Original Research Article

Seismic Performance Analysis of Conjoined Structures with Inhomogeneous Stiffness Distribution

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Abstract: Two or more independent towers are joined together through a connectome to form a conjoined structure. The deformation and internal force of the tower are complex, and the coupling effect between the two towers is remarkable when the earthquake is subjected. In this paper, elastic -plastic time -history analysis is adopted to research the dynamic dynamic response under the action of rare earthquakes. Moreover, in order to analyze the influence of symmetry and span parameters on the dynamic response of structures, elastic-plastic time-history analysis is carried out on structures with different symmetries, different stiffness distributions in planes and different spans.

Keywords: Conjoined structure; Different stiffness distribution; Different symmetry; Seismic performance.

1. Introduction

With the development of construction engineering, various uniquely shaped high-rise and super high-rise buildings have emerged one after another. Among them, twin towers and multi tower connected structures are a distinctive architectural form. It generally refers to a building structure that connects several buildings into one entity through one or more connecting bodies. Connected structures have many advantages and have been increasingly applied in construction projects in recent years. Although connected structures have many advantages, there are also some problems in terms of structural seismic resistance. Due to the setting of the connecting body, there is a significant change in the stiffness of the connected structure on both the plane and the facade. A corridor is the deformation coordination part of two towers in a connected structure. Under the action of an earthquake, it bears not only vertical loads but also additional loads generated by the vibration deformation of the two towers. Under earthquake action, the number of coupled translational and torsional modes and local modes significantly increases, and the torsional effect is significant, which can easily cause local stress concentration in the structure.

Domestic and foreign scholars have conducted extensive analysis and research on the structural response of connected structures under earthquake action. Bao Shihua et al. [1] derived the differential equation of a multi tower structure with a large chassis under horizontal vibration using a continuous approach at different stages along the height. Based on the obtained structural natural vibration period and its corresponding vibration mode, their vibration characteristics were discussed. Huang Kunyao et al. [2] analyzed and calculated the seismic response of connected structures with different stiffness using a cohesive model. The results showed that the different stiffness of symmetric connected structures would have a significant impact on the anti symmetric torsional mode shape of the connected structure, but had no effect on its symmetric translational mode shape. For asymmetric connected structures, the different stiffness of connected structures had a significant impact on the various vibration modes of the structure. Wu Zhehua et al. [3] established a high-precision finite element spatial particle system calculation model considering the elastic deformation inside the floor slab, and conducted modal analysis and single point acceleration response spectrum analysis using Block Lanczos solution technology. Han Jianping et al. [4] studied the response characteristics of asymmetric twin tower connected

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structures under earthquake action. Modal analysis, response spectrum analysis, and elastic and elastic-plastic time history analysis were conducted on three structural models: damping connection and rigid connection between the non connected and connected structures

and the main structure. Wang Jimin et.al. [5] regarded the connecting body as an elastic beam and applied the time history analysis method to study the influence of stiffness changes of the connecting body on the dynamic characteristics and seismic response of the structure. References [6]-[8] studied the dynamic response of structures after installing spring and damping connection devices between buildings. The study found that installing connection devices can effectively coordinate the displacement between adjacent buildings and improve the seismic performance of the structure.

At present, research on connected structures is mostly within the elastic range, and there is relatively little research on the nonlinear issues of connected structures. Moreover, the response of structures under vertical seismic action is generally ignored, and the research on them under bidirectional seismic action is not comprehensive enough. Therefore, this article takes the symmetrical twin tower connected structure as an example and uses large-scale universal finite element software to establish a three-dimensional spatial dynamic model. At the same time, considering the material nonlinearity of the structure and the multi-dimensional seismic motion, the elastic-plastic dynamic time history analysis method is used to analyze the elastic-plastic seismic response of the structure, restoring the seismic form as much as possible, and comprehensively analyzing the response of such structures under earthquake action, Provide reference for the application design of such structures in practical engineering.

2. Research Object and Computational Model

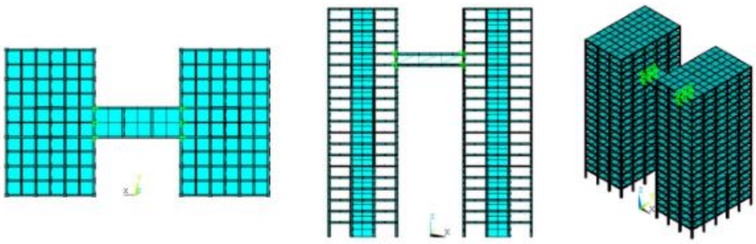
The basic model of the twin tower connected structure studied in this article is a symmetrical twin tower connected structure of a frame core tube system. The structural tower has 20 floors, with a height of 4m on the ground floor and 3m above the second floor; 3 spans in the X direction and 5 spans in the Y direction. The connected structure is located on the 16th floor with a span of 18m. The steel truss structure system with a height of 3m is adopted for the connection, and the arrangement of steel truss slant support adopts the inverted V-shaped scheme. The connected structure is hinged with the two towers on both sides, which not only provides good integrity and high stiffness, but also makes the construction of the connection relatively simple. This article uses the finite element software ANSYS to establish a three-dimensional spatial dynamic analysis model. The beams and columns use beam188 elements. The shear walls and floor slabs both use the shell181 element. The material models of reinforced concrete and steel both use the multilinear isotropic strengthening model MISO and comply with the yield criterion of isotropic strengthening Mises. Select EL Centro wave, Tianjin wave, and Baja wave as input seismic waves, and adjust their peak values to 400 gal.

3. Elastic-plastic Analysis of Connected Structures with Different Symmetries

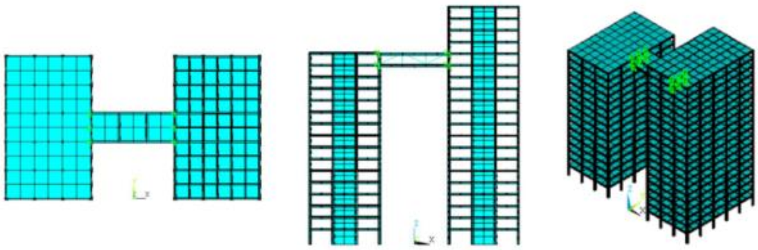
In order to study the influence of different symmetries on the elastic-plastic response of structures, this paper adopts four comparative models (Figure 1) to analyze and compare the influence of structural symmetry on the elastic-plastic response of structures. Through calculation, the layer displacement and interlayer displacement of structures are compared (Figure 2).

From Figure 2, it can be observed that compared to the X-direction layer displacement and inter story displacement, Model B has the smallest maximum layer displacement and inter story displacement, but its graphical pattern differs significantly from the other three models, especially the layer displacement and inter story displacement of the bottom few layers are the largest. As the floors increase, their displacement decreases, indicating that in coupled earthquakes, asymmetric structures have a limiting effect on the displacement of higher floors of tall towers, Has a magnifying effect on the bottom few layers. In the comparison of displacement in the y-direction, Model B has the largest layer displacement, and the interlayer displacement between Model B and

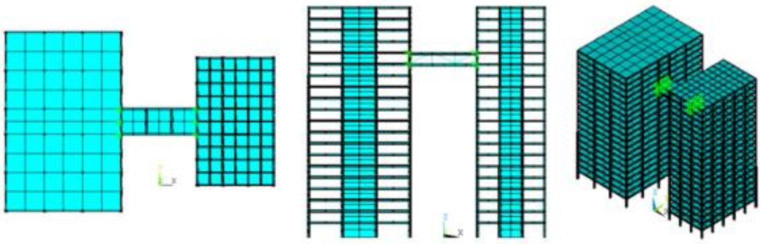
Model D is significantly different from the other two models. The layer displacement and interlayer displacement of Models A and C are similar, indicating that the asymmetric stiffness of the structure has a much smaller impact on the Y-direction displacement compared to the other two asymmetric forms.



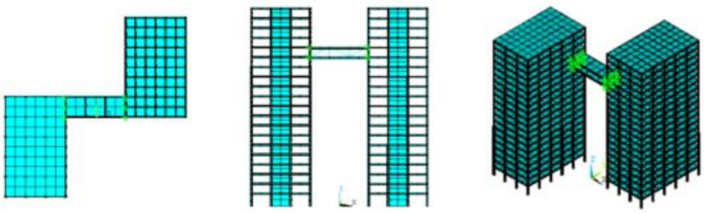
(a) Model A



(b) Model B



(c) Model C



(d) Model D

Figure 1 Calculation model diagram for different symmetric structures.

4. Comparison of Elastic-Plastic Analysis of Structures with Changes in Stiffness in the X-Direction

Under the condition that the stiffness in the Y direction of the calculation model remains unchanged, the influence of the change in stiffness in the X direction of the tower on the elastic-plastic response of the structure is analyzed by adjusting the stiffness in the X direction. The analysis model is shown in Figure 3. By calculation, the story displacement and inter story displacement of the structure were obtained, as shown in Figure 4.

Through calculation, it was found that under the three-dimensional coupled seismic action, both the layer displacement and inter story displacement in the X direction increase with the decrease of the X stiffness, while the effect of the decrease in the X stiffness on the Y displacement shows an irregular pattern, with Model A>Model C>Model B. This is mainly because the change in stiffness causes changes in the tower size, which has a certain impact on the displacement of the structure.

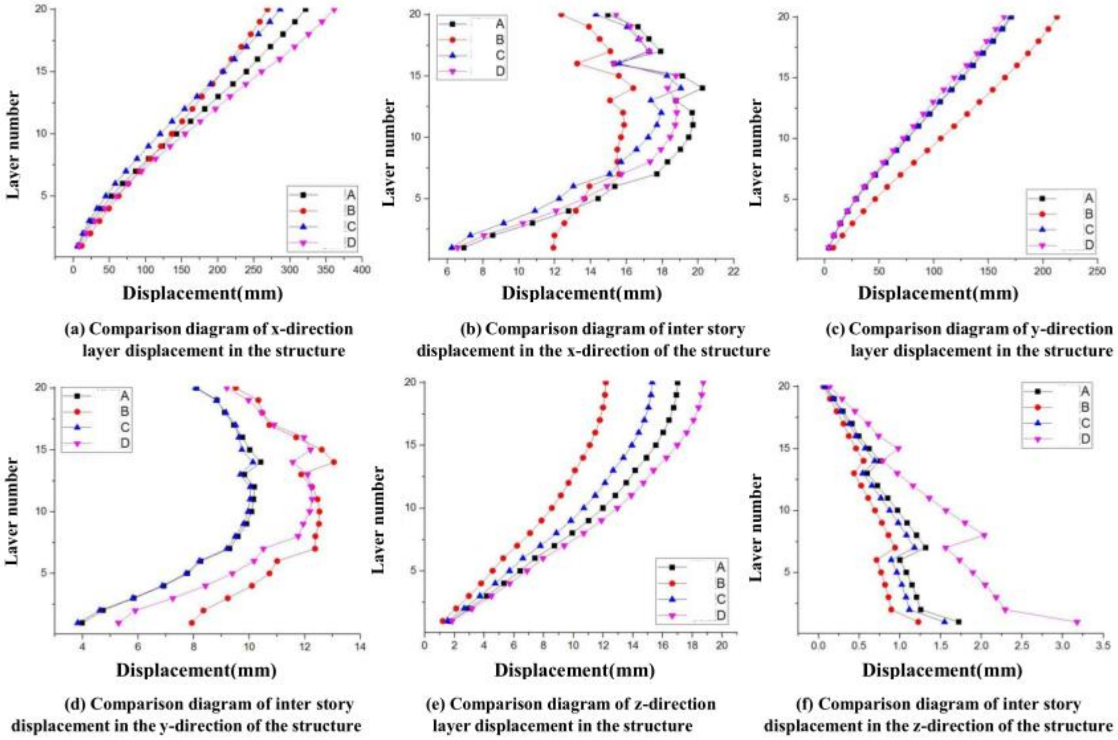
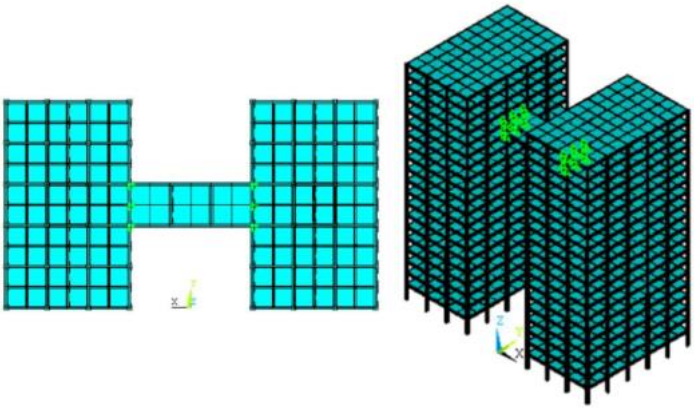
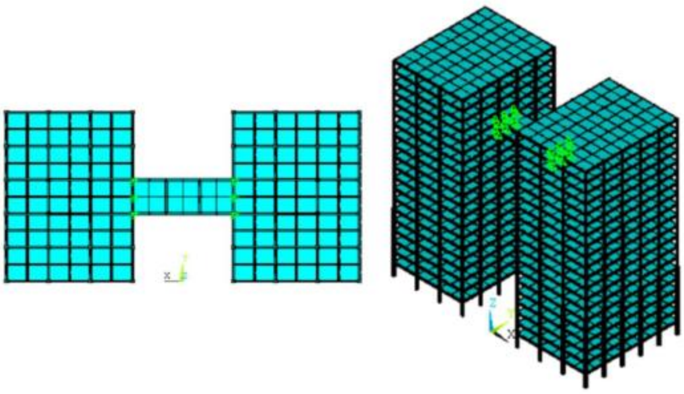


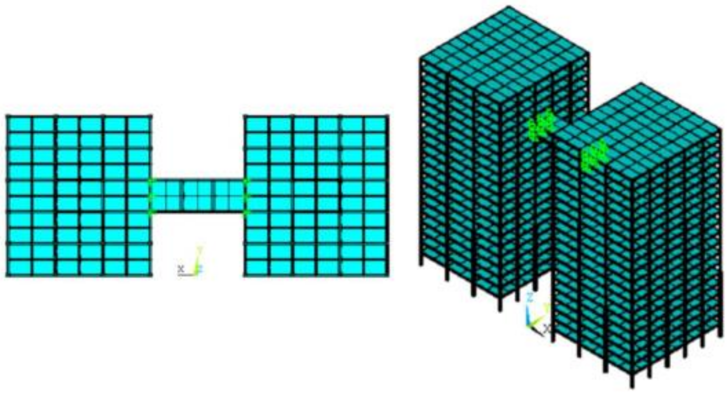
Figure 2 Displacement comparison diagram.



(a) Model A

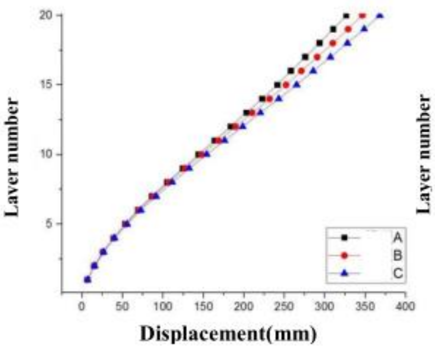


(b) Model B

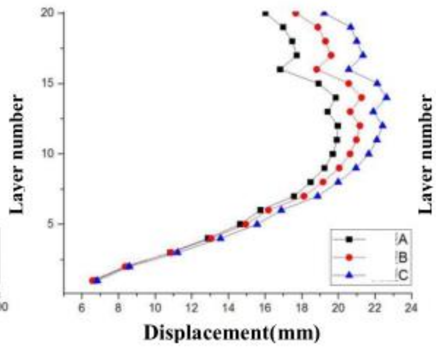


(c) Model C

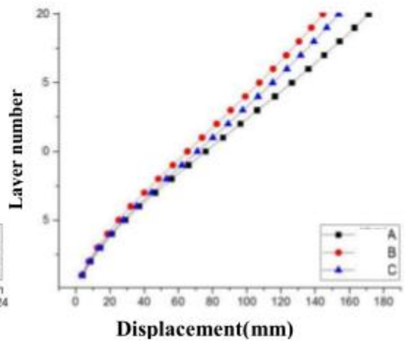
Figure 3 Calculation model diagram with different Y-direction stiffness.



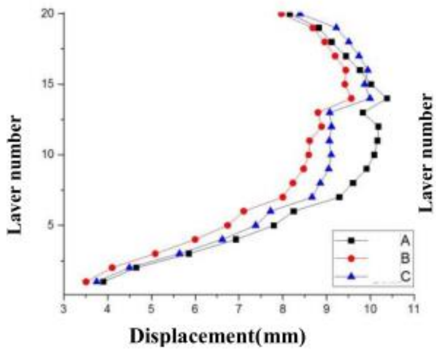
(a) X-direction layer displacement



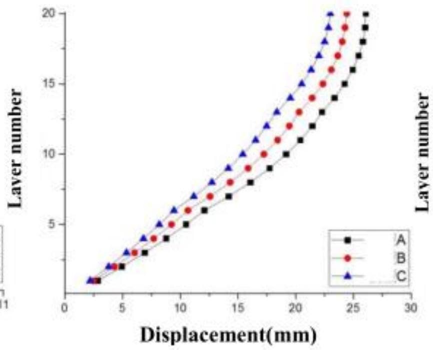
(b) X-direction interlayer displacement



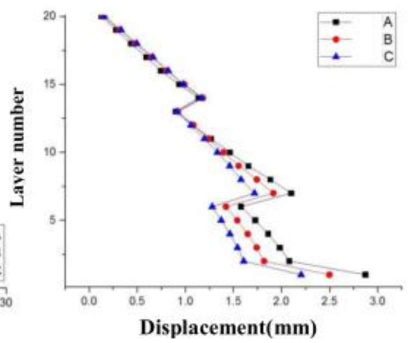
(c) Y-direction layer displacement



(d) Y-direction interlayer displacement



(e) Z-direction layer displacement



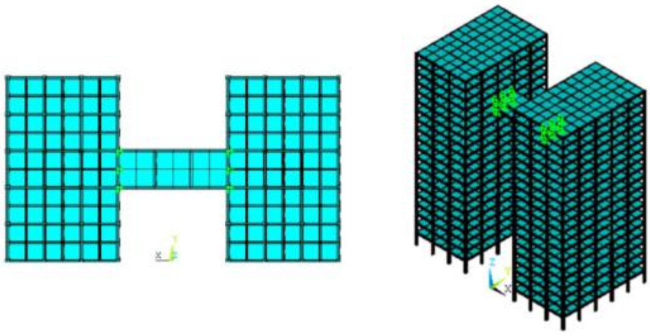
(f) Z-direction interlayer displacement

Figure 4 Displacement comparison diagram.

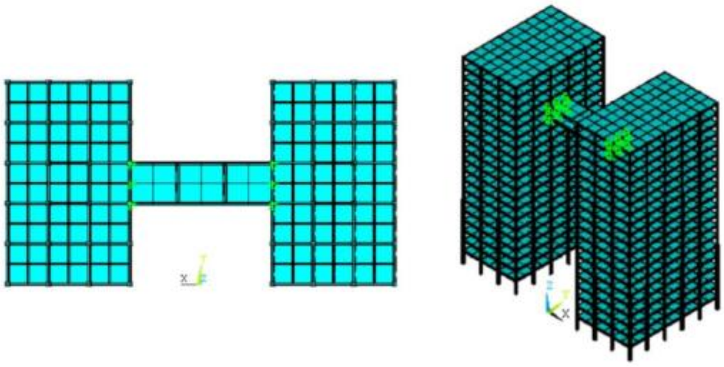
5. Comparison of Elastic-Plastic Analysis of Structures with Different Spans

Due to the significant impact of connectors on the elastic-plastic response of structures, the influence of span changes on the elastic-plastic response of structures is analyzed by calculating the tower response under different span conditions of connectors. The structural model is shown in Figure 5, and the calculated displacement and inter story displacement of the structure are shown in Figure 6. At the same time, the vertical displacement time history curve of the center point of the connected structure is shown in Figure 7.

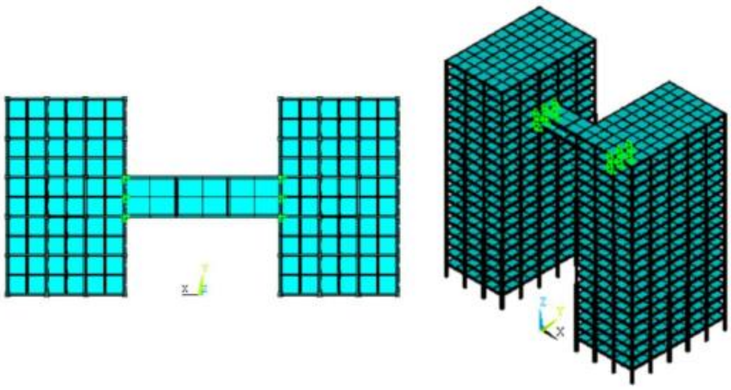
Analysis has found that the variation of structural span has little effect on the displacement of the tower in all directions, mainly because the variation of the connected span of the structure, stiffness, strength, and other changes are not significant, and the impact on structural displacement is not significant. By comparing the vertical displacement of the nodes in the middle of the corridor, it can be found that as the span of the connecting body increases, the vertical displacement of the connecting body increases.



(a) Model A



(b) Model B

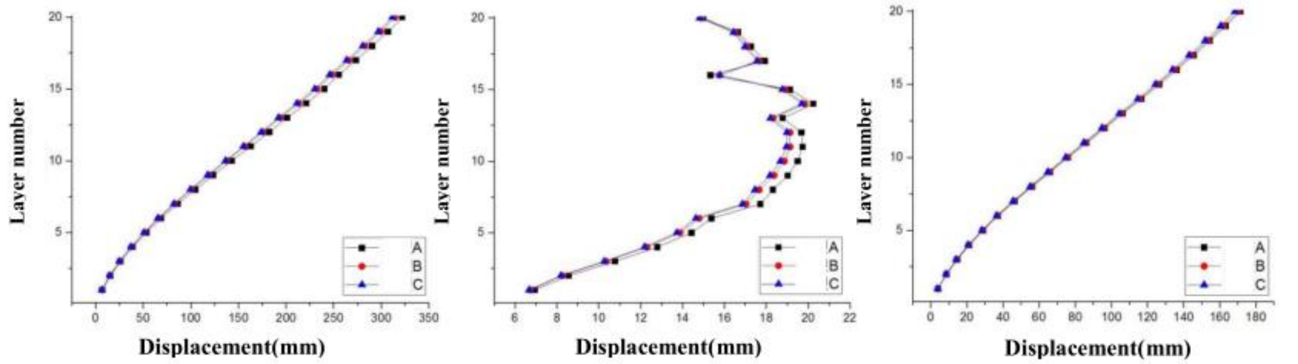


(c) Model C

Figure 5 Model diagrams of various computational structures.

6. Conclusion

By calculating the elastic-plastic time history of connected structures, the responses of symmetric structures, asymmetric structures, and connecting body spans to the elastic-plastic behavior of the structures were analyzed. The following conclusion can be drawn: (1) The symmetry of connected structures has a significant impact on the displacement changes of the structure, especially for structures with asymmetric three directions. (2) The symmetry of the structure has a certain impact on the plastic development time and plastic occurrence area of the structure, but it is mainly determined by the nonlinearity of the material. (3) The change in X-axis stiffness of the structure has a significant impact on the displacement and plastic changes of the tower, and it can be appropriately increased to enhance seismic performance. (4) The span variation of the structure has little effect on the anisotropic displacement of the structure, but has a greater impact on the connected body itself. The change in span has a certain impact on the development of the plastic region of the structure. As the span increases, the coordination ability decreases, and the development of the plastic region changes significantly.



(a) X-direction layer displacement map **(b) X-direction interlayer displacement map** **(c) Y-direction layer displacement map**

(d) Y-direction interlayer displacement map **(e) Z-direction layer displacement map** **(f) Z-direction interlayer displacement map**

Figure 6 Comparison of displacement curves.

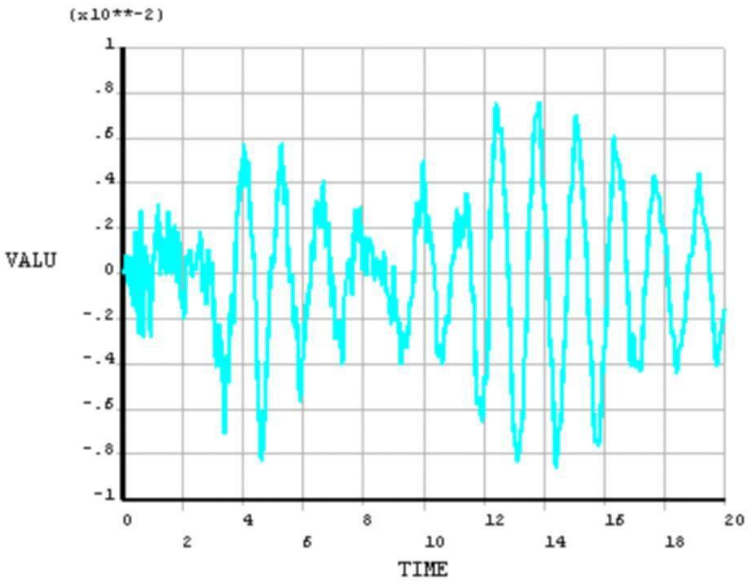


Figure 7 Time history curve of vertical displacement at the center point of a connected structure.

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