Numerical Simulation Method for safety assessment of buildings on seismic site

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ABSTRACT：

Previous safety assessment of buildings on seismic site were completed by experiences of experts in earthquake emergency field through analysis on earthquake damage condition,such as crack of walls，damage of column、beam and roof ,the falling of ornament damage. Meanwhile, the buildings were also assessed by seismic actions, nature of using, capacity of seismic resistance, seismic site、foundation and damage of adjacent buildings and so on. The advantage of this method is that the buildings on seismic site can be assessed in short time and the assessment results are accurate and reliable, if there have enough experts. The disadvantage is that the number of experts in our country too little to meet the demand on seismic site. Meanwhile, the experts can not be transported.

Based on above reasons, a kind of method is needed, which not only uses expert knowledge and experience, but also meets timeliness, and avoids affecting assessment efficiency because of limit expert number. In the paper, safety assessment of building method is advanced, which is in the base of math model. Firstly, the aim and meaning of safety assessment is explained, in the same time, theory basis of numerical calculation method is introduced. Otherwise, through summarizing and concluding of prior a large of post-assessment experience, three kinds of functions is selected, which is geared for safety assessment. These functions use most computing examples to go in inversion analysis, so that, correctional parameter in the function and weighted value of each affected site. In the end, according to example calculation analysis of larges of buildings at many times earthquake, and comparing to real earthquake damage statues, the reliability of math model and calculation method is verified.

KEYWORD:

Post-Earthquake; Safety Assessment; Numerical Method; Weight

INTRODUCTION

The practice of numerous seismic casualties proves that during the earthquake emergency, safety assessment of shake buildings fast, timely, effectively on post-earthquake is an effective way of finding a room for the victim of the disaster properly. However, in our country, experts carrying on safety assessment of buildings on post-earthquake have already had sturdy project theory knowledge and abundant work experience of post-earthquake, it takes a long time to train outstanding expert, and rare at the same time. Expert's quantity has influenced the efficiency limitedly in the safety assessment of buildings on post-earthquake of our country, which can't far meet the current demand of the people of disaster area. Because the earthquake is a little probability incident, and from economic situation of our country at the same time, it is impossible to invest a large number of funds training thousands of professional and technical personnel to carry on this job like developed countries such as USA, etc., but our country is one of the most serious countries suffering earthquake disaster. Because of this kind of contradiction, the safety assessment system of buildings on post-earthquake is developed [4].

The safety assessment system of buildings on post-earthquake is base of the national standard <Post-earthquake field works the second part: Safety assessment of Buildings> (GB18208.2-2001), and adopts VB to program. The main characteristic of System is to make 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.

1.SAFETY ASSESSMENT ALGORITHMS

The key part of safety assessment system of buildings on post-earthquake is the safety assessment module of buildings, whose realization depends mainly on the choosing of the safety assessment algorithm. Safety assessment algorithm is put forward based on a large number of experts' experience and the scientific evidence with normal and rigorous national standard. Brief introduction of the safety assessment algorithm, comparison of algorithms and the choosing basis, method and result of systematic parameters in the algorithm are discussed in detail below.

1.1 Brief introduction of the safety assessment algorithm

Based on timeliness of safety assessment on post-earthquake and expert's experience, three kinds safety assessment algorithms in the safety assessment system of buildings on post-earthquake are proposed. The composition and meaning of each safety assessment algorithm are introduced in detail below.

Algorithm one:

This algorithm uses formulae 4-1 for kernel to make safety assessment module of buildings.

$$D_j = X_{\max} + \beta \times \log_\alpha \left(\sum_{i=1, i \neq \max}^{n} X_i + 1 \right) \qquad (4\text{-}1)$$

The meaning of every variable in formula 4-1:

D_j represents earthquake damage index of the jth position;

$$X_{\max} = MAX\{X_1, X_2, \cdots, X_n\}$$

Here：$X_i (i = 1, \cdots, n)$ represents evaluation coefficient of the ith detail seismic status(its choosing method is in detail introduced blow）; $X_{\max}$ represents maximum of n evaluation coefficient of detail seismic status.

α, β represents correction coefficient(get through a large number of instance analyses and inverse calculation, its choosing method is in detail introduced blow).

Then the earthquake damage index value of the whole building is got by calculating formulae 4-2.

$$D_z = \sum_{j=1}^{m} D_j \times w_j \qquad (4\text{-}2)$$

The meaning of every variable in formula 4-2:

D_z represents whole seismic damage index of building;

w_j represents weight value of the jth position(its choosing method is in detail introduced blow);

Algorithm two:

This algorithm uses formulae 4-3 for kernel to make safety assessment module of buildings.

$$D_j = X_{\max} + \beta \times (1 - \frac{\alpha}{1 + \sum_{i=1, i \neq \max}^{n} X_i}) \qquad (4\text{-}3)$$

The meaning of every variable in formula 4-3 is the same as in formula 4-1.

Then the earthquake damage index value of the whole building is got by calculating formulae 4-2.

Algorithm three:

This algorithm uses formulae 4-4 for kernel to make safety assessment module of buildings.

$$D_j = X_{\max} + \beta \times (1 - e^{-\sum_{i=1, i \neq \max}^{n} X_i}) \qquad (4\text{-}4)$$

The meaning of every variable in formula 4-4 is the same as in formula 4-1

Then the earthquake damage index value of the whole building is got by calculating formulae 4-5.

$$D_z = \{D_1, D_2, \cdots, D_m\}\{w_1, w_2, \cdots, w_m\}^T \qquad (4\text{-}5)$$

The meaning of every variable in formula 4-5:

D_z represents whole seismic damage index of building;

$D_j (j = 1, 2, \cdots, m)$ represents earthquake damage index of the jth position;

$w_j (j = 1, 2, \cdots, m)$ represents weight value of the jth position.

1.2 The comparison among safety assessment algorithms

The selection basis of three kind safety assessment algorithms is the same. The choice way of appraisal coefficient, the weight value of the position and systematic parameter are the same in the algorithm. The algorithmic flow is the same. But the systematic parameter value is different (The small matter is introduced in detail later). Kernel calculation formula in algorithm is different.

Introduce the procedure of the algorithm, every parameter choice way and result of choosing in the algorithm in detail by way of comparing below.

1.2.1 Safety assessment algorithmic flow

In design style of System Architecture, safety assessment algorithm was designed with the independent component style, and the interfaces of other modules were designed with the call/ return style. Safety assessment algorithm module is designed with the dataflow style. The procedure of safety assessment algorithm as follows:

1. Transfer two kinds of judgment before calling the safety assessment module:

First, if there has been seismic fortification, it need to judge the relation among seismic fortification intensity, predictive seismic intensity, current seismic intensity, from which confirm whether to need calling safety assessment module, judgment modes as shown in Fig. 1.

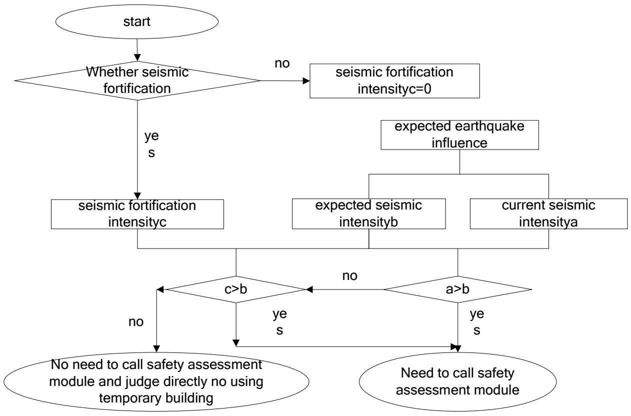

Fig. 1 The flow diagram of judgment modes one

Second, judge whether there are various environmental impact to determine whether to call safety assessment module or not, judgment modes as shown in Fig. 2.

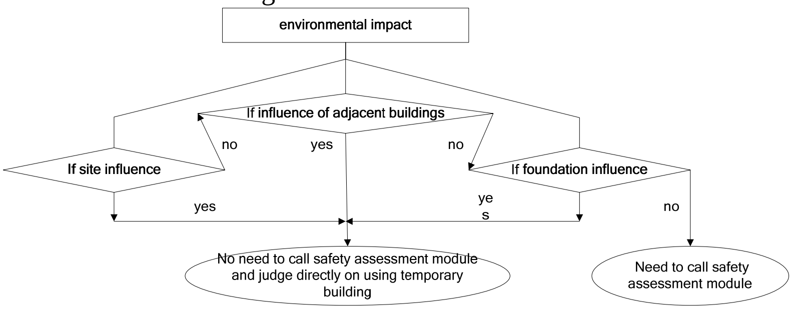

Fig. 2 The flow diagram of judgment modes two

2. According to the judgment result of step 1, if need to call safety assessment module further, use the module call function Call calculation (txtBuildNo.Text) to call the safety assessment module, which txtBuildNo.Text is the transmission parameter of call module.

3. The procedure of safety assessment module is:

First of all, connect database, depending on the parameter value transmitted, read the system database, and get the parameter value carrying on safety assessment.

Secondly, the classification of the building is classified on the basis of choice. Every kind structure building is calculated as follows:

1) Seismic status string resulting from database is analyzed according to detail total number in position;

2) Calculate the earthquake damage index value of each position separately according to the position categorized number of the building, the calculation procedure of each position is as follows:

a) Read database, and make the weight value of the position;

b) Analyze the string got in step 1 as the unit in six characters;

c) Read database, and make earthquake damage index of position detail;

d) Calculate the earthquake damage index of position according to the algorithm kernel calculation formula introduced by the small matter above.

3) Calculate whole seismic damage index of building according formula $D_z = \sum_{j=1}^{m} D_j \times w_j$.

Finally, transmit and get earthquake damage index, close database.
The concrete procedure is as shown in Fig. 3.

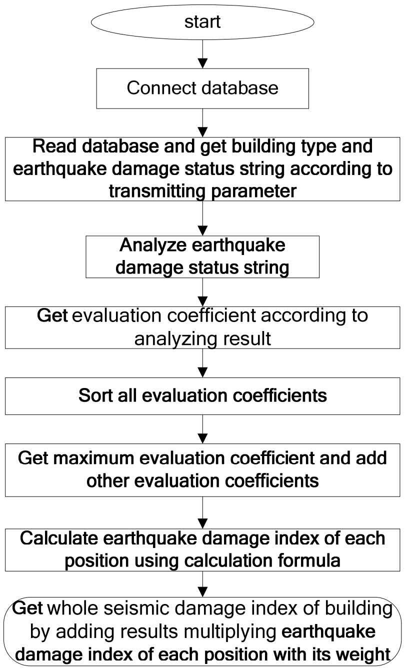

Fig. 3 Safety assessment algorithmic flow diagram

4. According earthquake damage index got in step 3, connect database more, read database, and get judgment standard parameter. According to conditions in destroy grade earthquake damage interval form, judge destroy grade of building.

5. Close database.

1.2.2 The choosing of weight value of the position

The choosing mode and choosing value of position weight in three algorithms basically are the same. The choice way and choice result of the position weight value are explained taking for the algorithm one case below.

In the past, appraisal factor weight is confirmed by adopting the analytic hierarchy process (abbreviated as AHP). Analytic hierarchy process (abbreviates as AHP) raised by the American famous operations researcher A. L .Saaty is a method confirming appraisal factor weight[1]. AHP method makes thought process of expert quantitative, and can deal with the inconsistent situations of expert opinions through consistency check. It expects much to the operator's mathematical, and can get the better reliability [2, 5]. This method only takes expert to provide to relative importance between indexes, and then calculate the weight adopting the root finding approximation and do consistency check [3]. While using AHP method to measure relatively important intensity of the index, relatively important Scale of nine points is introduced (Table 1), which form a judgment matrix A. In matrix A, each element a_{ij} represents comparison value of relatively important intensity between row factor X_i and column factor X_j. Taking multi-story masonry structure as an example, relative importance judgment of evaluation factor is made by some expert as shown in Table 2.

Table 1 evaluation proportion scale table

Ratio between Methyl index and Ethyl index	extremely important	Very important	important	Slightly important	equal	Slightly unimportant	unimportant	Very unimportant	Extremely unimportant
	9	7	5	3	1	1/3	1/5	1/7	1/9
	Fetch 8,6,4,2,1/2,1/4,1/6,1/8 as middle value of above evaluation value								

Table 2 judgment matrix A made by expert

Appraisal factor	Bearing wall（X_1）	Nonbearing wall（X_2）	Roof（X_3）	nonstructural components、dependent architecture（X_4）
Bearing wall（X_1）	1	7	4	8
Nonbearing wall（X_2）	1/7	1	1/5	2
Roof（X_3）	1/4	5	1	5
nonstructural components、dependent architecture（X_4）	1/8	1/2	1/5	1

Obviously, matrix A has $a_{ij} > 0$， $a_{ii} = 1$， $a_{ij} = 1/a_{ji}$. So, each judgment needs making only n (n +1)/2 times comparison.

Analytic hierarchy process has scientific foundations, but it is quite tedious to calculate. So, in order to calculate simply and conveniently, and according to the expertise, experience method is adopted to confirm the weight value of every position in algorithms.

According to this method, the weight value of multi-story masonry structure is provided as shown in Table 3.

Table 3 the weight value of multi-story masonry structure

masonry structure	Bearing wall	Nonbearing wall	Roof position	**nonstructural components、dependent architecture**
Weight value	0.4	0.2	0.3	0.1

1.2.3 The choosing of evaluation coefficient in position detail

The choosing way of evaluation coefficient in position detail in three kinds of algorithms is basically same.

Selection method of evaluation coefficient value of the position detail is explained taking for the algorithm one as the example below.

In the system, earthquake damage evaluation coefficient method is adopted to select evaluation coefficient of position detail. Earthquake damage evaluation coefficient method means that earthquake damage of each building detail is done quantitative disposal by discussing of several experts, and provides t each kind earthquake damage status for evaluation coefficient. Evaluation coefficient characterized the severity of house detail earthquake damage, whose choosing value is a number between 0-1, and the intensity of earthquake damage increases from 0 to 1 sequentially. If evaluation coefficient is 0, it proves this detail has not been earthquake damage; Evaluation coefficient is close to 1, it proves house earthquake damage more seriously. The appraisal coefficient in this text is got by a large number of example verification after the expert make for the first time and many times adjustment, which has already avoided the error that the artificial subjective factor brings maximum. So, this method is quite believable. In addition, this method is simple and practical, and easy to be accepted. It can make some nonprofessional personnel to reach professional personnel's level through training briefly, and has avoided greatly trouble because of the on-the-spot expert's not enough to bring. The choosing result of evaluation coefficient is not provided in space reason.

1.2.4 The choosing of revision coefficient

The choice of revision coefficient decided the reliability of numerical method applying to safety assessment of buildings on post-earthquake. If selecting different α and β, earthquake damage indexes calculated have major difference. The revision coefficient choice method is different in three kinds of algorithms. The revision parameter choice methods are basically the same in the last two kinds of algorithms, but the choice result range of revision coefficient is all different in three kinds of algorithms. The difference while choosing the revision parameter between three kinds of algorithms is introduced separately below.

The choice method of revision parameter in algorithm one is: according to on-the-spot earthquake experience, possible value range of α and β are estimated. In this paper, estimation range of α is 10-50， and estimation range of β is 0.1-1.0; nine kinds of hypothesis are made as following: 1）Each detail earthquake damage statuses of building assessed are all individual, slightly. 2) Each detail earthquake damage statuses of building assessed are all individual, middle. 3) Each detail earthquake damage statuses of building assessed are all individual, seriously. 4) Each detail earthquake damage statuses of building assessed are all minority, slightly. 5) Each detail earthquake damage statuses of building assessed are all minority, middle. 6) Each detail earthquake damage statuses of building assessed are all minority, seriously. 7) Each detail earthquake damage statuses of building assessed are all majority, slightly. 8) Each detail earthquake damage statuses of building assessed are all majority, middle. 9) Each detail earthquake damage statuses of building assessed are all majority, seriously. The principle of choosing revision coefficients is that earthquake damage index calculated by the first assumption should be slightly greater 0.1, the result of calculation of the 4th kind of assumption should be slightly greater than 0.4, the result of calculation of the 7th kind of assumption should be slightly greater than 0.6, the result of calculation of the 9th kind of assumption should be close to 0.9.

Revision coefficient choice methods are both to use the border value and exhaustive method in the last two kinds of algorithms. In this text, two border values that determine revision coefficient choice value together are selected according to earthquake damage status of position detail, two border values are: individual and slightly, majority and seriously.

The choice graphic presentation of revision parameter in the second algorithm is shown as Fig. 4, Fig. 5.

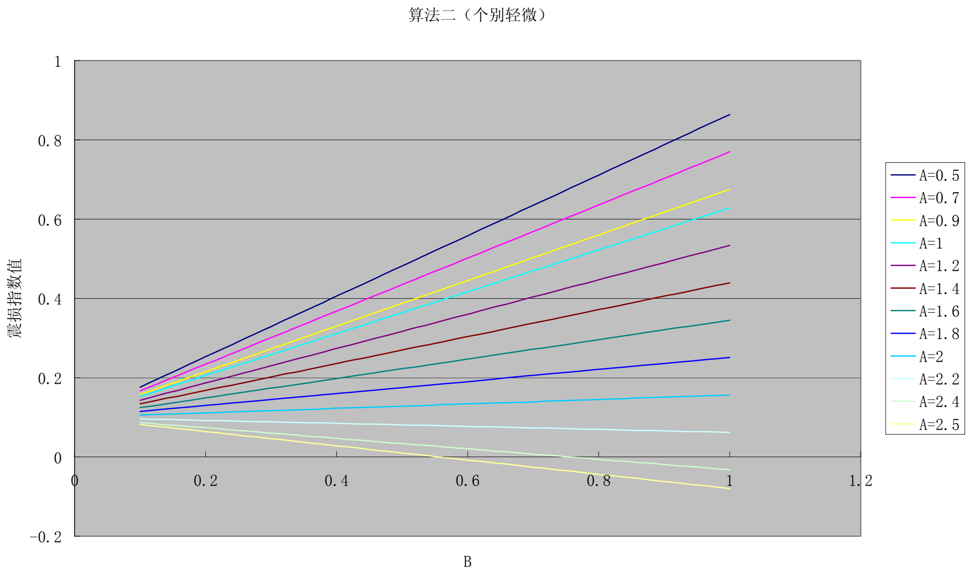

Fig.4 Figure when the position detail is all selected individual and slightly

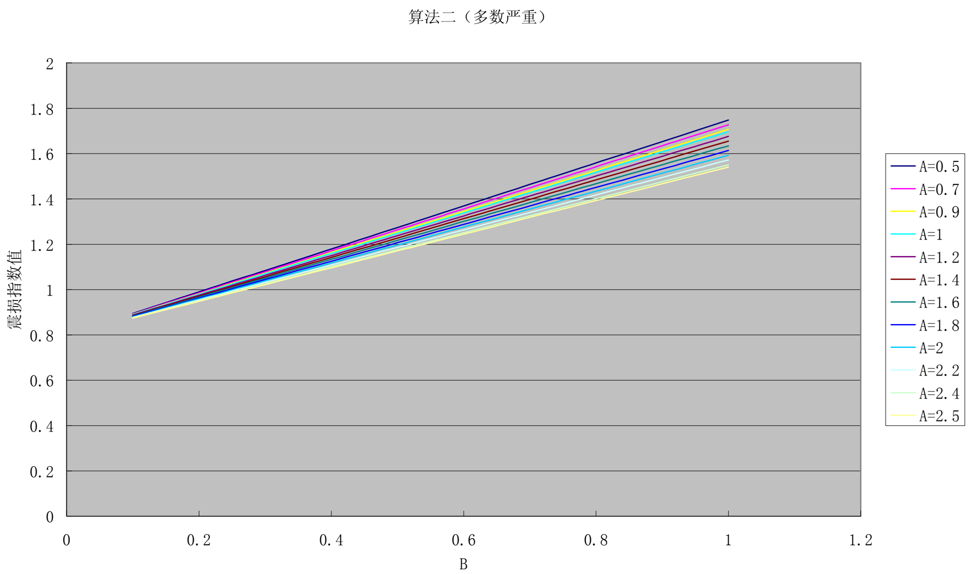

Fig.5 Figure when the position detail is all selected majority and seriously

Here, A，B represent separately revision parameter α 、β ,the above two graphics are got by a large number of data exhaustion. On the above graphic, choice range of revision coefficient in algorithm two are separately: α is 0.5-2.5，β is 0.1-1.0.

The choice graphic presentation of revision parameter in the third algorithm is shown as Fig. 6, Fig. 7.

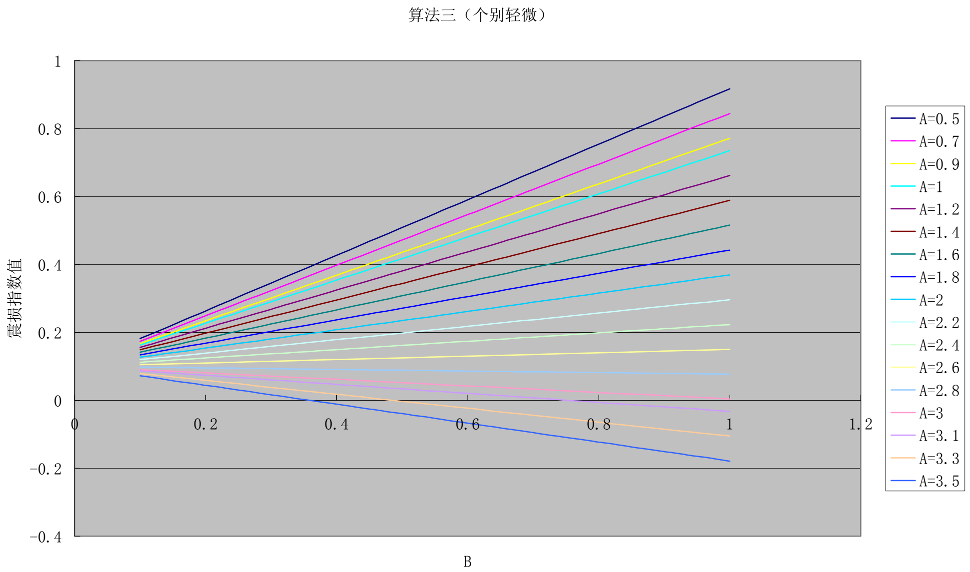

Fig.6 Figure when the position detail is all selected individual and slightly

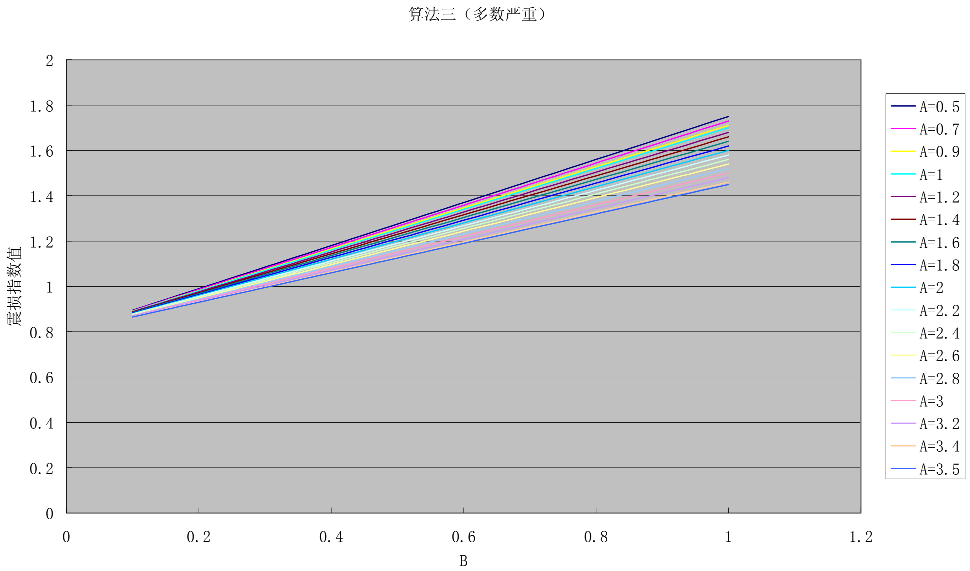

Fig.7 Figure when the position detail is all selected majority and seriously

Here, A，B represent separately revision parameter α 、 β ,the above two graphics are got by a large number of data exhaustion. On the above graphic, choice range of revision coefficient in algorithm two are separately: α is 0.5-3.5， β is 0.1-1.0.

2.ANALYSIS OF EXAMPLES

The selection of parameter is carried on first before analysis of example. Because of the space reason, the evaluation coefficient value of the position detail of the building no longer is explained in detail. The choice of weight only fetches the weight value of the multi-story masonry structure as shown in Table 4.

Table 4 the choosing of building position weight value

Structural type of building	Position of building	Weight value
multi-story masonry structure	Bearing wall	0.5
	nonbearing wall	0.2
	floor	0.2
	Non structural components	0.1

The choice value of revision coefficients （α , β）in three kinds of algorithms are separately:（20，0.4）;（0.9，0.2）;（0.9，0.2）.

Three kinds of algorithms are tested correctly taking multi-story masonry house as an example below. The test result is as shown in Table 5.

Table 5 TangShan earthquake analysis of example of multi-story masonry structure

Serial number	Algorithm one		Algorithm two		Algorithm three	
	The ones that calculate shake the grade of decreasing	Shake the index of decreasing	The ones that calculate shake the grade of decreasing	Shake the index of decreasing	The ones that calculate shake the grade of decreasing	Shake the index of decreasing
1	heavy	0.696	heavy	0.739	heavy	0.767
2	heavy	0.699	heavy	0.725	heavy	0.752
3	heavy	0.683	heavy	0.676	heavy	0.771
4	middle	0.433	middle	0.457	middle	0.463
5	slight	0.366	slight	0.212	slight	0.200
6	heavy	0.640	heavy	0.710	heavy	0.741
7	middle	0.593	middle	0.447	middle	0.463
8	slight	0.135	slight	0.158	slight	0.160
9	slight y	0.120	slight	0.143	slight	0.140
10	normal	0.060	normal	0.080	normal	0.080
11	slight y	0.120	slight	0.198	slight	0.130
12	middle	0.437	middle	0.477	middle	0.491
13	normal	0.068	normal	0.080	normal	0.080
14	middle	0.421	middle	0.457	middle	0.485
15	middle	0.431	middle	0.477	middle	0.504
16	middle	0.429	middle	0.457	middle	0.470
17	slight	0.168	slight	0.225	slight	0.160
18	slight	0.183	slight	0.237	slight	0.176
19	middle	0.421	middle	0.475	middle	0.463
20	middle	0.423	middle	0.430	middle	0.463
21	slight	0.130	slight	0.140	slight	0.150
22	normal	0.061	normal	0.090	normal	0.080
23	normal	0.088	slight	0.100	slight	0.100
24	heavy	0.717	heavy	0.725	heavy	0.721
25	middle	0.445	middle y	0.477	middle	0.491
26	middle	0.441	middle	0.488	middle y	0.478

From the above table, the safety assessment result that algorithm 2 and algorithm 3 test is comparatively greater, and the safety assessment result that algorithm 1 tests is comparatively smaller, So, the systematic revision parameter needs further choosing through a large number of examples, and is confirmed to make users satisfied. But say, the accuracy of three kinds of algorithms is all very high, and can reach more than 95%. This has met systematic accuracy demand.

3.SUMMARY

In this text, the composition and meaning of the safety assessment algorithm of buildings on post-earthquake is researched in detail, among which analyzes three kinds of different algorithms; The determination methods of various parameters in safety assessment algorithm is researched in detail; The procedure of the algorithm is recommend even, among which analyzed in detail the condition of calling safety assessment module; Finally, according to example analysis, parameter choice is introduced in detail, and analyzes the influence of parameter choice on assessment result, among which briefly analyzed the difference between three kinds of algorithms by examples.

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