Experimental study of failure mechanism of thick pile caps

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Experimental study of failure mechanism of thick pile caps

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Abstract. The failure mechanism of four-pile thick caps are analysed by experimental research. From the figure of crack development, analyse the impact of different reinforcement form of the bottom of the cap and different reinforcement form of horizontal mat. The analysis of the effect of concrete strength for loading capacity of the cap.

1. Introduction
From the research results of pile caps both at home and abroad the strut-and-tie theory can be used to simulate the stress state of thick pile cap. The strut-and-tie model of the thick pile caps refers to considering the concrete between the bottom of the column and the top of the pail as a compressed rod and considering reinforcement between the pile and pile as a pull rod. Based on this theory, the article put ward some design suggestions on pile caps by experiment and theoretical analysis.

2. Experimental research
The test adopted elector-hydraulic universal testing machine (WAW-2000) which is controlled by computer, the dimension of test pile cape as shown in Fig.1 and the reinforcement form of pile cap as shown in Fig.2.

![Fig.1 The test pile cap](image-url)
3. Experimental research results
SYNTHESIZE THE EXPERIMENTAL RESULTS OF THE LITERATURE AND WE GIVE OUT COMPARISON SHOWN AS TABLE 1.

Table 1. Result of the experiment.

| NO.  | HRB335 concrete reinforcement form | Cracking load | Ultimate load |
|------|-----------------------------------|---------------|---------------|
| ZJCT1 | 12Φ12 C40 A                        | 620           | 810           |
| ZJCT2 | 12Φ12 C40 C                        | 630           | 850           |
| CT1*  | 12Φ12 C30 A                        | 450           | 700           |
| CT2*  | 12Φ12 C30 B                        | 450           | 750           |
| CT4*  | 12Φ12 C30 C                        | 400           | 780           |

Specimens ZJCT2 and CT4 adopted the same dimensions and the same reinforcement form, but the concrete strength level increased from C30 to C40, from the test result, cracking load enhanced conspicuously. The first reason is adopting higher mark of the concrete, the second reason is that the specimen ZJCT2 has been maintained indoor for over three months before being tested, but as a result, the strength of the concrete has enhanced and the concrete at surface of the cap have carbonized at the same time. But comparatively speaking, the enhanced of the ultimate load is inconspicuous. But its test value also exceed designed bearing capacity.

Therefore, during the designing, the concrete level can be enhanced properly, in order to enhance the cracking load. At the same time. The requirement in norm can be adopted, adopting 60d or 90d strength of the concrete to design the proportions of concrete mix, in order to save the concrete, under the premise of it also satisfy the bearing capacity requirement.

In order to show the pull rod effect the reinforcement should be placed between pile and pile. Combine with the result of test in chart 1 and analyze its placing form: Under the certain condition that the quantity of reinforcement is the same and the reinforcement is placed between pile and pile then the bearing capacity of the cap can be enhanced conspicuously. Placing reinforcement at slanting stitch cannot enhance the cracking load, it only can enhance the bearing capacity of the cap a little. From the figure of crack development (Fig.3), diagonal placement can retard the pile cap of the corner pile cracking firstly, because the reinforcement at slanting stitch work together with Two-way parallel reinforcement can strengthen the Anchoring effect of cap at corner. But which make the fissure are assembled at the bottom of the pile cap at the diagonal direction, because one side diagonal reinforcement parallel with the crack development direction, it has nothing to do with restraining the development of the fissure. Analyze from the above points, reinforcement form at Bottom, can still use the conventional two-way parallel arrangement, but, further study is needed, about arrangement above the pile top.

For the width of the reinforcement which is assembled at the top of the cap, the current research conclusions are not uniform, the literature [2] propose to arrange it within 1.5 times of the pile diameter. Based on the experimental results of numerous literature, even when the cap reaches the limit load, bottom reinforcement not yielding, it shows that even if the concentration of reinforcement in the pile diameter range is not fully be used. The breach of the cap depends on the breach of the concrete pull rod, so in order to achieve the purpose of optimizing the arrangement of reinforcement, we can take a small range, that is twice the diameter of the pile within the assemble of the centralized
arrangement of reinforcement is enough. The other positions of the bottom of the pile cap should also be provided with the reinforcement rate should not less than 0.1%.

See from the experiment, the crack is developed firstly at the middle of the bottom side of the cap, this is the typical position of the bending crack, but, there was no significant increase in the mid-span fracture. When the limit load is reached, the crack is developed from the top of the pile to the bottom of the column, the cap is divided into four parts, and this is a typical form of punching destruction. Therefore, the destruction form of thick pile cap, obviously, it is neither the flexural destruction, nor the direct shear destruction, but the destruction of the diagonal tensile stress caused by shear stress and bending stress. For the whole cap, it can be regarded as bending shear destruction, but for each of the diagonal rod is a split destruction. In order to reduce the cracks caused by the tensile stress, the reinforcement mesh can be settled along the horizontal direction at the height of the cap. (Although there is no clear requirement in the code of the pile foundation, but in the concrete specification has been put forward, for thick reinforced concrete slabs, two way reinforcement mesh is settled at the middle part of the plate thickness, in order to improve the shear behavior. because, for the development of the inclined crack of pile foundation, Effect of horizontal reinforcement, not only reflected in the vertical direction of the crack, so as to improve the interlocking of the shearing force transfer of aggregate, also because of the role of the bolt can be provided to help shear transmission. The literature [3] also show that the horizontal reinforcement mesh can improve the bearing capacity of the cap. From the perspective of strut-and-tie model, it is to strengthen the anti-cracking ability of concrete diagonal rod.

**Fig.3** the figure of crack development
4. Conclusion

Based on the experimental study and theoretical analysis, the stress of pile cap is in accordance with the principle of strut-and-tie model. It can improve the bearing capacity of the pile cap by configuring the horizontal reinforcement mesh. Late strength of concrete can be used to optimize the mix proportion of concrete and reduce the amount of cement. Based on the strut-and-tie model, the bearing capacity of the platform can be improved under the condition of using less reinforcement.

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