ISSN : 0974 - 7435 Volume 10 Issue 14

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(14), 2014 [7870-7877]

Research on upgrading the collapse resistant capacity of building structures based on BIM

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ABSTRACT

For a long time, the aseismatic capacity of engineering structures has always been a major research direction of architecture. As is known to all, building collapse is one of the major earthquake devastating consequences. Damages of buildings generally reflect the degree of earthquake disaster. As a result, the aseismatic capacity of building structures, especially their capacity to prevent collapse, is of great importance to the overall earthquake defense system of the society. During the long term of research, some researchers have provided several excellent ideas. However, on account of lacking of the data summarization, a great many of studies have been stagnant. The ice is not broken until information technology represented by computers is widely used in architecture. On three major phases (design, construction and management) of building life cycle, Building Information Modeling (BIM) is of great importance to promote the data information exchange and sharing, accelerate decision speed, reduce the project cost and improve the production quality. On the basis of introducing BIM development, this paper elaborates the functions of BIM on the research on upgrading the collapse resistant capacity of building structures, hoping to promote the application of BIM on the research on the collapse resistant capacity of building structures.

KEYWORDS

Building structures; Seismic performance; BIM.

INTRODUCTION

Because of megaseism, people pay more attention to the architectural safety such as seismic performance. In industrial countries, the buildings lying in active earthquake zones are equipped with damped system, which prevents their collapse. While confronted with the same earthquake as happened in Haiti, these buildings would shake and twist. These aseismatic designs tested by practices make great contributions to the capacity of collapse resistant capacity of building structures. However, with the buildings getting higher, the architectural designs are becoming more complex. The present aseismatic designs cannot meet the demands of architectural designs.

For a long time, because of the limitation of design tools, designers have taken 2D graphs as the medium of sending messages and the means of presenting design ideas. 2D design presentation is gradually set as thinking pattern. The essence of 2D design is to transfer 3D objects into different fragments in plan and study them, then build complete judgment through the comprehensive thinking of brains. On the process of design, designers constantly switch the thinking ways between 3D imagery thinking and 2D abstract thinking, which not only limits the designers' imagination but also results the difficulty to eliminate design mistakes. To overcome the limitation of 2D presentation, designers present their ideas by means of 3D modeling.

Architecture is a group work, so Autodesk first proposed the concept of Building Information Modeling (BIM) in 2002. BIM changes the cooperative ways between partners participating in the project, leading a thorough revolution. 3D design of BIM not only contributes to better present the rank order set in regional earthquake resistance and damage prevention system, but also assists researchers to improve the research on upgrading the seismic capacity of the buildings and infrastructure, which helps people to construct the first line of earthquake resistance and damage prevention.

THE APPLICATION STATUS OF BIM IN THE WORLDWIDE ARCHITECTURE

International background

At present, there are two problems to be solved in the worldwide civil construction. One is that lacking of cooperation between production procedures results the inefficiency of production and severe waste of resources. The other is that constant repetitive work, especially the repeated revisions between the designs of buildings and structures, increases the production cost. The data of US National Institute of Standards and Technology present that there is about $15.8 billion loss annually (statistic data in 2004) because of the lack of cooperation, accounting for about 30% of fund waste of the $418 trillion total investment (statistic data in early 2008). The research also shows that civil construction consumes about 40% of global raw materials and 40% of energy (also consumes 65.12% of American electrical energy). About 40% of the emission of air pollutant comes from civil construction. Besides, 20% of the soil supply is applied in engineering construction project. Figure 1 is the comparison of the investment flow between the current international manufacturing and construction. It can be seen from it that the value added in manufacturing is 62% and accordingly results 26% of waste. On the contrary, the value of civil construction only adds 10%, but wastes 57% of fund.

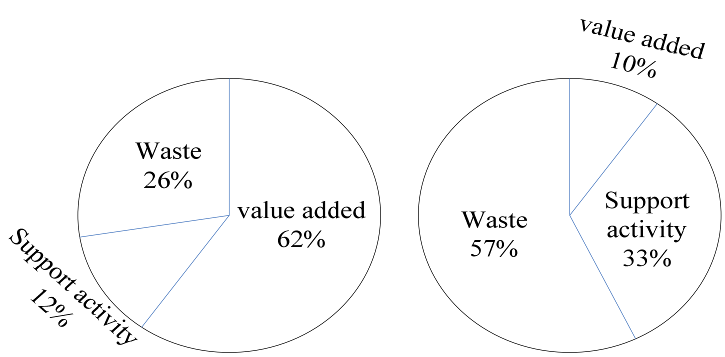

Figure 1 : The comparison of investment flow between manufacturing and construction

Domestic background

In recent years, China has been in the rapid development of urban construction. With the increasingly prominent problems of energy and environment, the developing model of civil construction must change from the traditional model with high consumption and high pollution to the high efficient developing model with resource conservation, favorable environment and people oriented. It has become the focus of engineering to solve the above problems, increase the efficiency of civil construction and adhere to the developing model of green buildings.

Currently, China has become one of the largest architectural markets in the world. According to the research, the total production of the worldwide architecture reached 416 trillion in 2006, one trillion of which belonged to East Asia (mainly referring to China). But the growth of civil construction mainly depends on investment and scale expansion. Therefore, while keeping the rapid speed of the architectural development, green building market which is beneficial to environment must be constructed. Green building advocates utilizing energy, soil resources, water resources and building materials reasonably and efficiently, influencing the environment in the minimum. BIM is emerging at the right moment when the global civil construction is in the critical period of sustainable development in the new century.

THE BREAKTHROUGH MADE BY BIM IN THE RESEARCH ON UPGRADING THE COLLAPSE RESISTANT CAPACITY OF BUILDING STRUCTURES

The status and difficulty of the research on upgrading the collapse resistant capacity of building structures

Based on the basic concepts of systems science, the functions of a complex system mainly depend on the integrality of this system. The core and goal of the system approach is the integrality of a system, which simply means that the integrality is not equal to the sum of parts. For building structural systems, on one hand, the functions of components depend on the system functions of the whole structure. If any component leaves the integral structure, it will lose the role which it plays in the structural system. On the other hand, components also affect the functions of the whole structural system. If any component leaves the integral structure, the lost functions of the integral structure will not be equal to the component’s functions in the structure, which could be more or less.

Each degree increased in the seismic fortification intensity, the construction cost will increase 10%. On the past designs involved in seismic grade, it is inevitable of repeated and complicated procedures, which results that business owners have to pay too many intangible cost. As mentioned above, each degree increased in the seismic fortification intensity, the construction cost will increase 10%. Currently, at the beginning of the architectural design and structural design, it has become a heated topic how to give a reasonable aseismatic design under the limited cost budgeting.

On the basis of BIM, the breakthrough of upgrading the collapse resistant capacity of building structures

Since 2004, the building information researches taking BIM as the center have emerged in international architecture. BIM is the digital expression to the architectural physics and functional characteristics, providing reliable and sharing information for the whole life cycle of architecture from the birth of architecture. Based on IFC, it is the summation of all kinds of information during the architectural life cycle. The basic premise of it is to provide cooperation between different participants (such as architects, structural engineers and constructors) on the process of civil construction, which is convenient for the participants to update and amend information data. As a result, BIM is the sharing digital information description model based on IFC and applied in cooperation.

Adopting parameterization, BIM describes the building unit, considering the architectural components like wall, window, roof beam and column as basic objectives (seen in Figure 2) rather than geometrical elements like point, line and plane in CAD. Moreover, it simulates all realistic features of the building unit by parameterization and carries on related data information description.

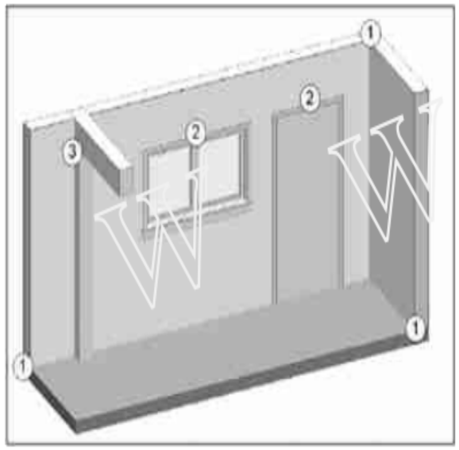

Figure 2 : The basic units of BIM: wall, window, roof beam and column

In BIM, building unit can simulate some non-geometric features as material information, cost information, equipment and so on except geometric shapes. BIM utilizes relevance to describe building unit. If architects or structural engineers amend the features of some unit component, building model will update the information automatically, and the update is relevant. Relevance not only increases the efficiency of design, but also copes with the information mistakes, missing and deficiencies between drawings. Throughout the retire life cycle phases of engineering project including design, construction, operation and management, BIM is a spiral intelligent design process.

There are four characteristics of BIM as following. First, it takes building unit as basic description object. Second, the generation, modification and maintenance of building information document are simple. Besides, relevant amending can avoid the differences automatically between surface, façade and profile on the process of 2D drawing design. Third, support the cooperation of different disciplines. Fourth, its visual representation and analysis can clearly analyze the possible problems during the design.

THE FUNCTIONS OF BIM IN THE RESEARCH ON UPGRADING THE COLLAPSE RESISTANT CAPACITY OF BUILDING STRUCTURES

The target of the research on upgrading the collapse resistant capacity of building structures

Under strong outside force (extreme disaster such as megaseism), components in the building will be damaged. Under this circumstance, the strong nonlinear characteristics of interaction between components will be noticed, so will the meaning and value of the integrity of the building structure system to the safety of the complete structure system. Figure 4 presents the integral action of the structure system under the function of the horizontal earthquake by the lateral load- displacement curve. B point in Figure 3 is the macroscopic yield point in the structure system. The integral stiffness of the structure system obviously changes before and after the yield point. D point in the figure is the critical point at the collapse of the structure system, called collapse point. There is no identical conclusion about the definition of collapse point up to now. This paper defines the collapse point according to the concept of the stability of structural integrity. It believes that if the whole structure still can bear its self-weight and recover elastic deformation to some degree after the effect of horizontal force, as DE curve showing, the building structure will not collapse. If the whole structure warps out of control at a short time under the function of self-weight, as DF curve showing, the structure will collapse. The critical point between two situations is the collapse point of the structure. The collapse resistant capacity of building structures is related to its emergency capacity. But there are similarities and differences between the emergency capacity concepts of structural system and components.

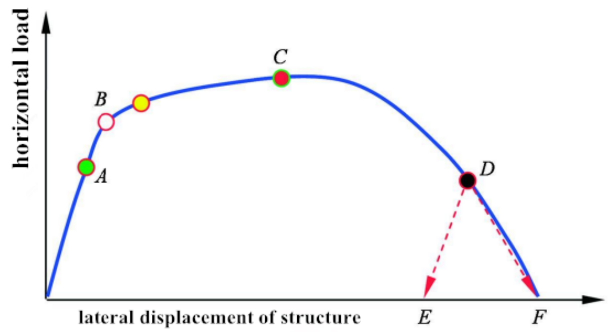

Figure 3 : Lateral force resisting of structure

The evolution method of the structure collapse vulnerability takes IM $_{\text{Threshold}}$ at the critical state of collapse as the measure index of collapse resistant capacity (CRC). The bigger IM $_{\text{Threshold}}$ is, the stronger CRC which the structure has. Because of the randomness of earthquakes, the different IM $_{\text{Threshold}}$ at the critical state of structure collapse in every seismic oscillation is analyzed by IDA. IM $_{\text{Threshold}}$ analyzed by IDA is taken as statistic sample of random variable CRC. It is estimated parametrically as log-normal distribution. And it will be concluded the probability distribution of CRC, as shown in Figure 4.

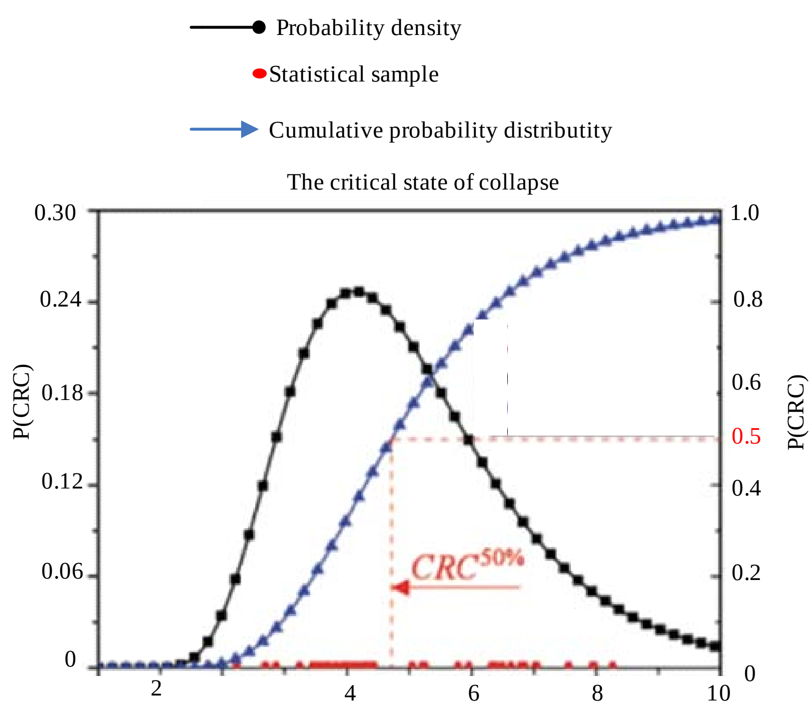

Figure 4 : probability of CRC

CRC of building structures shall prevent damaging from "small earthquakes"

At the design phase of "no damaging in small earthquakes", considering all possible random factors and structural emergency capacity at normal state, specification set a small earthquake point below yield point B to ensure the structure is not yielding, as A point shown in Figure 4. At this stage, the emergency capacity of structure is mainly ensured by the bearing emergency capacity of each structural component, which is equal to the bearing emergency capacity of the component having the smallest emergency capacity in number. This emergency capacity is called the basic bearing emergency capacity of the structure system, which is the distance between A point and B point in Figure 4. Its engineering meaning is to ensure the safety and suitability requirement of the structure system meeting the normal situation. The requirement is only ensured by the emergency capacity of the component. At present, all kinds of structural design specifications in China mainly aim to the emergency capacity, which means that the current structural design only resolves the component's security, but ignoring to define the security in the integral structure system. The security in integral structure system must consider the limitation of the whole system.

CRC of building structures shall prevent collapsing from megaseism

To prevent collapsing from megaseism, the reasonable point of "no collapsing in megaseism" must be chosen before the collapse point D as the ultimate state of the integral structure system, such as C point in Figure 4. In the current specifications in China, C point corresponds to the requirements of structure elastic-plastic story drift. For example, RC structure and high-rise steel structure requires the elastic-plastic story drift no more than 1/5. The collapse point D is objective reality, but C point is designed and estimated the limitation according to the man-made level of earthquake through considering all random elements and emergency capacity. In fact, from C point to D point, the structure may not collapse completely but damage to some degree.

The significant effect brought by BIM on the research on upgrading the collapse resistant capacity of building structures

The visualized technology of BIM

BIM has incomparable advantage in earthquake resistance and disaster prevention. Based on the most advanced 3D digital design solution, the concept constructs visualized digital building model, providing the scientific cooperative platform to simulate and analyze for architects and engineers. To achieve this, architects need to not only change design instruments from 2D to 3D, but also break through the shackle of simple architectural design at design stage. Integrated with cooperative design, green design and sustainable design, the complete engineering project achieves to realize energy saving, cost saving, pollution reduction and efficiency increase at design, construction and application stages. Up to now, this concept has become the model and milestone of the sustainable design in global engineering construction field. At the complete stage of design, construction, operation and maintenance, designers and architects are available to simulate and analyze the seismic performance. During the construction, they also can learn the quality of engineering material in time presented by visualized way. Thus, it is achieved to construct seismic buildings for people through sustainable design.

The advantages of BIM on the process of engineering design

Applied instruments based on BIM such as Autodesk Revit and AutoCAD Civil 3D at design stage, the most reasonable seismic planning will be concluded according to the local geological environment and architectural design plan. Meanwhile, considering the according structures, operation and materials, the possible problems in construction can be predicted at the beginning of design, saving the unnecessary construction cost of subsequent integration and demolition and improving the advantages of quality, design ability and cost saving. Besides, aiming to different geological environment demands in different areas, BIM software such as Autodesk Revit are equipped with plugins and paraphrase programs, which can contain the elements of seismic demands, seismic facilities and seismic plans at design stage.

The architectural miracle in seismic belt based on BIM----ASTRA Montenegro

ASTRA Montenegro lies in the Republic of Montenegro. Its appearance is like two filled sails designed by BIM software. It is like a castle in fairy tales, standing on the cliffs. Travelers can enjoy the outside sceneries through the French windows in the hotel. Depending on its unique appearance and predominant location, it has become one of the remarkable buildings in East Europe. But you can not imagine that such a unique hotel is built in high frequency earthquake belts.

The architectural feature of ASTRA Montenegro is the architectural design idea, which is that two sails form graceful architectural streamline, constructing a remarkable modern architecture. It is impossible to construct this architecture according to the traditional ideas. But by utilizing the simulation and optimizing of BIM, designers succeed to transfer the design concept to the feasible architectural plan. The internal construction of ASTRA Montenegro is very complicated. The design of every small area is different, which demands the design team to have enormous computing and data operation ability. It is impossible to complete the design without the simulation and data support of BIM.

Because ASTRA Montenegro lies in earthquake belt, the excellent construction quality and maximizing building floor area must be ensured in order to achieve the stability and security of the building. From the traditional architectural theory perspective, the above two demands are restricted, which cannot be ensured both ways. Relying on the specific data processing and simulated analysis of BIM, through the accurate simulated analysis, the structure can bear the same weight but its column can shrink, enlarging the unit using area. Shrinking the column can save cost for the business owners. It is on the basis of the advanced BIM design that the magnificent ASTRA Montenegro can be seen today.

CONCLUSION

It is vitally important for decreasing earthquake casualty to realize the buildings' collapse prevention in megaseism. Through the examples of a great many of buildings damaging and collapsing in Wenchuan megaseism, this paper discusses the design ideas to improve the collapse resistant capacity of the buildings. The main conclusions as follows:

(1)The complete seismic performance of the building structures firstly depends on the design of structure system, secondly on the earthquake resistant measures, finally on the specific seismic calculation design.

(2)The emergency capacity of the architectural structure system includes the basic emergency capacity, the overall emergency capacity and accident emergency capacity. The basic emergency capacity depends on the emergency capacity of components, which is relatively complete researched. The overall and accident emergency capacity belong to the capacity of integral structure system. There is not enough researches on this.

(3)The security of structure system under the predicable load effect can be ensured through the basic emergency capacity. Its disaster prevention capacity relies on the overall and accident emergency capacity of the structure system. The deficient accident emergency capacity is one of the main cause of the severe damages of building structures in Wenchuan megaseism.

(4) We shall pay attention to the engineering education of structure system. The current design of "emphasizing on the component but ignoring the structure" must be changed. Improve the ability of Chinese architectural structure designers. BIM is the digital presentation to the engineering project information and the direct application of digital technology in architecture. It represents the new direction of information technology applied in architecture.

BIM has profound influence on the design process, because it not only influences every step of the design process but also reforms the traditional design methods. BIM provides a design idea model closer to the real world. It adopts the method of simulating the real world to realize the visualized and intelligent design. In short, the application of BIM makes it possible for designers to solve the problems in the real world by using the theories in the real world.

REFERENCES

[1] Bai Liang, Yip Liaoyuan, He Jizheng, Fei Weishui, Huo Junrong; Langcang-The Disadvantages and Analysis of Multi Levels of Brick Building in Gengma Earthquake [J], Journal of Yunnan Institute of Technology, **5(3)**, 35-43 **(1989)**.

[2] Dian Lihua, Yin Lifeng, Xinjiang Bachu; The Characteristic and Analysis of Brick Buildings Damaged in

6.8 Magnitude Earthquake in Jiashi [J], Inland Earthquake, **21(3)**, 238-243 **(2007)**.
[3] Fei Minglun, Zhou Guangquan, Lu Yongkun; The Typical Earthquake Damaging Analysis of Modern Architectures in Ninger County in 2007 [J], Journal of Seismological Research, **30(4)**, 359-363 **(2007)**.
[4] Yip Lieping, Cheng Guangyu, Lu Xinzheng, Feng Peng; The Analysis of Robustness of Earthquake Resistant of Building Structures [J], Building Structure, **38(6)**, 11-15.
[5] Sun Liqun; The Failure Law and Characteristic of Earthquake Disaster of Different Engineering in Tangshan Megaseism [J], Architecture Technology Journal, **18(9)**, 23-27 **(1987)**.
[6] Code for Design of Concrete Structures (GB50010—2002) [S], Beijing : China Architecture & Building Press, **(2002)**.
[7] Building Standard Law [S], **(1981)**.