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A DAMAGE INDEX FOR MASONRY STRUCTURES AND ITS APPLICABILITY FOR SEISMIC RISK ANALYSIS

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SUMMARY: A model for evaluating the seismic damage to masonry structures proposed by Kwok and Ang (1) is studied for its possible application to seismic risk analysis. A damage scale is presented in terms of different damage levels as well as of a numerical damage ratio. A practical application is performed by using the observed damage during the 1987 Ecuador Earthquake.

THE DAMAGE INDEX MODEL: A damage model proposed by Kwok and Ang (1) is adopted. This model is applicable for unreinforced masonry buildings. The seismic damage to masonry is presented as a function of the maximum deformation and the absorbed hysteretic energy. The damage index D is defined as

$$D = L(R_a,\ t_d,\ T/T_g)/R(T,Uu)$$

where L= Load Function, R= Resistance Function, R_a= rms acceleration, t_d= Duration of the strong motion phase, Uu= Ultimate displacement of the structure and T= Fundamental period of the structure. To carry out seismic risk analysis, many factors (seismic intensity, structure properties, materials characteristics, etc.) are to be assumed. Therefore, the influence of the main parameters on D is investigated (Figs. 1-2) and several recommendations are presented for the use of the damage index.

DAMAGE SCALE: The applicability of D to different types of masonry construction, say concrete block, brick and adobe masonry, is investigated by using the results of laboratory tests carried out in the United States and Peru. The influence of such important factors as the seismic history (previous seismic excitations) and the simultaneous action of two horizontal components is also studied. Based on these studies, a damage scale is proposed in terms of the damage index D. The validity of the proposed scale is examined by using actual earthquake damage data in different regions of the world.

For practical purposes, it is more convenient to have a quantitative damage scale to define the damage of a structure. A damage ratio is defined as the ratio of the earthquake damage costs divided by the replacement value. A new damage scale showing the relation between the damage ratio and the damage index D is proposed (Fig. 3).

APPLICATION OF THE DAMAGE INDEX TO THE 1987 ECUADOR EARTHQUAKE: As a practical application of the proposed damage scale, the distribution of D values for a typical dwelling in Ecuador is determined for the March 5, 1987 Earthquake and compared with the observed damage (Fig. 4). More than 200 sites were considered and the relation between the distribution of the damage index and the distribution of the seismic intensities is analyzed.

CONCLUSIONS: The following conclusions can tentatively be drawn:
- General similarity exists among the responses of concrete block, brick and adobe masonry, implying a wide applicability of the damage index D.
- The damage index is very sensitive to the variation of the acceleration when it is applied to long-period structurtes.
- There is a strong influence of the compressive strength of the mortar in the final value of the damage index when high values of acceleration are considered.
- The simultaneous action of two horizontal seismic inputs does not increase the damage of masonry the structures. The progressive damage

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may not also be an important factor.
- A value of D= 0.30 is proposed as a threshold value above which collapse is likely to occur.
- There is a good correlation between the damage index and the seismic intensities, indicating that the damage index can be effectively used for seismic risk analysis.
- The Damage Ratio vs. Damage Index scale is found very useful for the determination of the potential loss of masonry construction.

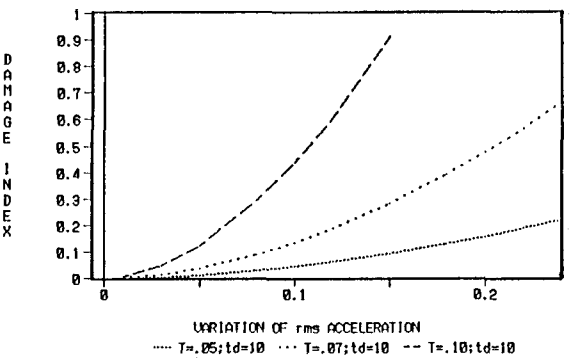

FIG. 1 VARIATION OF D WITH THE rms ACCELERATION (Uu= 8 mm)

REFERENCES:
1.- Ang, A.H.S., Kwok, Y.H., "A Seismic Damage Model for Masonry Structures," US-Austria Seminar on Stochastic Structural Mechanics, Florida Atlantic University, Boca Raton, 1987.
2.- Lomnitz, C., et al., "El Terremoto de la Zona Centro-Nororiente del Ecuador, 5 de Marzo de 1987," CERESIS/UNESCO, Lima, 1987.

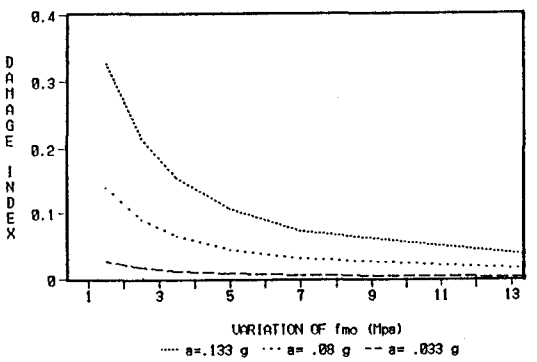

FIG. 2 VARIATION OF D WITH THE MORTAR STRENGTH fmo (td = 10 SEC)

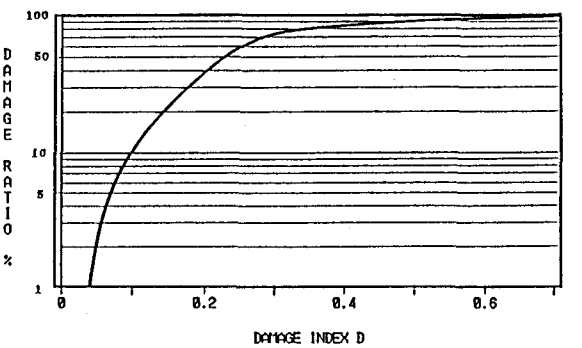

FIG. 3 DAMAGE RATIO (%) SCALE IN TERMS OF THE DAMAGE INDEX D

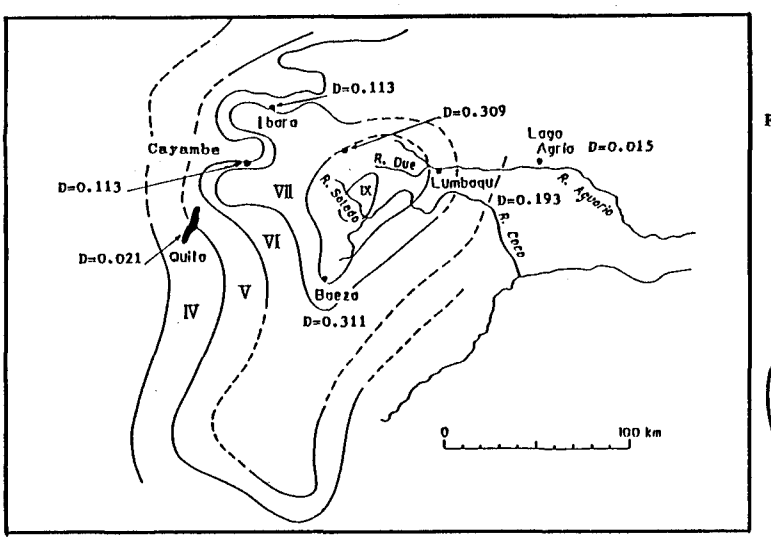

FIG. 4 DISTRIBUTION OF DAMAGE INDEX FOR THE 1987 ECUADOR EARTHQUAKE