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Research on seismic design of high-rise building structures based on virtual reality technology

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ABSTRACT

In order to promote the structural design work more quickly, accurately and humane, this paper proposes the use of virtual reality technology to construct a virtual environment with an architectural model, discusses the research status in this regard and proposes basic modules based on virtual reality technology building structure design of the system to verify the feasibility of virtual reality technology in the field of architectural design. This paper analyzes and discusses the seismic analysis of existing high-rise buildings and some of the issues should pay attention to the structural design, in the end puts forward some views on the development of high-rise building structural seismic design.

KEYWORDS

Virtual reality technology; Seismic design; High-rise buildings; Structural design.

INTRODUCTION

High-rise building structural system is developing with the development and progress of science and technology. Since Chicago Home Insurance Company Building (Home Insurance Building) construction of a high-rise building in 1885 the world's first, has been 100 years of history. Not only gradually diversified high-rise buildings in the material and structural system, but also a substantial increase in height. After entering the 1990s, structural seismic analysis and design has been referred to the countries of architectural design schedule. In particular, China is in an earthquake-prone area, high-rise buildings earthquake-proof engineering design is an urgent task facing. As the basis for seismic design engineering, high-rise building seismic analysis is in a very important position[1].

Currently, the building structure design processes generally: architectural design staff based architectural design programs to build the force structure of the model and the model will force people to lose structural analysis and design software, mechanical analysis and structural design. Hence, throughout the design process, structural designers are faced abstract force model rather than the real building. In computer technology tends to be more humane today, structural design work is also bound to human trend.

Application of virtual reality technology may be able to be a completely new prospect in front of us. Through virtual reality technology, we will be able to offer the building to be constructed realistic virtual scenes, designers through the three-dimensional input device, you can immerse establish or modify the architecture in the virtual environment, and real-time view of stress components, deformation, and real-time optimization of the component.

VIRTUAL REALITY TECHNOLOGY

1965, Sutherland in the paper titled "Ultimate Display" first proposed, including interactive graphics, force feedback devices and virtual reality system voice prompts basic idea. Jaren plus nier in the early 1980s formally proposed the term "Virtual Reality".

Although it has been decades research on virtual reality, but until the 1990s, with the rapid development of computer performance, people just getting their attention.

The basic idea of virtual reality technology is the use of modern computer means to artificially create a virtual space where people can realize watching, listening, mobile and other interactive activities in this space, just like in real environments[2].

Virtual reality systems shall meet the following three basic elements: the ability to give users the feeling of three-dimensional virtual environment; able to give users the feeling of the first person, and has a free real-time any activity; user can manipulate and change in real time through a number of control devices user's virtual world. That is, virtual reality technology is a fundamental requirement for human-computer interaction. Virtual reality system has a better sense of immersion in hardware on the need to have a helmet mounted display, CAVE systems, data gloves, etc., in the software, including input processing, simulation engine, voice processing, virtual rendering of the world, other perceptual processing, etc.. Therefore, the virtual reality technology itself is a combination of modern technology, many technical fields related to graphics and image processing, real-time distributed systems, databases, stereo surround sound, tracking, etc., computer graphics, image processing, learning, pattern recognition, intelligent interface, artificial intelligence, sensors, networks and parallel processing, multi-disciplinary synthesis[3].

RESEARCH STATUS

Virtual reality in terms of domestic research focused on the areas of aircraft manufacturing, aerospace, military, medical, etc., but the results of the application in the field of structural engineering is still not formed there.

Virtual research environments abroad in structural design are:

1995, Iowa State University developed a virtual environment cantilever stress analysis and design of interactive systems, designers can modify various properties of the cantilever in a virtual environment, and enables real-time three-dimensional perspective view.

1998, the University of San Diego U.S. Murakami and Nishimura developed a virtual reality computer-aided design system truss structure system.

In 2000, excluded Clark Atlanta University in the United States has developed a virtual data environment tool - DVET. It may consist of existing finite element software, read out property components, analysis, and display it with a virtual environment.

2001, American Virginia State University, Institute of Mehdi began to study the cooperative building structure design and analysis software Visual-SAP, in order to strengthen the effectiveness of coordination architectural design, structural design and construction side.

THE STRUCTURAL DESIGN OF THE VIRTUAL ENVIRONMENT SYSTEM

Virtual reality technology development system based on architectural design, in addition to the structural design of the building should have a function and it should also be able to build a realistic, virtual, virtual environment interaction.

Therefore, the system should include three modules: the virtual environment module, a data analysis module, and the module structure, as shown in Figure 1.

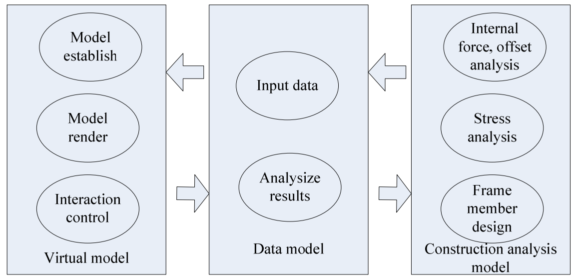

Figure 1 : Structural design system modules in virtual environment

Virtual environment model

The role of a virtual environment module is to build an interactive, immersive environment. Through user interaction, this module is responsible for establishing or modifying the model, and the model for real-time rendering.

To accelerate the development of virtual environment module, a suitable development platform is very important. Currently, the development platform Windows systems are mainly: SVE (Georgia Institute of Technology), Tuen Luo (Central University of Florida) and VR Juggler (Iowa State University). These have a device-independent development platform, providing support for a variety of virtual reality input and output devices. On these platforms to develop, just write the application part, without having to care about their connected devices, so that the development faster and easier.

In a virtual environment module, the true extent of the effect of the virtual building is very important. To achieve better authenticity, in addition to having good rendering, the system generates the rendered scene perspective change the user should follow to generate a new scene and timely. At the same time it generates a scene conversion rate should reach 10 per second or more, in order to have a smooth transition effects perspective. Obviously, the more complex scenes, the model more sophisticated, their computing power requirements are also higher. Therefore, the development of the module should be on the computing power and the extent of the problem and detailed rendering of the scene, can be balanced in order to achieve the best results.

Structure analysis module

Core structural analysis module is mainly composed by the finite element analysis program. But differ with other finite element analysis program, the module functions in addition to the calculation of internal forces and deformation of the members, should also have the ability to meet the specifications of design analysis and pass the results of the data to the virtual environment, allowing users to intuitively to see the structure of the analysis results, thereby to optimize the design[4].

Data module

Data transmission between the data module and the module is responsible for the structure of the virtual environment analysis module. First, the model property, it is passed to the analysis module, the analysis is completed, then the analysis result is transmitted to the virtual environment. Whether or analysis model property, the amount of data is very large. How to transfer data quickly and accurately is important. Typically, there are two methods: the text file, and memory transmission is passed.

Text file transfer mode that uses a text file transfer model data and results data. Because the general finite element software has a text file input and output functions, so you can use existing finite element software to replace the structural analysis module, so that the development effort is relatively small. But because the file transfer mode is hard disk data read and write operations, and its speed is slow, difficult to achieve virtual environments speed requirements.

Memory interactive data transfer mode that is fully completed in the computer memory. Because access is fast, fully meet the requirements of real-time virtual environment. However, using this mode, you must develop finite element analysis module itself. Therefore, the development of the workload is relatively large.

From the point of view of two transmission modes, because speed is an important factor affecting the performance of the virtual environment, the use of memory transfer mode will undoubtedly have a high applicability.

THE MAIN CONTENT OF TALL BUILDING SEISMIC ANALYSIS AND DESIGN

In rare earthquake, the seismic structure will partially into the plastic state, in order to meet the functional requirements of the structure under earthquake action, there is need to study elastic-plastic deformation capacity and computing structure. The current seismic design trends at home and abroad, is based on the performance requirements or deformation structure under seismic action at different levels of probability of design, structural elastic-plastic analysis will become a necessary part of the seismic design. However, due to the complexity of the structure of elastic-plastic analysis on how to calculate and how to set the specific requirements of the problem, national practices are different.

China's current seismic code (GB50021-2001) requires high-rise buildings in seismic computing mainly multi-earthquake action under (small earthquakes), according to theoretical calculations earthquake response spectrum, the internal forces and displacements calculated elastic approach and limit state design method with a member. For important buildings or when there are special requirements, when to use complementary computing history analysis and checking deformation under earthquake effect. This first encounter with a multi-earthquake structural design, then check the rare earthquake structural elastic-plastic deformation method, namely the so-called two-stage design methods. Meanwhile specification defines the structure of elastic-plastic analysis of the structure of elastic-plastic deformation in the rare case of earthquake under.

Structural elastic-plastic analysis can be divided into elastic-plastic dynamic analysis (time history analysis) and elastic-plastic static analysis (thrust computing) two categories.

Elastic-plastic dynamic analysis, using a simplified model of the structure of the rod and the layer model computing model, the seismic waves recorded direct input structure, consider the elastic-plastic properties of the structure, the establishment of dynamic equations based on the structure of elastic-plastic recovery characteristics, obtained directly by the gradual integration of seismic process displacement, velocity and acceleration schedule changes, which can describe the structure under earthquake action, force changes in the elastic and inelastic stages, as well as structural members gradually cracking, yield, damaged until the collapse of the entire process. Advantages of rod model calculations are that you can get the rod status change with the course of time, the reaction can also be obtained on each floor. But time-consuming and expensive, the results of data analysis and comparison of large and cumbersome, in foreign countries rarely use. Layer model calculations to get responses from the floor, for example, the shear layer, and the layer between floors lateral corner, the interlayer displacement ductility ratio, it is mainly from the macro that inter laminar deformation test structures under earthquake safety action. Data layer model calculations is relatively small, suitable for macro inspection, but also easy to calculate the number of seismic waves.

Both models use the rod or layer model nonlinear time history analysis, designers are required to have a high level of expertise, and greatly influenced by the results of seismic waves, there is no single answer, and sometimes it is difficult to judge. Scholars in some countries the mid-1990s have been proposed elastic-plastic static analysis method (Push-over Analysis) seismic analysis of the structure. This method is not new, but there are more advantages. Elastic-plastic static analysis using spatial collaborative model or three-dimensional planar structure model; each component (beams, columns, walls) are in accordance with its cross-sectional dimensions, reinforcement and materials to determine their elastic-plastic deformation relations; infliction of the structure floor level load distribution, progressively increasing; with the load gradually increased, some rod end yield, plastic hinges appear until the inter-layer plastic hinge enough or large enough angular displacement calculation ends. By elastic-plastic static analysis, we can understand the structure of the mutual relationship between internal forces and bearing capacity of each member as well as between each rod bearing capacity, check whether the strong column weak beam (or strong shear weak bending), and found weak parts of the design, but also get lateral deformation stages by different forces, given the bottom of the curve and lateral shear vertex inter laminar shear layer deformation curve and so on. The latter can be used as a layer between the floor shear layer displacement skeleton, it is time history analysis carried elastic layer model parameters necessary. As long as the structure of certain (size, reinforcement, materials), and the results are not affected by seismic waves, while the distribution of the initial load of the relevant floor level.

SOME OF THE PROBLEMS IN SEISMIC DESIGN OF HIGH-RISE BUILDINGS

Height problem

According to technical specification of the existing high-rise building concrete structures (JGJ3-2002) provides that in certain types of fortification and a certain structure, reinforced concrete high-rise building has a suitable height. This height is the next level of our current research building, economic development level and the level of construction technology, more secure, but also with the current phase of the civil standard system of coordination. But in fact, there are many high-rise buildings of concrete structure height exceed this limit, for example as shown in Table 1. For ultra-high building limit, caution should be taken science: one must be experts, the two have a model shaking table test. Under the force of the earthquake deformation ultra-destructive state will limit the building has undergone great changes. Because with increasing height of buildings, many factors will change in nature, that some parameters themselves beyond the appropriate scope of existing norms, such as safety indicators, ductility requirements, material properties, load value, mechanics model selection and so on.

Axial compression ratio and short column

Section is large, and the column longitudinal reinforcement in reinforced concrete structures in high-rise buildings, often in order to control the axis column compression ratio for the structure but leaving the column reinforcement. Even with high-strength concrete column section size can not be significantly reduced. Restrictions column axial compression ratio is to make the column in a major bias state, to prevent less than the yield and tensile reinforcement concrete was crushed, small plastic deformation column, the ductility of the structure of the poor. When the earthquake hit, and absorb the seismic energy dissipation less structure can easily be destroyed. However, if in the framework designed to ensure strong column weak beam, and the beam with good ductility, the pillars into the possibility that the yield is greatly reduced, then you can relax axial compression ratio. In addition, many high-rise buildings while the bottom layers of the column slenderness ratio of less than 4, but not necessarily a short column. Because is not a short column to determine the parameters of the column shear span ratio, only the shear span ratio W/V<2 column is short columns. Some experts and scholars put forward the current seismic code should be higher axial compression ratio. But even if we can adjust the axial compression ratio, the column cross-section can not due to a slight increase in axial compression ratio significantly reduced. Therefore, the use of reinforced concrete in high-rise building in the earthquake is reasonable is debatable.

Lower seismic intensity

Many experts and scholars suggested that the existing building structure can not meet the needs of design safety conditions that may be the lowest of access to the structural design of safety in the world, and advocates building structure design safety level should be greatly improved. In addition, not bad for a small earthquake, the earthquake can repair, earthquake seismic design principles that do not fall under the new situation also has to re-examine the need. China's current seismic standards is relatively low, the shock is equivalent to the prescribed design reference period (50 years) was 10% probability of exceed seismic intensity. It also provides the correspondence between seismic intensity of the basic design earthquake acceleration as were 0.10g (0.15g) and 0.20g (0.30g) 7 degrees and 8 degrees, where g is the acceleration due to gravity. Fortification standard low fundamental reason lies in consideration from the national financial and material resources limited conditions.

Seismic design of building structures in addition to lower fortification, the seismic safety of concrete structures prescribed calculation method and not as a foreign country, in a series of requirements to ensure the seismic ductility reinforcement ratio, axial compression ratio, and so far beams matching carrying capacity not as good as foreign stringent. With the growth of social wealth, the loss of structural failure caused by increasingly large proportion of the total cost structure coupled with the decline in investment, which was advocated structure under fortification should adopt a flexible design.

TRENDS IN HIGH-RISE BUILDINGS SEIMIC ANALYSIS AND DESIGN

Seismic design of structures based on offset

China's current seismic design of structures, based on carrying capacity based design. Namely: computing structures under small earthquakes internal forces, using linear elastic displacement method; checking the member section with a combination of internal forces, so that the structure has a certain carrying capacity; displacement limits that required the use stage, but also to protect the non-structural components ; ductility and energy dissipation capacity of the structure is obtained by constructing measures.

The mid-1990s, American scholar proposed based seismic design (Displacement-Based Design, referred DBD), which is a new method for seismic design concept. DBD is an important step in achieving seismic design features (Performance-Based Design, referred to as PBD) is based. It requires a quantitative analysis, so that the deformation capacity of the structure to meet the expected earthquake in the deformation requirements. The expected earthquake generally refers earthquake. So in addition to checking the bearing capacity of the outer member, to limit or control structure displacement angle displacement ductility ratio between the layers under earthquake action; according to component deformation and structural displacement relationship to determine the deformation value components; and strain to reach the size of a cross-sectional and strain distribution, to determine the structural requirements of members.

In order to achieve displacement-based seismic design, the first step needs to study a simple structure (such as frame and cantilever wall) relationship with a member deformed reinforcement to achieve the requirements according to the deformation component design; then study the entire structure after entering the elastic-plastic deformation and member deformation relationship. This requires that in addition to the calculation of small earthquakes stage, but also by the deformation under the effect of earthquake design, which is truly two-stage seismic design, which is the development trend of structural seismic design.

Dynamic response analysis of state space iteration method

The methods of modern control theory state space theory is applied to high-rise building structural dynamic response problems, according to the structural dynamics, displacement and speed of the introduction of state variables, derived equation of state, given the non-homogeneous solution of the equation of state, and then establishment of the state space iterative calculation format. Engineering examples are checking with high accuracy. Special power of multi-degree of freedom system multi-input, multi-output and other issues in response solutions is high efficiency.

Seismic reliability analysis of the material parameters of fuzzy randomness

The method starting from the overall performance of the structure, change the past, the study of seismic loads only consider the reliability of uncertainty while ignoring the many other uncertain factors, considering the variation of material parameters, seismic intensity and randomness impact on the reliability of seismic intensity level of the boundaries of randomness and fuzziness. The research results can be used in existing structures seismic reliability assessment can be used to guide structural seismic design based on reliability theory.

Promotion and application isolation and energy dissipation design

CONCLUSIONS

Structural design based on virtual reality technology will greatly accelerate progress not only designed to make the design more humane, more creative and in the current technically feasible. With the development of computer technology and the popularity of virtual reality input and output devices, virtual reality technology in the field of structural design will have a wider range of applications. Meanwhile, economic and security relations are important technology policy seismic design. From a long-term point of view, how seismic design of high-rise buildings of international departure can develop from the status quo and development trend of high-rise buildings to explore a practical and feasible two-step or three-step rational seismic analysis and design methods fortification should be a new direction for the development of high-rise buildings earthquake zone.

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