Development of applied software of intelligence-aided system for safety assessment of buildings on seismic site

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ABSTRACT:

In this paper, the definition, usage and development and present status of the Aided Decision system of safety assessment of building at post-earthquake is introduced at first, and the effect, method and meaning of application at post-earthquake is explained. Moreover, the function, design analysis and hierarchical structure of the intelligent assisted system is introduced, and calculation model of this system, its theoretical basis and analysis of model algorithm is emphatically introduced. The function, business process and total design of the intelligent assisted system is delved into, and some functions such as system requirement, data collection and administration, modal calculation, result output, query, statistical analysis is discussed, and the interface design method and interface diagram of the intelligent assisted system is briefly introduced, in the same time, the further extension of system is advanced opinions.

KEY WORDS:
post-earthquake field；safety assessment；Aided Decision System

INTRODUCTION

Aided Decision System can use HCI to help decision-makers to make decisions through data, models and knowledge. It is based on computer science, management science, control theory, behavioral science, operations research and use computer technology, simulation technology and information technology to assist decision-makers to make the right decision. At the same time it can also provide analysis, model building, simulating the decision-making process and programmers of the environment for policy makers and call all kinds of information resources and analytical tools to help policy makers improve the level and quality of decision-making.

Today, the decision-making system has been used in almost all the project areas. The questions which were only solved by experiences of subjective judgment in the past can be deal with through scientific, quantitative, standardized and effective channels. In china, the experts in post-earthquake field not only have a solid theoretical knowledge, but also have rich experiences. At the same time, good experts are rare, for a very long time should be needed to nurture an outstanding expert. A limited number of experts in earthquake reduced our efficiency in the work of safety assessment of buildings at post-earthquake, which is far unable to meet demand in affected areas. China is one of the most serious countries suffered earthquake disaster, but we cannot put in a lot of training for thousands of professional and technical personnel to carry out the work like America according our economic situation. In view of this, it is very important to establish a practical intelligence-aided system for safety assessment of buildings on seismic site, which can make evaluators and general civil engineering and technical personnel dispatched by the local government share the knowledge and experience of experts, master the method of safety assessment of buildings in short time, and improve the efficiency and reliability of identification results.

The difference between the intelligence-aided system that this paper introduced and the previous ones reflected in the following three aspects.

First, not only the algorithm this system used, but also the method and processes that identify various system parameters are different from the previous ones. A few models can be selected according to different situations in post-earthquake field.

Secondly, the design and implementation of the interface in the system compared with the previous system has been improved greatly. The system has a stronger visual interface and human-computer interaction function.

Finally, the system employs a number of advanced technologies, such as multi-media technology, infrared technology and GIS technology.

1.SYSTEM FUNCTIONS AND DESIGN ANALYSIS

The aided Decision System in this paper was established in connection with the mature technology of safety assessment of buildings at the scene. The system absolutely comply with the national standards《work in post-earthquake field the second part: safety assessment of buildings》and can quickly assess the buildings in post-earthquake field.

1.1Function analysis

The intelligence-aided system for safety assessment of buildings based on the database, remote data exchange is the Windows Application Software System. Its aim is to support rapid decision-making in the post-earthquake field. The system's main functions are as follows:

1. Access database system is built-in, and it support many functions include data query, data maintenance, data modification and numerical - graphics conversion.
2. The system can first determine the extent of damage and then determine the availability of housing according to the assessment of buildings.
3. The system also support making and output of statistics proportion maps, output of identified house in the form of Excel list, output of identification results table and master mist in the form of Word, photo and video in post-earthquake field.
4. In addition, the system can locate position of identified house by using GIS systems. Specific function and structure as shown in Figure 1.

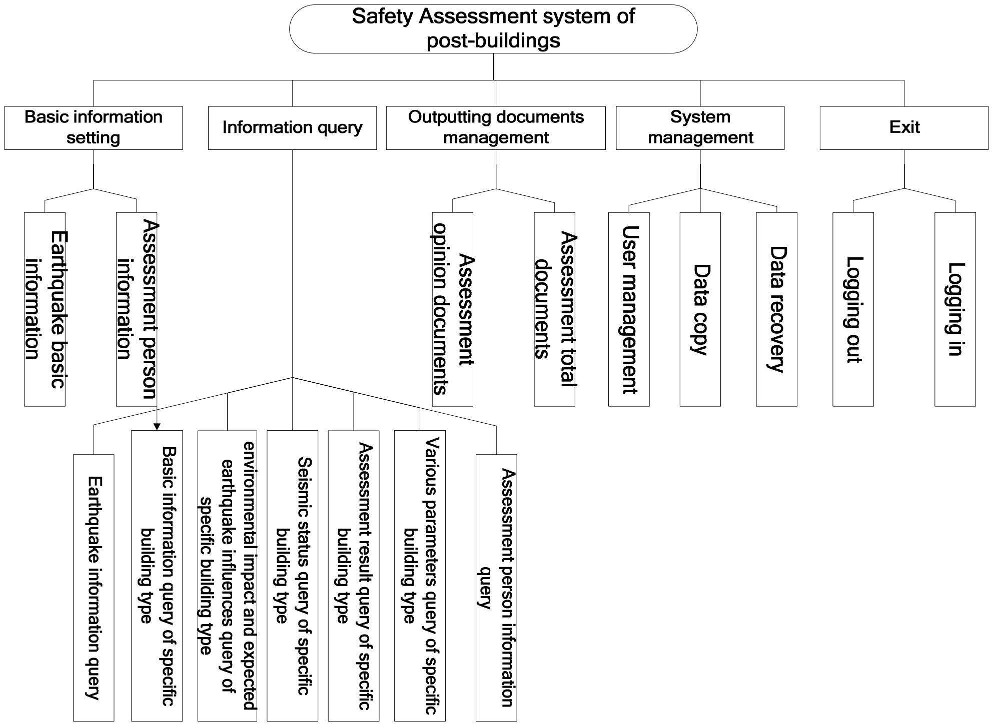

Fig.1 Function structure diagram of system

The system uses the menu of ebControlPanel in MDI to achieve the control and operation. The main menus includes: information systems, basic information, safety assessment of buildings, statistical analysis; information systems consist of building new database, opening database ,importing (merging) database, setting a password on, help and exit; basic information includes information of appraise personnel, basic information of earthquake; seven types of buildings can be assessed in the menu of safety assessment of buildings such as multi-story masonry building, multistoried and tall reinforced concrete buildings, inner-frame houses and the bottom frame for brick houses, reinforced concrete one-story mills, single-layer brick plant and spacious buildings, wood house, soil and stone wall buildings; statistical analysis includes the whole building points and Parameters amendment. In Addition, the system use controls skTabBtn in every relevant sub-forms to achieve preservation, update, delete of system data , picture and video importing and the links between modules.

1.2 Business Process

From the business process analysis, seismic safety of buildings, this system supports four business process:

（1）The system supports the establishment of evaluation models and storage models to model library by visualization of the way.

（2）The system supports data acquisition by possible ways(notebook, desktop, PDA) from a variety of sources

（3）The system supports users to select different computing model according to building styles and application.

（4）The system supports output of assessment results by various means, such as charts, tables, maps, Word documents.

Specific assessment process and functions as shown in Figure 2:

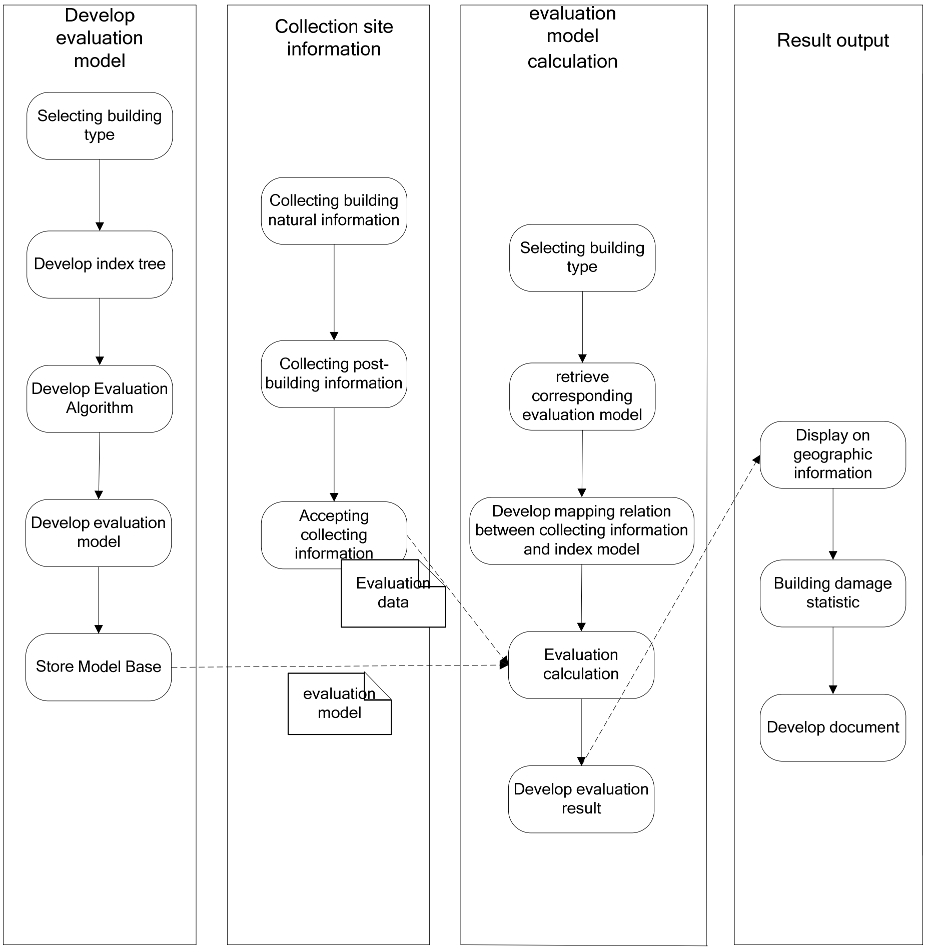

Fig.2 Business process of intelligence-aided system for safety assessment of buildings on seismic site

1.3 Overall design

As shown in Fig. 3, the aid decision system of safety assessment of buildings on post-earthquake is made up of many separate modules, mainly includes system login, seismic loss calculation, assessment personnel's basic information, earthquake basic information, database establishment, assessment information, statistical information, help etc. Control module is a brain of the whole system, and is responsible for coordinating and assigning the work among every module. Database module as the center of data store has important function too [4]

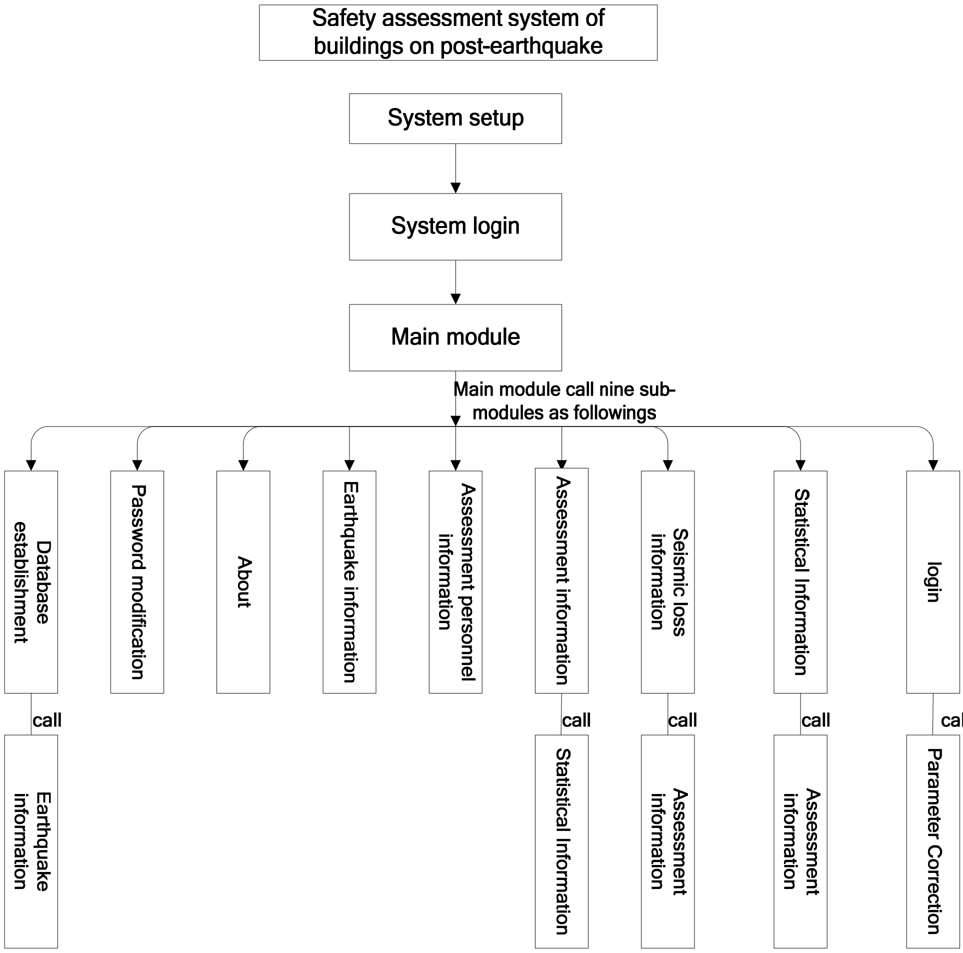

Fig.3 Logical function module drawing of safety assessment system

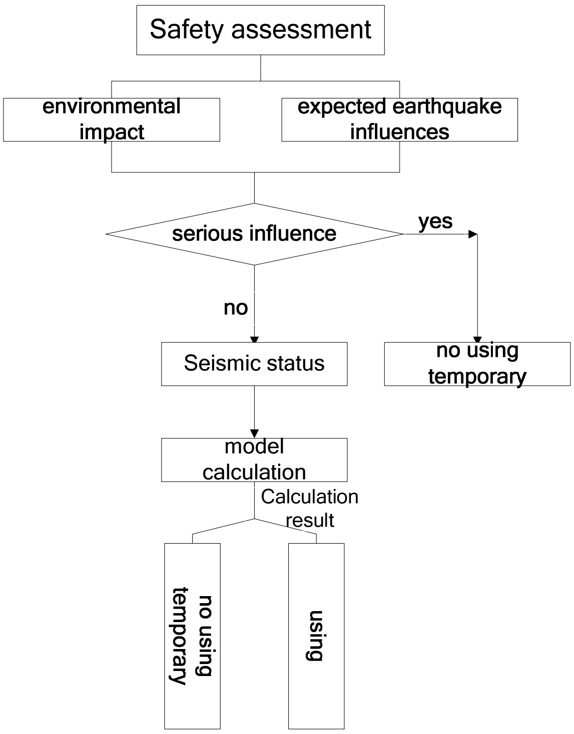

Fig.4 Diagram of system constitution

As shown in Fig. 4, the systematic procedure can roughly be divided into information inputting, analyzing and dealing with of earthquake damage, organizing and analyzing database, information outputting. The concrete procedure is as follows:

(1) Information inputting: First, the basic information of the earthquake, basic information of appraises personnel need to be collected. Collected information will be directly entered into the system and stored in the database which has been established in the document. At the same time, database files are updated.

(2) Analyzing and dealing with of earthquake damage:

Information of earthquake damage of building’s every position are stored in computer according to the norm (GB18208-2001) and a large amount of on-the-spot practical experience. (as a kind of optional interface) When the building is appraised, choose to the same selecting of damage state with this building, then analyze that calculates.

(3) Organizing and analyzing database: Information of assessed building can be stored in database files according to housing code which system automatic generate. The system supports the searching, updating, analyzing of database parameters.

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4) Information outputting: The system support user utilize many ways (like Chart, Excel, word) to export the result of assessing.

1.4 Operational mode

The system support over Win2000 operating system and the note-books or desktops in Win32 platform on the operational mode; at the same time the development of both notebooks and PDA hardware configuration will try to be considered. There are three kinds on the operational mode：One kind is that the information gathering, assessment and calculation are totally based on note-book; another kind is that PDA is used to gather information, and the send gathered information to the note-book which finishes assessing and calculating; the third kind is that information are totally carried on to gather , assess and calculate by PDA. The information totally based on note-book as shown in Fig. 5.

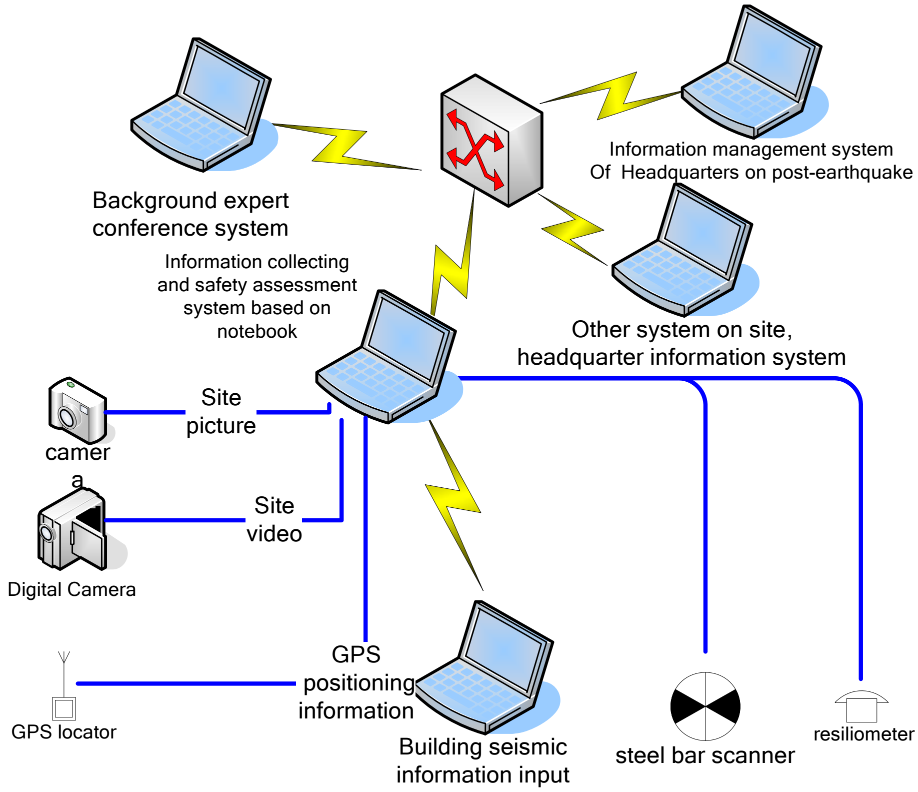

Fig.5 Information gathering and calculation of evaluation based on notebook computer

2.SYSTEMATIC HIERARCHICAL STRUCTURE AND MODEL BUILDING

2.1 Systematic hierarchical structure

Safety assessment of buildings should consider many factors, such as earthquake effecting, building's use of nature, the earthquake damage of buildings, original seismic resistance level, as well as the effects of sites, foundations and adjacent earthquake damage.Then, the model in which many related factors are considered will be established according to the experience that different factors affect assessment by different ways.

The system of safety assessment in post-earthquake field is divided into the peripheral environment on the whole, basic information gathering, internal processing, result output, as shown in Fig. 6.

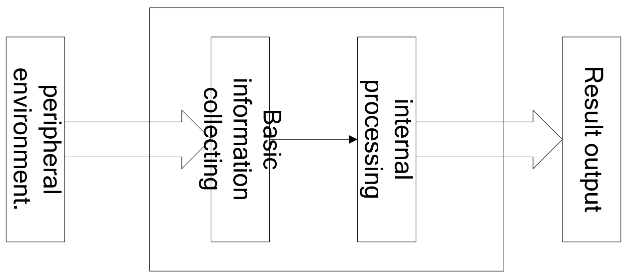

Fig.6 System hierarchical structure chart

2.2 The calculation procedure of models

The basic step is as follows:

(1) First, classify the structure of the house according to the national standard. And then find out the influence factors and sub-factors of the different kinds of houses. The influence factors of multi-story masonry buildings are as shown in Fig. 7.

(2) Based on code for safety assessment, deal with sub-factors by quantitative method. Endow differ power to different position according to the importance of different position.

(3) Utilize the quantization index of the sub factor to calculate the damage index of every position of structure by mathematical model.

(4)Get the whole damage index of decreasing of house by carrying on the weighting to every position, and then we can know the damage state of the structure. Calculation procedure is shown in Fig. 8.

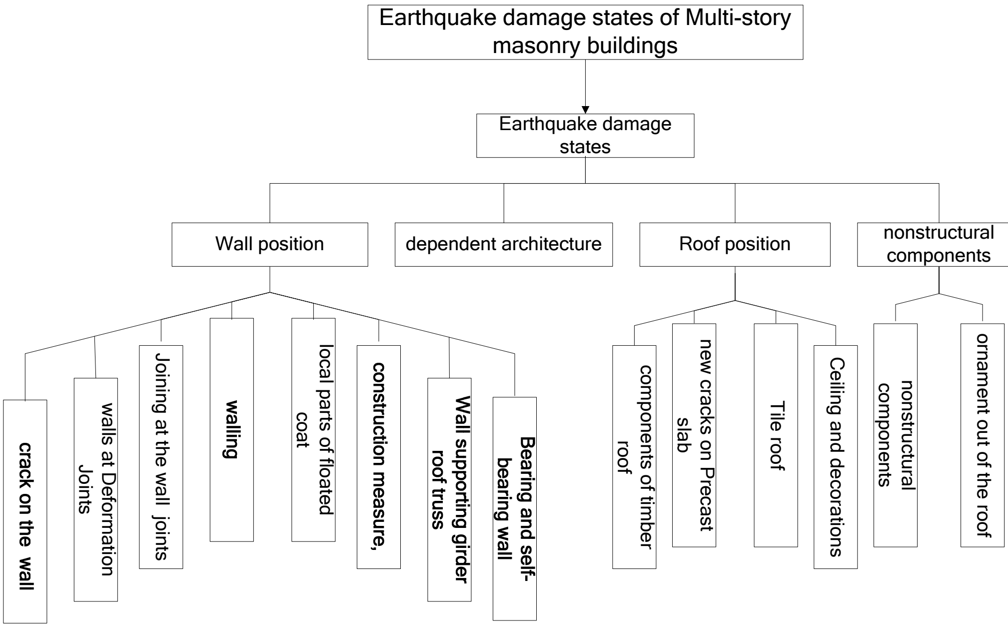

Fig.7 Effective factor of multistory masonry structure

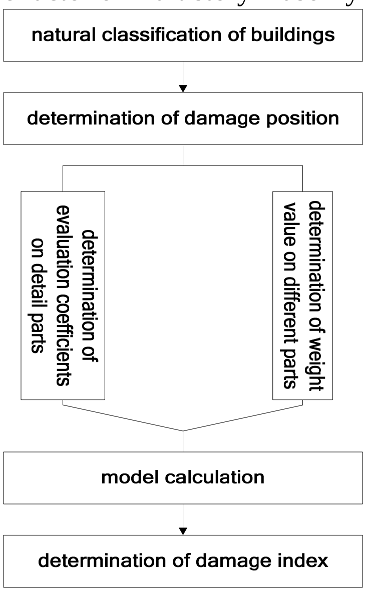

Fig.8 Calculation process of earthquake damage

2.3 The foundation of the model

Draw the following conclusions through a large number of earthquake instance analyses and the expert's experience: the position which is damaged most seriously control the safety degree of whole house. Other positions which are destroyed lightly contribute a little to the safety degree of houses .According to this principle , three reasonable numerical models are built through a large number of instance analyses. Three models are as follows:

Mode 1: $$\mathrm{D}_j = X_A + \beta \log_\alpha \Big(\sum_{i=1, i\neq A}^{n} X_i + 1 \Big) \qquad (1)$$

Mode 2: $$D_j = X_A + \beta \Big(1 - \frac{\alpha}{1 + \sum_{i=1, 1\neq A}^{n} X_i} \Big) \qquad (2)$$

Mode 3: $$D_j = X_A + \beta \Big(1 - \alpha e^{-\sum_{i=1, i\neq A}^{n} X_i} \Big) \qquad (3)$$

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

X_i—— evaluation coefficient of i position;

X_A—— the maximum value of evaluation coefficient among different position.

D_j—— damage index of j position.

α , β——correction coefficient.

$$\mathrm{D}_Z = \{D_1, D_2, \cdots, D_j, \cdots, D_m\}\{v_1, v_2, \cdots, v_j, \cdots, v_m\}^T \qquad (4)$$

v_j——weighting value of j position.

D_Z——damage index of whole house.

3.EXAMPLES

The following instance were analyzed by using model one. In this process, we fetch the systematic correction coefficient α =20, β =0.4.

Ten samples of multi-storey masonry structure were selected at random, as shown in Table 1; Table 2cshow the comparison between true earthquake result and the result of calculation.

Table 2 Earthquake damage examples

The name of building	Damage state	Damage degree
1.Epidemic diseases Ward House of 255 hospital，Tangshan	First and second layer walls severely cracking. The bottom layer wall has cross crack and seriously slided. Some walls between windows seriously expand and partial drop. The deformation of inner vertical walls is undulate.	heavy
2.26 middle school，Tangshan	The inner vertical walls of corridor inclined toward medial axis the deformation of middle piece is significantly while the deformation of the bottom piece is seriously the upper and lower of the window of outer vertical walls have level cracks the cross walls have shear cracks the tip of gable walls have arc shape cracks.	heavy
3.Meidaxi house of Tangshan	The south side indoor floor has a crack. The south vertical walls subside and incline outside.the cross and vertical walls has crack under the tension stress,the cross walls has incline cracks.the damage of top layer is more serious than the bottom.	middle

4. Residential of QiXin cement plant, Tangshan	The first and second layer walls between windows gable walls and cross walls at stairway have thin cracks,the first layer walls damage more seriously than the second layer walls.the roof slab slide slightly.a few chimneys has torsion deformation.	slight
5. Integrated building of reeducation unit,JiuJiang	Stairway has thin cracks.	normal
6. Dormitory of middle region in DingJiashan, JiuJiang	Prefabricated plate and north side of vertical walls have cracks.there are significantly cracks between windows.	middle
7. Office building of architectural instrument factory,TianJin	A few door and window angles have thin cracks.	normal
8. Housing of bureau of culture on DaGuNan road, TianJin	The wide wall surface of inner vertical walls have obviously inclines cracks .fist and second layer of outer vertical walls have thin cracks.	slight
9. Teaching building of HongQi Road primary school, TianJin	Half of inner vertical walls at bottom layer,lobby at first and second layer and cross wall at stairway have inclined cracks and cross cross cracls.the angles of doors and windows at three layer crack.the ceiling depart from the walls around.	middle
10. Teaching building of BeiLou primary school	The indoor ground have cracks.some walls crack slightly.the prefabrication at the Westside of second layer loose and have cracks.	normal

Table 3 Calculation result

Number	Final damage index	Calculated damage degree	Real damage degree
1	0.684	heavy	heavy
2	0.641	heavy	heavy
3	0.533	middle	middle
4	0.272	slight	slight
5	0.138	normal	normal
6	0.392	slight	middle
7	0.070	normal	normal
8	0.341	slight	slight
9	0.616	heavy	middle
10	0.167	normal	normal

Form above examples we can see that the accuracy of this algorithm reached 80 percent’s this export system can identify fast the structure of buildings at earthquake fields fast and accurately. in the future work of the earthquake field we can solve the problem that caused by lack of experts.

4.CONCLUSIONS

Aided Decision System for safety assessment of buildings on seismic site is a bold attempt that computer applied to the field of seismic, its success will greatly promote the development of China's housing security identified at the field of seismic. And the system design is based on the modular approach so that the subsystem or the increase of its functions is to increase the functional module, the system needn’t re-adjusted to ensure that the system has strong adaptability and scalability. In future, in order to further expand the system features, we can also join the earthquake damage prediction, the economic loss assessment module [5], and enrich the use of the system function. Various modules will be integrated in the same system, can also save a lot of unnecessary trouble, which allows the user to select modules based on the need to use.

REFERENCES:

[1]Tang AiPing, Tao Xiaxin, Xie LiLi, Wen RuiZhi. Study of aided-decision system for post-earthquake emergency response [J]. Earthquake engineering and engineering vibration, 2001, 5 (1): 145-151
[2]GB18208.2-2001. The norm of safely assessment of buildings.
[3]Wang Dongming. Study on safety assessment of buildings on post-earthquake field [D]. Institute of Engineering Mechanics, China Earthquake Administration . 2003.
[4]Sun BaiTao, Wang Dongming, Yang DeSheng .Development of applied software of intelligent-aided system for safety assessment of buildings on seismic site [J]. Earthquake engineering and engineering vibration, 2004, 6 (3): 152-157
[5]Wang XiaoQing, Ding Xiang. The manual of geographic information system of earthquake disaster loss evaluation in post-earthquake field [M].The centre of analysis and prediction , China Earthquake Administration. 2001.