A new method of improving the pressure bearing capacity of the thin wall——prestress

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Abstract: Through calculation of the finite element software, we can get the thin wall's stress state during normal working. To constrain the displacement and improve the crack resistance of the wall width direction by the two ways of bonded and non-bonded prestressed concrete application form. Explore the working state of the prestressed concrete in the two different ways, and to analyse the influence of the prestress method on the ultimate bearing capacity of the wall. The results showed that, the two kinds of prestress method can improve the stress state of concrete and improve its ultimate bearing capacity. Compared with the method of bonding, the crack resistance of confined concrete in the width direction can be improved by using the non-bonded form. Finally improve the ultimate bearing capacity of the thin wall largely.

1. Foreword

Local compression is the stress state that only some of the area is under the surface of the component. Because the surface of the component is not uniform, the stress is concentrated, which makes the structure of the structure in the normal use state, the board of the first failure, eventually leading to the occurrence of the accident.

In order to prevent the occurrence of the above, the stress state of the concrete is improved by the method of prestress and the finite element analysis software is used to analyze the failure mode of the wall in the thickness direction.In the case of a certain pressure area, by comparing the difference of the normal working state of 100mm thin wall and prestressed constrained the working state of the failure mode, getting the improvement of ultimate bearing capacity by the method of prestress and post tensioning method, and analyzes the influence on bearing capacity of prestressed thin wall with different thickness limit.

2. Model building process

In this paper, the finite element software Ansys is used to build the model, due to the partial pressure of the thin wall, the modeling of the plate is close to the position of the pressure. The wall size is 500x100x800mm, concrete strength grade is C30, the axial pressure on the wall. The bearing area is 100x100mm, the load is 50MPa, and the bottom of the wall is completely fixed.Reinforced by prestressed steel wire diameter 5mm, 78.54mm2 area, steel plate size is 100x100x50mm. Thin wall modeling uses SOLID65 element. The yield criterion of Mises is used to reinforce the concrete plasticity. Link8 element is used for prestressed reinforcement. The plastic property of that is based in the bilinear model. The constitutive data are shown in Table 2. See Table 3 for specific material properties. Cooling method is adopted to apply prestress to prestressed bar, and the size of prestress is $\sigma_p = 0.7 f_{ptk} = 1302 MPa$ .The unit size of the grid is 0.05m.

Table 1 data table of concrete constitutive relations

Data points	Stress（N/mm^2）	Strain
1	1.3943	0.0001
2	3.9683	0.0003
3	7.293	0.0006
4	9.974	0.0009
5	12.012	0.0012
6	13.728	0.0016
7	14.3	0.002
8	14.3	0.0033

Table 2 data table of the constitutive relation of the prestressed rebar

Data points	Stress（N/mm^2）	Strain
1	487.5	0.0025
2	1581	0.01
3	1860	0.02

Table 3 material properties table

	Modulus of elasticity（N/mm^2）	Poisson's ratio	Elastic properties	Expansion coefficient
Concrete	29500	0.2	The same sex	
Steel plate	21000	0.3	The same sex	
Rebar	19500	0.3	The same sex	$1.2x10^{-5}$

3. Calculation results and analysis

3.1 Normal working condition of thin wall

Because the model described in this paper is a symmetrical model, the model is cut along the midline, easy to observe the internal stress distribution of thin wall. The results are as follows: the first principal stress, the third principal stress and the crack distribution of the wall are respectively. When the load is applied to 20.65t, the wall is destroyed. By the third principal stress cloud images can be seen, the maximum pressure stress of the wall is 16.458MPa, which is located in the region of the local load. Compared with the concrete strength grade, the concrete in this area is not the ultimate compressive strength, therefore, it is not destroyed. By the first principal stress contour can be seen, when the wall is broken, the maximum tensile stress in the wall is located on the two sides of the wall and the surface of the compression area. Thin wall under axial compression, on both sides of the bearing plane, the tension stress is caused by the deformation of the bearing. And then a small displacement is generated in the direction of the edges of the two sides. Finally, under the joint action of the tensile stress and the bottom boundary constraint condition of the wall, a strong tension stress is generated at both sides of the wall which near the top edge. In addition, the first principal stress and fracture distribution of thin wall can be seen, In the middle part of the thin wall, the concrete is composed of a letter "Y". At this time, the crack in concrete along the upper position of maximum tensile stress to the central region and then downward crack. This is because when the concrete partial pressure, its pressure stress along the middle of the line is inverted cone down, concrete in the internal space to form a "arch" to resist the pressure stress.Concrete in the lower middle area is in the space to bear the horizontal direction of the tensile stress [1], After the ultimate concrete reached the cracking load, the internal "arch" top of the compression split. The crack is formed in the lower middle part of the concrete, and then the "Y" type crack is formed, which leads to the failure of the thin wall of the [2].

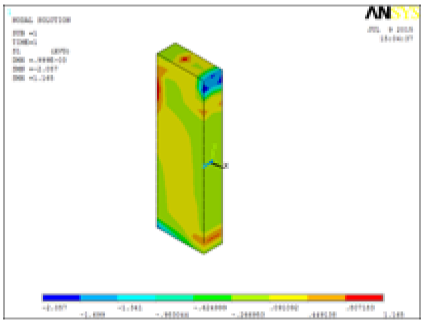

Fig. 1 the first principal stress contour of normal working state

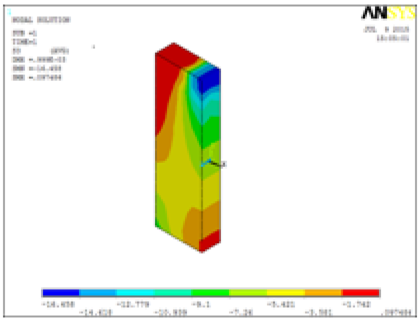

Fig. 2 the third principal stress contour of normal working state

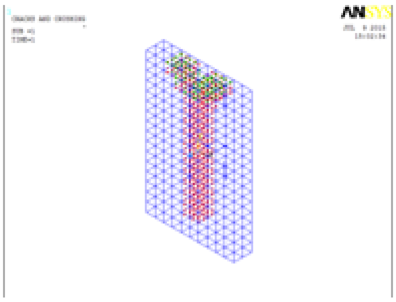

Fig. 3 crack distribution map

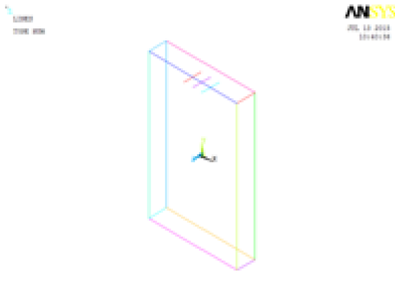

Fig. 4 Schematic diagram of the position of the prestressing rebar

3.2Working state of thin wall under the prestressed restraint of bond

Taking into account the actual situation of the project, it is difficult and not economical to apply prestress in the length direction of the wall. So this paper explores the influence of prestress on the width of the wall. Through the stress state analysis, If the location of the prestressed reinforcement is too large for the location of the wall, it will cause the application of the prestressed concrete to be pulled. In order to avoid this situation and let the pressure in the concrete into the three state of compression. Now in the thin wall, the distance between the top of the 50mm, wide 100mm compression area lays prestressed reinforcement with 3 50mm spacing by pretensioning system. Changing the stress state of the concrete in the confined area of the top. It is changed from one way pressure to three pressure, so that it can improve the local pressure bearing capacity. Prestressing rebar is applied with cooling method. According to the formula $\Delta T = -\frac{\sigma}{\alpha E}$ (α -the expansion coefficient of prestressed steel bar, E -the elastic modulus of prestressed steel bar). Get $\Delta T = -334$℃. The bond strength between the prestress steel bar and concrete is realized by combining the joint. The position of the prestressed reinforcement is shown in Figure 4.

The calculation results are shown in the following figure. The first principal stress cloud, the third principal stress and crack distribution of the thin wall under the restraint of the bond.When the load is applied to 25.93t, the wall is destroyed.Compared with the normal working state, the ultimate bearing capacity of the lifting of the 25.57%, can enhance the effectiveness of the obviously. By the third principal stress cloud can be seen, when the wall is destroyed, the maximum pressure stress on the wall is still in the local area. Combined fracture distribution map, the maximum tensile stress of the concrete under the action of load and prestressing force is 34.02MPa,which reaches the concrete compressive strength. Concrete has been crushed and more cracks in the confined area. From the first principal stress cloud can be seen, under the strong restraint of prestressed tendons, the confined area concrete has a small displacement in the direction of Z axis. At the same time, the confined area of concrete is also effected of the load on Y axis. That makes the top pressure area on both sides of the thin wall concrete become a two-way tension state from the one-way tension state of normal working. And then the large area of concrete in the thin wall has cracks. Because as a result of the bonding method in the application of prestress mainly rely on the bond between the steel and concrete, each of the prestressed steel bars can only be in a small range to have a "restrict" effects on the surrounding concrete. Finally, the concrete of the bearing is also produced a lot of cracks. In the X direction, the stress state is not changed. Because of that, the lower part of the concrete is still in the direction of the X into the "arch" to bear the force transmitted by the upper part. So the concrete is still in the middle of the line to produce vertical cracks. But due to the ultimate load becomes large, many concrete to achieve cracking load, so the cracks increased.

3.3Working state of thin wall under the prestressed restraint of non bond

By way of unbonded prestressing the thin wall, the layout of prestressed reinforcement is the same as that of the first one. Both ends of the steel plate anchorage model, see below.

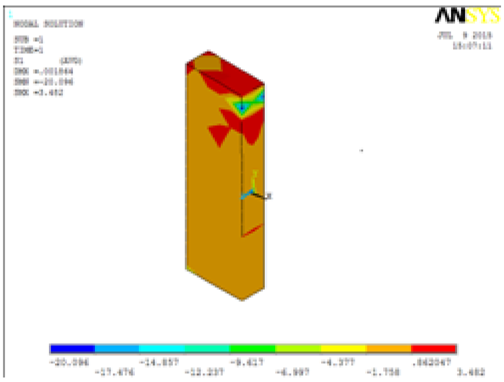

Fig. 5 the first principal stress contour of the bonded prestress

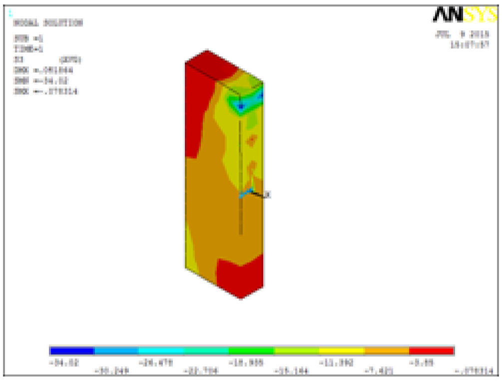

Fig. 6 the third principal stress contour of the bonded prestress

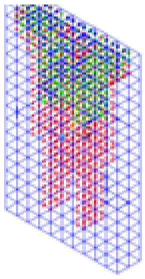

Fig. 7 crack distribution map

The calculation results are shown in the following figure. The first principal stress cloud, the third principal stress and crack distribution of the wall under the non binding prestress. When the load is applied to 34t, the wall is destroyed. The ultimate bearing capacity of the normal working state is increased by 64.64%, and the ultimate load bearing capacity of the wall can be greatly improved by using the non bonding method. From the third principal stress cloud can be seen that because of the thin wall at both ends of the steel plate in prestressed constraints on wall under local compression area of concrete has a strong restriction on the Z direction. Because the steel plate effect area obviously than that of bonded prestressed concrete large alone. The compression zone of concrete is influenced by the stress of Y and Z in two directions, and the boundary conditions of the X direction, the ultimate load bearing capacity of the wall is increased by three. The failure when the maximum compressive stress is 53.275MPa, is located in the area near the center of bearing steel plate position. Combined with the first principal stress cloud and crack distribution diagram shows , due to steel plate in prestressed transfer more evenly, thus making regional confined concrete in good stress state. The maximum tensile stress in the wall is 2.846MPa, which is located at the top of the four corners of the confined region. Concrete here were to bear by local pressure load and prestressed steel plate on the X direction of tensile stress, crack first from here produced and downward diffusion. Due to the failure of the load and the prestress larger, more areas of thin wall is affected by tensile stress, and the cracks are carried out more. At the bottom of the concrete, the stress state of the concrete is not changed, still in the "arch" bear the force, because the ultimate bearing capacity, crack development gradually increased.

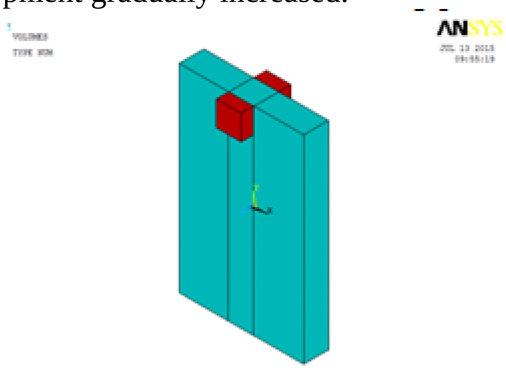

Fig. 8 schematic diagram of the model

4. Conclusions

(1)The ultimate load bearing capacity of the wall is improved by using the method of bonding and non bonding. The ultimate carrying capacity of these two modes are 34t and 25.93t, the lifting ratio is 25.57% and 64.64%. Both of the two methods have a greater contribution to the pressure bearing capacity of the wall, and the way of non bonding is better.

(2)The bonded prestress due to restrictions, can not make the concrete confined area under uniform pressure stress. In comparison with that, the stress state of the confined concrete can be improved by applying prestress of non bonding, which can improve the bearing capacity of the concrete better.

(3)The two kind of application of prestress increases the crack resistance of concrete in the upper bearing area, but can not improve in the lower part. With the gradual increase of the ultimate load, the crack of the bottom concrete will increase gradually.

(4) Whether the thin wall prestressed or not, the weak position is on both sides of the confined area .

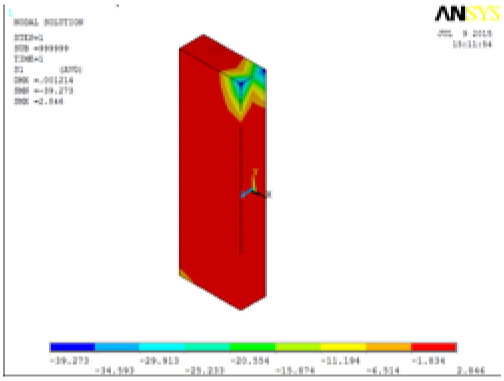

Fig. 9 the first principal stress contour of the non bonded prestress

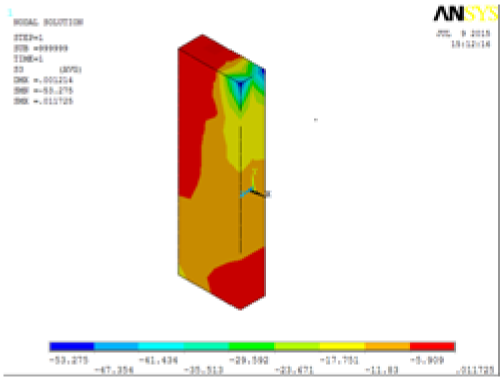

Fig. 10 the third principal stress contour of the non bonded prestress

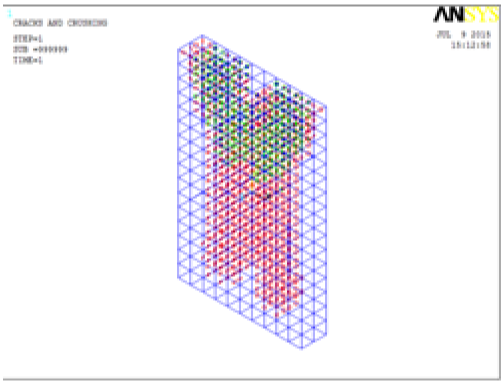

Fig. 11 crack distribution map

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