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THE METHOD FOR PREDICTION OF SEISMIC DAMAGE FOR SINGLE-STORY MILL BUILDING

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SUMMARY

In this present study a great many damaged samples have been collected. The stepwise regression has been adopted. Several regression equations have been obtained. Fuzzy mathematics method has been also established and used to check the results of regression equations. It found to be satisfactory. Some practice also have been done in the light of this method. It also proveded that well reflect the actuality.

INTRODUCTION

In recent years, most strong earthquakes in our country have occured in low-intensity areas. This poses the following questions: Will the buildings experience damage when the large-probability earthquakes take place?(i. e. the small earthquake.) What will happen when the small-probability earthquake comes? (the large earthquake.) What must be done before the coming of an earthquake? These problems give us a new task: to predict seismic damage. This will enable policy decisions to be made for the people. In the prediction, the concept of quantity must be considered. The inner relationships of damage will be found on the basis of the examples of earthquake events. This relationship will be improved and completed by considering the recent research results. It is the common method to determine the approach of prediction of seismic damage in China and abroad.[Ref.1,2,3,4.]

The results of seismic damage prediction are the basis for a plan to mitigate urban seismic damage. They include the following points: (1)Giving the general percentage of failure for various buildings, determining the limit line for strengthening, and assessment of the strengthening cost. (2) Giving the failure percentage at an overall urban area and each microzonation,assessing the expense for strengthening these districts. (3)Assessing the cost of direct and indirect damage, for both industrial areas and populated areas. (4) Making arrangements for the rescuing stations in accordance with the failure percentage. (5)Giving the failure index of individual building which is fundamental data for choosing the sort of strengthening for the building.

THE ESSENTIAL TRAIN OF THOUGHT

The Analytical Model It is desirable that the analytical model of single-story mill buildings is very simple and their loading state is very explicit. Recent earthquakes provide a lot of informations for seismic design and considering information from statistics, the following analytical model is used. For a mill building with R/C column and brick column in turn.

$$N=a_0 W^{a_1} b^{a_2} d^{a_3} H^{a_4} \beta_d^{a_5} \alpha_H^{a_6} (L/90)^{a_7} \tag{1}$$

$$N=b_0 W^{b_1} b^{b_2} d^{b_3} H^{b_4} R^{b_5} \alpha^{b_6} (L/90)^{b_7} \tag{2}$$

where, N denotes the seismic damage index; W,the load on the top-of-column; b,d, width, height of column section in turn; H, L, height, length of building in turn; β_d, the ratio of the height at upper part section to the heght at lower part section; α_H, the ratio of the length of the upper part to length of the whole column; R,the compressive intensty of masonry; α , the corrective coefficient of structural shape and a_i,b_i($i=0,1,2\cdots7$)are coefficients determined from damage information.

The Samples and Selection of Their Parameters. The samples of the single-story mill buildings are collected form the past events. They are listed in Table-1

Table-1 Number of Samples

Category of Sampls	Intensity,class of site	Number	Total
Buildings with R/C Column	8 II	53	112
	8 III	49	
	Other Condition	10	
Buildings with Brick Column	8 II	103	237
	8 III	36	
	9 II	54	
	Other Condition	44	

First, the damage degree of above mentioned samples is numerically expressed by the seismic damage index N, which is referred to as a dependent variable. Secondly, the main factors that have influence on the damage are not only the predominant factor in the effects on the damage but also very convenient, reliable to use and easy to quantify. On the basis of this principle, the seven factors in formulae(1),(2) are selected to be the variates.

PREDICTION METHOD

Statistical Analysis of Samples For comparison, the two statistical analytical methods,the stepwise regression and stepwise distinguishment,are used. To make the statistical analysis, the logarithmic transformation has been made from formulae(1),(2) to (3),(4) which is the linear equations of a mill building with R/C column and brick column in turn.

$$Y_1=a_0+\sum a_i x_i \quad (i=1,2\cdots7) \tag{3}$$

$$Y_2=b_0+\sum b_i x_i \quad (i=1,2\cdots7) \tag{4}$$

The stepwise regression is currently regarded as a reliable method. The main idea is to introduce these independent variables which have a marked influence on Yi in the regression equations. At first,choose the independent variables which are most influential on Yi and attracted to the regression equation only when they pass the F-test. Then select the variable which has the maximum regression square sum with the Yi from other variables. In the same manner, they will also be used in the F-test and be attracted if they have remarkable influence. Finally, the regression equations get from stepwise regression method including the variables which is the most marked effect on N (or Yi). In general these regression equations are optimized. This has already been proven.[Ref.5,6,7] In the stepwise discriminating method the samples can be classified according to the value of the index of the damage degree N. The independent variables can be sorted out. These variables having the most effective discrimination can make up the discriminating functions for every class of samples. According to the maximum value of these discriminating functions from these figured out, the class of the samples can thus be decided By comparing these two methods, as far as the examining indexes, the results obtained by the stepwise regression method are suitable for the conditions here. In addition we also use the comprehensive evaluation with multifactor method of fuzzy mathematics. Thus we establish the prediction approach. Better fit has been achieved after the examination of the prediction results[8].

What we do next is to make some comparitive analyses.(1) Compare the two results by using statistics. The one makes statistics of the samples with the same intensity and same class of site,the other makes statistics of the samples with the different intensities and the different classes of site both converted into same intensity and some class of site; (2) Compare the two results by using statistics. The one makes statstics of the samples with the seismic damage degree to be roughly divided into five grades,the other of which every grade is subdivided into four levels; (3) Various sets of samples are used for statistical comparison; (4) Determine the influence on the seismic damage of various intensities or classes of sites by comparing their statistical data ; (5) Determine the influence of the attached members on the seismic damage degree; and (6) Make statistical calculations before some important factors are selected as independent variables.

<u>The Analysis of the Statistical Results</u> The regression equation of the one, Two, three, four and seven variables can be obtained by means of the stepwise regression method according to various test criteria. The complex related coefficients, the residual standard deviation, the F-value in the test of significance and the residual error of every sample can also be gained. The above data show that most of the so-called principal factors accord with the mechanical concepts and the aseismic experiences. However a few factors do not seem as important as the others. This is because, althongh the samples of damage buildings are very valuable,they are so complicated that it become difficult to quantify. Therefore,the sixth comparison is added above. In other words, the experiences induced form the past events should and must be modified or improved by the current theories on the aseismic.[Ref.1,9,10] The above date also show that: the more the samples,the more possible to get rid of some contingency. The subdivision of the damage degree is helpful to find the quantitative relations between it and other factors. The damage caused by some key factors fundamentally accord with the value we initially determined.

<u>Selection of the Prediction Model</u> On the basis of the above work, we suggest that the prediction of seismic damage conld be used formulae (5),(6) and (7),(8) for mill buildings with R/C column and brick column in turn:

$$N=0.2843\frac{H^{1.8666}}{d^{1.4589}}+10 \quad (5)$$

$$N=0.2674\frac{H^{1.9319}\beta_d^{0.1446}(L/90)^{0.0194}}{d^{1.4497}}+10 \quad (6)$$

$$N=40847\frac{(L/90)^{0.4722}}{(7R)^{1.5208}}+10 \quad (7)$$

$$N=4777\frac{H^{1.5309}(L/90)^{0.5347}}{d^{1.2825}(7R)^{1.6412}}+10 \quad (8)$$

ON PRACTICE

By means of the approach propssed,the seismic damage index for buildings within a district and an individual building can be evaluated. The latter will determine whether strengthening is necessary. This is very demanding work which should be accomplished by staff members. In order to quickly master and flexibly use this method under the guide of the expert, it is required that this method has not only sufficient reliability but also simplicity. It means that the independent variables in the prediction formulae are concretely quantified and easy to be collected, the computation is so simple that it can be accomplished only by using a calculator. We have carried out a test in a middle sized city to examine the above requirements.

First step, we choose a microzonation of three kilometers square as a experimental unit on the basis of which we extend its application to the whole city. This microzonation takes three people ten days to collect the date of 69 industrial buildings with R/C column and 253 of brick column, which covered $90039M^2$ and $72446M^2$ in turn. The efficiency of them is 10.7 buildings ($5420M^2$) per day. This test showed that after an introduction of several hours, it is possible for people to work together at once and after 2~3 days to finish the work. The tools are only a tapeline and a simple calculator. All the results are put together in five days. The results are listed in Table-2.

Table-2 Predicting percentage of Damage in the Microzonation

Levels of the Damaged Buildings		Intact	Slight	Moderate	Severe	Collapse
Class II Intensity 7	Bldg.with R/C.Col.	95.00	5.00	/	/	/
	Bldg.with Brick Col.	72.50	19.17	6.50	1.83	/
Class II Intensity 8	Blag.with R/C.Col.	4.02	71.31	24.67	/	/
	Blag.with Brick Col.	2.56	49.62	28.54	12.37	6.91

On the basis of the above microzonation, it takes eight days to collect samples in the whole city. Samples of 818 buildings with about $530,000M^2$ have been collected. By means of the prediction approach the results of the whole city are in Table-3.

Table-3 Predicting Percentage of Damage in the Whole City

Levels of the Damaged Buildings		Intact	Slight	Moderate	Severe	Collapse
Class II Intensity 7	Bldg.with R/C.Col.	91.45	8.55	∕	∕	∕
	Bldg.with Brick Col.	69.19	23.32	6.35	1.14	∕
Class II Intensity 8	Bldg.with R/C.Col.	3.08	48.87	48.05	∕	∕
	Bldg.with Brick Col.	0.67	46.84	38.32	11.47	2.70

The figures of the bildings with brick column in the above two tables are very near and the percentage of R/C column is inclined to be higher in the intensity 8 and moderate column of Table-3. The initial data have shown that the most sections of the column in this city are inclined to be smaller, for instance,a column of 10～12M high building only have a section of 60 CM height, apparently smaller. This has been reflected in the class II and intensity 8 of site, although nothing is seen in the class II and intensity 7 of site. It is so important that it must be noticed in the consideration of strengthening.

The above mentioned classification of damage is a common way of dividing the damage into five levels. Regarding the convenience of application,a threshold level is suggested. About this level, there are two sides: the building is "in need of strengthening" and the building "must be strengthened" . The safety of the former is analogous to the damage criterion of the small earthquake, beyond which a damage will come that needs to be thoroughly repaired. This has a larger influence on the recovery of production after an earthquake. But the seismic probability is very small, and it is a problem for the making of policy whether these buildings are necessary to be strengthened. This threshold level is called "in need of strengthening" . It is in vicinity of a value of index N of 30. The latter threshold level is the line where the index N has a value of 70, where safety is in accord with the damage criterion of the large earthqnake, beyond which the buildings are likely to collagse when the event comes. It will be unduly hazardous to life and limb. These events must be avoided. So the buildings must be strengthened,according to this requirement and this threshold level is called "must be strengthened" . The percentages of the above criteria in this city are listed in Table-4.

Table-4 Predicting Percentage of Strengthening of Buildings

Category of Strengthened	Class II Intensity 7			Class II Intensity 8		
	no need	need	must	no need	need	must
Building with R/C Column	100.00	∕	∕	54.24	45.76	∕
Building with Brick Column	85.72	14.28	∕	32.67	59.00	8.33

CONCLUSIONS

This prediction approach has also been used by other departments and it has been proven that the prediction results are in keeping with the reality and can well reflect the actual problem. It is because the key factors that have predominant influence on the damage have been thoroughly taken into account. In most cases, the prectical problems can be discovered by using this approach as well as to make estimation of the damage for individual buildings, so as to provide a basis for the strengthening. This is the first feature of this approach.

The approach is in the simplication of the knowledge and the tools needed, for example, only the general sampling and statistics knowledge and a tapeline are required.

The primary data collected using this approach are very concrete and clear so that it is unnecessary to make judgement. It is the third character of this approach.

It is apparent that this approach has higher reliability, convenience for mastering,simplication for use which makes it worth popularizing.

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