Application and Seismic Analysis of changing masonry structure into bottom frame structure

Pengfei Dou¹, Xinsheng Xu ¹*, Yujiao Liu ²

¹ School of Civil Engineering and Architecture, University of Jinan, 336 Nanxinzhuang West Road, Jinan 250022, Shandong, China
² Huaiyin District Education and Sports Bureau, 367 Zhangzhuang Road, Jinan 250021, Shandong, China
* Corresponding author’s e-mail: xinsheng_xu@163.com

Abstract. In order to meet the requirements of people for the use of large space, the masonry structure building is underpinned, the load-bearing wall of the building is removed, and the underpinning beam is constructed to replace the original load-bearing wall to bear the upper load, the bottom masonry structure is transformed into a large space frame structure. Based on the analysis of two different underpinning methods, this paper selects the structural underpinning method according to their advantages and disadvantages, and takes an example as an example to summarize the construction of underpinning beam structure first. Then the main construction methods and matters needing attention of the underpinning technology for removing the load-bearing wall in the construction process, so as to provide a certain basis for the future construction of the structure. Through the displacement loading method, the bearing capacity of frame beam and underpinning beam is analyzed, and the data are processed, and the advantages and disadvantages of underpinning beam and frame beam under load are obtained.

1. Introduction

The bottom floor of the masonry structure is transformed into a bottom frame structure by structural underpinning, which not only meets the requirements of the large space of the building, but also saves resources and protects the environment [1]. M.A.Biof analyzed a variety of different buildings, and concluded that flexible ground floor buildings have better seismic performance [2]. After strict design, the bottom frame structure can reduce the vibration of the structure under the earthquake, and the height of the anti-seismic wall has a great influence on the deformation capacity and anti-seismic capacity [3-7]. The strict control of the floor stiffness ratio of the bottom frame structure is an important measure to ensure the seismic performance of the structure, and the reasonable value of floor stiffness ratio is the key to engineering construction. This paper makes a comparison between the bottom frame structure and the modified bottom frame structure, and discusses whether there is any difference in seismic performance between the modified bottom frame structure and the bottom frame structure.

2. Analysis on the Reconstruction Scheme of a Post and Telecommunications Office

2.1. General situation of the project

A post and telecommunications office in Dingtao County is located in Dingtao County, Heze City. The building was built at the beginning of the 20th century and has a five-story brick-concrete structure.
basic intensity of seismic fortification is 7 degrees, the height of the story is 3.6m, and the walls are 240mm. Each floor is equipped with circular beams, four corners of the outer wall, stairwell and inner walls with structural columns.

Due to the expansion of business and office needs, the original building has been unable to meet the current requirements. Therefore, in order to meet the requirements of the owners, it is necessary to transform the bottom into a large space structure. Now, through the requirements of the owners and the inspection and appraisal of the project site, it is decided to remove part of the wall on the first floor, underpinning the wall to be removed, and the underpinning beam instead of the load-bearing wall to bear the load, which has met the requirements of the house.

2.2. Underpinning scheme
According to the main construction schemes of the current mature underpinning technology, the following two schemes are mainly considered: the first is to set up a temporary support to bear the load of the load-bearing wall to be removed, then remove the wall, and finally construct the underpinning beam; the second is to construct the underpinning beam first, and then remove the wall when the underpinning beam reaches the design strength after the construction of the underpinning beam is completed. The first scheme is the single joist underpinning technology introduced above, which is convenient for construction, but the structure is a five-story masonry structure. When underpinning on the ground floor, the load on the upper part of the structure is large, which will lead to the high height of the beam. And construction safety can not be guaranteed. The second scheme, that is, the double underpinning technology mentioned above, according to the actual project and cost requirements, this scheme adopts reinforced concrete beam underpinning technology. Although the construction technical requirements are higher, the scheme avoids the setting of temporary support, and the construction safety is guaranteed. And the underpinning beam can bear a large load and can meet the requirements of the use of the indoor space of the house. Therefore, after comprehensive consideration, it is decided to adopt the second plan for construction underpinning.

After the construction of the underpinning beam is completed, the concrete beam and column should be maintained, and the strength change of the concrete should be closely monitored during this period. When the concrete beam and column reach the design strength, the original wall should be removed. Attention should be paid to the strength of the demolition, especially when demolishing the wall of more than two stories, it is strictly forbidden to use a sledgehammer or push the wall down directly on the ground to avoid greater impact. Damage to the lower layer, in addition, attention should be paid to monitoring the stress of the underpinning beam and the upper masonry when demolishing, so as to ensure that the beam can bear the upper load smoothly.

Story displacement refers to the lateral displacement produced by the structure under the horizontal load, and the inter-story displacement angle is to ensure the stiffness of the structure, avoid excessive displacement under the load, and then affect the use of the structure and even cause the destruction of the structure. In this paper, through the analysis of the structure under the earthquake action under the PKPM software, the story displacement and the inter-story displacement angle curve of the structure under the earthquake action are obtained. The floor displacement curve is shown in figure 1 and figure 2, and the inter-story displacement angle is shown in figure 3 and figure 4.
According to the above figure and calculation, it can be seen that in the elastic stage, the maximum displacement in the X direction is 3.9mm, and the maximum interlayer displacement angle is $\theta_{\max} = 314^\circ$, the maximum displacement in Y direction is 4.0mm, and the maximum interlayer displacement angle is $\theta_{\max} = 203^\circ$. According to the limit value of elastic inter-story displacement angle stipulated in Chinese seismic design code, it can be found that the limit value of inter-story displacement angle of reinforced concrete frame-seismic wall structure is $\theta_{\max} = 80^\circ$, from which it can be concluded that the modified structure meets the requirements of seismic design code.

After the design and reinforcement of the underpinning structure is completed, the stress analysis of the structure is carried out by using PKPM software, and it is verified that after the beam bears the upper load instead of the original load-bearing wall, the shear force and bending moment meet the design requirements of the beam, and under the elastic condition, the floor displacement and inter-story displacement angle produced by the structure under earthquake meet the requirements of the code, which provides a basis for the reliability of this design. After transforming the bottom of the structure into a large space structure, the project meets the requirements of the owner for the use of the large space of the building, and there is no large deformation of the underpinning beam, cracking of the upper part of the masonry and other hidden dangers in the course of use. up to now, all aspects of building use meet the requirements.
3. Analysis of bearing capacity of frame Beams and underpinning Beams

Figures 5 and 6 show the load-displacement curves of frame beams and underpinning beams. As can be seen from the diagrams, the beams have gone through three working stages of ordinary beams, the first stage: the stage before the crack, when the whole section of the beam works, at this time, the concrete and steel bar are under tension, the longitudinal steel bar is under tension, and the stress is proportional to the strain. The second stage: the working stage with cracks, at this time, cracks begin to appear on the concrete beam, and the concrete in the tension area is destroyed. Due to the destruction of concrete, the tensile stress of steel bar increases, and the tensile stress of steel bar increases with the increase of load. The third stage: the crack develops rapidly, the longitudinal stress of steel bar remains unchanged, but the tensile strain of steel bar increases rapidly, the crack of concrete beam develops rapidly, and finally reaches the ultimate bearing capacity of the beam.

Figure 5 Load-displacement curve of frame beam

Figure 6 Load-displacement curve of underpinning beam

It can be seen from the diagram that the time of the three stages of frame beam and underpinning beam is basically the same, the end of the first stage occurs at the displacement of 0.003m, that is, point A in the diagram, the end of the second stage occurs at the displacement of 0.01m, that is, point B in the diagram, and the third stage occurs at the displacement of 0.021m, that is, point C in the diagram.

Although the time of the three stages is basically the same, the load at the displacement is quite different. As can be seen in figure 5, point A is at the end of the first stage, when the displacement is 0.003m and the load is 150kN. Point B is the end of the second stage, when the displacement is 0.01m and the load is 270kN. Point C is the third stage, when the displacement is 0.021m, and the load reaches the ultimate load of the beam, which is 300kN. As can be seen in figure 6, point A is at the end of the first stage, when the displacement is 0.003m and the load is 250kN. Point B is the end of the second stage, when the displacement is 0.01m and the load is 410kN. Point C is the third stage, when the displacement is 0.021m, and the load reaches the ultimate load of the beam, which is 520kN.

According to the diagram and data analysis, in terms of the bearing capacity of the beam, the deflection of the frame beam and underpinning beam is basically unchanged under the condition of displacement loading, but the bearing capacity of the beam is very different, and the bearing capacity of the underpinning beam is much larger than that of the frame beam. In the three stages, the ultimate bearing capacity of the underpinning beam is larger than that of the frame beam. The main reason is that the underpinning beam is applied on both sides of the wall. The moment of inertia between the beams increases, and the original ring beam and wall part between the beams also strengthen the bearing capacity of the beam to a certain extent, resulting in the bearing capacity of the underpinning beam is higher than that of the frame beam.

4. Conclusion

This paper analyzes the underpinning schemes of masonry buildings through practical projects, introduces two different underpinning schemes, and summarizes the advantages and disadvantages of
the two schemes, the bearing capacity of frame beam and underpinning beam is analyzed by
displacement loading method, and the data are processed, and the advantages and disadvantages of
underpinning beam and frame beam under load are obtained, and the following conclusions are drawn:

(1) Through the actual project case, taking the underpinning transformation of Dingtao Post and
Telecommunications Bureau as the research object, the two underpinning schemes of masonry structure
are analyzed and compared. this paper introduces the advantages and disadvantages of the two schemes
and adopts the scheme of constructing underpinning beam first and then removing the wall to transform
the project, and summarizes the process of underpinning construction and the problems needing
attention in construction. In this scheme, the underpinning structure is constructed first, and then the
wall is cut off when the strength of the beam meets the design requirements, so as to avoid the risk of
setting temporary support when the wall is removed first. However, before the construction of the
underpinning structure, it is necessary to locally chisel off the wall of the underpinning structure, so the
reinforcement scheme and construction sequence must be carefully designed, and the construction
process must be strictly monitored to ensure the safe construction of the underpinning structure. And
the load-bearing wall can be removed smoothly.

(2) At the end of this paper, the bearing capacity of frame beam and underpinning beam is studied.
In terms of the bearing capacity of the beam, under the condition of displacement loading, the deflection
of the frame beam and the underpinning beam is basically unchanged, but the bearing capacity of the
beam is very different, and the bearing capacity of the underpinning beam is much larger than that of
the frame beam. In the three stages, the ultimate bearing capacity of the underpinning beam is greater
than that of the frame beam. According to the data of this paper, the bearing capacity of the underpinning
beam is about 40% higher than that of the frame beam.

Acknowledgments
The authors acknowledge the financial support provided by the Key Research and the School of Civil
Engineering and Architecture at the University of Jinan. I would like to thank Professor Xu Xinsheng
for his patient guidance and meticulous attention, as well as the help of the seniors.

References
[1] Cui Jianhua, Qi Yi. (2009) Application technology of wall underpinning of brick-concrete structure
[J]. Science and Technology Information.
[2] Biot.M.A. (1943) Analytical and Experiment Methods in Engineering Seismology [J].
In:Proc.ASCE, 108—112.
[3] Zheng Shansuo. (2000) Study on Seismic behavior and Design method of Brick Building with
frame-Seismic Wall at the bottom [D]. Doctoral thesis, Xi'an University of Architectural
Science and Technology.
[4] Zheng Shansuo, Yang Yong, Zhao Hongtie. (2004) Experimental study on seismic behavior of
frame-shear masonry buildings at the bottom [J].Journal of Civil Engineering. 37 (5): 23-31.
[5] Zheng Shansuo, Yang Yong. (2000) Shaking table test of the bottom two-story frame-concrete
seismic wall and the upper five-story brick building model [J]. Infrastructure Optimization,
521 (4): 24-26
[6] Zheng Shan Lock, etc. (1998) Shaking table experiment of brick building model with frame-brick
seismic wall on the ground floor [J]. Journal of Xi'an University of Architectural Science and
Technology, 30 (3): 327-331.
[7] Zheng Shan Lock, etc. (2000) Shaking table experiment of brick building model with bottom two-
story frame-brick seismic wall [J]. Journal of Xi'an University of Architectural Science and
Technology, 529 (2): 183-187.