EXPERIMENTAL STUDY ON BOND BEHAVIOUR OF THREADED HEADED BARS

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Abstract

Headed reinforcement is a relatively new product and has been extensively used in the construction of offshore oil platforms. Using headed reinforcement removes the tail extension of hooks and allows fewer larger bars to be used, greatly reducing the congestion of the reinforcing cage.

Hooked and bend-up bars create a large amount of congestion in the reinforcing cage which leads difficulty during construction and causes honeycombing in the structure. Headed reinforcement also reduces cost of construction and it reduces the area of steel. The introduction of high strength steel in reinforced concrete structures requires an efficient form of mechanical anchorage.

For experimental purpose, 24 specimens were casted to study the bond behavior of M25 grade concrete and TMT ribbed bars with various circular Head size and different embedded length. This project deals with the experimental study on the Pullout capacity of the newly developed headed bars to be used in the reinforced concrete structures.

The result will be facilitated to develop the design recommendation for the exterior beam column joint using threaded headed bars.

Key words: TMT ribbed bars; compressive strength; split-tensile strength; flexural strength; bond stress.

1. Introduction

In Beam Column Joint Hooked bars create congestion problems and affect the fabrication of reinforcement cage and consolidation of concrete pouring is difficult Mechanical connectors requires special construction methods, equipments. In order to reduce the congestion problem headed bars have been used instead of standard hooked bars in joint. Bond is the interaction mechanism that transfer the force between the reinforcing bars and surrounding concrete there by securing the composite action between the two materials

1.1. Headed reinforcement

Heads attached to bar by high-quality friction weld or by using threaded connection is known as Headed reinforcement. They are usually circular, square, and rectangular in shape. Head area is typically in the range of 5 to 10 times the bar area. Larger heads are useful for confinement or shear reinforcement; smaller heads are sometimes convenient for longitudinal reinforcement. Headed bars in beam-column joints can be replaced for standard hooks. Primary motivation is to ease fabrication of reinforcement and placement of concrete.

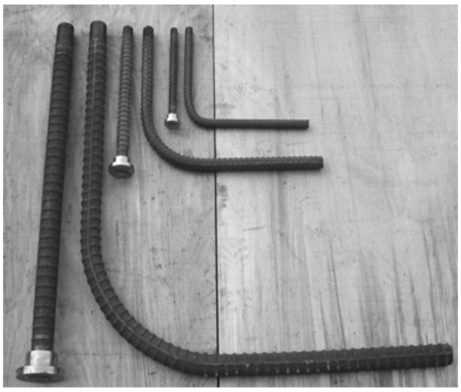

Figure 1- *Headed Reinforcement and Hooked Bar*

1.2. Need for headed reinforcement

Hooked bars may result in steel congestion with the difficulty of steel fabrication and concrete placement leads to honeycombing in concrete. Headed bars have been considered as an alternative to hooked bars in steel congestion and to ease fabrication, construction, and concrete placement.

1.3. Advantages of headed reinforcement

- Desirable anchorage strength with very small embedded length.
- Reduces steel consumption.
- Ease the fabrication work and speed of construction.
- It reduces the construction cost.

2. Literature review

G.V. Annapoorna. et al (2017), presented results of an experimental program to determine bond behavior of reinforcing bars in plain and fiber reinforced concrete. In this journal they used two grades of concrete M20 & M30 and they used various diameters of steel bars such as 16mm, 20mm, 25mm dia steel rebar’s. Pullout test were conducted on cube specimen size of 150mm & slip was measured using LVDT. Steel fiber with aspect ratio 80, length 60mm & 6mm diameter mild steel rebar was used for making helix confinement. Bond strength decreased with increase in diameter of the rebar & the slip was found to increase with the deceased in bond strength of the cubes. Mild steel helix reinforcement shows better result than fiber reinforced concrete. FRC didn’t contribute as much to the bond strength but post cracking behavior of specimens were improved. Bond strength increased with decrease in diameter and increase in compressive strength. Slip was decreased with increased in bond strength.

T.H. Praveen Kumar. et al (2016), investigated about the bond behavior of steel rebar’s in reinforced concrete for plain and ribbed bars. In this journal they used two grades of concrete M25 & M30 and they used 25 mm dia steel rebar. Pullout test were conducted on cube specimens & slip was measured using LVDT. The specimen surface was supported on a 25mm thick plate with central hole for accommodates the rebar. Ribbed bars shows better bond strength than a plain rebar’s, the bond strength increased with increased in compression strength and bond strength decreased as the embedded length increased. The failure pattern is smoothly removal of bar for plain rebar’s and splitting failure for ribbed bars.

Yogesh D. Patil. et al (2016), investigated about the Pullout capacity and bond behavior of Headed reinforcement in concrete. In this journal different shape of heads was used such as square, rectangular & circular heads were used. The thickness of head is kept constant. Different embedded depth of rebar’s in concrete for Pullout test. The Pullout test was conducted on cylinder specimens and a mild steel hollow ring of outside diameter 150mm & inside diameter 140mm placed at the top portion of the cylinder so that top surface of cylinder does not directly contact with the machine. The bar was passed through the central hole then the bar is anchored into the hydraulic gripping in UTM machine. Bond strength of rectangular headed bar is minimum as compared to the circular and square. Circular heads shows better results and the Pullout load increases with increase in embedded length & head size. Bond strength decreased with increased in embedded length. Bond strength increased with increase in compressive strength of cube specimens. The failure mode occurred on Pullout test were conical fracture of concrete, splitting failure, thread failure & yield failure of bar.

S. M. Kulkarni. Et al (2015) presented results of an experimental program to determine bond behavior of Headed reinforcement bar. In this journal they used three grades of concrete M20, M30 & M40 and they used various diameters of rebar of 12 mm, 16mm & 20mm dia steel rebar. Different shape of heads was used such as square, rectangular & circular heads were used. Different embedded depth of rebar’s 10 times the diameter of bar, 12 times the diameter of bar & 14 times the diameter of bar. The Pullout test was conducted on cube specimens & slip was measured using LVDT. Circular heads shows better results and the Pullout load increases with increase in embedded length & head size. Bond strength decreased with increased in embedded length and diameter of bar. Bond strength increased with increase in compressive strength of cube specimens. The failure mode occurred on Pullout test were splitting failure, Thread failure & cracks formation

3. Scope and objective

The main objective of the work is to study the bond behavior between the M 25 grade concrete & 16 mm diameter ribbed bars with different head size and embedded length.
The Various circular head sizes are

- 20mm diameter &15mm thickness

- 30mm diameter &15mm thickness
- 40mm diameter &15mm thickness.

4. Experimental programme

In this experimental programme the preliminary investigations were done for basic ingredients of controlled concrete. From, the material property results, mix proportions were obtained for controlled concrete of M25 grade with target strength.The bond behaviour of concrete and TMT ribbed bars were studied in this work. The details of number of specimens and size of specimens are shown in Table 1a and Table 1b.

Table 1a: *Specimen description for conventional cubes*

S.NO	Description	No of Specimens
1	Cube 150x150x150 mm	6

Table 1b: *Specimen description for Pullout Test*

Description	Head size(H)	Embedded length(E)	No of Specimens
Cube 150x150x150 mm(E-100 &H-0)	0	100 mm	3
Cube 150x150x150 mm(E-100 &H-20)	20 mm	100 mm	3
Cube 150x150x150 mm(E-100 &H-30)	30 mm	100 mm	3
Cube 150x150x150 mm(E-100 &H-40)	40 mm	100 mm	3
Cube 150x150x150 mm(E-120 &H-0)	0	120 mm	3
Cube 150x150x150 mm(E-120 &H-20)	20 mm	120 mm	3
Cube 150x150x150 mm(E-120 &H-30)	30 mm	120 mm	3
Cube 150x150x150 mm(E-120 &H-40)	40 mm	120 mm	3

4.1. Materials used

4.1.1. Cement: Cement is the well-known building material with adhesive and cohesive properties, which is capable of binding mineral fragment into compact mass. There are several types of cement. The most popular Ordinary Portland cement (OPC-53) is used in this project.

4.1.2. Coarse aggregate: Aggregate which passes through 75 mm IS sieve and retained on 4.75 mm IS sieve is known as coarse aggregate. Aggregates should be properly screened and if necessary washed before use. Coarse aggregates containing flat, elongated or flaky pieces should be rejected. The grading of coarse aggregates should be as per specifications of IS 383-1970. In this project, 20 mm size of coarse aggregate is used.

4.1.3. Fine aggregate: Aggregate which is passed through 4.75 mm IS sieve and retained on 75 micron IS sieve is termed as fine aggregate. It fills the voids in coarse aggregate. Usually, the natural river sand is used as fine aggregate. Ordinary river sand conforming IS 383-1970 is used in this project.

4.2. Casting programme

Casting of the specimens were done as shown in figure, preparation of materials, weighing of materials and casting of specimens for Pullout Test. The mixing, compacting and curing of concrete are done.The cube specimens (150mmx150mmx150mm) are casted with a 12mm dia single Reinforcing ribbed bars inside the cube vertically along the central axis of each specimen with the help of wooden reapers as shown in figure-2. Then the specimen is cured on water for 28 days. After the curing period the specimen is taken out from the curing tank and wipes is clean.

Figure 2- Casting Setup of Specimens for Pullout Test

The plain samples were cured for 28 days in water pond at room temperature by placing them in shade. The M25 grade of concrete is designed and the material required per cubic meter of concrete is shown in Table 2.

Table 2: *Mix Design*

	cement	water	Fine aggregate	Coarse aggregate
Kg/m^3	438	197	653.7	1091
ratio	1	0.45	1.3	2.4

4.3. Testing

4.3.1 Slump Test: Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It does not measure all factors contributing to workability. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

4.3.2. Compressive strength: The cube specimens were tested on compression testing machine. The bearing surface of machine was wiped off clean and sand or other material removed from the surface of the specimen. The specimen was placed in machine in such a manner that the load was applied to opposite sides of the cubes as casted that is, not top and bottom. The axis of the specimen was carefully aligned at the centre of loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on specimen was recorded. f_c = P/A , where, P is load and A is area.

4.3.3. Pullout Testing: The pullout tests were conducted on universal testing machine and the surface of the specimen is supported on a 20mm thick plate with a central hole of 20mm dia to accommodate the reinforcement as shown in figure 3. Then the bar is pulled axially from the concrete with a rate of loading 2250kg/min. The loading is taken until the specimen failure by any of the failure mode such as removal of bar, splitting, thread failure. All the specimens are loaded and tested as shown in figure 3.

Figure 3: *Experimental Setup for Pullout Test*

The average bond stress is calculated from the pullout load is assumed at the ultimate bond strength between two materials. The equation for determining the bond strength in pullout test

$$\tau = \frac{F}{\pi d_b l_d}$$

The bond area is depended on the diameter of the reinforcement bar and the bonded length of reinforcement embedded in concrete. The bond area is calculated by using this equation

$$A = \pi d_b l_d$$

Where p is the maximum pullout load and d_b and l_d are the diameter of bar and the bonded length of the bar embedded in concrete.

4.3.4. Failure Mechanism: Various modes of failure were observed: smooth removal of bar, splitting failure of the concrete .The following presence a brief description of these modes of failure.

1) Smoothly removal of bars: Smoothly removal of bar occurs at specimen with 100mm embedded length & without head smoothly removal of bar from the concrete & the ribbed bars leaves some marks, cracking on surface of concrete.

2) Splitting failure: Splitting failure occurs when the embedded length increases and also occurs at specimens with threaded headed bars. In the 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 bars.

These are several parameters that govern the mode of failure such as: embedded length, Headed bar size, rate of loading

5. Results and discussion

1. The average compressive strength of the samples is taken as compressive strength of corresponding concrete grade. The test results for controlled mix at 7^{th} day & 28^{th} day curing are given below in table 3 and table 4.

Table 3: *Test results for* 7^{th} day compressive strength

Control Mix	Load(KN)	Compressive Strength(N/mm²)	Average Strength(N/mm²)
Specimen 1	408.5	18.15	20.63
Specimen 2	480.7	21.36	
Specimen 3	503.8	22.39	

Figure 4: *Test results for* 28th day compressive strength

Control Mix	Load(KN)	Compressive Strength(N/mm²)	Average Strength(N/mm²)
Specimen 1	723.2	32.14	31.83
Specimen 2	686.1	30.5	
Specimen 3	739.4	32.8	

2. The test result for pullout test conducted on specimens with varying head size and embedded length is compared with specimen without head and having same embedded length. The Pullout test results are given below in table 5

Table 5: *Test Results for Pullout test*

Control Mix	Pull Out Load(Kg)	Bond Area(mm²)	Bond Strength (N/mm²)
E-100 & H-0	2600	3769.9	6.8
E-100 & H-20	3360	3769.9	8.9
E-100 & H-30	3860	3769.9	10.25
E-100 & H-40	4200	3769.9	11.13
E-120 & H-0	3160	4523.8	6.8
E-120 & H-20	3530	4523.8	7.8
E-120 & H-30	4360	4523.8	9.6
E-120 & H-40	4830	4523.8	10.68

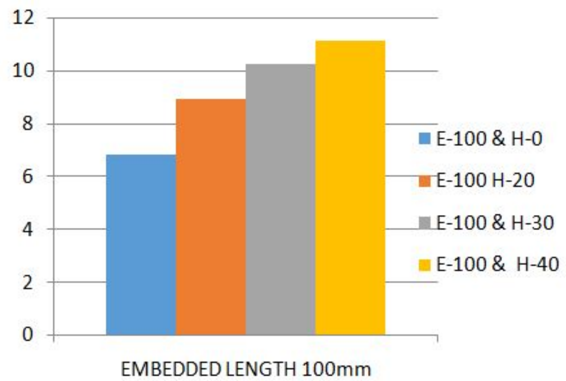

Figure 4: *Variation of Head size with same embedded length 100 mm*

Figure 4 shows the variation of head size in specimens with 100mm embedded length at 28th day. The bond strength of concrete is increased with the increased in head size. The bond Stress of the specimen with embedded length 100mm and without circular head has value of 6.8 N/mm². Then using 20mm diameter circular heads with same embedded length gets 31% increase in bond stress, using 30mm diameter circular heads gets 50.7% increase in bond stress and using 40mm diameter circular head gets 63.6% increase in bond stress

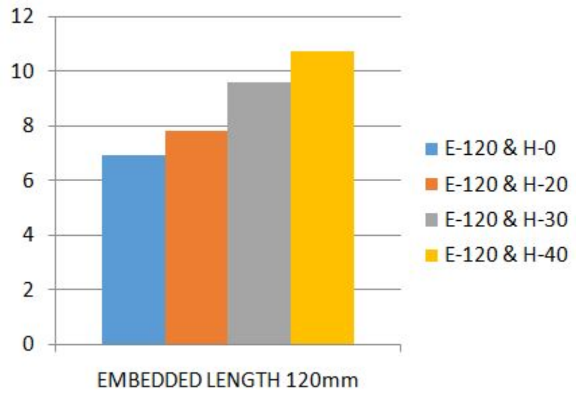

Figure 5: *Variation of Head size with same embedded length 120 mm*

Figure 5 shows the variation of Head size in Specimens with 120mm embedded length at 28th day. The bond strength of concrete is increased with the increased in head size. The Bond Stress of the specimen with embedded length 120mm and without circular head has value of 6.8 N/mm². Then using 20mm diameter circular heads with same embedded length gets 15% increase in bond stress, using 30mm diameter circular heads gets 41% increase in bond stress and using 40mm diameter circular head gets 57% increase in bond stress

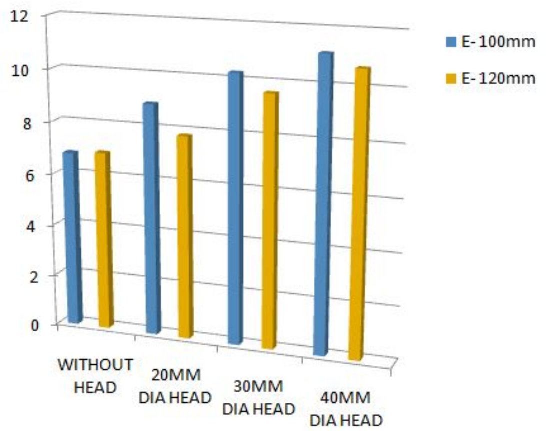

Figure 6: *Comparison of embedded length 100 mm and 120 mm with Various Head size*

Figure 6 shows the comparison various Head size in Specimens with 100mm embedded length and 120mm embedded length at 28th day. The bond strength of concrete is decreased with the increased in embedded length. The specimen without circular head gets same bond stress with embedded length 100mm and 120mm. The bond stress of specimen with embedded length 120mm with circular head 20 mm decreased 12% when compared to same head size with 100mm embedded length. The bond stress of specimen with embedded length 120mm with circular head 30mm decreased 6.5% when compared to same head size with 100mm embedded length. The bond stress of specimen with embedded length 120mm with circular head 40 mm decreased 4% when compared to same head size with 100mm embedded length.

6. Conclusion

The use of headed reinforcement in concrete and their advantages had been thoroughly studied from reputed journals in this work. The preliminary investigations were done for basic ingredients of controlled concrete. From, the material property results, mix proportions (1: 1.3: 2.4) obtained for controlled concrete of M25 grade with target strength 31.6N/mm^2. The results for the tested compressive strength (31.8 N/mm^2) achieved nearly as of about the obtained target strength.

From the performed pullout Test, the pullout load increases (from 2600 kg to 4830 kg) with increase in head size (20 mm, 30 mm and 40 mm) & embedded length (100 mm and 120 mm). The bond strength increases (from 6.8 N/mm^2 to 11.13 N/mm^2) with increase in head size & the bond strength decreases (from 11.13 N/mm^2 to 10.68 N/mm^2 for 40 mm diameter head size) with increase in embedded length, so that the anchorage length in joint can be reduced that is considered while designing a exterior beam column joint

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