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SAN FERNANDO EARTHQUAKE DAMAGE STATISTICS

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16. Abstract (Limit: 200 words)
Damage probability matrices constructed from the data base information give the probability that different damage states occur for various levels of earthquake insensity, namely, the Modified Mercalli Scale. Each matrix relates damage to intensity for a particular class of building. As of August, 1972 the data base contained 1663 buildings with usable damage information for about 305 buildings. This report presents the various damage probability matrices which have been constructed since the beginning of the project. A computer program has been developed which computes damage probability matrices by height, age, structural type, and foundation type groupings. Both the damage cost and building value sources can be searched for in any pre-specified order and their values scaled by a prescribed factor. In the computation of a given matrix, therefore, several damage sources can be selected and searched in a predetermined order. Similarly, building value sources can also be selected. By scaling the several floor area categories, they can be converted to a present building cost value. In addition, the buildings can be placed in any intensity zone and the damage state cost ratio ranges can be varied. Future work in this area is also discussed.

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List of Internal Study Reports

1. R.V. Whitman, "Preliminary Work Plans and Schedules," August, 1971.

2. E.H. Vanmarcke and R.V. Whitman, "Background for Preliminary Expected Future Loss Computations," October, 1971.

3. P.J. Trudeau, "Identification of Typical Soil Profiles in the Boston Basin Area," November, 1971.

4. J.M. Biggs, "Comparison of Wind and Seismic Forces on Tall Buildings," December, 1971.

5. R.V. Whitman, "Contribution to State-of-the-Art Report of the Earthquake Committee of the IABSE-ASCE Tall Buildings Committee--Economic and Social Aspects," March, 1972.

6. J.E. Brennan and R.J. McNamara, "Optimum Seismic Protection for New Building Construction in Eastern Metropolitan Areas," April, 1972.

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8. R.V. Whitman, J.W. Reed, P. Marshall, "1967 Caracas Venezuela Earthquake Tall Building Damage Review," May, 1972.

9. R.V. Whitman, E.H. Vanmarcke, "Damage Statistics from Japanese Earthquakes," May, 1972.

10. E.H. Vanmarcke, J.W. Reed, D. Roth, "Evaluation of Expected Losses and Total Present Cost: Preliminary Sensitivity Analysis," July, 1972.

11. R.V. Whitman, et al., "1964 Alaskan Earthquake Tall Building Damage Review," July, 1972.

12. R.V. Whitman, J.W. Reed, "San Fernando Earthquake Data Base Computer Storage Format," August, 1972.

1.0 Introduction

From the start of the San Fernando Earthquake study, attempts have been made to construct damage probability matrices from the Data Base information. These matrices give the probability that different damage states occur for various levels of earthquake intensity (i.e., Modified Mercalli Scale). Each matrix relates damage to intensity for a particular class of buildings. The first guess at the various matrices was admittedly crude since the Data Base contained relatively little information. Presently (August, 1972) the Data Base contains 1663 buildings, with usable damage information for about 305 buildings.

The purpose of this report is to present the various damage probability matrices which have been constructed since the beginning of the project. The background of the construction of these matrices also is given. Finally, future work in this area is recommended.

2.0 General Background

Shown in Figure 1 is a damage probability matrix which represents buildings of all height, age, structure type, and foundation type groups. The assumptions made for this matrix are the same as for the matrices in Section 4.0. This is a composite matrix which includes all buildings for which both damage and building value information exist.

For this particular matrix 8 damage state categories are used. Shown in Figure 2 is a written description of these damage states and their associated ratios to present building cost. Both central values and ranges for damage/present cost ratios are given. The last two categories in Figure 2 have been combined into one category for the matrix computation shown in Figure 1. The various damage levels shown were selected on the basis of studying the results of looking in detail at about 10 buildings in the area affected by the San Fernando earthquake. The information on these buildings was obtained for M.I.T. by the firm of Ayres, Cohen, and Hayakawa of Los Angeles. By comparing both the description of damage with the damage cost, the states and corresponding ratios in Figure 2 were obtained.

Shown in Figure 3 is a map of the San Fernando/Los Angeles area. This map gives the assumed boundaries between the several Modified Mercalli intensity zones.

In constructing the matrices, there are several sources of information available for both damage costs and building values. The various damage cost and building value sources are explained in detail in an Internal Study Report to be written shortly.

A computer program has been developed which computes damage probability matrices by height, age, structural type, and foundation type groupings. Both the damage cost and building value sources can be searched for in any pre-specified order and their values scaled by a prescribed factor. Therefore, in the computation of a given matrix, several damage sources can be selected and searched in a predetermined order. Similarly, building value sources can also be selected. By scaling the several floor area categories, they can be converted to a present building cost value. In addition, the buildings can be placed in any intensity zone and the damage state cost ratio ranges can be varied. The matrix shown in Figure 1 was computed by this program.

3.0 Preliminary Damage Matrices

In February, 1972, a first set of damage probability matrices were computed based on information avaiable at that time. From the Ayres I Questionnaire survey results and the damage costs published by Steinbrugge, et al., 184 building damage costs were used to construct several matrices. For buildings for which building values were not available, it was assumed that this value could be computed by multiplying the gross floor area by $25. This factor was obtained by relating value to area for buildings for which both values and areas were known. Presented in Figure 4 is a plot of present building value vs. gross floor area. As shown, $\$25/ft^2$ is the average value. These values in Figure 4 include both present assessed value and construction values.

Figure 5 shows the 5 preliminary damage matrices which were computed as described above. Note that the total number of buildings for each intensity zone is given at the bottom of the matrices. Where the number of buildings participating in the computation is less than 10, the results are not too reliable. Buildings that were constructed prior to 1933 had no provision for earthquake forces. Hence, these buildings can be considered as having a UBC Code: Zone 0 earthquake design strategy.

In contrast, buildings designed after 1947 were designed for earthquakes and conform to a UBC Code: Zone 3 design strategy.

Comparing the matrices for the two building classes, the new buildings faired much better than the older weaker structures.

Shown in Figure 6 is a matrix computed using only the buildings for which Steinbrugge reported damage. All of these buildings are over 8 stories and are modern (Post 1947) structures.

4.0 Current Damage Matrices

There are approximately 300 buildings for which both damage cost and building value information are presently (August, 1972) available. Using the computer program described in section 2.0, the Data Base was searched and the resulting matrices which were computed are shown in Figure 7. For the determination of the earthquake damage cost the Data Base damage groups were searched in the following order:

Ayres II Questionnaire
Ayres I Questionnaire
BOMA Questionnaire
Steinbrugge Damage

The building value groups were searched for in the following order:

Ayres II Value
BOMA Value
Data Base Permit Value
Ayres II Area (times $25./ft^2)
Ayres I Area (times $25./ft^2)

Comparing the current matrices with the preliminary ones in Figure 5 there appear to be slight inconsistencies. This is primarily due to small differences in intensity zone boundaries and corrections and additions to the Data Base made subsequent to the computation of the preliminary matrices.

5.0 Generalized Average Damage Matrices

In February 1972, an attempt was made to generalize on the Figure 5 matrices and to develop "average" matrices for different design strategies. Shown in Figure 8 is the matrix set which was developed. These matrices are directed to buildings between 8 and 13 stories high. Note that the Zone 0, M.M.I. VII column corresponds closely to the pre-1933, 8-13 story matrix in Figure 5. Similarly, the Zone 3, M.M.I. VII column compares to the post-1947, 8-13 story Figure 5 matrix. From these starting points other probabilities were fixed by interpolation, extrapolation, and judgement. The Zone 4 strategy is intended to correspond to a base shear requirement 2 to 3 times the requirement for the Zone 3 strategy.

From comparing current and preliminary matrices (Figures 5 and 7) it is apparent that no one set of matrices is the "right" one. As more damage statistics become available, the matrices will change. Even small variations in the location of the intensity boundaries will alter the probability values. What is desired is "average" probability matrices; average in the sense that slight variations in the parameters (i.e., intensity, zone locations, number of sample buildings, etc.) will cause probability variations about the "average" values. In another sense, if similar earthquakes in similar cities occurred, an average of the several sample matrices would give this "average" matrix.

The set of matrices shown in Figure 8 is an attempt to generalize on the results of the preliminary matrices shown in Figure 5. Shown in Figure 9 is an updated set of generalized matrices partially reflecting the results of the current matrices shown in Figure 7. Each matrix can be constructed by sliding the M.M.I. VIII column to the left and raising it one row. A zero probability is placed in damage state 7 and the extra probability number required to bring the total to 100% is added to the damage state 0 value. Hence, to construct any of the matrices only the last column of probabilities is required. Although the agreement with the Figure 7 matrices is not very good, these generalized matrices attempt to be an average of all earthquakes -- including the San Fernando experience.

6.0 Future Work

In addition to redoing the matrices after the last of the questionnaire forms have been returned, there are several other sources of information which should be exploited. This section is devoted to suggesting future work which might lead to more complete and accurate damage matrices.

As of this writing, neither the Veterans Administration Hospital or the Holy Cross Hospital have been included in the Data Base. They both are probably in M.M.I. IX and hence will not affect the matrices constructed to date (only M.M.I. zones VI, VII, and VIII are considered). However, they both should be discussed and put in their proper place.

Ayres has completed the list of building damage per the Los Angeles County 1971 Disaster Value Report EQ-88. This report gives the reduction in assessed building and land value caused by the earthquake. All building owners whose buildings sustained damage could apply for a reduction. Approximately 150 owners of buildings over 5 stories availed themselves of this opportunity. Although some of the buildings overlap ones already studied, many are new both to the Data Base and to the damage statistics. Currently Ayres is sending questionnaires to all these owners, with the intent of obtaining a detailed damage cost breakdown. Whether a damage distribution is obtained or not, the total damage should be included in the Data Base. Since these statistics do not represent an unbiased sample (only damaged buildings are included), their inclusion in the matrix computations should be done with care.

The damage permit application values from the damage lists of the Los Angeles City Department of Building and Safety are complete only through September 1971. Presently Ayres is obtaining an updated list for us. The new permit values should be added to the Data Base. As of now none of these values have been used in the matrix computations. This is because the permit values are for structural damage only, and total damage may be 4 to 10 times greater. After updating this information, it would be worthwhile to compare these values with the corresponding total damage costs obtained from the questionnaire surveys, disaster report values, etc. After a correlation is obtained and a "fudge" factor determined, these permit values could be used in the matrix computation. Again care must be exercised since this set of buildings does not include non-damaged buildings.

For about 10 to 20 buildings for which we have building damage data, both present value and floor area statistics are missing. It would be worthwhile obtaining this information and including these buildings in the matrix computations.

Presently Ayres (through Schader) is obtaining structure, foundation, and soil information for all buildings for which we have damage information. After this work is complete, matrices can be obtained for different foundation classes.

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 305

HEIGHT: 5 to 100 STORIES

AGE: 1800 to 1972

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.676	0.248	0.324	0.0
1	0.00300	0.0	0.0	0.216	0.286	0.147	0.0
2	0.01250	0.0	0.0	0.081	0.239	0.118	0.0
3	0.03500	0.0	0.0	0.027	0.107	0.294	0.0
4	0.07500	0.0	0.0	0.0	0.056	0.059	0.0
5	0.20000	0.0	0.0	0.0	0.043	0.029	0.0
6	0.65000	0.0	0.0	0.0	0.021	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.029	0.0
NUM. OF BUILDINGS		0	0	37	234	34	0

FIGURE 1: Example Damage Probability Matrix

	Description of Level of Damage	Ratio to Present Cost: Central Value	Range
0	No Damage	0	0-.0005
1	Minor non-structural damage--a few walls and partitions cracked, incidental mechanical and electrical damage	.001	.0005-.003
2	Localized non-structural damage--more extensive cracking (but still not widespread); possibly damage to elevators and/or other mechanical/ electrical components	.005	.003-.0125
3	Widespread non-structural damage--possibly a few beams and columns cracked, although not noticeable	.02	.0125-.035
4	Minor structural damage--obvious cracking or yielding in a few structural members; sub-stantial non-structural damage with widespread cracking	.05	.035-.075
5	Substantial structural damage requiring repair or replacement of some structural members; associated extensive non-structural damage	.10	.075-.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	1.0	.65-1.0
8	Collapse	1.0	

FIGURE 2: Earthquake Damage States

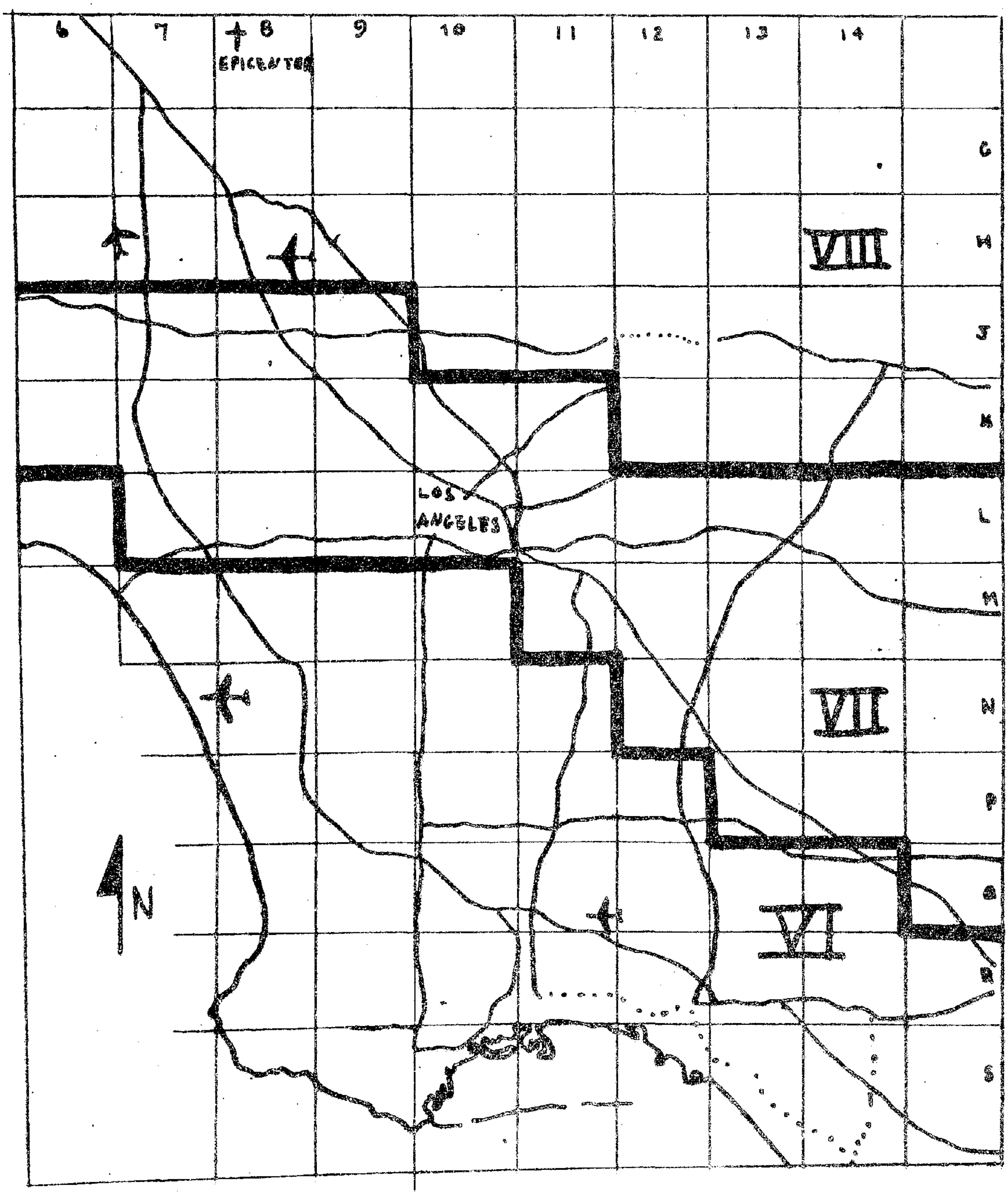

FIGURE 3: Modified Mercalli Intensity Zones

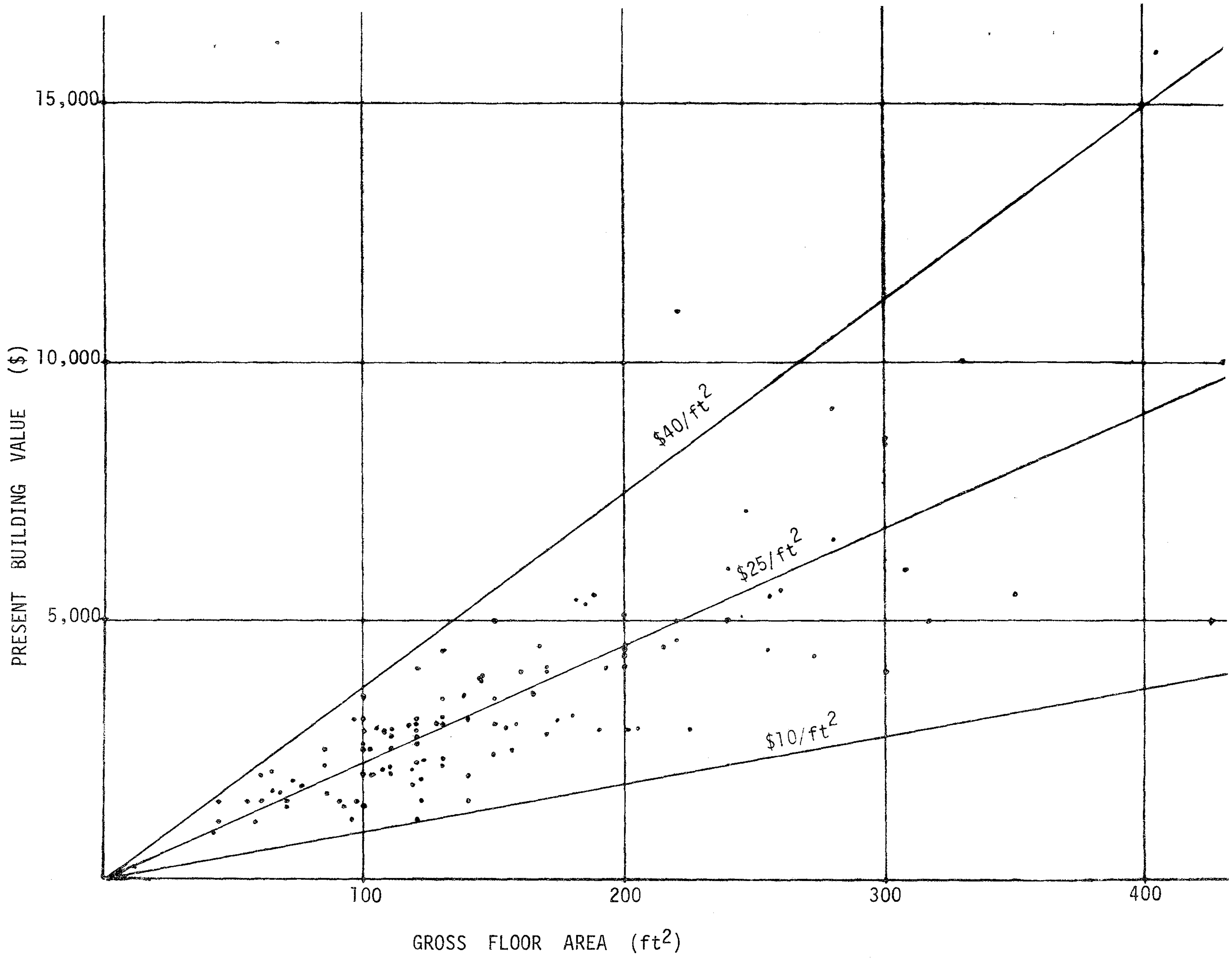

FIGURE 4: Present Building Value/Gross Floor Area Correlation

Earthquake Damage Summary

Name of Earthquake (Location): San Fernando

Date of Earthquake: February 9, 1971

Building Group Designation

Building Code or Age: Pre-1933

Height Zone 5-7

Construction Type:

Probability Matrix

			Mercalli Intensity					
General	Detailed	Damage Cost Ratio	4^-	5	6	7	8	9^+
No Damage	0	0			67%	18%		
Light	1 2	.001 .005			33%	18% 18%		
Moderate	3 4	.02 .05				28% 9%		
Heavy	5 6	.10 .30				0 0		
Requires Replacement	7 8	1.0 1.0				9%		
TOTAL NUMBER BUILDINGS					6	11		

FIGURE 5: Preliminary San Fernando Earthquake Damage Matrices

Earthquake Damage Summary

Name of Earthquake (Location): San Fernando

Date of Earthquake: February 9, 1971

Building Group Designation

Building Code or Age: Pre-1933

Height Zone 8-13

Construction Type:

Probability Matrix

			Mercalli Intensity					
General	Detailed	Damage Cost Ratio	4^-	5	6	7	8	9^+
No Damage	0	0			100%	3½%		
Light	1 2	.001 .005				21% 37%		
Moderate	3 4	.02 .05				21% 10½%		
Heavy	5 6	.10 .30				7%		
Requires Replacement	7 8	1.0 1.0						
TOTAL NUMBER BUILDINGS					3	28		

FIGURE 5(cont.): Preliminary San Fernando Earthquake Damage Matrices

Earthquake Damage Summary

Name of Earthquake (Location): San Fernando
Date of Earthquake: February 9, 1971

Building Group Designation
Building Code or Age: Post-1947
Height Zone 5-7
Construction Type:

Probability Matrix

			Mercalli Intensity					
General	Detailed	Damage Cost Ratio	4^-	5	6	7	8	9^+
No Damage	0	0				50%	20%	
Light	1 2	.001 .005				25% 17%	20% 20%	
Moderate	3 4	.02 .05				8%	20% 20%	
Heavy	5 6	.10 .30						
Requires Replacement	7 8	1.0 1.0						
TOTAL NUMBER BUILDINGS						12	5	

FIGURE 5(cont.): Preliminary San Fernando Earthquake Damage Matrices

Earthquake Damage Summary

Name of Earthquake (Location): San Fernando

Date of Earthquake: February 9, 1971

Building Group Designation

Building Code or Age: Post-1947

Height Zone 8-13

Construction Type:

Probability Matrix

			Mercalli Intensity					
General	Detailed	Damage Cost Ratio	4^-	5	6	7	8	9^+
No Damage	0	0			43%	20%	16%	
Light	1	.001			43%	41%	0	
	2	.005			14%	24%	0	
Moderate	3	.02				8%	0	
	4	.05				2%	16%	
Heavy	5	.10				5%	50%	
	6	.30					18%	
Requires Replacement	7	1.0						
	8	1.0						
TOTAL NUMBER BUILDINGS					14	60	6	

FIGURE 5(cont.): Preliminary San Fernando Earthquake Damage Matrices

Earthquake Damage Summary

Name of Earthquake (Location): San Fernando

Date of Earthquake: February 9, 1971

Building Group Designation

Building Code or Age: Post-1947

Height Zone 14+

Construction Type:

Probability Matrix

			Mercalli Intensity					
General	Detailed	Damage Cost Ratio	4^-	5	6	7	8	9^+
No Damage	0	0				20%		
Light	1 2	.001 .005				47% 27%		
Moderate	3 4	.02 .05				6%		
Heavy	5 6	.10 .30						
Requires Replacement	7 8	1.0 1.0						
TOTAL NUMBER BUILDINGS						39		

FIGURE 5(cont.): Preliminary San Fernando Earthquake Damage Matrices

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 54

HEIGHT: 5 TO 100 STORIES

AGE: 1800 TO 1972

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.0	0.196	0.0	0.0
1	0.00300	0.0	0.0	0.0	0.451	0.333	0.0
2	0.01250	0.0	0.0	0.0	0.294	0.0	0.0
3	0.03500	0.0	0.0	0.0	0.059	0.333	0.0
4	0.07500	0.0	0.0	0.0	0.0	0.0	0.0
5	0.20000	0.0	0.0	0.0	0.0	0.333	0.0
6	0.65000	0.0	0.0	0.0	0.0	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.0	0.0
NUM. OF BUILDINGS		0	0	0	51	3	0

FIGURE 6 Steinbrugge Buildings Matrix

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 35

HEIGHT: 5 TO 7 STORIES

AGE: 1800 TO 1933

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.714	0.217	0.600	0.0
1	0.00300	0.0	0.0	0.143	0.043	0.0	0.0
2	0.01250	0.0	0.0	0.0	0.348	0.200	0.0
3	0.03500	0.0	0.0	0.143	0.087	0.200	0.0
4	0.07500	0.0	0.0	0.0	0.174	0.0	0.0
5	0.20000	0.0	0.0	0.0	0.087	0.0	0.0
6	0.65000	0.0	0.0	0.0	0.043	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.0	0.0
NUM. OF BUILDINGS		0	0	7	23	5	0

FIGURE 7: Current San Fernando Earthquake Damage Matrices

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 64

HEIGHT: 8 TO 13 STORIES

AGE: 1800 TO 1933

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.750	0.089	0.500	0.0
1	0.00300	0.0	0.0	0.250	0.125	0.250	0.0
2	0.01250	0.0	0.0	0.0	0.357	0.0	0.0
3	0.03500	0.0	0.0	0.0	0.196	0.250	0.0
4	0.07500	0.0	0.0	0.0	0.054	0.0	0.0
5	0.20000	0.0	0.0	0.0	0.125	0.0	0.0
6	0.65000	0.0	0.0	0.0	0.054	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.0	0.0
NUM. OF BUILDINGS		0	0	4	56	4	0

FIGURE 7(con't): Current San Fernando Earthquake Damage Matrices

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 4

HEIGHT: 14 TO 18 STORIES

AGE: 1800 TO 1933

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.0	0.250	0.0	0.0
1	0.00300	0.0	0.0	0.0	0.250	0.0	0.0
2	0.01250	0.0	0.0	0.0	0.500	0.0	0.0
3	0.03500	0.0	0.0	0.0	0.0	0.0	0.0
4	0.07500	0.0	0.0	0.0	0.0	0.0	0.0
5	0.20000	0.0	0.0	0.0	0.0	0.0	0.0
6	0.65000	0.0	0.0	0.0	0.0	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.0	0.0
NUM. OF BUILDINGS		0	0	0	4	0	0

FIGURE 7(con't): Current San Fernando Earthquake Damage Matrices

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 46

HEIGHT: 5 TO 7 STORIES

AGE: 1947 TO 1972

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	1.000	0.200	0.308	0.0
1	0.00300	0.0	0.0	0.0	0.400	0.154	0.0
2	0.01250	0.0	0.0	0.0	0.200	0.154	0.0
3	0.03500	0.0	0.0	0.0	0.167	0.231	0.0
4	0.07500	0.0	0.0	0.0	0.033	0.077	0.0
5	0.20000	0.0	0.0	0.0	0.0	0.0	0.0
6	0.65000	0.0	0.0	0.0	0.0	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.077	0.0
NUM. OF BUILDINGS		0	0	3	30	12	0

FIGURE 7(con't): Current San Fernando Earthquake Damage Matrices

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 100

HEIGHT: 8 TO 13 STORIES

AGE: 1947 TO 1972

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.667	0.268	0.091	0.0
1	0.00300	0.0	0.0	0.222	0.437	0.182	0.0
2	0.01250	0.0	0.0	0.111	0.169	0.091	0.0
3	0.03500	0.0	0.0	0.0	0.070	0.455	0.0
4	0.07500	0.0	0.0	0.0	0.042	0.091	0.0
5	0.20000	0.0	0.0	0.0	0.014	0.091	0.0
6	0.65000	0.0	0.0	0.0	0.0	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.0	0.0
NUM. OF BUILDINGS		0	0	18	71	11	0

FIGURE 7(con't): Current San Fernando Earthquake Damage Matrices

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 22

HEIGHT: 14 TO 18 STORIES

AGE: 1947 TO 1972

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.500	0.500	0.0	0.0
1	0.00300	0.0	0.0	0.250	0.278	0.0	0.0
2	0.01250	0.0	0.0	0.250	0.167	0.0	0.0
3	0.03500	0.0	0.0	0.0	0.0	0.0	0.0
4	0.07500	0.0	0.0	0.0	0.056	0.0	0.0
5	0.20000	0.0	0.0	0.0	0.0	0.0	0.0
6	0.65000	0.0	0.0	0.0	0.0	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.0	0.0
NUM. OF BUILDINGS		0	0	4	18	0	0

FIGURE 7(con't): Current San Fernando Earthquake Damage Matrices

GROUP CHARACTERISTICS

NUMBER OF BUILDINGS: 29

HEIGHT: 19 TO 100 STORIES

AGE: 1947 TO 1972

STRUCTURAL TYPE: ALL TYPES

FOUNDATION TYPE: ALL TYPES

DAMAGE PROBABILITY MATRIX

DAMAGE STATE		MERCALLI INTENSITY					
STATE	DAMAGE COST RATIO UPPER BOUND	IV	V	VI	VII	VIII	IX
0	0.00050	0.0	0.0	0.0	0.464	0.0	0.0
1	0.00300	0.0	0.0	1.000	0.357	0.0	0.0
2	0.01250	0.0	0.0	0.0	0.143	0.0	0.0
3	0.03500	0.0	0.0	0.0	0.036	0.0	0.0
4	0.07500	0.0	0.0	0.0	0.0	0.0	0.0
5	0.20000	0.0	0.0	0.0	0.0	0.0	0.0
6	0.65000	0.0	0.0	0.0	0.0	0.0	0.0
7	1.00000	0.0	0.0	0.0	0.0	0.0	0.0
NUM. OF BUILDINGS		0	0	1	28	0	0

FIGURE 7(con't): Current San Fernando Earthquake Damage Matrices

	Damage State	MODIFIED MERCALLI INTENSITY IV	V	VI	VI.5	VII	VIII
Zone 0 Strategy	0	97	90	40	20	4	0
	1	3	8	30	30	21	0
	2	0	2	20	35	37	5
	3	0	0	10	10	21	20
	4	0	0	0	5	10	35
	5	0	0	0	0	7	25
	6	0	0	0	0	0	10
	7	0	0	0	0	0	4
	8	0	0	0	0	0	1
Zone 1 Strategy	0	98	92	42	23	9	3
	1	2	7	35	35	27	4
	2	0	1	19	31	33	8
	3	0	0	4	8	17	21
	4	0	0	0	3	9	30
	5	0	0	0	0	5	20
	6	0	0	0	0	0	12
	7	0	0	0	0	0	2
	8	0	0	0	0	0	0
Zone 2 Strategy	0	99	95	44	27	14	6
	1	1	4	36	40	33	8
	2	0	1	18	25	29	11
	3	0	0	2	6	13	23
	4	0	0	0	2	8	25
	5	0	0	0	0	3	15
	6	0	0	0	0	0	11
	7	0	0	0	0	0	1
	8	0	0	0	0	0	0

FIGURE 8: Generalized Damage Probability Matrices
(Numbers in percent)

	Damage State	MODIFIED MERCALLI INTENSITY IV	V	VI	VI.5	VII	VIII
Zone 3 Strategy	0	100	97	45	30	20	10
	1	0	3	40	45	40	13
	2	0	0	15	20	25	15
	3	0	0	0	5	10	25
	4	0	0	0	0	5	20
	5	0	0	0	0	0	10
	6	0	0	0	0	0	7
	7	0	0	0	0	0	0
	8	0	0	0	0	0	0
Zone 4 Strategy	0	100	100	95	50	40	30
	1	0	0	5	40	40	25
	2	0	0	0	10	15	30
	3	0	0	0	0	5	10
	4	0	0	0	0	0	5
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
	7	0	0	0	0	0	0
	8	0	0	0	0	0	0

FIGURE 8(con't): Generalized Damage Probability Matrices
(Numbers in percent)

	Damage State	MODIFIED MERCALLI INTENSITY IV	V	VI	VI.5	VII	VIII
Zone 3 Strategy	0	89	75	58	24	11	0
	1	7	14	17	34	13	11
	2	4	7	14	17	34	13
	3	0	4	7	14	17	34
	4	0	0	4	7	14	17
	5	0	0	0	4	7	14
	6	0	0	0	0	4	7
	7	0	0	0	0	0	4
Zone 0 Strategy	0	98	93	87	70	29	10
	1	2	5	6	17	41	19
	2	0	2	5	6	17	41
	3	0	0	2	5	6	17
	4	0	0	0	2	5	6
	5	0	0	0	0	2	5
	6	0	0	0	0	0	2
	7	0	0	0	0	0	0

FIGURE 9: Generalized Damage Matrices
(Numbers in percent)