STUDY ON QUANTITATIVE METHOD FOR SAFETY ASSESSMENT OF BUILDINGS ON SEISMIC SITE

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ABSTRACT :
In this paper, contrapose to assessment problem of a qualitative index----earthquake damage condition of buildings, Quantitative method is developed and Quantitative index---earthquake damage exponential is introduced who assesses whole earthquake damage of building based on National Standard <Post-earthquake field works the second part: Safety assessment of Buildings>(GB18208.2-2001). Mathematics assessment model of earthquake damage identification of buildings is developed through a lot of instances analysis of earthquake damage of buildings along with experience summary. Specific analysis process is as follows: Hierarchy-Relation of post-earthquake safety assessment is confirmed; Evaluation Coefficient of bottom earthquake damage is confirmed; Weight values of sites of earthquake damage of buildings are confirmed; Grade division of earthquake damage; calculation analysis. Through instance calculation analysis of much building structures in anciently more times earthquake, The Reliability of Mathematics model and Calculation method in this paper is validated relative to real earthquake damage condition.

KEYWORDS:
post earthquake; safety assessment; Analytic Hierarchy Process; evaluation coefficient; earthquake damage index

INTRODUCTION

According to Analyzing seismic experience of domestic and overseas, the buildings' destruction and collapse is the leading cause of loss in people's life and property due to earthquake. Statistics suggested most 95% casualties of life in earthquake is due to the buildings' destruction. Practices of multiple earthquake emergency response proved that it is an effective way of properly arranging seismic people to safety assessment of seismic buildings on post-earthquake quickly timely and effectively during earthquake emergency. It can effectively avoid many safe leaks because seismic people live shelter after earthquake, and can prevent secondary disaster caused by freely housing unsafe building under strong aftershock. It ensured strongly the safety of seismic people's life and property and reduced casualties and property losses. It is the important role to recover normal order and maintain social stability; at the same time, during earthquake emergency, it provides the basis of exactly measuring devotion of manpower, material resources and financial power and avoiding unnecessary waste, and making use of these resources effectively. Thus, Safety Assessment of Buildings on Post-earthquake is an important and urgent task of developing earthquake relief during earthquake emergency.
In USA, during earthquake emergency, safety assessment of buildings in post-earthquake is highly regarded. In 1994, after earthquake of Northridge of Los Angeles area, USA, American emergency transaction management and local emergency management department in time recognized three thousand professional technical personnel to assess safety of buildings on post-earthquake. According to assessment, inspection syndrome departed unified by government department is posted on buildings. The color of inspection syndrome is can be divided into green, red and yellow, in which green represents safe building, red represents unsafe building and yellow represents limit useful building. The whole work developed rapidly and regularly, and it represents work efficiency of specialized personnel.
In our country, safety assessment of building post-earthquake originates from the M7.0 LIJIANG earthquake in YUNAN on February 3, 1996. Later, safety assessment of building post-earthquake is developed in the M6.9 JASHI earthquake in XINJIANG on March 19, 1996 and the M6.4 west BAOTOU in NEIMENGGU on Friday

3, 1996. Because experts developing safety assessment of buildings on post-earthquake not only have solid engineering theory but also have plenty of post-earthquake work experience, it takes much time to nurture an excellent expert and it is impossible to do that. Finite expert number affects efficiency of safety assessment of buildings on post-earthquake, and is too few to meet the current demand of seismic people. Because earthquake is little probability event, at the same time, our country cannot spend much money to nurture thousands of special technology personnel as same as America according to our economic condition. However, China is one of the most serious countries that suffering from earthquakes, such as earthquake activity is frequent, earthquake strength is large, earthquake disaster is serious. Based on this contradiction, it has important realistic meanings to build a practical safety assessment of buildings on post-earthquake, which makes assessment persons carrying safety assessment of buildings on post-earthquake and civil engineering technician dispatched by local government share expert knowledge and experience in the domain, and master effective method of safety assessment of buildings on post-earthquake in short time to develop assessment efficiency and assessment result reliability.

Safety Assessment of Buildings on Post-earthquake, which is different from seismic assessment of buildings and dangerous buildings based to fortification intensity in pre-earthquake or after earthquake, needs very strong timeliness, so it is impracticable to inspect and investigate carefully buildings and to survey and check accurately structure. Thus, subjective qualitative fast assessment method based on expert experience is used in prior post-earthquakes. According to some destruction of buildings after earthquake, experts assess earthquake damage, and judge synthetically safety of seismic buildings based on seismic action, use of building, primary seismic fortification and some other factors, such as site, foundation, effect of adjacent earthquake damage and so on. Expert experience has a shortcoming, which is that the difference of expert knowledge background, work experience and cognition maybe lead to the difference of assessment results.

Based on above analysis, it is important how to find an assessment model that not only fully uses comprehensive experience of expert but also makes assessment results accurate and reasonable. In this paper, author, who is mainly complier of <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001), transformed creatively prior safety assessment only by qualitative to quantitative and developed new method based on mathematic model according to seismic experience of prior earthquakes and practice of safety assessment of buildings on post-earthquake. Plenty of examples prove that the method can safely assess to monomer structure conveniently, fast and effectively.

1. LEVEL RELATION OF SAFETY ASSESSMENT ON POST-EARTHQUAKE

Safety assessment of buildings on seismic site is appraised safely to mean during the emergency after stronger earthquake took place, through checking seismic buildings state and original anti-seismic ability of buildings, distinguishing and evaluating. security under expect earthquake effect.

Safety assessment of seismic buildings should be judge synthetically according to earthquake function, applying character of buildings, seismic loss status and primary anti-seismic fortification level and the field, foundation and adjoining the influence of the earthquake. Then, according to different influence factors to safety assessment of buildings that influences the difference of ways, the level relation model of every influence factor is established. So, according to the national standard <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001) [2], Combining safety assessment of buildings on post-earthquake ripe technology at present and use experience that expert appraise for reference, and leveling every influence factor of safety assessment of buildings on post-earthquake, a set of practical security levels of safety assessment of buildings on post-earthquake c have been established.

The security of buildings on the post-earthquake is determined by the environmental impact, expecting earthquake function, seismic loss status these three factors playing a controlling role of state of the building. Among them the influence of any one has exceeded the regulation of the national standard <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001), can judge for the unsafe building.

(1) Environmental impact: mean the field, foundation and adjoined seismic building of assessment building to the impact on degree of safety. Around the safety building, should accord with the following requirements:

a) The field is steady, massif does not collapse, come down, collapse on the influence that bank,

liquefaction, flood etc, threaten the security of building;

b) Hold the soil layer stability of strength in the foundation, there is no influence causing the upper structure to be damaged of slipping to move, not subside, bear the weight of strength and drop evenly etc.;

c) Seismic loss of adjoining building will not jeopardize the security of appraising the building.

When the above does not meet requirements at all, the house can be judged to be not available temporarily, judging flow as shown in Fig. 1.

(2) The expect earthquake function: Mean that estimates the earthquake function about to suffer again may shake the building in advance according to the analysis of earthquake situations. It includes:

a) Influential intensity than send earthquake little earthquake function already, abbreviate as little to shake.

b) The influential intensity, with sending the earthquake function with roughly equal or heavier earthquake after shaking, abbreviated as and shaken greatly.

The size of expected earthquake function judged earthquake trend after shaking according to the accident rescue command of on-the-spot anti-detonation. Seismic building can, make safety assessment according to earthquake function for being little or heavy to shake. Generally speaking, safety assessment can go on in accordance with a kind of earthquake function, when two kinds of earthquake situations analyze the opinion, and can be in accordance with influencing stronger earthquake function to go on. According with expected earthquake function that is the seismic building of heavy safety assessment requirement that shakes, it is the safe building too in the little earthquake function that shakes. When seismic building determine need, fortification intensity of seismic fortification building original design or seismic assessment can check through the inspection current situation, and according to checking the result is adopted. The buildings which provided fortification against earthquakes can judge the corresponding fortification intensity that the original building reaches anti-detonation in the earthquake before shaking and appraises in the standard live. Synthesizing the above information can expect to the house the influence degree on earthquake function is judged, the procedure is as shown in Fig. 2.

(3) Seismic status: Mean the structure of the house is shaken and produced the state damaged. Only when environmental impact and expected earthquake influences two major factors meet the standardizing requirement, the model of building seismic loss status is just carried on. Because of most situations, environmental influence factor and expected earthquake influence factors all meet the requirement of standardizing, seismic influence at this moment becomes the real control condition, often assessment at the scene, seismic status must carried on detailed appraisal. To a building, it is numerous to seismic influence factor, as to different structural types, its influence factor is not the same, and the influence degree of different influence factors is different. So this text regards it as the focal point, the quantization treatment to that various influence factors and sub factors have suitable for calculation at first, and have proposed being suitable for the calculation model of safety assessment on post-earthquake. Aiming at through the quantization evaluation index of the different positions of building - - seismic loss evaluation coefficient, the whole seismic coefficient of building is went out, and can judge the security of building structure.

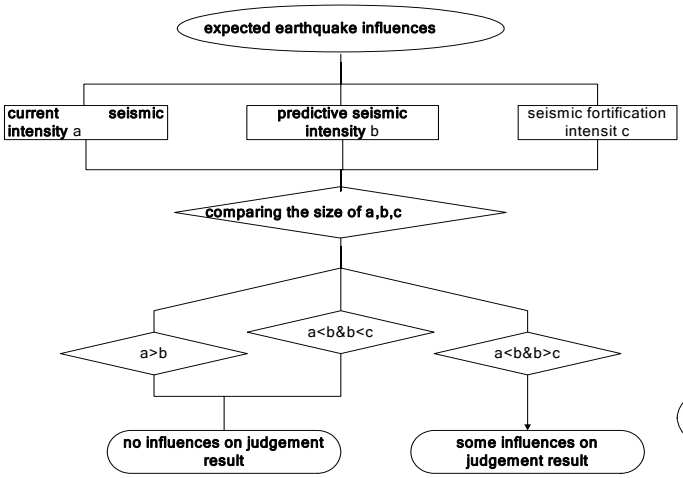

Fig.1 Expect earthquake affect

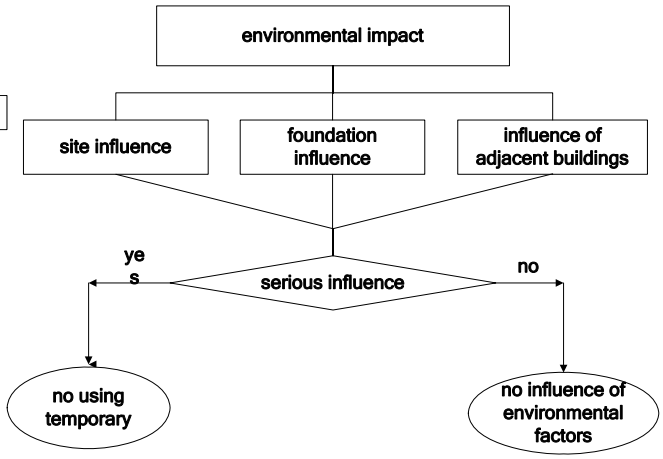

Fig.2 Environment impact

2.CALCULATION METHOD OF EARTHQUAKE DAMAGE INDEX

2.1 Calculate the procedure

As building assessed satisfied with expected earthquake function and the environmental impact, it can go on the calculation of seismic status. In this text, exactly based on time and effective of post-earthquake work, the new, convenience, reliable method suitable for building seismic assessment is put forward, the basic step is as follows:

(1) As shown in Fig. 3, according to the national standard at first <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001) Classify the structure of the house, and find out the seismic influence factor and sub factor of the different kinds of houses.

(2) Based on the national standard <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001), building seismic sub factor go on quantize treatment, and according to each seismic position to seismic influence different degree of whole, it offered every weight value with different position.

(3) Set up mathematical model, utilizing the quantization index of building influence sub factor, shake and decrease, that is to say, seismic evaluation coefficient calculated seismic index of every position of structure.

(4) Carry on the weighting to seismic index of every position, and get the whole seismic index of building, and then know the real seismic index of the structure of the house. Calculate specifically the procedure is shown in Fig. 4.

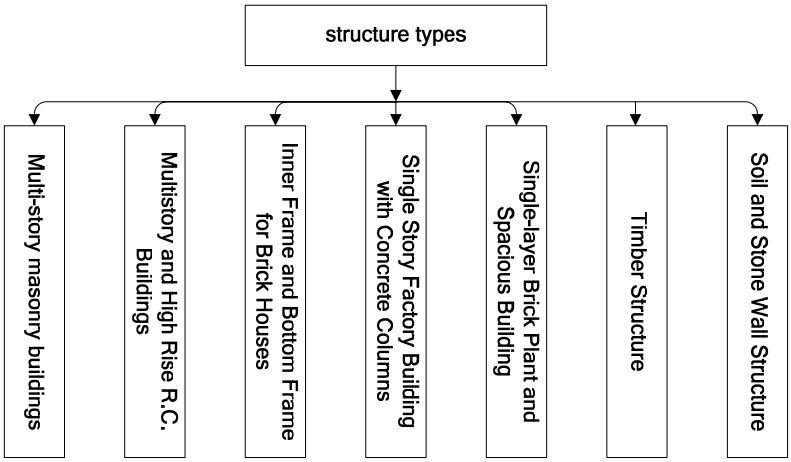

Fig.3 Structure types

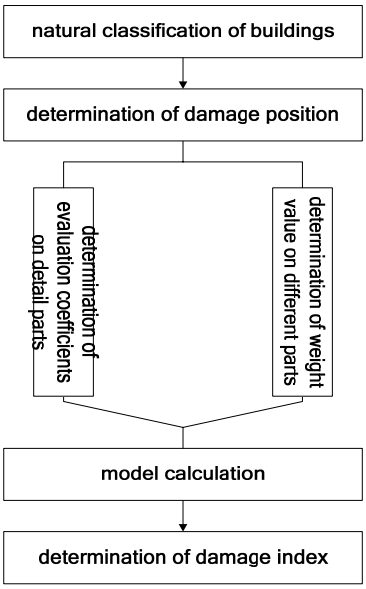

Fig.4 Calculation process of earthquake damage

2.2 Determination of seismic loss evaluation coefficient

Before carrying on comprehensive appraisal, appraise target clearly at first, and through investigation and relevance analyze, set up science reasonable comprehensive evaluation index system. A great deal of variable influencing the safety assessment of building, in order to reach overall examination and comprehensive appraisal, need using considerable, controllability of the index as judging the assessment criteria[3]. Primary step of multi-objective decision is to carry on goal analysis. The security qualification of the on-the-spot house is used as the total goal, after the total goal is confirmed, decompose thinning according to the important intensity, and set up the sub goals that can be divided one more layer of under the sub goals, then the lowest floor is seismic status of detail of the house, the establishment of all indexes is based of the national standard <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001), which have just carried on some modifications and increased to the norm partly.

Now, the method that is appraised to the multifactor complicated system is numerous, mainly have a fuzzy comprehensive evaluation assessment, Beye's method, gray cluster's method, etc. These methods have played a very good role in its one's own applicable fields, but there are a lot of defects. Because of the urgency of the rescue work of post-earthquake, it need to find a kind of building safety assessment method to meet theory needs of safety assessment of on-the-spot house which can also be conveniently, swiftly, high-efficiently appraise to the house safely. In the end, it is confirmed to use seismic evaluation coefficient method to quantize simulation detail seismic status of on-the-spot house.

Seismic evaluation coefficient method mean to discuss quantize treatment each detail of on-the-spot house seismic by several expert, and each kind for appraisal coefficient. Appraise coefficient signifies the severity degree of the detail of the house seismic damage, whose choosing value is a number between 0-1, and seismic intensity to increase from 0 to 1 sequentially. If appraise coefficient is 0, it proves this detail has not been seismic; Appraise coefficient is close to 1, and proves that the house seismic damage is more serious. What merits attention is, any fuzzy appraise method have sure subjectivity, the method herein is no exception. But the appraisal coefficient in this text passes the verification of a large number of examples after the expert make for the first time, then adjusted and get for several times, so it has already avoided maximum the error that the artificial subjective factor brings. Thus, this method is quite believable. In addition, this method is simple and practical, easy to be accepted, can make some non-professional personnel reach professional personnel's level through training briefly, and have avoided greatly trouble to bring because of the on-the-spot expert's not enough. The following is the appraisal of every detail of multi-layer masonry structure, as Fig. 6 - Fig. 7 shows.

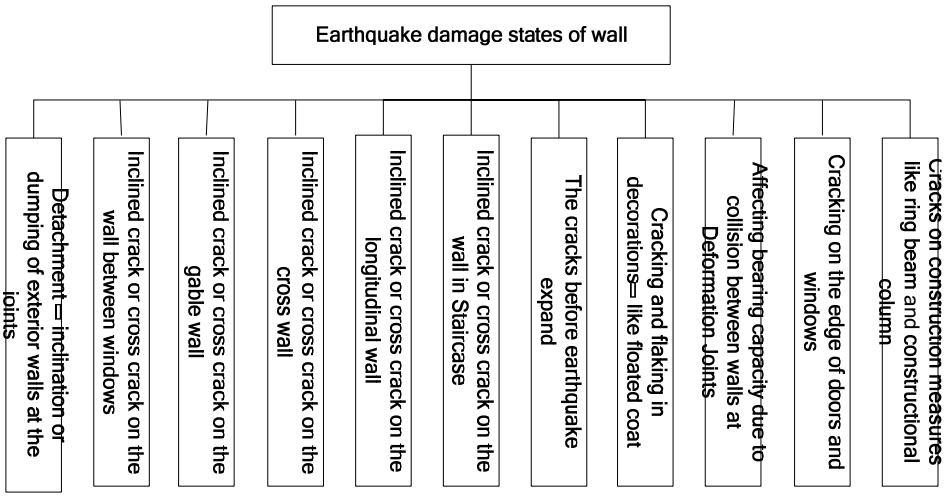

Fig.5 Earthquake damage of walls

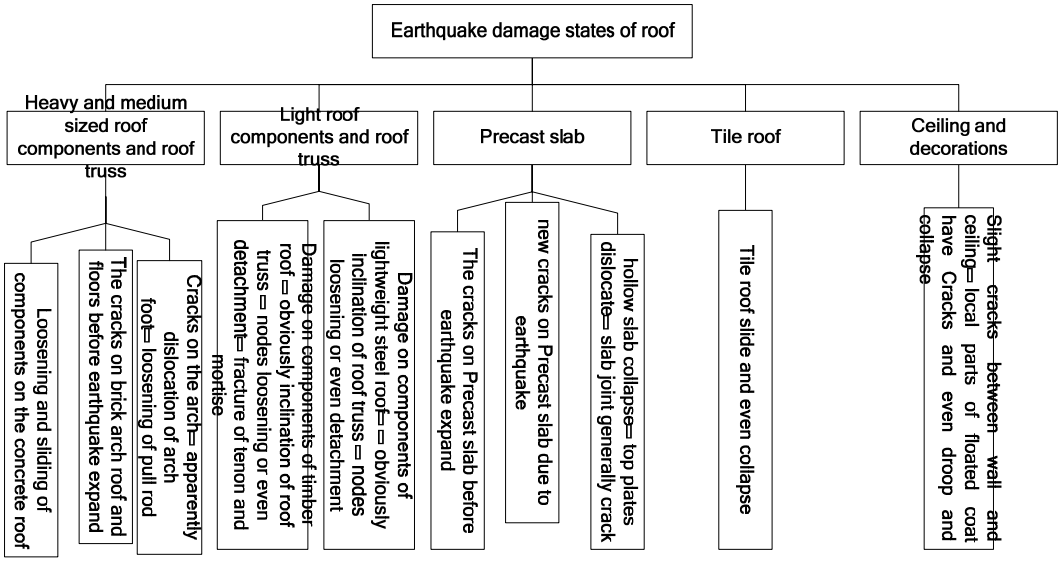

Fig.6 Earthquake damage of roofs

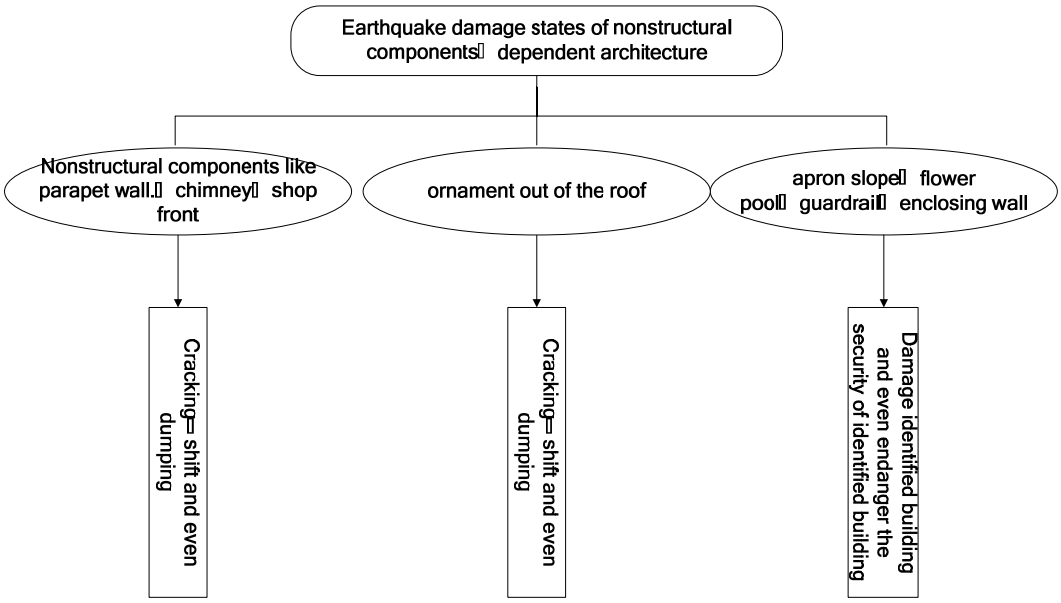

Fig.7 Earthquake damage of nonstructural components and attachment structure

2.3 Determination of Weight

In carrying on comprehensive appraisal to the great multi-factor system, the determination of the weight value of the index has been the important respect that workers have needed to study all the time, and main method includes weight value factor judge form law, expert ocular to judge law, analytic approach of level, Philippines of Del, etc.[4].

This literary grace is with A.L. that the American famous operations research family put forward. Level analytic approach (analytic hierarchy process, abbreviates as AHP) that Saaty puts forward confirmed and appraised the factor weight. AHP law makes thought process of expert quantitative and can treat the inconsistent situations of expert opinion through the test of consistency. It expects much to the operator's mathematical, and can get the better reliability. This method only takes the experts to apply the relative importance comparison between indexes, and then can calculate the weight adopting the approximation method of root, and do the test of consistency. This text only provides the weight value of multi-layer masonry structure as shown in Table 1.

Table 1 Weight values of multistory masonry structure

masonry structure	Bearing wall	Unbearable wall	Roof position	Subsidiary structure and essay of the non-structural thing
Weight value	0.4	0.2	0.3	0.1

2.4 Calculation model

Once confirm seismic evaluation coefficient in detail seismic damage of the house, we can gets earthquake damage index of every position of the house according to the calculation model of safety assessment of building, and then gets the weight value through the method preceding paragraphs 2.2, and can get the whole earthquake damage index of final house. The key to the whole course is to find a rational calculation model.

Draw the following conclusions through a large number of earthquake instance analyses and the expert's experience: Serious house detail seismic damage, detail seismic damage that has largest seismic evaluation coefficient plays control function to global security of house, and other relatively lighter details only plays a secondary role to whole security of house. According to this conclusion, we can find out a kind of mathematical model which accord with the above-mentioned conclusions to imitate, the mathematical model is as follows:

$$X_A = MAX\{X_1, X_2, \cdots, X_n\} \tag{1}$$

Here: X_i ——evaluation coefficient of the ith detail seismic status

X_A ——maximum of evaluation coefficient of detail seismic status

$$D_j = X_A + \beta \log_\alpha \left(\sum_{i=1, i \neq A}^{n} X_i + 1 \right) \tag{2}$$

Here: D_j ——earthquake damage index of the ith position

α , β ——correction coefficient(get through a large number of instance analyses and inverse calculation)

$$D_Z = \{D_1, D_2, \cdots, D_j, \cdots, D_m\} \{v_1, v_2, \cdots, v_j, \cdots, v_m\}^T \tag{3}$$

Here: v_j ——weight value of the jth position

D_Z ——whole seismic damage index of building

2.5 Division of seismic loss grade

Evaluating safety degree of the house for being more thinning, we consult academician Hu YuXian's division of seismic damage grade [5], and have introduced the concept of seismic damage grade. Seismic damage grade mean in advance to classify whole seismic intensity of house, including Intact, Damage slightly, Medium damage, Serious damage, Destroy five kinds. House seismic intensity depends on destruction situation of its component each, and evaluate seismic damage grade of the house according to destruction grade of component.[6] Then we have introduced the concept of earthquake damage index to describe quantitatively evaluation of seismic grade, as shown in Table 2. Earthquake damage index mean to carry on one quantization to above destroy grade, and quantitatively describe to the seismic damage intensity of the building structure. In this way we can compare the whole index of the house calculated with interval index, thus confirm the seismic damage intensity of the house.

Table 2 Earthquake damage index

Destruction grade	Intact	Damage slightly	Medium damage	Serious damage	Destroy
Upper and lower limits of the index	$0 \leq D_Z \leq 0.2$	$0.2 < D_Z \leq 0.4$	$0.4 < D_Z \leq 0.6$	$0.6 < D_Z \leq 0.8$	$D_Z > 0.8$

3. EXAMPLE ANALYSIS

Regard the earthquake and structural house of multi-layer masonry structure respectively of the earthquake of Jiujiang of Jiangxi of Tangshan as the example, carry on computational analysis. The basic information of the example is as shown in Table 3, evaluation coefficient value and result of calculation as shown in Table 4.

Table 3 Basic information of instances

Information	Example 1	Example 2
Earthquake name	Earthquake of Tangshan	Earthquake of Jiujiang of Jiangxi
Earthquake time	1976	2005
Building name	The 26th teaching building of middle school of Tangshan	Dormitory of center district of copper mine of mountain of the Ding 's of Jiujiang county
Earthquake damage describing	The vertical wall slopes towards the pivot in the corridor, the midsection is prominent, and the ground floor lays particular stress on. The window of vertical wall is sewn competently from head to foot outside; The horizontal wall shears to sew. The gable is sewn arcually sharp.	Struggle against, the prefabricated board emptily, the crackle of vertical wall of north. There are obvious cracks on the wall among the windows.
Earthquake damage state actually	Damage seriously	Medium damage

Table 4 Calculation result of earthquake damage index

Structural name	Structural position	Mainly earthquake damage description	Evaluation coefficient	Earthquake damage index of the house
The 26th teaching building of middle school of a Tangshan	Bearing wall	There is phenomenon of sloping seriously in a few bearing walls	0.7	0.712
		There are serious cracks at most bearing wall windows	0.8	
	Unbearable wall	There are serious cracks at most windows of unbearable wall	0.5	
		Most unbearable walls slope seriously, flash outside alikely	0.5	
Dormitory of center district of copper mine of mountain of the Ding 's of 2 Jiujiang counties	Bearing wall	There are serious cracks at a few bearing wall windows	0.7	0.588
	Unbearable wall	There are medium-sized cracks in most unbearable walls	0.3	
	System of roof truss	Fight emptily, prefabricated board	0.2	

The results of calculation of the above two are in conformity with reality, which has proved the feasibility of this method tentatively. Calculate a large number of house samples in numerous different earthquakes by the above-mentioned methods, the analysis result and tabulate in Table 5.

Table 5 Sample analysis

Origin of sample	Sample quantity	Accord with earthquake damage actually	not accord with earthquake damage actually	Error (%)
Earthquake of Tangshan	26	25	1	3.8
Earthquake of Jiujiang	22	22	0	0
Earthquake of Baotou	10	10	0	0
Total number of samples	58	57	1	1.7

We can know by Table 5, the error of the overall sample is smaller than 3, and can be accepted. Prove, the method of this text can carry on the accurate, reliable security qualification to the house structure of post-earthquake, and can well replace past expert's subjective appraisal method. Employ, it can solve in our country post-earthquake expert quantity enough difficult seriously at present.

4. CONCLUSION

Carrying on the research safety assessment in on-the-spot house, there should be a rational mathematical model at first. So, this text has been explained Quantization method based on the national standard emphatically <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001), level relation of safety assessment, and the foundations of mathematical model. Calculate the examples after choosing the earthquake samples in the earthquake of Jiujiang and Tangshan, and we can think the computing method herein is more accurate too, the result of calculation is more reliable, which can offer previous technology for further research work

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