Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.VII)

12-1-1

COMPARISON BETWEEN VULNERABILITY ASSESSMENT AND DAMAGE INDEX, SOME RESULTS

Paolo Angeletti[1], Alba Bellina[2], Elisa Guagenti Grandori[1],

Alberto Moretti[3] and Vincenzo Petrini[1]

[1]Department of Structural Engineering, University of Milan, Italy
[2]Private Architet
[3]Private Engineer

SUMMARY

In order of assessing seismic vulnerability in masonry buildings, a subjective approach was attempted in Italy since 1982. So far some tests have been performed on buildings damaged by earthquakes and different corrections have been proposed to obtain a better correlation damage-vulnerability. In this paper a method to evaluate expected damages for buildings is presented.

INTRODUCTION

The determination of expected damages or victims occurring during an earthquake requires, over all, the evalutation of two factors, i.e. seismicity and vulnerability. The second factor is depending on seismic performance of buildings and many ways have been attempted for its assessment.

A method for evaluating expected victims was used by Seismic Safety Commission, in California (Ref. 1), simply multiplying a vulnerability factor (LRS), a seismicity factor (SCF), an occupancy factor (ECO). The numerical value of (LSR) rappresents the number of expected victims per 10,000 inhabitants. An evalutation of expected damages can be done by means of vulnerability curves (Ref. 2). If the damage is defined and an intensity scale is choiced, each type of construction is identified by a curve damage vs. intensity. Different curves are obtained if constructive characteristics vary and if the definition of damage varies. Calculating the frequency of a damage level vs. seismic intensity for each construction typology (class of vulnerability) allows an evalutation of probability matrices. This way was followed after the Nov. 23,1980 earthquake in Southern Italy for some typology classes (ref. 3). Another way to determine the expected damage of building classes is partially deducted from numerical procedures. Each seismic intensity level can be represented by numerical values of ground acceleration. It determines interstory drifts at each floor of the building (representing the vulnerability class). If experimental curves damage vs. interstory drift are determined for each constructive component, a global damage vs. seismic intensity can be calculated for each building considered (Ref. 4).

A subjective approach has been attempted for evaluating vulnerability by means of scores attributed to a certain number of parameters choiced as representing different aspects of seismic performance of the building. This way has been attempted for masonry buildings (Ref. 5) and r.c. buildings (Ref. 6). A list of these parameters, with scores associated to each class is presented as following:

No	Parameter (classes)	A	B	C	D	Weight
1	Type of resisting system	0	5	20	45	1.00
2	Quality of resisting system	0	5	25	45	.25
3	Conventional safety factor	0	5	25	45	1.50
4	Foundations	0	5	25	45	.75
5	Diaphragms	0	5	15	45	(varying)
6	Plan	0	5	25	45	.5
7	Elevation	0	5	25	45	(varying)
8	Max walls center line distance	0	5	25	45	.25
9	Roof	0	15	25	45	(varying)
10	Non structural elements	0	0	25	45	.25
11	Damages and decay	0	5	25	45	1.00

The total score is obtained summing up the scores of parameters multiplied by their weights.

Of course the method requires reliability tests by means of comparisons damages-vulnerability. Different test and optimitazion approaches have been attempted on different samples (Refs. 7,8,9,10).

DIRECT COMPARISON DAMAGES VS VULNERABILITY

Samples taken into account in the present paper are these of Venzone 1976, Parma 1983, Middle Italy 1984 earthquakes. Venzone sample is composed of two sub-samples, first one on 98 buildings surveyed after May 1976 (IX MCS) earthquake, second one on 65 buildings surveyed after September 1976 (IX MCS) earthquake. Parma sample (VII MCS) is composed of 398 buildings surveyed by means of a list of 10 parameters slight different from the above one. Middle Italy sample is composed of 2,134 buildings hit by a VI MCS seismic intensity and 1,543 buildings by VII-MCS intensity, both selected from 70,000 buildings surveyed after May 1984 earthquake in Middle Italy. Barrea sample is composed of 116 buildings in an historical town, hit by a VII-MCS intensity quake, beloging to seismic events of May 1984 in Middle Italy.

Assuming the vulnerability model shown above, a distribution damage vs. vulnerability score can be seen in fig.1 for Venzone and in fig.2 for Barrea. As shown in figures, scattering is very high and it is over all due to these two following reasons:

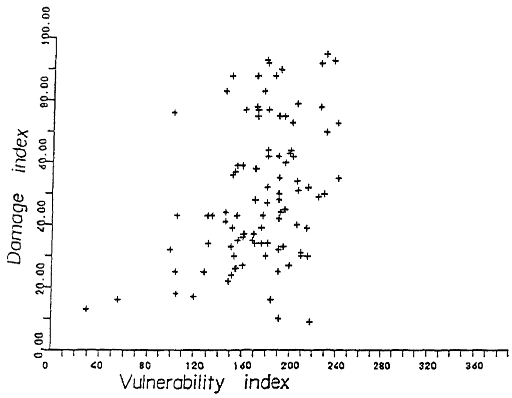


Fig. 1 Data from Venzone

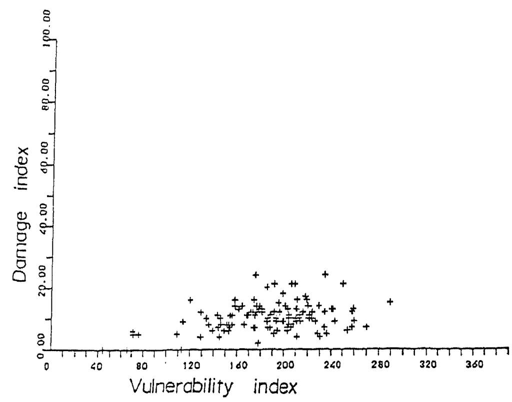
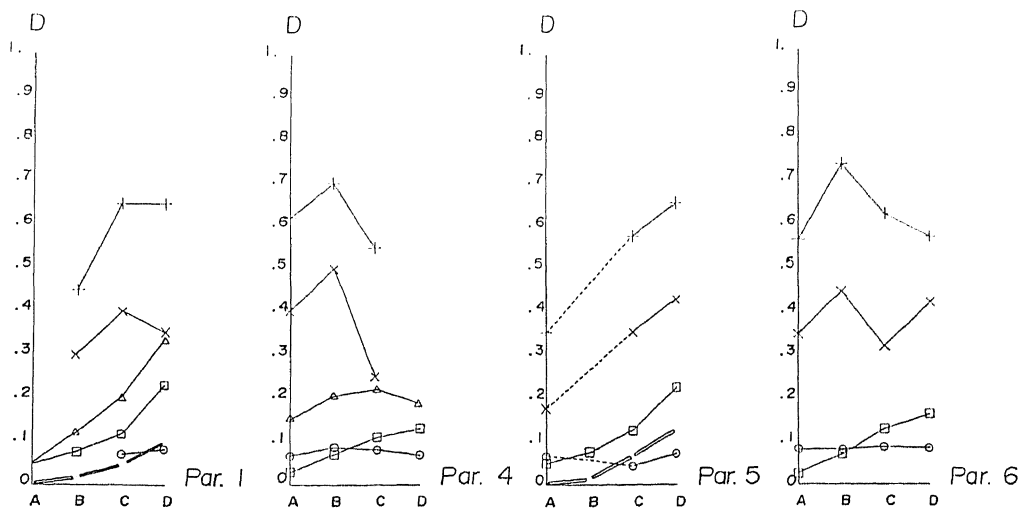


Fig. 2 Data from Barrea

a) type of evaluation of damage;
b) uncorrected scores in vulnerability model.



×Venzone (a) + Venzone (b) □ Middle Italy (VI MCS) △ Middle Italy (VII MCS) ○Barrea ⫽Theoretical

Fig. 4,5,6,7. Damage vs.vulnerability for parameters
1,4,5,6. Damage index is an average of the four contributions

In order to correct the scores, the parameters are analyzed by means of curves showing the distribution of damage for buildings belonging to each class of each parameter; curves significantly increasing passing through A to D mean a significance for the parameter taken into account; in the other hand curves with unsignificant increase mean that the parameters has low importance in the model. Of course this is true if parameter do not have significant interaction one each other. In figs. 4 to 7 curves for the eleven parameter are shown.

Damage can be defined in different manners; based on the weight attributed to 4 constructive components surveyed, i.e. vertical elements, horizontal elements, non-bearing walls, plasters and appendages. It could be seen that curves of figures would be different because of different contributions to damage, but with no significant influence on the behavior of curves.

As it can be seen, curves for parameters no. 4 (Foundations), no. 6 (Plan) and also no. 8 (Max walls center line distance) disagree with an expected increasing damages passing through 4 classes. Other curves agree and damage increases as the score increases. As expected, damage is often greater than zero at vulnerability level A for the parameter considered and for Venzone (a) and (b) samples (IX-MCS) damage level at D class is less than C class, surely for the absence in the sample of collapsed buildings. This last consideration was also noted in a sample composed bt r.c. buildings surveyed in S.Angelo dei Lombardi and Lioni after Nov. 23,1980 earthquake in Southern Italy.

Assessing the experimental weight of each class and each parameter is possible if a simple comparison between groups of buildings differying on each other just for a defined class of a parameter, is done. Of course this method requires a large number of buildings of different typologies and it is in progress.

DAMAGE - VULNERABILITY CURVES

Fitting data sets of samples examined with curves as following is a second step of analysis:

$$D = 100 \left(\rho + k\, v + \frac{V^2}{(V^2 + A^2)} \right)$$

where D and V are respectively damage (percentage) and vulnerability; ρ , k, A are numerical coefficients. An example of curves fitting data of Barrea and Venzone samples is shown in fig. 8

Damage can be related to the seismic intensity passing through a relation ship between ground acceleration and intensity, and a linear correlation between damage and ground acceleration (Ref. 11).

$$D = 100 \cdot \frac{(y - y_i)}{(y_c - y_i)}$$

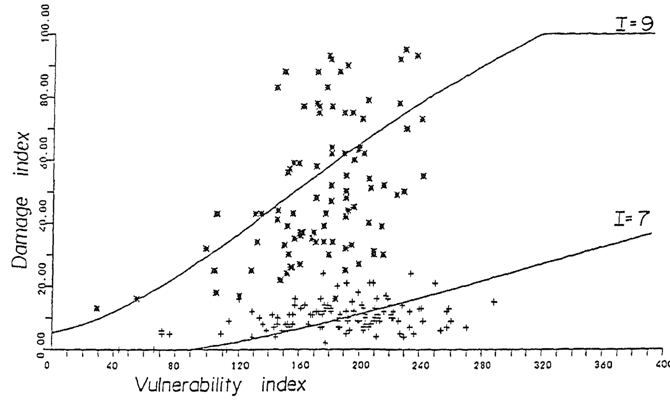


Fig. 8 Curves fitting data of VII and IX MCS intensity

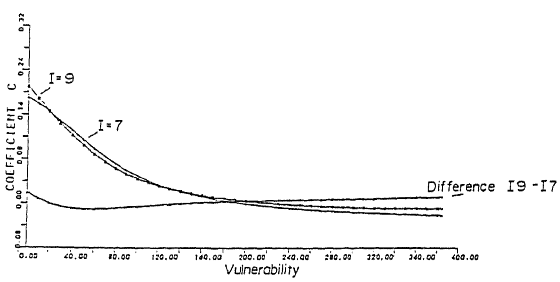
where y is the ground acceleration, y_i and y_c are acceleration of initial damage and final damage (collapse) respectively, and:

$$y_i = b_i + a_i \cdot C$$
$$y_c = b_c + a_c \cdot C$$

where C is the seismic design coefficient, b, a are numerical coefficients (of i-nitial and c-ollapse damage):

$$\ln y/g = \alpha + \beta \cdot I$$

g is the gravity acceleration, I is the seismic intensity, α, β are numerical coefficients.



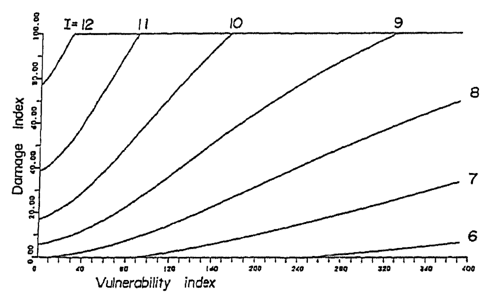


Fig. 9 Curves C vs. V for VII and IX MCS intensity (and their difference)

Fig. 10 Curves D vs. V for intensities different from these of samples

If the function C(D) is done, a relationship, C(V) becomes possible. In fig. 9 the two curves for Barrea (VII MCS) and Venzone (IX MCS) obtained by optimization on a_i, b_i, a_c, b_c, are shown. Passing through this function and now optimizing on ρ, k, A, curves D(V) for other seismic intensities become possible, as shown in Fig. 10

CONCLUSIONS

An approach to perform a better vulnerability assessment and to evaluate a fuction D (I, V) is presented. Some results are obtained from surveys done on buildings damaged by earthquakes of different intensity level.

REFERENCES

1. Seismic Safety Commision :"Evaluating the seismic hazard of state owned buildings", SSC 79-01, Sacramento (1979)
2. K.V.Steinbrugge :''Extension of loss estimation techinques to Metropolitan Salt Lake City, Utah'', (December 1979)
3. F.Braga, M.Dolce, D.Liberatore: ''Assessment of the relationship between macroseismic intensity, type of buildings ang damage, based on the recent Italy earthquake data''. 8th EECE, Lisbona (1986)
4. Roger E. Scholl, Onder Kustu, Cynthia L.Perry, John M. Zanetti :''Seismic damage assessment for high-rise buildings", URS Blume, San Francisco (July 1982)
5. D.Benedetti, V. Petrini: '' Sulla vulnerabilita' sismica degli edifici in muratura: proposta di un metodo di valutazione ''. L'Industria delle Costruzioni n. 149, Rome (March 1984)
6. C.Gavarini, P. Angeletti: '' Assessing seismic vulnerability in view of developing cost-benefit ratio for existing r.c. buildings in Italy ''. 8th WCEE, San Francisco (1984)
7. C.Gavarini: ''Dalla ricostruzione alla prevenzione: l'esperienza della riattazione''. Convegno Nazionale : '' Indagini ed Interventi sulla vulnerabilita' degli edifici in zona sismica'' SAIE Bologna (Oct. 23,1986).
8. D.Benedetti, G.M. Benzoni: '' Seismic vulnerability index versus damage for unreinforced masonry buildings''. Us-Italy Workshop on Seismic Hazard and Risk Analysis (Damage Assessment Methodologies). Varenna (April 1-3 1985).
9. E.Cartapati, A.Cherubini, A.Zingali :'' Vulnerability-damage correlations in a masonry buildings sample after Nov. 1980 earthquake in Irpinia, Italy''. (th EECE, Lisbona (1986).
10. P.Angeletti, V.Petrini: ''Confronto fra danni rilevati e vulnerabilita' sismica ''. L'Ingegneria Sismica in Italia 3rd National Conference. Rome (Sept. 30,1987)
11. Giuseppe Grandori, Vincenzo Petrini :''Comparative analysis of the seismic risk in site of different seismicity '', International Journal of Eartkquake Engineering and Structural Dynamics, Vol. 5,53-65 (1977).