Seismic Response Analysis of Indoor Engineering Structures Based on Cloud Computing

Yuanjing Zhao[1], Wei Tang[2]

[1]Chongqing Vocationl Institute of Engineering, Chongqing 402260, China

[2]The 3th Engineering Co.,Ltd.of China Railway 12th Bureau Group, Taiyuan 030024

Keywords: Cloud computing, Indoor, Engineering structure, Earthquake, Response analysis

Abstract: In order to improve the computational efficiency of seismic response analysis of super-large engineering structures, a scheme of using cloud server to carry out numerical simulation of seismic response is proposed. Based on ten cent cloud and other cloud computing environments, this paper introduces the feasibility of cloud computing for structural seismic response analysis, and explains the construction of cloud computing environment. Open Sees and other software are used to analyse and compare the computing efficiency of different free degree and different size examples in cloud platform and local computing environment. Results the computing performance of the cloud platform is comparable to that of the local computing environment, and it can replace the local computing environment for seismic response analysis. Computing efficiency can be greatly improved by using cloud platform to process computing tasks in parallel. Conclusion cloud server has the characteristics of high computing efficiency, flexible setting and low cost in the numerical simulation of seismic response of engineering structures, and has a good development prospect.

1. Introduction

In recent years, earthquake disasters happen frequently, and the importance of earthquake engineering becomes more and more prominent. It is an important content of seismic engineering research to predict the seismic response of engineering structures by computer simulation. The development of computer technology makes it possible to construct fine models and carry out large-scale numerical calculation for structural seismic response analysis. However, due to the fact that the degree of freedom of the fine model can reach millions of orders of magnitude, and the whole process nonlinear simulation algorithm of catastrophic failure is very complex, the calculation amount is very large, the general performance of the computer is difficult to get the results in a short time. Therefore, how to improve the computational efficiency of structural seismic response analysis and break through the limitation of hardware and software capability is undoubtedly an urgent problem to be solved in seismic engineering. The rapid development of supercomputers provides a solution to this problem. The Integrated Simulation (IES) project at the University of Tokyo USES a supercomputer, known as kayo, to do large-scale engineering numerical calculations. The supercomputer “Jing” has 88 128 processors and 705 024 cores, with high peak computing performance 11.28 Plops, which can greatly improve the computing efficiency of the model. However, although supercomputers solve the problem of large-scale numerical calculation in structural seismic response analysis to some extent, their high cost and use cost make it difficult to be widely used in engineering practice. Therefore, it is necessary to find a high performance computing solution suitable for engineering applications, which can not only meet the huge computing needs in seismic engineering, but also do not generate expensive investment costs.

Cloud computing is one of those solutions. According to the definition of the national institute of standards and technology (NIST), cloud computing is a computing mode that makes use of the Internet to achieve anytime, anywhere, on-demand and convenient access to Shared resource pools (computing facilities, storage devices, applications, etc.). Users (scientific research personnel, design units) may, according to their own needs, using cloud computing operators offer cloud

  DOI: 10.25236/ISMHI.2019.003

products, flexible lease required scale of computing resources, avoid buying expensive hardware devices, so as to make full use of cloud computing advantage, flexible configuration, low computational cost greatly breakthrough in the current civil engineering computer simulation on the hardware and software resource constraints.

In the field of civil engineering, some research projects also put forward the prospect of further research combined with cloud computing. For example, has-china put forward the preliminary assumption of building the earthquake disaster loss assessment system based on cloud computing platform. Literature attempts to build a structural health monitoring system based on cloud computing platform. However, in general, the application of cloud computing in the field of civil engineering is still not extensive and mainly focuses on the theoretical level. However, cloud computing is essentially a kind of “used” like public facilities of computing resources, its advantage is to provide users with flexible abundant and low-cost computing services, and because of the cloud computing service has provided a lot of more mature product, therefore, the direct use of this kind of cloud computing products compared from the theoretical level to build cloud computing platform more suitable for engineering application.

In order to practically explore the feasibility of using Cloud computing for structural seismic response analysis and calculation, the author combined with Ten cent Cloud and other mainstream commercial Cloud servers to study the engineering structural Cloud computing. By renting cloud computing resources of different scales under different cloud computing platforms, running Elastoplast static reciprocating pushover analysis and seismic dynamic time-history analysis, the calculation time consumption and cost are compared, and the parameter allocation method of cloud computing is discussed. Finally, the performance of cloud computing in seismic response analysis of large single structure and regional seismic damage analysis is tested by running examples of high-rise buildings and urban areas, which provides a reference for introducing cloud computing technology into seismic engineering research.

2. Experimental Procedure

Cloud computing transfers the storage, calculation, analysis and processing of data and information from the personal computer or server of the user to the computer cluster system at the other end of the Internet through high-speed network transmission capacity, and obtains the storage and computing capacity on demand. It is a new business computing model. In the clustered environment, there is a master node M rite: and multiple slave nodes Slaver, in which the master node is the control node and is a data management and distribution center, and the slave node is controlled by the master node to realize data storage and calculation. In this master-slave mode, the computer allocates computing resources according to the needs of customers and performs computation and access, so as to achieve the same computing power as the supercomputer, thus reducing costs. The idea of cloud computing is to connect a large number of storage and computing resources through the network for unified management and scheduling of resources, thus forming a resource pool to provide on-demand services to users at any time. In the eyes of users, the resources in the “cloud” can be infinitely expanded, readily available and used on demand, just like the gas and water and electricity commonly used in our mouth. Centralized and unified storage and management make it convenient for timely access and low cost. This enables individuals and enterprises to avoid buying expensive hardware and software products and only need to pay for the part of services they need. It also saves the maintenance of hardware and tedious upgrade of software, and is more secure and reliable. In addition, cloud computing is the development of grid computing, parallel computing and distributed computing. With the “cloud”, users can easily obtain powerful computing power, storage capacity and infrastructure services through the network.

With the rise of computer science, researchers' research methods in the field of seismic resistance of indoor engineering structures are also improving constantly. Constantly updated ideas and advanced computing tools also promote the leapfrog progress of seismic resistance research of indoor engineering structures. Substructure method and dynamic finite element method have been proposed. At present, prototype observation, model test and theoretical analysis are the main means of seismic research of indoor engineering structures.

Prototype observation method is to analyse the hazards and characteristics of seismic response of indoor engineering structures according to the actual earthquake or the real data measured by some measuring devices. Prototype observation method is divided into two methods, the first is a seismic observation method, seismic observation method refers to before the earthquake happened in the important parts of the interior structure and surrounding rock in installation of measuring device, to measure the results of the dynamic response at the time of the earthquake, but because we are unable to accurately predict the time and place of the earthquake, this method implementation is difficult. The second is the earthquake damage survey, earthquake damage survey is based on the occurrence of the earthquake data and information statistics, in order to obtain important information of seismic research, but this method is only a one-sided analysis of the earthquake, cannot reproduce the actual earthquake response. Strictly speaking, it is because earthquake action is a concept of field, which is difficult to realize in the actual model test.

The research on seismic response of indoor engineering structures can also be realized through shock test, which is the so-called model test method. Because the shock force of this experiment cannot reach the actual size, it is difficult for indoor engineering structures to reach a relatively high stress state, and it is not widely used in practical research. The simulation of shaking table test is more close to the reality. It is a direct method to study the seismic response and failure mechanism of indoor engineering structures.

Due to the lack of abundant research and application of cloud computing in seismic response analysis of structures, it is necessary to test the configuration method and computing performance of cloud computing environment. The specific test method is to upload the computing software and example model to the cloud server for computing, and evaluate the analysis time and cost.

Open System for Earthquake Engineering Simulation is Open source finite element analysis software for structural damage, which has been widely used in seismic performance research of structures and components. Therefore, the author chooses Open Sees software to test the seismic response analysis capability of a single structure on a cloud server. The example model used is a nonlinear fibre beam and layered shell element, among which example 9 is a 142m high and 42-storey high-rise building (see figure 1). The test conditions of example 1 ~ 3 are all elastic-plastic static reciprocating pushover analysis. The test conditions of example 4 ~ example 9 were all elastic-plastic time history analysis. El-Centro seismic wave was selected as the input, peak acceleration (PGA) was set as 0.4 g, analysis time was 40 s, and the initial analysis step was 0.01s. The output parameter was the displacement time history of all nodes.

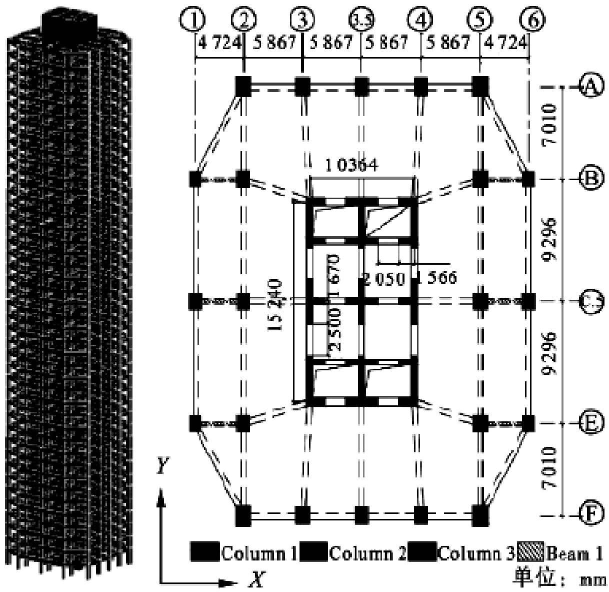

Fig.1 Overview of Model

Regional building seismic damage analysis ability of cloud server, the use of the group to write Ur regional seismic analysis software - ban Seismic Sims test. Layer model are adopted to simulate the structure under seismic action of elastic-plastic response. Test area as a centre of west China city construction data, contains 67 32 s building, 99 of them. 8% is not higher than 10 layer of low-rise buildings.

3. Results and Discussion

Currently, more mature cloud computing platforms include alien, ten cent cloud, sheng daunt and Microsoft cloud, etc., all of which allow users to specify the software and hardware configuration parameters of the cloud server. Hardware parameters including central processing unit (CPU) model with the core number, memory size, and the size of the data set, public network bandwidth, etc. As engineering structure seismic response numerical simulation problems usually can only in a specific operating system, so the author discuss cloud server hardware parameters configuration only. In order to select the most superior performance of cloud computing platform, and give appropriate cloud server hardware configuration parameters, using Open Sees software and numerical example (1) a pet-name ruby, The hardware configuration scheme of cloud computing environment is compared and analysed. The main comparison indexes are model computing time, result file transmission time, service price, etc.

The constitutive model of concrete is the key to describe its mechanical properties and understand its failure mechanism. The failure of concrete in earthquake is a gradual process, from the initiation, expansion and accumulation of micro-cracks to the final appearance of macro-cracks, the failure of concrete can be regarded as the process of damage accumulation. In addition, the concrete material in tension and compression showed significantly different when the nonlinear mechanical properties of the nonlinear behaviors of tension is mainly due to the damage caused the stiffness degradation, and the damage characteristics of pressure when it’s not only show the obvious, plastic softening phenomenon still exist, therefore in the concrete material constitutive model is set up, the need to fully consider the nonlinear mechanical properties of the concrete material. The plastic damage model of concrete material is shown in figure 2.

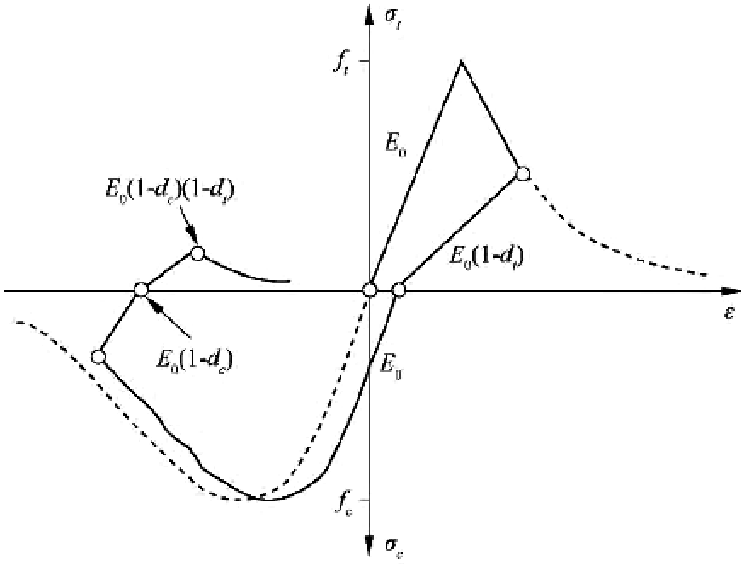

Fig.2 Stress-Strain Relationship of Concrete Materials

One obvious characteristic of concrete material is that it has strong compressive strength, while its tensile strength is usually only 1/20 ~1/10 of its compressive strength. Therefore, when analyzing the stress response of the lining structure of hydraulic tunnel, it is more concerned whether the tensile stress exceeds the tensile strength of concrete. FIG. 3 shows the time history of maximum principal stress at the monitoring point.

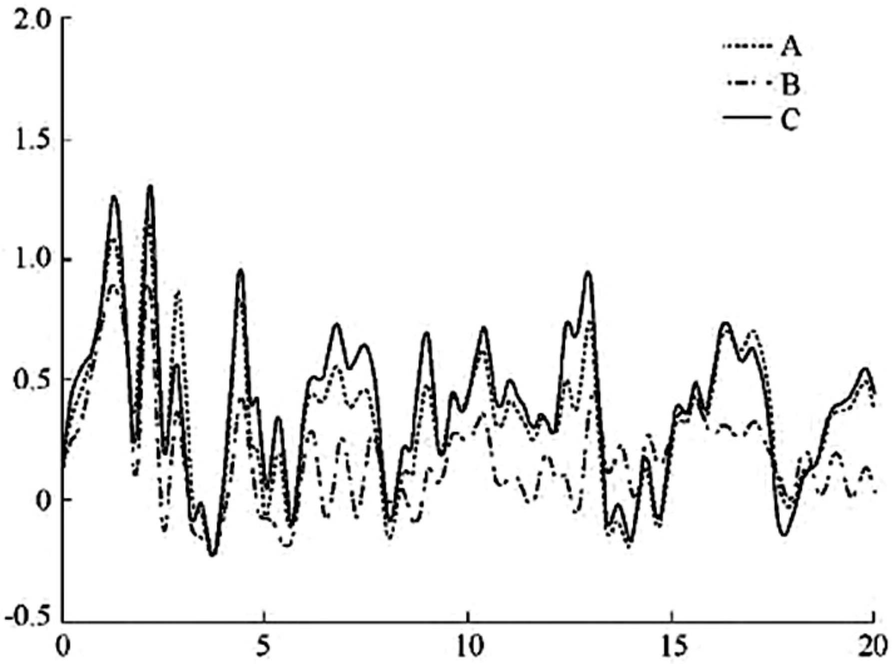

Fig.3 Time History of Maximum Principal Stress At Monitoring Point

As can be seen from figure 3, the maximum principal stress of the top arch, waist and bottom arch of the lining before the earthquake is about 0.25mpa, at which time the lining structure is mainly affected by hydrostatic pressure. As the seismic wave input, three monitoring stations began to rapidly increase, the stress time history curve and in 0 to 5 s most violent period fluctuation, at this time inside lining, waist and bottom arch roof arch tensile stress reached the maximum value, the maximum tensile stress value were 1.21 MPa, 1.30 MPa, 0.82 MPa, obviously the lining structure roof tensile stress of the arch and waist than concrete tensile strength 1.2 MPa, suggests that these areas appear the cracking phenomenon. By comparing the maximum principal stress of the lining structure before and during the earthquake, it can be seen that the influence of internal water pressure on the maximum tensile stress of the cracked part of the lining is about 20%. By comparing the stress time history curves of three monitoring points, it can be seen that the stress response at the waist of the lining structure is the largest, followed by the top arch, and the bottom arch is the smallest. The large deformation at the waist of the lining structure results in the large tensile stress there.

4. Conclusion

The traditional seismic design idea is to improve the ability of building structure to resist earthquake, that is, to increase the strength, stiffness and ductility of structural components, so as to reduce the seismic response of the structure. This way is shown as “three levels” in the current code for building seismic design. In order to achieve this goal, the members of the structure need to have high bearing capacity and plastic deformation ability at the same time, to resist the earthquake excitation and dissipate the earthquake energy. The seismic method is widely used at present, however, this method has a series of flaw: on the one hand, the traditional seismic design method is passive, this approach requires the building structure design in the specific seismic fortification, lack of self-adjusting characteristics, so as long as the structure in high intensity earthquake, a lot of damage of the structures will, at this point it is difficult to guarantee the safety and reliability of structures; On the other hand, this design method is essentially to increase the size of structural components and strengthen the reinforcement to improve the seismic performance, but this will make the normal use area of the building structure reduced, and the economic cost also greatly increased. In particular, for very important building structures, such as medical and health building structures, following the strong earthquake action is an important earthquake rescue work, therefore, under the strong earthquake action, these structures not only require the main body cannot collapse, but also must require its internal working equipment can operate normally. Therefore, the traditional seismic design concept - “hard resistance” is obviously unfavourable.

Idea is different with the traditional seismic isolation technology is to isolate earthquake to buildings and that is between the upper structure and building foundation (base isolation) or in the middle of the upper structure between a floor set isolation layer (layer interval shock), blocking up seismic energy department structure, in order to reduce the seismic response of the structure, ensure the safety and reliability of structures. Isolation technology is a passive control. Base isolation is set the position of the isolation layer between the foundation and upper structure, the level of the isolation layer stiffness is very “soft”, relative to the upper structure under earthquake excitation, as the bearing stiffness is not big, the isolation layer can have the effect of “blocking”, absorb the energy release of the quake, reduce the seismic response of the upper structure.

Acknowledgement

The Science and Technology Project Foundation of Chongqing Vocationl Institute of Engineering under Grant No. KJB201715)

References

[1] Ichimura T, Hori M. Structural seismic response analysis based on multiscale approach of computing fault–structure system[J]. Earthquake Engineering & Structural Dynamics, 2010, 38(4):439-455.

[2] Ding J H, Jin X L, Guo Y Z, et al. Numerical simulation for large-scale seismic response analysis of immersed tunnel[J]. Engineering Structures, 2006, 28(10):1367-1377.

[3] Takahashi M, Kobori T, Nasu T, et al. Active response control of buildings for large earthquakes - seismic response control system with variable structural characteristics[J]. Smart Materials & Structures, 1998, 7(7):522.

[4] Abbas A A, Mohsin S M S, Cotsovos D M. Seismic response of steel fibre reinforced concrete beam–column joints[J]. Engineering Structures, 2014, 59(59):261-283.

[5] BASU, GUPTA, V. K. Stochastic seismic response of single-degree-of-freedom systems through wavelets[J]. Engineering Structures, 2000, 22(12):1714-1722.

[6] Bo Z, Wang Y, Chen Z, et al. Research on the random seismic response analysis for multi- and large-span structures to multi-support excitations[J]. Earthquake Engineering & Engineering Vibration, 2015, 14(3):527-538.

[7] Zhang J, Makris N. Seismic response analysis of highway overcrossings including soil–structure interaction[J]. Earthquake Engineering & Structural Dynamics, 2010, 31(11):1967-1991.

[8] Guo Y, Jin X, Ding J. Parallel computing for seismic response analysis of immersed tunnel with domain decomposition[J]. Engineering Computations, 2007, 24(2):182-199.

[9] Yong L, Astroza R, Conte J P, et al. Nonlinear FE model updating and reconstruction of the response of an instrumented seismic isolated bridge to the 2010 Maule Chile earthquake[J]. Earthquake Engineering & Structural Dynamics, 2017, 46(15).