

Research on internal force of 3-D modeling of fish belly beam supported in foundation pit based on computer intelligent stress monitoring system

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Abstract. High prestressing force stiffness fish belly beam tool type combined internal support system, referred to as IPS construction method, is a new type of internal support structure system for deep foundation pit support, which is developed based on the principle of prestress and aiming at the shortcomings of traditional concrete internal support and steel support through a large number of engineering research and practical application, it is composed of fish belly beam (high-strength and low relaxation steel strand as the upper chord member. H-shaped steel as the stress beam, and H-shaped steel support beam with different length, butt brace, corner brace, column, cross beam, pull rod, triangular joint, preloading and jacking device and other standard components, and prestress is applied to form a plane restressed support system and three-dimensional structure system. Compared with the traditional concrete internal support and steel support, it greatly improves the overall stiffness and stability of the support system. Combined with the remote real-time monitoring system, it can effectively and accurately control the displacement of the foundation pit and greatly reduce the deformation of the foundation pit. This technology has made a major breakthrough in the internal support technology of deep foundation pit support. It is the most advanced internal support technology in the world. In this paper, a 3-D model of fish belly beam foundation pit support system is established completely, the stress characteristics of the support system are analysed by computer intelligent stress monitoring system, and the distribution areas of prestress and internal support stress are summarized, which can be used as a reference for this type of engineering experience in the future.

Keywords: computer intelligent stress monitoring; 3-D modeling; Fish belly beam; Foundation pit support; steel strand.

1. Introduction

Based on the measured data of foundation pit, the working mechanism and environmental impact of prefabricated prestressed fish belly beam support system are studied from three aspects [1], prestress control, deformation control and stiffness control. The results show that compared with the traditional internal support, the prestress applied to the retaining structure fully excites the passive earth pressure before the excavation of the foundation pit, which makes the retaining structure deform outside the pit, so as to greatly restrict the inward displacement [2-3]. The measured data shows that the overall deep displacement of the retaining structure is less than 10mm [4-6]. At the same time, fish belly beam supporting structure limits the deformation around the foundation pit by applying prestress to improve the apparent stiffness of the system, and the measured surface settlement does not exceed 18mm, reducing the impact of foundation pit excavation on the environment. In addition, in view of the stress concentration defect of the traditional internal support, the steel strand is overcome by the full-span reaction force of the support system, which shows that this construction method has a broad application prospect in deep foundation pit engineering [7-10].

In this paper, the modeling is carried out in strict accordance with the prototype size of the actual project, in which the purlin and web member adopt beam element, the diagonal brace, angle brace and diagonal web member adopt rod element, and the steel strand adopts tie rod only element [11].

Due to the large stiffness, the large triangular truss can be considered as a rigid region compared with a single H-shaped steel, so the large triangular truss adopts plane plate element. The biggest feature of fish belly beam support is that it can apply large prestress, but ordinary structural analysis software cannot apply prestress. Prestress needs to be applied in IPS support simulation in this project, so MIDAS / GTS is preferred for calculation [12-14]. The established support structure model is shown in Figs 1-2.

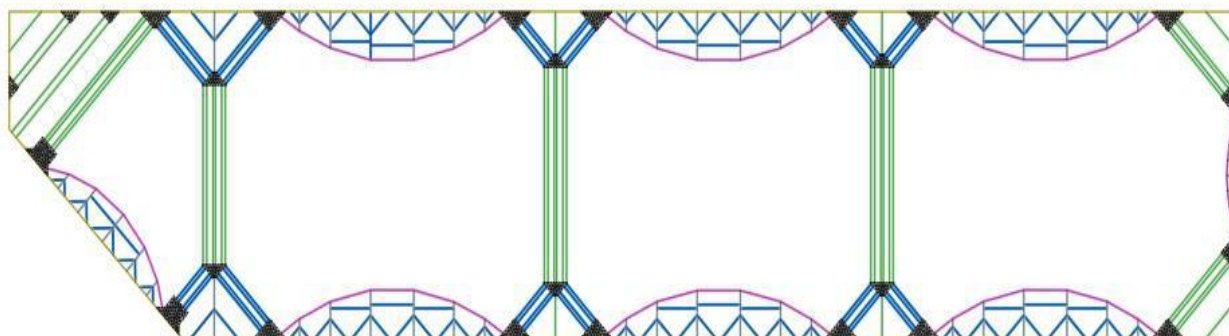


Figure 1. Fish belly beam foundation pit support system model.

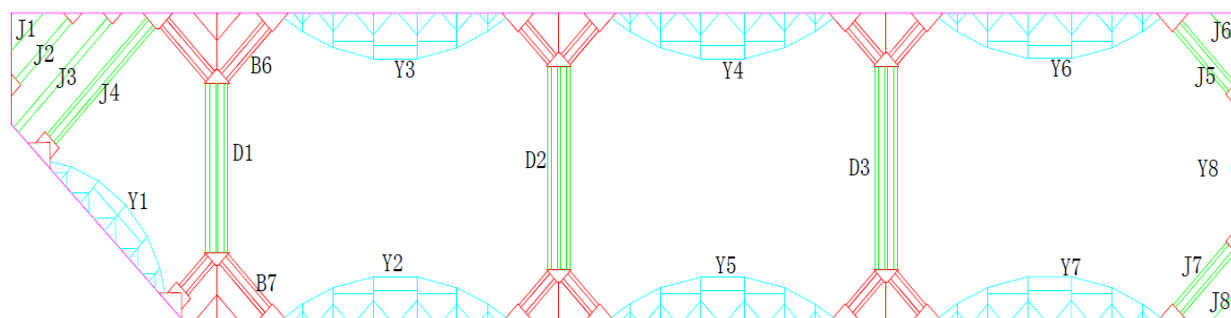


Figure 2. Model component numbering drawing.

2. Numerical model establishment and material component parameters

The surrounding soil is supported by the Structural wall deformation [15]. The characteristics of soil constraint on support are the elastic resistance acting on the retaining [16] wall below the excavation surface in the pit is related to the nature of soil layer, and is directly related to the time sequence of foundation pit excavation and support, with time-space effect. In the whole process of foundation pit excavation, the elastic resistance of soil is constantly changing [17].

In this calculation, it is considered that the distribution mode of elastic resistance is the elastic resistance at the excavation surface is zero, and the sub soil layer below the excavation surface is distributed according to the rectangular mode [18].

The coefficient of subgrade bed on the passive side of soil mass is calculated by "m" method, and the limit value of ultimate earth pressure is not considered for soil resistance; The elastic resistance of soil on the wall is simulated by the normal spring support of the wall, and the spring stiffness is calculated according to the stiffness calculated in the foundation pit specification. The diaphragm wall on one side of the completed subway platform is considered as a single structure, and there is no elastic resistance on the wall. During calculation, activate the spring bearing below the excavation surface and passivate the spring bearing above the excavation surface, and material parameters of foundation pit support components are shown in Table 1.

Table 1. Unit material parameter table.

Numble	Component type	Component material	Section size/mm	Modulus of elasticity/GPa	measure of area/m ²
1	Purlin	H-section steel	400×400	2.06	0.0172
2	Straight web member	H-section steel	350×350	2.06	0.0172
3	Oblique web member	H-section steel	350×350	2.06	0.0172
4	Symmetrical support	Steel pipe support	DN619	2.06	0.0067
5	steel strand	6 strand steel strands	Φ15.2	18.60	0.0085

The applied values of prestressing force of diagonal brace, angle brace and steel strand are shown in Table 2.

Table 2. Numerical calculation of member prestress.

Numble	Component number	Component type I	Component number	Component type II	Component type
1	J1-J4	260kN	Y1-Y4	5000kN	steel strand
2	J5-J8	1000kN	Y5-Y7	7500kN	steel strand
3	D1	700kN	Y8-Y9	6850kN	steel strand
4	D2	440kN	B1	4000kN	Symmetrical support
5	D3	1000kN	B2	500kN	Oblique web member

The numerical calculation is divided into three working conditions according to the installation sequence of prestressed fish beam combined steel support.

Working condition1: activate the grid group of supporting structure except steel strand, apply boundary earth pressure spring, and apply the prestress of opposite brace and angle brace.

Working condition 2: apply the prestress value of steel strand as shown in Table 2.

Working condition 3: earth pressure load is applied.

3. Analysis of stress characteristics of internal support of fish belly beam

It can be seen from Fig. 3 that the maximum displacement of the support structure is 27mm, and the maximum displacement point occurs at the feet of splayed brace B1 and B2, mainly in the Y direction, mainly due to the action of steel strand tension and earth pressure. The total displacement distribution of the supporting structure is: the displacement of the purlin in the middle of the fish belly beam and at the position of the large opposite brace and corner brace is small, which is mainly due to the result of controlling the deformation by applying prestress.

The displacement near the joint between the end of the fish belly beam and the corner brace is too large. For example, the displacement of the purlin at the connection between the fish belly beam Y7 and the corner brace J7 is 20mm, which is mainly due to the displacement of the purlin at the end of the web beam into the pit caused by the tensioning of the steel strand. The prestress applied by the corner brace and the lateral earth pressure transmitted from the corner brace can offset part of the displacement, However, it is not enough to offset the displacement of the purlin at the end of the fish belly beam towards the foundation pit caused by the tensioning of steel strands and the active earth pressure.

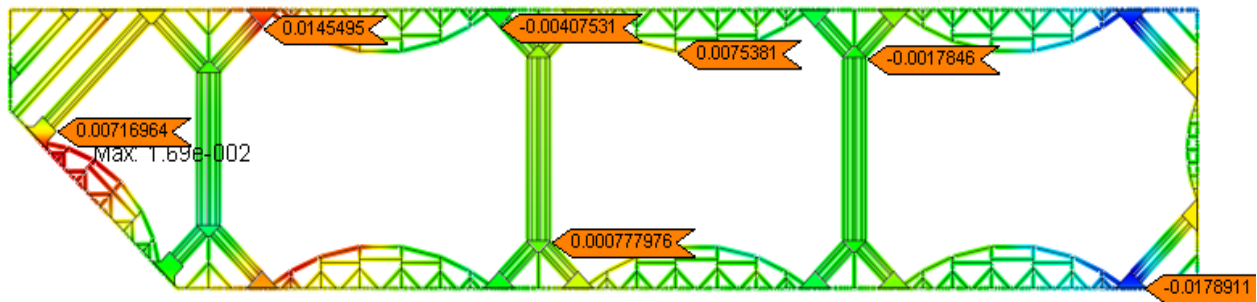


Figure 3. Displacement diagram of support structure in X direction (m).

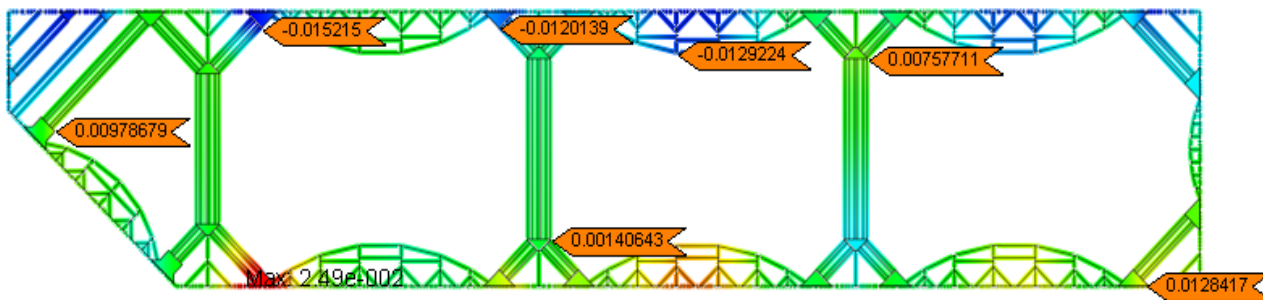


Figure 4. Displacement diagram of support structure in Y direction (m).

Moreover, when displacement of the purlin at the connection between the foot of the splayed brace B1 and B2 of the fish belly beam and the end Y2 and Y3 of the fish belly beam is too large, which is shown in figure 4. Simultaneously, where the reason is as mentioned above, because of the large displacement of steel strand tensioning and the active earth pressure entering the foundation pit.

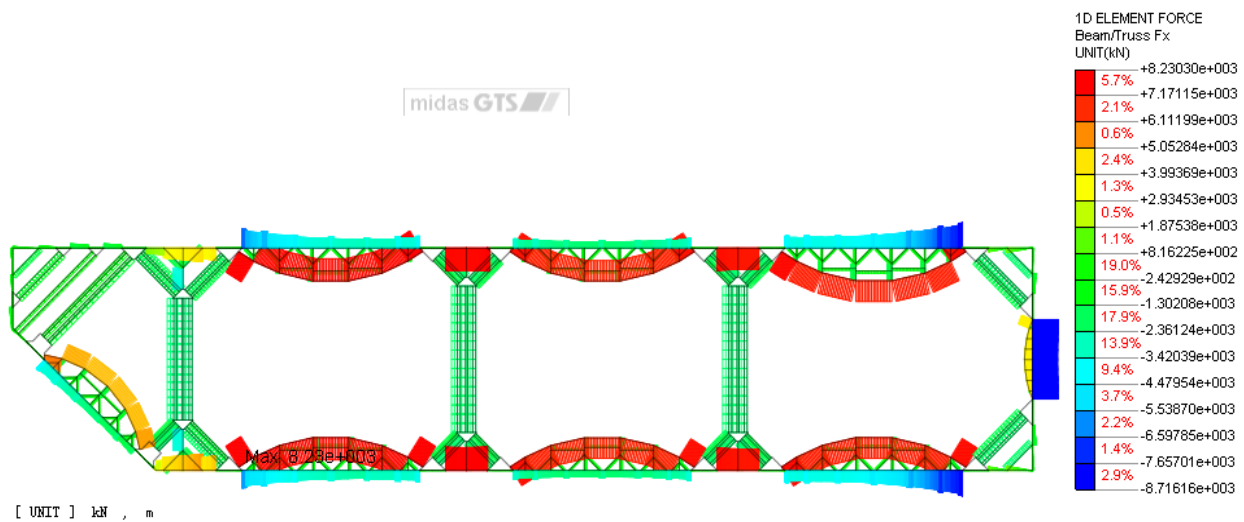


Figure 5. Axial force of internal supporting structure of fish belly beam (kN/m).

From the axial diagram shown in figure 5, it can be seen that the structural purlin, opposite brace and angle brace are only subject to large compressive axial force, and the steel strand is only subject to tensile axial force. Among them, the axial force of the purlin within the scope of fish belly beam is greater than that of other parts, because the tension of steel strand makes the stress of the purlin within the scope of fish belly beam too large.

According to the comparison of axial force, the axial force of steel strand does not change before and after the earth pressure, because the prestress value of steel strand is applied according to the axial force value of steel strand calculated when the earth pressure is applied, so the axial force value of steel strand will not change significantly after the earth pressure is applied. The advantage of pretensioning steel strand prestress is that it can effectively control the deformation of purlin.

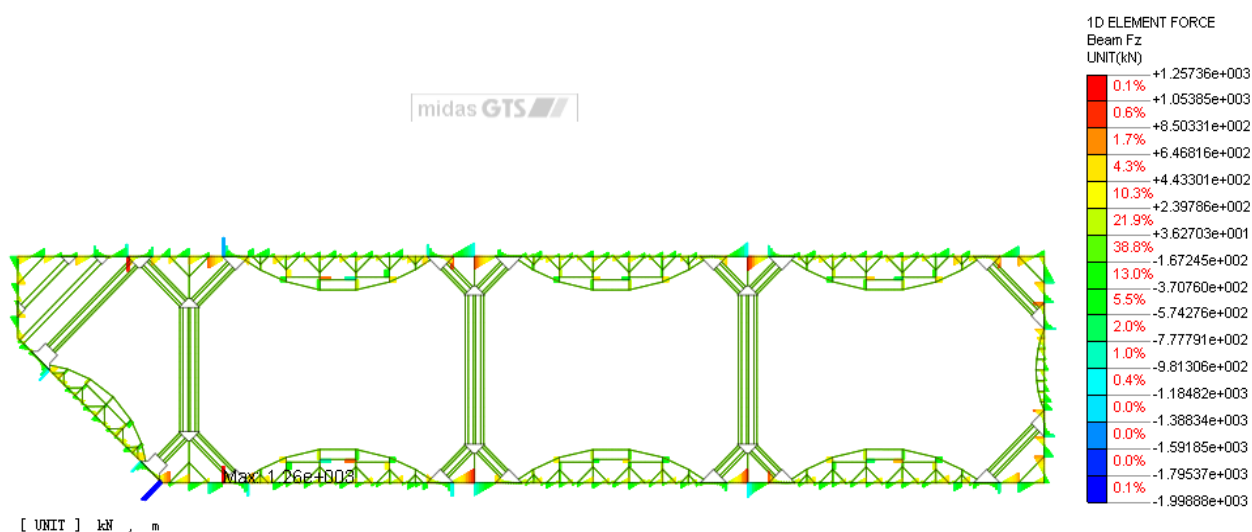


Figure 6. Bending moment diagram of internal support structure of fish belly beam (kN / m).

The common law of shear force and bending moment distribution is that the shear force and bending moment at the corner of the triangular rigid region of the opposite brace and corner brace and the connection point of the surrounding purlin deviate from each other, which is shown in figure 6.

It can be seen from the figure that the bending moment of opposite brace and angle brace is very small and mainly transmits axial force, which can be approximately regarded as a two-force rod. Because the steel strand is a rod element, there is no bending moment. The bending moment is mainly concentrated in the triangular parts at both ends of the opposite brace and corner brace, which is mainly caused by the transmission of axial force from the opposite brace and corner brace to the end. Compared with the plane numerical calculation model, the axial force calculated by the bending axis of the surrounding purlin is smaller. The reason is the same as above, that is, the purlin node is coupled with the wall element node, and the stiffness of the wall element is much greater than that of the purlin, and most of the bending moment transmitted to the purlin is absorbed by the wall element.

4. Conclusions

The prestressed fish belly beam support system successfully realizes the prestressing before foundation pit excavation, makes full use of the prestressing to stimulate the passive earth pressure, greatly limits the displacement of foundation pit support structure and reduces the impact of foundation pit engineering on the environment. The main conclusions are as follows:

1) The construction period of prestressed fish belly beam steel support is about 55.5% less than that of concrete support under the same conditions, with strong reusability and good economic benefits.

2) Compared with the traditional internal support, the prestress applied to the retaining structure during the action of the prestressed fish belly beam support system fully excites the passive earth pressure before the excavation of the foundation pit, deforms the retaining structure outside the pit, greatly restricts the inward displacement, and the overall deep displacement of the retaining structure is controlled within 10mm.

3) Finally, it is shown that fish belly beam support system with small stiffness combination limits the deformation around the foundation pit by applying prestress to improve the apparent stiffness of the system. The measured internal force of steel strand does not reach 35% of its material strength, which effectively controls the deformation impact of foundation pit excavation on the environment.

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