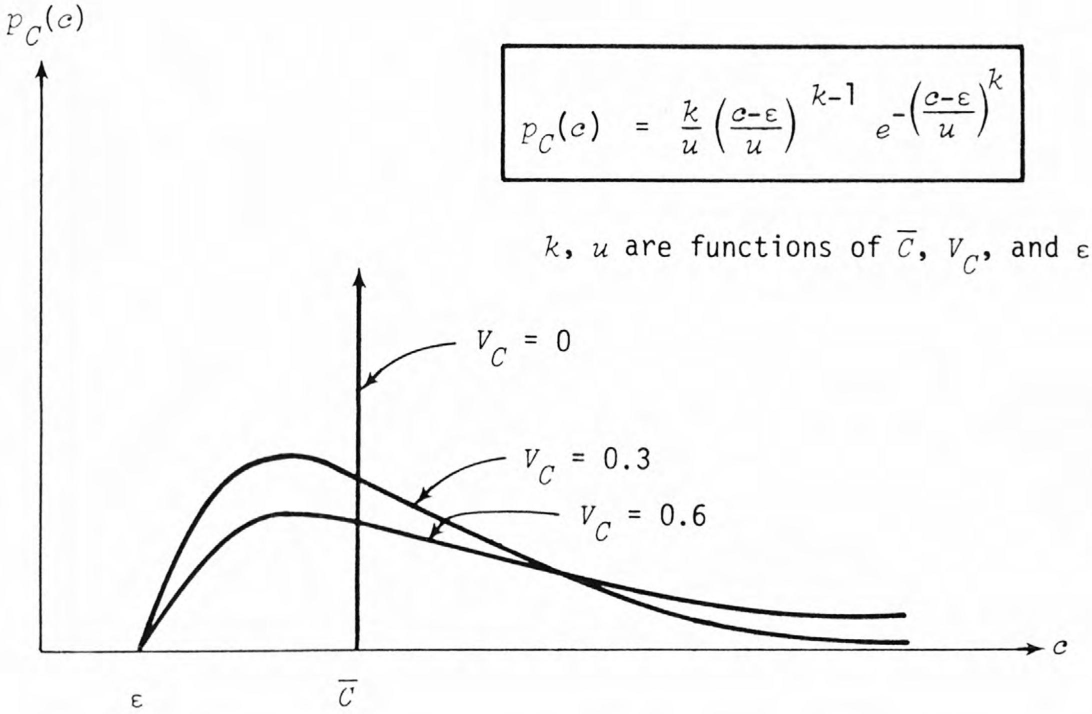


FIGURE F.4 EXAMPLES OF WEIBULL PROBABILITY DENSITY FUNCTIONS OF CAPACITY