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Experimental study on the effect of swimmer bars as shear capacity enhancement in footing

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Abstract
One of the governing factors in the design of reinforced concrete footing is the punching shear failure. It is a disagreeable failure mode, since it outcomes in a failure of brittle nature. In this study, two types of shear reinforcement are compared, traditional reinforcement and swimmer bars. Swimmer bar is an inclined bar system, with its both ends bent horizontally for a short distance, welded at the top and the bottom of the longitudinal bars. Earlier studies are limited to effectiveness of swimmer bars in reinforced concrete beams, deep beams and flat slabs. This study presents the use of pyramid shaped swimmer bar arrangement and its influence in enhancement of punching shear resistance in isolated footings. The experimental studies were conducted using loading frame setup. The objective of this experimental study is to assess the effect of using swimmer bars in isolated footings.

Keywords: Isolated footings, loading frame setup, punching shear failure, swimmer bar arrangement

Introduction

Choosing the right type of foundation is the most important step during the design process of a structure. Failures at this stage can lead to either inadequate performance in service or signify risks to the protection of the building. Footings undergo two kinds of shear failure mechanism which may be critical in the design of footings; the first one is the diagonal tension failure; applicable particularly to footing, in which slab consider as wide beam by which potential diagonal crack extends in a plane across the entire width of the slab; the second is the punching shear failure in this failure, potential diagonal cracks following the surface of a truncated cone or pyramid in foundation slabs below the column. The angle of inclination depends upon the nature and amount of reinforcement in the column- footing slab; it may range between 20° and 45°. The critical shear section is taken at d/2 from periphery of the support. In pad foundations, where weight and depth are not so critical, its effects are satisfied by providing sufficient depth.

Shear reinforcement is designed to resist shear or diagonal tension stresses. Shear reinforcement are given in the form of stirrups to hold the longitudinal reinforcement and to take shear to which the structure is subjected to. The main problem of shear failure is due to the diagonal cracks in the footing. Therefore shear reinforcement is provided to protect from shear failure. This will reduce the possibilities of an immediate failure.

A swimmer bar is another type of shear reinforcement. It is a small inclined bar, with its both ends bent horizontally for a short distance, welded at the top and the bottom of the longitudinal bars. There are three major standard shapes namely, single swimmers, rectangular shape swimmers, and rectangular shape with cross bracings.

Experimental procedure

- **Specimen details**

Two specimens were tested in this study, 0.85 m x 1.85 m and 0.2m thick each. The first one RF is regular footing with no swimmer bars, which is used as the control sample and the other one, FSW is reinforced with pyramid shaped swimmer bars of 8mm diameter. The second specimen is reinforced by #6-8mm⌀ in both directions. The steel reinforcements of the column located at the centre of slab was reinforced by #4-16mm⌀. The first specimen which has no swimmer bars RF, made by conventional reinforcement with column at the middle of the slab. The second specimen, FSW, was reinforced by eight swimmer bars, four pyramid shaped swimmer bars were placed at intersection of bottom reinforcement bars and other four at the middle distance between of these intersections as shown in Figure 1. All specimens were cast with concrete from same mix. All specimens were tested by the loading frame setup at the age of 28 days. The uniaxial compressive strength of concrete was determined using standard cubes tested at 3 days, 7 days, 14 days and 28 days. The average 28 day concrete compressive strength was calculated to be 27.9MPa. The steel used in this experiment is of grade Fe500.

Fig 1: Second specimen, FSW showing the swimmer bars

Table 1: Main parameters of test specimens

Speci men	Dime nsion (m)	Total depth(h) (m)	Effective depth (d) (m)	Shear reinforc ement Swimm er bars
RF	0.85 x 0.85	0.2	0.146	-
FSW	0.85 x 0.85	0.2	0.146	#8- 8mm⌀

Test procedure

All the test specimens were painted with white emulsion so that detection of cracks during testing became easier and pencil marking on the side of cracks made them clearer. The test of the footings of 0.85m x0.85m is carried on Loading Frame of capacity 50T by keeping the four ends of footing supported. Magnetic dial gauges with least count 0.01mm and maximum range of 10mm is used to measure the deflection values. Demountable Mechanical Strain gauge and steel discs are used to calculate the strain values at the required positions. Strain and deflection measurements of the test specimens were noted after each load increment, for the initial crack until failure by punching shear.

Fig 2: Test setup

Test results

The reference specimen RF, that has no swimmer bars and one which is used as control specimen was tested first. For RF, loading started at 20kN, when loading reached at 120kN initial cracks appeared at the side perpendicular to the supports. When increasing the load, cracks appeared and increased in width at the bottom face of specimen punching shear occurred at an ultimate load of 229kN, which was a brittle mode of failure. For the second specimen FSW, loading started at 20kN, and initial cracks appeared at 163kN, cracks appeared and increased in width at the bottom face of specimen and punching shear occurred at a ultimate load of 264kN, which was similar to the mode of failure of reference specimen.

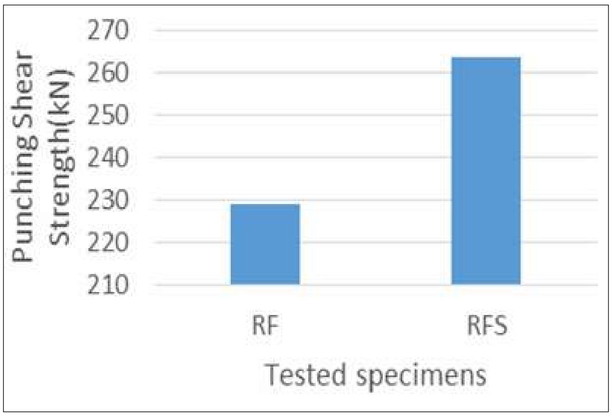

Fig 3: Punching shear strength for tested specimens

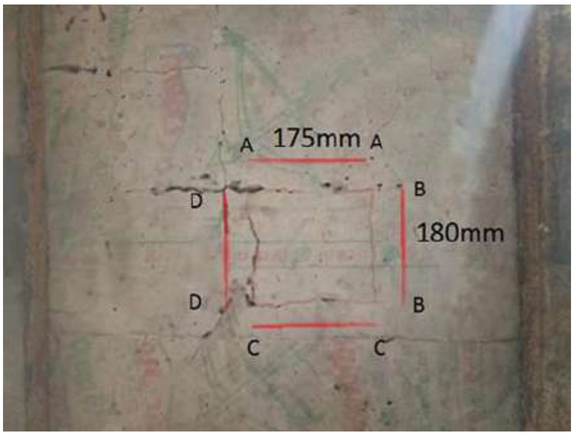

Fig 4: Failure of specimen RF

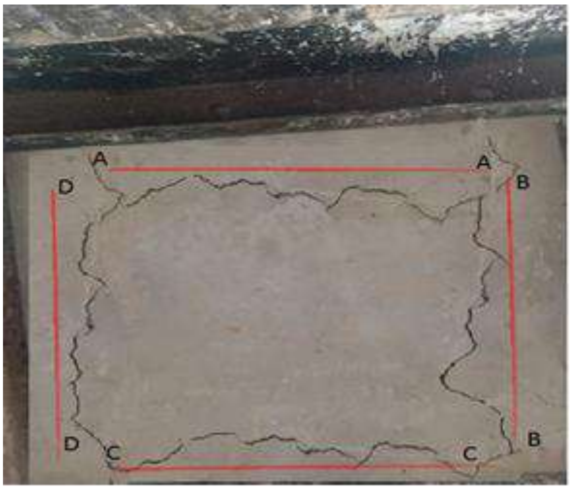

Fig 5: Failure of specimen FSW

Deflection

The deflection was measured at each increment of load. The load deflection was plotted for tested samples as shown in fig 6. The load versus deflection curve was plotted taking the deflection along the X axis and the load along Y axis. The dial gauge were used to measure the deflection at the centre of the specimen. It was observed that the deflection increases as the load increased that is the load and deflection were directly proportional. In the comparison it shows that the deflection is proportional to load applied during the initial loading stage and after which there is a sudden increase in deflection. This shows the deflection increases after the forming of crack.

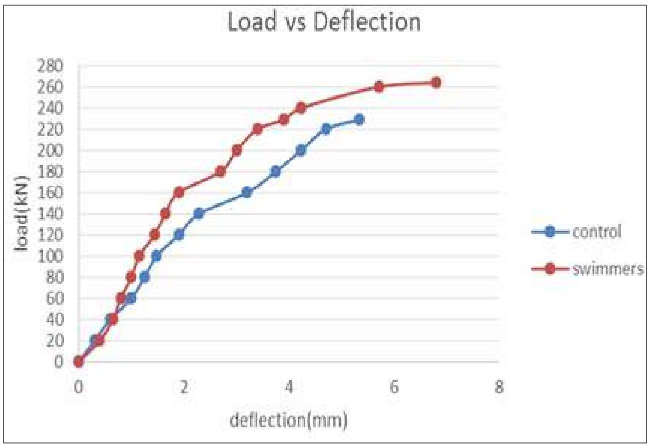

Fig 5: Load vs. deflection curve for tested specimens

Effect of strain on footings

The bottom strain of the control specimen have been measured by strain gauge as shown in fig 7. It can be seen that strain is small at elastic stage as the loading is applied, and then it increases after the first crack when loading is applied.

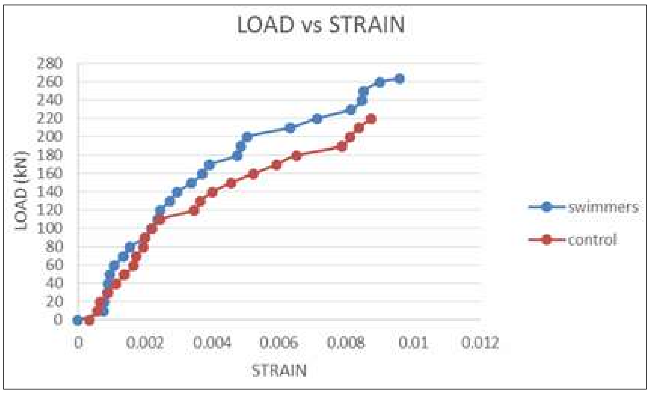

Fig 6: Load vs. strain curve for tested specimens

Conclusions

- Test results shows that this form of swimmer bars increased punching shear strength of footing specimen with swimmer bars.
- The results shows that footing with swimmer bars enhanced punching capacity up to 13% compared with reference footing.
- The specimen with swimmer bars fails at 264kN and control specimen fails at a load of 229kN that is the specimen with swimmer bars fail at a load higher than reference specimen.
- This type of punching shear reinforcement showed considerable increase in the slab rigidity by reducing the deflection.

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