International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 10 ǁ October 2022 ǁ PP. 251-256

Study on mechanical properties of cast-in-place pile ring beam joints

WangGangsheng,Li Jingfeng,Gao Ling,Zhou Hang
(University of Shanghai for Science and Technology，Shanghai 200093，China)

Abstract
In order to study the reliability of the interface between cast-in-place pile and ring beam and the mechanical performance of the ring beam joint, the static loading method was used to conduct the test in the field. The reliability of the interface was verified and the mechanical performance of the cast-in-place pile ring beam joint was analyzed by measuring the reinforcement strain, the displacement of cross beam and ring beam and the crack development process at different positions under different levels of load. The analysis shows that the interface of the cast-in-place pile ring beam joint with roughening treatment does not slip obviously, the interface connection is reliable, the joint performance meets the engineering needs, and the ultimate failure of the test piece occurs at the ring beam. The results of this test can provide a reference for the study of the connection performance of the cast-in-place pile ring beam joint with the interface roughening treatment, and promote the engineering application of the beam column joint connection in the top-down pile column integration..

Keywords: *cast in placepilering; beam joint; gouging treatment; interfacemechanicalproperties; experimental study*

Date of Submission: 24-09-2022 Date of acceptance: 08-10-2022

I. INTRODUCTION

At present, under the background of urban renewal, the demand for adding basements under existing buildings is increasing. In the construction process, it is often necessary to carry out reverse construction of pile foundation. This process generally uses lattice column or steel pipe column inserted into cast-in-place pile to form a vertical support system, which requires high indoor clearance, especially in existing buildings. Therefore, we propose a "pile column integration" support structure system to solve the above problems. During the construction of the "pile column integration" structure, the joint design and construction must be carried out at the junction of the cast-in-place pile and the floor and the frame beam. Among them, the ring beam joints of concrete structure better meet the requirements of mechanical properties of joints, simplicity and economy of construction, and do not affect the appearance and use of buildings.

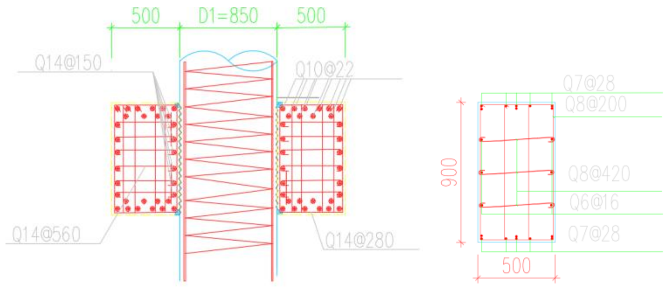
At present, the relevant research on ring beam joints is focused on concrete-filled steel tubular ring beam joints, and some achievements have been made [1-6]. However, most of the researches are focused on the mechanical performance and seismic performance of concrete-filled steel tubular ring beam joints, and there is no experimental study on the reliability and mechanical performance of cast-in-place pile ring beam joints. Therefore, it is necessary to carry out experimental research on the mechanical properties of cast-in-place pile ring beam joints to provide theoretical basis for the design of beam column joints in the pile column integration.

In order to study the reliability and mechanical properties of the interface between cast-in-place pile and ring beam after roughening the interface, a test piece of cast-in-place pile ring beam joint is designed according to the ratio of 1:1, and the static load test is carried out in the field. Through experimental observation of interface slip, reinforcement strain, displacement of ring beam and cross beam and crack development process, the strain and displacement changes of joints under different levels of load are analyzed, and the reliability and mechanical properties of joints are obtained by combining the crack bearing capacity, yield bearing capacity and ultimate bearing capacity of the specimens.

1.1 Experimental site

In this test, the parameters of the cast-in-place pile ring beam joint specimen with interface roughening treatment are as follows: the diameter D_1 of the cast-in-place pile is 0.85m, the diameter D_2 of the ring beam is 1.85M, and the height is 1.00m. Cross beam section dimension B × H is 0.5 × 0.9m^2。 The concrete strength grade is as follows: the cast-in-place pile is C40, the ring beam is C35, and the cross beam is C35.

See Fig. 1 for reinforcement of test piece.At the interface between the cast-in-place pile and the ring beam, the surface of the cast-in-place pile shall be chiseled by pneumatic impact drill until the mainreinforcement is exposed. After the chiseling is completed, the loose aggregate, gravel, scum and dust on the surface of the concrete of the original member shall be removed with tools such as steel wire brush, and washed with clean pressurized water. Then, the ring beam reinforcement shall be bound at the outer side for pouring. The specific connection mode is shown in Fig. 2.



（a）Ring beam reinforcement drawing （b）Cross beam reinforcement drawing

Figure.1reinforcement diagram of test piece

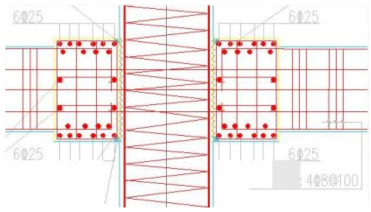


Figure.2 connection diagram of chiseling node

According to the standard for test methods of concrete structures (GB / t50152-2012), four groups of 200t hydraulic jacks are used to apply vertical upward and outward loads to the four cross beams and ring beams of the test piece. The four loading points are arranged at the lower edge of the cross beam 1m away from the outer side of the ring beam, as shown in Fig. 3.

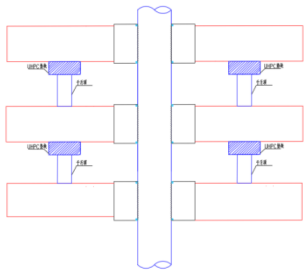


Figure3 Diagram of test device

This test is carried out according to 40t level I, loading step by step until the test piece is damaged. After the loading of each level of load is completed, the load holding time shall not be less than 20min, and the test phenomenon and test point data shall be observed and recorded.In the test, a total of 15 deformation observation points were arranged, and the displacement sensor with a range of 30mm was used to collect deformation data, as shown in Fig. 4. Among them, measuring points dp1-dp10 are used to observe the deformation law of ring beam and cross beam in tension area, and measuring points dp11-dp14 are used to observe the deformation of Jack bottom at the loading point. Dp15 is used to observe the deformation of the bottom of the reaction plate.

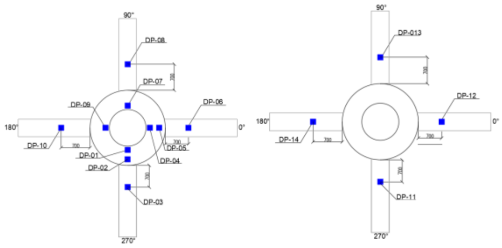
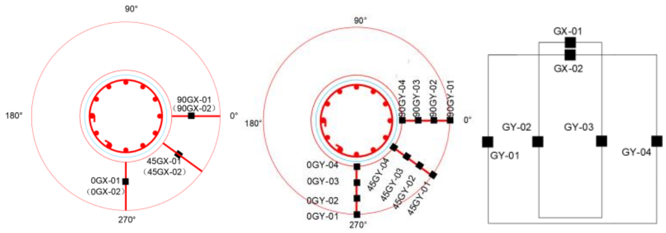
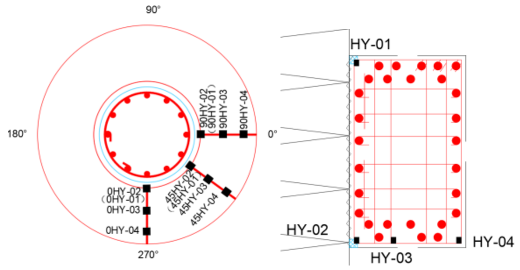


Figure 4 layout of deformation measuring points of test piece

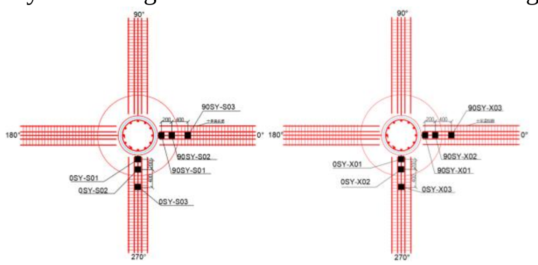
The arrangement of reinforcement strain measuring points of the test piece is shown in Figure 5 below.



（a）Layout of hoop beam stirrup strain



（b）Layout of longitudinal reinforcement strain of ring beam



（c）Layout of longitudinal reinforcement strain of cross beam

Figure 5 layout of reinforcement strain measuring points of test piece

II. RESULT AND DISCUSSION

2.1 Experimental results

When the test load of a single cross beam reaches 30t, the specimen is cracked, and multiple vertical micro cracks appear on the side of the cross beam, and multiple small vertical micro cracks appear at the lower part of the interface between the cross beam and the ring beam.

When the test load of a single cross beam reaches 40t, the radial cracks under tension begin to appear on the bottom surface of the ring beam, and the vertical micro cracks at the interface between the ring beam and the cross beam gradually increase. When the load is 50t, the vertical micro cracks at the interface between the ring beam and the cross beam begin to extend to the side of the ring beam, and the tensile transverse cracks appear at the bottom of the cross beam, and the tensile transverse cracks appear at the junction of the bottom of the ring beam and the pile body. Subsequently, the inclined cracks caused by torsion on the side of the ring beam gradually increased, and several shear inclined cracks appeared on the side of the cross beam.

When the test load of a single cross beam reaches 80t, the vertical crack at the interface between the ring beam and the cross beam reaches 0.206mm, the transverse crack appears at the bottom of the ring beam, the radial crack increases, and the tensile transverse crack appears at the middle of the side of the ring beam. Subsequently, the tensile transverse and radial cracks on the bottom surface of the ring beam increase, and the tensile radial cracks extend to the outside of the ring beam. The shear inclined crack on the side of cross beam continues to grow. The shear oblique cracks on both sides of the ring beam side intersect, and the vertical cracks at the interface between the ring beam and the cross beam and the transverse cracks at the bottom of the cross beam gradually become wider.

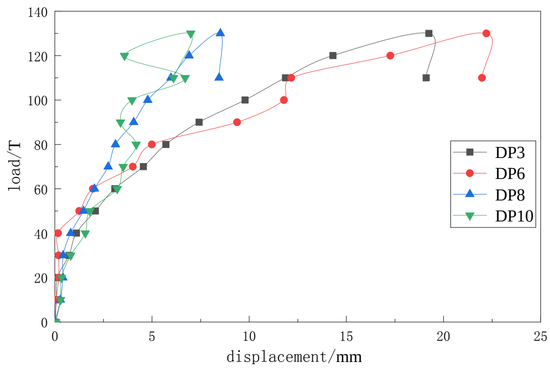
When a single cross beam is loaded from 120t to 130t, the load cannot be sustained. The final surface crack distribution of the test piece is as follows: the maximum transverse crack on the bottom of the ring beam reaches 2.300mm, and the radial crack reaches 1.100mm. The inclined crack near the lower edge of the junction between the ring beam side and the cross beam reaches 2.17mm. The transverse crack on the bottom surface of the cross beam reaches 1.248mm, and the oblique crack on the lower edge of the junction of the cross beam and the ring beam reaches 2.124mm. Since the maximum crack width on the concrete surface exceeds 1.5mm, it is determined that the test piece is damaged and the test is terminated

According to the observation, the concrete in the compression area of the test piece has not been crushed, and the interface between the ring beam and the cast-in-place pile has not significantly slipped. The settlement of the reaction plate in the experiment is very small and can be ignored. During the test, the change law of each quadrant of the test piece is similar, and the final failure mode of the test piece is shown in Fig. 6. Select any quadrant crack change to draw the final crack distribution diagram, as shown in Fig. 7.

Figure. 6 final failure mode of test piece

2.2Analysis of experimental results

As shown in Fig.7, the displacement changes of the four cross beams are slightly different, mainly showing that the displacement changes of 90 ° and 180 ° , 0 ° and 270 ° cross beams are similar. Before 30t, the load deflection of cross beam changes linearly. Then it increasesnonlinearly with the increase of load. Finally, after the 120t failure load is reached, the maximum deformation at the cross beam measuring point reaches about20mm..



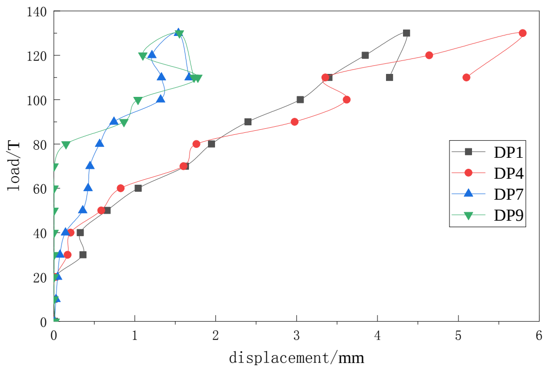


Figure.7 load deflection curve of cross beamFigure.8 load-displacement curve of joint surface

As shown in Figure89 above, the load displacement difference of the four cross beams at the joint surface of cast-in-place pile ring beam is the same as the displacement of the cross beam, which indicates that the whole member is slightly inclined during the actual test and is not completely at the original horizontal plane. The overall displacement at the joint surface is small, and the maximum displacement is about 5mm.

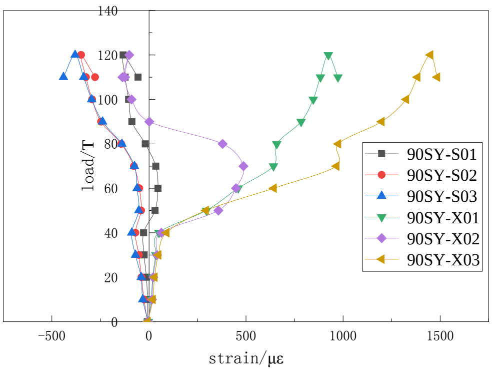
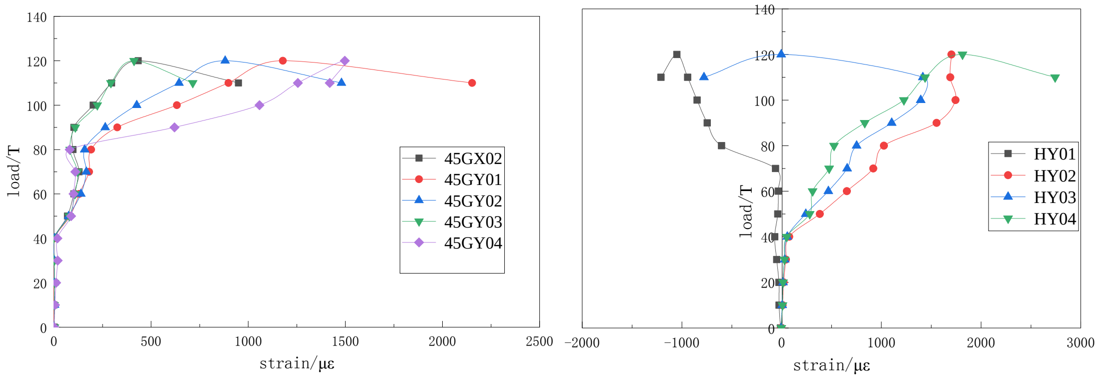


Figure.9Deformation curve diagram of Jack base

As shown in Fig9, the overall deformation of the jack base is small, and the influence on the displacement and deformation of the cross beam during the test is small, which can be ignored.

The load strain curve of hoop beam stirrup is shown in FIG. 10 (a).Before 0t, the hoop beam stirrup is basically free of strain and stress. Subsequently, with the increase of load grade, the overall longitudinal stirrup strain is larger than the transverse stirrup strain. Finally, when 120t is loaded to 130t, the strain of the outermost 45 ° longitudinal stirrup reaches yield.



（a）Load strain curve of longitudinal stirrup of ring beam（b）Load strain curve of transverse stirrup of ring beam

Figure.10 load-strain curve of ring beam reinforcement

The load strain curve of the longitudinal reinforcement of the ring beam is shown in Fig10 (b). The strain at hy01 measuring point is negative, which corresponds to the compression on the upper surface of the actual test ring beam. The tensile deformation of the lower surface is always greater than the compressive deformation of the upper surface. Similarly, before 40t, the overall strain of the longitudinal reinforcement of the ring beam is very small, and the load is basically borne by the concrete. After that, the strain of the longitudinal reinforcement gradually increases, and the concrete gradually exits the work. The load is mainly borne by the longitudinal reinforcement. When the 120t failure load is reached, the outermost longitudinal reinforcement hy04 in the tensile area of the ring beam will yield.

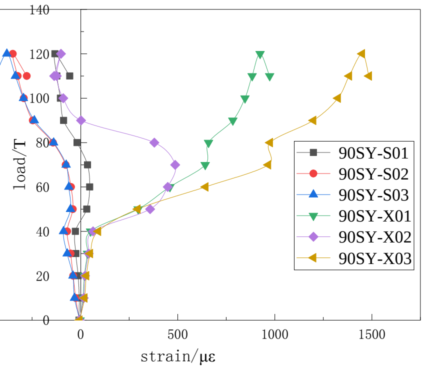


Fig.11 load-strain curve of longitudinal reinforcement of cross beam

Load strain curve of longitudinal reinforcement of cross beam is shown in Fig11. Before 40t, the load stress of longitudinal reinforcement of cross beam changes linearly, and the test piece is in elastic working state, and then increases nonlinearly with the load increasing step by step. When the failure load reaches 120t, the tensile longitudinal bar on the lower surface of the cross beam does not yield. The tensile strain of the longitudinal bar on the lower surface is always greater than the compressive strain on the upper surface.

2.3 Experimental conclusion

The experimental results are as follows:

1) The test results of cast-in-place pile ring beam specimen with interface roughening treatment show that the cracking load is 30t for a single cross beam. The failure load is 120t for a single cross beam. The maximum deformation at the loading point of the cross beam reaches 20mm. Finally, the tensile longitudinal reinforcement at the outer side of the ring beam and the 45° longitudinal stirrup at the outer side will yield

2) The interface between cast-in-place pile and ring beam has no obvious slip, the interface connection is reliable, and the node performance meets the engineering needs. The failure load value of the chiseled cast-in-place pile ring beam joint specimen meets the design requirements.

3)The maximum crack width at the tensile zone at the bottom of the ring beam and the interface between the ring beam and the cross beam of the test piece exceeds the limit, and the failure of the test piece occurs in the ring beam. It is similar to the failure state of existing test literature [7-9] of concrete filled steel tubular column ring beam joints.

III. CONCLUSION

The analysis shows that the interface of the cast-in-place pile ring beam joint with roughening treatment does not slip obviously, the interface connection is reliable, the joint performance meets the engineering needs, and the ultimate failure of the test piece occurs at the ring beam. The results of this test can provide a reference for the study of the connection performance of the cast-in-place pile ring beam joint with the interface roughening treatment, and promote the engineering application of the beam column joint connection in the top-down pile column integration.

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