SECM/15/140

BOND STRENGTH BEHAVIOR OF HEADED REINFORCEMENT BAR WITH VARYING EMBEDMENT LENGTH

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Abstract: Headed reinforcement is a relatively new product and has not been used in many applications. Headed reinforcing bars have been extensively used in the construction of offshore oil platforms where hooked bars have traditionally been used to anchor longitudinal reinforcement or bars bent for ties and transverse reinforcement. Hooks and bent-bar ties create a large amount of congestion in the reinforcing cage which leads to difficulties during construction. Using headed reinforcement removes the tail extensions of hooks and allows fewer larger bars to be used, greatly reducing the congestion of the reinforcing cage. It has been found that the use of headed reinforcement can greatly decrease the time needed to erect the reinforcement resulting in large cost savings. Headed reinforcement has also been used in a few projects for strengthening and repairing footings of highway structures.

A total 81 Pullout test were performed to the study of Bond behavior of Headed reinforcement bar in concrete with different Embedment length with various diameters of bars, various grade of concrete and various sizes of cubes.

In this research project, it is proposed to execute experimental work by using headed reinforcement bars. The effect of different parameters like embedment length, head shapes and concrete grades, threaded headed reinforcement bars can be study. The results will be used to develop design recommendations for the application of headed reinforcement bars.

Keywords: headed reinforcement; pullout; embedment length; diameter of bars.

1. Introduction

Headed bars are created by the attachment of a plate or nut to the end of a reinforcing bar to provide a large bearing area that can help anchor the tensile force in the bar. Figure 1.2 shows an example of a headed bar. The tensile force in the bar can be anchored by a combination of bearing on the ribs and on the head. This chapter discusses the current state-of-the-art of headed bar technology.

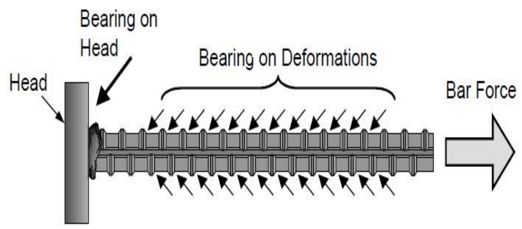


Figure 1.1: Anchorage of a headed bar

$$\text{Relative Head Area} = \frac{\text{The net head area}}{\text{The nominal bar area defined by ASTM A615}}$$

A_{nh} = the net head area

A_{gh} = the gross head area

A_b = the nominal bar area defined by ASTM A615

1.1: ASTM Code: Designation A970/A970M − 13A

Standard Specification for Headed Steel Bars for Concrete Reinforcement. Specification covers deformed steel reinforcing bars in cut lengths, with a head attached to one or both ends for concrete reinforcement. Heads are forge-formed machined from bar stock, or cut from plate. Attachment can be accomplished through

Welding Integrally hot forging of a head from the reinforcing bar end Internal threads in the head mating to threads on the bar end Separate threaded nut to secure the head to the bar. Head dimensions shall define the head geometry including thickness, diameter

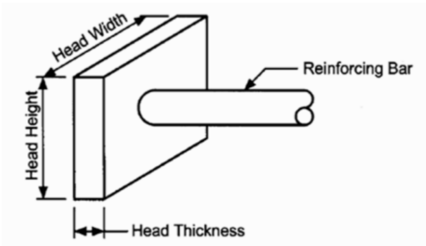


Figure 1.2: Headed Reinforcing Bar

1.2 Commentary Section 12.6 IN ACI 318 States

The limitation on obstructions and interruptions of the deformations is included in Code Section 3.5.9 because there are a wide variety of methods to attach heads to bars, some of which involve obstructions or interruptions of the deformations that extend more than $2d_b$ from the bearing face of the head. These systems were not evaluated in the tests used to formulate the provisions in Code Section 12.6.2, which were limited to systems that meet the criteria in Code Section 3.5.9." Some of the types of headed bars added to this specification after the 2009 version may have obstructions or interruptions in deformations exceeding the requirements of ACI 318 and thus not comply with the design requirements. Those types of headed bars explicitly satisfying the geometrical requirements in A970/A970M – 09 and Annex A1, comply with the minimum requirements provided in ACI 318, Sections 3.5.9 and 12.6.

2. Preparation for Experiment

- Heads and Bars 20 mm , 16 mm , and 12 mm
- For 20 Mm Φ Bars
  Cube size (300X300X300)
  Headed bar Size
  1. Square (50X50X10) mm,
  2. Rect.(105 X30X10) mm,
  3. Circular 57 mm dia.

  or height and width of the head.
- For 16 MM Φ Bars
  Cube size (250X250X250)
  Headed bar size
  1. Square (40X40X8)mm,
  2. Rect. (67X30X8) mm,
  3. Circular 46 mm dia.
- For 12 MM Φ Bars
  Cube size (200X200X200)
  Headed bar size
  1. Square (30X30X6)mm.
  2. Rect. (38X30X6) mm.
  3. Circular 34 mm Dia
- No's of Specimens:

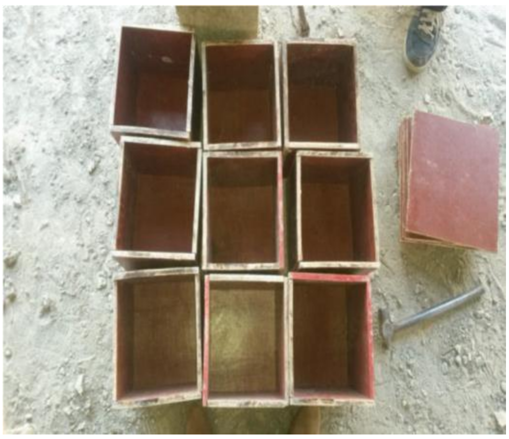
Grade of Concrete	Shape of Heads			Total No's of Specimens
	Rec.	Square	Circular	
M20	9	9	9	81
M30	9	9	9	
M40	9	9	9	

Diameter of Bar Db mm	Area of Bar (A_b) mm^2	Embedment Depth/Length (E_d) mm				Thickness of Head (Th)mm		A_{nh} mm^2
12	113.076	$10D_b$	120	160	200	$0.5D_b$	6	$8A_b$
16	201.024	$12D_b$	144	192	240		8	
20	314.1	$14D_b$	168	224	280		10	

Square	Size	Rectangular	Size	Circular	D_h mm	Formwork size (A)
904.608	30x30	904.608	38x30	1152	34	200x200x200
1608.192	40x40	1608.192	67x30	1536	46	250x250x250
2512.8	50x50	2512.8	105x30	1920	57	300x300x300

3. Work Done

- ➢ Heads and Bars 12 mm, 16 mm, 20 mm
- ➢ Headed bar length is 1 m for all dia. of bars
- ➢ Specimen’s formworks
- ➢ Specimen’s castings



5.Embedment lengths of headed bars

Sr. No	Dia. Of Bar	Grade of Concrete	Embedment length (mm)	Shape of Heads		
				Rectangular	Square	Circular
1	20	M20	10 x20 = 200	2R1	2S1	2C1
2	20	M20	12 x 20 = 240	2R2	2S2	2C2
3	20	M20	14 x 20 = 280	2R3	2S3	2C3
4	20	M30	10 x20 = 200	3R1	3S1	3C1
5	20	M30	12 x 20 = 240	3R2	3S2	3C2
6	20	M30	14 x 20 = 280	3R3	3S3	3C3
7	20	M40	10 x20 = 200	4R1	4S1	4C1
8	20	M40	12 x 20 = 240	4R2	4S2	4C2
9	20	M40	14 x 20 = 280	4R3	4S3	4C3

Sr. No	Dia. Of Bar	Grade of Concrete	Embedment length (mm)	Shape of Heads		
				Rectangular	Square	Circular
1	16	M20	10 x16 = 160	2R1	2S1	2C1
2	16	M20	12 x 16 = 192	2R2	2S2	2C2
3	16	M20	14 x 16 = 224	2R3	2S3	2C3
4	16	M30	10 x16 = 160	3R1	3S1	3C1
5	16	M30	12 x 16 = 192	3R2	3S2	3C2
6	16	M30	14 x 16 = 224	3R3	3S3	3C3
7	16	M40	10 x16 = 160	4R1	4S1	4C1
8	16	M40	12 x 16 = 192	4R2	4S2	4C2
9	16	M40	14 x 16 = 224	4R3	4S3	4C3

Sr. No	Dia. Of Bar	Grade of Concrete	Embedment length (mm)	Shape of Heads		
				Rectangular	Square	Circular
1	12	M20	10 x12 = 120	2R1	2S1	2C1
2	12	M20	12 x 12 = 144	2R2	2S2	2C2
3	12	M20	14 x 12 = 168	2R3	2S3	2C3
4	12	M30	10 x12 = 120	3R1	3S1	3C1
5	12	M30	12 x 12 = 144	3R2	3S2	3C2
6	12	M30	14 x 12 = 168	3R3	3S3	3C3
7	12	M40	10 x12 = 120	4R1	4S1	4C1
8	12	M40	12 x 12 = 144	4R2	4S2	4C2
9	12	M40	14 x 12 = 168	4R3	4S3	4C3

5.1 Notifications of Specimens of 20mm

- 2R1,2R2,2R3 are the M20 Grade of Concrete Rectangular Head with different Embedment Length 200mm,240mm and 280mm respectively
- 3R1,3R2,3R3 are the M30 Grade of Concrete Rectangular Head with different Embedment Length 200mm,240mm and 280mm respectively
- 4R1,4R2,4R3 are the M40 Grade of Concrete Rectangular Head with different Embedment Length 200mm,240mm and 280mm respectively
- 2S1,2S2,2S3 are the M20 Grade of Concrete Square Head with different Embedment Length 200mm,240mm and 280mm respectively
- 3S1,3S2,3S3 are the M30 Grade of Concrete Square Head with different Embedment Length 200mm,240mm and 280mm respectively
- 4S1,4S2,4S3 are the M40 Grade of Concrete Square Head with different Embedment Length 200mm,240mm and 280mm respectively
- 2C1,2C2,2C3 are the M20 Grade of Concrete Circular Head with different Embedment Length 200mm,240mm and 280mm respectively
- 3C1,3C2,3C3 are the M30 Grade of Concrete Circular Head with different Embedment Length 200mm,240mm and 280mm respectively
- 4C1,4C2,4C3 are the M40 Grade of Concrete Circular Head with different Embedment Length 200mm,240mm and 280mm respectively.
- These notifications are also applicable in 16mm dia. of Bars (embedment depth 160mm , 192mm, 224mm) and 12 mm dia. of bars (embedment depth 120mm,144mm,168mm) respectively.

5.2 Specimens testing photos

(1) 2R1 = M20 Rect. Head with Embedment length 200mm (20mm dia. of Bar)

Specimens Set-up

Cracks Develops

Splitting failure of Cube (SFC)

pull out headed bar

(2) 2S1 = M20 Square Head with Embedment length 200mm (20mm Dia. of Bar)

Specimens Set-up

Splitting failure of Cube

Pull out headed bar

(3) 4R1 = M40 Rect. Head with Emb. Length 200mm (20mm Dia. of Bar)

Specimens Set-up

Cracks formation

Thread failure

(4) 3C2 = M30 Circular Head with Emb. Length 240mm (20mm Dia. of Bar)

Specimens Set-up

Crack formation

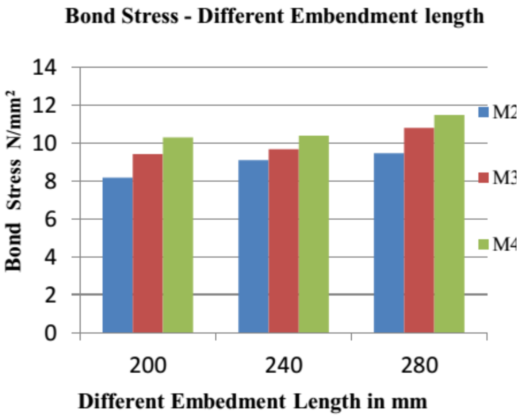
Thread failure

5.3 Results & Conclusion

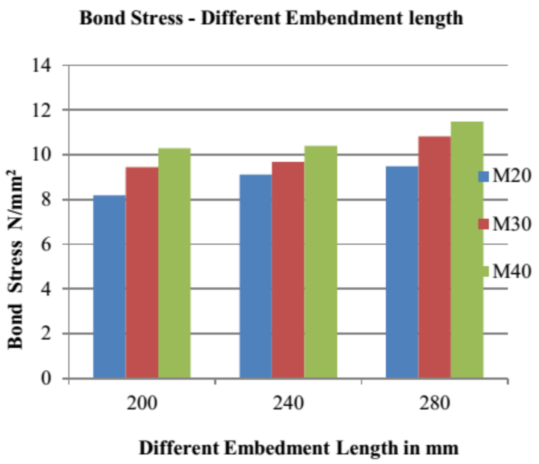
(20mm,16mm,12mm Dia. Of Bars)

- **Bond Stress - Different Embedment Length**

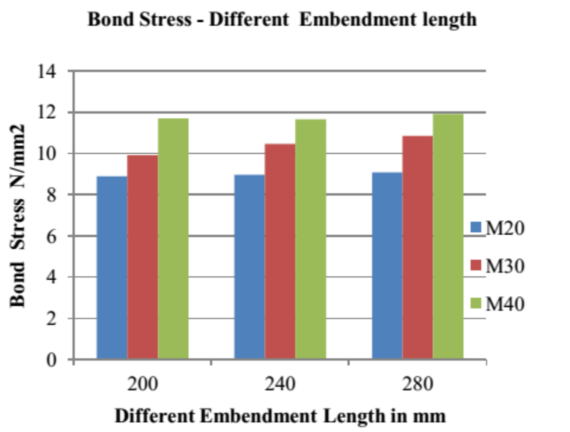
(a) Rect. Head, 20mm Dia., M20, M30 & M40



(b) Square Head, 20mm Dia., M20, M30 &M40

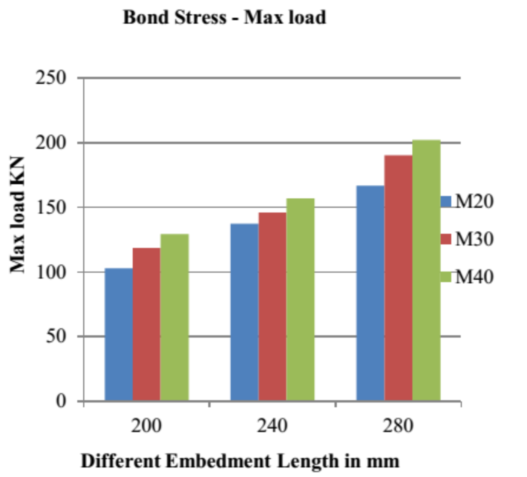


(c) Circular Head,20mm Dia.,M20,M30& M40

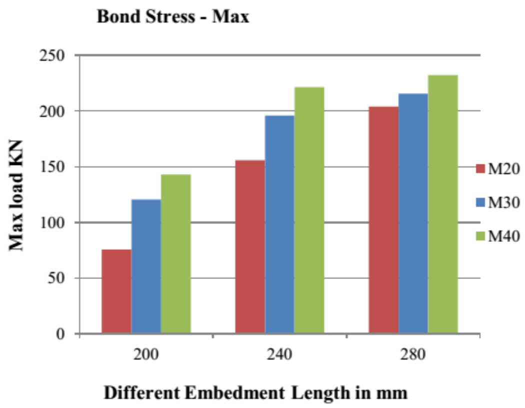


- **Bond Stress – Max load**

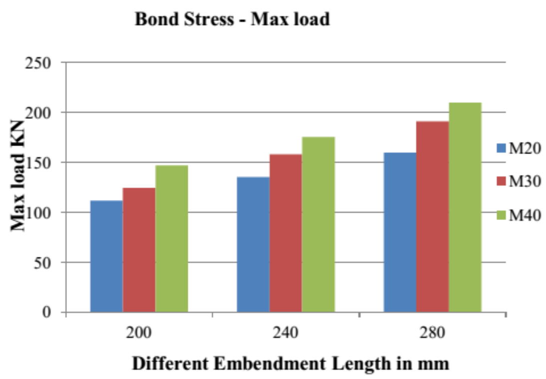
(a) Rect. Head, 20mm Dia., M20, M30 & M40



(b)Square. Head, 20mm Dia., M20, M30 & M40



(c)Circular. Head, 20mm Dia., M20, M30 & M40



- These kinds of results are also found in 16mm dia. of Bars (embedment depth 160mm , 192mm, 224mm) and 12 mm dia. of bars (embedment depth 120mm,144mm,168mm) respectively
- Bond stress increases with increment in embedment length.

- Pull out load increases with increment in embedment length.

Abbreviations:

- A_{brg}: Net Bearing Area Of The Head
- A_b: The Bar Area
- Db: Diameter of Bar
- Ed: Embedment Length
- Ah: Area of Head
- Dh: Diameter of Head
- La: Anchorage Length
- Sh: Size of Head
- Hd:EmbedmentDepth

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