International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 12 Issue 1 ǁ January 2024 ǁ PP. 263-267

Analysis and Research on Vertical Deformation of Super High-rise Construction of Ningbo Bank of China Tower

Guilong Wu[1],Feng Jiang[1],Pei Li[1],Kuashi Pan[1]
**1 School of Environment and Architecture,University of Shanghai for Science and Technology, Shanghai*
Corresponding Author: Guilong WU

Abstract
The construction simulation analysis of super high-rise buildings considering the shrinkage creep of concrete was carried out by using midas/gen finite element software with Bank of China Tower in Ningbo as the engineering background. The model of concrete shrinkage creep in CEB-FIP (1990) specification was used to calculate the effects of shrinkage creep on vertical displacement and displacement difference of structural members. The results show that shrinkage creep causes large vertical deformations and differential vertical deformations in high-rise structures, and it is necessary to analyze the structure for the construction process considering shrinkage creep.
Keywords: *Ultra-high rise, vertical deformation, shrinkage, creep, construction simulation analysis.*

Date of Submission: 10-01-2024 Date of acceptance: 24-01-2024

I. INTRODUCTION

Under the background of rapid development of building height, more than one hundred super high-rise buildings over 300 m have been built or are under construction in China [1]. The vertical displacement of super high-rise buildings has always been a key concern for engineers [2], and this displacement will make the vertical members on the same horizontal plane produce a large vertical displacement difference [3], which will make the beams produce a large additional moment [4], the elevator shafts are damaged, and even the structure is damaged, which affects the safety performance of the structure. For the frame core system, due to the differences in the material combination form, cross-section form, and the load borne by the vertical members of the frame part and the core part, coupled with the effects of the shrinkage and creep of concrete, and the time difference in construction and installation, it will lead to differences in the vertical deformation between the vertical members. The vertical deformation seriously affects the vertical elevation of the structure, the location of the pre-buried parts and the installation of other assembled components, and if it cannot be effectively controlled and adjusted, it will bring great inconvenience to the structural construction and generate great secondary stress in the structure, which may in turn affect the service life of the structure [5]. According to the Technical Specification for Coagulated Structures of High-rise Buildings (JGJ3 I 2010): it is required to consider the effect of vertical deformation differences for high-rise structures with a height of more than 50m or a height-to-width ratio of more than four. Liang Fuhua [6] and other ultra-high-rise buildings with a building height of 180 m conducted long-term monitoring and found that the maximum vertical displacement difference of the structure at the completion of 2 years could reach about 1.6 mm. Zhao Jian [7] and others analyzed the construction process of a super high-rise building with a structural height of 540 m considering the shrinkage and creep of concrete, and investigated the effect of the vertical displacement difference on the internal force of key members. Li Ye [8] et al. analyzed the construction simulation of super high-rise structures using different shrinkage creep prediction models and compared the differences between different shrinkage creep simulation calculations. In the paper, the construction simulation analysis considering the time-varying characteristics of concrete was carried out for a retractable super high-rise building, and the CEB-FP (1990) model was used to perform the calculations. Finally, the analytical results are compared with those of the elastic condition, and the effect of concrete shrinkage creep on the vertical displacement and displacement difference between the frame columns and the core is derived.

II. SUMMARY OF WORK

Located in Ningbo, Zhejiang Province, BOC Tower Ningbo is a comprehensive office building. The project consists of a 49-story office tower, a 4-story commercial podium, a steel canopy connecting the tower and the podium, and a 3-story underground parking garage. The structural roof elevation of the tower is 246.000 m; the roof elevation of the podium is about 24.000 m. The total building area is about 145,000 square meters, of which the above ground building area of the tower is about 107,000 square meters and the underground building area is about 38,000 square meters. The tower adopts the hybrid structure system of steel pipe concrete columns + floor steel beams frame reinforced concrete cylinder. The core cylinder of the tower is round below the 19th floor; above the 19th floor, the peripheral round wall is converted into a small square cylinder with cut corners; the peripheral frame columns are steel pipe concrete columns. The whole tower plane is gradually twisted around the center from bottom to top, forming a twisted building shape. The upper structure of the tower adopts the hybrid structural system of steel pipe concrete columns + steel beam frame concrete core. In order to make the core cylinder have enough bearing capacity and ductility, steel profiles are set up at the corners of the core cylinder with up and down penetration. The frame columns adopt circular steel pipe concrete columns, and the frame beams adopt welded H-beams, which are rigidly connected with the frame columns to meet the requirements of the peripheral frame as the second line of seismic defense.

III. FINITE ELEMENT MODELING AND ANALYSIS METHODS

3.1 Finite element modeling

The structure was modeled and analyzed using midas/gen and the finite element model is shown in Fig. 1. The steel pipe and concrete are modeled using beam units, and the kernel The core cylinder and floor slab are simulated by slab unit, and all other components are simulated by beam unit. The construction step is divided into two floors and one construction stage, and one construction stage is 14 d. The structure is calculated separately. The construction steps are divided into two floors and one construction stage, and one construction stage is 14 d. The vertical displacements after the completion of the structure are calculated respectively. Take the analysis results of frame column and core cylinder at the location of Fig. 2.

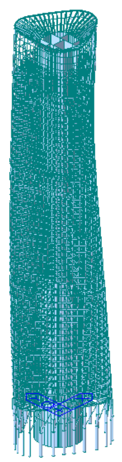

Figure 1. Finite element model

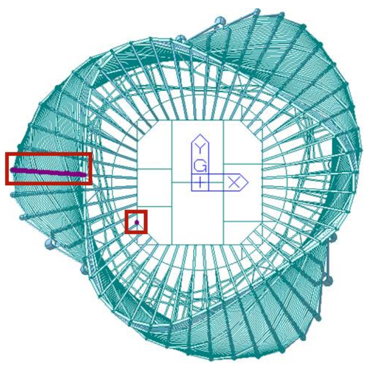

Figure 2. Vertical deformation selection location

3.2 Analytical methods

In order to calculate the effect of concrete shrinkage and creep on the structure, scholars at home and abroad have fitted some prediction models, such as ACI model, CEB-FIP (1990) model and B3 model, through a large number of component test data. At present, the commonly used model in China is the CEB-FIP (1990) model.
The expression of CEB-FIP (1990) creep calculation model:

$$(t, t_0) = (\infty, t_0)\beta_c(t - t_0)$$

In formula: $\phi(\infty, t_0)$ is the nominal creep factor;$\beta_c(t - t_0)$ is the coefficient of development of creep with time.

The CEB-FIP (1990) contraction calculation model is expressed as follows.

$$\varepsilon_{cs}(t, t_s) = \varepsilon_{cs0}\beta_s(t - t_s)$$

In formula: ε_{cso} is the nominal shrinkage factor of concrete; β_s is Development factor for time-dependent shrinkage changes; t_s is the age at which concrete shrinkage begins

IV. ANALYZING THE RESULTS

4.1. Vertical displacement

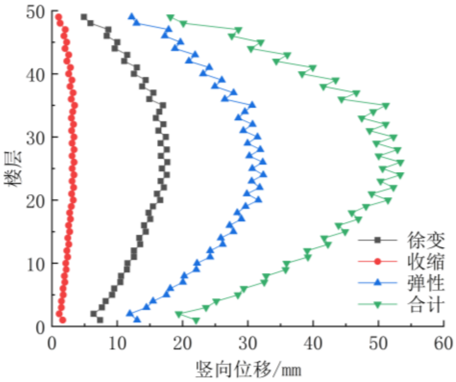

Figure 3. Vertical deformation of frame column

As shown in Figure 3, the vertical displacement values of the frame columns show a trend of large in the middle and small at both ends, the vertical displacement curve is fish-belly, and elastic deformation > creep deformation > shrinkage deformation. When the structure was completed, the maximum vertical displacement of the frame columns occurred in the 26th floor, with a value of 53.36 mm, and the vertical displacement produced by the structure under the elastic condition was 32.28 mm, accounting for 60.5% of the total displacement; the vertical displacement produced by the creep condition was 17.69 mm, accounting for 33.15% of the total displacement; the vertical displacement produced by the shrinkage condition was 3.38 mm, accounting for 6.4% of the total displacement. 6.4%.

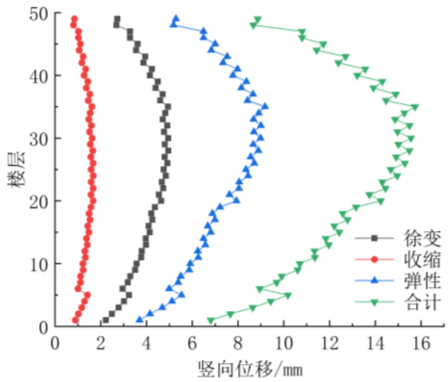

Figure 4. Vertical deformation of the core

As shown in Fig. 4, the vertical displacement of the core cylinder shows a trend of large in the middle and small at both ends, the vertical displacement curve is in the shape of the belly of a fish, and the elastic deformation > creep deformation > shrinkage deformation. When the structure was completed, the maximum vertical displacement of the core occurred at the 35th floor, with a value of 15.73 mm, and the vertical displacement under the elastic condition was 9.18 mm, accounting for 58.4% of the total displacement; the vertical displacement under the creep condition was 4.94 mm, accounting for 31.4% of the total displacement; and the vertical displacement under the shrinkage condition was 1.6 mm, accounting for 10.1% of the total displacement. In the contraction condition, the vertical displacement was 1.6 mm, accounting for 10.1% of total displacement.

From the above, it can be seen that the maximum vertical displacement of frame columns and core cylinder occurs in the middle and upper part of the structure, and although the total vertical deformation of the structure is dominated by elastic deformation, the proportion of deformation caused by shrinkage creep is as high as 42.5% in the floors with the greatest influence of shrinkage creep effect at the time of structural capping, which can be seen that, for the purpose of accurately analyzing the vertical deformation of the structure and eliminating the structural surcharge, the vertical deformation caused by the shrinkage creep effect should not be neglected in the calculation and analysis. effect caused by the vertical deformation.

4.2 Differential vertical displacements

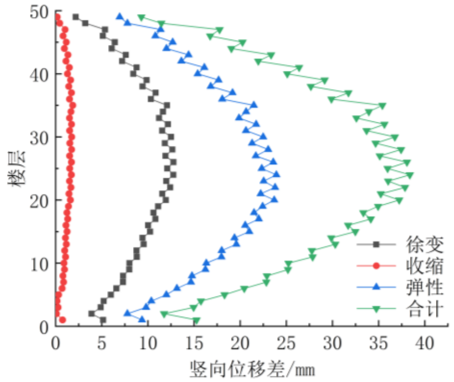

Figure 5. Difference in vertical deformation of frame columns and cores

As shown in Figure 5, the vertical displacement difference between the frame column and the core cylinder shows a trend of large in the middle and small at both ends, the vertical displacement difference curve is fish-belly shaped, and elastic deformation > creep deformation > shrinkage deformation. When the structure was completed, the maximum vertical displacement difference between frame columns and core cylinder occurred at 26th floor, with a value of 38.06 mm, and the vertical displacement produced by the structure under elastic condition was 23.57 mm, accounting for 61.9% of the total displacement; the vertical displacement produced by creep deformation was 12.77 mm, accounting for 33.6% of the total displacement; the vertical displacement produced by shrinkage condition was 1.72 mm, accounting for 4.5% of the total displacement. The vertical displacement under contraction condition was 1.72 mm, accounting for 4.5% of the total displacement.

From the above, it can be seen that the maximum vertical displacement difference of frame columns and core occurs in the middle and upper part of the structure, and although the vertical deformation difference is dominated by elastic deformation, when the structure is topped out, the deformation ratio caused by shrinkage creep is as high as 37.2% in the floors most affected by shrinkage creep, and with the development of shrinkage creep, the vertical displacement difference of the structure is gradually increased, which may eventually increase the bending moment of the frame beams on the same horizontal plane and cause damage in serious cases. increase, leading to damage in severe cases.

V. CONCLUSION

1) The vertical displacements of frame columns and core barrels and the vertical displacement difference between the two show a trend of big in the middle and small at both ends, and the vertical displacements and vertical displacement difference curves are fish-belly shaped, with elastic deformation > Xuyi deformation > shrinkage deformation.

The vertical displacement and vertical displacement difference curves are in the shape of a fish belly, and elastic deformation > Xu deformation > contraction deformation.

2) The maximum value of vertical displacement and vertical displacement difference of the structure appears in the middle and upper part of the structure, which should be paid attention to when designing and constructing the structure.

It should be emphasized in the design and construction of the structure.

3) In the floors most affected by shrinkage creep, the proportion of deformation caused by shrinkage creep in the total vertical deformation is as high as 41.5%, therefore, it is important to analyze the vertical deformation in the construction of super high-rise structures.

Therefore, when analyzing the construction of super high-rise structures, the effect of shrinkage creep of concrete should be considered.

4) The numerical calculation results show that the vertical displacement difference between the frame columns and the core is very large. This difference will cause large additional moment and additional shear force.

REFERENCES

[1]. Wang Dasui, Bao Lianjin. Structural development and prospect of supertall buildings in China[J]. Building Structure, 2019, 49(19): 11-24.

[2]. J. Wu, J. Liu. Analysis and measurement of time-varying effects of a super high-rise frame-core structure[J]. Journal of Donghua University (Natural Science Edition), 2016, 42(4): 559-565.

[3]. Jiu-Rong Wu, Li-You Wu, Qiang-Wu Liang. Simulation analysis of construction of a super high-rise building with vertical arrangement along the height internal coding[J]. Building Structures, 2020, 50(5): 71-76. 49.

[4]. Xie Dongming, Wang Haowei. Midas/gen-based analysis of structural creep and shrinkage of high-rise buildings[J]. Journal of Harbin University of Commerce (Natural Science Edition). 2020, 36(3): 351-356.

[5]. Wang Xiaobei, Gao Zhenfeng, Wu Xiaoping, et al. Long-term vertical deformation of Shanghai Center Building[J]. Analysis of long-term vertical deformation of the structure of Shanghai Center Building[J]. Journal of Building Structures, 2015, 36(6): 108-116.

[6]. Liang Fuhua, Han Jianqiang, Gan Haifeng, et al. Measured and analyzed vertical deformation difference of super high-rise frame-core structure Chuan[J]. Journal of Building Structures, 2016, 37(8): 82-89.

[7]. ZHAO Jian, ZHOU Dingsong, ZHOU Jia, et al. Influence and control of concrete shrinkage creep on vertical deformation and internal force of critical members in super high-rise mega hybrid structures Chuan[J]. Building Structure, 2020, 50(1): 44-51.

[8]. LIU Feng, LIU Junjin. Analysis of the effect of concrete shrinkage and creep on the construction simulation and predeformation of Tianjin hitch[J]. Building Structure, 2012, 42(9): 142-145.