<u>OPTIMUM SEISMIC PROTECTION FOR NEW BUILDING</u>

<u>CONSTRUCTION IN EASTERN METROPOLITAN AREAS</u>

NSF Grant GK-27955X

Internal Study Report No. 8

# 1967 CARACAS VENEZUELA EARTHQUAKE
# TALL BUILDING DAMAGE
# REVIEW

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May 1972

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## Purpose of Review

Building damage probability matrices are a central component of the risk analyses being performed for our Boston Earthquake Study. These matrices quantify the relationship between the distribution of the amount of damage and the intensity of ground shaking. Presently our estimates of these matrices have primarily been derived from the 1971 San Fernando earthquake experience. To add confidence to these matrix estimates we are reviewing the building damage caused by several historic earthquakes. These include:

1967 Caracas earthquake
1952 Kern County earthquake
1957 San Francisco earthquake
1965 Seattle earthquake
1964 Alaskan earthquake

and hopefully several others. Although these reviews will be a magnitude less sophisticated than our study of the San Fernando earthquake, we hope to establish a trend of consistency between damage caused by earthquakes in general. This report is the first in a series of internal study reports on historic earthquakes, and is directed to the building damage caused by the 1967 Caracas earthquake.

The 1967 Caracas Earthquake

On 29 July 1967, an earthquake of Richter magnitude 6.5 and an epicenter located about 60 km. northwest of downtown Caracas shook the Caracas area. In the city the peak acceleration, while not actually measured, was probably about 0.08g(1).* This corresponds to a Modified Mercalli Intensity of about VI to VII. Strong shaking occurred for 15-20 seconds, with the entire event lasting about 40 seconds (1).

Damage from the earthquake was widespread throughout the Valley, but the Los Palos Grandes area was particularly hard hit. Four major buildings there collapsed. Total loss of life exceeded 275 people.

By January 1968, a Presidential Commission under the Ministerio de Obras Publicas (MOP) compiled a series of maps scaled 1 to 5000 indicating the amount or lack of damage to all structures over 8 stories and the amount of damage to all damaged structures from 3 to 8 stories. Later the same commission supplied a similar map for the Los Palos Grandes area providing more detailed damage information about all buildings of 3 or more stories, whether damaged or not.

Other studies (1,2,3) both prior to and after the MOP maps compilation, also proved helpful in assessing building damage. One major conclusion of these other studies is that the action of the soil beneath a building heavily influences the amount of damage that a bulding sustains. The most important single measure of the soil effect is the depth-to-rock distance.

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* References as given at the end of report.

The quality of the damage data dictated that the variability of the alluvium could be meanfully considered only by dividing the Caracas Valley into two areas. These are the Los Palos Grandes district, where the soil is more than 450 feet deep, and the rest of the valley, where tall buildings are constructed over relatively shallow soils.

The Valley of Caracas is an area of high density construction and population. Extensive building since the 1950's has resulted in a large number of high-rise structures, nearly all of which are of reinforced concrete design.

## Earthquake Design Criteria

Most of the tall buildings were designed according to the 1955 Venezuela Standard for Building Design. For the Caracas valley the horizontal static earthquake force equivalent at a particular floor level was:

$$F_i = \frac{0.3}{N + 4.5} W_i$$

where: $F_i$ = static force at the $i^{th}$ floor level

$N$ = number of floors above the floor under consideration

$W_i$ = dead weight of the $i^{th}$ floor level

The base shear, V, for the 1955 Venezuela code was:

$$V = \sum_{\text{all stories}} F_i$$

Shown in Table 1 is a comparison between the 1955 Venezuelan Code and the SEAOC Code base shears. It is assumed in this comparison that the building mass is distributed uniformly. As seen in Table 1, buildings constructed according to the 1955 Venezuelan Code correspond to a "strong" zone 2 strategy. Including considerations of ductility, etc., the tall buildings present in the Caracas Valley during the 1967 earthquake had roughly a zone 2 strength.

Base Shear, V/Total Building Dead Weight, W

| Building height, N (Stories) | Venezuelan Code* | SEAOC CODE** | Ratio: $\frac{\text{SEAOC}}{\text{Venezuelan}}$ |
|---|---|---|---|
| 1 | 0.067 | 0.100 | 1.50 |
| 5 | 0.049 | 0.062 | 1.26 |
| 10 | 0.038 | 0.050 | 1.31 |
| 15 | 0.031 | 0.044 | 1.42 |
| 20 | 0.027 | 0.040 | 1.48 |
| 25 | 0.024 | 0.0316 | 1.32 |

* $V/W = \frac{1}{N} \sum_{i=o}^{N-1} \frac{0.30}{i+4.5}$

** $V/W = KC$

where: $K = 1.0$
$C = 0.05/\sqrt[3]{T}$ (C = 0.1 for single story building)
$T = 0.1N$

Table 1 1955 Venezuelan Code - SEAOC Code Comparison

Damage Probability Matrices

Based on the information from the MOP maps, damage probability matrices were prepared for the Caracas valley area. The valley was divided into the Los Palos Grandes region and the rest of the valley. Matrices were constructed for buildings in height ranges: 5 - 8 stories, 9 - 14 stories, and 15 - 19 stories.

Shown in Table 2 is a summary of the number of buildings by height and location used in developing the matrices.

| Building Location | Building Height (Stories) | | |
|---|---|---|---|
| | 5-8 | 9-14 | 15-19 |
| Los Palos Grandes | 88 | 105 | 22 |
| Non-Los Palos Grandes | 502 | 470 | 118 |

Table 2 Number of Buildings in Survey

Because of the lack of accurate earthquake intensity information, an average Modified Mercalli Intensity 6.5 was assigned to the entire Caracas Valley. This implies that only one column of a damage probability matrix (for each region and height zone) was estimated. It is recognized that it may be possible to assign different intensity values to the Los Palos Grandes area and the rest of the Caracas Valley. Several qualitative observations from theoretical investigations can be made about spectral acceleration (Sa) values for each building height category.

For buildings 5-8 stories high Sa appears to have been smaller in the Los Palos Grandes area than the rest of the valley. This may be due to the filtering of higher frequency earthquake components by the deep Los Palos Grandes soil. Buildings 9 - 14 stories high had similar Sa values in both areas. However, nonlinear analyses would probably show more serious damage in the Los Palos Grandes region.

Finally, 15 - 19 story high buildings in the Los Palos Grandes area had higher Sa values due to soil amplification. For the purpose of this review a common intensity was assumed. It is hoped that in the future several intensity values will be assigned. Shown in Table 3 are the matrix values for the MMI 6.5 columns for 6 matrices (2 areas times 3 height zones).

Probability Damage Matrix Values for Modified Mercalli 6.5 Intensity

| | | Los Palos Grandes | | | Non-Los Palos Grandes | | |
|---|---|---|---|---|---|---|---|
| Damage Category | Replacement Cost Ratio (Central Value) | 5-8 Stories | 9-14 Stories | 15-19 Stories | 5-8 Stories | 9-14 Stories | 15-19 Stories |
| No Damage | 0 | .91 | .75 | .23 | .30 | .73 | .52 |
| Light | .005 | .08 | .13 | .50 | .60 | .22 | .45 |
| Heavy | .20 | .01 | .07 | .22 | .10 | .05 | .03 |
| Requires Replacement | 1.0 | 0 | .05 | .05 | 0 | 0 | 0 |

Table 3 Probability Matrix Values, Caracas 1967

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1. Sozer, M.A., et al., Engineering Report on the Caracas Earthquake of 29 July, 1967, National Academy of Sciences, Washington, D.C., 1968.

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

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