Estimation Method of seismic damage prediction of Single Building

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ABSTRACT:

An estimation method of seismic damage prediction of Single Building is advanced in this paper, considering that the basal information of buildings may be insufficient and the regional database may be imperfect. In the situation of insufficiency of structure data, a new coefficient, magnification factors (K), is introduced into the model based on document [1], and its value decreases with increasing the numbers of the available seismic damage influence factors. The value of K is calculated by formula, or is advised by experts. In the situation of the imperfectness of the regional database of the predicting zone, a larger range of regional database that contains that of predicting zone, or the database of the adjacent regions of predicting zone, is taken in the estimation model, and the database is selected according to concrete situation. The result of prediction is conservative with the characteristics of the predicting zone and conceivable precarious situations. In the end, a case is analyzed with the method of the estimation method.

KEYWORDS:

estimation method, seismic damage prediction of Single Building, magnification factors, seismic damage impact factor, average damage prediction index.

INTRODUCTION

If a construction with plenty basal information is carried on the seismic damage prediction with the methods of seismic damage prediction of Single Building such as Semi-experience and semi-theory method, Structure computing method etc. [2], its result may be very satisfactory. However, if a quantity of constructions are carried on the prediction of earthquake calamity at the same time, and under the situation that the data relatively lacking, the results are hard to tell. The main reason is that the methods described above have very high expectations for the basal information of building, for example sectional size, reinforcement, flat elevation drawing etc., and these data are very difficult to receive for general single structure.

While carrying on the seismic damage prediction to the real single building, the past method may have the following difficulties, they are also the bottleneck that many theory formulae applied to practice: (1) the building data utilized of the collected are fewer. (2) Some data are ambiguous, unable to judge. (3) the key data are lacked. (4) Regional database is not set up or is set up but relatively coarse (The second is directed primarily to some theory methods depended on statistics). The situations described above have a tremendous influence on the result of seismic damage prediction of Single Building, and they must be considered. So, an estimation method of seismic damage prediction of Single Building is proposed in this paper, considering drawbacks above synthetically.

1. Estimation method

1.1.Average damage prediction index

The average damage prediction index means the average of the seismic damage prediction index of a kind of buildings under J earthquake intensity, namely it is the sum that the destruction rates that building account for multiply the corresponding seismic damage index. The average damage index shows the average seismic damage degree of this kind of building. Through the calculations of different damage indexes of all kinds of structures, it can be compared with the quality of the seismic behavior between all kinds of buildings. The concrete description is as formula (1).

$$D_j = \sum D \cdot (n_p / N)$$

$$\text{OR} \quad D_j = \sum D \cdot P(D_p \mid J) \qquad (1)$$

Here, D∈ [0, + 1.0] ，Mean Value of the earthquake index.

n_p, the number of the structure with p class destruction in certain region,(class Ⅰ: Basic intact, class Ⅱ: Slight damage, classⅢ: Medium damage, classⅣ: Serious damage, class Ⅴ: Destroy).

N, the total number of a kind of structure in an appointed area.

$P(D_p \mid J)$, the destruction rate of a certain kind of structure with p class destruction under J earthquake intensity.

J∈ [6, 10] or ground peak acceleration [0.05g, 0.80g] in the norm.

1.2.Seismic damage impact factor of the single building

In this text, the seismic damage of single building is considered from the macroscopic utilizing seismic damage impact factors. Seismic damage impact factor, a physical quantity, signifies a certain impact factor to the seismic impact degree of the structure under the specific earthquake intensity, namely the degree of membership of seismic damage impact factor to the whole earthquake jurisdiction collection. Generally speaking, the seismic damage impact factor includes: Structure type, Built year of the structure, Layer of the structure, use of the building, Construction standard, Integrity of the building, Regularity of the building, Intensity of material, Site type, The current situation appraising etc[3].Because of the discreteness of the seismic damage impact factor, its impact on seismic damage of the single building is changed with the changes of regional geology, characteristics of structure etc. Though the discreteness, considering irreplaceable between each factor, all factors are supposed separating with each other while calculating seismic damage impact factor, formula as follows:

$$C = \prod_{i=1}^{n} C_i \qquad (2)$$

Among them, C is the comprehensive evaluation index of the seismic damage impact factor. N is the number of the seismic damage impact factor of the single building. C_i is the evaluation index of the ith seismic damage impact factor. Sees calculation formula (3):

$$C_i = \frac{D_i}{D_{[i]}} \qquad (3)$$

Here, D_i is average damage prediction index of a kind of structure including the ith seismic damage impact factor in certain regional range and under some earthquake intensity. $D_{[i]}$ is the average damage prediction index of the identical kind of structure excluding the ith seismic damage influence factor under the same term as Di does.

Here, every seismic damage impact factor C_i can be further thinned according to different division standard (For example, layer counts of the structure include 1 layer, 2 layers, 3 layers etc.)**.** Therefore, as to a structure, its thinning result is unique(that is structure information), supposing the ith seismic damage influence factor can be detailed to turn into s factors, then $C_i = [c_1, c_2, \cdots, c_i, \cdots, c_s] \cdot e_i$

1.3.The revision of seismic damage impact factor of single building

Preceding paragraphs have mentioned, while calculating seismic damage impact factor in practice, the situation with insufficient structure information often appears. Then, the formula described above needs to be revised. The magnification factor K is introduced in this paper, the value of K is a number not less than 1.0, decreasing with number of available seismic damage impact factor increasing. So, combining with the formula (2), seismic damage impact factor revision formula is as following:

$$C_k = K \cdot \prod_{i=1}^{r} C_i \tag{4}$$

Among them: C_K is the revised comprehensive evaluation index of the seismic damage impact factor, when the data is plenty, there should be C= C_K. C_i is the same in meaning in formula (2). r is the number of the available seismic damage impact factor, and 1.0≤r≤n. K is magnification factors, and K⩾1.0, while r = 1.0, the information is the least full and accurate, and the estimated value of K is the greatest; While r = n, the information is the most full and accurate, K =1.0; Other value lies between medium values. While calculating K, two kinds of solutions are provided, the details are as follows.

Scheme (One):

Suppose one structure has n kinds of seismic damage impact factor, r kinds of seismic damage impact factor known, n-r unknown, considering that every seismic damage impact factor have the most unfavorable situation, combining (2, 4), K is adopted following formula:

$$K = \sqrt[(n-r)]{\prod_{i=n-r}^{n} \max(C_i)} \tag{5}$$

Among them, r, n=1,2⋯, and r≤n.

Scheme (Two):

Utilizing the understanding of seismic damage impact factor of ‘the structure to be tested’ by different experts, possible seismic damage is analyzed, and K value is marked, see following formula specifically (6):

$$K = \sum_{i=1}^{s} a_i \cdot k_i \tag{6}$$

Among them, K is magnification factor; s is expert's number; a_i is the expert's weight (it can be regarded as confidence value or authority degree), and $\sum a_i=1$; k_i is expert's score to K value.

1.4.Calculation of seismic damage prediction index of single building

After K value is confirmed according to method described above, the seismic damage situation of the single building can be got by the formula (7).

$$d = C_K \cdot D_j$$

$$\text{OR} \quad d = K \cdot \left(\prod_{i=1}^{r} C_i\right) \cdot D_j \tag{7}$$

Among them, d is the seismic damage prediction index of the single building, and 0⩽d⩽1.0; D_j is the average damage prediction index of this type of structure under j earthquake intensity. See preceding paragraphs in meaning of other parameters.

After calculating the seismic damage prediction index of single building, the seismic damage situation of single building is provided according to table 1 below.

Table 1 definition of seismic damage prediction index

Destruction grade	Basic intact	Slight damage	Medium damage	Serious damage	Destroy
The defined seismic index	0.05	0.2	0.4	0.7	1.0
upper and lower limits of the index	[0,0.1]	(0.1,0.3]	(0.3,0.55]	(0.55,0.85]	(0.85,1.0]

2.EXAMPLES

In this paper, taking government office building of Jinjiang city as an example, the seismic damage situation under ground peak acceleration is calculated by the method introduced above, compared with the original prediction result. Example is as following:

Government office building of Jinjiang city is six-layer Reinforced Concrete Frame Structure, which is designed by architectural engineering design firm of Huaqiao University. It was built in 1991, and its building area is 3004m^2, irregular plane, 7 degree intensity earthquake resistance protection. The photo is supplied in figure 1.

fig.1 Government office building of Jinjiang city

Analyze: in above description, the available seismic damage impact factors include: layer counts, built year, use, Construction standard, regularity. From above content, five seismic damage factors are confirmed. So, the estimation method of seismic damage of single building is used while calculating the seismic damage of structure. Based on above introduction, some complementary seismic damage impact factors are supplied as followings: Site type, current situation appraising, Intensity of concrete. Other seismic damage factors are fetched default value 1.0 on calculation.

Calculation: the database is composed of 124 multi-layer Reinforced Concrete buildings of Jinjiang city, based of which the calculation is carried out. Available seismic damage impact factors and results are tabulated in table 2.

Table 2 available seismic damage impact factors and results

ground peak acceleration (g)	Layer counts -6	Built year-90	Use-office	Construction standard	Regularity of the building	Multi-layer Reinforced Concrete frame
0.05	1.0000	1.0000	1.0000	1.0000	1.0000	0.0500
0.15	0.9400	0.8184	1.0044	1.0000	1.0008	0.1105
0.20	0.9100	0.8909	1.0169	1.0000	1.0462	0.2198
0.40	0.9300	0.8612	1.0126	1.0000	1.0144	0.3847
0.80	0.9700	0.9041	1.0197	1.0000	1.0148	0.6871

It can be found out from Table 2: The impact of factors such as layer counts, Built year, etc. to the structure of multi-layer reinforced concrete frame has nothing in common with each other. Built year is the most influential, Layer counts takes the second place. And as to the structure of multi-layer reinforced concrete frame, use, regularity of the building all have certain influence on seismic damage of the structure, but not obvious.

According to the analysis above, the complementary seismic damage impact factors and magnification factor (K) are calculated with the formulae 2, 3 and 5, tabulating the results in table 3 below.

Table 3 complementary seismic damage impact factors and results

ground peak acceleration (g)	Site type	The current situation appraising	Intensity of concrete	Value of K
0.05	1.0000	1.1500	1.0030	1.0487
0.15	1.0479	0.9946	0.9923	1.0113
0.20	1.0870	1.1194	1.0082	1.0705
0.40	1.1565	1.1046	1.0347	1.0975
0.80	1.2396	1.1532	1.0336	1.1390

The seismic damage of the structure, under different ground peak acceleration, can be calculated with the value of table 2, 3 and formulae 7, tabulating the results in table 4 below. Utilizing the method in document [3], the maximum elastic seismic shear of the floor can be calculated with finite element method, and the yield shear of the floor can be calculated according to the real situation of the building. The yield shear coefficient of floor is the ratio of the yield shear and maximum elastic seismic shear of the floor, according to the relationship of the yield shear coefficient of floor and the average value of maximum elongation of the floor, and the seismic damage of the building is evaluated by the maximum elongation of the floor, synthetically considering construction measure and characteristics of the structure, etc... , tabulating the results in table 4 too.

Table 4 the seismic damage situation comparison with that with theory method

ground peak acceleration (g)	The result with the method of the text		The result [6] with method of document [3]
	seismic damage index	Destruction grade	Destruction grade
0.05	0.052437	Basic intact	Basic intact
0.15	0.086413	Basic intact	Basic intact
0.20	0.202945	Slight damage	Slight damage
0.40	0.347332	Medium damage	Medium damage
0.80	0.710189	Serious damage	Serious damage

It can be found that the result with the method of this text and theory method are roughly identical by the result of Table 4. In the theory method the calculation of the maximum elastic seismic shear and the yield shear of the floor needs detailed information of the structure, and if the structure is complicated, the calculation will be more tedious.

3.CONCLUSIONS

In the paper, synthetically considering the influence of seismic damage impact factors and the situation of the basal information of buildings that is insufficient, an estimation method of seismic damage prediction of single building is set up. The model of this method is simple and there is certain practicability. In the model of estimation method, the magnification factors (K) can be gained by two kinds of ways. With basal information of buildings is plenty, the results will be more accurate. Generally, the results of prediction with the method above are conservative. The same as document [1], a regional database is also needed in the estimation method, and many samples in the database are results of seismic damage prediction, thus the results of seismic damage prediction of authoritative mechanism are the best choice.

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