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Building characteristics and earthquake damage are documented for approximately 370 high-rise buildings shaken by the San Fernando earthquake of 9 February 1971. The resulting data are organized into damage probability matrices, showing the relationships among earthquake resistance, intensity of ground shaking and damage. Results are given separately for steel and concrete buildings, and damage to the various structural and non-structural components is described separately. The difficult process of collecting these data is explained, and suggestions are made for similar efforts during future earthquakes.
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# OPTIMUM SEISMIC PROTECTION AND <br> BUILDING DAMAGE STATISTICS 

## Sponsored by National Science Foundation Grants GK-27955 and GI-29936

## Report No. 7

DAMAGE STATISTICS FOR HIGH-RISE BUILDINGS IN THE VICINITY OF THE SAN FERNANDO EARTHQUAKE
by

Robert V. Whitman
Sheu-Tien Hong
John W. Reed

April, 1973

## ABSTRACT

Building characteristics and earthquake damage are documented for approximately 370 high-rise buildings shaken by the San Femando earthquake of 9 February 1971. The resulting data are organized into damage probability matrices, showing the relacionships among earthquake resistance, intensity of ground shaking and damage. Results are given separately for sceel and concrete buildings, and damage to the various structural and non-structural components is described separately. The difficult process of collecting these data is explained, and suggestions are made for similar efforts during future earthquakes.

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## PREFACE

This is the seventh in a series of reports prepared under National Scfence Foundation Grancs GK－27955 and GI－29936。 A list of previous reports appears on the next page．There are three principal investigators for the overall study： Professors Robert V．Whitman，John Mo Biggs and C。Allin Cornell－all faculty in the Department of Civil Engineering．The data collection effort described in this report was carried out by Dr．John W．Reed，who then was Visiting Assistant Professor of Civil Engineering and now is Senior Research Engineer with URS／ John A．Blume Associates Research Division in Las Vegas，Nevada．Dr．Sheu－Tien Hong，Research Associate in Civil Engineering，has carried through with the analysis and discussion of the data．

Many other MoI．T．personnel also contributed to the study：Dr。Exik Vanmarcke，Assistant Professor of Civil Engineering；Messers Michael Ackroyd， Robert Czarneckis John Isbell．Jorge Diaz－Padilla and Edwardo Kausel－all Graduate Research Assistants；and undergraduate students，Craig Schweinhart and Richard Yue．

In addition，many individuals outside of $M$ ．I．T．also look part in chis effort．Much of the actual data－gathering was performed under subcontract to M．I．T．by two firms with offices in or near Los Angeles：J．H．Wiggins Co． and Ayres，Cohen and Hayakawa．The Building Owners and Managers Association （BOMA）of Los Angeles cooperated in the data－gathering effort，and credit is due to Messers Edward Gibbons and Phil Bauman for this great assistance． Mr．Eugene Schader of Los Angeles contributed much valuable advice and infor－ mation．Finally，thanks are due to the many individuals and organization who responded to our requests for data and information．

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## Chapter 1

## INTRODUCTION

### 1.1 OBJECTIVES AND MOTIVATION

The overall objective of chis study was to document the degree of damage (including non-damage) experienced by high-rise buildings in the Los Angeles area during the San Fernando earthquake of 9 February 1971, and to compile the damage statistics based upon this documentation for purposes of this study, high-rise buildings are defined as having 5 or more stories above ground.

These statistics were sought as input to a study of the cost and benefirs of seismic design being conducted at M.I.T. under a separace grant from the Nacional Science Foundation. (This study is described briefly in Chapter 2.) It is further expected that the documentation will be useful to other investigators and to various governmental agencies.

### 1.2 SCOPE OF THE STUDY

As already noted, this study encompassed buildings having 5 or more stories. There were several reasons for adopting this restriction.

1. It was desirable to concentrate this effort upon buildings for Which engineering considerations (such as the lateral force provisions in section 2314 of the Uniform Building Code) play a major role in design.
2. Considerable attention had already been directed, both in this earchquake and in previous earchquakes, to 1-scory co 4-scory residences (ESSA, 1969; Steinbrugge et al., 1971).

The same restriction on scory height also applies, for the same reasons, to the study of optimum seismic protection.

The geographic area covered by this study of damage is indicared in Fig. 1.1. This area more-or-less coincides with the area lying south of the epicenter that experienced a modified Mercalli intensity of ground shaking of VI or greater. There were very few buildings with 5 or more stories north of the epicenter. The scudy thus encompassed a region in which the damage
ranged from none to extreme. In addition, the area also concained many buildings constructed before the advent of earthquake design requirements as well as many buildings designed and constructed in accordance with modern code requirements.

Ideally, this study would have resulted first in a list of all buildings of 5 or more stories within the geographic area, together with information concerning the important characteristics of each building. Then, ideally, the degree of damage (including non-damage) would have been documented for each building. Unfortunately, the resources available to this study were insufficient for achieving these ideal goals.

In the first place, it proved quite difficult simply to obtain an accurate list of all buildings. Based upon the studies, it is believed that there were at the time of the earthquake about 1650 buildings having 5 or more stories within the area shaken with intensity VI or greater. Further, it was necessary to limit the number of building characteristics to be documented to: (a) date constructed, (b) number of stories, (c) valuation or gross area, and (d) geographic location. This information was obtained for approximately 1500 buildings. Table 1.1 liscs the number of documented buildings according to story height and intensity of shaking. There were only 4 buildings with 5 or more stories within the epicentral region, too few for any meaningful statistical scudy. The buildings are divided into two age groups: those built before design for lateral forces was first required in 1933, and those built since 1947 under modern code requirements. Because of the Depression and World War II, relatively few large buildings (only about 60) were conscructed between 1933 and 1947.

Documenting damage for each building proved to be even more difficult for reasons that will be discussed in detail subsequently. In essence, documentation of damage to any building required direct contact with the owner or manager of the building, and such direct contact was both time-consuming and sometimes impossible. Damage has been documented for about 370 buildings. Table 1.2 indicates the breakdown of these docunented buildings according to the categories used in Table 1.1.

While more complete documentation would have been desirable for some purposes, it is believed that the level of documentation achieved represented
a good compromise from the standpoint of the needs of the optimum seismic protection study.

### 1.3 SCOPE OF REPORT

As already noted, Chapter 2 describes the concurrent study concerning optimum seismic protection. This chapter provides background necessary for understanding the decisions made concerning the documentation of damage from the San Fernando earthquake. Chapter 3 provides a history of the data gathering effort; this history is incended both to indicate the scope and accuracy of the data presented and as guidance to those who may face a similar data gathering task in future earthquakes. Chapter 4 describes in brief the data handling process, presents the data collected in the study, and discusses the accuracy of the data. Chapter 5 uses the data to construct estimates of damage probability for use in risk/benefit studies relative to seismic design. A summary of the results of the study is presented in Chapter 6 .

This report deals primarily with the general level of damage experienced by buildings. Very detailed damage information has been documented for a dozen buildings so that damage may be compared with results of detailed dynamic analysis. This detailed damage information and the resulting comparisons are presented in a separate report by Czarnecki (1973)。

In this report, the modified Mercalli intensity assigned to each sub-area is used to indicate the ground shaking experienced by each building. Efforts are now underway to use the many records of actual ground motion to provide a better representation of the strength of the ground shaking, and the results of this effort will also appear in a subsequent report.

Table 1.1

NUMBER OF HIGH-RISE BUILDINGS SHAKEN BY EARTHQUAKE*

|  | Pre-1933 |  |  | Post-1947 |  |  |
| :--- | ---: | :---: | :---: | :---: | :---: | :---: |
|  | VI | VII | VIII | VI | VII | VIII |
| $5-7$ | 36 | 346 | 0 | 117 | 321 | 17 |
| $8-13$ | 21 | 236 | 0 | 79 | 231 | 6 |
| $14-18$ | 2 | 8 | 0 | 36 | 37 | 0 |
| $19+$ | 0 | 2 | 0 | 12 | 41 | 0 |
| Total | 57 | 592 | 0 | 244 | 630 | 23 |
|  |  |  |  |  |  |  |
| *Only buildings with height |  |  |  |  |  |  |
| listed. |  |  |  |  |  |  |

Table 1.2

NUMBER OF BUILDINGS WITH DOCUMENTATION OF BUILDING VALUES AND DAMAGE COSTS

|  | Pre-1933 |  |  |
| :--- | ---: | :---: | :---: |
|  | VI | VII | VIII |
| $5-7$ | 10 | 33 | 0 |
| $8-13$ | 9 | 78 | 0 |
| $14-18$ | 0 | 2 | 0 |
| $19+$ | 0 | 1 | 0 |
| Total | 19 | 114 | 0 |


| Post-1947 |  |  |
| :---: | :---: | :---: |
| VI | VII | VIII |
| 14 | 41 | 12 |
| 28 | 70 | 4 |
| 12 | 19 | 0 |
| 3 | 26 | 0 |
| 57 | 156 | 16 |



FIGURE I. GEOGRAPMCAL AREA OF STUOY WITH ZONES OF MODIFIED MERCOLLI INTENSITY

## Chapter 2

## DECISION ANALYSIS FOR SEISMIC DESIGN

### 2.1 OVERALL OBJECTIVES

It is generally agreed that a tall building should not collapse during the largest earthquake that is realistically imaginable. In addition, earthquakes which can be expected to occur during the lifetime of the building should not cause damage that is economically unacceptable to an owner or socially unacceptable to a community.

While both of these principles are widely accepted as the basis for seismic design, it is difficult to be precise in the implementation of these principles. The second principle clearly implies a balancing of risk of future loss against the initial cost of providing a stronger building. Even the first principal implies some balancing of risk since the phrase "largest realistically imaginable earthquake" hardly provides a precise definition. The engineer by himself should not be expected to determine the balance points for this choice involves many considerations affecting the owner and the community. Rather, the engineer's responsibility is to marshall all available facts into a form which makes the costs and risks clear to owners and public bodies.

For many years, engineers have used the available facts so as to recommend a reasonable balance between initial cost and risk of fucure damage, although seldom has the actual balance been stated in an explicit way. Today, it is beginning to be possible to face this balance openly and realistically. In fact, the city of Long Beach, California, has recently adopted a new code that is explicitly based upon balanced risk (Wiggins and Moran, 1971).

In arriving at a reasonable balance between cost and risk, it is necessary to consider many adverse aspects of the overall problem and to analyee the interrelationships between these aspects. These interrelationships generally are quite complicated. Hence, it appears necessary to have an organized, systematic method for assembling che available facts and for carrying out the required analyses. Just such a methodology is now being developed ar MoI.T. under Grant GK-27955 from the National Science Foundation (NSF).

The methodology is designed only to provide systematic and rational information concerning benefits and risks; public bodies must still make the final decision concerning the proper balance between these conflicting considerarions. The proposed methodology can never (and should never) be a substitute for judgment and experience, but rather provides for a systematic organization of such experience and judgment. The major benefit of the methodology is to force specific consideration of the many factors included.

### 2.2 GENERAL METHODOLOGY

Figure 2.1 outlines, by means of a flow chart, the methodology for analyzing the costs and risks associated with designing tall buildings against earthquakes. As outlined in Figure 2.1, the methodology is aimed at selecting seismic design requirements for a specific project or for use in a building code. However, the same general methodology can be used as a basis for insurance considerarions or for federal disaster relief laws. A very similar methodology has already been applied to estimating possible future losses to residential dwellings in California (ESSA, 1969).

The heart of the methodology is examination, in probabilistic terms, of the damage which one earthquake will cause to a particular building system built with a particular design strategy. This evaluation is repeated for different levels of earthquakes, different design strategies and, where appropriate, different building systems. For each different design strategy, the initial cost required by that strategy is added to the present value of possible future losses.

In simplest terms, a particular building system might be defined, for example, as: all buildings having 8 to 13 stories. In a more refined study, a building system might, for example, be: 8- to l3-story reinforced concrete buildings with ductile moment resisting frames. Other building systems are then defined by different ranges of stories, different construction marerials, and different lateral force resisting systems. The soil conditions upon which the building is to be built also form part of the definition of the building system.

The simplest statement of design strategy is: design in accordance with the Uniform Building Code for Zone 2 (or 0,1 or 3). More refined variations on the design requirements may also be considered, such as requirements concerning ductility, allowable drift, requirements concerning mechanical equipment, etc. The initial cost is a function of the design strategy. This cost might be expressed as the extra cost to design for Zone 2 requirements as compared to making no provision for earthquake resistance.

One key step is determining the earthquake occurrence probabilicy. This is the probability that a ground motion of some given intensity will occur during, say, 1 year, at the site of interest. Intensity may be expressed by the modified Mercalli scale, or better yet by the spectral acceleration for the fundamental dynamic response period of the building system. Methods now exist for making reasonable estimates for the earthquake intensity probability for any location, by appropriate analysis of the historical record and of geological information (Cornell, 1971).

The effect of various levels of ground motion upon the building system is expressed by a family of damage probability matrices. Each matrix applies to a particular building system and design strategy, and gives the probability that various levels of damage will result from earthquakes of various intensities. Table 2.1 shows one possible categorization of levels of damage. These levels of damage are described both by words and by the racio, to replacement cost, of physical damage to the building and its contents. Fig. 2.2 illustrates a damage probability matrix based on the categories of damage in Table 2.1 (damage states 7 and 8 have been combined in this matrix). For example, the numbers in the column labeled intensity VIII (modified Mercalli) show the fraction of all buildings expected to experience each of the levels of damage, given that an earthquake of intensity VIII occurs (see Fig. 2.3 for a summarized version of the modified Mercalli scale of intensity).

With each damage state, there is an incident cost. These are different from the costs shown in Table 2.1 which are intended only to identify the level of damage. The total incident cost for each damage scate includes loss of function or loss of time during repairs and, in extreme cases, injury and loss of life and impact on conmunity. Not all of the factors can be readily expressed in dollars, and many people find it very difficult to accept the
notion of placing any sort of value on life. Yet today communities already make such judgment implicitly. For example, how do we know that it is better to make a building owner pay extra for added resistance to earthquakes instead of contributing the same sum toward a transit system which would reduce highway deaths? The constraining factor is that the total resources available are in fact limited.

If it were possible to express all losses in dollars, then the criterion for optimum design would be minimum present total expected cost. Actually, future losses will be only partly expressible in dollars, and multi-attribute objectives must be considered. Nonetheless, the approach outlined here will serve to make clear the considerations which must be balanced to achieve a balanced design.

### 2.3 DAMAGE PROBABILITY MATRICES

A family of damage probability matrices is required: one for each different building system and each design strategy for that building system. The matrices are at the heart of the optimization study. The final results of applying the optimization methodology can be no better than the information incorporated into these matrices. Hence, a major effort is necessary to compile information concerning damage to buildings during earthquakes. Two approaches may be used: (a) one which relates actual observed damage (or non-damage) directly to intensity of earthquake ground motion, and (b) a second method in which theoretical predictions of dynamic xesponse are used to interpret and extrapolate the empirical information concerning damage and non-damage. The documentation and analysis of damage from the San Fernando earchquake - the subject of this particular report fits into the first approach.

Table 2.1

## EARTHQUAKE DAMAGE STATES

|  | Description of Level of Damage | Central Value | Range |
| :---: | :---: | :---: | :---: |
| 0 | No damage | 0 | 0-0.05 |
| 1 | ```Minor non-structural damage-ma few walls and partitions cracked, incidental mechanical and electrical damage``` | 0.1 | 0.05-0.3 |
| 2 | ```Localized non-struccural damage-more extensive cracking (but still not wide- spread); possibly damage to elevators and/or other mechanical/electrical components``` | 0.5 | 0.3-1.25 |
| 3 | Widespread non-structural damage--possibly a few beams and columns cracked, alchough not noticeable | 2 | 1.25-3.5 |
| 4 | Minor structural damage--obvious cracking or yielding in a few structural members; substantial non-structural damage with widespread cracking | 5 | 3.5-7.5 |
| 5 | ```Substantial structural damage requiring repair or replacement of some structural. members; associated extensive non-structural damage``` | 10 | 7.5-20 |
| 6 | Major structural damage requiring repair or replacement of many structural members; associated non-structural damage requiring repairs to major portion of interior; building vacated during repairs | 30 | 20-65 |
| 7 | Building condemned | 100 | $65-100$ |
| 8 | Collapse | 100 |  |

* Ratio of cost of repair to replacement cost


FIGURE R.I: FLOW DIAGRAR FOR GENERAL METHODOLOGY

GROUP CHARACTERISTICS: NUMBER OF BUILDINGS: 368. HEIGHT: 5 to 100 STORIES. AGE: 1800 to 1972. STRUCTURAL TYPE: ALL TYPES. FOUNDATION TYPE: ALL TYPES。

DAMAGE PROBABILITY MATRIX

DAMAGE STATE

|  | DAMAGE RATIO <br>  <br>  <br> UPPER BOUND | MERCAILI INTENSITY |  |  |
| :---: | :---: | :---: | :---: | :---: |
| STATE | $(\%)$ | VI | VII | VIII |
| 0 | 0.05 | 80.5 | 25.1 | 6 |
| 1 | 0.3 | 15.6 | 24.7 | 19 |
| 2 | 1.25 | 3.9 | 26.2 | 44 |
| 3 | 3.5 | 2.7 | 14.2 | 13 |
| 4 | 7.5 | 0 | 5.8 | 6 |
| 5 | 20 | 0 | 2.5 | 12 |
| 6 | 65 | 0 | 1.5 | 0 |
| 7 | 100 | 0 | 0 | 0 |

FIGURE 2.2 EXAMPLE DAMAGE PROBABILITY MATRIX

## Chapter 3

## GATHERING THE DATA

### 3.1 PREPARATIONS FOR DATA GATHERING

The idea of conducting this study arose during the month following the San Fernando earthquake. The grant for study of risk and benefits of seismic protection (see Chapter 2) had just been made by the National Science Foundation, and it appeared that the San Fernando earthquake offered an excellent opporrunity to determine damage probabilities. A considerable number of tall buildings had been inspected for damage immediately following the earthquake (Steinbrugge et al., 1972).* However, from contacts with engineers in the Los Angeles area, it was evident that data sufficient for determining damage probability matrices had not already been documented, and that further field work was essential.

The study described in this reporc began 1 June 1971 - nearly 4 months after the earthquake. At the time, it was feared that this unavoidable delay might hinder gathering of meaningful data, and indeed subsequent experience proved that the trail was somewhat cold. Nonetheless, it was believed at the time that data gathering was still feasible - and this has proved to be true.

Prior to 1 June, faculty from M.I.T. had already visited Los Angeles to view the damage caused by the earchquake. From this visit, and from the abovementioned contacts with local engineers, a general picture of the scope and nature of the task had been formulated. As stated in the original proposal, it was deemed essential to establish associations with one or more engineering firms located in the Los Angeles area; such arrangements would provide first-hand knowledge of local political and commercial organizations that might assist with the study, and also personnel to make the necessary local contacts and undertake the necessary digging out of information.

[^0]During the period prior to award of the grant, several such firms had been contacted and proposals had been obtained.

Chronologically, the data gathering effort may be divided into 3 phases: June 1971 through November 1971; December 1971 through February 1972; and March 1972 through the present.

### 3.2 JUNE 1971 THROUGH NOVEMBER 1971

### 3.2.1 Building Lists

During June, M.I.T. entered into a subcontract with the J. H. Wiggins Company of Palos Verdes Estates, California. Basically, the subcontract called for compiling a list of all buildings having five or more stories and for assembling whatever damage information could be obtained without undertaking a questionnaire. As part of this subcontract, the Wiggins Company also assembled, as they became available, results from other studies of the San Fernando earthquake by Los Angeles engineers, and funnelled these results to M.I.T. A graduate student from M.I.T. spent two months working with the Wiggins Company during the summer of 1971.

The specific requirements for the building list went through several changes as the task evolved. Initially a long list of significant building characteristics was prepared. However, it rapidly became apparent that the effort to document all of the characteristics was unwarranted. Finally, it was decided to concentrate effort upon the following building characteristics:

Address - to indicate intensity of ground shaking and for use in possible subsequent questionnaire surveys. A location code, based upon the grid lines of a commonly used map of Los Angeles (Thomos Bros. map), was recommended by Wiggins for use in coding this information.
Date of construction - to indicate the lateral force provisions in effect at the time the building was designed.
Number of stories - to indicate the fundamental period of the building.

> Value - against which damage repair costs could be compared.
> Gross area - as an alternate indicator of total building value and to call attention to buildings of unusual size.

For the time being at least, it was necessary to abandon efforts to document, for each building, such important characteristics as structural system type and foundation type.

It was not a simple matter to obtain a list of all buildings having 5 or more stories, together with the desired information. No such list was already in existence. There were lists, together with very useful maps, of all buildings having 8 or more stories builit since 1946 ; this information had been compiled by the Western Economic Research Company of Sherman Oaks, California. The Economic Research Departmenc of the Security Pacific National Bank provided a list of all buildings having 5 or more stories built from 1960 through 1967. It was the 5- co 7-story buildings prior to 1960 and the buildings built prior to 1947 that were the problem. Various City and County agencies were contacted, but they did not have the required information in usable form. At one stage, consideration was given to abandoning the attempt to list all 5 -story buildings, and to concentrate on very limited geographic areas and visually sight and personally document each building within these small areas. Three areas were tentatively selected for this approach; about 20 blocks in downtown Los Angeles, the Beverly HillsWestwood area, and the San Fernando Valley. Finally, it proved possible, through the courtesy of the California and Los Angeles City Elevator Divisions, to obtain a listing of all licensed elevators. By interpretation of this elevator list, it was possible to prepare a building list giving address, date of construction and number of stories.

With this building list, it was then possible to go to the County Assessor's office to obtain current assessed valuation. However, because of the format in which the records were kept, this was a time-consuming and hence expensive task. Appendix $B$ describes the procedure that must be followed. In addition, the address used by the Elevator Division often did not coincide with the address used by the Assessor's Office. Hence, at this stage, this procedure was followed only for buildings for which damage repair
permits were obtained in the preliminary damage study. The lists of the Western Economic Research Company and of the Security Pacific National Bank gave building permit valuations for recent buildings and this information was an alternative to looking up assessed valuation.

The building list and building characteristics compiled in this way were not entirely perfect. (Their accuracy will be discussed in Chapter 4). However, they provided a very satisfactory starting point. This information was made available to M.I.T. by the end of September 1971 in the form that facilitated key punching for storage into a computer. Table 3.1 summarizes the chief information sources used to compile these lists; Chapter 4 will discuss the data in detail.

### 3.2.2 Preliminary Damage Study

It quickly became clear that considerable effort in the form of questionnaires and personal follow-up was going to be required to prepare a satisfactory documentation of damage. Hence, as a preliminary effort, the Wiggins Company was charged with documenting the evidence available in the public record.

One source of data was the file of damage repair permits at the Los Angeles City Department of Building and Safety. The Department kindly made the file of these permits available. Fortunately, each permit showed the number of stories in the building. Hence, by going through the many file boxes card by card, it was possible to compile a list of buildings having 5 or more stories for which application had been made for a repair permit. There were approximately 100 such permits. Two points must be made concerning these data:

1. This was not a perfect source of information. The Wiggins Company was unable to find permits for several buildings that were well known to have been damaged and repaired. In addition, the addresses given on 30 of the permits could not be marched with addresses in the Assessor's Office.
2. It was widely believed that the estimated repair cost was less than the actual damage. One reason for this belief was that the cost
of the permit was related to the estimated cost of repair. Another reason was the belief that a permit was required only for that portion of the repairs that affected safety. The Wiggins Company asked four practicing, competent professional engineers to estimate the ratio of the repair cost as shown on permit applications with the actual value of damage caused by the earthquake. The four estimates were $25 \%, 33 \%, 50 \%$ and $40 \%$ 。 The average of these estimates was $37 \%$; however, the Wiggins Company felt that the actual ratio was lower than this average estimate.

For these reasons, these data concerning damage were rather unsatisfactory.
The County of Los Angeles had excellent records of building damage stored in a computer. However, when the printout was examined, it was found that there were virtually no buildings having 5 or more scories under County jurisdiction.

Phone calls were made to building officials in the smaller cities lying Within Los Angeles County. Since there were very few tall buildings in most of these cities, and since most of them experienced only intensity VI ground motion, the building officials could readily report on the damage which was generally minimal to nonexistent.

All of this damage information was incorporated in the Original Data Base provided to M.I.T. at the end of September 1971.

At M.I.T.'s request, the Wiggins Company also made proposals as to the format of a questionnaire to be used for seeking more information on damage and made recommendations as to the administration of a questionnaire approach. The suggested questionnaire and cover letter may be found in Appendix $C$.

### 3.2.3 Detailed Damage Study for Limited Number of Buildings <br> During July, a second subcontract was entered into with the firm of

 Ayres, Cohen and Hayakawa located in Los Angeles. This firm, which specializes in electrical and mechanical aspects of building design, previously had studied non-structural damage in Anchorage caused by the 1964 Prince William Sound earthquake, and was already engaged in a similar study ofnon-structural damage caused by the San Fernando earthquake. Under the subcontract with M.I.T., the Ayres firm was to compile detailed, floor-byfloor, damage cost information for 17 buildings. This survey was carried out exclusively by personal interviews. The survey covered the basic characteristics of the building, such as age, height, type and cost of the construction, together with the nature of the earthquake damage and repair cost of various components in the building. The interviewer used a prepared 3-page questionnaire (see Appendix C) and wrote down information gathered from the interview.

These specific buildings were generally well known high-rise buildings in the greater Los Angeles area built after 1960. The majority of them have installed strong motion accelographs. The position of the interviewed person varied from building owner, manager, managing agency, maintenance engineer to construction superintendent. Barring a few exceptions, the majority of the persons interviewed cooperated with the effort. In many cases, the nature of various building damages were obrained from maintenance engineers located in the surveyed buildings, whereas the cost information was obtained from the owner or manager located elsewhere. Consequently, two or more trips were involved for these buildings.

The first survey was conducted approximately eight months after the San Fernando earthquake. A great majority of the damage repair work was completed. Based on the timing of the survey and the attitudes of the owners and managers during interview, it appears that the cost information gathered was more factual than if the survey had been conducted immediately after the earchquake.

The repair costs sometimes were misleading because some owners elected to take this opportunity to lump other routine maintenance repair work inco the damage repair. Some of the repair work was not limited to the restoration of the damage but went beyond that into preventative work to strengthen the existing installation. Many of the repair costs were revised several. times by subsequent interviews in an attempt to single out the "repair cost due to earthquake damage."

In an effort to gather detailed floor-by-floor construction cost or partitions, additional field trips were made to 5 buildings to measure partition lengths from tenant drawings and determine the type of partitions used. Unit cost for various types of partitions were obtained from the owners and in some cases with the help of partition contractors and gypsum and plascer manufacturers.

The data gathered from this effort has been used by M.I.T. as part of a detailed comparison between damage and dynamic response (see Reporr No. 4). The total damage costs from this effort have also been included in this report.

### 3.3 DECEMBER 1971 THROUGH FEBRUARY 1972

By this time, it was evident that it was essential to collect additional data about damage. Hence, a questionnaire survey was planned. This survey had two objectives:

1. To serve as a pilot study for a possible subsequent and more extensive survey.
2. To give additional damage information for certain specific classes of buildings as is explained below.

This survey was the main data gathering effort during this period. The task of encoding data for storage in a computer, as described in subsequent chapters, also began at this time.

### 3.3.1 Categorization of Buildings

Several decisions had been reached about the grouping of buildings for purposes of analyzing the data.

First, buildings were grouped into three categories according to date of construction: pre-1933, 1933-1946, and post-1947. Requirements for design against earthquake first appeared in 1933 after the Long Beach earthquake. Hence all buildings built before that dace could be presumed to have litcle or no planned resistance to earthquakes. Based upon analyses prepared by the Wiggins Company, the level of earthquake resistance required by the Los Angeles building code had remained more-or-less constant since 1933 , and thus all buildings built since that date could be presumed to have more-or-less the
same level of required resistance to earthquakes (see Appendix D). While different code provisions have applied at different times for Los Angeles City and County and for other municipalities within the County, these differences can be ignored for the purposes of this study. The year 1947 marked the time at which there was a major jump in the quality of readily available information regarding the characteristics of buildings. Since very few buildings were constructed between 1933 and 1947 , it finally was decided to concentrate upon two age groupings:

1. Pre-1933 - having essentially no planned resistance to earthquakes.
2. Post-1947 - having a minimum earthquake resistance as required by current codes.

As was seen in Table 1.1 , there were considerable numbers of buildings in each of these age groupings.

Second, buildings were grouped into four categories according to the number of stories: 5 to 7,8 to 13,14 to 18 , and 19 plus. The break at 8 stories reflects the lowest story height for buildings listed on the excellent maps of the Western Economic Research Co. The break at 13 stories reflects the height limitation imposed by the City of Los Angeles building code from 1933 uncil relatively recently. The break at 18 stories was chosen rather arbitrarily to provide a compact grouping of buildings of medium story height.

Use of two principal age groupings and four height groupings, plus three ground shaking intensity levels (modified Mercalli VI, VII and VIII) resulted in a total of 24 categories into which buildings would fall. About six of these categories contained fewer chan 10 buildings; the remaining caregories were reasonably well populated. As a goal for the pilot survey, it was decided that enough questionnaires should be sent so that:

1. When there were fewer than 10 buildings in a category, all buflding owners would be contacted.
2. When there were more than 10 buildings in a category, damage information would be obtained for at least 10 buildings.

Thus the minimum number of 10 buildings was selected as the fewest required to provide meaningful damage statistics. To determine the number of additional questionnaires to be sent, the number of buildings for which damage information had already been obtained was subtracted.

### 3.3.2 Administration of Questionnaire Survey

After reviewing various possible forms of questionnaires, it was concluded that: (a) the questionnaire itself must be very simple and be no longer than one page with an addressed stamped envelope to facilitate return; (b) every effort must be made to establish the legitimacy of the survey and to satisfy respondents that their building would not be identified by name or address in published reports; and (c) follow-up contact would be necessary to ensure a reasonable return.

Fig. 3.1.a shows the questionnaire used for this survey. Some of the questions were aimed at verifying building characteristics previously documented by the Wiggins Company. Other questions requested information thac usually was not already known: type of occupancy and cype of building construction. A final group of questions requested information about damage.

A covering letter on M.I.T. stationery (Fig. 3.1.b) described the purpose of the study and requested cooperation from the addressees. In addition, the Building Owners \& Managers Association (BOMA) of Los Angeles agreed to endorse the survey and Mr. Phil Bauman (General Manager of BOMA) wrote a second cover letter (Fig. 3.I.c). Since the building owners' names were not known at the time of mailing, the envelopes (which gave M.I.T. as the return address) were addressed to the "Building Manager." The return envelope was addressed to the BOMA office.

Because unexpended funds remained in the subcontract with Ayres, Cohen and Hayakawa, and because that firm was experienced with the type of personal follow-up that was expected to be necessary, the Ayres firm was requested to administer the survey. M.I.T. provided listings of buildings in the various categories, and specified 9 sub-geographic areas of particular interest and the number of returns desired for each caregory. Ayres ${ }^{\text {f firm randomly selected }}$ the particular buildings to be addressed, mailed the questionnaires, collected the returns from the BOMA office, compared the returns with the mailing Iist, and undertook follow-up as necessary.

The initial mailing was 200. Approximately $25 \%$ of the questionnaires were completed and returned within a month. (The rate of return dropped rapidly after the first two weeks.) Over $15 \%$ of the mailings were returned by the Postal Service with the indication that the street number could not be
found. New addresses were picked from the building list in order to meet the desired quotas of building location and type. The total final mailing was 267 questionnaires.

The follow-up procedure was developed by trial-and-error. Without knowing the name of the building owner, it was difficult to find the telephone number of the building manager. Since the selected buildings were clustered in a few 4 -mile square areas, it was decided that personal interviews conducted in a few field trips could be made effective. The first field trip started two weeks after the initial mailing. In all, twelve field trips were made with each of the one-day trips covering approximately 18 buildings. These field trips were judged very effective in that approximately 90 returns were attributed directly or indirectly to the result of these efforts.

A follow-up was made for each mailing returned by the Postal Service as undeliverable. In a few instances, the building proved to be a special type, such as a parking garage; in some other cases, the building simply no longer existed. These buildings were then eliminated from the building list. In most cases, the problem was that the address on the elevator list was different from the current mailing address; The address on the $M . I . T$. building list was then corrected.

The Ayres firm reported that, in general, the fact that M.I.T. conducted the survey appealed to the building owners. They surmised that it made owners feel that the survey was part of academic research that would not be used in any way against them. A few owners expressed the unwillingness to get involved with BOMA, and some of them simply refused to cooperate with the survey as a whole.

A cotal of 141 questionnaires eventually were received of which 135 contained usable information.

### 3.3.3 BOMA Questionnaire

Independently of the M.I.T. study, in August 1971 BOMA had sent 500 questionnaires to its membership seeking information about earthquake damage. A very comprehensive earthquake form had been used: A sample of this form appears in Appendix C. Only 40 of the building owners responded. It was felt that the poor return was caused by the lengthiness and complexity of the form.
M.I.T. purchased copies of the completed questionnaires from BOMA. Of the 40 returns, 33 were for buildings having 5 or more stories.

### 3.4 MARCH 1972 THROUGH DECEMBER 1972

At this stage, the $M . I . T$. study had available from various sources damage information for about 200 buildings. Some building categories (date of construction, height, intensity) still were poorly represented. More data still was desired.

### 3.4.1 MIT/BOMA Questionnaire Survey

The success of the first questiomaire survey, and the interest of both MIT and BOMA in obtaining the best possible documentation of the earthquake damage, inspired a second questionnaire survey conducted jointly by M.I.T. and BOMA. Mr. Eugene Schader, an engineer for the Insurance Service Office, acted as a consultant to BOMA on this project. (Mr. Schader undertook this work as an individual rather than as a representative of the Insurance Service Office。)

A new questionnaire form was prepared, representing a compromise between the first MIT and BOMA forms (Fig. 3.2.a). The same M.I.T. cover letcer was used once again, while BOMA prepared a new cover letter. Again the forms were returned to the BOMA office, and the Ayres firm administered the effort.

Over 700 questionnaires were mailed during April and May. Many of the building addresses were furnished by BOMA; these buildings were scattered in Los Angeles and Orange County. The majority of the BOMA addresses in Los Angeles County overlapped the addresses on MIT Data Base, and considerable effort was spent matching these addresses to keep the record straight and to avoid duplicate mailing. The remaining buildings exhausted the addresses in the MIT Data Base for the San Fernando Valley, and the Hollywood and Pasadena areas, and for all of the aparment buildings.

The returns, with a lesser degree of success, followed the same pattern as the initial survey. Approximately $15 \%$ of the building owners answered the questionnaire within two weeks of mailing and the rate of return dropped quickly.

Again, over $15 \%$ of the mails were rejected by the Postal Service (including a few supplied by BOMA). Field rrips were much less effective this time, mainly because of the wide geographic spread of the addresses. The average number of buildings visited per trip dropped to 12. Owing to budgetary considerations, only 7 field trips were made with approximately $15 \%$ of the returns attributable to the field trip effort. The total return from the mailing and follow-up was about 200 questionnaires.

In late June, 1972, an analysis was made of the returned questionnaires from the standpoint of coverage of the different location-agenheight categories. A new priority list of categories was drawn up emphasizing buildings in intensity zone $V I$, and another 151 questionnaires were mailed. Three field trips were specifically aimed at completing this list. This effort yielded about 20 addicional completed questionnaires.

At this stage, over 1200 questionnaires had been mailed or distributed covering all building/location categories of primary interest. From this and other efforts, "complete" data were then available for about 370 buildings as indicated by Table 1.2. The sources of these data were:

$$
\begin{array}{lr}
\text { BOMA Questionnaire } & \sim 33 \\
\text { MIT Questionnaire } & \sim 140 \\
\text { Main MIT/BOMA Questionnaire } & \sim 200 \\
\text { Special mailing and follow-up } & \sim 25
\end{array}
$$

in summer and falls 1972
The number of buildings with "complete" daca was less than the total number of returned questionnaires from the several surveys plus entries from other sources because a number of the same buildings were included in several of the surveys.

It was then the unanimous opinion of the M.I.T. staff, BOMA and the Ayres firm that the gathering of damage information had reached the point of diminishing returns. Several more field trips were made in the fall of 1972 co cover all remaining addresses in the San Fernando Valley. This last effore served mainly to eliminate from the data base structures that did not meet the criteria for the study, but did yield several more completed questionnaires for buildings in the zone of high intensity.

### 3.4.2 Data on Structural Type and Foundation Type

On the MIT and MIT/BOMA Questionnaires, respondents were requested to indicate simply whether the building was constructed of steel, concrete or brick masonry. It was felt that it would be beyond the knowledge of the respondents to provide further differentiation between particular structural systems suck as concrete ductile frame construction, concrete shear wall construction, etc. Similarly, no information concerning type of foundacion was requested on the questionnaires.

From the questionnaires, information on general structural type was obtained for nearly all buildings for which damage information was obtained. In addition, Mr. Schader offered to provide from his files information concerning type of foundation and type of structural system for the buildings for which there was otherwise complete information. He was able to provide this additional information for about 125 buildings.

To complete this particular information, it appeared that it would be necessary to contact the architects and/or engineers for each remaining building. Another possibility, the use of information in the files of the regional Office of Civil Defense, had been explored earlier in the study. The records in that Office were in a form that made it very difficult to match up their list of buildings with the MIT 1ist.

### 3.4.3 Assessment Reduction for Building Damage

Mr. Schader also pointed out another potential source of data. According to law, building owners are entitled co a reduction in the assessed value of cheir building for one year. The amount of reduction was based upon owners ${ }^{\text {f }}$ estimates of damage subject to verification by the County appraiser. Presumably, the ratio of reduction to actual damage would be the same as the ratio of assessed value to actual value. The reduction was received only by those owners applying for it.

This information was available in a report, "1971 Disaster Value Report EQ-88," by the Los Angeles County Assessor's Office dated September 9, 1971. At M.I.T.'s request the Ayres firm examined this report. Since the entries in the report did not indicate the size of the building, Ayres listed all buildings with an assessed value of $\$ 50,000$ or more. They then matched addresses with those on the MIT building list, and where a match could not be made a

MIT/BOMA Questionnaire was mailed to the address in the Assessor's report. Approximately 110 questionnaires were sent (this number is included in the total MIT/BOMA mailing described in section 3.4.1) of which about 30 were returned by the Postal Service as undeliverable. (One does wonder just how the yearly tax bills reach these particular owners!) This source of information yielded damage values for 20 buildings.

### 3.4.4 Additional Assessed Valuations

During the late fall of 1972, it was decided that assessed evaluations should be documented for all (if possible) of the buildings for which damage information had been collected. The Ayres firm assembled this information from the County Assessor's Office using the method described in Appendix B. Even after considerable effort, it still proved impossible to match a few of the building addresses with any address in the files of che Assessor's Office.

### 3.4.5 Encoding and Interpretation of Data

Encoding of data for storage in the computer began in January 1972 and continued steadily throughout 1972, and chere was continued improvement in a computer program for extracting data from storage. The format for storage in the computer is described in Chapter 4. During the fall of 1972, the accuracy of all computer-stored information has been double-checked back against the original sources.

There also was continued analysis of the data as a basis for deciding how much additional data is required. Damage probability matrices were generated from the data at several different states. Such matrices are discussed in Chapter 5.

### 3.5 COMMENTS ON DATA GATHERING EFFORT

At the outset of this study, the M.I.T. staff recognized that this form of experimental research would be every bit as difficult as good research in the laboratory. Indeed, it proved to be difficult and expensive to compile accurate and useful statistics. The task was certainly complicated by the human element.

Having completed the effort, questions arise. Which data gathering procedures proved most effective? Should still other procedures be used? What steps might be taken before an earthquake to facilitate data gathering after an earthquake? The following sections comment on some of these questions. Inevitably, these comments will suggest that some governmental agencies should make some changes in their practices. These comments are not intended as criticisms; rather they are suggestions based upon lessons learned. All of the City, County and State agencies contacted in the course of this study were extremely cooperative in making their records and files available.

### 3.5.1 Building List

The single most important step to facilitate a similar damage study, in Los Angeles or any other area, is to prepare in advance a list of all buildings giving their most significant characteristics and their addresses. Such a list would have ocher uses as well: (a) in a benefit/risk analysis to assist in choosing the optimum level of required resistance to earthquakes and other rare events; (b) as a basis for a program of phasing out older buildings that present hazards, etc.

Several key decisions must be made as a starting point for drawing up the list. First, it must be decided what types of buildings should be included. Presumably the list would not include just tall buildings with 5 stories or more. First priority might be given to listing especially important structures vital to community functioning. At the other end of the spectrum, single family residences might be individually listed only in certain limited areas spread out to give suitable geographical coverage. The second decision concerns the building characteristics to be documented. From the standpoint of earthquake damage studies for tall buildings, the following characteristics are suggested:

```
Dates of original construction and major modifications
Number of stories
    Structural system (steel, concrete frame, etc.)
    Type of partitions
    Type of exterior cladding
    Type of ceilings/overhead lighting
```


## Type of foundation

Nature of soil (for any city it should be possible to develop a small number of typical soil profiles for this purpose)
Address (location address and mail address of owner)
Ocher characteristics presumably would be added to meet objectives other than earthquake damage studies.

It will also be necessary to designate one municipal or county agency to be custodian of this data bank. For cities in the United States, at least, perhaps the best agency would be the Assessor ${ }^{\text {s }}$ Office. Such offices already have all properties listed together with an address where the owner can be reached. Other information, presumably to be researched and evaluated by other agencies, can be added readily. Using modern data bank techniques (Schumacker, 1971) it is possible to store the information in such a way that many of the building characteristics could be used to access the information. It would help greatly just to have the stored information readily accessible by location address, and to have this same address used by all governmental agencies.

It will be a formidable task to develop a building list for a large metropolitan area. At a recent national workshop on planning for disaster mitigation, it was recommended that the federal government find a pilot effort to develop suitable methods and procedures (McClure, 1972). One potentially useful source of information, not used in the study described in this report, is the maps prepared by the Sanborn Company (see comments in ESSA, 1969). M.I.T. has subsequently used these maps for preparing building lists, and has found them very useful for identifying what buildings exist as well as cheir heights, sizes and structural characteristics. These maps alone do not solve the problem of matching reliable mailing addresses to buildings. In addition, the information concening structural characteristics is not always accurate.

### 3.5.2 Damage Data

The best method for assembling statistics concerning damage caused by future earthquakes will depend greatly upon the nature of the community where the earthquake occurs. The best method will also depend upon the overall objectives of the damage study. For example, immediately after an
earthquake a community must estimate the total loss for purposes of applying for disaster relief. A survey with this objective will be quite different from the type of survey described in the preceding sections.

The following discussion pertains to establishing data of the type discussed in this report. Within this general context, the following general observations may be made:

1. Substantially complete damage information can be collected only if a municipal agency has the responsibility and authority to assemble this information. The law must require cooperation by building owners, and should contain a specific requirement for reporting the level of damage. 2. It is essential to establish, within the first one or two weeks after an earthquake, the general level of damage for each building in the group of buildings to be studied. It is not essential that the actual cost of damage be estimated during a visit to a building; rather, it will suffice to use damage descriptors such as those in Table 2.1. Such damage descriptors will permit a community to estimate dollar damage for purposes of applying for disaster relief. Armed with such information, it should be possible to obtain at a later date the actual dollar cost of the damage for purposes of a study such as the one described in this report.
2. The first responsibility of municipal employees after a major earthquake is to protect lives. Municipally employed building inspectors and engineers will not be able to undertake the survey of less damaged buildings; all such employees will be very, very busy with essential functions.

Note that a two-stage process is envisioned: (1) an initial survey to establish a general picture of the damage and to identify buildings for which more information would be desirable, and (2) a later questionnaire survey to pin down actual damage costs.

These observations suggest that the initial survey of the damage of "all" buildings would best be undertaken by volunteer engineers from the community with a municipal agency providing the impetus and direction. Jusc how to organize this volunteer effort will certainly depend very greatly upon the community. (Possibly advanced undergraduate and graduate students from engineering schools will be the best available pool of manpower for this
purpose. Such students are always anxious to help in an emergency and, with proper briefing, would be very capable at matching visually discovered damage to damage descriptors.) Such "volunteer inspectors" will have to be provided with documents authorizing them to inspect. They should be instructed not to force entrance into buildings where owners resist the inspection: such building owners must be approached later through more formal channels. The volunteer inspectors also must be instructed not to offer judgements concerning safety of a building, and indeed not to enter any building where they personally are concerned about safety. In effect, the job of the volunteer inspectors would be to document moderate to light to no damage; inspection of heavy damage should be left to municipal engineers or to engineers specifically designated by the municipality.

For maximum effectiveness and minimum chaos, such a survey effort will require considerable preplanning and coordination. An essential ingredient is a building list. Before the earthquake, the building list should be broken up into geographical and building type units to facilitate the assignment of a manageable number of buildings to groups of volunteer inspectors.

If the preplanning has not been done, and if the building list does not exist, the whole effort will be much more difficult. Considerable hastilyorganized planning will have to be done during the first few (already hectic) weeks after the earthquake. Based upon the experience from the present study, a few suggestions can be made.

1. Study the apparent zones of different intensity and the geographic groupings of buildings with different ages.
2. Select no more than 5 (and preferably only 3) geographic locations, each perhaps 5 blocks square, and concentrate efforts in these zones. 3. Send observers into each geographic area to record, block-by-block, the size and characteristics (apparent age, apparent structural type) of each building, and also to describe the apparent damage. 4. Identify, if possible, large managing companies controlling groups of buildings, and plead for their cooperation in recounting the damages to their buildings.
The key here is selection and concentration on a few limited areas.
The questionnaire survey to establish actual damage costs should be
conducted within a year after the earthquake. The information on damage from the initial survey should provide leverage for securing cooperation from owners: however, follow-up undoubtedly still will be necessary. Follow-up should begin within two weeks after the mailing. By selecting a limited number of geographic areas for detailed study, the cost of the follow-up can be greatly reduced. A survey matrix should be established giving types of buildings by location, and targets (number of buildings with actual cost data) should be set for each category of the matrix.

Table 3.1

SUMMARY DESCRIPTION OF WIGGIN'S INFORMATION SOURCES

## INFORMATION SOURCE

State and L.A. Ciry Elevator Division Lists

High-Rise Activity in Southern California 19601967 published by Economic Research Department, Security Pacific National Bank

New Hi-Rise Apartment Buildings, map prepared by Western Economic Research Co. (WERC)

## INFORMATION OBTAINED

For all buildings containing elevators:

1) address of building
2) number of elevator landings
3) date of elevator installation

For all buildings 5 stories and above and a valuation of $\$ 500,000$ or more

1) address
2) valuation
3) date permit issued
4) height in stories
5) building use

For all apartment buildings 8 stories and above built from 1945-1970 in the Los Angeles-Orange County region

1) date of construction
2) building name \& location
3) height in stories
4) permit valuation

New Hi-Rise Office Buildings, map prepared by Western Economic Research Co. (WERC)
L.A. County Assessor ${ }^{\text {is }}$ Office Assessed Values

For all office buildings 8 stories and above built from 1947-1970 in the Los AngelesOrange County region

1) date of construction
2) building name
3) height in stories
4) permit valuation
5) gross floor area

For building and propercy, assessed values were found

GENERAL COMMENTS
Addresses often slightly in error. Building height assumed equal to number of lands minus 1. Only $90 \%$ of lifts over 5 stories include a base-ment-hence some 5-story buildings were unavoidably omitted.

Compiled from building permits issued by various city and county building departments in the 10 southern counties of California

Map shows 88 buildings

Map shows 207 buildings

Market value assumed to be 4 times assessed value. Very expensive procedure to obrain assessed values.

## DEPARTRANT OF CIMM ENGINEERING

 MASSACHUSETTS INSTITUTE OF TECHNOLOGY-Quescionnaire.

1. What is the basic function of the building?
$\qquad$
2. What year was the building constructed? $\qquad$
3. Please identify the type of building construction used:
$\qquad$ steel frame $\qquad$ concrete frame
$\qquad$ brick masonry $\qquad$ other (define)
4. What is the total building floor area (gross sq. ft.)? $\qquad$
5. What is the building height above the ground level? $\square$ stories
$\qquad$
feet
6. What was total ripair cost for physical damage caused by the San Fernando earthquäke? \$ $\qquad$
7. Please indicate the percentage repair cost breakdown for the items listed below:

Structural (beams, columns, concrete walls, etc.) $\qquad$ \%

Non-structural:
Mechanical (plumbing, heating, ventilating, and air conditioning, etc.)
\%
Electrical (transformers, lights, etc.)
$\qquad$

Elevators, escalators, and/or dumb waiters \%

Other (partitions, walls, ceilings, glass, etc.)
Total
$100 \%$
8. Was there any inconvenience cost caused by the earthquake (i.e. rental loss, employee time loss, etc)? $\qquad$ - If so, what do you estimate this cost to be? \$ $\qquad$
9. Would you be willing to give a detailed cost breakdown? $\qquad$ If 50 , who should be contacted?

Name $\qquad$ Firm $\qquad$
Address $\qquad$
City $\qquad$ Phone $\qquad$
Thank you for answering the questionnaire.
FIGURE 3.1a. FIRST M.I.T。 QUESTIONNAIRE $\qquad$

January 1, 1972

Dear Sir:
The Massachusetts Institute of Technology is conducting a study of the damage caused by the earthquake of February 9. 1971. This work is sponsored by the National Science Foundation. The information obtained will be used as a data base for estimating losses which might occur from future earthquakes.

The earchquake of february 9, 1971 caused varying degrees of damage to high-rise buildings. Because this earthquake is the most recent large shake to occur in a populated United States area it has drawn the attention of the people who are responsible for changing building codes. it is fair to state that in the future, earthquake code load factors will be either increased or remain the same. It is in your best interest that decisions affecting codes be based on accurate data.

The first step in this effort is to obtain an assessment of the damage which occurred during the San Fernando earthquake. It is for this reason that we ask you to please answer the attached questionnaire. The answers you provide will become part of a comprehensive damage data base for selected parts of the Los Angeles area. Please be assured that your responses will remain annoymous.

It is not critical that the cost infomation requested is exact. We appreciate that the time you have to answer the questionnaire is fimited. and we ask only that you be reasonably accurate. Even if your building did not suffer any damage, please still answer the questionnaire. The fact that your building had no damage is very important information. Please return the completed questionnaire in the enclosed envelope.

Thank you for your cooperation.
very truly yours,
Rubert V. culitwem
Robert $V$. Whitman
Professor of Civil Engineering
Head of Soil Mechanics and
Structural Engineering Divisions
FIGURE 3.1b. M.I.T. COVER LETTER FOR FIRST M.I.T. QUESTIONNAIRE


TO: BUILDING OWNERS AND MANAGERS
FROM: PHIL BAUMAN, GENERAL MANAGER
SUBJECT: EARTHQUAKE QUESTIONNAIRE

In a continuing effort to assemble information on the effects of last year's earthquake on office buildings, BOMA is participating with the National Science Foundation and the Massachusetts Institute of Technology in additional data gathering programs.

It is in our vital interest to have factual information available when emotional, restrictive building code legislation is proposed and we urge your cooperation in helping to assemble that information.


ADVISORY COUREll
WILLIAM R. PRABL Viee Preotdent TRUST COMPANY
Robert E. Sherhan senar tice Prasdeme $A$
JOHN H. WILLAMS
Vice Presidont


PHIL BAUMAN
General Manager

## OFBIEESS

M. DOW RuIC: $\triangle$ TRYOOKT IMPERTAI, TOURERS

| GEMERAL BUILDING INFORMATION <br> A. Year built (original building) . . . . . . . . $\qquad$ <br> Have there been additions <br> to the original building? Yes $\qquad$ ${ }^{\mathrm{N}} \mathrm{O}$ $\qquad$ 0 $\qquad$ <br> B. Building Height: <br> 1. Stories Above Main Entry . . $\qquad$ <br> 2. Building Height...... $\qquad$ <br> C. Total Building Floor Area. . (gross sq. ft. $)$ (based on exterior dimensions, ex- $\qquad$ cluding subterranean parking areas) <br> D. Building Function (Occupancy): <br> 1. Office Building. $\qquad$ 5. Hotel . . . . $\qquad$ <br> 2. Apartment . . . . $\qquad$ 6. Other (describe): <br> 3. Hospital $\qquad$ <br> 4. store...... $\qquad$ $\qquad$ <br> E. Type of Building Construction <br> 1. Stee? Fiame . . . $\qquad$ 4. Other (describe) <br> 2. Concrete Frame. $\qquad$ $\qquad$ <br> 3. Brick Masonry. $\qquad$ $\qquad$ <br> F. If available, please give County Assessor's "Assessed" Value. (25\% of Fair Market valuc) Improvemen is only, excluding land. <br> 1. Pre-earthquake (1970).... $\qquad$ <br> 2. Post-earthquake . . . . . $\qquad$ <br> 3. Reduction (due to earthquake damago) . . $\qquad$ |
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## II EARTHQUAKE DAMAGE INFORMATION

A. that was the total repair cost for physical damage caused by the San Fernando Earthquake? Including all categories in Part 8 below). $\$$ $\qquad$ or
none $\qquad$
B. Please indicate the percentage repair cost breakdown for the items listed below. Indicate $0 \%$ where repairs were not required or amount negligible.

1. Structural
(beams, columns, shearwalls, floors, etc.
2. Non-Structural:
a. mechanical (plumbing, tanks, heating, ventilating, and/or air conditioning, etc.) _..... is
b. Electrical (transformer, lights, etc.). . $\qquad$ \%
c. Elevators, escalators, and/or dumb waiters _o_
d. Ornamentation, Interior \& E

Exterior (marble, tile, otc. $\qquad$ \%
e. partition walls (excluding painting) . . .... $\%$
$f_{u}$ ceilings (excluding painting) . . . . . $\qquad$ \%
9. Exterior non-structural walls (excluding glass and painting) $\qquad$ $\%$

i. painting . . . . . . . . . . . . . . ___ \%
j. Contents (furniture, fixtures, personal property, ét.c.) ......... $\qquad$ \%
K. Other (including profossional fees, building department fees, etc

Toíal . . . . . . $100 \%$
C. Was there any inconvenience cost caused by the earthquake (i.e., rental loss, employee time loss, etc. )? Yes $\qquad$ $\mathrm{NO}_{2}$ $\qquad$ If so, what is the estimate of this cost? $\$$ $\qquad$ ; number of days building unusablo $\qquad$ -
D. Would you be willing to discuss this further? Yes $\qquad$ No $\qquad$ If yes, who should be contacted?
$\qquad$
adaress
$\qquad$
$\qquad$

Thank you for answering ihis questionnaire.

FIGURE 3.2a。 JOINT M.I.T./BOMA QUESTIONNATRE
$\qquad$


* PHIL BAUMAN
Generat Manager

April, 1972

## TO: BUILDING OWNERS AND/OR MANAGERS

FROM: PHII, BAUMAN, GENERAL MANAGER
SUBJECT: SHORT FORM EARTHQUAKE QUESTIONNAIRE
As you know, BOMA is the only agency uniquely capable of obtaining high rise earthquake and other data from and for our industry. In a continuing program of assembling usable information which can allay the effects of future shakes, we are participating with rhe National Science Foundation, Massachusetts Institute of Technology and their consulting firm of Ayers, Cohen and Hayakawa, in this final data gathering program.

If you have participated in our regular survcys on Occupancy or Building Operating Costs, you know the information is held in confidence and reference is never made to a specific building in the published reports. Let me assure you that this survey information will be treated with that same confidence.

From information obtained in this and earlier surveys, valid and reasonable preventative measures will be developed and recommended for implementation later this year.

We urge your earliest cooperation in this effort and pledge our continuing perseverance in your and the industry's behalf.

Thank you very much.


FIGURE 3.2b. BOMA COVER LETTER FOR JOTNT M.I.T./BOMA QUESTIONNATRE

## Chapter 4

## DATA BASE

### 4.1 SUMMARY OF DATA AND INFORMATION SOURCES

The construction of the data base has already been described chronologically in Chapter 3. To provide an overview of the data base, the information sources and the contents of the data base are described briefly in the following subsections. Table 4.1 provides a cross reference between sources and data.

### 4.1.1 Information Sources

(a) SSR-Steinbrugge/Schader Report

Immediately after the earthquake, a damage survey was conducted by the Pacific Fire Rating Bureau (now the Insurance Service Office), 465 California Street, San Francisco, California. The results were published in a report entitled, "San Fernando Earthquake, February 9, 1971" by Steinbrugge and Schader. The damage information along with some building characteristics for 59 high-rise buildings was given in the report and is reproduced here in Appendix A.
(b) WERC - High-Rise Building Maps Published by Wescern Economic Research Company

Information concerning high-rise buildings of 8 stories and above built between 1946 and 1970 in the Los Angeles-Orange County Region was published by Western Economic Research Company, 13737 Vencura Blvd., Sherman Oaks, California in two separate maps entitled, "New Hi-Rise Apartment Buildings" and "New Hi-Rise Office Buildings." Contained on the maps are the building name, date of construction, location, height, gross floor area, and permit valuation. Altogether, 88 aparment buildings and 207 office buildings are shown on the maps.
(c) SP - "High-Rise Activity in Southern California 1960-1967 by

Security Pacific National Bank"
This report presents a comprehensive record of all high-rise construction activicy in Southern California during the period from 1960 to
1967. In general, high-rise buildings are defined as having 5 or more floors and a value of $\$ 500,000$ or more. Information provided in this report includes building function, date of construction, height, address, and permit valuation.
(d) EERI - A Map Published by Earthquake Engineering Research Institute

Encitled, "San Fernando Earthquake February 9, 1971, Plot of Maximum Recorded Basement Acceleration"

This is a map published by the Earthquake Engineering Research Institute co show the location of the strong motion instruments and che maximum accelerations recorded by the instruments during the San Fernando Earthquake. Forty-eight high-rise buildings are included in the map. Most of the information can also be found in the NOAA EERI, described next.
(e) NOAA EERI - NOAA-EERI Report Entitled, "Strong Motion Inscrumental Data on the San Fernando Earthquake of February 9, 1971"

Given in this report are the building address, height, structural type, location of strong motion recorder, and the maximum acceleration recorded during the San Fernando earthquake. There are 61 high-rise buildings contained in this list.
(f) EQ-88 - "1970 Disaster Value Report EQ-88" by L.A. County Assessor ${ }^{\text { }}$ s Office, September 9, 1971

This report contains the assessed building values which are approximately one quarter of the market values and the assessed value reduction after the earthquake and prior to repair of the damages.

The devaluation of high-rise buildings is determined from owner's estimates verified by the councy appraiser. The devaluations are accredited toward 1971 's property tax only. After 1971, the buildings are assumed to have been repaired and the 1972 property tax was figured assuming the buildings were restored to the pre-earthquake assessed value. It is up to the owner to appear for reappraisal if repair has not been completed. Apparently, the possible building devaluation after repair has not been considered.
(g) LADRP - L.A. City Damage Repair Permits

Approximately 100 copies of damage repair permits have been obtained from the Department of Building and Safety, the City of Los Angeles. Given in the permit are the building function, number of stories, date of
construction, size of the building, description of the repair, and the cost of repair.
(h) LACA - L.A. County Assessor's Office

The assessed present building value (approximately one quarter of the fair market value) may be obtained from this office.
(i) WIGGINS - Wiggins Building List

This is a list including most of the high-rise buildings 5 stories and above in the Los Angeles area produced by J. H. Wiggins Company. The M.I.T. building number and location code are assigned to each building on the list. The date, height, value, structural damage, and non-structural damage are recorded if available. Information concerning date of construction and height was obtained from the State and City Elevator Division Lists of the L.A. area. In doing so, it was assumed that the elevator was installed when the building was constructed and that the building height equals the number of elevator landings minus 1 (to account for a basement). The building value was obtained from the Security Pacific report, WERC maps and the County Assessor's Office. The structural damage is derived from repair permits; the non-structural damage is obtained mainly from private conversations and cost estimates for a few public buildings.
(j) BMQ - BOMA Questionnaire Survey as described in Section 3.3.3
(k) MIQ - MIT Questionnaire Survey as described in Section 3.3
(1) MBQ - MIT/BOMA Questionnaire Survey as described in Section 3.4.1
(m) SCHADER - Eugene Schader of the Insurance Service Office

Mr. Schader provided information on foundation and structural system for some 125 buildings while he acted as a consultant to BOMA in the MIT/BOMA joint effort on the MIT/BOMA Questionnaire Survey.
(n) ADR - Ayres Detailed Report as described in section 3.2.3

### 4.1.2 Data

The data stored in the several portions of the data base are identified and defined as follows.

ACCEL - The maximum acceleration recorded in the building during the earthquake.
BLDG FUNCT - The basic function of the building. The key for the entries is as follows:

O Office
A - Apartment
H - Hotel
OT - Other
MIT NO. The building identification number, from 1 to 1851 , used in the construction of the data base. MIT NO. and BLDG NO. are different.

STRUCT TYPE - The cype of building frame construction. The key for the entries is as follows.

C - Concrete
S - Sceel
BM - Brick Masonry
OT - Others
BLDG VALUE - The value of the building in dollars.
DAMAGE COST - The total cost of repair in dollars.
DATE - The year in which the building was constructed.
EERI NO. - The building idencification number assigned in the EERI map entitled "San Fernando Earthquake February 9, 1971. Plot of Maximum Recorded Basement Acceleration."

FOUND TYPE - The type of foundation construction. The key for the entries is as follows:

1 - Isolated spread footing
2 - Spread and combined footing
3 - Piles foundation
4 - Caisson foundation
5 - Others
BLDG NO. - A number used to identify buildings for purposes of this report. These BLDG NO.'s were assigned randomly and bear no systematic relationship to any other building idencification number. A list equating BLDG NO. and MIT NO. has been retained in the files at M.I.T.

GROSS FLOOR AREA - The gross floor area in square feet of the entire building.
HT - The height of the building in stories above ground level.

INCONV COST - The inconvenience cost suffered by the owner and occupants (including the rental loss, employee time loss, etc.) in dollars. LOC - Location of the building in reference to the Thomas Bros. Map Code. The Los Angeles area is divided into approximately four mile square areas. Each area is assigned a number which corresponds to a page in the Thomas Bros. "Los Angeles Councy - Popular Street Atlas - 1972 Edition." The area locations and the corresponding numbers are shown in Fig. 4.1. In a few instances, the assigned numbers deviate slightly from the Thomas Bros. Map. This figure also shows the correlation, as used in this study, between location and modified Mercalli intensity.

NOAA EERI NO. - The building identification number in the NOAA EERI report entitled, "Strong Motion Instrumental Data on the San Fernando Earthquake of February 9, 1971."
\% COMPONENT - Component repair cost expressed as a percentage of the
total repair cost. Components include:
STRUCT - Structural damage
MECH - Mechanical damage
ELEC - Electrical damage
ELEV - Elevator, escalator damage
ORN - Interior ornamentation damage
PART - Partition, walls damage, excluding painting
CEILING - Ceiling damage, excluding painting
GLASS - Glass damage
EXTERIOR - Non-structural walls damage, excluding glass and painting

PAINT - Painting cost
OTHER - Any other damage-related cost (including professional fee, Building Department fee, etc.)
REDUCT MARKET VALUE - The reduction of the building value after the earthquake and prior to the completion of the repair in dollars.

STRUCT DAMAGE - Structural damage in dollars in Wiggins' 1ist. NON-STRUCT DAMAGE - Non-structural damage in dollars in Wiggins ${ }^{\circ}$ list. STEIN NO. - The building number listed in the Steinbrugge/Schader Report (Appendix A).

### 4.2 DATA GROUPS

To facilitate access to the data from the various origins, the information is organized in four principal groupings and stored in the Information Processing Center (IPC) of the Massachusetts Institute of Technology. They are named:
(1) Original Data Base Data (ODB)
(2) BOMA Quescionnaire Data (BMQ)
(3) MIT Questionnaire Data (MIQ)
(4) MIT/BOMA Questionnaire Data (MBQ)

Each group of data represents a particular phase of the data base construction as described in the following sections. When the first set of data was encoded, the final scope of the data was not yet known, and the same was true at successive stages. Rather than change the entire input format at each stage, a new data group was created. Four disk files are allocated for the data base information. Each file consists of 2000 records. Information for each building is assigned to a separace record. However, information for a particular building resides at the same record location in all files. For example, building number 551 has information stored in the $551 s t$ record of the "Original Data Base Data and the 551st record of the BOMA Questionnaire Data" file。 Even if there is no information for a particular building, a record has still been allocated in each file. While this is somewhat wasteful of disk space, the storage meeds will never exhaust the disk capacity. The main advantage of this system is in the logical simplicity of the data structure. The record size, of course, varies from file to file. In order co protect the buildings being identified, the details of the system used to store and process the data along with several computer programs for data analysis are given in Appendix $J$ under a separate cover with distribution restricted to only the concerned parties. The structures of the data groups are as described in the following subsections.

### 4.2.1 Original Data Base Data

The information contained in chis group includes MIT NO., LOC, DATE, HT, BLDG, VALUE, GROSS FLOOR AREA, STRUCT TYPE, STRUCT DAMAGE, NONSTRUCT

DAMAGE, STEIN NO., STEIN DAMAGE, EERI NO., NOAA EERI NO., ACCEL, and FOUND TYPE. The information sources for each item are listed in Table 4.2. In the case where inconsistent information exists, the data from latter sources (further to right in table) supercedes the former data. For purposes of illustration, the first page of this listing is shown in Fig. 4. 2 with MIT NO. being replaced by BLDG NO.

### 4.2.2 BOMA Questionnaire Data

The information contained in this group includes MIT NO. STRUCT TYPE, bldg value, damage cost, \% struct, \% mech, \% Elec, \% elev, \% other, and DAMAGE/VALUE (the ratio DAMAGE COST/BUILD VALUE, expressed as \%). All data, except the BLDG VALUE which is obtained from WERC, is obtained from the BOMA Questionnaire. This data group is illustrated in Fig. 4.3 with the MIT NO. being replaced by the BLDG NO.

### 4.2.3 MIT Questionnaire Data

The information contained in this group includes MIT NO., STRUCT TYPE, DAMAGE COST, \% STRUCT, \% MECH, \% ELECT, \% ELEV, \% OTHER, GROSS FLOOR AREA, and BLDG FUNCT. All data was obtained from the MIT Questionnaires. The first page of the listing is shown in Fig. 4.4 with the MIT NO. being replaced by the BLDG NO. The total listing is given in Appendix F, also with the MIT NO. being replaced.

### 4.2.4 MIT/BOMA Questionnaire Data

The information contained in this group includes MIT NO., STRUCT TYPE, bldg Value, Damage cost, \% struct, \% MECH, \% ELEC, \% ELEV, \% ORN, \% PART, \% CEILING, \% EXTERIOR, \% GLASS, \% PAINT, \% OTHER, GROSS FLOOR AREA, BLDG FUNCT, INCONV COST, and REDUCT MARKET VALUE. The data was obtained from the MIT/BOMA Questionnaire, the Ayres Detailed Report, and the County Assessor's Office. The first page of the listing is shown in Fig. 4.5, with the MIT NO. being replaced by the BLDG NO. The total listing is given in Appendix G, also with the MIT NO: being replaced.

### 4.3 DATA PRESENTATION

In order to provide a unified picture of the data base and to facilitate comparisons between data from different sources, the data from various sources is collected and princed in a summery building list for all buildings for which damage information has been collected. In doing so, two measures are undertaken to minimize the possibility of the buildings on the list being identified. First, the new BLDG NO. is assigned randomly to replace the old MIT NO.; thus, the original data base listing (which had some limited distribution) cannot be used to identify buildings for which damage data have been collected. Second, the building height is printed as $19 t$ for all buildings taller than 18 stories. The information contained in the summary list includes BLDG NO., HT, DATE, LOC, STRUC TYPE, FOUND TYPE, BLDG FUNC, VALUE CODE, BLDG VALUE, DAMAGE CODE, DAMAGE COST, and DAMAGE/VALUE (ratio of DAMAGE COST to BLDG VALUE). The first page of the summary list is shown in Fig. 4.6 and the cotal listing of the buildings with damage informacion is given in Appendix $H$. All of the notations, except VALUE CODE and the DAMAGE CODE which are discussed below, used in this listing are either defined in Chapter 4.1 .2 or are self-explanatory. Note that -9 is used to indicate that the data are unknown.

Since the data base was constructed from various information sources and the degree of accuracy varies from one to the other, inconsistency in the data itself is unavoidable. The success and meaningfulness of the data analysis depends on the care taken in discriminating the accurate data from the inaccurate. This is not necessarily an easy task, and it appears desirable co present all the factual data to the readers along with a discussion on the accuracy of the data which is given in the following section to provide some kind of confidence measure on the data's validity. The VALUE CODE and DAMAGE CODE are designed to indicate the source of information for building values and damage costs, respectively. The key for entries of the VALUE CODE is:

1. Original Data Base value
2. BOMA value
3. Original Dara Base area times $\$ 25 / f t^{2}$
4. MIT Questionnaire area times $\$ 25 / f t^{2}$
5. MIT/BOMA area times $\$ 25 / \mathrm{fc}^{2}$
6. Replacement cost as defined in Section 4.4.4.
7. Present market value (assessed value $\times 4$ )

The key for entries of the DAMAGE CODE is:

1. Original Data Base Data
2. BOMA Questionnaire Data
3. MIT Questionnaire Data
4. MIT/BOMA Questionnaire Data
5. Steinbrugge Damage Data

In addition to the cotal damage cost, the component damage information is also provided in the BOMA Questionnaire, the MIT Questionnaire, and the MIT/BOMA Questionnaire. Since lengthiness of the components damage information prevents them from being included in the summary building list, the listings of the BOMA Questionnaire, the MIT Questionnaire, and the MIT/BOMA Questionnaire are presented in Appendix E, Appendix F, and Appendix G, respectively.

### 4.4 DISCUSSION OF THE DATA

As described previously, the data base is constructed from various sources of information over a period of time. A scrutiny of the data base is helpful in discriminating the conflicting information, and an estimation of the confidence level for the data collection may thus be obtained. The discussion on the date of construction, building height, building type, building value, and damage cost follows.

### 4.4.1 Date of Construction

For most of the buildings, the date of construction came from the Wiggins Building List which in turn adopted the date of elevator installation from the Elevator Division List. It is assumed that the elevator was installed when the building was constructed. However, these dates were superceded if so indicated by the Security Pacific, M.I.T. Survey Questionnaires and the WERC maps. The construction dates are accurate to within 2 or 3 years, the older buildings (pre-1940) being the least accurace. For the purpose of distinguishing the seismic code provision, the accuracy of construction date may be considered to be sufficient.

### 4.4.2 Building Height in Stories

The primary source of this entry is the Wiggins Building List which in turn adopted the information from the Elevator Division List. It is assumed that the building height equals the number of elevator landings minus 1 to account for a basement. The attempt here is to count all stories beginning with the ground floor. These heights were checked against the Security Pacific List, the survey questionnaires and the WERC maps. In general, the building heights are accurate to within $\pm 1$ story. For buildings with damage information, the building height generally is perfectly accurate.

### 4.4.3 Structural Type

The structural type gives the type of building frame construction and is roughly divided into steel, concrete, brick masonry, and other to give a general indication of the ductility of the buildings. The sources of the building type information are the survey questionnaires, the WERC maps, and the information provided by Mr. Schader, and can be considered to be reliable.

### 4.4.4 Building Value

In order to normalize the building damage cost so that the buildings may be placed in a certain damage state classified according to the damage ratio (damage cost to present building value), estimates for the present building values are essential. There are at least two ways of assessing the present building value: the current market value and the replacement cost. The difference between chese two values, which arises from depreciation, inflation, and market conditions, may not be significant for the modern building constructed in recent years, while it will be great for the old buildings. From the standpoint of our study, the replacement cost is considered more appropriate since this cost is a more-or-less definite quantity unaffected by changeable factors such as assessing practice, market conditions, and inflation. On the other hand, the assessed market value may be more meaningful for studies conducted by the insurance industry.

The market value by itself is seldom a definite quantity but rather a random variable depending on many factors affecting the building owner and the economical strength of the community. It appears that the best way to
obtain a consistent estimate of the market value is to multiply the assessed value, which can be obtained from the County Assessor's Office, by a certain factor. It is believed to be a common practice in the Los Angeles area that the assessed value is approximately one quarter of the fair market value. Procedures for evaluating assessed values are presented in Appendix $B$, and assessed values have been obtained for most of the buildings with complete damage and building information, except some non-taxable public buildings and the buildings with no damage reported. In all, more than 300 assessed values were recorded with most of them coming directly from the Assessor ${ }^{\text {i }}$ s Office and part of them from the MIT/BOMA Questionnaire. The assessed values alone are not necessarily accurate; for example, a building may be divided into several parts for the purpose of tax reporting, or a huge building complex may be taxed by a single bill. Hence the assessed values will not be realistic unless the building listed in the data base is identical to that listed in the Assessor's Office. Checking the market value against the replacement cost, which is defined next, appears to be the best way to eliminate some errors. About 30 assessed values were considered totally unreasonable and were eliminated from the record as a result of this exercise.

The replacement cost is more-or-less a definite value as noted previously. The best way to obtain the replacement cost is to start with the permit values at the time of construction and then to correct chis value by mulciplying by an inflation index (Table 4.3). The permit values of most of the modern high-rise buildings are available from the WERC maps and the Security Report. For the old buildings built before 1946, and the 5- to 7story buildings built before 1960 , no permit values are readily available from public literature, and consequently are very difficult to obrain. For these buildings, the replacement cost may be estimated from the total gross floor area. The dollar values per square foot of floor area for a number of buildings are plotted in Fig. 4.7. The average value of 25 dollars per square foot is adopted for all types and ages of buildings to estimate the replacement cost based on the cotal floor area.

A comparison of the market value and the replacement cost is presented in Fig. 4.8. The market value is higher than the replacement cost for the
buildings completed within one or two years. The average market value-toreplacement cost drops sharply in the first several years after the building has been completed then becomes more-or-less constant. However, che scatter of the data is fairly large.

To explain the behavior of the market value-ro-replacement cost ratio, an understanding of assessing practice is essential (since the market value is defined as $4 \times$ the assessed value). A building is first assessed for tax purposes when construction has been completed. The building is reassessed at varying time intervals depending on the economic growth of the community in which it is located. In rapidly developing communities in the Los Angeles area, a building may cypically be reassessed every year. However, in areas of very slow growth, the time between assessments may be 4 to 5 years. Normally, the real market value is higher than that computed from the assessed value because of the effect of inflation during the period since last assessment. The sharp drop in the market value-to-replacement cost ratio for the newly constructed buildings is explained by the fact that, while the replacement cost can presently be determined for all buildings, the assessed value data are available for only those years in which the buildings were constructed. For the older buildings which have at least been reassessed once, the inflationary effect is common to all, and hence the market value-to-replacement cost ratio is more-or-less steady, with a very slow decreasing rate with age if the building has been properly maintained. The scatter of the data may result mainly from the difference in improvements and maintenance that a building received during the past years. Either version of present building value, the marker value or the replacement cost, may be used for data analysis depending on how the results will be interpreted. It is desirable to use both values for the construction of the damage matrices and to compare the results. The information at hand, however, does not provide complete data for both sets of values, and compromises must be made. For the market values, more than $90 \%$ are derived from the assessed values and the rest are estimated from the permit value or the floor area: for the replacement cost, about half are obtained from the corrected permit value, the other half from the gross floor area.

### 4.4.5 Damage Cost

Damages incurred during earthquakes can be roughly divided into two categories: physical damage (repair cost) and nonphysical (incident) damage. The damage cost hereafter refers only to physical damage. While some data is derived from the Steinbrugge/Schader Report, damage repair permits, and the EQ-88 Report, most of the cost data is obtained from the Ayres Detailed Report and the survey questionnaires. The accuracy of the data from each data source is discussed next.

Since the questionnaire return is a voluntary response and the owners have been assured that the information will be used for a general statistical study only, it is reasonable to assume that the damage cost indicated in a questionnaire is the true figure or estimate. During the follow-up interviews it was learned that the extent of the damage does not affect the attitude of a person answering the questionnaire. The building owners were very cooperacive once they were convinced that the damage information would be kept confidential and that che study results could be very helpful to them. The covering letter from BOMA of Los Angeles undoubtedly helped greatly in this respect.

From a limited number of comparisons, the data from the MIT and MIT/BOMA Questionnaires agreed very well, while the data from the BOMA Questionnaires differed slightly from that of the MIT or MIT/BOMA Questionnaires. This difference is reasonable because the damage costs from the BOMA Questionnaires were estimated before the completion of the repair.

The Ayres Detailed Report covers the damage floor-by-floor, and the data is believed to be excellent.

The matching of buildings in the Steinbrugge/Schader report with buildings on the M.I.T. list was based on the writers' judgement and has not been confirmed by the authors of that report. While most of the damage costs estimated from the Steinbrugge/Schader Report agree well with those obtained from the questionnaire survey, substantial differences do exist in some cases. This is not totally unreasonable since Steinbrugge's damage costs were estimated before repair completion. Additionally, the chance of mismatching the buildings always exists.

The damage cost shown on the repair permit does not reflect the true amount, but rather is estimated to be abour $25 \%$ co $50 \%$ of the toral cost.

This practice is followed because the cost of the repair permit increases with the repair cost. Note that only structural damage repair requires application for a permit, while the nonstructural damage may be repaired without permit authorization, and hence may not be included in the data. Therefare, the damage costs from the repair permit are very unreliable and are not used in constructing the damage matrices.

Presumably, the assessed value reduction (from the County Assessor's Office) should equal one quarter of the total damage repair cost. The correlations between the assessed value reduction and the damage cost from the questionnaires for a number of buildings are shown in Fig. 4.9. It can be seen from the figure, that the assessed value reduction equals the damage cost in the average sense, and hence the assessed value reduction may be considered as the damage cost.

However, because it may bias the data population toward the damaged side, the information from the assessed value reduction has not been incorporated into the data base construction. Fig. 4.10 shows the difference between the damage distributions derived from the whole data base and from the EQ-88 Report.

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Table 4.1 Continued

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REDUCT MARKET VALUE
STRUCT DAMAGE
NON-STRUCT DAMAGE STEIN DAMAGE

Table 4.2

## STRUCTURE OF ORIGINAL DATA BASE DATA

DATA INFORMATION SOURCES
BLDG NO WIGGINS (modified by M.I.T.)
LOC WIGGINS
DATE WIGGINS, SP, BMQ, MIQ, MBQ, WERC
HT
WIGGINS, SP , LADP, BMQ, MIQ, MBQ, WERC
BLDG VALUE
SP, WERC, LACA
GROSS FLOOR AREA SSR, LADP, WERC
STRUCT TYPE
WERC, BMQ, MIQ, MBQ, SCHADER
STRUCT DAMAGE WIGGINS
NONSTRUCT DAMAGE ..... WIGGINS
STEIN NO* ..... SSR
STEIN DAMAGE ..... SSR
EERI NO ${ }^{+}$ ..... EERI
NOAA EERI NO ${ }^{+}$ NOAA EERI
ACCEL ..... EERI, NOAA EERI
FOUND TYPE

* The correspondence between BLDG NO and STEIN NO is given in Appendix A. This correlation is a "best judgement" made by the writers and has not been officially confirmed. It is probably accurate for about 54 out of 59 buildings cited in SSR.
${ }^{\text {the corespondence between BLDG NO and EERI NO and NOAA EERI is }}$ not given in this report so that buildings cannot be identified in the lists which contain damage information.


## Table 4.3

BUILDING COST INDEX (FROM ENGINEERING NEWS RECORD)

| YEAR | BASE YEAR $1913=100$ | FACTOR TO GET 1971 COST |
| :---: | :---: | :---: |
| 1971 | 943 | 1 |
| 1970 | 835 | 1.13 |
| 1969 | 790 | 1.20 |
| 1968 | 721 | 1.31 |
| 1967 | 676 | 1.40 |
| 1966 | 652 | 1.44 |
| 1965 | 627 | 1.51 |
| 1964 | 612 | 1.54 |
| 1963 | 594 | 1.59 |
| 1962 | 580 | 1.63 |
| 1961 | 578 | 1.64 |
| 1960 | 559 | 1.69 |
| 1959 | 548 | 1.72 |
| 1958 | 525 | 1.80 |
| 1957 | 509 | 1.86 |
| 1956 | 419 | 1.92 |
| 1955 | 469 | 2.01 |
| 1954 | 446 | 2.11 |
| 1953. | 431 | 2.19 |
| 1952 | 416 | 2.26 |
| 1951 | 401 | 2.35 |
| 1950 | 375 | 2.52 |
| 1949 | 352 | 2.68 |
| 1948 | 345 | 2.74 |
| 1947 | 313 | 3.02 |
| 1946 | 262 | 3.70 |



FIGURE G. BUILDNG LOCATION CODE ANO INTENSITY RONATION
兪要䔨
I



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章 ※ x






© 苟苞






（

| BLDG |  |  |  | BLDG | FOUND | BLDG | value | bldg | damage | damage | DAMAGE/ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NO | HT | date | LOC | TYPE | TYPE | FUNCT | CODE | value | CODE | COST | value |
| 1 | 19 | 1928 | 44 | S | -9 | 0 | 1 | 2400000 | 4 | 1300000 | 0.08667 |
|  |  |  |  |  |  |  | 3 | 3750000 |  |  |  |
|  |  |  |  |  |  |  | 5 | 15000000 |  |  |  |
|  |  |  |  |  |  |  | 6 | 15000000 |  |  |  |
| 2 | 15 | 1968 | 44 | s | 1 | 0 | 1 | 2800000 | 4 | 128000 | 0.03490 |
|  |  |  |  |  |  |  | 3 | 2550000 |  |  |  |
|  |  |  |  |  |  |  | 5 | 2550000 |  |  |  |
|  |  |  |  |  |  |  | 6 | 3668000 |  |  |  |
|  |  |  |  |  |  |  | 7 | 3500000 |  |  |  |
| 3 | 5 | 1962 | 44 | -9 | -9 | -9 | 0 | -9 | 0 | -9 | -9.00000 |
| 4 | 5 | 1936 | 4.4 | -9 | -9 | -9 | 0 | -9 | 0 | -9 | -9.00000 |
| 5 | 5 | 1927 | 44 | S | -9 | от | 1 | 68000 | 4 | 76638 | 0.01703 |
|  |  |  |  |  |  |  | 5 | 4500000 |  |  |  |
|  |  |  |  |  |  |  | 7 | 1708000 |  |  |  |
| 6 | 5 | 1920 | 44 | -9 | -9 | -9 | 0 | -9 | 0 | -9 | -9.00000 |
| 7 | 7 | 1924 | 44 | -9 | -9 | -9 | 0 | -9 | 0 | -9 | -9.00000 |
| 8 | 7 | 1932 | 44 | 5 | 4 | 0 | 5 | 8400000 | 4 | 212000 | 0.02524 |
|  |  |  |  |  |  |  | 6 | 8400000 |  |  |  |
| 9 | 6 | 1953 | 44 | c | 4 | OT | 4 | 4325000 | 3 | 0 | 0.0 |
| 10 | 5 | 1953 | 44 | -9 | -9 | -9 | 0 | -9 | 0 | -9 | -9.00000 |
| 11 | 19 | 1967 | 44 | $s$ | -9 | A | 1 | 9477000 | 4 | 920 | 0.00007 |
|  |  |  |  |  |  |  | 5 | 8000000 |  |  |  |
|  |  |  |  |  |  |  | 6 | 13267800 |  |  |  |
|  |  |  |  |  |  |  | 7 | 9477000 |  |  |  |
| 12 | 5 | 1926 | 34 | -9 | -9 | -9 | 0 | -9 | 0 | -9 | -9.00000 |
| 13 | 10 | 1965 | 44 | -9 | -9 | -9 | 1 | 1200000 | 0 | -9 | -9.00000 |
|  |  |  |  |  |  |  | 3 | 1450000 |  |  |  |





FIGURE AS DAMAGE RATIO VERSUS ASSESSED VALUE REDUETION FOR BUMDIGG AFFECTED BY THE SAN FERNANDO EARTHOUAKE, 1971

## DAMAGE DISTRIBUTION (\%)

| DAMAGE | EQ-88 $^{c}$ |  | WHOLE DATA |
| :---: | :---: | :---: | :---: |
| STATE | VERSION A* | VERSION $\mathrm{B}^{+}$ | BASE |
| 0 | 0 | 4 | 25 |
| 1 | 9 | 21 | 25 |
| 2 | 17 | 35 | 26 |
| 3 | 26 | 28 | 14 |
| 4 | 25 | 38 | 6 |
| 5 | 15 | 4 | 3 |
| 6 | 4 | 0 | 1 |
| 7 | 0 | 0 | 0 |

*Version A is computed by assuming: Repair cost $=$ Reduction value times 4 .
${ }^{+}$Version $B$ is computed by assuming: Repair cost $=$ Reduction value.

FIG. 4.10. DAMAGE DISTRIBUTIONS FOR ALL TYPES OF
BUILDINGS IN MMI VII ZONE OBTAINED FROM THE EQ-88
REPORT AND THE WHOLE DATA BASE.

## Chapter 5

## DATA ANALYSIS

Establishing a relacionship berween earthquake damage to high-rise buildings and ground motion incensity is the principal objective of this study. Since both the strength of a building and the local ground motion partern are to a large extent random in nature, it is not possible to obtain a deterministic relation between the damage state and the ground motion for a particular building. The most logical way is to proceed in a probabilistic manner and to establish a statistical relationship based on available damage data.

In so doing, buildings and the ground motion intensity must be categorized according to the pertinenc characteristics which relate to damage: damage is determined by a complex interaction between building and ground motion characteristics. The ideal approach is to combine the building and ground motion characteristics into a single parameter which correlates well with building damage and is useful to indicate the damage porential of an earthquake loading to a particular building system. Such a paramerer, however, is not presently available and the building and ground motion cacegorization must be made subjectively based on currenc pertinent knowledge. A precise categorization for both building and ground motion is very difficult, if not impossible, because of the great number of factors which affect the behavior of buildings during an earthquake. The building and ground morion categorization used for this study is discussed in section 5.1 .

The categorization of the building and ground motion makes it possible to construct a statistical relationship between the damage states and the ground motion intensity for a particular class of buildings. The damage matrices described below represent such relations. The damage macrices are essencially the lumped probability densicy functions of the damage cost rario (the ratio of the total damage cost to the building value) and from them the building damage behavior may be discerned.

In addition to the information concerning the cotal damage cost, it is also desirabie to investigate the damage cost in view of different damage
components, so that effective design procedures may be implemented to reduce the cotal damage in a future earthquake. The component damage macrices as described in section 5.2 are constructed for this purpose.

### 5.1 DAMAGE MATRICES

A typical damage probability matrix has been shown in Fig. 2.2. Each column of the matrix represents the probability of incurring the given damage states for buildings belonging to a particular category under the excitation of a certain earthquake intensity. The sum of each column is always unity. The whole matrix in turn represents the probability of incurring the damage states under all ranges of the earthquake intensities for a particular building category.

Because of the difficulties in obtaining enough accurate damage information and in categorizing buildings and ground motion intensity, it is hardly possible to establish a set of damage matrices which have small (say less than 0.5 ) coefficients of variation and/or which can be used co describe the earthquake damage behavior observed in other areas. However, this study does represent the first effort of this kind and provides a valid understanding of damage behavior of high-rise buildings, at least those in Southern California, under earthquake loading.

For many purposes, it will suffice to condense the information in each column of the matrix into a single quantity: the mean damage ratio (MDR). As used in this report, the mean damage ratio is computed on the average of the damage ratios for all buildings in a particular category subject to the specified intensity. That is, in this report:

$$
\mathrm{MDR}_{I}=\frac{1}{\mathrm{n}_{\mathrm{I}}} \sum_{\mathrm{i}=1}^{\mathrm{n}_{I}} \mathrm{DR}_{i I}
$$

where $n_{I}=$ cotal number of buildings in a particular category subject to ground motion intensity, I.
$D R_{i I}=$ damage ratio for the $i^{\text {th }}$ buildings in a particular category and subject to ground motion intensity $I$.

An alternative method for computed $\mathrm{MDR}_{\mathrm{I}}$ would be:

$$
\mathrm{MDR}_{I}=\sum_{S=0}^{8} \quad \mathrm{P}_{\mathrm{SI}} \mathrm{CDR}_{\mathrm{S}}
$$

where $P_{S I}=$ probability that a building of a particular type will experience damage state $S$ when subject to ground motion intensity I.
$C D R_{S}=$ central damage ratio for damage state $S$ (see Table 2.1). This alternative method is not used in this report. The two methods will yield similar but not identical values.

For this study, the type of construction is divided into steel and concrete to give a general indication of the ductility of the building. There were insufficient brick masonry buildings to justify treacing such buildings in a separate category. The ductility, of course, varies from building to building for each type of construction and hence it would be desirable to obtain a more uniform grouping of buildings to furcher classify the buildings according to particular structural systems, e.g., concrete shear wall construction, concrete duccile frame construction, etc. However, the limited amount of data available does not warrant a breakdown according to the particular structural systems.

The building height is used to estimate a range for the fundamental frequency of the building. It is divided inco four categories, namely: 5 to 7,8 to 13,14 to 18 , and 19 scories or higher. In addicion, matrices have been computed for all buildings taken together. The classification is largely subjective as discussed in section 3.3 ; refinement is impractical for the limited amounc of data presently available.

The foundation type gives an indication of the local soil properties and could be a very important factor in a complicated geological locarion. However, the effect of the foundacion type is neglected because of (a) limited information on the foundation type and (b) the fairly consistent geological conditions (ac least in a gross sense) in the Los Angeles area.

The design code provision is characterized by reference co the Uniform Building Code (UBC): Zone 0 of UBC (no earthquake provision) for the pre-1933 buildings and Zone 3 of UBC for the post-1947 buildings. The years between

1933 and 1947 are a transition period in the earthquake code evolution and the variations in earthquake resistance in this period are discussed in Appendix D. Because only a few high-rise buildings were built during the Depression and World War II, the age category $1934-1946$ was omitted in the analysis.

The building categorization is summarized in Table 5.1. For each intensity zone, damage probabilities and mean damage ratios were determined for each of the 45 combinations represented by this table.

### 5.1.1 Building Categorization

For purposes of this study, the primary factors influencing the response of a high-rise building to an earchquake are:

1. The type of building construction
2. Natural periods of the building
3. Foundation cype
4. Design seismic resistance

Building height will be used as an indicator of natural period, while building age will be used as an indicator of design seismic resistance.

### 5.1.2 Ground Motion Intensity

Since the invention of the strong motion recorder, the incensity of earthquake ground motion can be described in two ways: a qualitative measure such as the modified Mercalli intensity scale and a quantitative measure such as the maximum ground acceleration. Various intensity scales in each category have been proposed in past years; yet none of them is perfect by itself. As a first step in this effort, the modified Mercalli intensity, the most popular qualitative intensity scale used in the United Staces, is used in this study. The attempt to use a quanticative measure of the ground motion intensity will be the subject of another report. A description of the modified Mercalli intensity scale is shown in Fig. 2.3.

Because modified Mercalli incensicy involves a very subjective evaluation, inevitably there was some difficulty in assigning intensities to each location zone. The isoseismals used for chis study have been indicared in Fig. 1.1 and the corresponding relationship between location code and intensity has been shown in Fig. 4.1. While the buildings in the epicentral region (location
codes 2 and 3) are included in the data base, they have been excluded from the statistical analysis presenced in chis report.

The isoseismal lines in Fig. 1.1 were sketched by the writers using the preliminary isoseismal map by Scott (1970). Scott's original map covered a large area of California, and the writers applied considerable judgement, based upon their own observations of damage, in refining the isoseismals to make them applicable to the smaller area of interest in this study. When shown Fig. I.I, Scott suggested the revisions indicated in Fig. 5.la. If Scotc's suggestions were to be followed, the implication would be virtual elimination of intensity zone VIII. For purposes of this study, it was decided to stick ro the version in Fig. 1.1; this point is discussed furcher in section 5.3.3.

The NOAA version of the epicencral incensities shows values from VIII to XI (see Fig. 5.1b). However, many of the intensities appearing on this map are influenced by observed damage to high-rise buildings and must be creaced with care.

Of course, the damage matrices can at any time be recomputed using a different relationship between locacion code and intensity. However, the best prospect for clarification of this confusion lies in development of a quanticacive measure of intensity of ground motion.

### 5.1.3 Computation of the Damage Matrices

A computer program has been developed which computes damage probability matrices by height, age, strucrural cype, and foundarion rype groupings. In constructing the matrices, there are several sources of information available for boch damage costs and building values. The various damage cost and building value sources are explained in detail in Chapter 4. Boch the damage cost and building value sources can be searched for in any prespecified order and their values scaled by a prescribed factor. Therefore, in che compuration of a given matrix, several damage sources can be selected and searched in a predecermined order. Similarly, building value sources can also be selected.

Two sets of damage matrices have been generated based on the replacement cost and on the marker value. There are approximately 370 buildings for which boch damage cost and building value information, along with ocher building characteristics, are available. The searching order is:
MIT/BOMA QuestionnaireMIT QuestionnaireBOMA QuestionnaireSteinbrugge Damage
for the damage costs, and
Corrected Permit Value
MIT/BOMA Area ( $\times \$ 25 / \mathrm{ft}^{2}$ )
MIT Area ( $\times \$ 25 / f t^{2}$ )
Data Base Area ( $\times \$ 25 / f \tau^{2}$ )
Markec Value (assessed value $\times 4$ )
for the building values of the replacement cost version and
Marker Value (assessed value $\times 4$ )
Corrected Permit Value
MIT/BOMA Area ( $\times \$ 25 / \mathrm{ft}^{2}$ )
MIT Area ( $\times \$ 25 / \mathrm{ft}^{2}$ )
Data Base Area ( $\times \$ 25 / \mathrm{ft}^{2}$ )
for the building values of the market value version.
The replacement cost version and the market value version of the damagematrices are summarized in Figs 5.2 and 5.3, respectively. Note that allprobabilities and mean damage ratios are expressed as percentages. The meandamage ratios of the marker value version are almost twice as high as those ofthe replacement cost version.
An alternate way to present the damage data is to group the data according to geographic location of the buildings racher than according to building category. In this way all damage data are presenced in a single matrix with each column of the matrix representing the distribution of damage ratios for one particular area. The replacement cost version of chese damage ratio distributions has been computed for both the pre-1933 and post-1947 buildings. The number of buildings, the mean damage ratio, and the standard deviation for each area are summarized in Fig. 5.4.

### 5.2 COMPONENT DAMAGE MATRICES

The damage information for a parcicular building category in a certain intensity zone are lumped together and rearranged to show the percentage of the component damage cost in relation to the total damage. Because the damage components breakdown of the MIT/BOMA Questionnaires is different from that of the MIT and the BOMA Questionnaires, two sets of component damage matrices are creaced. The first sec, designared as Version $A$, uses only the MIT/BOMA Questionnaires, while the second set, designated as Version $B$, employs all of the survey questionnaires, $i . e .$, the MIT/BOMA, MIT and BOMA Questionnaires. For Version $A$, damage is divided into 11 components: structural, mechanical, electrical, elevator, ornamentation, partition, ceiling, exterior walls, glass, paincing, and others. For Version $B$, damage is divided inco only five components: structural, mechanical, electrical, elevator, and others. The term "others" covers all those not included in the previous components in each set. Sample matrices of Versions $A$ and $B$ are given in Fig. 5.5 and Fig. 5.6. respectively. Each row of the component matrix represents the probability of incurring the given component damage ratio (component damage cost to the rotal damage cost) for buildings belonging to a particular category. The sum of each row is always unity. The mean component damage ratio and its scandard deviation for each component are also given (as \%) at the right end of the matrix and the sum of the mean component damage ratio is always $100 \%$. Some representative component matrices are selected and presented in Appendix $I$. The mean component damage ratios from Versions $A$ and $B$ are sumarized in Figs 5.7 and 5.8, respectively.

The building damage may be considered to be closely related to the maximum inter-story displacement and the maximum acceleration which the building experienced during the earthquake excitation. The mechanical, electrical, and elevator damage may be more closely related to the maximum acceleration, while the other components are more closely related to the maximum inter-story displacement.

In general, for buildings in intensity zone VI, the damage was about $5 \%$ structural, $5 \%$ elevacors, and $90 \%$ partitions and finish. For newer buildings in zone VII, these numbers were approximately $20 \%$ structural, $5 \%$
mechanical, $10 \%$ elevacors and $65 \%$ particions and finish. In zone VIII, even though the total dollars spent for repairs increased, the percentage of these repairs spent on structural damage decreased compared to zone VII. These results may be compared with those compiled by Steinbrugge (1972) for 27 buildings mostly in zone VII: $3 \%$ to $25 \%$ structural, $48 \%$ to $56 \%$ interior finish, $23 \%$ to $34 \%$ extexior finish, and $4 \%$ to $7 \%$ for mechanicalelectrical.

### 5.3 DISCUSSION OF THE DAMAGE MATRICES

As stated previously, the damage matrices are probabilistic statements relating earthquake intensity to damage state for each particular building category, while the component damage matrices illustrate the damage distribution among the various damage components. The confidence level of these distribution matrices depends on the amount of data available and on the complexity of the building groupings. Even though it may not be possible to place great confidence upon each number in the matrices, the general pattern of the damage behavior may be examined and the mean damage ratio may be used with reasonable confidence. The following discussion is based mainly on the variation of the mean damage ratios while the damage matrices are used to detect some abnormal behavior of the mean damage ratio and to substantiate explanations. The mean component damage ratio and the component damage matrices are discussed in a similar way. The following discussions are based on the damage matrices of the replacement cost version

### 5.3.1 Damage Behavior in MMI VI Zone

The MMI VI zone covers a large area as shown in Fig. 1.1 and chere are a great number of high-rise buildings in this area. However, because most of the buildings suffered very litcle or no damage, less effort has been devored to the collection of data in this area. As a result, there are only 76 buildings with complete damage information located in this zone. The distribution of the buildings in each category is shown in Fig. 5.2.

A study of the damage matrices reveals that most of the buildings suffered no damage at all. All of the building categories, except the

8- co 13-story, post-1947 concrete buildings which had a mean damage ratio of $0.15 \%$, recorded a mean damage ratio of less than $0.1 \%$. The overall average damage ratio was $0.06 \%$ 。

Upon examination of the component damage ratios, it appears that painting, partitions, and glass were the major damage components, while the structural damage, mechanical damage, electrical damage, and elevator damage are negligible. It appears that the damage is closely related to the inter-story displacement and the flexibility of the partition walls and glass panels. At this level, the structural strength is not an important factor in the extent of building damage. Improvement of the flexibility of the partition wall and the glass panel may be one of the most effective ways to reduce the cotal damage in MMI VI.

Based on the damage matrices, some observations follow:

1. The performance of the pre-1933 buildings was superior to that of the post-1947 modern buildings, especially in the case of concrete buildings. The possible explanations are that the modern partition wall and glass panel construction is weaker than their councerparts in the old construction and/or that the old buildings are stiffer than the new ones and hence less inter-story displacement incurred during the earthquake.
2. The post-1947 steel buildings suffered less damage than did the post-1947 concrete buildings. This is consistent for all height categories. It is not clear why the partition wall and the glass panel of a modern concrete building is weaker than that of a modern steel building.
3. The 8- to 13-story buildings had higher damage than other height categories. This is true for both steel and concrece buildings. This observation may be related to the predominant period of the ground motions at a moderate distance from the epicenter.

### 5.3.2 Damage Behavior in MMI VII Zone

As shown in Fig. 1.1, this zone covers downtown Los Angeles and some highly populated areas. Most of the very rall buildings are located in this area. Because the buildings suffered from light to severe damage, considerable data gathering effort has been devoted to this area and there are 275 buildings with complece damage information located here. The damage statistics
generated from this zone are much more reliable than those from the other two intensity zones.

It is apparent from the damage matrices that only $20 \%$ of the buildings were free from damage and that the post-1947 modern buildings performed quice satisfactorily while the old pre-1933 buildings reported very high repair costs. Some of the pre-1933 buildings were very close to collapse. A study of the mean component damages shows that the painting and partition wall still accounted for the major part of the repair cost, but structural damage and elevator damage both represented a sizable portion. The wide scatter of the component damage matrix values reveals that the damage patcern varied greatly from building to building. This may imply that the earchquake damage is always going to occur in the weakest part of the structure owing to improper design or bad workmanship, and it is always possible to reduce the earthquake damage by paying attention to detailing and workmanship. Some observations from the damage and component matrices follow:

1. The most striking point from the damage matrices is that the pre-1933 buildings, both concrete and steel structures, suffered moderate damage and recorded a mean damage ratio of $2.75 \%$, while the post-1947 buildings had only light damage with a mean damage ratio of $0.5 \%$. The extent of damage of the old buildings is 5.5 times that for the modern buildings. This may result from the following:
a. The effectiveness of the earthquake design provision in reducing the earthquake damage.
b. In repairing the structural damage of the old buildings, it is a common practice to not only bring the strength to the previous scate, but also to reinforce it to reach the strength required by the current building code.
c. Many defects and cracks existed in the old buildings before the earthquake. Owners took the opportunity, when repairing the earthquake damage, to refinish che building and reported these costs as part of the earthquake damage. It is very difficult indeed to separate earthquake and non-earthquake damages at the time of repairing.
2. For the post-1947 modern buildings, there is a general trend that the taller the building, the lighter the damage (see Fig. 5.9). It is
probably because the UBC code is more conservative for the caller buildings and the wind force consideration, instead of the earthquake provision, may govern the design for lateral resistance for the faller buildings.
3. In general, concrete structures suffered higher damages than their steel building councerparts (see Fig. 5.9). Also, concrete buildings suffered a higher degree of structural damage than the steel buildings. This seems to be reasonable since yielding is more visibly evident in concrete members than in steel members.
4 . The elevator damage was approximately $10 \%$ of the cotal cost of all building categories. It is worthwhile to note that the elevator damage is not uniformly distributed among the buildings but rather concentrated in a few buildings. Since the function of the elevator is of vital importance to the tall buildings especially in the case of emergency, it is advisable to improve the elevator design to eliminate the possibility of elevator failure during severe earthquake. Addicionally, the failure of an elevator may cause much inconvenience and employee time loss.

### 5.3.3 Damage Behavior in the Epicentral Region

The modified Mercalli intensities in the epicentral area according to the intensity rating by the Seismological Field Survey, NOAA, is shown in Fig. 5.1.b. Also shown in Fig. $5.1 . b$ are the area codes as defined in Fig. 4.1. the locations of the high-rise buildings with damage informations and the boundary lines of the intensity zone used in chis scudy. Since the high-rise buildings with damage information are located only in areas 2, 7, 15 and 16, the discussion hereafter will be mainly focussed on these four areas.

The high-rise buildings in area 2 were all heavily damaged: The Olive View Hospital nearly collapsed, the Holy Cross Hospital suffered very severe damage and may yet be demolished, and the Indian Hill Medical Center sustained a damage ratio of $26 \%$. All three buildings were modern reinforced concrece construction. Therefore, no comparison of the behavior of steel and concrete structures can be made. The details of the damages co these buildings are available in other publications, e.g., The Engineering Features of the San

Fernando Earthquake, Feb. 9, 1972, EERI. The intensity at the locations of these three buildings was rated as MMI X. A multi-story tower at the Pacoima Memorial Lutheran Hospital (area 3, intensity IX) was also very severely damaged and was demolished.

Even chough the intensities in the areas of $7,15,16$ and 17 were rated as MMI VII by the Seismological Field Survey, it was decided to include these areas in the MMI VIII zone for this study for the following reasons:

1. Even though the damage to modern steel buildings in this area was comparable to the damage observed in MMI VII zone, the modern concrete construction suffered a much higher degree of damage than was recorded in the MMI VII zone.
2. There would be no damage data at all for MMI VIII if these areas are included in MMI VII. The inclusion of these areas inco MMI VII does not affect the damage matrices for MMI VII to a major extent as shown in Fig. 5.10.
3. At their minimum, the intensity of these areas was right on the boundary line becween MMI VII and MMI VIII. It seems reasonable to use the damage data in these areas as a representative measure of the damage behavior in the MMI VIII zone, at least as a lower bound.

One lesson we may learn from the building damage behavior in the epicentral area is that the steel structures suffered far less damage than the concrete buildings did at high levels of ground motion intensity.

### 5.3.4 Additional Observations

For the older steel buildings in MMI VII (see Fig. 5.9) and also in MMI VI, the damage to 8- to 13-story buildings exceeded the damage to 5-to 7-story buildings. Considering all post-1947 buildings, the mean damage ratio attenUates more rapidly with distance for 5 - to 7 -story buildings than for $8-$ to 13-story buildings outside the epicentral region (see Fig. 5.11). The observations may be related to differences in the rate of attenuation of high and low frequency components of the ground motion. The trend was reversed in the epicentral region. It seems, however, that the limited amount of data available in the epicentral region is not sufficient to provide a confident estimate.
Table 5,1
SUMMARY OF BUILDING CATEGORIES

| BUILDING | BUILDING | FOUNDATION | DESIGN |
| :--- | :---: | :---: | :---: |
| TYPE | HEIGHT | TYPE | STRATEGY |
| All types | AIl heights | AII types | AIl buildings |
| Steel | $5-7$ |  | Pre-1933 |
| Concrete | $8-13$ |  | $1947-1971$ |
|  | $14-18$ |  |  |



FIGURE 5.lO ALTERNATE YERSION OF THE ISOSEISMAL MAP OF THE SAN FERNAMDO EARTHOUAKE

FIGURES.H MODIEIED MERGALLI NNTENSITUS IN THE EPGENTRAL REGON 1972)


[^1]|  |  |  |  | $00000000000$ | $\left\|\begin{array}{llllllllll} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 \end{array}\right\|=$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\stackrel{ }{5}$ | $=\left[\begin{array}{c} \infty \\ 0 \\ 0 \\ 0 \end{array}\right.$ |  |  |  |  |  |
|  |  |  |  |  | $\left.\begin{array}{l} \text { A } \quad \text { in } \\ \boldsymbol{N} \\ \hline \end{array}\right]$ |  |
|  |  |  |  |  | $\left.\begin{array}{llllllllll} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \stackrel{\circ}{0} & 0 \\ 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \\ 0 & 0 & & \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \stackrel{0}{0} & 0 \\ 0 & 0 & 0 & -1 \end{array} \right\rvert\,$ |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  | 00000000000 |  |
|  |  |  |  |  |  |  |
| THOT |  |  |  | $8{ }^{\text {T-7T }}$ | +6T |  |

PRE-1933
POST-1947


FIG. 5.4. SUMMARY OF MEAN DAMAGE RATIO FOR EACH AREA, REPLACEMENT COST VERSION

|  | MMI | VI |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | AGE | PRE－1933 |  |  | POST－1947 |  |  | ALL |  |  |
|  | StRUCT TYPE | ALL | C | S | ALL | C | S | ALL | C | S |
|  | 0 | 90 | 100 | 80 | 86 | 86 | 85 | 88 | 90 | 83 |
|  | 1 | 10 | 0 | 20 | 14 | 14 | 14 | 12 | 10 | 17 |
|  | 塁 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 或3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| it | ） 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | \％ 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | －6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | M．D．R． | 0.0003 | 0 | 0.0006 | 0.0003 | 0.0002 | 0.0003 | 0.0003 | 0.0002 | 0.0004 |
|  | St deviation | 0.0008 | 0 | 0.0011 | 0.0006 | 0.0005 | 0.0006 | 0.0007 | 0.0005 | 0.0008 |
|  | No OF bldcs | 10 | 0 | 5 | 14 | 7 | 7 | 24 | 10 | 12 |
| $\left.\begin{aligned} & n \\ & 1 \\ & \infty \end{aligned} \right\rvert\,$ | 0 | 78 | 80 | 75 | 75 | 46 | 94 | 74 | 56 | 86 |
|  | 1 | 11. | 20 | 0 | 14 | 27 | 6 | 13 | 25 | 5 |
|  | ＊ 2 | 11 | 0 | 25 | 7 | 18 | 0 | 11 | 13 | 9 |
|  | 委3 | 0 | 0 | 0 | 4 | 9 | 0 | 3 | 6 | 0 |
|  | －4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | \％ 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | － 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | M．D．R． | 0.0010 | 0.0002 | 0.0021 | 0.0012 | 0.0027 | 0.0002 | 0.0013 | 0.0019 | 0.0008 |
|  | ST DEVIATION | 0.0026 | 0.0004 | 0.0036 | 0.0033 | 0.0049 | 0.0006 | 0.0033 | 0.0042 | 0.0022 |
|  | NO OF BLDGS | 9 | 5 | 4 | 28 | 11. | 1.7 | 38 | 16 | 22 |
| $\left.\begin{array}{r\|} \infty \\ \\ 1 \\ -1 \\ -1 \end{array} \right\rvert\,$ | 0 | 0 | 0 | 0 | 75 | 67 | 83 | 75 | 67 | 83 |
|  | 1 | 0 | 0 | 0 | 25 | 33 | 17 | 25 | 33 | 17 |
|  | 压 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 安 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 近 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | M．D．R． | 0 | 0 | 0 | 0.0007 | 0.0009 | 0.0005 | 0.0007 | 0.0009 | 0.0005 |
|  | St deviation | 0 | 0 | 0 | 0.0012 | 0.0013 | 0.0010 | 0.0012 | 0.0013 | 0.0010 |
|  | NO OF BLDGS | 0 | 0 | 0 | 12 | 6 | 6 | 12 | 6 | 6 |
| す | 0 | 0 | 0 | 0 | 67 | 0 | 100 | 67 | 0 | 100 |
|  | 1 | 0 | 0 | 0 | 33 | 100 | 0 | 33 | 100 | 0 |
|  | 思 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | ${ }_{\circ}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 1 戒 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 咎 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | M．D．R． | 0 | 0 | 0 | 0.0003 | 0.0007 | 0.0001 | 0.0003 | 0.0007 | 0.0001 |
|  | St deviation | 0 | 0 | 0 | 0.0003 | 0.0 | 0.0001 | 0.0003 | 0.0 | 0.0001 |
|  | No Of bldes | 0 | 0 | 0 | 3 | 1 | 2 | 3 | 1 | 2 |
| 匂 | 0 | 84 | 88 | 78 | 77 | 60 | 91 | 78 | 67 | 86 |
|  | 1 | 11 | 1.3 | 11 | 18 | 28 | 9 | 16 | 24 | 10 |
|  | 留 2 | 5 | 0 | 11 | 4 | 8 | 0 | 5 | 6 | 5 |
|  | － | 0 | 0 | 0 | 2 | 4 | 0 | 13 | 3 | 0 |
|  | －管4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 发 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | M．D．R． | 0.0006 | 0.0001 | 0.0012 | 0.0008 | 0.0015 | 0.0003 | 0.0009 | 0.0012 | 0.0006 |
|  | St deviation | 0.0019 | 0.0004 | 0.0026 | 0.0024 | 0.0035 | 0.0007 | 0.0024 | 0.0031 | 0.0017 |
|  | No or bldgs | 19 | 8 | 9 | 57 | 25 | 32 | 77 | 33 | 42 |

FIG．5．3．SUMMARY OF MEAN DAMAGE RATIO，MARKET VALUE VERSION
＊Data for damage states expressed in percentage．M．D．R．＇s and standard $\therefore$
STRUCTURAL TYPE: S


| $\%$ | OF |
| :---: | :---: |
| TOTAL DAMAGE |  |
| MEAN | STN DEVIATION |
| 2.50 | 2.50 |
| 5.00 | 5.00 |
| 5.00 | 5.00 |
| 0.0 | 0.0 |
| 87.50 | 12.50 |


|  | mMI | vi |  |  |  |  |  |  |  |  | VII |  |  |  |  |  |  |  |  | VIII |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | AGE | PRE-1933 |  |  | Post-1947 |  |  | ALL |  |  | PRE-1933 |  |  | POST-1947 |  |  | ALL |  |  | POST-1947 |  |  |
|  | Struct type | ALL | c | s | ALL | c | $s$ | ALL | c | s | ALI | c | s | ALL | c | 5 | ALL | C | S | ALL | C | S |
| in | Structural | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 14 | 10 | 20 | 28 | 13 | 18 | 24 | 12 | 32 | 52 | 3 |
|  | MECHANICAL | 0 | 0 | 0 | 8 | 15 | 0 | 8 | 15 | 0 |  | 4 | 5 |  | 7 | 9 | 7 | 6 | 8 | 9 | 8 | 9 |
|  | ELECTRICAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $0+$ | 0 | 1 | 1 | 04 | 1 | $0+$ | $0+$ | 1 | 1 | 2 | 1 |
|  | elevator | 0 | 0 | 0 |  | 0 | 100 | 50 | 0 | 100 | 7 | 11 | 1 |  | 12 | 11 | 10 | 11 | 9 | 7 | 1 | 17 |
|  | ornament | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 8 | 19 | 2 | 2 | 3 | 5 | 4 | 6 | 4 | $0+$ | 9 |
|  | Partition | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 22 | 6 | 19 | 15 | 22 | 18 | 17 | 19 | 11 | 16 | 4 |
|  | CEILING | 0 | 0 | 0 | 8 | 15 | 0 | 8 | 15 | 0 | 3 | 1 | 6 | 7 | 5 | 9 | 6 | 3 | 9 | 1 | O+ | 2 |
|  | Exterior | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 7 | 1 | 1 | 2 | 1 | 2 | 3 | 1 | 5 | $0+$ | 11 |
|  | glass | 0 | 0 | 0 | 2 | 5 | 0 | 2 | 5 | 0 | 5 | 7 | 1 | 2 | 3 | 2 | 3 | 4 | 2 | 2 | 4 | $0+$ |
|  | painting | 0 | 0 | 0 | 27 | 55 | 0 | 27 | 55 | 0 | 33 | 25 | 48 | 24 | 23 | 24 | 27 | 25 | 29 | 18 | 10 | 29 |
|  | OTHER | 0 | 0 | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 2 | 2 | 2 | 5 | 3 | 5 | 4 | 3 | 4 | 10 | 7 | 15 |
|  | so OF bldg | 0 | 0 | 0 | 2 | 1 | 1 | 2 | 1 | 1 | 11 | 7 | 4 | 27 | 12 | 15 | 40 | 21 | 19 | 10 | 6 | 4 |
| $\stackrel{\cdots}{\substack{n}}$ | STRUCTURAL | 0 | 0 | 0 | 8 | 0 | 15 | 4 | 0 | 8 | 8 | 11 | 5 | 18 | 22 | 13 | 12 | 17 | 8 | 34 | 17 | 50 |
|  | mechamical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | $0+$ | 1 | 7 | 8 | 7 | 4 | 4 | 4 | 1 | 0 | 2 |
|  | electrical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | $0+$ | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
|  | elevator | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 5 | 11 | 7 | 2 | 14 | 8 | 3 | 12 | 14 | 4 | 25 |
|  | ornament | 0 | 0 | 0 | 8 | 0 | 15 | 4 | 0 | 8 | 6 | 7 | 5 | 6 | 3 | 9 | 5 | 5 | 6 | 0 | 0 | 0 |
|  | Partition | 24 | 0 | 47 | 42 | 70 | 15 | 33 | 35 | 31 | 22 | 23 | 20 |  | 18 | 12 | 19 | 20 | 17 | 2 | 0 | 4 |
|  | ceiling | 0 | 0 | 0 | 12 | 0 | 25 | 6 | 0 | 12 | 5 | 6 | 2 | 4 | 3 | 7 | 5 | 4 | 4 | 0 | 0 | 0 |
|  | Extertor | 0 | 0 | 0 | 10 | 0 | 20 | 5 | 0 | 10 | 9 | 7 | 12 | 4 | 5 | 3 | 7 | 6 | 8 | 0 | 0 | 0 |
|  | class | 6 | 0 | 12 | 0 | 0 | 0 | 3 | 0 | 6 | 2 | 2 | 3 | 11 | 11 | 10 | 7 | 8 | 6 | 0 | 0 | 0 |
|  | painitig | 70 | 100 | 41 | 20 | 30 | 10 | 45 | 65 | 25 | 35 | 34 | 38 | 19 | 19 | 19 | 27 | 26 | 30 | 5 | 0 | 10 |
|  | OTHER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 3 | 7 | 8 | 4 | 5 | 6 | 4 | 44 | 79 | 9 |
|  | vo OF BLDC | 2 | 1 | 1 | 2 | 1 | 1 | 4 | 2 | 2 | 33 | 15 | 17 | 29 | 17 | 12 | 63 | 33 | 29 | 2 | 1 | 1 |
| $\stackrel{\infty}{\underset{\sim}{ \pm}}$ | strictural | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | michanical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 2 | 0 | 2 | 0 | 0 | 0 |
|  | electrical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 7 | 3 | 0 | 5 | 0 | 0 | 0 |
|  | elevator | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 70 | 1 | 24 | 70 | $0+$ | 0 | 0 | 0 |
|  | ORMAMEYT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | partition | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 20 | 40 | 15 | 57 | 37 | 15 | 48 | 0 | 0 | 0 |
|  | Ceiling | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 20 | 5 | 8 | 3 | 7 | 8 | 8 | 0 | 0 | 0 |
|  | EXTERIOR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 2 | 0 | 2 | 0 | 0 | 0 |
|  | glass | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | painting | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | 60 | 5 | 7 | 3 | 14 | 7 | 18 | 0 | 0 | 0 |
|  | OTHER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 23 | 11 | 0 | 17 | 0 | 0 | 0 |
|  | No OF BLDG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | 2 | 3 | 6 | 2 | 4 | 0 | 0 | 0 |
| $\stackrel{+}{d}$ | Strectural | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 22 | 19 | 0 | 20 | 0 | 0 | 0 |
|  | mechantcal | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
|  | electrical | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
|  | elevator | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 13 | 0 | 14 | 12 | 0 | 13 | 0 | 0 | 0 |
|  | orvament | 0 | 0 | 0 | 10 | 10 | 0 | 10 | 10 | 0 | 36 | 0 | 36 | 3 | 0 | 3 | 5 | 0 | 5 | 0 | 0 | $\sim$ |
|  | partition | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 50 |  | 0 | 26 | 26 | 0 | 28 | 6 | 0 | - |
|  | ceiling | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | $\bigcirc$ | 0 | - |
|  | EXTERIOR | 0 | 0 | 0 | 0 | 0 |  | $\bigcirc$ | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 3 | 0 | 3 | 0 | 0 | 2 |
|  | giass | 0 | 0 | 0 | 90 | 90 | 0 | 90 | 90 | 0 | 1 | 0 | 1 | $0+$ | 0 |  | $0+$ | 0 | $0+$ | 0 | 0 | 0 |
|  | paintixg | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 10 | 0 | 10 |  | 95 | 28 | 31 | 95 | 27 | 0 | 0 | 0 |
|  | other | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 1 | 1 | 5 | 1 | 0 | 0 | 0 |
|  | yo of bldg | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 16 | 1 | 15 | 17 | 1 | 16 | 0 | 0 | 0 |
| $\dot{\vec{x}}$ | Structural | 0 | 0 | 0 | 3 | 0 | 8 | 2 | 0 | 5 | 8 | 12 | 5 | 18 | 22 | 15 | 14 | 18 | 12 | 32 | 47 | 12 |
|  | :Echanical | 0 | 0 | 0 | 3 | 5 |  | 2 | 4 | 0 | 1 | 1 |  | 6 | 7 |  | 4 | 4 | 4 | 8 |  | 8 |
|  | electrical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $0+$ | 1 |  | 1 |  | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
|  | Elevator | 0 | 0 | 0 | 20 | 0 | 50 | 14 | 0 | 33 | 8 | 7 | 9 |  | 10 | 12 | 10 | 8 | 11 | 8 | ; | 19 |
|  | ORCAME.ST | 0 | 0 | 0 | 5 | 3 |  | 4 | 2 | 5 | 8 | 7 | 8 | 4 | ? | 4 | 5 | 4 | 6 | 3 | $0+$ | 7 |
|  | partition | 24 | 0 | 47 | 17 | 23 | 7 | 18 | 18 | 21 | 21 | 23 | 19 | 20 | 16 | 23 | 1 | 19 | 22 | 10 | 24 | 4 |
|  | ceilimg | 0 | 0 | 0 | 5 | 5 | 12 | 6 | 4 | 8 | 5 | 4 | 4 | 5 | 4 | 6 | 5 | 4 | 5 | i |  | 2 |
|  | Extertior | 0 | 0 | 0 | 4 | 0 |  | 3 | 0 | 7 | 8 | 7 | 9 | 3 | 4 | 2 | 4 | 5 | 4 | 4 | 1 | 8 |
|  | glass | 6 | 0 | 12 | 19 | 32 |  | 15 | 24 | 4 | 3 | 4 | 2 | 5 | 7 | 3 | 4 | 6 | 3 | 2 | 3 |  |
|  | paimting | 70 | 0 | 41 | 19 | 28 | 5 | 34 | 46 | 17 | 35 | 31 | 39 | 22 | 22 | 23 | 27 | 26 | 28 | $\bigcirc 5$ | 9 | 25 |
|  | OTHER | 0 | 100 | 0 | 2 | 4 |  | 2 | 2 | 0 | 3 | 3 |  | 5 | 6 |  | 4 | 5 | 4 | 16 | 17 | 14 |
|  | NO Of bldg | 2 | 1 | 1 | 5 | 3 | 2 | 7 | 4 | 3 | 46 | 22 | 23 | 77 | 32 | 45 | 126 | 57 | 68 | 12 | 7 | 5 |

FIG. 5.7. SUMMARY OF THE MEAK COMPONENT DAMAGE RATIO, VERSION A

| $<1933$ | $>1347$ |
| :---: | :---: |
| sfeelo | 0 |
| concruie | 耳 |



FIGURE 5. VAREATION OF DARAGE WTH BULLDING MEIGHT FOR

INTENSITY VII

| ZONATION |  |  | AS IN FIG． 1.1 |  |  |  |  | ALTERNATE ISOSEISMAL IN FIG．5．1a |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| MMI |  |  | VII |  | VIII |  |  | VII |  |  | VIII |  |  |
| G | AGE | POST－1947 |  |  |  |  |  | POST－1947 |  |  |  |  |  |
| $\left\lvert\, \begin{aligned} & \text { 臭 } \end{aligned}\right.$ | $\begin{gathered} \text { STRUCT } \\ \text { TYPE } \end{gathered}$ | ALL | C | S | ALL | C | S | ALL | C | S | ALL | C | S |
|  | 0 | 24 | 21 | 24 | 0 | 0 | 0 | 19 | 17 | 17 | 0 | 0 | 0 |
|  | 1 | 27 | 26 | 28 | 25 | 0 | 38 | 29 | 23 | 31 | 0 | 0 | 0 |
|  | ＊ 2 | 27 | 16 | 38 | 50 | 25 | 62 | 29 | 17 | 46 | 0 | 0 | 0 |
|  | 岕3 | 15 | 26 | 5 | 17 | 50 | 0 | 15 | 30 | 3 | 0 | 0 | 0 |
| $\left.\begin{aligned} & 1 \\ & 1 \\ & n \end{aligned} \right\rvert\,$ | ［19 4 | 7 | 11 | 5 | 8 | 25 | 0 | 8 | 13 | 3 | 0 | 0 | 0 |
|  | 近 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | － 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | M．D．R． | ． 0082 | ． 0105 | ． 0066 | ． 0117 | .0267 | ． 0042 | ． 0092 | ． 0134 | ． 0060 | 0 | 0 | 0 |
|  | No OF BLDGS | 41 | 19 | 21 | 12 | 4 | 8 | 48 | 23 | 29 | 0 | 0 | 0 |
| $\left\lvert\, \begin{gathered} m \\ \overrightarrow{1} \\ 1 \end{gathered}\right.$ | 0 | 36 | 27 | 44 | 25 | 0 | 50 | 34 | 25 | 44 | 0 | 0 | 0 |
|  | 1 | 31 | 33 | 31 | 0 | 0 | 0 | 30 | 31. | 29 | 0 | 0 | 0 |
|  | 谷 2 | 20 | 32 | 6 | 25 | 0 | 50 | 21 | 31 | 9 | 0 | 0 | 0 |
|  | E3 | 11 | 8 | 16 | 0 | 0 | 0 | 11 | 8 | 15 | 0 | 0 | 0 |
|  | $\mathrm{Cx}_{4} 4$ | 2 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 |
|  | ¢ 5 | 0 | 0 | 0 | 50 | 100 | 0 | 3 | 5 | 0 | 0 | 0 | 0 |
|  | －6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | M．D．R． | ． 0047 | ． 0043 | ． 0052 | ． 0494 | ． 0963 | ． 0025 | ． 0072 | .0090 | ． 0051 | 0 | 0 | 0 |
|  | NO OF BLDGS | 70 | 37 | 32 | 4 | 2 | 2 | 73 | 39 | 34 | 0 | 0 | 0 |

FIG．5．10．VARIATION OF THE DAMAGE MATRICES DUE TO THE CHANGE OF INTENSITY ZONATION
＊Data for damage states expressed in percentage．
M．D．R．＇s are not expressed in percentages．


FIGURE S.II VARIATION OF DAMAGE WITH INTENSITY FOR POST-1g47 BUILOINGS

## Chapter 6

## SUMMARY AND CONCLUSIONS

The preceding chapters have described the assembling, processing and analyzing of the data concerning earthquake damage to high-rise buildings, 5 stories and higher, during the San Fernando earthquake of February 9, 1971. Lessons learned and results derived from this exercise are sumnarized in the following paragraphs.

The data collection effort has been described, chronologically, in detail in Chapter 3. The first step in this effort was the construction of a building list which would contain all buildings 5 stories and higher in the Los Angeles area. This was done by adopting the information obtained from a listing of all licensed elevators provided by the State and Los Angeles City Elevator Divisions. It was learned later that the Sanborn maps prepared by the Sanborn Company of New York could be the most useful documents for the construction of such a building list. To obtain the damage cost, building value and structural type, effort was first spent in studying published literature and in consulting with local engineers and government agencies. It was quickly learned chat a questionnaire survey with subsequent personal follow-up would be necessary if a sufficient quanticy of data were to be compiled; hence, questionnaire survey constituted a major part of this tocal effort. In all, about 370 of 1650 buildings on the list had damage data available with most of the information coming from the questionnaire survey. It is believed that all possible avenues have been explored and that the data collection effort has reached the point of diminishing return. Indeed, the task of compiling accurate and useful statistics proved to be difficult and expensive. Some suggestions are made concerning possible similar efforts following future earthquakes. The importance of having an adequare building list in advance of an earchquake is stressed.

The data have been organized into a formar suitable for storage in a computer to facilitate ready display in useful form. The main features of the dara are compiled in the Summary Building List (Appendix H), and information concerning component damage can be found in the listings of the BOMA

Questionnaire Data (Appendix E), the MIT Questionnaire Data (Appendix F) and the MIT/BOMA Questionnaire Data (Appendix G). In presenting the data, it has been kept in mind that the data may be used in different ways by different researchers in the future. Every effort has been made to check the validity of the data, and it is believed that it is reasonably accurate and reliable.

The data have been analyzed in Chapter 5 by constructing and examining damage marrices and component matrices. The damage matrices give the probabilistic distribution of the damage ratio (the total damage cost divided by the building value); the component matrices show the probabilistic distribution of the component damage ratio (component damage cost divided by the total damage cost). Two versions of the damage matrices, the replacement cost version and the market value version, have been presented in Figs 5.2 and 5.3, respectively. Differences between these two versions result from the two ways that the building values were evaluated. Also, two versions of the component matrices have been presented in Figs 5.7 and 5.8, and in Appendix I. Differences between these two versions result from the different number of components used in each version. In addition to the matrices mentioned above, the mean damage ratios for each geographical area have been computed and are shown in Fig. 5.4. From study of the matrices and mean damage ratios, the following conclusions may be drawn:

1. At the level of MMI VI earthquake excitation, most buildings suffered no damage. Some buildings had partition wall cracks but only to a very limited extent.
2. At MMI VII, the pre-1933 buildings suffered considerable damage while the performance of the modern buildings, both concrete and steel, was quite satisfactory.
3. At MMI VIII, only the post-1947 steel buildings did not suffer extensive damage. The post-1947 concrete buildings were damaged considerably.
4. In general, concrete buildings experienced a higher degree of damage than the steel buildings.
5. Generally, the taller the building, the smaller the damage for the high-rise buildings (5 stories and above).
While these trends have already been observed by others based on limited data,
the detailed and extensive study of damage caused by the San Fernando earthquake has served to document these trends in probabilistic terms.

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## APPENDIX A

High-Rise Buildings in Steinbrugge Report

| BLDG NO | STEIN NO ${ }^{+}$ | DIST LOCATION | CONSTR DATE | STORIES <br> ABOVE/ <br> BELOW <br> GRADE | AREA* | EXTERIOR AND ORNAMENTATION |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 607 | 1 | Wilshire | 57-59 | 6/3 | 350,000 | Marble facing crkd |
| 1799 | 2 | Beverly Hills | 1955 | 8/1 | 92,000 | Windows 5th \& 7th |
| 559 | 3 | Beverly Hills | 59-60 | 8/1 | 85,000 | Windows 3rd |
| 783 | 4 | Van Nuys | 63-64 | 8/0 | 97,000 | Lobby walls crkd. 4th - 7th |
| 16 | 5 | Sherman Oaks | 64-65 | 8/1 | 45,000 | Windows 1st, 4 th, 8th |
| 345 | 6 | Sunset Strip | 60-61 | 9/3 | 100,000 | Front window |
| 304 | 7 | Hollywood | 63-64 | 10/0 | 110,000 | Conc. ext. walls crkd |
| 1513 | 8 | Beverly Hills | 63-64 | 10/1 | 100,000 | None |
| 109 | 9 | Downtown L.A. | 62-63 | 11/2 | 280,000 | Windows broke \& shifted |
| 173 | 10 | Hollywood | 58-59 | 12/1 | 102,000 | Windows 2, 5, 6, 8, 9 |
| 1169 | 11 | Miracle Mile | 55-56 | 12/1 | 110,000 | Ext. conc. wall crkd |
| 663 | 12 | Sunset Strip | 62-63 | 12/1 | 159,000 | None |
| 434 | 13 | Westwood | 60-61 | 12/1 | 128,000 | Tile facing crkd. |
| 1260 | 14 | Hollywood | 65-67 | 12/1 | 200,000 | None |
| 828 | 15 | Hollywood | 55-56 | 13/0 | 95,000 | Windows, all flrs |
| 1539 | 16 | Wilshire | 57-58 | 13/1 | 200,000 | Tile loose |
| 3 | 17 | Hollywood | 68-69 | 14/0 | 188,000 | None |
| 860 | 18 | Westwood | 61-62 | 15/2 | 231,000 | Window crkd 8th |
| 1150 | 19 | Sunset Scrip | 63-64 | 15/1 | 140,000 | None |
| 1407 | 20 | Century City | 68-70 | 15/3 | 340,000 | None |
| 640 | 21 | Miracle Mile | 63-64 | 18/1 | 160,000 | None |
| 19 | 22 | Hollywood | 61-64 | 19/3 | 90,000 | None |
| 269 | 23 | Miracle Mile | 59-61 | 22/1 | 210,000 | None |
| 856 | 24 | Wilshire | 60-61 | 22/1 | 453,000 | Marble crkd in lobby |
| 1353 | 25 | Wilshire | 61-63 | 22/1 | 356,000 | Ext. conc. walls crkd |
| 782 | 26 | Westwood | 69-70 | 24/4 | 605,000 | Window seals broken |
| 1089 | 27 | Wilshire | 67-69 | $31 / 1$ | 750,000 | Marble broke in lobby |
| 1702 | 28 | Miracle Mile | 1968 | 31/4 | 475,000 | None |
| 109 | 29 | Downtown L. A. | 1963 | 32/2 | 700,000 | Tile damage ext. walls |
| 1486 | 30 | Downtown I.A. | 65-67 | $42 /$ | 700,000 | None |
| 1699 | 31 | Van Nuys | 66-67 | $7 / 0$ | 59,000 | Ext. pl. crkd |
| 1389 | 32 | Encino | 64-65 | 8/1 | 68,000 | Wall pl. crkd |
| 537 | 33 | Hollywood | 63-64 | 8/3 | 120,000 | Window slippage all flrs |
| 785 | 34 | Beverly Hills | 61-62 | 8/1 | 79,000 | Glass loose |


| 337 | 35 | Encino | 65-67 | 9/1 | 110,000 | None A. 3 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 754 | 36 | Sunset Strip | 62-63 | 9/1 | 100,000 | None |
| 1371 | 37 | Wilshire | 61-63 | $9 / 1$ | 117,000 | None |
| 132 | 38 | Sunsect Strip | 62-63 | 10/2 | 140,000 | None |
| 276 | 39 | Downtown L.A. | 63-64 | 10/0 | 85,000 | Crkd conc. wall all flrs |
| 910 | 40 | Beverly Hills | 64-65 | 10/1 | 60,000 | None |
| 796 | 41 | Beverly Hills | 63-65 | 10/2 | 120,000 | None |
| 826 | 42 | Miracle Míle | 47-48 | 10/0 | 425,000 | Windows broke 3 rd to 10 ch |
| 897 | 43 | Downtown L.A. | 68-69 | 10/2 | 130,000 | None |
|  | 44 | Downtown L.A. | 1964 | 10/0 | 133,000 | ML\&P crkd (south) |
| 1062 | 45 | Hollywood | 66-68 | 11/1 | 130,000 | Windows broke lst |
| 555 | 46 | Miracle Mile | 1951 | 11/1 | 100,000 | Crkd conc. walls |
| 301 | 47 | Wilshire | 65-67 | 11/3 | 330,000 | Window broke (3) |
| 870 | 48 | Sherman Oaks | 69-70 | 12/2 | 118,000 | None |
| 855 | 49 | Miracle Mile | 62-64 | 12/0 | 65,000 | None |
| 1837 | 50 | Wilshire | 65-67 | 12/1 | 150,000 | None |
| 589 | 51 | Panorama City | 61-62 | 13/1 | 130,000 | 15 windows broke |
| 733 | 52 | Sherman Daks | 65-67 | 13/0 | 200,000 | None |
| 1.564 | 53 | Sherman Oaks | 65-66 | 13/2 | 200,000 | Marble loose, conc. cols crkd |
| 1616 | 54 | Century Ciry | 61-63 | 13/3 | 300,000 | None |
| 1250 | 55 | Century City | 62-64 | 13/3 | 300,000 | None |
| 1787 | 56 | Encino | 69-70 | 14/0 | 190,000 | Marble crkd in front |
| 1280 | 57 | Century City | 69-70 | 15/3 | 251,000 | None |
| 1666 | 58 | Century City | 67-69 | 19/4 | 200,000 | None |
| 652 | 59 | Universal City | 1969 | 20/0 | ------ | Tile facing fell |

*Area is total square footage above grade.

For structural steel buildings, the numbers shown here are idencical to those of the SSR. For reinforced concrete buildings, the numbers shown here are those of the SSR plus 30 .
A.1. High-Rise Buildings Listed in the Steinbrugge/Schader Report (Buildings in Course of Construction Not Listed)

INTERIOR AND CONTENTS
Filing cabinets over, ML\&P part. crkd Part., celling tiles damg.

ML\&P stairwell crkd 4 th to $6 t h$
ML\&P part. crkd Restr. damg. 2nd
Books, pictures fell
File cabinets, books, light fixtures fell
Intr. Walls crkd, books fell, Eurno damg.
All flrs ML\&P crkd, ceiling tile fell
L\&P walls crkd all f1rs
So. stairwells damg.
Books, lamps, file cabinet fell
Slight cracking to L\&P
Drywl. crkd all flrs
Slight drywl. crkd
Crkd dryw1. 3rd to 9th
Crkd bsme walls (conc.), crkd L\&P
Crkd ML\&P walls thruout
2 cracks in drywl., books fell
Crkd, ML\&P dryw1. all flrs
Stairwell conc. wall crkd
Crkd drywl. all flrs
Crkd ML\&P walls
Crkd ML\&P core, books fell
Crkd drywi. 4th to 14 th
Ceiling tile fell, books fell
Conc. Elrs crkd 21st to 25 th
ML\&P walls crkd all flrs
Crkd drywl. all flrs
L\&P walls crkd all flrs
L\&P cores crkd stairs \& elev.
Vinyl wall covering buckled, drywl. crkd, furn. damg.

All flr. drywls. crks, X-ray equip. damg.
Minor cracks all drywls
ML\&P lst crkd, books, statues, watercooler fell

BUILDING EQUIPMENT (MILES)

AC \& boilers moved 22.5

None
22.0

Slight damg. elev. wts. 22.0

None
14.0

Elev. wts. loose 17.0
None
20.0

None
20.0

Slight to elev. 22.0
None 24.0
None 20.0
AC yoke broke 22.5
None 20.0
None 22.0
$A C$ moved 20.0
Beacon light fell 20.0
None 22.5
None 20.0
None 22.0
$A C$ out of adjust 20.0
None 23.0
Slight ele. damg. 22.5
Cable in elev. damg. 20.0
Elev. damg. 22.5
Elev. cables jumped 22.5
Elev. wis. moved 22.5
Elev. cable \& wts. moved 22.0
Elev. cables damg. 22.5
Elev. broke loose from track 22.5
$A C$ fan shifted 24.0
Elev. cables damg. 24.0
Elev, oil spilled, bach tubs \& t1ts crkd 14.0

None 18.0
None
20.0

Elev. wts. off track, sprkl. pipe broke 22.0
None AC moved slightly ..... 18.0
None
Cracks in ML\&P and spandrelsNone20.0
Elev. wes. loose ..... 22.5
Elev. wts. loose ..... 20.0
$A C$ off mount ..... 23.0
Boiler damg., elev. wts. ..... 22.0
None ..... 22.0
Pipes in fan rm. broke ..... 22.5
None ..... 23.0
Slight damg. to elev. ..... 24.0
Elev. relay dang. ..... 20.0
None ..... 22.5
AC compr. moved ..... 22.5
None ..... 17.0
Elev. wts damg. ..... 22.5
Elev. wts damg. ..... 22.5
None ..... 13.0
Power surge in $A C$ ..... 17.0
Drywl crkd, file damg.None17.0
coustic ceiling fell, pl. broke near elev
None ..... 23.0
Dxywl crkd 1st \& 3rd stairwells
None ..... 23.0
None ..... 18.0
Elev. cars damg. ..... 23.0
Elev. cable damg. ..... 23.0
None ..... 16.0

## APPENDIX B

Procedure for Determining Assessed Valuations

The following description was prepared by Ayres, Cohen and Hayakawa

Each building is identified by a serial number in the Assessor's Office. This number is known as the parcel number. In order to find the ownership and assessed values of a building, one must first find its parcel number. Knowing the address, the following items are needed to find the parcel number of a building:

## Item 1. Thomas Map

The county of Los Angeles is subdivided into several thousand areas. Each area consists of approximately 30 city blocks. Details of these blocks in each area are described in the map book. Figure B.1, atrached, shows an example of a section of the marked Thomas Map divided into many areas where the numbers in each area correspond to a map book number.

Irem 2. Map Book

Figure B.2, attached, shows a typical page of a map book. The numbers at the upper left hand corner are the number of the map book and the page number of the book. The numbers in the map are the parcel numbers in the specific city block. No street address is given in the map book.

Item 3. Assessor's Roll

The Assessor's Roll is a series of books containing information about each parcel including its parcel number, building address and assessed values. Figure B.3, attached, shows a sample page in an Assessor's Roll book.

The procedure for obtaining the assessed value is as follows:

# Step 1: Obtain the marked Thomas Map (Item 1) to find the number of the map book (Item 2) in which a particular building is located. 

Step 2: Obtain the Assessor's Roll book (Item 3) which includes informarion of the particular building.

## Step 3: Place the map book and the Assessor's Roll book side by side and proceed to find the particular address in the Assessor's Roll by matching parcel numbers in the two books.

We estimate that the time required to obtain the assessed values of 304 buildings will be approximately sixteen man days.


FIGURE B.I Section of Thomas Map

| ROP BOOK 5184 |
| :---: |
| $\begin{aligned} & \text { PAGE } \\ & \text { 2B } \end{aligned}$ |



9TH ST.


FIGURE S2 SARPLE PAGE MN MADOOK
OWNER ADDRESS

| BUILDING ADDRESS | MAP | PAGE | PARCEL | LAND | IMPROVED |  |
| :--- | :--- | :---: | :---: | :---: | :---: | ---: |
| OWNER NAME | BOOK | NO. | NO. | VAIUE | VALUE | USE |
|  | 5144 | 27 | 20 | 55,000 | 111,250 | 1800 |

117 W . 9 th ..... 5144 ..... 28 ..... 1
RM 1200 LA. 15
117 W .9 ch
LA. 15
GARLAND, Wm ..... 5144
28 ..... 2Figure B.3. Sample Page in Assessor's Roll Book

## Appendix C

## Questionnaire Forms

This appendix contains a questionnaire form proposed by the J. H. Wiggins Co. (Chapter 3.2.2), the questionnaire used for the BOMA survey (Chapter 3.3.3), and the worksheets used by the Ayres firm for detailed documentation of damage (Section 3.2.3). The Wiggins Co. remarked that their proposed form undoubtedly was too long and needed to be shortened. Their approach was to first include all desired information before attempting to shorten the form.
J. H. WIGGINS COMPANY, Inc.
. Hazard Analysis and Evaluation 2516 Via Tajon Palos Verdes Estates, California 90274 Gentlemen:

The J. H. Wiggins Company is charged with the responsibility for collecting information on damage and economic losses resulting from the San Fernando earchquake of February 9, 1971. This work is being performed under subcontract with the Massachusetts Institute of Technology who reports to the National Science Foundation.

The information will be used as a data base for the development of a method to predict losses which may occur from future earthquakes. This research is necessary in order to provide a better means of coping with a future disaster, should one occur. In this parciculax study, we are limiting the survey to high-rise buildings in the Los Angeles County area.

Your name was obtained from the 1971 County Assessor's tax rolls as the owner of the building located at the address on the bottom of this letter. The building was randomly selected from all high-rise buildings in Los Angeles County. It would be greatly appreciated if you would complete the questionnaire and return it in the enclosed envelope. Please be assured that your response will remain anonymous.

In order to insure anonymity of response, the completed questionnaire does not contain any addresses or owner information. The code number on the questionaire merely identifies a general geographic location in the County of Los Angeles (i.e., San Fernando Valley, downtown Los Angeles) in order that we can correlate earthquake ground motion to building damage.

We thank you in advance for your cooperation and prompt attention to this request.

Very truly yours,

William J. Petak
Vice President
Enclosures

Building Map Code: $\qquad$

1. Have you owned the building located at the address on the attached letter since the San Fernando earthquake of February 9, 1971?
$\qquad$ Yes $\qquad$ No
2. In what year was the building constructed? $\qquad$
3. What is the basic function of the building?
$\qquad$ office _._ hospital store _......... apartment
$\qquad$ warehouse manufacturing other (define)
4. What is the maximum number of floors above ground level in the building? (DO NOT include basement, roof or penthouses in your count) $\qquad$ .
5. From the following list, please identify the type of building construction:
steel frame
steel reinforced concrete
steel reinforced brick masonry
unreinforced brick masonry
6. Did the building sustain any damage as a result of the San Fernando earthquake of February 9, 1971?
$\qquad$
Yes No
7. From the following list, identify the types of damage
a) major structural damage requiring the services of a structural engineer:
$\qquad$ Foundation $\qquad$ building frame $\qquad$ roof and floors
$\qquad$ walls partitions other (define) $\qquad$
b) major electrical or mechanical damage:
___ elevators inoperative
___ ruptured water or sewer lines within the building loss of electrical power due to failure within the building
$\qquad$ mechanical or electrical equipment broken loose from mounts or skids causing damage or inoperative condition
$\qquad$ light fixtures broken loose from anchorage
$\qquad$ other (define)
$\qquad$
c) non-structural damage:
$\qquad$ plaster cracking
$\qquad$ window and door glass breakage
___ external facade damage (i.e., parapets, outer brick veneer)
d) other rypes of damage (please define):
$\qquad$
$\qquad$
$\qquad$
8. For each of the above types of damage expexienced, please provide either the actual or estimated mount required to repair the damage:
a) major structural $\qquad$
b) major electrical or mechanical
$\$$
\$
c) non-structural damage
$\qquad$

- plaster

- glass breakage
- $\quad$ -
$\qquad$
$\qquad$
- external facade $\qquad$
- other (define) $\qquad$
$\qquad$
$\qquad$
d) other types of damage $\qquad$
$\qquad$

3. Please estimate the total damage in terms of a percentage of the market value of the building (excluding land value):
(cotal damage)
(market value of structure) $\qquad$ \%
4. Please estimate the dollar cost involved due to loss of operation or inconvenience resulting from damage to the building:
\$ $\qquad$
5. Did you obtain a building permit from the city or county in order to repair your building?
$\qquad$ Yes No
6. Did you retain an engineer to survey your building and provide you with a professional opinion regarding its structural soundness:
$\qquad$ Yes $\qquad$ No
How much was his fee \$ $\qquad$

Is the fee included in damage costs listed above? $\qquad$ Yes $\qquad$ No
13. Did a member of the county or city engineer's office examine your building for structural integrity and safety?
$\qquad$ Yes $\qquad$ No
If yes, did you request the examination? $\qquad$ Yes
$\square$
$\qquad$ No
14. Did the SFEQ result in your making any structural improvements to the building?
___ Yo If yes, please explain what type of improvements were made:
$\qquad$
$\qquad$
15. What is the estimated cost of the improvement (s) excluding cost of repairs of damage?
6. If you lease space in the building, did you have any tenants move or refuse to renew leases due to the earthquake?
$\qquad$ Yes
No If yes, please answer the following:

- Number of tenants moving $\qquad$
- Reason for moving $\qquad$
- To what geographical area did tenant(s) move?


DATE：JULY， 1971
TO：ALL BUILDING OWNERS AND MANAGERS

FROM：
SUBJECT：FEBRUARY 9， 1971 EARTHQUAKE STIDY

YOU HAVE INFORMATION WIIICII WHEN COMBINED WITH THAT OF OTHER BUILDINGS，WILL BE OF MAJOR IMPORTANCE TO YOU AND THE ENTIRE OFFICE BUILDING INDUSTRY。 THAT INFORMATION CONCERNS THE EFFECTS OF THE FEBRUARY 9th EARTHQUAKE ON OFFICE BUILDINGS IN SOUTHERN CALIFORNIA。

YOU WILL BENEFIT FRROM THE DETAILED AND EXCLUSIVELY OFFICE BUILD－ ING ORIENTED NATURE OF THE COMPOSITE EXPERIENCE EXCHANGE INFOR－ MATION WHICH CAN BE DERIVED FROM THE COMPLETED QUESTIONNAIRES ENCLOSED。
THE BOMA EARTHQUAKE COMMITTEE HAS SPENT FOUR MONTHS DRAFTING， ALTERING，REFINING AND CREATING THE ENCLOSED QUESTIONNAIRES。 THEY ARE DESIGNED TO PRODUCE DATA WHICH IS SIMPI，Y NOT AVAILABLE FROM ANY SOURCE FOR OUR INDUSTRY．
BY PARTICIPATING YOU WILL ASSURE YOURSELF OF THE ONLY WAY OF RECEIVING THE RESULTS OF THE SURVEY．

THE QUESTIONNAIRE IS MADE UP OF 6 SECTIONS．PLEASE FILL OUT THOSE SECTIONS APPLICA BLE WITI ALL DELIBERATE SPEED AND RETURN TO THE BOMA OFFICE BY JULY 30， 1971.
IN ORDER TO ASSURE THE MOST MEANINGFUL INFORMATION，PLEASE DUPLICATE AND COMPLEETE THE QUESTIONNAIRES FOR EACH BUILDING UNDER YOUR JURISDICTION．
NATURALLY THIS INFORMATION WILL BE HELD IN STRICTEST CONFIDENCE AND REFERENCE WILL NOT BE MADE TO ANY SPECIFIC BUILDING IN THE PUBLISHED REPORT．

WITH YOUR INIDISPENSABLE COOPERATION THE RESULTS WILL BE COMPILEDs PRINTED AND DISTRIBUTED BY AUGUST 31， 1971.

THANK YOU
BOMA EARTHQUAKE COMMITTEE
CHALRMAN：J。EDWARD GIBBONS，PRESIDENT，UNION REALCO
COORDINATOR：PHIL BAUMAN，GENERAL MANAGER B．O．M．A．


Indicate direction of North by arrow.
B-Elevational view of building: Mark main entry level
Show height of building above and below entry level

## C. 9

| SERIES 200 |
| :--- |
| REPAIRS AND IMSURAMCE |


| . tle | Tel. $\mathrm{NO}_{0}$ |
| :---: | :---: |



| BUILDING OMNERS ABD MANAGERS Association of Los Angeles |  |
| :---: | :---: |
|  | Fobruary 9, 9978 Earthquake Comisico Survey |
|  | Building Code No. |
|  | Brief Name |

206-What was the total amount of Earthquake Insurance coverage?
$\$$

207-What amount was deductitite
A- $\qquad$
R-\$ $\qquad$

208-what percentage of total damage will be recovered under your Earthquake insurance?
\%

person
Answering

Tel.
No.
INDICATE FLOORS DAMAGED AND DEGREE OF DAMAGE BY GROUPS OF FLOORS:
 (1) Sene 308-308)

A-SHEAR WALLS
1-Diagonal wood sheathing or plywood

2-Poured concrete
3-precast concrete
u-Reinforced masonry
5-unreinforced masonry
6-0ther (describe)

B-OTHER WALLS
1-wood stud and plaster
2-wood stud and plaster ...board
3-Metal stud lath and ..plaster

4-Metal stud and plaster ...board

5-Drywall
6-Cavity walls
7-Unreinforced masonry
8-Reinforced masonry
g-other (describe)

C-frame
1-wood vertical support
2 -hood moment frame
3-steel vertical support
4-steel moment frame
5-Steel braced frame 6-Concrete vertical support

7-Concrete moment frame
8-Ductile concrete moment frame

9-Concrete braced frame 10-Other (describe)

BUILDING OKAERS ARD HAEAGERS
Association of Los Angeles
Fobruary \%. 197s Eurthquake Conal tree survey
Building
Code No.
Brief
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lovor)

SERIES BOO
COHSTRUCTION QUESTIOAS
person
Answering
(e


BUILDING OHERS AND MARAGERS
Association of Los Angeles
Fobruary 9, 2971 Earthquako Comisisoo Survay

Building
Code NO.
Brief
Name

(over)


C. 15




630-YOUR AGE $\qquad$
631-__Mal $\qquad$
632-(optional)

Your name $\qquad$
Street address $\qquad$
City, State, Zip Code $\qquad$
Ayres, Cohen, Hayakawa WorksheetC. 18
1971 SAN FERNANDO EARTHQUAKE
SURVEY ON NON-STRUCTURAL DAMAGE
MIT - NSF

1. Name of Building, Address, and Function:
2. Basic Structural Characteristic and Building Orientation:
3. Number of Stories:
4. Year It Was Built:
5. Estimated Area/Floor or Approximate ..... Size:
6. Original Cost of Construction:
7. Original Engineer
Architect:
Structural:
Mechanical:
Electrical:
8. Current Engineer on Repair -
Archirect:
Structural:
Mechanical:
Electrical:
9. Repair Costs:
Struc. Mech. Elec. Arch. Elev. ..... Total
10. Repair Done By:
11. Appraised Value and When Appraised:
12. Ceiling:

Lobby
Typical
a. Type:
b. Nature of Damage:
13. Lights:

Lobby
Typical
a. Type:
b. Nature of Damage:
14. Particion:
a. Type:
b. Nature of Damage:
15. Glazing or Curtain Wall:
a. Type or Manufacture:
b. Safety Glass Used:
c. Method of Repair:
d. Type of Mount:
e. Nature of Damage:
16. Mechanical and Plumbing - A/C, Pump, Ducts, Cooling Tower:
a. Type of Mount:
b. Where Located:
c. Nature of Damage:
d. Method of Repair:
17. Electrical - Emergency Generator, Transformer:
a. Where Located:
b. Type of Mount:
c. Nature of Damage:

# Appendix D <br> Variations in Earthquake Resistance Required by Codes 

The J. H. Wiggins Co. prepared three different estimates of the relative strengths of buildings in Los Angeles by code year. Two of these were obtained by prominent California engineers: Mr. Don Moran and Dr. John A. Blume. The thixd was prepared by Dr. Wiggins himself. The three estimates are shown in Figs D. 1, D. 2 and D.3.

Mr. Moran estimates that the wind provisions that came in about 1925 increased the relative strength slightly; but the earthquake provisions in 1934 increased the relative strength considerably by a factor of 4 . However, in 1959: Mr. Moran believes that the ductility provisions, among others, caused the code in general to be lowered. However, in some instances, it may be even higher--such as for shear walls.

Dr. Blume has estimated the relative strength for various types of buildings. These are shown in Fig. D.2. Mr. Blume notes that most buildings only doubled in strength; however, schools were considerably strengthened by the field act.

Dr. Wiggins took the various factors, such as live load change, wind loads, earthquake mass, earthquake acceleration (used in design), concrere allowable stress, steel allowable stress, and wood allowable stress, and noted the changes over the years. Dr. Wiggins weighted each of these seven factors differently. He gave live loads, wind loads, and concrete, steel and wood stresses a weighting factor of 1 ; whereas, he gave earthquake mass and earchquake acceleration a weighting factor of 4 . Dr. Wiggins then added the factors together, making them relative to the lowest series of years during which changes took place. The results are shown in Fig. D.3.

From these three estimates, derived independently of one another and by various techniques, it is fairly obvious that structures designed before 1934 axe about $40 \%$ as resistant to earthquake forces as structures designed after 1934.


FGUREDE DOHA BLUNE'S ESTHNATE OF RELATIVE STRENGTH
BY CODE YEAR


APPENDIX E

BOMA Questionnaire
Data












APPENDIX F

MIT Questionnaire
Data














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\begin{aligned}
& \begin{array}{l}
0020000-00-600 \\
\therefore 0-5 \circ 0.00 .0000
\end{array}
\end{aligned}
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1500900000000
\end{array}
\end{aligned}
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\begin{aligned}
& \text { のかいこひ心のひのひくいいの }
\end{aligned}
$$

APPENDIX G

## MIT/BOMA Questionnaire


#### Abstract

G. 4        

















#### Abstract

          











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[^2]













## H. 1

APPENDIX H

Summary Building List

|  |  |  |  |  |  |  |  |  |  |  |  |  | H． 2 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & \text { N} \\ & 0 \\ & \hline 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \text { B } \\ & \text { N } \\ & \text { O} \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{y}{0} \\ & 8 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \text { N} \\ & \text { W } \\ & \text { O} \\ & 0 \\ & \circ \\ & \hline \end{aligned}$ | $\begin{aligned} & 0 \\ & C \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \vec{~} \\ & \underset{\sim}{2} \\ & \vdots \end{aligned}$ | $\begin{aligned} & \text { n} \\ & \stackrel{3}{8} \\ & \stackrel{8}{0} \\ & 0 \end{aligned}$ | $\begin{aligned} & \tilde{\omega} \\ & \underset{\sim}{0} \\ & \underset{0}{0} \\ & \dot{0} \end{aligned}$ | $\begin{aligned} & \overrightarrow{0} \\ & \stackrel{\rightharpoonup}{0} \\ & \stackrel{0}{0} \\ & \dot{0} \end{aligned}$ | $\begin{aligned} & E \\ & \vdots \\ & \hdashline \end{aligned}$ | $\begin{aligned} & \text { in } \\ & 0 \\ & 0 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ |  | $\begin{aligned} & \text { N } \\ & 0 \\ & 0 \\ & \text { B } \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \stackrel{8}{\circ} \\ & \stackrel{0}{8} \\ & \circ \\ & \circ \end{aligned}$ |
| $\begin{aligned} & 4 \\ & 0 \\ & y_{4} \\ & \sum_{0} \\ & 0 \end{aligned}$ | $\begin{aligned} & \circ \circ \\ & \hline 8.8 \\ & \hline 8 \end{aligned}$ | $\begin{aligned} & \stackrel{0}{m} \\ & \underset{\sim}{n} \end{aligned}$ | $\begin{aligned} & \circ \\ & 8 \\ & 8 \end{aligned}$ | $\begin{aligned} & \text { O} \\ & \stackrel{3}{N} \\ & \sim \end{aligned}$ | $\begin{aligned} & \stackrel{0}{N} \\ & \stackrel{N}{*} \end{aligned}$ | $$ | $\begin{aligned} & \circ \\ & \stackrel{\circ}{\mathrm{O}} \end{aligned}$ | $\begin{aligned} & 0 \\ & 8 \\ & 8 \\ & \text { in } \end{aligned}$ | $\begin{aligned} & 2 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \hat{3} \\ & = \\ & = \end{aligned}$ | $\underset{\underset{\sim}{\underset{\sim}{*}}}{\stackrel{\rightharpoonup}{7}}$ | $\begin{aligned} & \stackrel{g}{n} \\ & \underset{\sim}{N} \end{aligned}$ | $\begin{aligned} & 09 \\ & 0.3 \\ & 0.8 \end{aligned}$ | $\stackrel{0}{\hat{N}}$ |
|  | －m | $\cdots$ | u | $\leqslant$ | ir | $\pm$ | $\checkmark$ | m | $m$ | ． | $\checkmark$ | $\stackrel{ }{ }$ | nis | 5 |
| $\stackrel{\underset{\sim}{x}}{\stackrel{y}{y}}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & n \\ & n \\ & 0 \\ & n \end{aligned}$ |  |  |  |  |  |  | $\begin{aligned} & 08 \\ & 80 \\ & 08 \\ & 60 \\ & -1 \end{aligned}$ | $\begin{aligned} & 0 \\ & \text { م } \\ & \text { io } \\ & \infty \end{aligned}$ | $\begin{aligned} & 200 \\ & =8 \\ & =8 \\ & =8 \\ & =0 \\ & =0 \end{aligned}$ |  |  |  |  |
|  | $*$ | tor | $\rightarrow m \times r$ | nor | $\rightarrow m o r$ | －rior | His．or | ＋ | － | in 0 | －tion | H6cr | － | $\rightarrow \infty$ |
|  | － | － | 9 | c | $i$ | 0 | 0 | $\stackrel{ }{\llcorner }$ | $\checkmark$ | $c$ | $<$ | c | c | $\pm$ |
|  | $i$ | $\cdots$ | $\stackrel{\square}{1}$ | $\stackrel{\square}{1}$ | 9 | $\cdots$ | 9 | 9 | $\cdots$ | $i$ | $i$ |  | $\sim$ | 9 |
| $\begin{aligned} & \text { Qu } \\ & \frac{a}{2} \\ & \infty \end{aligned}$ | $\cup$ | u | $v$ | $\checkmark$ | 0 | － | $\checkmark$ | $n$ | 㐫 | $\sim$ | $\cup$ | $\sim$ | $n$ | $\checkmark$ |
| ك | $\stackrel{\circ}{\sim}$ | 5 | $\sim$ | ＊ | $\stackrel{*}{*}$ | $\stackrel{\square}{2}$ | $\stackrel{\sim}{n}$ | ＊ | $\pm$ | ＊ | w | $\pm$ | J | 웅 |
| $\stackrel{: ~}{:}$ | 충 | $\begin{aligned} & \vec{\sim} \\ & \underset{\sim}{0} \end{aligned}$ | $\begin{aligned} & \text { n } \\ & 0 \\ & \hline \sim \end{aligned}$ | $\stackrel{9}{8}$ | $\begin{gathered} \stackrel{\rightharpoonup}{c} \\ \stackrel{\rightharpoonup}{-} \end{gathered}$ | $\begin{aligned} & \underset{\circ}{\circ} \\ & \stackrel{y}{2} \end{aligned}$ | $$ | $\underset{\sim}{\approx}$ | $\underset{\sim}{\tilde{\sim}} \underset{\sim}{n}$ | $\stackrel{0}{\underset{\sim}{\alpha}}$ | $\begin{aligned} & \infty \\ & \stackrel{\infty}{\circ} \\ & \underset{\sim}{2} \end{aligned}$ | $\stackrel{0}{a}$ | $\frac{N}{2}$ | $\begin{aligned} & N \\ & \stackrel{\circ}{\circ} \\ & \stackrel{2}{2} \end{aligned}$ |
| 全 | ב | in | $\alpha_{i}$ | $\bigcirc$ | 』 | $\stackrel{\sim}{\circ}$ | 9 | $\cdots$ | $\bigcirc$ | $\geq$ | $\sim$ | $\simeq$ | $\sim$ |  |
| $\frac{0}{9}$ | $\because$ | $\sim$ | $\stackrel{\square}{\sim}$ | $\stackrel{ }{-}$ | $\stackrel{ }{ } 9$ | $\bigcirc$ | m | n | n | $\stackrel{4}{5}$ | i | $n$ | n | $\overline{0}$ |


|  | $\begin{aligned} & \underset{\sim}{0} \\ & \underset{\sim}{n} \\ & \stackrel{\circ}{\circ} \end{aligned}$ | $\because$ | $\begin{aligned} & \text { u } \\ & 0 \\ & \text { in } \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \hat{\sigma} \\ & \dot{f} \\ & \stackrel{8}{\circ} \\ & \dot{\circ} \end{aligned}$ | $\begin{gathered} \underset{\sim}{\infty} \\ \underset{\sim}{\underset{\sim}{c}} \end{gathered}$ | $\begin{aligned} & \text { ※ } \\ & = \\ & = \\ & \hline \end{aligned}$ | $\begin{aligned} & \circ \\ & 0 \\ & 0 \\ & 0 \\ & \tilde{W} \\ & 0 \\ & 0 \end{aligned}$ | O． | $\begin{aligned} & \sim \\ & \sim \\ & \sim \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \pm \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{gathered} \underset{\sim}{m} \\ \stackrel{N}{\gtrless} \\ \therefore \\ \therefore \end{gathered}$ | $\because$ | $\begin{aligned} & \vec{ज} \\ & \vdots \\ & 0 \\ & 0 \end{aligned}$ | $\because$ | ¢ | － | $\bigcirc$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & 0 \\ & \stackrel{8}{8} \\ & 0 \\ & 0 \end{aligned}$ | － | $\stackrel{\underset{\sim}{n}}{\underset{\sim}{n}}$ | $\begin{aligned} & 8 \\ & \text { in } \\ & \text { in } \end{aligned}$ | $\begin{aligned} & \stackrel{\Omega}{\underset{\sim}{2}} \\ & \underset{\sim}{2} \end{aligned}$ | $\stackrel{\sim}{\sim}$ | $\begin{aligned} & 0 \\ & 8 \\ & 8 \\ & \text { in } \end{aligned}$ | － | $\begin{aligned} & 8_{0}^{\circ} \\ & 8_{0} \end{aligned}$ | $\begin{aligned} & 0.8 \\ & 8: \\ & 0 \% \\ & N \\ & N \end{aligned}$ | $\stackrel{3}{3}$ | $\bigcirc$ | $\begin{aligned} & \circ \\ & 0 \\ & \\ & \hline \end{aligned}$ | 0 | － | $\bigcirc$ | $\bigcirc$ |
|  | $m$ | $\pm$ | $\checkmark$ | ＊ | $\star$ | $n$ | $\pm$ | $\stackrel{ }{*}$ | rin | M | $\checkmark$ | $\stackrel{ }{*}$ | r | $\checkmark$ | ＊ | $\checkmark$ | $\sim$ |
| $\begin{aligned} & E \\ & y \end{aligned}$ | $\begin{aligned} & 00 \\ & 80 \\ & 08 \\ & 0.8 \\ & 0.8 \end{aligned}$ |  |  |  | $\begin{aligned} & 00 \\ & 08 \\ & 08 \\ & 0_{0} \\ & \text { is } \\ & 10 \end{aligned}$ |  | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 5 \\ & 5 \end{aligned}$ | $$ | $\begin{aligned} & 0 \\ & \stackrel{B}{g} \\ & \underset{\sim}{5} \end{aligned}$ |  | $\begin{aligned} & 00 \\ & 80 \\ & \therefore 0 \\ & 100 \\ & 0 \\ & 0 \end{aligned}$ |  | $\begin{aligned} & \text { O} \\ & \stackrel{0}{5} \\ & \stackrel{0}{0} \end{aligned}$ |  |  |  | 8 <br> 8 <br> 8 <br> 8 |
| ：－ | ＋0 | $\rightarrow$＋60 | thor | $\rightarrow$－60 | un | －nmor | in | N | N | $\rightarrow \mathrm{m}=0$ | tr．n | －mins | $\stackrel{ }{ }$ | $\rightarrow$ inc | －600 | 5.6 | $\sim$ |
|  | $\square$ | r： | $\tau$ | $r$ | 0 | $i$ | $\stackrel{\leftarrow}{6}$ | $<$ | c | $\square$ | c | $\sigma$ | 5 | ＜ | － | 4 | $i$ |
|  | － | a | 9 | $\underset{1}{\infty}$ | $i$ | $i$ | $i$ | $i$ | $\checkmark$ | 9 | － | $\sim$ | 9 | $i$ | $i$ | $\cdots$ | $\cdots$ |
|  | $u$ | $\cdots$ | $\bullet$ | $\sim$ | $\cup$ | $\sim$ | $\sim$ | $\sim$ | $\cdots$ | $n$ | $\cup$ | $\sim$ | $\sim$ | $\cup$ | $\cup$ | $u$ | $\checkmark$ |
|  | $\stackrel{\text { G }}{\text { ¢ }}$ | 3 | $\pm$ | ～ | $\approx$ | $\stackrel{4}{9}$ | $\stackrel{-}{2}$ | $\stackrel{i n}{\sim}$ | $\stackrel{J}{*}$ | v | ज | 3 | 守 | $\stackrel{\sim}{2}$ | $\stackrel{\square}{\sim}$ | $\stackrel{\sim}{\sim}$ | m |
|  | $\stackrel{\underset{\sim}{\underset{\sim}{2}}}{ }$ | $\begin{aligned} & \stackrel{\rightharpoonup}{6} \\ & \underset{\sim}{\circ} \end{aligned}$ | $\begin{aligned} & \hat{o} \\ & \underset{\sim}{\circ} \end{aligned}$ | $\begin{aligned} & 5 \\ & \stackrel{5}{0} \\ & 0 \end{aligned}$ | $\begin{gathered} \stackrel{\rightharpoonup}{\circ} \\ \stackrel{y}{-1} \end{gathered}$ | $\begin{aligned} & 0 \\ & \stackrel{\circ}{\circ} \end{aligned}$ | $\begin{aligned} & \stackrel{~}{\mathbf{g}} \\ & \stackrel{y}{2} \end{aligned}$ | $\underset{\sim}{\underset{\sim}{\approx}} \underset{\sim}{\underset{\sim}{2}}$ | $\begin{gathered} 0 \\ \stackrel{0}{\circ} \\ \underset{\sim}{2} \end{gathered}$ | $\begin{aligned} & \text { n } \\ & \underset{\sim}{n} \end{aligned}$ | $\begin{gathered} \underset{\sim}{\alpha} \\ \underset{\sim}{2} \end{gathered}$ | $\underset{\sim}{N}$ | $\stackrel{i n}{\underset{\sigma}{\sigma}}$ | $\begin{aligned} & \text { N } \\ & \stackrel{0}{\sigma} \\ & \hline \end{aligned}$ | － | $\underset{\underset{\sim}{\tilde{E}}}{\stackrel{\sim}{\mid}}$ | $\hat{2}$ <br>  |
|  | $\sim$ | $\bigcirc$ | $\cdots$ | $\cdots$ | $\bigcirc$ | $\stackrel{ }{\square}$ | $\sigma$ | $\exists$ | in | $\stackrel{\sim}{\sim}$ | $\stackrel{m}{\sim}$ | $\Xi$ | $\sim$ | $\bullet$ | $\bigcirc$ | $\cong$ | $\bigcirc$ |
|  | $\pm$ | N | $\stackrel{\sim}{\sim}$ | $\vec{x}$ | $\underset{\sim}{\sim}$ | － | \％ | $\sim$ | $\underset{\Delta}{2}$ | $\stackrel{\approx}{\leftrightharpoons}$ | $\stackrel{\square}{\rightrightarrows}$ | $\stackrel{n}{\exists}$ | $\stackrel{\circ}{\sim}$ | $\stackrel{N}{\underset{\sim}{7}}$ | $\stackrel{\infty}{\sim}$ | $\underset{\sim}{\circ}$ | $\stackrel{\sim}{\sim}$ |



|  |  |  |  |  |  |  |  |  |  |  |  |  |  | H． 5 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & w \\ & 0 \\ & 0 \\ & 8 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | 8 | $$ | $0$ | $\bigcirc$ | － | $\begin{aligned} & \text { v} \\ & N \\ & \hat{O} \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 \\ & 0 \\ & 8 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | O | $\because$ |  | $\begin{aligned} & \underset{\sim}{0} \\ & \stackrel{\sim}{0} \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \text { in } \\ & \underset{\sim}{3} \\ & \hdashline \end{aligned}$ | $\begin{aligned} & \text { n } \\ & 0 \\ & 0 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ |
|  | $8$ | $\begin{aligned} & 00 \\ & 08 \\ & 08 \\ & 0.8 \\ & \text { in } \\ & \text { in } \end{aligned}$ | $\frac{2}{6}$ | $\begin{aligned} & \text { n} \\ & \hat{N} \\ & i n \\ & i n \end{aligned}$ | $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | $\begin{aligned} & 0 \\ & 8 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \stackrel{a}{⿷} \\ & \underset{玉}{*} \end{aligned}$ | $\bigcirc$ | $\bigcirc$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & \text { in } \end{aligned}$ | $\begin{aligned} & 00 \\ & 80 \\ & \therefore 0 \\ & -i n \end{aligned}$ | $\begin{aligned} & \sigma \\ & \sigma \\ & \sigma \end{aligned}$ | $\circ$ <br> $\stackrel{8}{6}$ <br>  |
|  | $\checkmark$ | $\rightarrow+$ | m | $\sim$ | ＊ | $\checkmark$ | $\cdots$ | ＊ | $\checkmark$ | $\stackrel{ }{ }$ | n | $\stackrel{\sim}{*}$ | $\rightarrow m$ | in | $\checkmark$ |
| $\begin{aligned} & 00 \\ & 80 \\ & 88 \\ & 08 \\ & 0 \\ & 8 \end{aligned}$ |  |  | $\begin{aligned} & 00 \\ & 80 \\ & 80 \\ & 80 \\ & 0 \\ & =1 \end{aligned}$ | $\begin{aligned} & 0 \\ & 8 \\ & 0 \\ & - \\ & -\quad \\ & \hline-5 \end{aligned}$ | $\begin{aligned} & 0 \% \\ & 0.5 \\ & 06 \\ & \% \\ & \text { onn } \end{aligned}$ | $\begin{aligned} & \stackrel{0}{n} \\ & \underset{\sim}{0} \\ & \stackrel{y}{n} \end{aligned}$ | $\begin{aligned} & 08 \\ & 08 \\ & 0.8 \\ & 88 \\ & 88 \\ & 8 \end{aligned}$ |  |  |  | $\begin{aligned} & 580 \\ & 288 \\ & \text { 트́ } \\ & i n g m \end{aligned}$ |  |  |  | $\begin{aligned} & 00 \\ & 80 \\ & 80 \\ & 08 \\ & N \sim \\ & N \end{aligned}$ |
| in $r$ | $\rightarrow \infty$ | －60N | ＋ | － | $-\infty$ | ¢ | $-\infty$ | －minor | rinor | $\rightarrow \operatorname{mos}$ | $\rightarrow m \sim$ | in r | $\rightarrow+0 \sim$ | tmor | in 0 |
|  | E | 0 | $\stackrel{\square}{\square}$ | $i$ | 0 | $\bigcirc$ | 0 | $\square$ | c： | $=$ | 9 | 1 | $\stackrel{5}{\square}$ | $i$ | － |
|  | $i$ | $i$ | a | $\cdots$ | $i$ | 9 | 9 | $i$ | $i$ | $i$ | 9 | $i$ | $\sim$ | 9 | ～ |
|  | v | $\cdots$ | $\cup$ | $\cdots$ | $\cdots$ | $n$ | $\sim$ | in | n | n | $u$ | $u$ | $\cup$ | $\sim$ | $n$ |
|  | $\stackrel{\sim}{\sim}$ | $\stackrel{\text { J }}{\text { ¢ }}$ | $\stackrel{\text { J }}{ }$ | $\stackrel{*}{*}$ | $\stackrel{n}{2}$ | $\stackrel{\sim}{\sim}$ | $\stackrel{m}{*}$ | ＊ | \％ | $\stackrel{5}{2}$ | $\stackrel{m}{m}$ | $\stackrel{\sim}{\sim}$ | ＊ | $\stackrel{m}{7}$ | 5 |
|  | $\underset{\sim}{a}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\stackrel{\hbar}{\hbar}$ | $\begin{aligned} & \underset{\sim}{\sim} \\ & \underset{\sim}{1} \end{aligned}$ | $\begin{aligned} & \infty \\ & \stackrel{0}{\alpha} \\ & \underset{\sim}{1} \end{aligned}$ | $\begin{aligned} & 6 \\ & \stackrel{6}{9} \end{aligned}$ | $\vec{a}$ | $\stackrel{\rightharpoonup}{\alpha}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & \hline \end{aligned}$ | $\begin{aligned} & \infty \\ & \stackrel{\infty}{\infty} \\ & \hline \end{aligned}$ | $\begin{aligned} & \mathrm{m} \\ & \stackrel{8}{9} \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{0}{-} \\ & \hline- \end{aligned}$ | $\underset{\sim}{\underset{\sim}{\sim}}$ | $$ | $\stackrel{\infty}{\sim}$ |
|  | N | in | in | $\exists$ | $\stackrel{\sim}{\sim}$ | $\sigma$ | $\stackrel{\sim}{\square}$ | $\stackrel{\sim}{2}$ | n | 9 | $\checkmark$ | $\bigcirc$ | 9 | $\pm$ | $\stackrel{m}{\sim}$ |
|  | $\underset{\tilde{i}}{\tilde{j}}$ | $\begin{aligned} & \text { N } \\ & \end{aligned}$ | $\stackrel{\otimes}{\sim}$ | $\stackrel{\infty}{\sim}$ | $\stackrel{\pi}{n}$ | $\underset{\sim}{N}$ | $\stackrel{\dddot{N}}{\cong}$ | $\tilde{\tilde{N}}$ | $\underset{\sim}{T}$ | $\stackrel{i n}{N}$ | ${\underset{N}{n}}_{n}^{n}$ | $\begin{aligned} & i n \\ & i n \end{aligned}$ | $\stackrel{\substack{n \\ \sim}}{ }$ | $\begin{aligned} & \dot{\sim} \\ & \stackrel{\sim}{\sim} \end{aligned}$ | $\stackrel{\sim}{\sim}$ |


|  |  |  |  |  |  |  |  | 1277000 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 276 | 7 | 1961 | 23 | $s$ | -9 | 9 | $\begin{aligned} & 1 \\ & 5 \\ & 6 \\ & 7 \end{aligned}$ | 3568800 165000 5852832 4590000 | 4 | 6980 | 2.01025 |
| 277 | 12 | 1930 | 44 | $s$ | -9 | c | $5$ | $\begin{aligned} & 6250000 \\ & 6250000 \\ & 1899032 \end{aligned}$ | 4 | 50000 | $0 . \operatorname{coson}$ |
| 284 | 7 | 1969 | 7 | s | -9 | or | 5 | 3688100 | 4 | 20000 | 0.60545 |
| 285 | 1) | 1928 | 75 | s | -9 | A | $\begin{array}{r} 5 \\ 6 \end{array}$ | $\begin{aligned} & 2062500 \\ & 2062500 \end{aligned}$ | 4 | 0 | 0.6 |
| 292 | 14 | 1962 | 70 | c | -9 | A | $\begin{aligned} & 1 \\ & 5 \\ & 6 \end{aligned}$ | $\begin{aligned} & 2647000 \\ & 3402090 \\ & 4314615 \end{aligned}$ | 4 | 0 | 0.0 |
| 293 | 10 | 1923 | 44 | s | -9 | or | $4$ | $\begin{array}{r} 1437500 \\ 2590 \end{array}$ | 3 | 30000 | 0.020 .97 |
| 301 | 11 | 1960 | 43 | c | -9 | $\square$ | $\begin{aligned} & 1 \\ & 3 \\ & 5 \\ & 6 \\ & 7 \end{aligned}$ | $\begin{aligned} & 100000000 \\ & 885,117 \\ & 8250000 \\ & 87400000 \\ & 12.631000 \end{aligned}$ | $\begin{aligned} & 4 \\ & 5 \end{aligned}$ | $\begin{aligned} & 18600 \\ & 21+50^{2} \end{aligned}$ | 0.00129 |
| 304 | 9 | 1964 | 3.4 | $c$ | 1 | 0 | $\begin{aligned} & 1 \\ & 3 \\ & 5 \\ & 6 \\ & 7 \end{aligned}$ |  | $\begin{aligned} & 4 \\ & 5 \end{aligned}$ | $\begin{array}{r} 25000 \\ 8250 \end{array}$ | 0.60738 |
| 32.4 | 11 | 1923 | $4 *$ | 5 | $-9$ | $-9$ | 7 | 524250 | 2 | 150000 | 0.28612 |
| 326 | 14 | 1901 | 41 | c | -9 | A | $\begin{aligned} & 1 \\ & 4 \\ & 6 \end{aligned}$ | $\begin{aligned} & 3900000 \\ & 3490750 \\ & 6396000 \end{aligned}$ | 3 | 0 | 0.0 |
| 328 | 11 | 1965 | \% 3 | c. | 1 | 0 | $\begin{aligned} & \frac{1}{4} \\ & 4 \\ & \hline \end{aligned}$ | $\begin{aligned} & 2951918 \\ & 750000 \\ & 4454500 \end{aligned}$ | 3 | 35000 | 0.00786 |
| 330 | 13 | 1929 | 43 | $s$ | -9 | 0 | $\begin{aligned} & 4 \\ & 6 \\ & 7 \end{aligned}$ | $\begin{gathered} 2000000 \\ 200000 \\ 280000 \\ 5 \end{gathered}$ | 3 | 18000 | 0.60900 |
| 337 | 10 | 1965 | 21 | c | -9 | -9 | $\begin{aligned} & 1 \\ & 3 \\ & 6 \\ & 6 \end{aligned}$ | $\begin{aligned} & 2856000 \\ & 275,910 \\ & 4312560 \end{aligned}$ | 5 | 0 | 0.0 |
| 346 | 5 | 1958 | 27 | c | -9 | 0 | 5 | 455000 | 4 | 0 | 0.3 |
| 348 | 19 | 1970 | 34 | s | -9 | H | $\begin{aligned} & 1 \\ & 5 \\ & 6 \\ & 7 \end{aligned}$ |  | 4 | 9780 | 0.00125 |



|  |  |  |  |  |  |  |  |  |  |  |  |  | н． 8 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\bigcirc$ |  | \％ | 吕 | $\stackrel{\because}{\square}$ |  | N En $\vdots$ |  | $\bigcirc$ |  | 100 | ： |  |  | $\bigcirc$ |
| － | $\underset{\sim}{\text { 高淢 }}$ | － | 彦 | $\begin{aligned} & \dot{c} \\ & \underset{\sim}{2} \end{aligned}$ | $\begin{aligned} & 008 \\ & \text { oren } \\ & \text { or } \\ & 080 \\ & 0 \end{aligned}$ | $\overrightarrow{\underset{\infty}{\vec{~}}}$ | － | － | $\underset{\sim}{\sim}$ | $\stackrel{\circ}{\square}$ | － | － | $\stackrel{\circ}{\circ}$ | － |
| $\checkmark$ | nm | $\stackrel{ }{*}$ | $\checkmark$ | $*$ | noms | $\sim$ | ＊ | m | $\sim$ | m | $\sim$ | $\cdots$ | $\cdots$ | $\checkmark$ |
|  |  |  |  |  |  | $\begin{aligned} & \stackrel{0}{\circ} \\ & \stackrel{\circ}{\circ} \\ & \stackrel{y}{\square} \end{aligned}$ | 吕会 | $\begin{aligned} & 0 \\ & 00 \\ & 0 \\ & 0 \end{aligned}$ | － |  |  |  |  |  |
| －mo | $\rightarrow$－M－ | ¢ 0 | mmar | noner | tmer | － | no | $\pm 0$ | r． | $- \pm 6$ | no | －＊or | －str | －no |
| $=$ | $\bigcirc$ | ＜ | $=$ | c | $\bigcirc$ | i | $E$ | E | i | $\stackrel{ }{5}$ | 工 | c | － | － |
| $i$ | $i$ | $i$ | $\sim$ | $i$ | $i$ | $\sim$ | $i$ | $\sim$ | $i$ | $\sim$ | $i$ | $\sim$ | － | i |
| n | n | $\checkmark$ | 0 | $\sim$ | $\cdots$ | $\cdots$ | $\cdots$ | $\sim$ | $\checkmark$ | $\checkmark$ | $n$ | $\checkmark$ | u | $\checkmark$ |
| $\stackrel{\square}{\text { ¢ }}$ | $\stackrel{\text { J }}{ }$ | $\stackrel{n}{\sim}$ | F | ＊ | ＊ | $\stackrel{\text { J }}{\text {＋}}$ | $\stackrel{\sim}{\sim}$ | $\stackrel{\square}{*}$ | ＊ | ＊ | $\stackrel{\sim}{2}$ | $\stackrel{*}{*}$ | F | $\sim$ |
| $\begin{gathered} \text { ö } \\ \text { 2 } \end{gathered}$ | $\begin{aligned} & \circ \stackrel{\circ}{\circ} \\ & \hline \end{aligned}$ | $\underset{\sim}{\tilde{\Sigma}}$ | $\stackrel{8}{\square}$ | $\stackrel{\text { ® }}{\text { ¢ }}$ | $\stackrel{\sim}{\sim}$ | $\stackrel{\stackrel{\rightharpoonup}{\alpha}}{\underset{\sim}{4}}$ | $\stackrel{\stackrel{\sim}{\approx}}{\approx}$ | $\stackrel{\text { a }}{\square}$ | $\stackrel{\text { ® }}{\text {－}}$ | $\stackrel{\sim}{\sim}$ | $\stackrel{\sim}{\sigma}$ | $\overline{\tilde{\sigma}}$ | $\stackrel{\approx}{\approx}$ | $\stackrel{\circ}{\square}$ |
| m | 三 | $\checkmark$ | $\simeq$ | ＊ | $=$ | 3 | $\bigcirc$ | $\stackrel{\square}{\circ}$ |  | $\sim$ | － | $\cdots$ | － | － |
| $\stackrel{\text { ？}}{\substack{\text { a }}}$ | 8 | $\stackrel{\sim}{6}$ | \％ | $\underbrace{n}$ | \％ | $\vec{\sim}$ | ＊ | $\stackrel{9}{5}$ |  | $\underset{\sim}{\sim}$ | $\stackrel{3}{3}$ | $\stackrel{\checkmark}{\text { in }}$ | $\stackrel{\sim}{n}$ | $\cdots$ |


|  |  |  |  |  |  |  |  |  |  |  |  |  | H． 9 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\sim$ | $\stackrel{\rightharpoonup}{5}$ | 0 | $\cdots$ |  | $\stackrel{\sim}{0}$ | $\cdots$ | $\stackrel{0}{0}$ | $\stackrel{ }{-}$ | $\stackrel{\sim}{*}$ | $\sim$ | $\sim$ |  | 5 |
|  | $\stackrel{\sim}{\sim}$ | $\stackrel{5}{m}$ | 0 | H |  | $\bigcirc$ | 0 | $\underline{m}$ | $\stackrel{\square}{-2}$ | $\stackrel{\sim}{\sim}$ | $\stackrel{5}{4}$ | － |  | W |
| 0 | 8 | $\cdots$ | $?$ | 8 | $\cdots$ | $\bigcirc$ | 8 | $\cdots$ | 8 | 8 | 6 | 8 |  | 8 |
| － | － | － | ， |  | $\because$ | \％ | ． | ？ | － | 0 | $?$ |  | $?$ |  |
| $\bigcirc$ | $\bigcirc$ | 0 | $\therefore$ | $\bigcirc$ | $\cdots$ | $\bigcirc$ | 0 | － | $\bigcirc$ | $\bigcirc$ | O | $\bigcirc$ | \％ | 0 |
| $\bigcirc$ | 00 | $\bigcirc$ | in | 0 | $\bigcirc$ | － | $\bigcirc$ |  | 0 | － | 0 | $\rho$ | － |  |
|  | 88 | m | N | 8 8 |  | 앙 | N | $F$ | ¢ | 8 | 8 | 5 |  | $\sim$ |
|  | 00 | N | － | $\sim$ |  |  |  | $\cdots$ | $\sigma$ | $\bigcirc$ | $m$ | $\square$ |  | $\cdots$ |
|  | N | v | m |  |  |  |  | $\rightarrow$ | $\cdots$ | $\rightarrow$ |  |  |  | $\cdots$ |
| 5 | －m | m． | $\checkmark$ | $\sim$ in | $m$ | $\sim$ | $\checkmark$ | in | $\stackrel{ }{ }$ | $\sim$ | $\pm$ | $m$ | $\checkmark$ | $m$ |
| w | 0 | 00 | in $n 0$ | 10000 | $\cdots$ | 0 | 0000 | 4000 | 0000 | 000以0 | $\bigcirc 0$ | moodo | Rooo | 00 |
| $\sim$ | 18 | $\bigcirc 0$ | NへO | 2096 | － | $\bigcirc$ | －0ㅇㅇ | O200 | 00900 | 0900 | 20 | O0Eㅇ | 200 | OO |
| － | $\stackrel{3}{2}$ | $\stackrel{1}{4} 8$ | － | ＝8N5 | 5 | 8 |  | 8898 | 8858 | 아능 | No | ㄷ8\％ | ¢응ㅇ | 88 |
| in | $\sim$ | ¢ | け50 | サ○Nam | $\sim$ | － | － $\mathrm{c}_{\text {cr }}$ | －06v | ○○\％ | mma－m | ～ | ccow | ¢ | －0 |
| $\stackrel{\sim}{\sim}$ | 0 | $\underset{-1}{0}+$ | mma | Nowno | $\infty$ | $\underset{\sim}{7}$ |  |  | $\operatorname{lin}_{\infty} \operatorname{in} \sigma 8$ |  | ¢ |  | くもへさ | $\stackrel{\square}{0} \sim$ |
| in | $\sim$ | $\leftrightarrow \sim$ | in 0 | Hmincr | ＋ | $\sim$ | －inor | Hmcr | Hrin or | －asmon | 10 | $\rightarrow$ がo | $\rightarrow \ln$ | $\rightarrow \mathrm{m}$ |
| c | E | $E$ | $\sigma$ | $c$ | $\sigma$ | 0 | 4 | $\sigma$ | 5 | $i$ | － | c | 0 | 0 |
| 0 | 0 | 0 | 0 | $\pi$ | 0 | $\stackrel{0}{0}$ | 0 | 0 | 0 | 0 | 0 | 0 | $\sigma$ | $\sim$ |
| 1 | 1 | 1 | 1 | 1 | 1 |  | 1 | 1 |  |  |  |  | ！ |  |
| 0 | － | in | $u$ | $\bigcirc$ | $n$ | u | $n$ | 0 | $n$ | 0 | 0 | $\backsim$ | a | $n$ |
| $\stackrel{n}{n}$ | $\pm$ | $\pm$ | む | $\stackrel{5}{4}$ | $=$ | ज | $\stackrel{+}{*}$ | N | S | $\cdots$ | $\stackrel{ \pm}{m}$ | $\stackrel{\sim}{\square}$ | $\cdots$ | vid |
| 0 |  |  | － | $\pm$ | $\infty$ | $\sigma$ | － | r |  | ＊ | N | $\cdots$ | － |  |
| $\stackrel{\sim}{6}$ | ${ }_{3}$ | $\sim$ | N | $\stackrel{\circ}{\circ}$ | $\stackrel{1}{6}$ | 1 | 8 | $\stackrel{\sim}{6}$ | 8 | 0 | － | $\stackrel{0}{0}$ | 0 | \％ |
| $\stackrel{-}{\sim}$ |  | $-$ | $\cdots$ | $\sim$ | $\bigcirc$ |  | $\cdots$ | $\rightarrow$ | $\rightarrow$ | $\sim$ | $\stackrel{ }{-}$ | $\cdots$ | $\stackrel{-}{-}$ | $\xrightarrow{-}$ |
| $\sigma$ | $0$ | 2 | $\underset{\sim}{\sim}$ | N | $\cdots$ | in | $\stackrel{0}{2}$ | $\cdots$ | $\sim$ | $\xrightarrow{-\sim}$ | in | $\infty$ | $\rightrightarrows$ | $\cdots$ |
| $\therefore$ | m |  | $\cdots$ | $\cdots$ | in | $\infty$ | － | in | 0 | $\rightarrow$ | $\omega$ | $\cdots$ | $\cdots$ | $N$ |
| $\hat{\sim}$ | 응 | N | $\sim$ | in | 出 | $\stackrel{+}{\sim}$ | in | in | in | $n$ | n | in | in | $\hat{N}$ |


|  | $\begin{aligned} & \pm \\ & \stackrel{\rightharpoonup}{\circ} \\ & \stackrel{3}{3} \\ & 0 \end{aligned}$ | $\begin{aligned} & \stackrel{C}{7} \\ & \underset{\sim}{N} \\ & \dot{O} \end{aligned}$ | $\begin{aligned} & - \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\bigcirc$ | $\begin{aligned} & \text { m } \\ & 0 \\ & \vdots \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \tilde{a} \\ & \stackrel{y}{+} \\ & \infty \\ & \infty \\ & \dot{0} \end{aligned}$ | $\because$ | $\bigcirc$ | $\begin{aligned} & \underset{\sim}{w} \\ & 0 \\ & 0 \\ & \hline \\ & 0 \\ & 0 \end{aligned}$ | $\stackrel{\circ}{\circ}$ | $\begin{aligned} & \sim \\ & \sim \\ & 0 \\ & 8 \\ & 0 \\ & \circ \\ & \hline \end{aligned}$ | $\begin{aligned} & \approx \\ & \stackrel{\sim}{8} \\ & 0 \\ & \hline \end{aligned}$ | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & \circ \\ & \stackrel{8}{7} \\ & \hline \end{aligned}$ | $\begin{aligned} & \stackrel{8}{0} \\ & \underset{\sim}{\sim} \end{aligned}$ | $\begin{aligned} & 0 \\ & 8 \\ & 8 \\ & 0 \\ & \hline \end{aligned}$ | － | $\begin{aligned} & \text { n } \\ & \text { N } \\ & \text { n } \end{aligned}$ |  | $\bigcirc$ | $\bigcirc$ | $\begin{aligned} & \circ \\ & \stackrel{\circ}{n} \\ & \stackrel{n}{n} \end{aligned}$ | － | $\infty_{0}^{\infty}$ | $\begin{aligned} & 00 \\ & \text { ㅇo } \\ & \text { yo } \\ & 10 \end{aligned}$ | $\begin{aligned} & 0^{\circ} \\ & 8_{0} \end{aligned}$ |
|  | ＊ | $\checkmark$ | $\checkmark$ | $\pm$ | m | $n+6$ | $\cdots$ | $\cdots$ | $\cdots$ | $\checkmark$ | ＊ | ＋ | nos |
|  |  |  | ㅁoos <br> －in 0 n <br> 玉芯芯 <br> $\underset{\sim}{m}$ <br> $+\rightarrow 6-$ | $\begin{aligned} & 98 \\ & 8 \\ & 88 \\ & 8 \\ & 8 \end{aligned}$ |  |  | $$ | $\begin{aligned} & 00 \\ & 00 \\ & 80 \\ & 80 \\ & h i n \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 . \\ & 0.0 \\ & 80 \\ & \text { in } \\ & \text { mim } \end{aligned}$ |  |  |  |  |
| がor | in $N$ | －600 | － $\ln$ or | no | $\rightarrow+$ O－ | Hemonor | 50 | $\infty$ | $\leqslant \infty$ | amoror | nor | romor | －win |
|  | 5 | e | E | ＜ | 0 | $\sigma$ | $\stackrel{\text { b }}{ }$ | 4 | $\bigcirc$ | $c$ | $\sigma$ | 0 | 0 |
|  | $i$ | － | i | $i$ | $\sim$ | $i$ | $i$ | $i$ | $i$ | － | $\stackrel{\square}{1}$ | i | $i$ |
|  | ت | $\cup$ | $u$ | 0 | ט | $u$ | $u$ | E | n | $\sim$ | $\sigma$ | $\cdots$ | n |
|  | $\stackrel{\sim}{m}$ | $\stackrel{\sim}{\sim}$ | 3 | $\stackrel{\square}{\sim}$ | ¢ | $\cdots$ | $\stackrel{\sim}{\sim}$ | 8 | $\stackrel{*}{*}$ | ง | $\pm$ | $\stackrel{\sim}{*}$ | $\stackrel{t}{*}$ |
|  | $\stackrel{\stackrel{4}{w}}{\stackrel{y}{*}}$ | $$ | $\begin{aligned} & \stackrel{\circ}{\circ} \\ & \underset{-}{2} \end{aligned}$ | $\begin{gathered} \underset{\sim}{N} \\ \hline \end{gathered}$ | $\frac{m}{a}$ | $\begin{gathered} \underset{\sim}{\sim} \\ \underset{\sim}{*} \end{gathered}$ | $\begin{aligned} & \underset{\sim}{N} \\ & \underset{\sim}{\alpha} \end{aligned}$ | $\begin{aligned} & \underset{N}{N} \\ & \underset{\sim}{n} \end{aligned}$ | $\begin{aligned} & \underset{\sim}{\sim} \\ & \underset{\sim}{*} \end{aligned}$ | $\stackrel{\pi}{\approx}$ | $\underset{\sim}{\underset{\sim}{\sigma}}$ | $\stackrel{\infty}{\stackrel{\infty}{\sim}}$ | $\stackrel{\sim}{c}$ |
|  | in | $\cdots$ | 0 | $\bigcirc$ | $\pi$ | $\stackrel{m}{\sim}$ | $\infty$ | n | $\cong$ | $\stackrel{\sim}{\sim}$ | $\stackrel{n}{9}$ | $\cdots$ | $\stackrel{9}{9}$ |
|  | $\stackrel{0}{\text { in }}$ | $\stackrel{0}{\stackrel{a}{2}}$ | $\overrightarrow{x_{n}}$ | $\stackrel{\infty}{\infty}$ | $\underset{\substack{\text { in } \\ \text { in }}}{ }$ | $\stackrel{\infty}{\infty}$ | $\stackrel{m}{c}$ | $\stackrel{\sim}{i}$ | $\cong$ | $\underset{6}{9}$ | $\stackrel{ \pm}{0}$ | N | $\frac{0}{6}$ |



|  |  |  |  |  |  |  |  |  |  |  |  | H． 12 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\bigcirc$ | O | $\stackrel{\infty}{\sim}$ $\stackrel{\sim}{\sim}$ $\stackrel{\square}{\square}$ | $\begin{aligned} & \mathrm{N} \\ & \underset{\sim}{\circ} \\ & \therefore \end{aligned}$ | $\begin{aligned} & \pi \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \text { जै } \\ & 0 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & N \\ & \tilde{N} \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 8 \\ & 8 \\ & 0 \\ & 1 \end{aligned}$ |  | $\begin{aligned} & \text { N } \\ & 0 \\ & 0 \\ & 8 \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \tilde{0} \\ & 0 \\ & \hat{n} \\ & 0 \\ & 0 \end{aligned}$ | 0 | $\begin{aligned} & \tilde{r} \\ & \tilde{n} \\ & \ddot{8} \\ & \dot{0} \end{aligned}$ | N O O 0 0 |
|  | － | $\bigcirc$ | $\begin{aligned} & 8 \\ & 8 \\ & \text { in } \end{aligned}$ | $\begin{aligned} & 0 \\ & 8 \\ & 8 \\ & 0 \end{aligned}$ |  | O | $\begin{aligned} & \circ \\ & 8 \\ & 0 \\ & \mathrm{O} \end{aligned}$ |  | $\begin{aligned} & \stackrel{\alpha}{i} \\ & i n \\ & \sim \end{aligned}$ | $\begin{aligned} & 88 \\ & 88 \\ & 8 \\ & 0 \end{aligned}$ | $\stackrel{\sim}{\sim}$ | $\begin{aligned} & 0 \\ & 8 \\ & 8 \\ & \text { in } \end{aligned}$ | $\bigcirc$ | $\begin{aligned} & \circ \\ & \text { in } \\ & \text { n } \end{aligned}$ | $\begin{aligned} & \infty \\ & \underset{y}{\infty} \\ & \underset{\sim}{\circ} \end{aligned}$ |
|  | $\checkmark$ | $\cdots$ | m | $*$ | $\cdots$ | $\cdots$ | $n$ | $\cdots$ | $\cdots$ | $\sim \mathrm{N}$ | $\cdots$ | $\cdots$ | s | $\sim$ | $\checkmark$ |
|  | $\begin{aligned} & 0 \\ & \stackrel{8}{8} \\ & \stackrel{0}{\sim} \\ & \underset{\sim}{2} \end{aligned}$ |  | $\begin{aligned} & 00 \\ & 80 \\ & \text { مio } \\ & \text { hin } \\ & m \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{\circ}{8} \\ & \stackrel{1}{\sim} \\ & \underset{\sim}{2} \end{aligned}$ |  |  |  | $i$ |  |  |  | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & \stackrel{E}{0} \\ & \hline \end{aligned}$ | $\begin{aligned} & 00 \\ & 80 \\ & \text { Bo } \\ & \\ & \end{aligned}$ |  | $\begin{aligned} & 008 \\ & 8.8 \\ & 888 \\ & \text { in } \\ & \text { in } 5 \end{aligned}$ |
| 6 | － | $\rightarrow \mathrm{mbo}$ | $\pm$＋ | in | $\rightarrow+$－ | $\rightarrow+0$ | anmor | $\bigcirc$ | rmor |  | $\rightarrow \mathrm{mor}$ | － | in N | sor | nor |
|  | － | c | $\bigcirc$ | － | 0 | $<$ | 8 | i | 9 | E | 9 | 4 | c | ¢ | 2 |
|  | $\stackrel{\square}{1}$ | $i$ | $\neg$ | m | $\sim$ | － | $i$ | m | 9 | 9 | 1 | 1 | 9 | $i$ | $\stackrel{\square}{i}$ |
|  | $\approx$ | 0 | $\checkmark$ | n | $u$ | $\sim$ | $n$ | 1 | 0 | $v$ | n | $\cdots$ | 0 | m | n |
|  | \％ | $\underset{\sim}{\sim}$ | \％ | 5 | $\stackrel{J}{\text { V }}$ | $\vec{*}$ | ज | in | $\sim$ | $\pm$ | $\sim$ | $\stackrel{5}{5}$ | $\cdots$ | m | $\pm$ |
|  | $$ | $\begin{aligned} & \vec{F} \\ & \underset{\sim}{2} \end{aligned}$ | $\stackrel{\underset{\sim}{\sim}}{\underset{\sim}{\sim}}$ | $\begin{gathered} \text { in } \\ \end{gathered}$ | $\stackrel{\underset{\sim}{\sigma}}{\underset{\sim}{*}}$ | $\begin{aligned} & \infty \\ & \stackrel{\circ}{\circ} \\ & \hline \sim \end{aligned}$ | $\begin{aligned} & \stackrel{\rightharpoonup}{c} \\ & \underset{\sigma}{6} \end{aligned}$ | $\begin{aligned} & + \\ & \stackrel{\circ}{\circ} \\ & \stackrel{1}{2} \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{0}{\sigma} \\ & \hline \end{aligned}$ | $\stackrel{\sim}{0}$ | 8 | $\frac{\pi}{a}$ | $\stackrel{\square}{\circ}$ | $\stackrel{\underset{\sim}{\sim}}{\underset{\sim}{\sim}}$ | $\stackrel{\sim}{\square}$ |
|  | $\infty$ | $\stackrel{ }{\sim}$ | $\sim$ | $\sim$ | $\cong$ | $\sim$ | 9 | $\infty$ | $\stackrel{m}{\sim}$ | $\pm$ | 0 | $\pm$ | $\rightarrow$ | $\bigcirc$ | $\stackrel{\sim}{\sim}$ |
|  | $\begin{aligned} & \underset{\sim}{x} \\ & \infty \\ & 0 \end{aligned}$ | $\vec{\sigma}$ | $\stackrel{m}{\sigma}$ | $\begin{gathered} \infty \\ \underset{\alpha}{\circ} \end{gathered}$ | $\overline{2}$ | $\underset{\sim}{\underset{\sim}{2}}$ | $\stackrel{\sigma}{2}$ | $\underset{\sim}{N}$ | $\stackrel{N}{N}$ | $\hat{N}$ | $\stackrel{\infty}{\sim}$ | $\stackrel{8}{5}$ | $\underset{\sim}{\sim}$ | $\stackrel{n}{i n}$ | $\stackrel{0}{c}$ |


|  |  |  |  |  |  |  |  |  |  |  |  | H． 13 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & \hat{O} \\ & \stackrel{a}{8} \\ & \stackrel{0}{\circ} \end{aligned}$ | $\begin{aligned} & N \\ & \tilde{n} \\ & \stackrel{3}{0} \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{\rightharpoonup}{0} \\ & \underset{U}{0} \\ & \dot{0} \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{0}{0} \\ & \stackrel{\rightharpoonup}{0} \\ & \therefore \end{aligned}$ | $\stackrel{\circ}{\circ}$ | 艺 | 0 | $\bigcirc$ | $\begin{aligned} & \infty \\ & \underset{\sim}{\sim} \\ & \stackrel{0}{0} \\ & 0 \\ & 0 \end{aligned}$ | $\because$ | $\begin{aligned} & \text { N } \\ & \stackrel{\sim}{心} \\ & \stackrel{1}{0} \\ & \circ \end{aligned}$ | $\begin{aligned} & \stackrel{N}{\sim} \\ & \stackrel{N}{2} \\ & \stackrel{O}{\circ} \end{aligned}$ | $\bigcirc$ |
| $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \text { oo } \\ & \text { B } \\ & \text { in } \\ & \sim \end{aligned}$ | $\begin{aligned} & \text { in } \\ & \text { og } \\ & \text { N } \end{aligned}$ | $\begin{aligned} & 0 \\ & 8 \\ & \text { in } \\ & \mathrm{m} \end{aligned}$ | $\frac{3}{3}$ | $\bigcirc$ | $\Xi$ | － | 0 | $\begin{aligned} & 0 \\ & 8 \\ & 8 \\ & 0 \end{aligned}$ | 0 | $\begin{aligned} & \stackrel{n}{\sim} \\ & \underset{\sim}{\infty} \\ & \infty \\ & \underset{\sim}{\infty} \end{aligned}$ | $\stackrel{N}{\underset{\sigma}{\sigma}}$ | － |
| $n$ | min | in | $m$ | in | m | $\cdots$ | $\checkmark$ | $\checkmark$ | $\cdots$ | m | tin | $n$ | ง |
| $\begin{aligned} & =00 \\ & =80 \\ & =09 \\ & =0 \\ & m=1 \\ & \infty \rightarrow=1 \end{aligned}$ |  |  |  | 0000 0880 888 88 08 $m$ $m$ | $\circ$ <br> $\underset{\sim}{n}$ <br>  <br>  | $\begin{aligned} & 380 \\ & \text { 308 } \\ & \text { in } \\ & \text { in } \\ & \text { in } \end{aligned}$ | $\begin{aligned} & 08 \\ & 80 \\ & 88 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & 80 \\ & 88 \\ & 88 \\ & i 8 \\ & 50 \\ & 0 \\ & 0 \end{aligned}$ |  | $\begin{aligned} & 8080 \\ & 8880 \\ & 8080 \\ & 080 \\ & \text { inN } \\ & \text { NNM } \end{aligned}$ |  |  |  |
| $\rightarrow \infty$ | －m＊or | Hmor | vor | Hmor | $\stackrel{ }{*}$ | Hor | － |  | $\rightarrow m * 0$ | －mso | monor | －mor | －mu． |
| $i$ | 0 | $i$ | $\bigcirc$ | $i$ | 0 | $\stackrel{\square}{6}$ | c | $c$ | 0 | E | c | $i$ | $\cup$ |
| $i$ | $\%$ | 9 | $\sim$ | $i$ | 9 | $i$ | 9 | 9 | 9 | $i$ | 9 | $i$ | $\stackrel{\square}{i}$ |
| in | in | $\cup$ | $\stackrel{\rightharpoonup}{c}$ | $u$ | in | － | $\sim$ | ט | $n$ | $\bullet$ | $n$ | $\cdots$ | es |
| $\vec{r}$ | 5 | $\sim$ | v | $\stackrel{\sim}{2}$ | s | ${ }_{5}$ | $\cdots$ | $\stackrel{\sigma}{v}$ | $\vec{\sim}$ | $\sim$ | $\stackrel{\sim}{*}$ | 5 | $\infty$ |
| $\underset{\sim}{\underset{\sim}{\alpha}}$ | $\begin{aligned} & \text { N} \\ & \text { B } \\ & \end{aligned}$ | $\begin{aligned} & \sim \\ & \stackrel{\circ}{0} \end{aligned}$ | $\stackrel{\propto}{\stackrel{\infty}{\underset{\sim}{\underset{\sim}{2}}}}$ | $\begin{aligned} & \text { n } \\ & \stackrel{\alpha}{\sigma} \end{aligned}$ | $\stackrel{\rightharpoonup}{o}$ | $\begin{aligned} & \underset{\sim}{c} \\ & \underset{\sim}{\sim} \end{aligned}$ | $\stackrel{\rightharpoonup}{\hat{\sigma}}$ | $\stackrel{\substack{\mathrm{N}}}{\underset{\sim}{2}}$ | $\begin{aligned} & \stackrel{\circ}{\circ} \\ & \stackrel{2}{\circ} \end{aligned}$ | $\stackrel{\text { ¢ }}{0}$ | $\begin{aligned} & \infty \\ & \stackrel{\infty}{\sigma} \end{aligned}$ | $\stackrel{\leftrightarrow}{\circ}$ | N $\sim$ $\sim$ |
| $\stackrel{\square}{-}$ | $\bigcirc$ | $\infty$ | $\infty$ | $\cdots$ | $\infty$ | $\infty$ | $\checkmark$ | － | $=$ | $\infty$ | च | $\stackrel{m}{\square}$ | $=$ |
| $\underset{\sim}{\sim}$ | $\underset{\sim}{\infty}$ | $\stackrel{\curvearrowleft}{\infty}$ | $\begin{gathered} \underset{\sim}{\alpha} \\ \underset{\sim}{2} \end{gathered}$ | $\stackrel{8}{8}$ | E | $\stackrel{\infty}{\underset{\sim}{\circ}}$ | $\overrightarrow{0}$ | $\begin{gathered} N \\ 0 \\ 0 \end{gathered}$ | $\stackrel{v}{\infty}$ | $\underset{\substack{N \\ \infty}}{\substack{0}}$ | $\stackrel{\sim}{\sim}$ | $\stackrel{n}{\infty}$ | $\underset{\sim}{\approx}$ |



| $\stackrel{4}{5}$ |  | N | in |  |  | O | $\sim$ | $\stackrel{5}{5}$ | 0 | 0 | $\stackrel{*}{*}$ | 0 | － |  | $\cdots$ | $\cdots$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| in |  | $\bigcirc$ | $n$ |  |  | $\square$ | N | in | 0 |  | N |  |  |  |  |  |
| 8 |  | 8 | $E$ |  |  | 8 | $3$ | $\xrightarrow{3}$ | 8 | 3 | 8 | 3 | $8$ |  | 8 |  |
| 8 | 0 | ． | $\%$ | $\bigcirc$ | 0 | O | － | 。 | \％ |  |  |  | 0 | 0 |  |  |
| $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | 0 | $\bigcirc$ | $\bigcirc$ | \％ | $\bigcirc$ | $\bigcirc$ | \％ | $\bigcirc$ | $\dot{\square}$ | $\bigcirc$ | ， | 0 | $\bigcirc$ |
| $\begin{aligned} & 0 \\ & 8 \\ & 8 \end{aligned}$ | 0 | $$ | $\begin{aligned} & \infty \circ \\ & 08 \\ & 08 \\ & 80 \end{aligned}$ | $\bigcirc$ | $\bigcirc$ | $\begin{aligned} & 0 \\ & 0 \\ & \text { in } \end{aligned}$ | $8$ | $\begin{aligned} & \circ \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & N \\ & \text { N } \\ & \text { on } \end{aligned}$ | $\stackrel{8}{\mathrm{i}}$ | $\begin{gathered} \infty \\ \underset{\infty}{\mathbf{s}} \end{gathered}$ | $\underset{\sim}{n}$ | $\begin{aligned} & 8 \\ & 8 \\ & \hline \end{aligned}$ | $\bigcirc$ | $\begin{aligned} & 0 \\ & 0 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0 \\ & \pm \\ & \stackrel{y}{*} \end{aligned}$ |
| ＊ | ＊ | in | $\sim$ | $\cdots$ | $m$ | $1 \sim$ | $\checkmark$ | s | in | $m$ | $\checkmark$ | ${ }^{*}$ | $\downarrow$ | $\cdots$ | $\checkmark$ | $m$ |
| $\begin{aligned} & 806 \\ & 88 \mathrm{a} \\ & 085 \\ & 05 \\ & 6 \mathrm{~F} 5 \end{aligned}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 5 \\ & 5 \\ & 5 \end{aligned}$ | $\begin{aligned} & 0060 \\ & 0880 \\ & 8806 \\ & 8 心 g 0 \\ & \text { m m m } \end{aligned}$ |  | $\begin{aligned} & 08 \\ & 88 \\ & 8.8 \\ & 50 \\ & 50 \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{0}{\delta} \\ & \stackrel{C}{\circ} \\ & \text { in } \end{aligned}$ |  | $\begin{aligned} & 0 \\ & 0 \\ & 8 \\ & 0 \\ & i n \\ & \end{aligned}$ | $\begin{aligned} & 02 \\ & 62 \\ & N N \\ & N N \end{aligned}$ | $\begin{aligned} & 06 \\ & 828 \\ & 868 \\ & 0.10 \\ & m i n \end{aligned}$ |  |  |  | $\begin{aligned} & n \\ & N \\ & N \\ & N \\ & N \end{aligned}$ | 2 <br> 8 <br>  <br>  | $\begin{aligned} & 00 \\ & 00 \\ & 06 \\ & 50 \end{aligned}$ | 0 <br> 0 <br> 0 <br>  <br>  |
| －150 | ～ | $\rightarrow m a r$ | $\rightarrow$ Hinom | $\bigcirc 0$ | $\checkmark$ | $\rightarrow \mathrm{mon}$ | $n$ | in 0 | $\rightarrow 0$ | $\rightarrow * \infty$ | $\rightarrow$ H 0 | $\rightarrow \ln 0 \mathrm{~N}$ | in | $\pm$ | Ln N | $\xrightarrow{+}$ |
| $c$ | $\pm$ | $i$ | 0 | 0 | $\stackrel{\square}{\square}$ | 9 | － | 0 | 9 | $<$ | ＜ | $c$ | $<$ | 0 | 0 | 0 |
| $i$ |  | $m$ | $\stackrel{i}{i}$ | － | $i$ | i | 0 | $\begin{aligned} & a \\ & 1 \end{aligned}$ | $\begin{gathered} \sigma \\ 1 \end{gathered}$ | $\begin{gathered} 0 \\ 1 \end{gathered}$ | $\begin{aligned} & 0 \\ & 1 \end{aligned}$ | $\begin{gathered} \sigma \\ 1 \end{gathered}$ | $\begin{aligned} & 0 \\ & i \end{aligned}$ | 9 | $\begin{aligned} & 0 \\ & 1 \end{aligned}$ | N |
| in | $\cup$ | $\omega$ | $\cup$ | $\omega$ | in | $\omega$ | $n$ | en | $n$ | $\cup$ | on | $\sim$ | a | $\cdots$ | $\cdots$ | $\omega$ |
| － | $i$ | $\stackrel{\square}{5}$ | $\stackrel{5}{5}$ | g | O | $\underset{y}{*}$ | $\underset{\sim}{\sim}$ | $\stackrel{\sim}{N}$ | \％ | $\vec{G}$ | $\cdots$ | J | $\underset{\sim}{\sim}$ | F | $\stackrel{\sim}{\sim}$ | $\pm$ |
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|  | u | $\bullet$ | - | $\checkmark$ | n | $\checkmark$ | a | $\checkmark$ | 2 | 9 | $u$ | し | $n$ | 0 | $\checkmark$ |
|  | $\stackrel{*}{*}$ | $\stackrel{\square}{\sim}$ | * | $\stackrel{*}{\text { m }}$ | $\pm$ | 9 | 5 | N | in | $\stackrel{3}{3}$ | $\stackrel{\sim}{*}$ | $\cdots$ | 9 | $\stackrel{m}{5}$ | $\stackrel{\sim}{2}$ |
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|  | $\infty$ | m | $\cdots$ | n | 2 | $\bigcirc$ | $\stackrel{1}{2}$ | $\bullet$ | $\cdots$ | $\bigcirc$ | 2 | $\simeq$ | $\bigcirc$ | $\because$ | in |
|  | $\stackrel{N}{ \pm}$ | $\begin{aligned} & \pm \\ & \pm \end{aligned}$ | $\begin{aligned} & \stackrel{\infty}{\sim} \\ & \underset{\sim}{4} \end{aligned}$ | $\underset{\Xi}{N}$ | $\begin{gathered} \Psi \\ \stackrel{~}{+} \\ \stackrel{2}{+} \end{gathered}$ | $\begin{aligned} & - \\ & \stackrel{\rightharpoonup}{-} \\ & \hline \end{aligned}$ | $\begin{aligned} & \alpha \\ & \underset{\sim}{a} \\ & \underset{\sim}{*} \end{aligned}$ | $$ | $\stackrel{\sim}{\substack{5 \\ \underset{\sim}{2}}}$ | $\stackrel{m}{\leftrightharpoons}$ | $\stackrel{m}{5}$ | $\begin{aligned} & \vec{r} \\ & \underset{\sim}{n} \end{aligned}$ | $\begin{aligned} & \infty \\ & \underset{\sim}{N} \\ & \end{aligned}$ | $\stackrel{N}{\stackrel{N}{n}}$ | $\stackrel{n}{\sim}$ |


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| $c$ | $i$ | 0 | $\square$ | $\stackrel{a}{i}$ | $9$ | $\sim$ | － | $i_{i}$ | $i$ | $\rightarrow$ | $i$ | $\sigma$ | 0 |
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| $\begin{aligned} & \infty \\ & \stackrel{0}{\Omega} \\ & \stackrel{y}{2} \end{aligned}$ | $\stackrel{Q}{Q}$ | $\begin{aligned} & \mathrm{m} \\ & \stackrel{0}{2} \end{aligned}$ | $\infty$ $\stackrel{8}{\circ}$ $\sim$ | $\begin{aligned} & \hat{0} \\ & 0 \\ & \stackrel{\rightharpoonup}{0} \end{aligned}$ | $\begin{aligned} & 17 \\ & 0 \\ & 0 \\ & \hline \end{aligned}$ | $\stackrel{\infty}{8}$ | $\begin{aligned} & \underset{\sim}{\Omega} \end{aligned}$ | $\frac{0}{0}$ | $\begin{aligned} & 0 \\ & \stackrel{\sim}{\sigma} \\ & \sim \end{aligned}$ | $\begin{gathered} \stackrel{\rightharpoonup}{b} \\ \stackrel{y}{c} \\ \underset{\sim}{2} \end{gathered}$ | $\begin{aligned} & \infty \\ & 0 \\ & 0 \\ & -1 \end{aligned}$ | $\begin{aligned} & 2 \\ & \stackrel{\circ}{-} \\ & - \end{aligned}$ | $\pm$ 0 8 |
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|  |  | $$ |  | $\begin{aligned} & 980 \\ & -88 \\ & 688 \\ & \infty \\ & \pm \\ & \pm \\ & \hline-1 \end{aligned}$ |  | $\begin{aligned} & 0 \\ & 8 \\ & 8 \\ & 8 \\ & 0 \\ & -1 \end{aligned}$ |  | $$ | $\begin{aligned} & \circ \ddot{0} \\ & 8 \underset{~}{8} \\ & \underset{8}{\sim} \\ & \underset{\sim}{\sim} \end{aligned}$ |  | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & \dot{N} \\ & \underset{\sim}{c} \\ & i \end{aligned}$ | $100 \cdots 0$ <br> rooro <br> 688\％ <br> cicon <br> ＊NNo゚ロ | $\begin{aligned} & \text { Nin } \\ & \text { ENO } \\ & \text { CNE } \\ & m m n \end{aligned}$ | $\begin{aligned} & 00 \\ & 08 \\ & 88 \\ & 88 \\ & 80 \\ & 6 \\ & 6 \end{aligned}$ |
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|  | $\rightarrow$ | $\underset{J}{J}$ | $\underset{\sim}{5}$ | $\underset{y}{n}$ | $\stackrel{N}{\sim}$ | $\pm$ | $\pm$ | $5$ | $\underset{\sim}{G}$ | $\begin{array}{r} G \\ G \end{array}$ | $\stackrel{n}{\sim}$ | $N$ | $\mathfrak{N}$ | N |
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|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | H． 28 |  |  |
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| $\checkmark$ | m | m | ＋ | $\cdots$ | ＊ | in | Nm | $\checkmark$ | mi | in | $\checkmark$ | $\checkmark$ | $*$ | ＊ | $\checkmark$ | $\cdots$ | in |
|  | $\begin{aligned} & 0 \\ & 0 \\ & 8 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 \\ & 8 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & 80 \\ & 28 \\ & 6.5 \\ & \pm .5 \end{aligned}$ | $$ | $\begin{aligned} & 620 \\ & 8.8 \\ & 8.8 \\ & \alpha_{i}^{\circ} \\ & \sim N \end{aligned}$ | $\begin{aligned} & 08 \\ & 80 \\ & 08 \\ & 0 . \\ & \text { in } \\ & i 0 \end{aligned}$ |  | $\stackrel{\stackrel{\rightharpoonup}{6}}{\stackrel{\rightharpoonup}{6}}$ |  |  | $\begin{aligned} & 0 \\ & \stackrel{2}{2} \\ & \stackrel{0}{6} \\ & 0_{i} \end{aligned}$ |  | $\begin{aligned} & 008 \\ & 088 \\ & 88 \\ & 0.8 \\ & 0 \\ & 0 \\ & i \end{aligned}$ | $\begin{aligned} & 500 \\ & 588 \\ & 508 \\ & =5 \end{aligned}$ | $\begin{aligned} & 00 \\ & 00 \\ & 0.8 \\ & 0 \\ & \text { K } \\ & \end{aligned}$ | $\begin{aligned} & 802 \\ & 88 \\ & 68 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | O 8 8 0 0 |
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| $i$ | $i$ | $i$ | 9 | $\stackrel{\square}{1}$ | $N$ | 0 | $\sim$ | $i$ | $\cdots$ | i | 9 | a | $\sim$ | $\rightarrow$ | m | $i$ | 9 |
| 0 | $\sim$ | u | $n$ | i | $\sim$ | $\cup$ | v | $\cup$ | in | $n$ | $\underset{\sim}{\square}$ | n | $\cdots$ | $\bigcirc$ | $\cup$ | $\cup$ | $\cup$ |
| $\underset{\sim}{2}$ | $\stackrel{\square}{7}$ | $\vec{\checkmark}$ | $\stackrel{1 n}{\sim}$ | 5 | $\stackrel{5}{5}$ | $\vec{\sim}$ | $\pm$ | $\stackrel{10}{\sim}$ | in | $\stackrel{\sim}{\sim}$ | $\stackrel{\circ}{\text { ¢ }}$ | $\stackrel{\sim}{0}$ | $\stackrel{+}{*}$ | $\cdots$ | $\stackrel{\sim}{m}$ | $\cdots$ | \％ |
| $\stackrel{\rightharpoonup}{+}$ | $\begin{aligned} & \stackrel{\rightharpoonup}{\circ} \\ & \stackrel{\sim}{⿷} \end{aligned}$ | $\stackrel{9}{-}$ | $\begin{gathered} \stackrel{\circ}{\underset{\sim}{c}} \\ \hline \end{gathered}$ | $\begin{aligned} & \underset{\sim}{\sigma} \\ & \underset{\sim}{\alpha} \end{aligned}$ | $\underset{\sim}{\tilde{\sim}}$ | $\therefore$ | $\stackrel{M}{\underset{\sim}{a}}$ | $\begin{aligned} & \text { m} \\ & \underset{\sim}{\otimes} \end{aligned}$ | $\begin{gathered} \stackrel{i}{\circ} \\ \stackrel{\circ}{\alpha} \end{gathered}$ | $\begin{gathered} i n \\ \underset{\sim}{n} \end{gathered}$ | $\begin{aligned} & \text { © } \\ & \text { in } \end{aligned}$ | $\begin{aligned} & \text { on } \\ & \stackrel{0}{8} \end{aligned}$ | $\stackrel{m}{\underset{\sim}{\sigma}}$ | $\begin{aligned} & \stackrel{\sim}{\sim} \\ & \underset{\sim}{\sigma} \end{aligned}$ | $\begin{aligned} & \underset{\sim}{\underset{\sim}{\sim}} \end{aligned}$ | $\begin{aligned} & 0 \\ & \underset{\sim}{O} \\ & 0 \end{aligned}$ | $\stackrel{\sim}{0}$ |
| 0 | $\stackrel{\sim}{\square}$ | $\bigcirc$ | $\stackrel{ }{*}$ | $\sigma$ | $\exists$ | $\pm$ | $\sim$ | $\pm$ | $\because$ | $\infty$ | v | $\sigma$ | $\stackrel{m}{ }$ | $\infty$ | $\cdots$ | $\bigcirc$ | $\simeq$ |
| $\stackrel{N}{N}$ | $\begin{aligned} & i n \\ & \stackrel{n}{n} \end{aligned}$ | $\begin{aligned} & \text { u1 } \\ & \stackrel{0}{E} \end{aligned}$ | $\begin{aligned} & 0 \\ & \stackrel{2}{2} \end{aligned}$ | $\stackrel{N}{\approx}$ | $\stackrel{\infty}{\stackrel{\infty}{\leftrightharpoons}}$ | $\underset{\sim}{\approx}$ | $\begin{aligned} & \infty \\ & \stackrel{\infty}{\rightleftharpoons} \\ & \hline \end{aligned}$ | $\begin{aligned} & \sim \\ & \sim \\ & \approx \end{aligned}$ | $\begin{aligned} & \stackrel{\rightharpoonup}{x} \\ & \underset{\sim}{7} \end{aligned}$ | $\begin{aligned} & \alpha \\ & \underset{\sigma}{\alpha} \end{aligned}$ | $\underset{\sim}{\mathrm{m}}$ | $\begin{aligned} & \vec{\sim} \\ & \underset{\sim}{n} \end{aligned}$ | $\stackrel{N}{\underset{\sim}{\sim}}$ | $\stackrel{\sim}{\approx}$ | $\begin{aligned} & \underset{i}{i} \\ & \dot{a} \end{aligned}$ | $\begin{aligned} & \sim \\ & \underset{\sim}{\sim} \end{aligned}$ | $\stackrel{\sim}{\sim}$ |



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APPENDIX I

## Component Damage Matrices

TABLE OF CONTENTS

| MMI | HEIGHT | DATE | STRUC. TYPE | PACE |
| :---: | :---: | :---: | :---: | :---: |
| VI | ALL | ALL | S | I-1 |
| VI | ALL | ALL | C | I-2 |
| VI | ALL | ALI | ALL | I-3 |
| VII | ALL | ALL | S | I-4 |
| VII | ALL | ALL | C | I-5 |
| VII | ALL | ALL | ALI. | I-6 |
| VII | ALL | PRE-1933 | S | I-7 |
| VII | ALL | PRE-1933 | C | I-8 |
| VII | ALL | POST-1947 | S | I-9 |
| VII | ALL | POST-1947 | C | I-10 |
| VII | 5-7 | ALI, | ALL | I-11 |
| VII | 8-13 | AtL. | ALL | I-12 |
| VII | 14-18 | ALI, | ALL | I-13 |
| VII | 19+ | ALI. | ALL | I-14 |
| VIII | ALL | ALL | S | I-15 |
| VIII | ALL | ALL | C | I-16 |
| VIII | ALL | ALL. | ALL | I-17 |

$$
0
$$

$$
\begin{array}{cc}
50-60 \% & 60-70 \% \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0
\end{array}
$$

MoD.R。:


$\qquad$


 $1.04 \%$
$80-90 \%$
3
0
0
2
0
10
0
0
0
4
0
$1.04 \%$
$80-90 \%$
3
0
0
1
7

 Ratio Distribution Damage
$40-50 \%$
3
2
0
0
0
3
0
2
0
2
0 No. of Buildings: 102
 of Buildings: Con $50-60 \% \quad 60-70 \%$ $\checkmark$ $\mathrm{N} O$ N 0 N 0 m 0 6

 0 $\checkmark$ 00 $\circ$ 0 m 0 $\cdots$ Modified Mercalli: VII

[^3]UILDIXG CHARACTERISTICS:
COMPONENT MATRICES A
$0-10 \%$ 70
84
98
83
86
60
86
86
86
39
86
COMgONENT MATRICES B

Component
STRUCTURAL
MECHANICAL
ELECTRICAL
ELEYATOR
OTHER

(Fig. 5.2)
㑤


Ratio Discriburion

    \(\begin{array}{cc}\text { amage } & \text { Ratio Dis } \\ 0-50 \% & 50-60 \% \\ 3 & 1 \\ 2 & 0 \\ 0 & 0 \\ 0 & 2 \\ 2 & 1 \\ 3 & 5 \\ 1 & 2 \\ 1 & 1 \\ 1 & 0 \\ 3 & 4 \\ 1 & 0\end{array}\)
        No. of Buildings: 126
        Component Damage
        Componeat
    $30-40 \%$
$0-30 \%$
2
7
1
9
3
10
6
4
1
13
2

$$
\begin{array}{cc}
\text { M.D.R. }: ~ & 1.44 \% \\
(\%) \\
70-80 \% & 80-90 \% \\
2 & 2 \\
0 & 1 \\
0 & 0 \\
1 & 1 \\
9 & 9
\end{array}
$$

กి

$$
\text { ö̀ } \sim \text { in } r \infty m
$$

$$
\begin{aligned}
& \text { ò } n \text { in } m \text { a } o \\
& \text { Ì } \\
& \text { O}
\end{aligned}
$$

a SaDIULVW LNaNOdNOD

$$
\frac{\ddot{0}}{\frac{1}{0}} \wedge \infty \circ \therefore \dot{\infty}
$$




$$
\left.\begin{array}{lllllll}
\because & & & & & \\
0 & \therefore & 0 & 0 & 0 & 0 & 0
\end{array}\right)
$$

BUILDING CHARACTERISTICS:
GROUND MOTION INTENSITY:
Modified Mercalli: VII
No. of Buildings: 22

Type: C
(Fig. 5.2)


Component Damage Ratio Distribution
$\begin{aligned} & \text { 믕 } \\ & 1 \\ & 1 \\ & 0\end{aligned}=0000$
$\begin{array}{lllll}0 & & & \\ 0 & & \\ 1 & N & 0 & 0 & 0\end{array}$
$\begin{array}{llllll}\text { Io } \\ 0 & & & & & \\ 1 & 0 & 0 & N & N \\ 0 & & & & & \end{array}$
Z5:şutptcng $50{ }^{\circ}$ ON


COMPONENT MATRICES B
$\begin{array}{lllll}\text { 잉․ } \\ \text { i } & \infty & \infty & \infty & \infty \\ 0 & 0\end{array}$

Component
STRUCTURAL
MECHANICAL
ELECTRICAL
ELEVATOR
OTHER

$$
\begin{array}{lllll}
00 \\
00 \\
i & n & n & 0 & N
\end{array}
$$

GROUXD MOTION LTTENSITY:
COMPONENT MATRICES A
No. of Bulldings: 60

$0-10 \%$

Component structural Mecranical Electrical ELEYATOR ORNAMENT BARTITIEN CEILIIAG
 GLASS PAINTIAG OTEER

COMPONENT MATRICES B

$$
\begin{gathered}
50-60 \% \\
0 \\
0 \\
0 \\
2 \\
0 \\
4 \\
0 \\
0 \\
0 \\
4 \\
0
\end{gathered}
$$

Component Damage Rario Discribution

$$
\begin{array}{cc}
\text { (Fig. } & \text { 5.2) } \\
\text { Mean } \\
90-100 \% & \begin{array}{c}
\text { Mean } \\
(\%)
\end{array} \\
4 & 14.8 \\
0 & 5.4 \\
0 & 1.4 \\
2 & 12.0 \\
0 & 4.3 \\
4 & 23.3 \\
0 & 5.8 \\
0 & 2.2 \\
2 & 3.5 \\
4 & 22.7 \\
0 & 4.7 \\
& \\
(5 i g . & 5.2) \\
& \\
90-100 \% & (\%) \\
3 & 12.7 \\
0 & 4.0 \\
0 & 1.0 \\
2 & 10.6 \\
47 & 71.7
\end{array}
$$


$\begin{aligned} & \ddot{0} \\ & 0 \\ & 0 \\ & \dot{0} \\ & \dot{y}\end{aligned}$

Struc. Type: All
Height: 5-7 Age: All
Modified Mercalii: VII
COMPONENT MATRICES A
$0-10 \%$
68
78
100
73
90
53
78
90
88
38
80
COMPONENT MATRICES B
Component structural mechanical ELECTRICAL ELEVATOR ORNAMENT PARTITION CEILING EXTERIOR GLASS gALNTIMG OTHER
No. of Buildings: 57



 $\begin{array}{lc}\text { COMPOnent } & 0-10 \% \\ \text { STRUCTURAL } & 70 \\ \text { MECHANICAL } & 83 \\ \text { ELECTRICAL } & 100 \\ \text { ELEVATOR } & 72 \\ \text { OTHER } & 7\end{array}$
 ※
 M．D．R．：1．56\％
 （\％）
 M．D．R．：1．56\％
 Ratio Distribution 50－60\％60－70\％ n 0 $\sim$

 No．of Buildings： 115

 COMPONENT MATRXCES A 00
$\stackrel{0}{1}$
$\vdots$
$\vdots$
 Component Damage
$20-30 \%$
2
6
0
8
3
8
6
5
2
6
2
$0-10 \%$
76
82
94
78
81
52
83
83
89
41
83 g SGOTMETK LNGROAKOO Component
STRUCTURAL
MECHANICAL
ELECTRICAL ELEVATOR ORNAMENT PABTITION CETLIAG
 GLASS
 OTRER Component Component MECHANICAL吾 ELEVATOR OTHER

$$
\begin{aligned}
& \text { 商 } \\
& \text { 옹 }
\end{aligned}
$$

0
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o
○NONN
0

| COMPONEAT MATRICES A |  | No. of Buildings: 6 |  |  | M.D.R.: $0.34 \%$ |  |  |  |  | (Fig. 5.2) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Component | Damage | Ratio Dis | ribution |  |  |  | Mean | St.Dev. |
| Component | 0-10\% | 10-20\% | 20-30\% | 30-4.0\% | 40-50\% | 50-60\% | 60-70\% | 70-80\% | 80-90\% | 90-100\% | (\%) | (\%) |
| structural | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MECRANTCAL | 83 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 | 3.7 |
| Electrical | 83 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.3 | 7.5 |
| ELPYAIOR | 67 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 17 | 23.5 | 34.9 |
| ORTAMENT | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARTITION | 33 | 0 | 17 | 17 | 0 | 0 | 0 | 0 | 17 | 17 | 36.8 | 36.1 |
| CEILING | 50 | 33 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.5 | 8.0 |
| ESTERIOR | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.5 | 3.4 |
| GLASS | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| gatnting | 50 | 33 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 14.2 | 20.9 |
| OTAER | 83 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 11.5 | 25.7 |
| COMPONENT MATRICES B |  | No. of Buildings: 12 |  |  |  |  |  | M.D.R.: 0.34\% |  | (Fig. 5.2) |  |  |
|  |  |  |  | Component | Damage | Rario Dis | ribution | (\%) |  |  | Mean | St.Dev. |
| Component | 0-10\% | 10-20\% | 20-30\% | 30-40\% | 40-50\% | 50-60\% | 60-70\% | 70-80\% | 80-90\% | 90-100\% | (\%) | (\%) |
| structural | 92 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 6.3 | 20.7 |
| mechanceal | 92 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . 8 | 2.8 |
| ELECTRICAL | 92 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 | 5.5 |
| ELEYATOR | 75 | 0 | 8 | 0 | 0 | 8 | 0 | 0 | 0 | 8 | 13.8 | 27.0 |
| OTHER | 0 | 8 | 8 | 0 | 0 | 8 | 8 | 0 | 8 | 58 | 77.4 | 31.9 |





$\begin{array}{cc}\text { M.D.R. }: & 0.39 \% \\ (\%) & \\ 70-80 \% & 80-90 \% \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ & \\ M . D . R .: & 0.39 \% \\ (\%) & \\ 70-80 \% & 80-90 \% \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 14 & 29\end{array}$
$\begin{array}{cc}\text { atio Distribution } \\ 50-60 \% & 60-70 \% \\ 20 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0\end{array}$
$\begin{array}{lllllll}\stackrel{\circ}{\circ} \\ \substack{0 \\ b \\ \vdots} & 0 & 0 & 0 & 0 & 0 & 0\end{array}$



$$
\text { HN O in } 0
$$

(Fig. 5.2)

| COMPONERT MATRICES A |  | No. of Buildings: 7 |  |  |  | Ratio Distribution |  | M.D.R.: | 5\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Componen | Damage |  |  | (\%) |  |
| Component | 0-10\% | 10-20\% | 20-30\% | 30-40\% | 40-50\% | 50-60\% | 60-70\% | 70-80\% | 80-90\% |
| STRUCTURAL | 14 | 14 | 29 | 0 | 0 | 0 | 0 | 14 | 14 |
| MECKANICAL | 71 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELECTRICAL | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EXEPATOR | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ORHAMENT | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARTITIOA | 43 | 29 | 14 | 14 | 0 | 0 | 0 | 0 | 0 |
| CBILING | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ESTERIOR | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GLASS | 86 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAINTING | 86 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 |
| OTEER | 57 | 29 | 0 | 0 | 0 | 0 | 0 | 14 | 0 |
| COMPONENT | MATRICES | B | No. of Bur | dings: |  |  |  | MoD.R.: |  |
|  |  |  |  | Componen | Damage | Ratio Dis | ibution | (\%) |  |
| Component | 0-10\% | 10-20\% | - 20-30\% | 30-40\% | 40-50\% | 50-60\% | 60-70\% | 70-80\% | 80-90\% |
| STRUCTURAL | 13 | 12 | 25 | 0 | 0 | 0 | 0 | 12 | 25 |
| MECHANICAL | 75 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELECTRICAL | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELEVATOR | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OTHER | 25 | 13 | 12 | 0 | 0 | 25 | 0 | 12 | 13 |




[^0]:    * The key tables from this report which became available co M.I.T. in September 1971 are reproduced in Appendix A.

[^1]:    - ©

[^2]:    

[^3]:     Component
    STRUCTURAL
    MECHANICAL岂
    0
    0
    0
    U
    品 ELEVATOR

