

Pullout Capacity and Bond Behaviour of Headed Reinforcement in concrete

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ABSTRACT: The introduction of high strength steel and concrete in reinforced concrete structures requires an efficient form of mechanical anchorage. Headed bars provide a practical alternative to hooked bars and eliminate congestion problems caused by standard hooks. Headed bar is also used to minimize slip, ease of placement, and more accurate dimension of reinforcing cages. This work presents an experimental investigation on the pullout capacity of the new developed headed bars to be used in the reinforced concrete structures. The main focus of this present study is the anchorage behaviour of headed bar embedded in concrete in terms of embedded depth and bond stress is investigated. The variables used for the experimental work are embedded depth of headed bar and different size and shapes of headed bar. The results of the test indicated that as the embedded depth increases bond stress increases also as the embedded depth is high it takes large load for pullout.

KEYWORDS: Headed bar, Pullout, Bond stress, Embedded depth.

I. INTRODUCTION

Headed bars were introduced in reinforced concrete construction because the provisions for anchorage of bars, splices, and continuity between elements pose significant difficulties for designers and contractors. Straight bar anchorages and lap splices are often so long that the resulting dimensions of elements are prohibitively large. The most common solution is to use hooked bars or to incorporate mechanical connectors. However, both options have drawbacks. Hooked bars create congestion problems and may make fabrication of reinforcement cages or placement and consolidation of concrete difficult when large amounts of reinforcement are required. Mechanical connectors require special construction operations and careful attention to tolerances. In order to reduce congestion problems, headed bars have been used instead of bent bars (hooks or ties) for shear reinforcement to anchor large diameter transverse reinforcement bars in the construction of reinforced concrete platforms for offshore development and petroleum production. Advantages of headed bars are the reinforcement can be placed exactly at the desired location. It develops full anchorage strength with very small embedded length, which reduces considerable steel consumption at the junction. It also saves considerable construction costs because the concentrated can minimize the member size, for example reduced concrete depth, formwork and excavation for footings. Fabrication and lying of 90° and 180° hooked bars with transverse reinforcement at the junction is really time consuming and laborious job. Headed bars are easy to place, even if no of bars are more which saves considerable time and labour. Reduced congestion and ease of placing of headed bars will improve construction thus speeding up a project. The concrete also benefits because adequate space for pouring and vibration will give better concrete up a project. Anchorage without utilisation of bond improves robustness at overload and accidental conditions. If spalling of concrete cover occurs (e.g. from fire or seismic loading) the heads still provide full anchorage without cover.

The headed bars with different head shapes such as square, rectangular and circular can be used (Choi, 2006; Choi et al, 2002; Park et al, 2003; Thompson et al, 2005; Chun et al, 2007), hence headed bars of such a head shapes were used in the present study and this headed bar embedded in three different depths in concrete cylinders as $8.4d_b$, $12.5d_b$ and $16.7d_b$. In this study the ratio (A_{brg}/A_b) is used to identify the size of head plate. The net bearing area A_{brg} is defined as the gross head area A_{head} minus area of obstructions A_{obs} . Three ratios of (A_{brg}/A_b) equal to 6 and 8 (B6

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and B8) are considered. The head plate thickness kept constant 8mm (t8) used which is about $0.67 d_b$. Two parameters, i.e. head size and embedded length are varied. Headed bar was formed by inserting the end portion of straight reinforcing bar into the centrally drilled hole of circular plate and welding it from both the sides. Fig 1 shows various headed bars compared to standard hook



Fig 1: - Various headed bars Compared to standard hooks

II. MATERIALS PROPERTIES AND TESTING

The materials required for the experimental work were tested in the laboratory to get necessary data for mix design.

Cement:-

Portland Pozzolana cement (PPC) of 43 grades (Conforming to IS 1489-1-1991) was used. The results of the cement are given in Table 1

Table -1- Properties of cement

Property	Average value	Recommended standards as per I.S.
Specific Gravity	4 (Standard)	4
Fineness (%)	4	< 10 %
Consistency (%)	28	-
Soundness (mm)	3.9	< 10
Initial setting time (min)	75	>30
Final Setting time (min)	170	< 600
Compressive Strength 28 days	48.3 (N/mm ²)	

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Fine Aggregate:-

Type: Natural River sand

Fineness Modulus = 3.5 (Sand conforms to grading Zone

II)

Specific gravity: $S_{fa} = 2.6$

Free surface moisture: Nil

Coarse Aggregate:-

Type = Crushed Basalt

Maximum size = 20 mm

Specific gravity: $S_{ca} = 2.79$

Free surface moisture: Nil

III. EXPERIMENTAL WORK

All the headed bars were pulled out of concrete cylinders in a Universal testing machine the loading was applied to the bar gradually. A mild steel hollow ring of outside diameter 150 mm and inside diameter 140 mm placed at the top portion of the cylinder so that top surface of cylinder does not contact directly with machine. The bar was passed through the hollow ring and anchored into hydraulic gripping mechanism that was bearing against the movable platen of Universal Testing Machine. The load at which the specimen breaks in different pattern is taken as maximum Pullout Load (P_n).



Fig 2: Experimental Set-Up

IV. EXPERIMENTAL RESULTS

Failure Mechanism:-

Various modes of failure were observed: Conical fracture of concrete, splitting of the concrete and Yielding of Bar. The following presents a brief description of these modes of failure.

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- 1) **Conical Fracture of Concrete:** - Conical fracture of concrete (**Fig 3**) is characterized by a cone of concrete centered on the head being pulled out with bar. Concrete breakout failure took place by the propagation of a roughly conical fracture surface from the bearing edge of the head.
- 2) **Splitting failure:** - Splitting Failure (**Fig 4**) occurs in case of embedded depth of in splitting failure the concrete part in the middle around the headed bar was breakout when the load is applied to the specimen. In splitting failure of concrete a wedge was noted around the Headed bar, the concrete leaves some marks on the Headed bar.
- 3) **Yield Failure of bar:**-Yield Failure of bar (**Fig 5**) occurs in case of embedded depth of even with small bearing ratio Because in this case pullout load exceeded the yield load and hence yield failure occurs. In yield failure mechanism some small amount of slip occurs and bar breakout is take place at some distance from the top of the specimen on the bar.

There are several parameters that govern the mode of failure such as: type of loading, rate of loading, size and shape of headed bar



Fig 3:- Conical Fracture of concrete



Fig 4:- Splitting failure



Fig 5:- Yielding Failure of bar

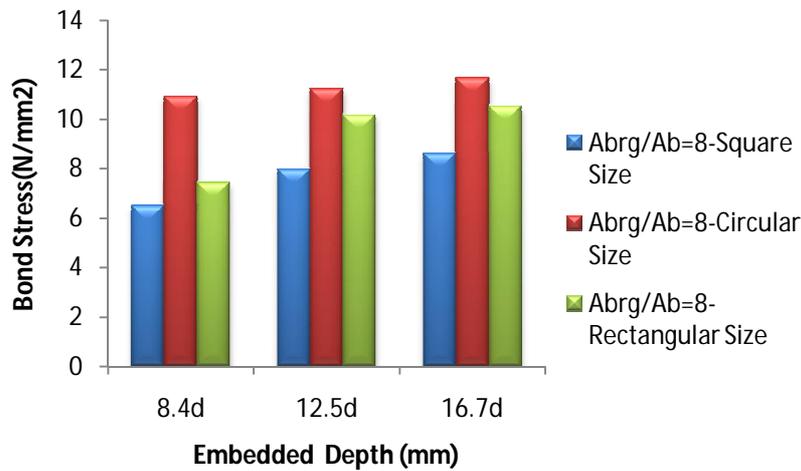
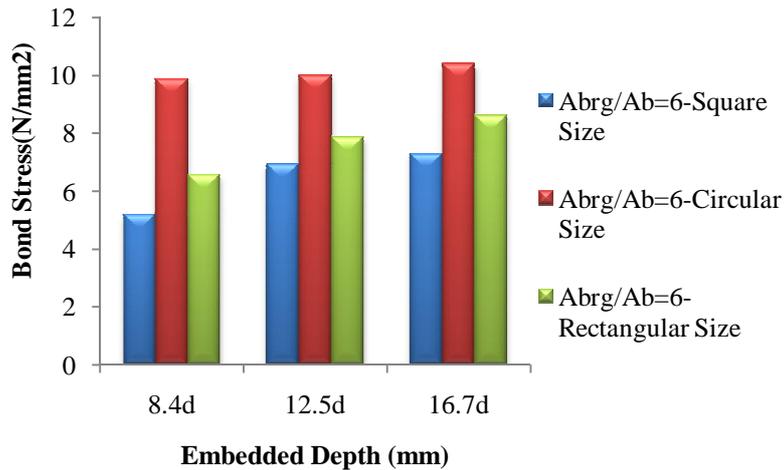
Effect of Embedded Depth vs. Bond stress:-

From all the test results it was found that as the embedded depth increases corresponding bond stress increases. In case of bearing ratio ($A_{brg}/A_b = 6$, and 8). Circular size of headed bar has maximum bond stress and minimum bond stress was observed in specimens of square size in all bearing ratio as compared to other. Bond stress of rectangular size of headed bar is minimum as compared to circular and Square. Below graphs shows comparison of Square, Circular and Rectangular headed bar of different bearing ratios It was observed that embedded depth is important parameter which affects the anchorage strength and Bond stress of headed bar. The load at which the cylindrical specimens break in different modes is taken as maximum Pullout Load (P_n) and bond stress is calculated by the formula ($P_n / \pi d_b E_d$).

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V. CONCLUSION

Larger embedded depth with (16.7d) with Bearing ratio ($A_{brg}/A_b=6$) effectively provided pullout resistance. But smaller embedded length (8.4d) with Bearing ratio ($A_{brg}/A_b=8$) cannot develop full anchorage strength. Conical fracture of concrete occurs in case of embedded depth of (8.4d) of all bearing ratio and size. Vertical splitting of concrete occurs in case headed bar of all size and shape of embedded depth (12.5d.) Yielding of bar occurs in specimens with embedded depth (16.7d) without any sign of anchorage failure of all bearing ratios. As embedded depth increases Corresponding bond stress increases it was found for all the specimens. Bond stress of circular size of headed bar is maximum with bearing ratios 6 and 8 as compared to other.

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