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Simulating the Stress-Strain Response of Building under Oscillating Wind Conditions

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Abstract

Wind load is one of the main lateral control loads that need to be considered in the design of high-rise building structures. It is also of great engineering significance to study the influence of static wind load or time-varying wind load on the dynamic response of structures. In this paper, a high-rise building with a rectangular section (46.8 m × 27 m × 33 m) is simulated based on Ansys18.0 APDL software. The real situation of its response under no lateral wind load and different fluctuating wind load conditions is simulated and the stress and strain response of the building under steady-state and time-varying wind load is given. The results show that the upper strain of the structure under wind load is about 1/1000 of the bottom strain, and the strain of the structure shows obvious accumulation from the top to the bottom, that is, the bottom strain of the building will be higher than the top strain. The influence of time-varying wind load on building structure is related to the loading position of wind load on the structure. The results provide a basis for the structural wind resistance design of this type of building.

Keywords

Multistory Framework, Cumulative Strain, Wind Load Analysis, Finite Element Tool

1. Introduction

In the past few decades, the load response of buildings has been widely studied, and the study of wind load is quite extensive [1]. The height-width ratio of buildings, especially high-rise buildings, is large, the horizontal stiffness is small, and the lateral load accounts for a considerable proportion of the total load. Therefore, wind load is one of the lateral control loads that must be considered in the design of high-rise buildings. Han Sangeul [2] studied the wind resistance performance and building shape of high-rise buildings and established a numerical derivation method. The static wind load of buildings can be studied based on wind tunnel. Liang, Sg [3] studied the static wind load of buildings based on wind tunnel tests. The study of Huang, JH [4] [5] shows that there is an inelastic response of high-rise buildings under wind load. The cross-wind response of high-rise buildings can be estimated by numerical models [6]. It is of great engineering significance to understand the static and dynamic wind loads acting on buildings and predict the dynamic response of buildings. It is difficult to measure the stress and strain response of buildings under real conditions. The wind load of buildings can be simulated by wind tunnel [7] [8] [9] [10]. Wind tunnel test can accurately control the experimental conditions, high dispersion and accurate experimental results, so it is widely used in automobile manufacturing, aerospace, housing construction and other industrial aerodynamic fields. However, due to the boundary effect and the large and difficult to obtain equipment, this technology cannot be widely used in the study of all buildings. With the continuous development of science and technology in recent years, the accuracy of structural simulation software is becoming more and more perfect. The use of engineering software for building modeling and simulation has become a new research method. The use of Abaqus software to simulate the finite element analysis of the structure has a long history [11]. Khot, SM [12] began to use Ansys and Matlab software to model and calculate the structural vibration response in 2011. Engineering software has gradually become one of the main and reliable means to describe the dynamic wind load of buildings. In this paper, the stress and strain response of the building under the condition of oscillating wind can be simulated by Ansys18.0 APDL classical engineering software.

Ansys is a commonly used building finite element modeling software in recent years [13]. It is widely used as a simulation response simulation software [14] [15] [16]. Ansys APDL is simple, modular and process-oriented. Its standard process includes: defining the model and its load, solving and interpreting the results. Through Ansys APDL, we can use programming language to organize commands and write parameterized programs to realize the whole process of finite element analysis. Therefore, it is widely used in free vibration behavior analysis [17], geometric nonlinear structure optimization [18], microstructure analysis [19] and building structure analysis [20].

In this paper, Ansys APDL is used to simulate the real situation of rectangular cross-section high-rise buildings under lateral fluctuating wind load. The finite element model code is in **Appendix**. The content is divided into structure setting and method, experimental process and simulation, the results and discussion of the fourth part and the final conclusion. The schematic diagram of the structural framework is shown in **Figure 1**.

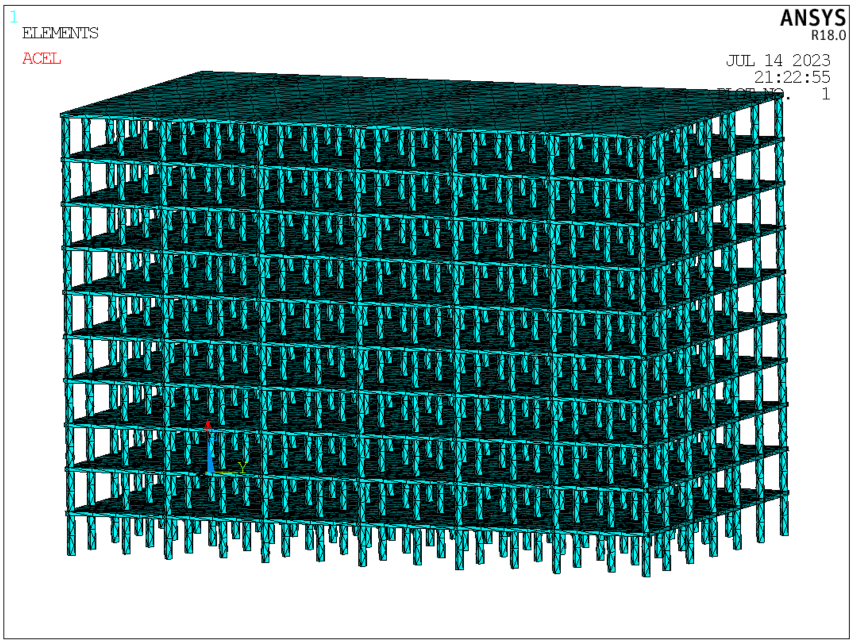

Figure 1. Structural framework.

2. Structure Setting and Method

In this simulation, the building structure is surrounded by an open environment, and there is no sliding displacement between the foundation and the ground. The building structure is a spatial three-dimensional frame structure, which is composed of floor, load-bearing column and load-bearing wall. For convenience, the floor, load-bearing column and load-bearing wall are assumed to be consolidated. The height of the structure is 33 m (3.3 m per floor, including a 3 m column and a 0.3 m floor), with a length of 46.8 m and a width of 27 m, the schematic diagram of the structural framework is shown in Figure 1. In order to have a basic understanding of the model, the model is constructed and analyzed in ANSYS APDL18.0 software. Model is constructed by the following steps:

1) Firstly, a 7.8 m × 4.5 m × 3.3 m single-story single-chamber frame model is established, which includes four load-bearing columns and no wall.

2) Use the command VGEN to copy the single-story single-chamber model, making it into a ten-story frame structure model.

3) Using Boolean Operation Directive (VADD) to merge all volumes.

4) Setting the mesh size and meshing.

5) Area constraint on the structural foundation (all degrees of freedom at the bottom).

6) Apply loads under different test conditions and enter the solver.

In order to simulate the structural response of real buildings under oscillating wind conditions, in this simulation, the stress-strain response of the structure under self-weight load (set as the control group) is first investigated. The purpose is to compare the structural response under other load conditions. Secondly, the stress-strain response of the structure under the combined action of self-weight load and lateral constant wind load was researched and compared with the control group. Finally, the load condition is changed from lateral constant wind load to lateral time-varying one, and the stress-strain response of the structure under its combined action with self-weight load is studied.

3. Experimental Process and Simulation

Because it is a solid structure, we use SOLID185 element in ANSYS APDL18.0, the relevant parameters in this model are: elastic modulus is 1e11 MPa, Poisson's ratio is 0.33, density is 4500 kg/m^3.

According to the steps (1)-(5) in the previous section, the frame structure is modeled, and then three different load combinations are applied as follows:

Experiment 1: Using the command ACEL to apply the self-weight load to the model, the gravity acceleration is set to 9.8 m/s^2 in the vertical direction and enters the solver.

Experiment 2: On the basis of Experiment 1, the command ASEL and SFA were used to apply a constant load of 300 KPa on one side of the structure (simulating the constant wind load of the building structure).

Experiment 3: On the basis of Experiment 1, the discrete value of load changing with time (time interval is 0.05 s) is set in advance. Use the loop command to simulate the time-varying wind load 300 sin(t)KPa applied to the building structure. For each changing load, command GET is used to read the time-varying load data, and the command ASEL and SFA are used to apply the read-out load on the side of the structure. Finally, command ENDDO ends the cycle and enters the solver.

The PLNSOL command is used to view stress and strain contours.

4. Results and Discussions

The results of three different loading methods are shown in **Figures 2-5**.

The first experiment as a control group shows that the simulated building (46.8 m × 27 m × 33 m) will produce a certain degree of strain under the action of its own weight. This strain is small at the top of the building, and will show a certain degree of accumulation at the bottom of the building. In the case of simulation according to the current international standards, the upper strain of the simulated building under the condition of its own weight is about the 1×10^{-6}, while the bottom strain is about 1×10^{-3}.

In experiment 2, a constant simulated wind load of 300 KPa was applied to the structure on the basis of experiment 1. The upper strain of the simulated building under the condition of simulated constant wind load is about 1×10^{-6}, while the bottom strain is about 1×10^{-3}.

In experiment 3 based on experiment 1, a time-varying simulated wind load of 300 sin(t)KPa (time interval of 0.05s) was applied to the structure. The upper strain of the simulated building under a time-varying simulated wind load is about 4.2 × 10^{-6}, the direction of strain generation is the same as that of time-varying wind load, and the mid strain is about 8.7 × 10^{-6}, the direction of strain generation is opposite to the trend of time-varying wind load, and the bottom strain is about 5.5 × 10^{-5}, the direction of strain generation is opposite to the trend of time-varying wind load. The input time-varying wind load and the stress-strain response of the structure over time are shown in Figure 4, Figure 5.

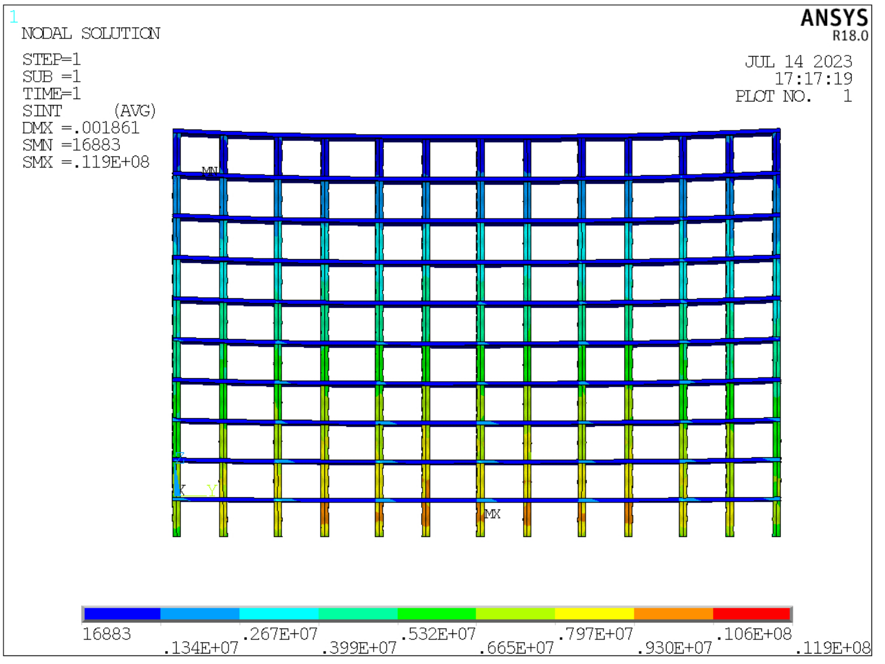

Figure 2. Under the condition of its own weight.

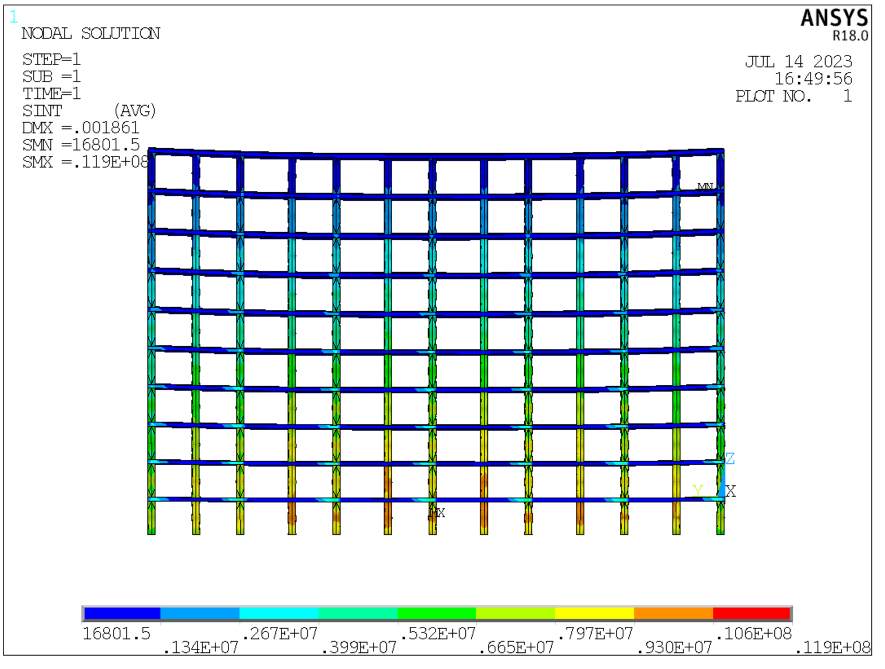

Figure 3. Under the condition of simulated constant wind load.

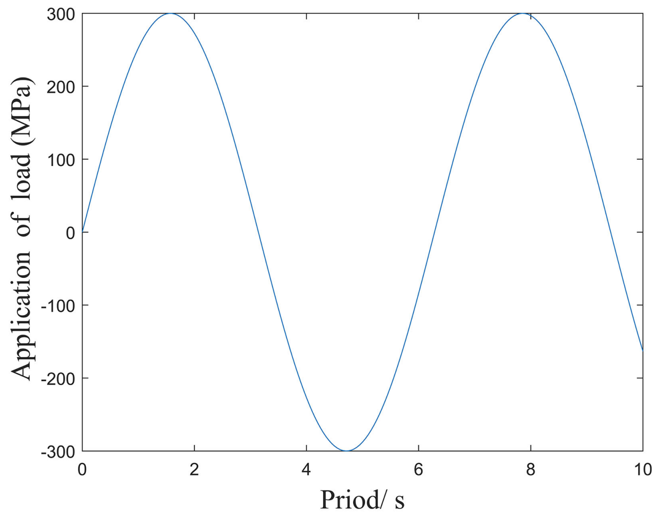

Figure 4. Input wind load.

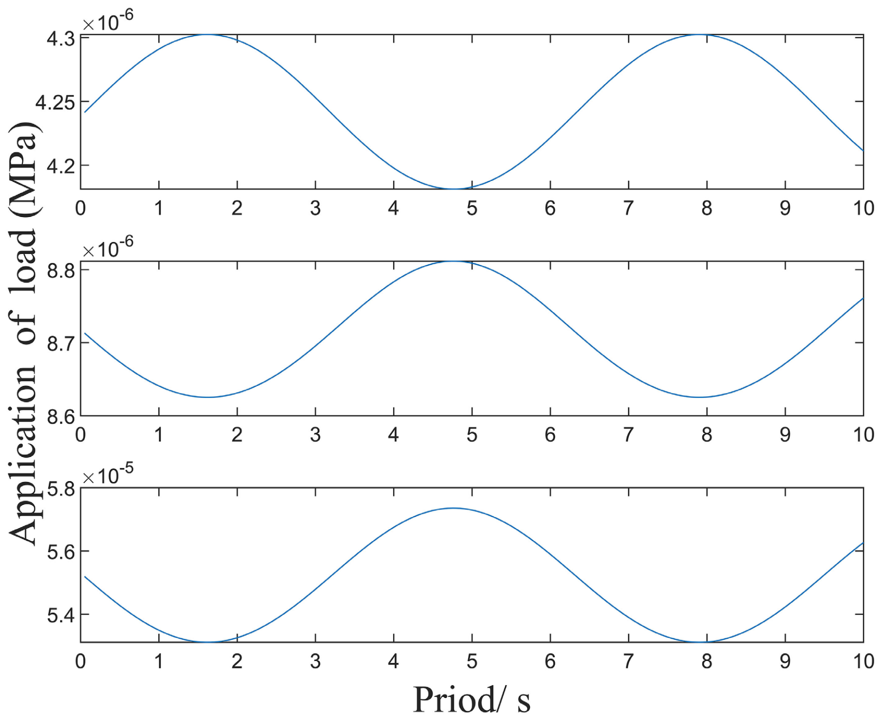

Figure 5. Under the condition of time-varying wind load.

5. Concluding Remarks

1) The building will produce a certain amount of strain under the action of its own gravity.

2) After the constant wind or oscillating wind is superimposed on the building, the strain of the building will be more obvious.

3) The stress-strain response of the structure under time-varying fluctuating wind has obvious correlation with the effect of wind.

4) The strain response of the building shows an upward trend from top to

bottom, and the strain of the building will accumulate to the lower layer.

5) Under the action of time-varying wind load, the direction of strain in the upper part of the structure is the same as that under the action of time-varying wind load, and the direction of strain in the lower part of the structure is opposite to that under the action of time-varying wind load.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

```
/BATCH
/COM,ANSYS RELEASE Release 18.0 BUILD 18.0 UP20161219 10:33:54
/input,menust,tmp,''
/GRA,POWER
/GST,ON
/PLO,INFO,3
/GRO,CURL,ON
/CPLANE,1
/REPLOT,RESIZE
WPSTYLE,,,,,,,,0
/REPLOT,RESIZE
/NOPR
KEYW,PR_SET,1
KEYW,PR_STRUC,1
KEYW,PR_THERM,0
KEYW,PR_FLUID,0
KEYW,PR_ELMAG,0
KEYW,MAGNOD,0
KEYW,MAGEDG,0
KEYW,MAGHFE,0
KEYW,MAGELC,0
KEYW,PR_MULTI,0
/GO
/COM,
/COM,Preferences for GUI filtering have been set to display:
/COM, Structural
/PREP7
ET,1,SOLID185
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,1,,1e11
MPDATA,PRXY,1,,0.33
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,DENS,1,,4500
BLOCK,0,4.5,0,7.8,0,0.3,
CYL4,0.3,0.3,0.3, , , ,-3
CYL4,2.25,3.9,0.3, , , ,-3
FLST,3,6,6,ORDE,2
FITEM,3,1
FITEM,3,-6
```

```
VGEN,6,all, , , 4.5, , , ,0
VGEN,6,all, , , , 7.8, , ,0
CYL4,26.7,0.3,0.3, , , ,-3
CYL4,0.3,46.5,0.3, , , ,-3
CYL4,26.7,8.1,0.3, , , ,-3
CYL4,26.7,15.9,0.3, , , ,-3
CYL4,26.7,23.7,0.3, , , ,-3
CYL4,26.7,31.5,0.3, , , ,-3
CYL4,26.7,39.3,0.3, , , ,-3
CYL4,4.8,46.5,0.3, , , ,-3
CYL4,9.3,46.5,0.3, , , ,-3
CYL4,13.8,46.5,0.3, , , ,-3
CYL4,18.3,46.5,0.3, , , ,-3
CYL4,22.8,46.5,0.3, , , ,-3
CYL4,26.7,46.5,0.3, , , ,-3
VGEN,10,all, , , , ,3.3, ,0
FLST,2,24,6,ORDE,2
FITEM,2,1
FITEM,2,-24
VADD,all
ESIZE,2,0,
MSHAPE,1,3D
MSHKEY,0
VMESH,all
FLST,2,20,4,ORDE,10
FITEM,2,13
FITEM,2,-16
FITEM,2,23
FITEM,2,-26
FITEM,2,33
FITEM,2,-36
FITEM,2,43
FITEM,2,-46
FITEM,2,53
FITEM,2,-56
/GO
ASEL,S,loc,z,-3,,,
DA,All,ALL
ACEL,0,0,9.8,
AllSEL,ALL
ASEL,S,loc,y,0,,,
SFA,all,,PRES,300,
AllSEL,ALL
```

```
/VIEW,1,1,1,1
/VUP,1,Z
SOLVE
```