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Simulation analysis of the construction process of column-free and long span underground spatial structure

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ABSTRACT

A city subway comprehensive transportation hub project is an underground three-story structure. The first two floors within the range of 51.2m×48m in the atrium are designed as column-free structures. The atrium is designed as beam-plate system, orthogonal beam arrangement. The actual construction process of the large-span structure was simulated with FEM, and the structural deformation and stress under different construction conditions were analyzed. Results show that, the maximum stress and deformation of steel beam, concrete slab and structural column occurred after removing the first temporary support. Under the most unfavorable condition, the maximum stress of steel beam reaches -128.7MPa and the maximum deflection reaches 55.7mm. This paper also analyzes three kinds of unloading plan. Results shows that, different unloading plans have little influence on the stress of steel beam, but have some influence on the deformation, and have great influence on the concrete slab. The maximum deformation difference of steel beam is 15%, the maximum stress difference of concrete slab is 26% and the maximum crack width difference is 37%.

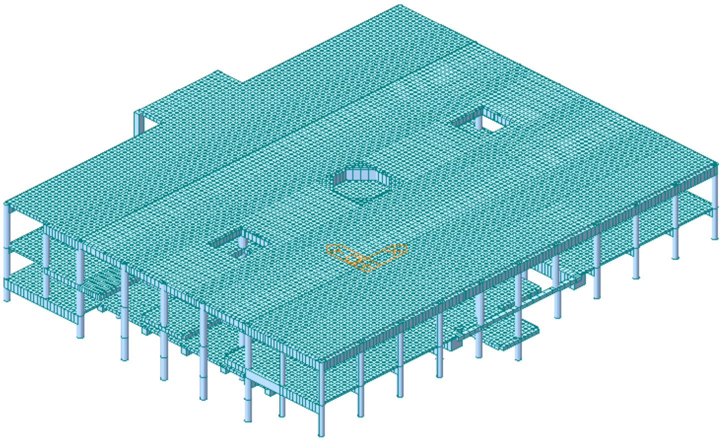

Fig. 1 Finite element model of underground spatial structure

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1. INTRODUCTION

Underground space is a direction of urban development. As early as 1863, the world's first underground railway was built in London, England, which opened the prelude of urban underground transportation development. In 1969, China built its first subway in Beijing, and by the end of 2014, 22 cities had opened urban underground rail transit routes[1].However, with the development of underground space structure, the span of underground space structure is getting larger and larger, and it will be more and more affected by surrounding tunnels, overpass highways and overpass Bridges. Therefore, more and more scholars at home and abroad have studied the related problems of underground space structure.

Some scholars have made seismic analysis on the underground space structure. He, Z. and Q. Chen[2] proposed a construction method of vulnerability curve of underground large space structure considering vertical seismic action. In terms of seismic capability, the bearing capacity curve of the central column is obtained by using the method of soil - underground structure nappe analysis considering vertical seismic load. Zhuang, H et al.[3] studied the impact of the concrete continuous wall on the seismic response of the underground structure by using numerical simulation method. The studied building has an irregular plane and a deep basement Shared with the adjacent buildings. A series of nonlinear time-history analyses are carried out for maximum considered earthquakes (MCE) and rare earthquakes (RE). Jeong. S.Y et al.[4] studied the influence of basement modeling methods . The modeling of the surrounding subsurface structure includes the transfer of torsional modes, which are easily amplified by the high frequency components of ground motion, causing local damage to the upper part of the building. Some Suggestions for the conservative design of the basement model with surrounding underground structure and non-soil-structure interaction are given. Zhuang, H et al.[5] installed an elastic sliding isolation support on the top of the column for the seismic failure process of the underlying structure. The results show that the sliding bearing can effectively reduce the seismic damage of the columns and plates in the underground structure. The results show that under the action of strong earthquake, the axial stress response of the central column decreases significantly and is completely under pressure, which can effectively improve the overall seismic performance of the underground station structure. Wu, W et al.[6] studied the seismic performance of a typical 2-storey and 3-span subway station in Shanghai on soft ground by combining shaking table test and numerical simulation. The structural model used granular concrete and galvanized steel wire to simulate the prototype of reinforced concrete. For solving the problem of scale effect, the synthetic model soil (a mixture of sand and sawdust) is used, and the similarity relation considering dynamic equilibrium is derived.

Another part of the scholars studied the influence of the underground space structure on the existing buildings. Li[7] to establish a true three-dimensional numerical model, the relative position of the different construction steps (elevated pile foundation, pile caps, pier, capping beam and the upper structure) and different main span under the condition of high construction risk and its influence on adjacent underground intercity railway station, analyses the station structure deformation, slab track position and overlying strata subsidence. Hui J S[8] in Shenzhen metro line 11 new station close posted both line 1 and the big town underground commercial street structure as the research background, used FLAC3D large calculation software for new 11 standard section of the main structure of a subway station, the three-dimensional numerical calculation model is established and simulated cover dig reverse construction method is used for the foundation pit construction, the process of the analysis of the structure of the new station near by construction respectively on the surface settlement, both the structure and the impact of the underground commercial street structure at the station. At the same time, the influence of existing structure on soil displacement, new structure and underground diaphragm wall is analyzed by establishing a comparative model of existing structure. Based on the analysis of numerical simulation results, the interaction between the newly built foundation pit and the existing structure of close sticking is summarized, and the safety and reliability of the foundation pit project is obtained, which provides reference for similar projects in the future, and the prospect of the follow-up research is put forward. Yuan, C et al.[9] used Midas software to conduct a real THREE-DIMENSIONAL numerical simulation of the stress and deformation of the terminal of Jiao Zhou Bay undersea tunnel in Qingdao during the construction of high-rise buildings. The foundation pit block, layered excavation, unloading and the stress of the whole building on the adjacent existing tunnel are simulated. The safety of the tunnel is evaluated by the influences of tunnel convergence, vertical and horizontal displacement, additional stress and curvature change of lining deformation.

Some scholars have also studied the settlement of underground space structure in the special soil layer. Wu, XT. And Liu, ZW[10] took Foshan metro Line 2 as the main research object, carried out finite element simulation of the construction process of the overlapping section, combined with the field measured data, and effectively predicted the ground settlement caused by the overlapping section construction, so as to take targeted control measures and verify the reliability of the formation reinforcement measures. The results show that reasonable reinforcement measures can be taken before the construction of the superposition section to effectively control the foundation settlement. Tang, B et al.[11] studied the dynamic interaction between silt-clay soil and irregular section of subway through shaking table test. In the test process, the lateral deformation of the model soil was measured by shape acceleration array (SAA), and the seismic failure process of the station structure was visualized and digitized by non-contact dynamic displacement measurement method. The typical test results, including the dynamic earth pressure, seismic settlement, deformation and acceleration of the structure, are explained. The results show that the motion of subway station is more controlled by the surrounding silt in terms of phase and amplitude. This method can effectively measure the deformation of soil, especially under the action of earthquake, the relation between the relative lateral displacement of soil and the depth of soil can be well fitted to the cosine function. The seismic settlement is significantly related to Arias strength, and the subway station has obvious non-uniform settlement, resulting in the vertical separation of soil-structure.

The study of underground space structure also includes the study of structural construction simulation. S. R. Macklin, H. C. Yeow[12] studied the London Underground Station of King's Cross St Pancras in central London, carried out numerical simulation, and monitored the construction process. Lin Ming chao[13] based on an underground space structure project across a subway tunnel in Guangzhou, this paper analyzed the influence of various construction conditions on existing subway tunnels during the construction of underground structures, and obtained the stress and strain laws of surrounding foundation pit, tunnel lining and surrounding rocks in various working conditions. Finally, the dynamic load of the subway in operation is analyzed, and the influence of dynamic load on the newly built underground structure is discussed. Tong, D [14] applied real-time control theory and method to the construction simulation method of underground powerhouse, and established a real-time control model of construction schedule and quality considering the construction process, geological conditions and resource constraints. A real - time control method of construction schedule and quality is proposed, and the actual control process is studied. Through real-time control of the construction schedule and quality of an actual underground workshop, good results have been obtained.

Gang Sha Bei Comprehensive Traffic Junction project is a newly built comprehensive traffic junction with 4 lines of transfer. The structural construction involves many surrounding structures, such as Shen nan Avenue guide renovation, steel bridge demolition, Cai tian Bridge reconstruction, and the effect of the surrounding environment on 22m deep foundation pit, which all increase the construction difficulty. The east-west direction of the large-span structure is 120m, and the south-north direction is 96m. There is a column-free atrium with a span of 51.2m×48.0m. There are many kinds of members, including concrete beams, steel beams and steel-mixed composite beams. Concrete beams can be divided into 65 kinds according to different sizes, with the maximum size of 1.8m×3m; steel beams can be divided into 8 kinds according to different sizes, with the maximum size of 2.2m×2.8m; steel-concrete beams can be divided into 2 kinds according to different sizes, with the maximum size of 1m×2.8m; steel beams can be divided into 3 kinds according to different sizes, with the maximum size of 1m×2.8m.The structural columns include concrete column, concrete-filled steel tube column and steel-concrete column. The diameter of the concrete column is 1.4m; the diameter of the concrete-filled steel tube column is 1.6m and 2m; the diameter of the steel-concrete column is 1.6m.The concrete slab has four thicknesses of 0.5m, 0.6m, 0.7m and 0.9m.Therefore, it is very important to simulate and monitor the whole construction process of the structure.

2. PROJECT OVERVIEW

2.1 Construction environment and construction flow

Gang Sha Bei Comprehensive Traffic Junction project is located at the junction of Shenzhen Futian Shen nan avenue and Cai tian bridge. In order to facilitate the construction of 22m deep foundation pit, Cai tian bridge should be dismantled first, and the steel bridge on the west side of the structure should be built to ease the traffic between the north and the south, and Shen nan Avenue should be changed to the north and south sides of the large-span structure to ease the traffic between the east and the west during the construction. Cai tian bridge and Shen nan Avenue should be restored after the structure is basically formed.

Gang Sha Bei Comprehensive Traffic Junction is the underground three - story structure. The minus one floor is the station hall floor. The negative second floor is the platform floor of Line 11 and 14, while line 11 and 14 are the east-west route. The negative third floor is the platform floor of Line 10, and line 10 is the north-south line. In order to ensure the building effect, there should be no columns for the negative one floor and the negative two floors in the interior of the 51.2m×48m atrium, but 12m×12m structural columns for the negative three floors. Due to the atrium scope of large-span structure all the top column span is too big, and cannot be built at one time, and Shen Nan Avenue guide renovation, steel bridge demolition, Cai tian Bridge reconstruction for large-span structure also has a great influence, in order to guarantee the safety of the structure before molding, 162 temporary steel supports are arranged at the bottom of the steel beam, including no column within the scope of the temporary support 63, temporary steel support consists of the servo system in place to ensure that the late synchronous unloading.

The overall construction of the large span structure of the atrium of Gang Sha Bei Comprehensive Junction can be divided into three stages: in order to restore the traffic of Shen nan Avenue as soon as possible, the first stage is to construct the span of the column-free, east and west span, east and west transition span, 13-17 axis south span; Cai tian bridge was rebuilt after Shen nan Avenue guide renovation. The second stage was the construction of the north and south span and transition span of 13~17 axes. Phase III construction of ancillary structures. Figure 2-1 shows the zoning plan of the construction stage. Figure 2-2 shows the distribution axis of the construction top beam.

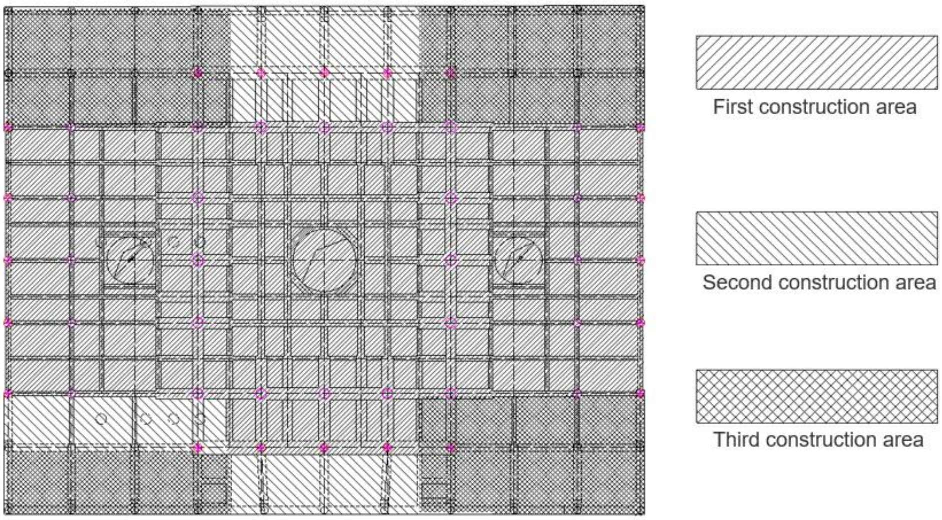


Figure 2-1 Construction phase zoning plan

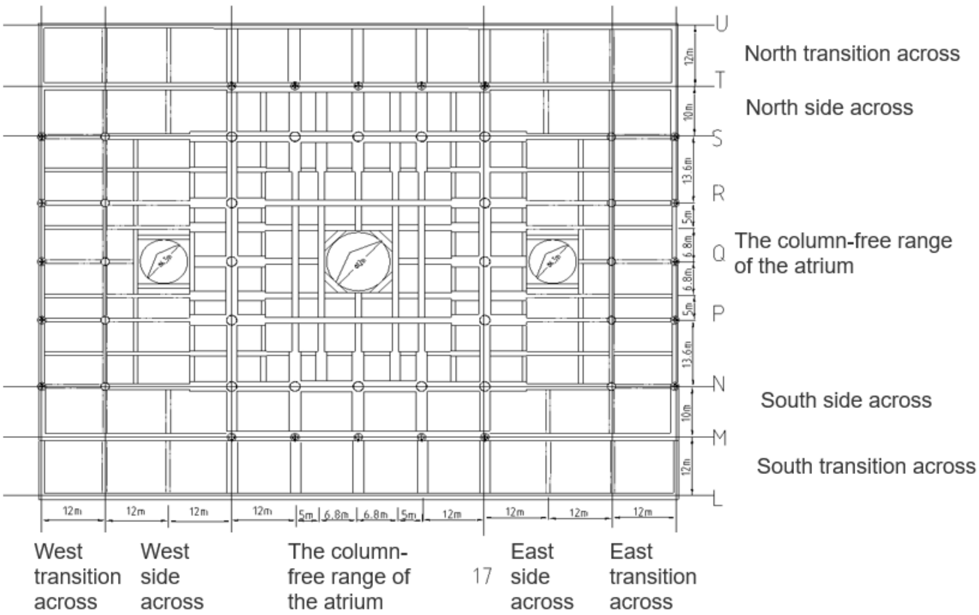


Figure 2-2 Construction top beam distribution axis diagram

The construction process of the first stage is as follows： Construction preparation→Floor construction under the platform and installation of embedded parts→Installation of steel pipe column (section steel column), construction of upper and bottom of cap→Negative three layers concrete support (the sixth passage) removal, temporary support installation→Construction of negative three layer side wall and negative two layer middle plate → installation of steel tube column (section steel column)→Negative two concrete support (fourth, fifth) removal, temporary support installation→Negative two side wall, negative one middle plate construction→Installation of steel tube column (shaped steel column)→Removal of the first concrete support and installation of temporary support on the negative floor (installation of servo system)→East and West bridge erection machine installation, steel box girder erection→Bridge erecting machine through hole, central steel box girder installation, east and west concrete roof pouring→East and West area cover plate excision, transition span steel beam construction→Servo system synchronous unloading, temporary support removal→Concrete pouring of the central roof, road guide transformation, cross construction of the south side→shennan Avenue guide renovation.

The second stage construction process is as follows: Construction of north side span and north and South transition span→rebuilt Cai tian bridge, steel bridge demolition→Missing beam section installation, long-span steel structure system conversion→ Maintenance access, ring corridor hanger installation.

The third stage is the construction of the attached structure.

2.2 Structure type

The bottom structure is reinforced concrete structure, the top beam is steel beam except the north-south transition span, the rest are concrete beams. Because the long-span structure is a central symmetric structure, the 1/4 beam plan is taken to illustrate the structural form of the top beam, and Figure 2-3 is the distribution diagram of the 1/4 top beam. Where B1, B3, B4, B5, B6, B6a and B7 are steel beams, SRC1 and SRC2 are steel reinforced concrete beams, and the rest parts are 1500mm×2200mm concrete beams. Table 2-1 shows the structural forms of top steel beam and steel bone beam.

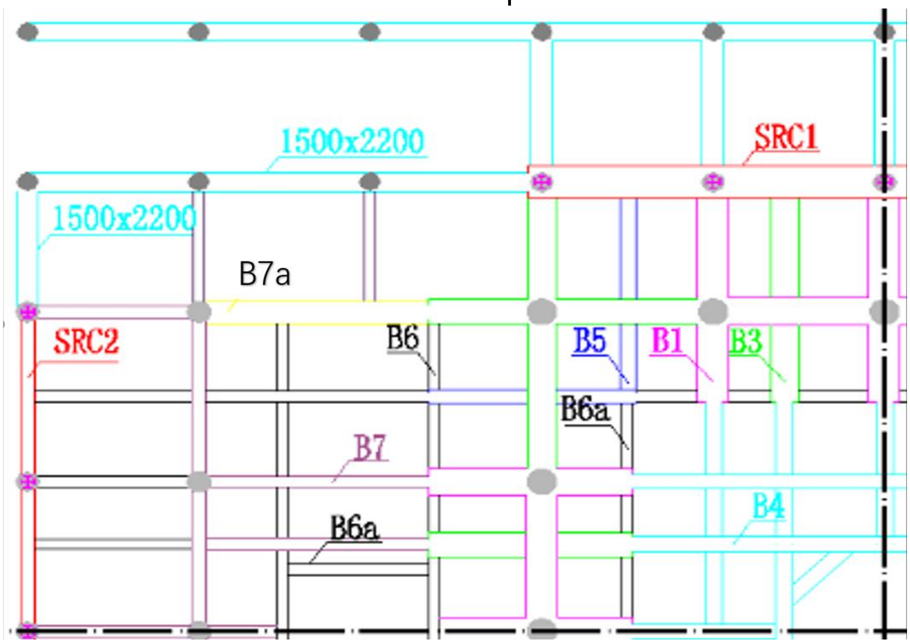
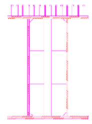
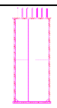
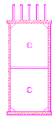


Figure 2-3 1/4 top beam distribution

Table 2-1 Structural form of top steel beam and steel bone beam

number	Beam type	Beam breadth (m)	High beam (m)	Top and Bottom Thicknes (mm)	The web thi-ckness(mm)	Cross section form
1	B1	2.2	2.8	80	45	
2	B3	2	2.8	50	45	
3	B7a	1.8	2.4	60	40	
4	B4	1.14	2.6	45	45	
5	B5	1.14	1.8	60	40	
6	B6	0.84	1.8	60	40	
7	B6a	0.84	1.6	60	40	
8	B7	0.94	1.8	80	45	
9	SRC1	1	2.8	60	60	
10	SRC2	0.5	1.8	60	40	

There are three types of large span columns in the atrium: concrete filled steel tube column (PC), steel reinforced concrete composite column (SRCC) and reinforced concrete column (Z). Due to the atrium scope of large-span structure all the top column span is too big, not a construction forming, and the late could dismantle steel and also built Cai tian bridge for large-span structure also has a great influence, in order to guarantee the safety of the structure before molding, using temporary steel support in bottom of steel beam, temporary steel support consists of the servo system in place to ensure that the late synchronous unloading. FIG. 2-6 is a schematic diagram of the layout of the columns and temporary support columns in the large span of the atrium. As shown in the figure, around the column-free range of the atrium, =2m concrete filled steel tube column is adopted, denoted as PC1, with a total of 16 columns. concrete filled steel tube column, denoting PC2, a total of 10 in east and west side span;φ=1.6m teel composite column, denoting as SRCC1, a total of 20 in south and north; The remaining nodes adopt =1.4m reinforced concrete column, denoted as Z1. The concrete slab of the long-span atrium of Gang Sha Bei Comprehensive Junction adopts C35 concrete. The thickness of the concrete slab of S~N axis on the top floor is 60cm, and the rest is 90cm.

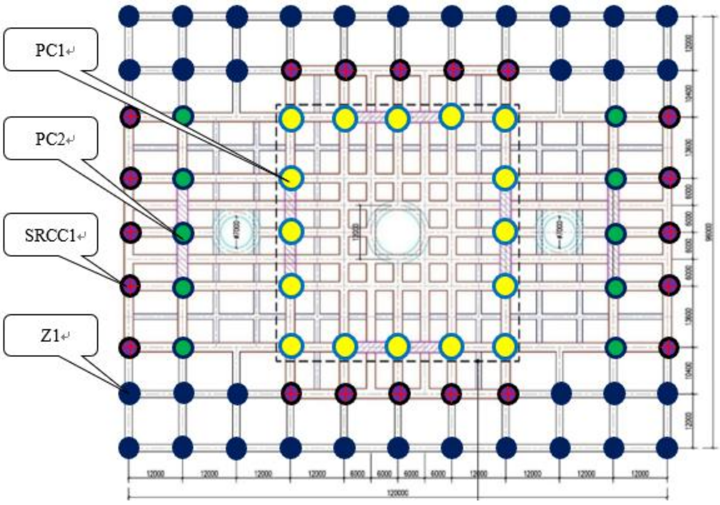


Figure 2-6a Structure column distribution plan

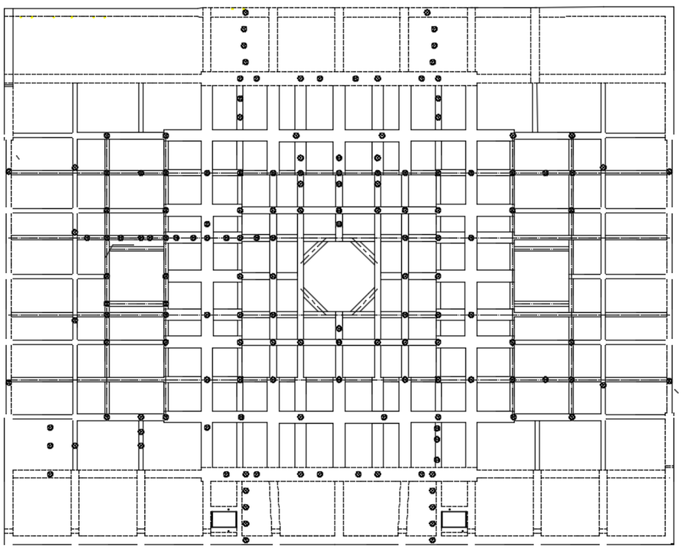


FIG. 2-6b Layout of temporary support column distribution

3. ESTABLISHMENT OF FINITE ELEMENT MODEL

Midas Civil was used to carry out finite element analysis on the large span structure of atrium, with a total of 31,281 nodes, 8907 beam unit and 27,343 plate units. Concrete slabs are dispersed by slab units, while concrete beams, steel beams, temporary bracing beams and structural columns are dispersed by beam units. Fixed boundary is adopted for the bottom of all columns, fixed boundary is adopted for the beam and plate on the wall, and joint connection is adopted for the beam, column and plate. Figure 3-1 shows the large span finite element model of the atrium.

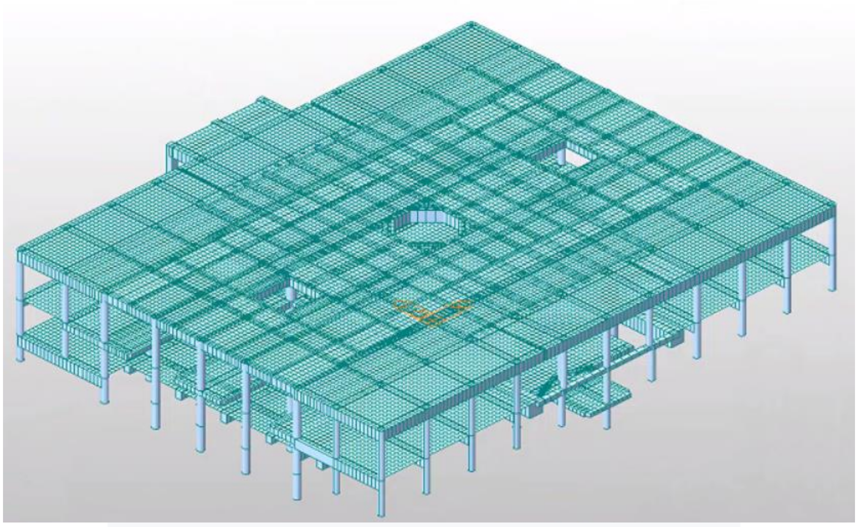


FIG. 3-1 Finite element model of large span atrium

According to the construction process, each construction condition is considered as shown in Table 3-1 below. Considering that there are many construction conditions, the most adverse conditions will be analyzed below.

Table 3-1 Construction conditions of the overall structure

condition	construction content	condition	construction content	condition	construction content
1	Construct minus 3 columns	2	Construct minus 2 layers of beams and slabs	3	Construct minus 2 columns
4	Construct minus 1 layers of beams and slabs	5	Construct negative 1 column	6	1-1-1 steel beam erection in the East and West district
7	1-1-2 steel beam erection in the East and West district	8	1-2-1 Erection of steel beam in the middle section	9	1-2-2 Erection of steel beam in the middle section
10	Construct 1-3 beam	11	Unloading west support	12	Unloading east support
13	Pouring west slab	14	Pouring east slab	15	Unloading central support
16	Pouring central slab	17	Pouring late poured band	18	Construct 2-1 beam
19	Construct 2-1 slab	20	Area 1 roof overburden	21	Construct 2-2 beam
22	Construct 2-2 slab	23	Rebuilt Cai tian bridge	24	Remove the steel bridge
25	Area 2 roof overburden	26	Construction accessory structure	27	Unload remaining supports

4. ANALYZE RESULTS

4.1 Analysis of overall calculation results

It can be seen from FIG. 4-1 that the initial nominal tensile stress of the concrete beam is about 2.7MPa at the beginning of working condition 2. After working condition 2, the nominal tensile stress of the concrete beam with negative two layers basically increases slowly. And reaches about 6MPa at the end of the structure forming. At the beginning of working condition 4, the construction of a negative layer concrete beam was completed, and the initial nominal tensile stress of the concrete beam was about 3.2MPa. After working condition 4, the nominal tensile stress of the concrete beam with negative layer basically increases slowly. And reaches about 6MPa after the structure is formed. At the beginning of working condition 10, the concrete beams of east-west axis 10 and 20 of the top floor begin to be poured. At this time, the concrete slabs on the concrete beams are not poured and the load of overburden is not applied, and the concrete beams are only affected by dead weight. The nominal stress of the concrete beams is basically within 1.2MPa. In working condition 15, after unloading the middle support, the middle part of the structure had some down-warping, leading to a significant reduction in nominal tensile stress of the concrete beams on both sides. Starting from working condition 21, pouring of concrete beams at the junction of north-south span and transition span was completed. Under working condition 23, the piers of Cai tian bridge were located on the north-south M and S axes, at which time the nominal tensile stress of the concrete beam increased by about 0.8MPa. Under working condition 25, the nominal tensile stress of the top concrete beam increased by about 2MPa under the influence of the overburden of the top concrete beam after the second construction. After unloading the remaining supports in working condition 27, the remaining supports are located on the concrete beam with north and south M and S axes of the top concrete beam, leading to an increase of about 1MPa in nominal large stress of the top concrete beam.

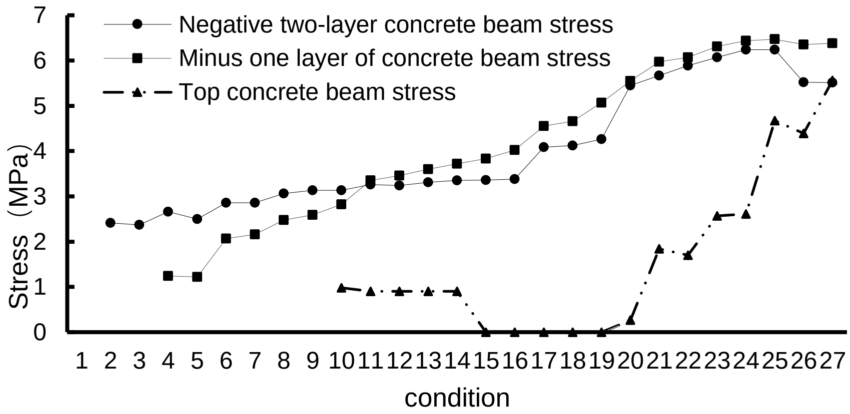


FIG. 4-1 Stress variation of concrete beams

It can be seen from FIG. 4-2 that the initial nominal tensile stress of the concrete slab is about 2.7MPa at the beginning of working condition 2. After working condition 2, the nominal tensile stress of the concrete slab with negative two layers basically increases slowly, and the nominal stress reaches about 6MPa after the structure is formed. At the beginning of working condition 4, the construction of a negative layer concrete beam was completed, and the initial nominal tensile stress of the concrete beam was about 3.2MPa.After working condition 4, the nominal growth of the negative layer of concrete slab is basically slow, and the nominal stress reaches about 6MPa after the structure is formed. Working condition 13 The concrete slab at the east and west sides of the top floor is poured and the initial stress of the concrete slab is about 1.1MPa.In working condition 16, after pouring the middle concrete slab, the maximum nominal tensile stress of the concrete slab is transferred to the middle concrete slab due to the large span of the middle area, and then the nominal tensile stress of the concrete slab reaches 1.5MPa.Since then, due to the construction scope is not on the top plate, the nominal tensile stress of the concrete plate does not change much. When the top plate is covered with soil in the first section of working condition 20, the concrete plate is subject to a great uniformly distributed load, and the nominal tensile stress increases to 3.5MPa, which is 102% higher than that in working condition 19, and the subsequent working condition basically remains at about 3.5MPa.

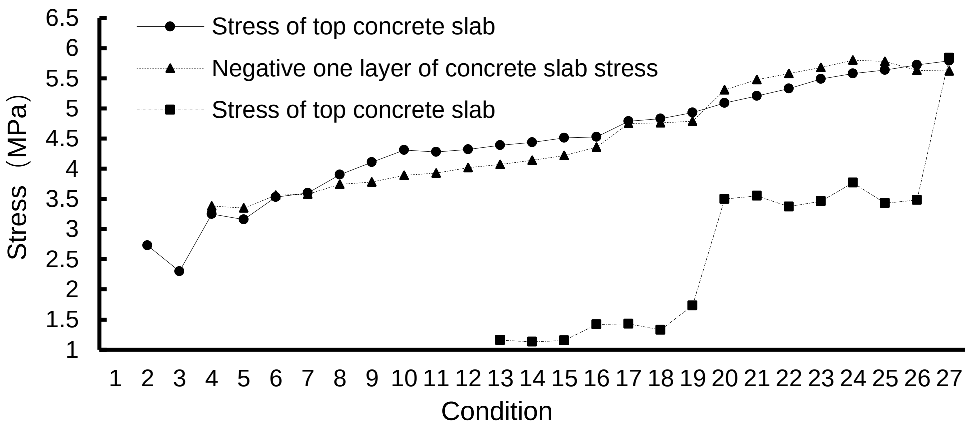


FIG. 4-2 Stress variation of concrete slabs

It can be seen from FIG. 4-3 that in working condition 1, the structure column is lifted to the specified position. At this time, it is only affected by the structural dead weight and the axial force is less than 500kN.Under working conditions 2 and 4, the concrete beams and slabs with negative two layers and negative one layer were respectively poured, and the axial force of the structural column increased by a total of 7000kN.Up to working condition 5, the axial force of the structural column is 8000kN.Working Condition 6-10 The top steel beam assumes that the axial force of the structural column increases slowly.

Due to the small weight of the steel beam, the increase of axial force of the structural column is also small, with a total increase of about 2000kN.Working condition 11 unloading things to temporary support, the axial force of the structural column increased by about 2200kN.In working conditions 13 and 14, when pouring the concrete slabs on the east and west sides, the load on the upper part of the structural columns increased significantly, and the axial force of the structural columns reached 17,000kN, which increased by 40,000kN compared with working conditions 12.Under working condition 15, the middle concrete support is unloaded, so the structure within the range of one zone is all supported by the structural column, and the axial force of the structural column reaches 19800kN.In working condition 16, casting of the central concrete slab and casting belt in working condition 17 will significantly increase the axial force of the structural column, and in working condition 17, the axial force of the structural column reaches 23,800kN.Under working conditions 18 and 19, the south transition span structure was constructed, which had little influence on the central PC1 structural column, and the axial force of the structural column was basically unchanged. The working condition 20 was the roof overburden of zone 1, and the axial force of the structural column increased significantly, increasing by 81% to 43,000kN. After that, the removal of the steel bridge and the accessories of Cai tian bridge, the transformation of Shen nan Avenue had little impact on the structural column, and the maximum change was not more than 700kN.

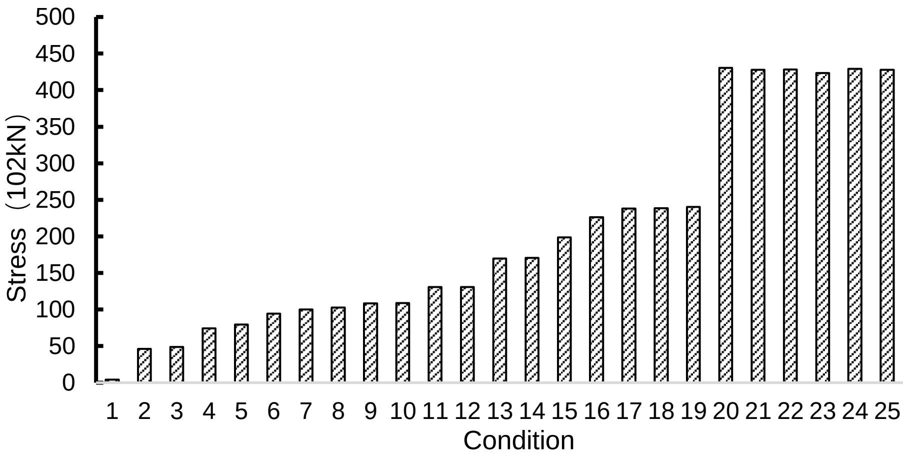


FIG. 4-3 Variation diagram of axial force of structural column

It can be seen from FIG. 4-4 and 4-5 that the erection of the steel beam under working condition 6 began and the erection of the steel beam under working condition 12 was completed, and the temporary supports on the east and west sides were unloaded. The stress of the steel beam was only 15MPa and the deformation was 4.7mm, indicating that the stress and deformation of the steel beam under dead weight were very small.

Under working conditions 13 and 14, the concrete slabs on the east and west sides were poured. The stress of the steel beam under the influence of concrete load increased to 29MPa and the deformation of the steel beam increased to 7mm.But working condition before 16, stress and deformation of the beam is small, working condition of 16 central pouring concrete slab and steel beam maximum deformation position from the west near the patio to the central courtyard, because the central span large, middle of concrete pouring has large on the deformation and stress of steel beam, the influence of steel girder stress had to 57 MPa, compared with 26 MPa of the working condition of 15, the growth of 119%, deformation to 23 mm, compared with 12 mm of the working condition of 15, a 92% increase. The casting of the post-cast belt and the construction of the south span have little influence on the middle steel beam. At working condition 20, the top layer of soil covering in zone 1 made the stress of the steel beam reach 129MPa and the deformation increase to 56mm. Compared with working condition 19, the stress increase reached 163% and the deformation increase reached 115%.After that, the stress and deformation of the steel beam will be reduced within the construction area 2 and the attached structure, and the final structural stress of the steel beam is 128MPa and the deformation is 53mm.

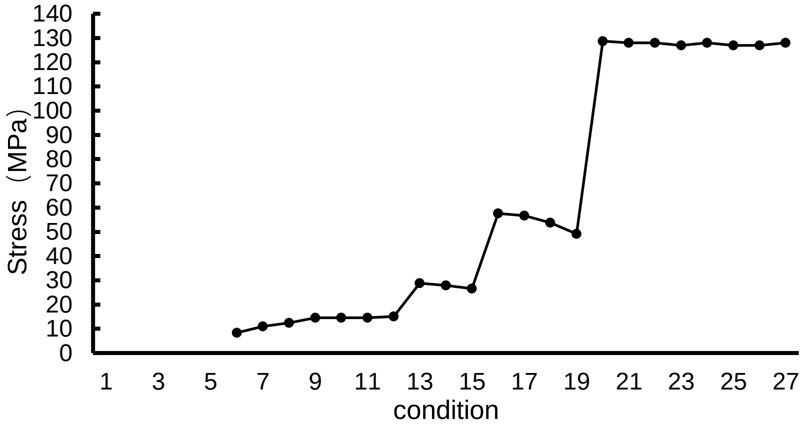


FIG. 4-4 Stress variation of steel beam

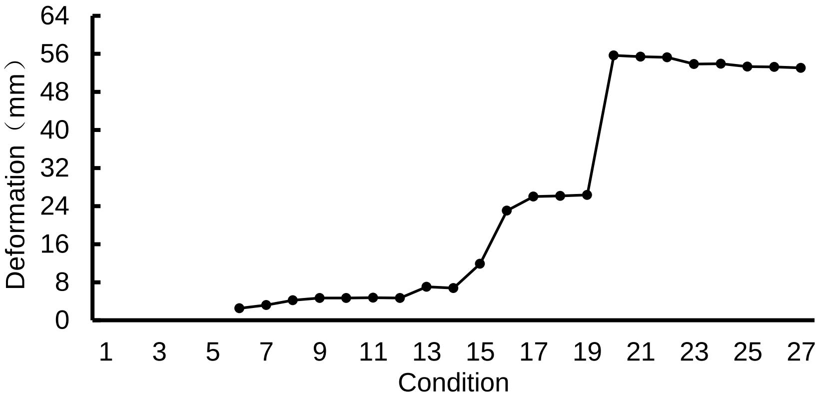


FIG. 4-5 Deformation diagram of steel beam

It can be seen from FIG. 4-3 that in working condition 1, the temporary support is lifted to the specified position, at this time, it is only affected by the structural dead weight, and the axial force is 22kN.In working conditions 2 and 4, the casting of the negative two floors and the negative one floor concrete beam and plate increases the temporary supporting axial force by 2335kN in total. In working conditions 5 to 8, the construction of the top steel beam has no influence on the maximum temporary supporting axial force basically due to the division erection of the steel beam. In working condition 10, the beam in zone 1-3 was constructed. The maximum axial force of temporary support occurred at the temporary support on the west side, and the beam in zone 1-3 had a significant influence on the temporary support. Working condition 11 is unloading the temporary support in the west area, and the maximum axial force position is transferred to the east side. Working condition 12 unloading the east temporary support, the maximum axial force transferred to the middle temporary support. Working conditions 13 and 14 are the concrete slab casting in the eastern and western regions, which has little influence on the axial force of the temporary support in the middle, and the axial force is basically unchanged. Working condition 15 is unloading the middle support, and the maximum axial force of temporary support is transferred to the t-axis of the north side. Under working conditions 16~ 20, construction in zone 1 is carried out, and the T-axis is located in zone 2. In this case, the temporary axial force is little affected by the construction, and the axial force is basically unchanged. Working condition 21 is the construction of the north span beam, and working condition 22 is the construction of the north span plate, both of which have a certain influence on the temporary support under the T-axis, making the temporary support axial force increase by 577kN in total, and the structural column axial force in working condition 22 is 2028kN. In working condition 23, Cai tian overpass was also built, and the Cai tian pier was located above the T-axis, making the temporary support axial force change significantly. Compared with working condition 22, the temporary support axial force increased by 996kN, an increase of 49%.In the working condition 25, the roof overburden was in the second zone. Compared with the working condition 24, the temporary bracing axial force increased by 523kN, an increase of 17%.

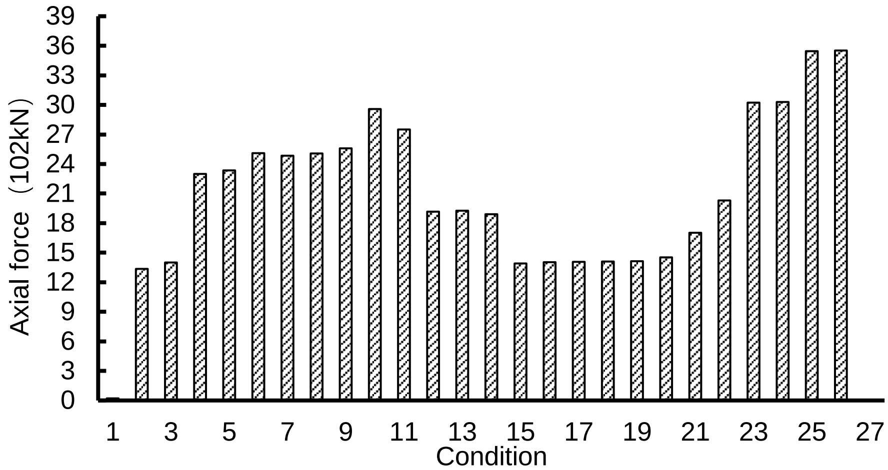


FIG. 4-6 Variation of temporary bracing axial force

4.2 The influence of different construction sequence on the most unfavorable working condition

For analyzing the impact of temporary support unloading on the structural stress, three plans are proposed for finite element analysis:

Plan 1: After the top concrete slab of zone 1 is poured and overburden is applied, the temporary support within zone 1 is unloaded.

Plan 2：After the top concrete slab casting in zone 1 is completed, the temporary support within zone 1 is unloaded, and then the top concrete slab covering in zone 1 is applied

Plan 3：After the erection of the steel beam is completed, the temporary support within the area 1 is unloaded, and then the top concrete slab of the area 1 is poured and covered with soil is applied.

For checking the security of the structure, the bearing capacity of three kinds of concrete structures is checked and the crack width at the maximum stress is calculated.

It can be seen from Table 4-1 that the stress of concrete beams in the three plans is basically the same, with the difference in stress not exceeding 2%. This is because the maximum stress of concrete beams occurs on the negative second floor, and whether temporary supports are properly unloaded has little impact on the formation structure. The maximum stress of the concrete slab occurs on the roof, so different unloading plans have obvious influences on the top concrete slab. The maximum bending moment of plan 3 is 279 kN·m compared with the maximum of the other two plans, which is about 40% of the bending moment calculated in plan 3, and the maximum shear force is 21kN compared with the maximum of the other two plans, which is about 5% of the calculated shear force in plan 3.It shows that different unloading plans have a great impact on the bending moment of the top plate, but the shear force of the plate is related to the load distribution on the plate, so different unloading plans have little impact on the shear force of the plate. It can be seen from Table 4-1 that option 3 is more reasonable.

Table 4-1 Checking calculation of bearing capacity of concrete structure in each plan

Plan \ Parameter		Calculated moment（kN·m)	flexural bearing capacity（kN·m)	Calculated moment（kN)	shear strength（kN)
Plan 1	Concrete slab	-984	2553	431	920
	Concrete beam	-8873	12189	3913	8377
Plan 2	Concrete slab	-887	2553	423	920
	Concrete beam	-8773	12189	3898	8377
Plan 3	Concrete slab	-705	2553	410	920
	Concrete beam	-8772	12189	3884	8377

As can be seen from Table 4-2, there is little difference in the stress of steel beams in the three plans. The maximum stress in plan 1 is -128.1MPa, and the maximum stress in plan 3 is -121.4, which is about 5% higher than that in plan 1.The deformation of the steel beam is 47.1mm in plan 1 and 54.2mm in Plan 3, which is about 15% larger than that in Plan 1.The maximum tensile stress on the top surface of the concrete slab in plan 1 is 1.3MPa higher than that in Plan 3, about 33% of that in Plan 3; the maximum tensile stress on the bottom surface of plan 1 is 0.7MPa higher than that in Plan 3, about 26% of that in Plan 3; the minimum crack width of plan 3 is 0.08mm; the maximum crack width of plan 1 is 0.11mm. Three kinds of plan comparison girder stress difference is not big, because the maximum compressive stress in the steel beam bottom, the maximum stress occurs at the PC1 structure column of steel beam bottom, the influence of different unloading plan of large structure column in the steel girder stress, but maximize beam stress is PC1 pillars supporting structure and different unloading plan can't clearly its stress difference. The maximum deformation of the steel beam occurred near the central patio. The earlier the temporary support was unloaded, the greater the deformation of the steel beam was. In the case of concrete, The concrete slab is unloaded, the smaller the crack width caused by the concrete stress. In conclusion, Different unloading plans have a great impact on the concrete slab. In addition, waterproofing of the top concrete slab should also be considered, and the structural cracks should be as small as possible. Therefore, the choice of Plan 3 is more reasonable.

Table 4-2 Stress, deformation, and concrete slab stress and crack width of the top steel beam after the structure is formed under different temporary support disassembly plans

Parameter / Plan	Stress of top concrete slab(MPa)		The steel beam stress (MPa)		Steel beam deformation (mm)	Crack width (mm)
	Topside tensile stress	Underside tensile stress	Top surface stress	The ground stress		
Plan 1	5.2	3.4	64.1/-70.0	101.4/-121.4	47.1	0.11
Plan 2	4.6	3.0	67.1/-75.0	106.7/-124.8	49.8	0.10
Plan 3	3.9	2.7	69.8/-82.5	106.2/-128.1	54.2	0.08

In addition, the paper also analyzed the different unloading plan without column range PC1 structure column axial compression, bending moment and the influence of lateral is small, can be seen from table 4-3 results, three different unloading plan has certain influence to the structure column stress, but the three plans on the structure of quantity is not more than 1 mm, lateral structure column axial force, bending moment has nothing to do with different unloading plan basic.

Table 4-3 Column deformation and maximum internal force of structure in column-free area of atrium under different temporary support disassembly plans

Parameter / Plan	The level of lateral (mm)		Minus one layer of axial pressure (kN)	Bending moment (kN·m)
	east-west direction	north-south direction		
Plan 1	0.36	0.46	-33219	22725
Plan 2	0.54	2.4	-33546	23433
Plan 3	0.94	3.34	-33977	24055

5. CONCLUSION

1. This paper conducts a finite element analysis of the structure of a subway station in Shenzhen, and analyzes the stress of each component in each working condition of the structure. The results show that the most unfavorable working condition is working condition 20 (covering soil within the first zone).Under working condition 20, the axial force of the structural column, the deformation of the steel beam and the stress of the steel beam all reach the maximum value, and the stress of the steel beam changes significantly before and after working condition 20. The stress of the steel beam reaches 129MPa and the deformation increases to 56mm. Compared with working condition 19, the stress increase reaches 163% and the deformation increase reaches 115%.The axial force of the structural column is 43000kN, which increases by 81%.The initial nominal tensile stress of the concrete structure with minus one layer and minus two layers is about 2.7MPa, which increases slowly with the working condition, and reaches about 6MPa after the structure is formed. The nominal tensile stress of the top concrete slab is 3.5MPa, which increases by 102% compared with the working condition of 19.The stress

of concrete beam structure increases with the construction progress, but the maximum stress state meets the requirements of flexural and shear capacity.

2. This paper analyzes the different unloading plan. Three unloading plans are considered, namely unloading temporary support after the assumption of the top steel beam is completed, unloading temporary support after the top concrete slab casting is completed, and unloading temporary support after the top concrete slab overburden is completed. Three schemes are simulated by finite element method The flexural and shear bearing of the concrete structure in the three plans are checked, and the bending moment, shear force, crack width of the top concrete slab, stress and deformation of steel beam, axial force of the structural column and bending moment of the structural column in the three plans are compared. Results show that different unloading plan of steel girder stress effect is very small, has a certain influence on deformation of steel beam, deformation of plan 3 is 15% more than plan 1, had a greater influence on the stress of concrete slab, the stress of plan 3 is 26% smaller than plan 1, the concrete slab crack of plan 3 is 37% smaller than plan 1, due to the deformation of steel beam in plan 3 is less than 6 cm, which less than the preset camber of 7 cm, so the plan comparison effect on top of concrete slab should be considered, at the same time the construction need to minimize the top concrete slab crack width, the final structure to plan 3 construction.

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