ON VULNERABILITY OF STRUCTURES AND INHABITANTS IN DISASTER PROBABILITY EXPRESSIONS

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SUMMARY

The structural vulnerability expressed by the degrees of damage does not make possible the direct estimation of the vulnerability of inhabitants owing to the pronounced nonlinearity of causal relation.

The paper use the event " disaster " defined as the associated realiza - tion of a severe structural damage and loss of human lives. The probabilistic relation between the input events and the disaster event and the correlation with the vulnerability histograms are further on presented.

Based on a real or chosen model for distribution of the different building systems and based also on the seismic hazard for a certain site, the disaster probability is established for selecting systems at the initial stage and in different reconstruction alternatives with selected systems.

INTRODUCTION

The term " vulnerability " used with different meanings by different authors, has been more accurately defined during the past few years in UNDRO, UNDP and UNIDO publications and projects (done under the aegis of UNDRO and UNDP/UNIDO) . Lots of theoretical and practical studies have been initiated on the observed and predicted vulnerability (Ref. 1,2,3). Relatively recent new details have been mentioned.

So, the observed vulnerability (Ref.4) should be expressed by a histograms system of the damage degrees and losses (separately defined for different seismic intensities) based on post - seismic studies and referring to a given class of structures. To use the data given by the damage scales, the maximum damage degree (e.g. 5 on MSK scale will be identified with the value of total theoretical loss (equal to one for vulnerability).

The developments of this kind make possible separate analysis of structural, human, economical and social losses in a direct or equivalent value expression (specific risk assessment by convolution of hazard with vulnerability and respectively the risk evaluation by convolution of specific risk with elements at risk. The nonengineered buildings that are quite numerous in many rural seismic zones are the source of damage and mass losses of human lives. The emergency of this case does not permit the use of sophisticated risk assessment.

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COMPARATIVE ESTIMATING POSSIBILITIES OF VULNERABILITY OF STRUCTURES AND INHABITANTS FOR DIFFERENT NONENGINEERED BUILDING SYSTEMS BASED ON A MINIMUM POST SEISMIC DATA

It is obvious that most post seismic reports supply only the following data:

- number of buildings [slightly, moderate and heavy and collapsed] damaged and sometimes according to damage degrees on MSK scale, to localities, zones and country;
- number of wounded or dead persons per localities, zones and country.

The predicted vulnerability that has as a reference the observed vulnerability implies an accurate selection of data. As a consequence of post earthquake survey (after the occurrence of some earthquakes), the following statistical operations can be performed with this reduced amount of data:

a) ratio between the number of damaged buildings or the collapsed ones (that are main causes for the losses of human lives) and the total number of buildings of a certain type;
b) ratio between the number of losses of human lives and the number of lodgers theoretically in danger (mortality);
c) ratio between the number of human lives losses and the number of heavy damaged or destroyed buildings (table 1).

As concerns the relation between these ratios and the probabilistic graphs used for vulnerability of structures and inhabitants the followings can be mentioned:

a) the ratios concerning the buildings have the meaning of relative frequencies and can be used in the damage degree histograms. Given the present methods it is necessary a very attentive selection of data on building systems and for zones with the same intensity in order to be correctly entered in the vulnerability histograms.

b) the ratios concerning the human lives losses have the meaning of relative frequencies if they are calculated for the damage degree of buildings that caused this loss, for the structural system and for a given intensity estimated in that zone. At present, data of this type are gathered and totally given on localities. Nevertheless, these ratios are influenced by parameters such as:relative inhabiting density, family age composition, time of earthquake, season that should be mentioned. Out of these reports, histograms can be drawn up concerning the loss degree of human lives for different structural systems at different damage degrees.

c) composite ratios (death per heavy damage) are frequently used for calculating it directly out of primary data (Ref. 5,6,8). The ratios do not have the meaning of relative frequencies.
For an increased utility and a good correlation with data from points a and b , it is necessary to gather data for structures of the same type and in zones with a relative uniform intensity estimated by other means.
Besides these, it should be mentioned that these ratios can be used only for comparisons between different zones only if population density of systems (zones) are of comparable values.

The ratios can be approximately transformed into relative frequencies of the mortality type (point b) by normalizing them as opposed to the inhabiting density if it can be estimated as a relatively uniform one in the structural systems (zones) [Ref.7].

TABLE 1

STATE OF THE ART OF GENERAL DATA ON VULNERABILITY OF BUILDINGS AND INHABITANTS AS RESULTS FROM SEVERAL POST SEISMIC REPORTS

No.	Date and place of earthquake	Place of investigation	I	Number of heavy damage	Number of exist. struct	Number of death	Heavy damage per exist struct	Death per heavy damage
1.	15.04.1979 Montenegro YUGOSLAVIA	Ulcinj	IX	3183	6726	29	0.47	0.009
		Bar	IX	3870	10357	44	0.37	0.011
		Budva	IX	565	2609	4	0.22	0.007
		Kotor	IX	1435	6432	13	0.22	0.009
		Herceg Novi	VIII	915	5737	4	0.16	0.004
		ALBANIA Shkodra	VIII	10143* (5522)		34 (34)		0.003* (0.006)
2.	4.03.1977 Vrancea ROMANIA	Zimnicea	VIII	800	4000	4	0.20	0.005
		Alexandria	VII	385	10000	3	0.039	0.007
		Galatzi County	VII	700	80000	0	0.008	0.000
		Vaslui County	VII	521	120000	0	0.004	0.000
3.	24.11.1976 Caldiran TURKEY	Van Province	IX	9232	23856	3840	0.387	0.416
4.	4.02.1976 GUATEMALA		M= 7.5	25169	250000	23000	0.100	0.913
5.	6.09.1975 Lice, TURKEY	Lice zone	VIII	8149	19992	2385	0.408	0.292
6.	30.07.1970 Karnaveh, IRAN	Karnaveh zone	VII	1000	2500	200	0.400	0.200
7.	31.08.1968 IRAN	Dasht-E-Bayaz		12000		(7000)* 12000		(0.58)* 1.000
8.	16.06.1964 Niigata JAPAN	Niigata	VIII	2130		26		0.012
9.	06.1962 IRAN	Buyin-Zara	IX	21310		12275		0.576
10.	1948 JAPAN	Fukuy		35400		3870		0.109

Note: 1. Data were reported after Ref.5,6,8,9,10,11,12,13.
2. Data with * refer to information occurring differently in various papers or mentioned as a range.

USE OF A SIMPLE PROBABILISTIC MODEL IN ESTIMATING THE SEISMIC RISK OF SOME NONENGINEERED BUILDING SYSTEMS

Besides the more complex probabilistic models that have been already used for estimating the seismic risk by convolution in separate expressions according to the elements subjected to risk (Ref.2,3,4) , Ref 7 suggests the direct use of data on structural damage and on the loss of human lives. The concept " disaster event " implies a simultaneously occurrence of the structural damage of the destroying type (event A) and of human lives loss (event B).

For a building system in a seismic zone with a constant intensity the notations are such as:

N_1 = number of initial existent structures;

n_1 = number of destroyed structures;

L_1 = total number of inhabitants for the N_1 structures;

l_1 = number of inhabitants for the n_1 structures;

l_2 = number of human losses caused by structural damage of the destroyed n_1 structures.

Then the probability of the disaster event is:

$$P^x (AB) = P^x (A) \cdot P^x (B/A) = \frac{n_1}{N_1} \cdot \frac{l_2}{l_1}$$

The destroyed n_1 structures include both the collapsed structures and the heavy damaged and unrepairable ones (characterized such as owing to the damage scales because of their members state). Owing to the nonlinearity between the damage degree and the effects on the inhabitants, the ratio n_1 / N_1 indicates only the frequency of the maximum damages and not the danger the inhabitants are subjected to. Consequently the definition of heavy damage in this paper means the fact that among the n_1 heavy damaged structures there are cases when the damaged structures do not cause human losses.

The ratio l_2/l_1 shows the frequency with which the analysed building system "protects" the life of inhabitants under severe damage state.

Two peculiarities of these expressions are interesting:

- when the inhabiting density is relatively uniform for the analysed building system (l_1/n_1) $\simeq$ (L_1/ N_1) the relation is

$$P^x (AB) \simeq \frac{l_2}{L_1}$$

The probability of the disaster event, for this case, is expressed by the mortality ratio for the whole analysed system (relative frequency) calculated according to the density of the analysed system;

- for an inhabiting density relatively uniform on the whole analysed area the relation is:

$$P^x(AB) \simeq \frac{l_2}{L} \cdot \frac{N}{N_1} \simeq \frac{l_2}{c.N_1} \simeq \frac{l_2}{L_1'}$$

$$\left(\frac{l_1}{n_1} \approx \frac{L}{N} = C \; ; \qquad c.N_1 = L_1' \right)$$

The relation expresses the mortality of the analysed system calculated with the density of the whole zone. The relative frequencies are significant for the human vulnerability histograms.

Using the " probability of the disaster event" the different building systems can be classified as compared with the system that has P min as the most advantageous under given conditions on a zone with a given intensity. Obviously in this case, it is advisable to use only those building systems that have P similar to the value of P min. Aiming to reduce the human losses it is advisable to use the reconstruction with the available selected systems on a local plan and according to the traditional practices. At the same time, structural improvements are suggested to be done based on structures with adequate behaviour.

THE EFFECT OF USING THE SELECTED SYSTEMS ON THE DISASTER PROBABILITIES IN A GIVEN ZONE

The case of a single earthquake

AT THE INITIAL STAGE (after survey but before reconstruction) for an i system in a zone with the same intensity, possibly with more sub-zones with different local conditions, the notations are:

C_i = event " heavy damage associated with human losses " in structures of the i type of the subzone S ;

$P(C_i)$ = realization probability (frequency) of the C_i event;

For n systems, the C_i events being compatible with each other, according to the total probability theoreme, the disaster probability will be:

$$P\left(\sum_{i=1}^{n} C_i\right) = \sum_{i=1}^{n} P(C_1) - \sum_{i,j} P(C_iC_j) + \sum_{i,j,k} P(C_iC_jC_k) \dots +$$

$$+ (-1)^{n-1} \cdot P(C_1C_2 \dots C_n)$$

If one takes into account that $P(C_i) = \alpha_i P_{min}$; $P(C_j) = \alpha_j P_{min}$;

and $\sum_{i,j} P(C_iC_j) = \sum_{i,j} P(C_i) \cdot P(C_j)$, $\alpha_i \geqslant 1$, then

$$P(\sum_{i=1}^{n} C_i) = \sum_i \alpha_i P_{min} - \sum_{i,j} \alpha_i \alpha_j P^2_{min} + \sum_{i,j,k} \alpha_i \alpha_j \alpha_k P^3_{min} +$$

$$+ (-1)^{n-1} \alpha_i \alpha_j \alpha_k \cdots \alpha_n \cdot P^n_{min}$$

AFTER THE RECONSTRUCTION:

a) If for the reconstruction only certain systems are replaced, in formula , the α values are replaced with the ones of the new introduced systems

$$P'(\sum_{i=1}^{n} C_i) = \sum_i \alpha'_i P_{min} - \sum_{i,j} \alpha'_i \alpha'_j P^2_{min} + \sum_{i,j,k} \alpha'_i \alpha'_j \alpha'_k \cdot P^3_{min} +$$

$$+ (-1)^{n-1} \alpha'_i \alpha'_j \alpha'_k \ldots \alpha'_n P^n_{min}$$

where $\alpha'_i \leqslant \alpha_i$, $\alpha'_j \leqslant \alpha_j$ according to the changed systems

b) If one replaces all systems with the one that has $P'(C_i) = P_{min}$ ($\alpha_i = 1$, $\alpha_j = 1$) then

$$P'(\sum_{i=1}^{n} C_i) = nP_{min} - nP^2_{min} + (-1)^{n-1} P^n_{min}$$

AT THE INITIAL STAGE for several zones with different intensities I , where I = V - X MSK degrees one has:

$D_I = \sum_{i=1}^{n} C_i$ = the damage event associated with human life losses for the n structural systems for each zone of intensity I.

$P(D_I)$ = the realization probability of D_I event

The events being compatible and using the total probability theoreme we shall have for the zones sum:

$$P(\sum_{I=V}^{X} D_I) = \sum_{I=V}^{X} P(D_I) - \sum_{I,J} P(D_I D_J) + \sum_{I,J,K} P(D_I D_J D_K) + (-1)^{n-1} . P(D_I D_J \ldots D_N)$$

where I,J,K,N are different intensities zones. The intensity range V-X has been chosen according to the earthquake behaviour of nonengineered structures in most cases. However, the intensity limits could be chosen as convenient and significant for case studies for each zone.

AFTER THE RECONSTRUCTION, the values can be recalculated taking into account the previous formula for the expected maximum intensities or the chosen model.

The case of several succesive earthquakes

The successive earthquakes (non-simultaneously) can be considered as a complete system of incompatible events.
In a zone with n building systems one has:

C = event " heavy damage associated with human loss"for the n structural systems;

H_i= earthquake event

Applying the total probabilities formulae

$$P(C) = \sum_{i=1}^{n} P(H_i) \cdot P(C/H_i)$$

$P(H_i)$ is determined from the seismic hazard maps and $P(C/H_i)$ is determined for each earthquake according to the previous case.
The formulae is valid for the overall comparison of the risk between zones or direct comparison for the risk of different systems in different zones, if the C event refers only to this system. The reconstruction duration and required resources should be correlated with the expected time interval between earthquakes given by hazard studies.

FINAL REMARKS

1. Structural and human vulnerability for nonengineered buildings could be estimated using a minimum amount of data obtained only by systematic post-earthquake survey.

2. The probabilistic sense of deducted data is strongly influenced by the mode of aquisition and selection of data concerning human vulnerability.

3. Using the "disaster event", structural systems having"minimum disaster probabilities"could be selected. The operation could be performed on a sum of systems or on zones, taking into account a single or several seismic events and the reconstruction effects.

4. The method permits useful correlations and offers data for risk studies based on vulnerability and seismic hazard convolution.

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