Structural Behavior of Reinforcing Struts and Ties in Reinforced Concrete Pile Caps

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ABSTRACT

The main aim of this study is to investigate the behavior of reinforced concrete pile caps when reinforced by only struts and ties as defined by the strut and tie model of ACI 318-14. The experimental work included constructing and testing twelve pile caps divided into three groups. The specimens dimensions were (494-600)mm length, (234-600)mm width and (267)mm height. The difference between the groups was the pile number in each cap; the first group contained pile caps supported by two piles, the second group contained pile caps supported by three piles, while the third group contained pile caps supported by four piles. Every group contained four specimens; the 1st and 3rd specimens were reference conventional pile caps which were reinforced conventionally. Whereas the 2nd and the 4th specimens were the two suggested pile caps in which only the struts and ties were reinforced in addition to removing the concrete shoulders in order to save cost and weight. The concrete shoulders were the concrete in which STM of ACI 318-14 did not pass through.

The center to center distance between piles was one of the study parameters. It was 300mm for the 1st and 2nd specimens and 400mm for the 3rd and 4th specimens in each group.

Test results included load-deflection response, 1st crack load, 1st crack deflection, crack characteristics (number of cracks, crack propagation, type of cracks and crack width), concrete surface average strains, strains of the reinforcing steel, failure loads and failure modes.

The experimental results showed that the conventional 1st and 3rd specimens of each group revealed an increase in the ultimate capacity about (5-51)% when compared with the traditional theoretical design loads of ACI 318-14. While the suggested 2nd and 4th specimens showed an increase in the ultimate capacity about (13-56)% in comparison with the traditional theoretical design load of ACI 318-14. That gain in ultimate capacity indicates that the proposed specimens are good alternatives to the conventional pile caps, in the sense that they saved cost and weight about (28-61)% and (50-70)%, respectively. Measuring strain in steel reinforcement and in concrete assisted in investigating the contribution of reinforcement to the strength of the struts. For example, in the case of the 300 mm center to center spacing between piles, the contribution in inclined struts was (8-13)%. These experimental contribution ratios were close to equations of (ACI 318M-14). Measuring strain also assisted in more clarifying the failure type that took place in the specimens.

For all specimens, measuring the width of the first cracks assisted in observing that the first flexural cracks exceed the limits of crack width, so they were critical. While the first shear cracks did not exceed the limits and they were not critical.

Finally, it should be noted here that there are statistically significant differences between the reference specimens and the specimens proposed in each group in terms of the width of the flexural and shear cracks in addition to their numbers. Where the flexural cracks in the proposed specimens were narrower and more in numbers than those obtained in reference specimens. As for the shear cracks, they were also narrower and more in numbers in the proposed specimens compared to those in reference specimens. This can be attributed to the fact that the main stresses are actually transmitted through the struts and ties that are joining the loading and supporting points.