Test Study on Slipping Performance of the Flexible Nodes of the Precast Concrete Exterior Wall Cladding Panel

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Abstract. To explore the performance of the flexible nodes between the precast concrete exterior wall cladding panel and the frame structure, a steel truss is used as an analogue of the frame structure to develop a test. In the test, one precast concrete exterior wall cladding panel was installed on the steel truss, and the connection nodes are designed to be able to slip vertically. Different horizontal forces were exerted on the steel truss to form certain drifts, and the deformation of panel and the slipping performance of the connection nodes were explored. It is found that precast concrete exterior wall cladding panel won't deform under the influence of the drifts, while the connection nodes between the frame structure and the panel were found to slip. The results show that the design of slipping connection node has enough reliability.

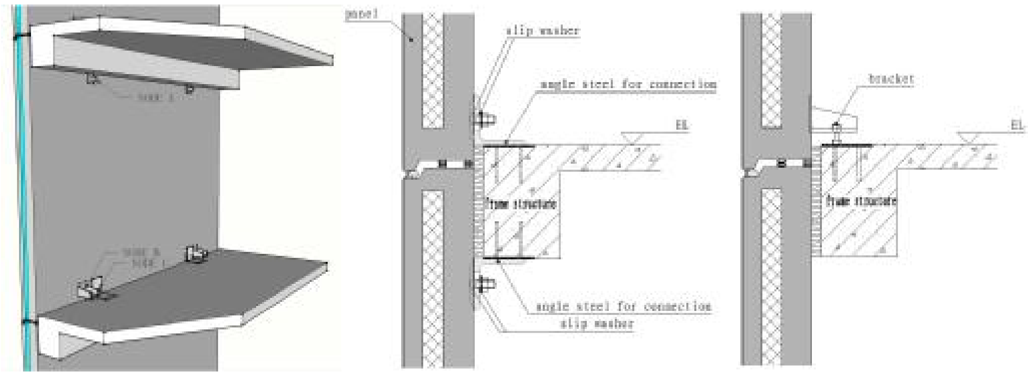
Introduction

Due to the advantages on energy saving, environmental protection, and convenient installation, concrete curtain wall has been applied more and more widely, and it has been an alternative curtain wall with envelope performance and decoration function after the glass curtain wall [1]. The concrete curtain wall is composed of a number of rigid concrete exterior wall cladding panels. Similar to glass curtain wall, there are several types of connections between the panels and the frame structure for concrete curtain wall [2]. Within these types, the vertical slipping connection has been widely applied especially in developed countries. However there is a lack of related study on the test of its reliability under the manufacturing level in China. The objective of this study is to explore the deformation of panel and the slipping performance of the connection nodes under the influence of the inter-story drift.

Fig.1 the concrete curtain wall project of Tianjin Vanke Donglihu

Testing plan

The height of the panel is 2900, it equals to the story height of the frame structure. The width of the panel is 3900, it equals to the column space. How the panel connecting with the frame structure is as follows: there are two vertical nodes at the bottom of the panel (the space is 2480), they are supported on the bottom-beam of the frame structure, there are two horizontal nodes at the top of the panel, and so does the bottom of the panel (the space is 2080). They are connected with the beam. When the frame structure deform, the node displace and the panel rotate (refer to Fig.2). The panel rotate to the original position when deform disappear, so the panel do not crack. The displacement is designed to be less than the one-one hundred of the story height according to the current code [3, 4].



(a) Installation diagram (b) Node a, c (c)Node b

Fig.2 Installation diagram and nodes detail

Testing Device

The schematic diagram of testing device is shown in Fig. 4. The device photo is shown in Fig.5. The device consisted of a steel truss, a piece of exterior wall cladding panel, a jack and several measuring instruments [5].

The upper beam of the steel truss was fixed, and the lower beam was hanged under the upper beam by the parallel rod and the hinged-support, the space between the upper beam and the lower beam is 2900, the lower beam can be movable to left or right by a jack. The exterior wall cladding panel was installed on the frame structure. The relative shift two beam, the rotated displacement of the wall panel and the displacement of the node are going to be measured (refer to Fig.3 4).

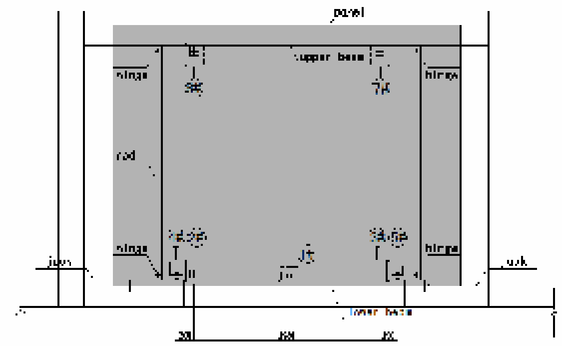


Fig. 3 The device of the testing

Fig.4 The device on site

Testing Process

The tests were performed using the following procedure. First the lower beam was been pushed by the jack to one direction (left of right), the relative shift of two beam is as follows: 1/400,1/300,1/250,1/200,1/150,1/125,1/100,1/85,1/75, there are totally 9 level, it was pushed back to the original position after 10 minutes later for every level.

The rotational displacement of the panel was recorded, as well the force of the jack. The displacement of every node was observed as well. (Refer to Fig.5,6,7)

Fig.5 Device debugging

Fig.6 Load and record

Fig.7 Observe and note

Testing Result and Analysis

Table 1 shows that the horizontal displacement of 1# position caused the vertical displacement of 2#, 3# and 5# when the lower beam was pushed to the right, Table 2 shows the same things when the lower beam was pushed to the left. The calculate value is calculated by Eq.1.

$$y_2 = \sqrt{2538^2 - (200 - x)^2} - \sqrt{2485^2 - x^2} - 45$$

$$y_3 = y_2 + 2080 \times tgq \qquad (1)$$

$$y_5 = y_2 + 2280 \times tgq$$

In equation:

x —horizontal displacement of No. 1#
y_2 —vertical displacement of No. 2#
y_3 —vertical displacement of No. 3#
y_5 —vertical displacement of No. 5#
θ — rotate angle of the panel

Table 1 Displacement of nodes(load from left to right)

Load Level	**1# (Horizontal) [mm]**	**2#(Vertical) [mm]**		**3#(Vertical) [mm]**		**5#(Vertical) [mm]**	
		Calculate Value	Testing Value	Calculate Value	Testing Value	Calculate Value	Testing Value
1th	+7.30	-0.15	+0.01	+0.09	+0.10	+0.24	+0.26
2th	+9.75	-0.19	+0.01	+0.13	+0.15	+0.33	+0.29
3th	+11.64	-0.22	+0.02	+0.19	+0.21	+0.39	+0.38
4th	+14.55	-0.12	+0.03	+2.85	+2.83	+3.27	+3.22
5th	+19.44	+0.17	+0.15	+7.08	+7.11	+7.84	+7.65
6th	+23.27	+0.42	+0.40	+10.57	+10.62	+11.51	+11.55
7th	+29.05	+0.86	+0.90	+15.78	+15.87	+17.30	+17.56
8th	+34.22	+1.23	+1.25	+20.33	+20.32	+22.33	+20.45
9th	+38.80	+1.54	+1.62	+24.31	+24.33	+26.78	+25.99

Table 2 Displacement of nodes (load from left to right)

Load Level	**1# (Horizontal) [mm]**	**2#(Vertical) [mm]**		**3#(Vertical) [mm]**		**4#(Vertical) [mm]**	
		Calculate Value	Testing Value	Calculate Value	Testing Value	Calculate Value	Calculate Value
1th	+7.28	-0.02	-0.02	+0.35	+0.33	+0.24	+0.24
2th	+9.73	-0.19	+0.02	+1.52	+1.64	+1.56	+1.72
3th	+11.70	+0.12	+0.10	+3.55	+3.15	+3.55	+3.41
4th	+14.65	+0.26	+0.25	+5.50	+5.48	+5.27	+5.97
5th	+19.38	+0.55	+0.53	+9.38	+9.39	+10.84	+10.23
6th	+23.28	+0.78	+0.82	+12.77	+12.78	+13.51	+13.90
7th	+29.07	+1.28	+1.29	+18.12	+17.89	+19.30	+19.50
8th	+34.21	+1.87	+1.71	+20.33	+22.62	+24.33	+24.66
9th	+38.80	+2.15	+2.07	+24.31	+26.69	+28.78	+29.12

It is + when the direction of horizontal displacement is the same as the load direction; the vertical displacement is + when it is upper ward and it is – when it is downward. The exact position of the every testing point (refer to the Fig.3).

Thus, referring to Table 1 and Table 2, it is observed that all the vertical displacement was increase when the horizontal displacement was increase, and the testing value was almost same as the calculate value (refer to the Fig.8).

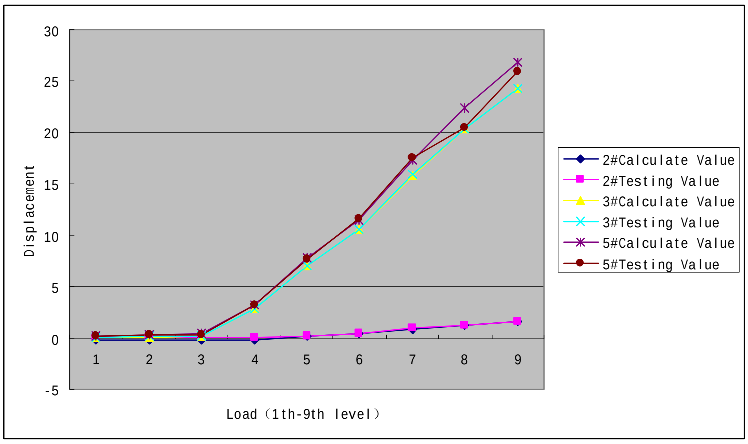
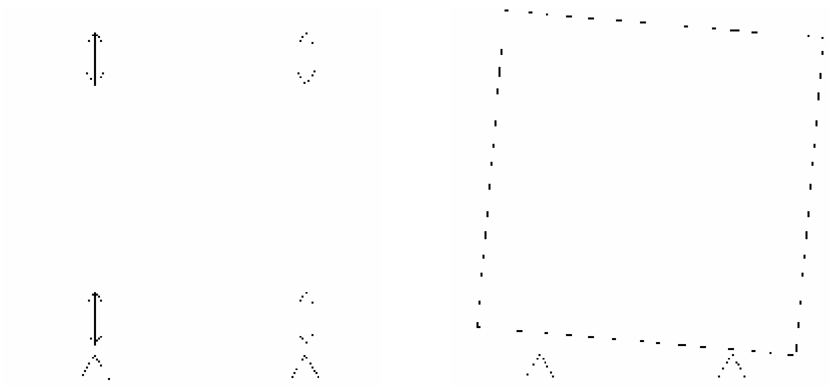


Fig.8 Comparison between calculate value and testing value

These finding are understandable because the panel's rigidity is big enough so it cannot move under the influence of the displacement of the frame structure, while the connection nodes slip with it (refer to the Fig.9). It appears that the panel do not exert on the frame structure because its node has been designed to be one that can be slip.



(a)The nodes slip vertically (b)The panel rotated

Fig.9 Diagram showing the move way of the nodes and panel

Conclusion

Nine-level displacements between two storeys were formed from 1/400 to 1/75 under the influence of loads exerted on the lower beam of the frame structure. As a result, the panel rotates in plane in the whole test process, and there is no deforming crack found in the panel, besides all four nodes appeared to slip vertically. While the displacements disappeared, the panel and the nodes recovered. It is concluded that the design can well meet the requirements of the code for design of concrete structure. This study will provide a test basis for the design of the concrete curtain wall.

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