THE ASSESSMENT OF PROBABLE ECONOMIC LOSSES CAUSED BY EARTHQUAKES IN RURAL DWELLINGS

by A.Kh.Koridze

SUMMARY

The realization of an economically reazonable policy of rural areas reconstruction giving priority to the replacement of the most potentially vulnerable dwellings necessitates the development of methods for predicting the extent of the loss which will be incurred in the rural dwellings of various types.

In this paper, the scale of losses for specific types of dwellings was arranged in form of damage probability matrices, containing distribution the number of dwellings according to degree of damage corresponding to different earthquake intensity and an estimate of loss occasioned by this or that degree of damage expressed as the ratio of cost of hypothetical repair to total dwelling cost.

Using these matrices made it possible to obtain values for the average probable degree of loss in dwellings of a given type during earthquakes of varying intensity.

INTRODUCTION

As the experience of earthquakes shows, the greatest economic losses fall on rural areas(1)(2).Only for the last 30 years 9 earthquakes with intensity 7-8 MSK scale have been occured in the Georgian SSR territory. And if the urban communities have practically avoided the damage, in rural areas numerous villages were subjected to destruction and damage. The predominant share of loss falls on individual residential sector - dwelling houses have been destroyed, domestic property damaged, live-stock lost.

The heavy loss in rural areas is explained mainly by the lack of any earthquake countermeasures in most part of old individual dwellings.

In spite of the fact that in recent years individual construction in rural areas is carried out according to the Earthquake Codes, vulnerable dwellings, considering their long lifetime, will be predominating for long period.

Thus, in condition of predominant share of potentially vulnerable dwellings in the rural areas, the only radical measure,allowing to reduce economic loss and timely accept economically effective earthquake protective measures, is predic-

Senior research worker,Institute of Structural Mechanics and Seismic Resistance,1 Zoya Rukhadze st.,Tbilisi,USSR

tion of expected loss in dwellings.

PREDICTION OF AVERAGE PROBABLE LOSSES

According to the official earthquake zoning map, the territory of the Georgian SSR is located completely in a seismically active region with maximum expected intensity 8 MSK. Therefore, we have considered in the paper the prediction of expected losses during the earthquakes of 6,7 and 8 intensity.

In the rural regions of the Georgian SSR, due to climatic peculiarities and availability of local construction materials certain types of individual dwellings are allocated in certain geographical zones of the republic. As has been already mentioned there are not any earthquake countermeasures in most of them. From these dwellings we have considered three the most widespread types - stone masonry structures the most vulnerable to the earthquake, brick masonry structures less vulnerable than stone structures and finally wooden ones the least vulnerable to the earthquake effect among all types of structures.

The loss scale for the each type of dwellings has been compiled in the form of so called damage probability matrices (3). In latters were assumed five damage states characterized both by word description and quantitative evaluation expressed as repair cost ratio to the total dwelling cost.

The description of each damage has been compiled on the basis of the actual data observed during inspection of the last heavy earthquakes in the Georgian SSR.

As for the quantitative evaluation of the damage states, due to lack of an actual data, these values have been established by cost interpretation of the repair works for standard structure among each type of considered dwellings. It was taken assumption, that certain damage state s may be experienced by any number k of different elements of the dwelling structure. For example, in a stone masonry structure damage of the fourth state (partial collapse of walls) may develop in one, several or at last in all walls. The rest walls of the same structure not damaged by the fourth state, have been considered as damaged by the lower state (s-1), i.e. by the third damage state (large, widespread cracks in walls).

Estimating the repair cost of different works for an each damage state (cost of repair of damaged walls Cw, injection of cracks Cc, plastering of walls Cp and etc.) in k=1, 2, 3.... n elements of the structure and suming them up, we have got a number of a quantities of the total loss for the each certain damage state:

$$Cs = \sum_{k=1}^{n} (Cwk + Cck + Cpk + \ldots) \qquad (1)$$

For present purposes we have considered only the extreme values Cs_{min} and Cs_{max} of the total losses. Dividing them on the replacement cost of the structure Cd we have got for each damage state minimum and maximum values of the relative losses:

$$DRs_{min} = Cs_{min} / Cd \; ; \quad DRs_{max} = Cs_{max} / Cd \qquad (2)$$

The next important step was establishing a relationship between earthquake damage state of a structure s and a ground motion intensity I. Since both the strenth of structure and the local ground motion pattern are to a large extent random in nature, it would be logical to express this relationship in a probabilistic manner.

Proceeding from the results of the statistical analysis we have assumed probabilistic distribution of damage states among dwellings Ps_I according to the normal law, taking as a basis the quantitative distribution of MSK scale(4). In the scale each intensity is estimated only by the two highest damage states, Smax to which correspond 5% of the total damaged dwellings, and Smax-1 -about 50%. Taking the normal distribution, the next lower damage states Smax-2 and Smax-3 must correspond 42% and 3% respectively from the total dwelling number. Then the sum of probabilities of all possible meanings of random value Ps_I is unity.

Having a number of relative loss values DRs for each damage states with probabilities Ps_I, damage probability matrices were constructed(Table 1). The average probable loss values corresponding to earthquake intensity I was defined as:

$$ADR_I = \sum_{s=1}^{5} DRs \; Ps_I \qquad (3)$$

where:

DRs - ratio of cost of repair to replacement cost for damage state s ;

Ps_I - probability that a strusture will experience damage state s subject to earthquake intensity I ;

I - earthquake intensity ;

s - damage state.

The solution of matrices constructed for different types of dwellings, allowed to obtain the minimum and maximum average probable loss values. For stone masonry structures for 6, 7 and 8 earthquake intensity the values compile 1 - 3‰, 14 - - 22‰ and 28 - 46‰ of the total dwelling cost respectively. For brick masonry structures the values are about twice lower and compile 1 - 2‰, 6 - 11‰ and 16 - 22‰. For wooden structures save to the action of moderate earthquakes, for 7 and 8 intensity the values compile 0.5 - 1‰ and 1 - 4‰ respectively.

ESTIMATION OF AVERAGE ACTUAL EARTHQUAKE LOSSES

For particular type of rural dwelling the reliability of the predictions made earlier have been confirmed by the analysis of data regarding losses sustained by rural dwellings during the Dmanisi earthquake of 2 January 1978, in Georgia, which in epicentral area reached intensity 8.

The area hit by earthquake is located in mountainous region of Georgia characterized by harsh winter conditions. Climate conditions and availability of local traditional

building materials explanes the similarity of dwelling structural types. The predominant dwelling type in region is rough stone structure with clay or weak lime mortar having thick walls and wooden rafter roof. Hence according to classification mentioned above this structure may be related to the first type - the most vulnerable to the earthquake.

For the purpose of assessment of actual earthquake losses we have analyzed the insurance payments covering losses of about 9.000 dwelling units in epicentral area. The value of the insurance payment after the earthquake has been estimated as the sum of expenditures necessary for repair or complete replacement of the dwelling.

According to the size of insurance payment and requirements for reconstruction, categories of losses r have been determined. The latters quantitatively correspond to the necessity, availability and expediency of reconstruction works. Each of loss categories has been considered in relative values LRr as ratio of insurance payment Lr to underwriting cost of the dwelling Ld

$$LRr = Lr/Ld \qquad (4)$$

For undamaged dwellings was given a loss index zero. For dwellings having light or minor damage(falling pieces of plaster, minor cracks in walls),where decorating repair was needed for rebuilding, loss has been estimated of 4-8‰ from the underwriting cost of the dwelling. In the dwellings under serious damage(large,widespread cracks in walls), where capital repair was need, the loss was estimated at wide range and compiled 15-25‰ from the underwriting cost of the dwelling.There were no cases of total collapse or ruine of the dwellings in epicentral area. As for the dwellings with collapsed parts of walls, they were beyond economic repair and therefore were demolished. For these dwellings, taking into account the remain part of materials after demolishing, the loss was estimated at 55-63‰ from the underwriting cost of the dwelling.

On the basis of the insurance payment lists data, compiled for each of 56 inspected villages, quantitative distribution of the dwellings according to the loss category were made. Using isoseismal map of area hit by earthquake these distributions for villages under the same earthquake intensity I were organized in corresponding groups.

For every single one of the three groups was considered the ratio between the number of dwellings Nr belonging to the loss category r and the total number of dwellings Nt

$$Nrı = Nr/Nt \qquad (5)$$

Values Nrı and LRr allow to construct actual loss matrix for stone masonry structures affected by 6, 7 and 8 earthquake intensity(Table 2).

By solution of matrix we have got the values of the average actual losses corresponding to the certain earthquake intensity I

$$ALRı = \sum_{r=1}^{4} Nrı\ LRr \qquad (6)$$

For 6, 7 and 8 earthquake intensity zones the average actual observed loss compiles 7 - 12%%, 17 - 23%% and 35 - 43%% of the insurance cost of the dwelling.

CONCLUSIONS

A comparison of predicted and actual observed values of average losses shows satisfactory agreement for areas with 7 and 8 earthquake intensities. As for area with 6 earthquake intensity, at this point predicted values are lower than corresponding actual ones. The latter apparently confirms the vulnerable point of the MSK scale taken by us as the basis of assumed relation between damage states and earthquake intensity. It should be remainded, that in MSK scale move up from 6 to 7 intensity is accompanied by damage increase on two units while from 7 to 8 intensity - only on unity.

The investigation could be considered as preliminary. In future it would be desirable to widen such investigations, using greater number of initial engeneering-economical parameters.

REFERENCES

(1) Polyakov S.V. Consequences of strong earthquakes.Moscow, Stroiizdat, 1978 (in Russian).

(2) Martemyanov A.I. Design and construction peculiarities of rural buildings in seismic regions. Moscow, Stroiizdat, 1975 (in Russian).

(3) Whitman R.V., Sheu-Tien Hong, Reed J.W.,"Damage Statistics for High-Rise Buildings in the Vicinity of the San Fernando Earthquake",Optimum Seismic Protection and Building Damage Statistics, Report No.7,MIT,April 1973.

(4) Shebalin N.V."The distribution of building damage states and its application for earthquake intensity evaluation". The seismic scale and seismic hazard assessment methods. Moscow, Nauka, 1975, pp.253-261(in Russian).

Table 1 - Damage probability matrix for stone masonry structures

№	Damage state	Description of damage	Damage ratio (%)	Earthquake intensity (%)		
				6	7	8
1	Light	Plaster cracking, thin cracks in partitions	1-5	50	3	0
2	Minor	Minor cracking in walls, falling of large pieces of plaster	7.5-15	5	42	3
3	Heavy	Large, widespread cracks in walls	18-25		50	42
4	Destructive	Partial collapse of walls	35-60		5	50
5	Collapse	Total collapse of a structure	60-100			5

Table 2 - Actual earthquake loss matrix for stone masonry structures

№	Loss category	Ratio of insurance payment to underwriting cost of a dwelling (%)	Earthquake intensity (%)		
			6	7	8
1	Undamaged	0	12	4	3
2	Decorating repair	4-8	66	52	17
3	Capital repair	15-25	28	23	23
4	Beyond economic repair	55-63	4	21	57