

Investigation of Bond Strength in Concrete Embedded with Steel Rebar Attached To Coupler Using Pull-Out Test

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ABSTRACT: The aim of this study is to assess the bond strength between steel rebar and concrete as it is very crucial to develop the composite behaviour of concrete. It is influenced by several factors such as bar diameter, cover of concrete over the bar, spacing of bars and aggregate used in concrete etc. Generally in a beam-column joint, the reinforcing bars are bent into the column and anchored. Due to this anchorage, rebar congestion takes place which restricts the flow of aggregates, thereby creating voids. Therefore an attempt has been made to attach couplers at the end of the bars without bending them. Cylindrical concrete specimens of M25 grade were casted and steel reinforcing bars of 16 mm and 20 mm diameter were inserted into it, leaving a cover of 40 mm from bottom. Pull-out test is carried out to assess the bond strength. Comparison is made with specimens in which steel bars are inserted and attached to couplers and steel bars not attached to couplers. Also 10 mm, 12 mm and 16 mm thick plates of sizes 54 mm x 54 mm and 58 mm x 58 mm are attached to these 16mm and 20mm couplers and comparison is made to assess the bond strength.

KEYWORDS: Bond strength, Pull-out test, Couplers, Base plates.

I. INTRODUCTION

Bond strength can be defined as the measure of effectiveness of the grip between concrete and steel. This factor is very crucial to develop the composite behaviour of concrete. It is well known that the overall behaviour of reinforced concrete structures is highly dependent on the interaction between steel and concrete. In other words, the behaviour of smooth reinforcing bars embedded in concrete is a key issue in the development of reliable procedures for the evaluation of available bearing and displacement capacities of historical buildings [1]. If the bond resistance is inadequate, slipping of reinforcing bar occurs thereby destroying composite action. In RC members sudden loss of bond between rebars and concrete in anchorage zones causes brittle failure [2]. It is influenced by various factors like chemical adhesion between steel and concrete, bar diameter, cover of concrete over the bar, spacing of bars and type of aggregate used in concrete etc.

The main aim of this study is from the concept of beam-column joint. The beam column joint is the crucial zone in a reinforced concrete moment resisting frame. The problems of detailing and construction of beam-column joints are often not appreciated by designers [3]. Because of the restricted space available in the joint block, the detailing of reinforcement assumes more significance than anywhere else. Indeed, the conflicting requirement of small size bar for good performance, and large size bars for ease of placement and concreting is more obvious at the joints than anywhere else[4]. Due to the anchorage of the bars, rebar congestion takes place which restricts the flow of aggregates, thereby creating voids. Therefore an attempt has been made to attach couplers at the end of the bars without anchoring them.

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II. LITERATURE REVIEW

Muhammad N.S Hadi conducted fourteen pull out tests to study about the bond of high strength concrete with high strength steel. This study concluded that pullout specimen with the smaller bar size has greater bond strength than the specimen with the larger diameter bar and the initial stiffness increased as the amount of concrete surrounding the reinforcing bar increased.

Guohua Xing, Cheng Zhou, Tao Wu, and Boquan Liu conducted pull out tests on six-group specimens with plain steel bars and two-group specimens with deformed steel bars to evaluate the bond behaviour between the reinforcing bar and surrounding concrete. This study concluded that the bond stress experienced by plain bars is quite lower than that of the deformed bars given equal structural characteristics and details. Averagely, plain bars appeared to develop only 18.3% of the bond stress of deformed bars.

III. EXPERIMENTAL PROGRAM

Materials:

Cement: 53 grade Ordinary Portland cement (OPC-53) conforming to IS 12269 is used in this study.

Aggregates: Fine aggregate: River sand conforming to zone-3 is used in this study. The specific gravity is found to be 2.53 and fineness modulus is 3.23.

Coarse aggregate: Aggregates shall comply with the requirements of IS: 383-1970. 10 mm and 20 mm size aggregates are used. The specific gravity of coarse aggregates is 2.76 and fineness modulus is found to be 6.87.

Water: Potable water is generally considered satisfactory for mixing concrete.

Steel bars: Mild steel bars of 16 mm and 20 mm diameter are used.

Couplers: Steel couplers of 16 mm and 20 mm inner diameter are used in this study.

Base plates: As there is no certain code provision for steel base plates, 15 mm projection from the base of the coupler is provided. Therefore sizes of 54 mm x 54 mm for 16 mm couplers and 58 mm x 58 mm for 20 mm couplers are used.

Specimens: Cylindrical moulds of size 150 mm x 300 mm conforming to IS 10086 are used.

Table 1: Specifications of couplers

S.No.	Description	16 mm coupler (mm)	20 mm coupler (mm)
1	Outer diameter	24	28
2	Height	28	48

Table 1 describes the dimensions of steel couplers considered for this study.

Table 2: Mix Design Proportions (As Per Code of IS10262-2009)

Specification	Cement	Fine Aggregate	Coarse Aggregate
For 1m ³ concrete	370kg	643.8kg	1298.7kg
In ratios	1	1.74	3.51

Table 2 describes the mix design proportions of the mix used for casting according to IS 10262-2009

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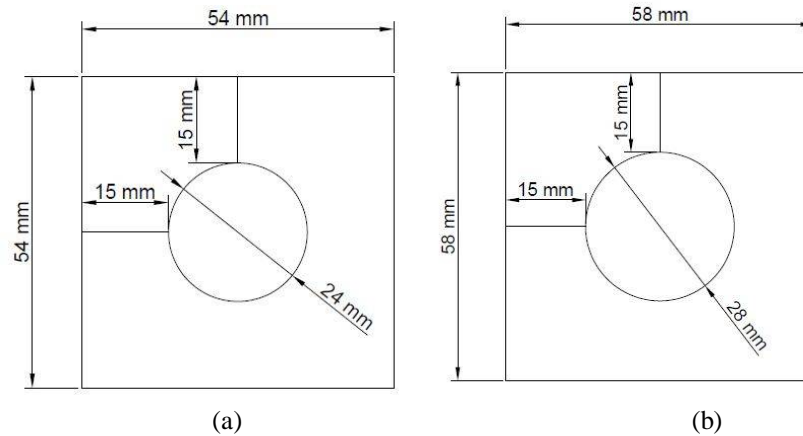


Fig. 1 Dimensions of base plate (a) 16 mm coupler base plate (b) 20mm coupler base plate

Fig. 1 describes the dimensions of base plates with 16 mm coupler and 20 mm coupler which are used in this study. Base plate with 16 mm coupler having dimension of 54 mm x 54 mm whereas for 20 mm coupler the base plate of 58 mm x 58 mm of various thicknesses i.e., 10 mm, 12 mm and 16 mm.

Casting and curing: First, plain concrete cylindrical specimens are casted and are kept under curing for 7, 14 and 28 days and the basic tests like compressive strength and split tensile strength tests are conducted to assess target strength of casted specimens. Then the steel rods of 16mm and 20mm diameter are inserted into the cylindrical specimen exactly at the centre leaving a cover of 40mm from the bottom. Care should be taken so that the rods are straight in position. Also the steel bars attached to couplers and the bars with couplers attached to base plates are inserted in same manner as mentioned above. All these specimens are carefully kept under curing for 28 days.

Testing: Pull-out test is used to determine the bond strength of concrete and steel by measuring the force required to pull the steel rod inserted in the concrete specimen. Pull-out testing is not a recent development. As early as 1938, the American Concrete Institute published a report of in-place concrete testing in the Soviet Union; pull-out tests were prominent among them. It was not until the 1970's however, following work by Richards and Malhotra that this approach to testing began to be regarded as a practical site method. The specimens are taken out from curing after 28 days and allowed to dry for some time. Then, these are mounted on the Universal Testing Machine (UTM) of 40 Ton capacity and pull-out test is carried to assess the bond strength between steel and concrete.

Table 3: Experimental test results

S.No	Description	Age (days)	Strength (Mpa)
1	Compressive strength (Cubes)	7	23.16
		14	29.82
		28	33.52
	Compressive strength (Cylinders)	7	23.19
		14	26.78
		28	29.04
2	Split Tensile strength	7	2.31
		14	2.52
		28	2.73

Table 3 describes the compressive strength achieved by cube specimens, cylinder specimens and Split tensile strength of cylinder specimens after 7 days, 14 days and 28 days respectively.

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IV. RESULTS AND DISCUSSIONS

- When couplers are attached to these 16 mm steel bars, there is an increase of 8.5% in bond strength when compared with steel bars not attached to the coupler
- When 10 mm thick base plate is attached to the steel bars with couplers, 25.13% increase in bond strength is observed when compared with steel bars not attached to the coupler and 15.3% increase in bond strength is observed when compared with steel bars attached to couplers.
- When 12 mm thick base plate is used, 27.33% increase in bond strength is observed when compared with steel bars not attached to the coupler, 17.34% increase in bond strength is observed when compared with steel bars attached to couplers and 1.76% increase in bond strength is observed when compared with steel bars attached with 10 mm base plates.
- When 16 mm thick base plate is used, 38.90% increase in bond strength is observed when compared with steel bars not attached to the coupler, 28% increase in bond strength is observed when compared with steel bars attached to couplers, 11% increase in bond strength is observed when compared with steel bars attached with 10 mm base plates and 9.08% increase in bond strength is observed when compared with steel bars attached with 12 mm base plates.
- Overall, highest bond strength is observed in steel bars attached to coupler with 16 mm base plate.

Table 4: Pull-out test results for 16 mm diameter bars

Description	Load (kN)	Embedded length (mm)	Age (days)	Bond strength (Mpa)
Without couplers	125	260	28	9.51
With couplers	135	260	28	10.32
With base plate 10 mm thick	155	260	28	11.90
With base plate 12 mm thick	158	260	28	12.11
With base plate 16 mm thick	172	260	28	13.21

Table 4 describes the failure load and bond strength attained by specimens of 16 mm diameter bars attached to couplers and base plates in the pull-out test at age of 28 days.

When couplers are attached to these 20 mm steel bars, there is an increase of 12.86% in bond strength when compared with steel bars not attached to the coupler. When 10 mm thick base plate is attached to the steel bars with couplers, 20.67% increase in bond strength is observed when compared with steel bars not attached to the coupler and 6.91% increase in bond strength is observed when compared with steel bars attached to couplers. When 12 mm thick base plate is used, 20.67% increase in bond strength is observed when compared with steel bars not attached to the coupler, 6.91% increase in bond strength is observed when compared with steel bars attached to couplers and same bond strength is observed when compared with steel bars attached with 10 mm base plates. When 16 mm thick base plate is used, 35.54% increase in bond strength is observed when compared with steel bars not attached to the coupler, 20.09% increase in bond strength is observed when compared with steel bars attached to couplers, 12.32% increase in bond strength is observed when compared with steel bars attached with both 10 mm base plates and 12 mm base plates. Overall, highest bond strength is observed in steel bars attached to coupler with 16 mm base plate.

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Table 5: Pull-out test results for 20 mm diameter bars

Description	Load (kN)	Embedded length (mm)	Age (days)	Bond strength (Mpa)
Without couplers	155	260	28	9.48
With couplers	175	260	28	10.70
With base plate 10 mm thick	187	260	28	11.44
With base plate 12 mm thick	187	260	28	11.44
With base plate 16 mm thick	210	260	28	12.85

Table 5 describes the failure load and bond strength attained by specimens of 20 mm diameter bars attached to couplers and base plates in the pull-out test at age of 28 days

COMPARISON BETWEEN 16 mm AND 20 mm DIAMETER BARS

- For 16 mm and 20 mm bars, without attaching to couplers, the bond strength is observed to be almost equal.
- When these bars are attached to couplers, there is an increase of 3.6% of bond strength in 20mm bar compared to 16 mm bar.
- When these bars are attached to 10 mm base plates, there is a decrease of 3.8% of bond strength in 20 mm bar with respect to 16 mm bar.
- When these bars are attached to 12 mm base plates, there is a decrease of 5.5% of bond strength in 20 mm bar with respect to 16 mm bar.
- When these bars are attached to 16 mm base plates, there is a decrease of 2.7% of bond strength in 20 mm bar with respect to 16 mm.

Fig.2 Graphical representation of bond strength of both 16 mm and 20 mm diameter bars

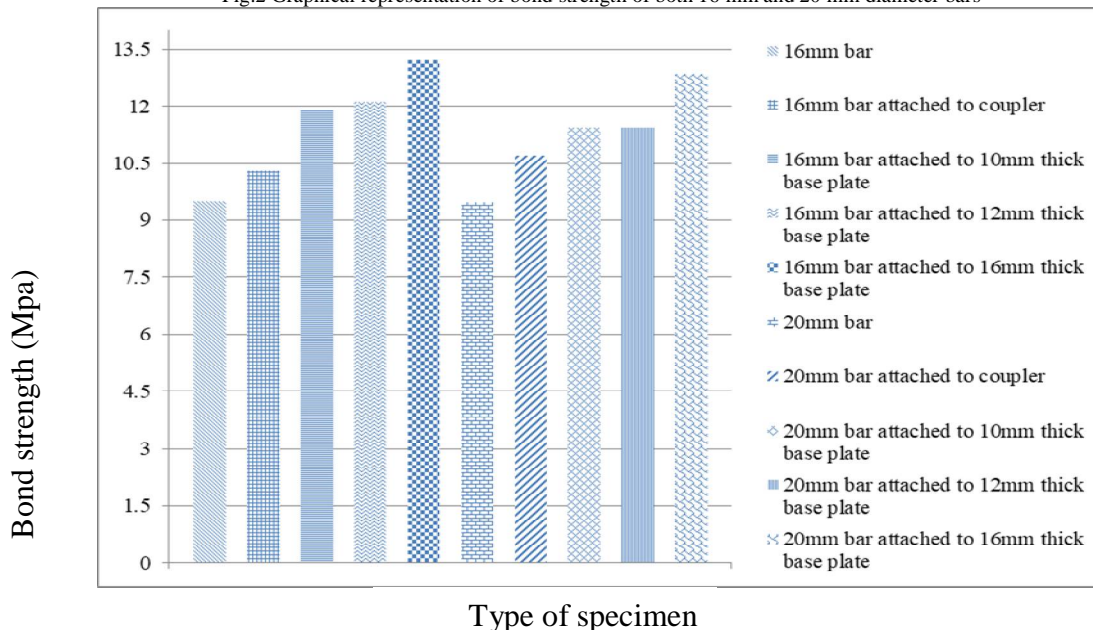


Fig. 2 represents the variation of bond strength of specimens with 16 mm diameter bars and 20 mm diameter bars attached to couplers and base plates

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V. CONCLUSIONS

- When overall comparison is made in 16 mm bars and 20 mm bars, the highest bond strength is observed when they are attached with 16mm thick base plate.
- It is observed that when the base plates are attached to the steel bars, there is a gradual decrease in the bond strength in 20 mm bars when compared with 16 mm bars.
- Overall in this study, it is observed that the bond strength between concrete and steel is higher when less diameter bars are used.
- Since the bond strength values for various cases is observed to be satisfactory, it is recommended that the steel bars attached to couplers and base plates can be used instead of anchoring or lap splicing the bars thereby avoiding congestion of reinforcement

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