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Comparison of Pull-Out Strength Behavior for Chemical Adhesive Anchors Installed in Concrete

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Abstract

Post installed reinforcement is widely used in the world as well as Bangladesh because of the need for it in rehabilitation and strengthening work. It help to contribute at the efficiency in the cost of construction in general and offer a level of confidence on the structural integrity of building and civil engineering infrastructural projects. Engineers need to be confident in the performance of adhesives anchor systems to be used where adhesives involved as a bonding agent between steel reinforcement bars and concrete. This research is investigated the effectiveness of several sorts of adhesives utilized in post-installed rebar connection under pull-out test. The cylindrical samples (36 + 12 Nos) of 15cm diameter 30 cm height with two different proportion ratio of ingredients for preparing concrete where brick chips as coarse aggregates with two different anchors grade (400W &500W) are used. The control samples (12 Nos) are the cast in-place rebar concrete specimens while other samples (36 Nos) are post rebar-installed concrete specimens where chemical adhesives like fischer, INDEX and mortar are used as bonding agents. The findings show that the pull-out load values are higher for lower reinforcement grade and lower amount of aggregates in concrete by applying chemical adhesive.

Keywords: Adhesive; INDEX; fischer; Retrofits; Pre-drilled etc.

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1. Introduction

Anchors are applied to supply connection between concrete and structural members are often separated into two common categories as cast-in-place anchors and post-installed anchor. Cast-in-place anchors are installed before the concrete is cast in order that they're normally used for predesigned facilities, generally for fixing different items that are made up of different materials. On the opposite hand post-installed anchors are generally provided for retrofit works called as retrofits anchors [3]. Retrofits anchors could also be tied during almost any position desired by installing them in a hole drilled in hardened concrete [6]. This method is employed for various purposes like binding new concrete to the old or pre-exiting one. This permits continuity, strengthening or homogeneous stress transfer within the structures by means of additional reinforcing bars. Such bars are typically glue or mortar bonded during a pre-drilled hole [2, 11, 12]. Post installed adhesive anchors are used around for several years but it wasn't until 1990's that they began gaining widespread use. In 1995 the primary adhesive anchor testing criteria, AC58, was adopted and later superseded by AC308 in 2005, with the goal of getting adhesive anchors adopted into the ACI 318 code. After the 1999 Post installed reinforcement are widely utilized in the planet also as Bangladesh due to the necessity for it in rehabilitation and strengthening work. A better understanding of the effects installation conditions have on the pullout strength of adhesive anchors is needed to expand their applications. These applications include, but are not limited to one structure. The efficiency of the bond strength of anchors for using different adhesive materials available at the local market in Bangladesh whereas the Brick chips with its proportion variety as well as the variety of anchorage strength/grade has never been checked.

2. Background Study

Existing concrete structures may require strengthening or stiffening in order to increase their ultimate flexural or shear capacity, or to control deflections and cracking [3] as well as to improve earthquake resistance. After the 1999 Kocaeli Earthquake, the use of chemically bonded anchors has seen a great growth for retrofits in Turkey. At the moment, no specific design codes are available for chemically bonded anchors. Currently, chemically bonded post-installed anchors are designed from related tables provided by adhesive manufacturers which involve a set of equations based on laboratory pullout tests on normal or high strength concretes. Unfortunately, concrete compressive strengths of existing buildings in Turkey, which need retrofit for earthquake resistance, ranges from 5 to 16 MPa according to data obtained from Ministry of Defense [10]. The objective of bonding-in or post-installing steel reinforcement in an existing reinforced concrete structure is to provide a connection between a new concrete element and the existing structure that is similar in strength and stiffness as cast-in reinforcement [9]. Understanding anchor behavior is necessary in specifying the appropriate anchorage for a given application. This includes an understanding of failure modes and strengths as well as load displacement and relaxation characteristics of various anchor types (ACI, 1991).it requires an in-depth understanding of the physical phenomena involved in the complete process of setting and loading in building material, mainly concrete [8]. Epoxy anchor systems consist of a steel threaded rod or rebar that is inserted into a drilled hole in a cured concrete member and securely bonded using epoxy. The epoxy itself consists of two parts, a bonding agent and curing compound. When mixed, the curing compound causes the epoxy to harden, forming the bond between the anchor and the concrete [5]. There are two widely used systems to mix the two agents, a glass

capsule system, and a two part injection system. In glass capsule systems, a glass capsule is inserted into the drilled hole containing the two unmixed components. When the anchor is inserted, usually by attaching it to a rotary hammer drill, the glass capsule is broken and the two components are mixed together. With the injection system, the two parts of the epoxy are kept in separate tubes and mixed together in a mixing nozzle as it is injected into the hole. The anchor is then inserted by slowing rotating it as it is placed in the holes [5]. This rotation ensures that the epoxy fills the threads on the rod. Once the epoxy cures, it allows for load transfer between the anchor rod and concrete base material.

3. Objectives

Since the aggregates by using bricks chips are frequently used in Bangladesh, it is necessary to know about the variation of strength for post installed rebar in these types of concrete. The principal objectives of this study are as follows:

- To evaluate the pull-out strength in post installed reinforcement bars if different types of adhesives used as bonding agent;
- To investigate the effectiveness of adhesives for variation of reinforcement grade;
- To determine the pull-out behavior for different type of mixture proportion.

4. Experimental Investigation

The compressive strength test of cement for cylindrical specimen conforms to the ASTM standards requirements of specification C 39. The tensile strength test conforms to the ASTM standard requirements of specification C 496 .The tensile strength of concrete is relatively low ,about 10 to 15% of the compressive ,occasionally 20% . The mechanical strength of hardened cement is the property of materials, which is perhaps the most important one for its structural use .The strength of cement is usually determined from test on mortar made with cement. The compressive and tensile strength of cement is used in this study has listed in the following table;

Table 1: Properties of cement

Normal consistency	Setting time (Min)		Compressive strength (MPa)		Tensile strength (MPa)	
	Initial	Final	3 days	7 days	3 days	7 days
27%	130	325	15.3	18.9	1	1.56

Table 2: Compressive strength of different concrete

Samples	Coarse aggregate	Ratio	Compressive strength(MPa)
B-R1	Brick chips	1:1.5:3	26.27
B-R2	Brick chips	1:2:4	25.5

Table 3: Properties of aggregates

Materials	Properties	Unit	Value
Fine aggregate	Specific gravity (OD)		2.55
	Absorption	%	1.20
	Unit Weight	Kg/m^3	1524
	Fineness modulus		2.40
Coarse aggregate	Specific gravity (OD)		1.85
	Absorption	%	16.83
	Unit Weight	Kg/m^3	1204
	Fineness modulus		7.21

a). Bricks samples b). Rebar samples c). fischer and INDEX samples

Figure 1: Materials used in research

Table 4: Properties of steel reinforcement

Rebar grade	Yield Strength (Mpa)	Ultimate Strength (MPa)
400 W	380	474
500 W	432	504

5. Methodology

The pull-out value recorded is the average of three replica values. The results are designated as B-Cs for cast-in place specimens for which bricks chips is used as coarse aggregates. Again for anchoring the post-installed steel reinforcement anchor to the cylinder are designated as B-Pfi (for using fischer), B-Pmo (for using INDEX (MOEPSE)) and B-Pm (for using mortar). The reinforcement grade is illustrated as a representing G1 for 400W and G2 for 500W.The mixture proportion is illustrated as a representing R1 for 1:1.5:3, and R2 for 1:2:4.

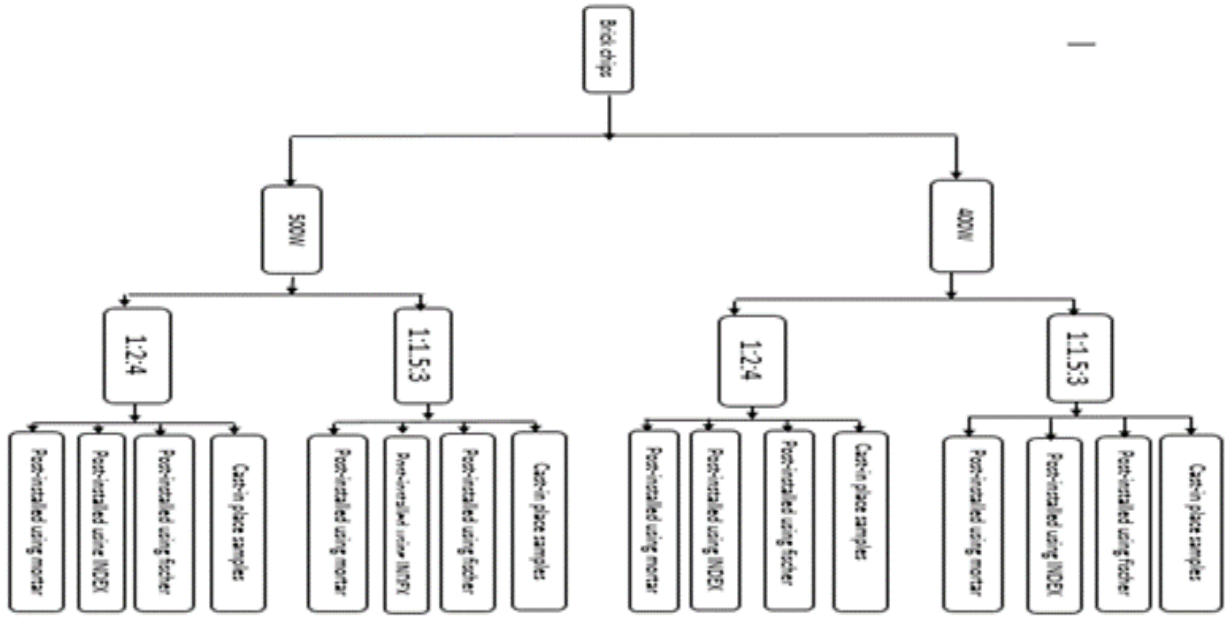

Figure 2: Experimental program flowchart

For instance, B-Pfi R1G1 can be described as the pull-out load value for post-installed 400W type rebar to cylinder which is made from brick chips type coarse aggregates with its cement, sand and brick chips mixture ratio 1:1.5:3 bonded by fischer.

Figure 3: Drilling operation and injecting adhesives operation

6. Results

The average pull-out load of 10mm reinforcement bars of post-installed samples (which is prepared by using with materials proportion ratio 1:1.5:3) using fischer adhesive with embedment length of 20Ø and for its two different reinforcement grade; 400 W (B-PfiR1G1) and 500 W (B-PfiR1G2) are about 90.89% and 78.64%, respectively of the cast in place pull-out load(B-CsR1G1 and B-CsR1G2).

Figure 4: Experimental setup of cylinder and Failure mode

The average pull-out load in post-installed rebar samples using INDEX adhesive for its two different reinforcement grade i.e,400W (B-PmoR1G1) and 500W (B-PmoR1G2) are about 75% and 68.67%, respectively of the cast in place pull-out load. It means that using fischer adhesive is better for concrete with its reinforcement grade 400W and 500W than INDEX adhesive. For using mortar the average pull-out loads in post-installed 400W(B-PmR1G1) and 500W(B-PmR1G2) rebar samples are about 80.74% and 82.16% respectively of the cast in place pull-out load.

Table 5: Pull-out load and failure mode of concrete specimens

For coarse aggregate(brick chips) and proportion ratio(1:1.5:3)				
Samples	Rebar grade	Pull-out load (kN)	Average pull-out load (kN)	Failure mode
Control	400 W	50.0	45.33	Splitting concrete specimen
		43.0		Splitting concrete specimen
		43.0		Anchor failure
	500 W	49.0	47.47	Pull-out of the anchor
		44.6		Anchor failure
		48.8		Pull-out of the anchor
fischer	400 W	42.2	41.20	Splitting concrete specimen
		43.4		Splitting concrete specimen
		38.0		Splitting concrete specimen
	500 W	38.6	37.33	Anchor failure
		36.4		Splitting concrete specimen
		37.0		Splitting concrete specimen
INDEX	400 W	35.0	34.00	Concrete cone & bond failure
		32.8		Splitting concrete specimen
		34.2		Splitting concrete specimen
	500 W	32.4	32.60	Anchor failure
		31.2		Anchor failure
		34.2		Pull-out of the anchor
Mortar	400 W	34.2	36.60	Pull-out of the anchor
		38.8		Pull-out of the anchor
		36.8		Pull-out of the anchor
	500 W	40.2	39.00	Pull-out of the anchor
		39.6		Pull-out of the anchor
		37.2		Pull-out of the anchor

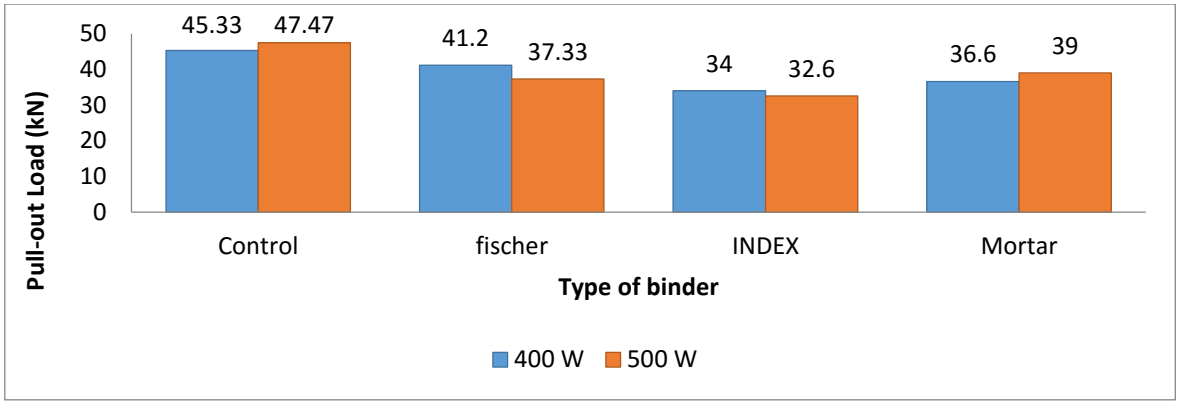

Figure 8: Capacity of bonded anchors using several types of adhesives (1:1.5:3)

The average pull-out load of 10mm reinforcement bars of post-installed samples (which is prepared by using with materials proportion ratio 1:2:4) using fischer adhesive with embedment length of 20Ø and for its two different reinforcement grade; 400 W (B-PfiR2G1) and 500 W (B-PfiR2G2) are about 99.18% and 80.49%, respectively of the cast in place pull-out load(B-CsR2G1 and B-CsR2G2).

Table 5: Pull-out load and failure mode of concrete specimens

For coarse aggregate(brick chips) and proportion ratio(1:2:4)				
Samples	Rebar grade	Pull-out load (kN)	Average pull-out load (kN)	Failure mode
Control	400 W	38.4	40.13	Splitting specimen
		45.2		Anchor failure
		36.8		Pull-out of the anchor
	500 W	47.4	45.47	Concrete cone & anchor failure
		47.0		Concrete cone & anchor failure
		42.0		Splitting concrete specimen
fischer	400 W	38.6	39.80	Splitting specimen
		35.2		Splitting concrete specimen
		45.6		Anchor failure
	500 W	35.2	36.60	Splitting concrete specimen
		38.2		Splitting concrete specimen
		36.4		Pull-out of the anchor
INDEX	400 W	36.2	33.73	Splitting specimen
		32.6		Splitting specimen
		32.4		Splitting specimen
	500 W	31.2	31.53	Splitting concrete specimen
		32.6		Splitting concrete specimen
		30.8		Splitting concrete specimen
Mortar	400 W	37.2	35.93	Pull-out of the anchor
		36.4		Pull-out of the anchor
		34.2		Pull-out of the anchor
	500 W	39.0	38.27	Pull-out of the anchor
		38.4		Pull-out of the anchor
		37.4		Pull-out of the anchor

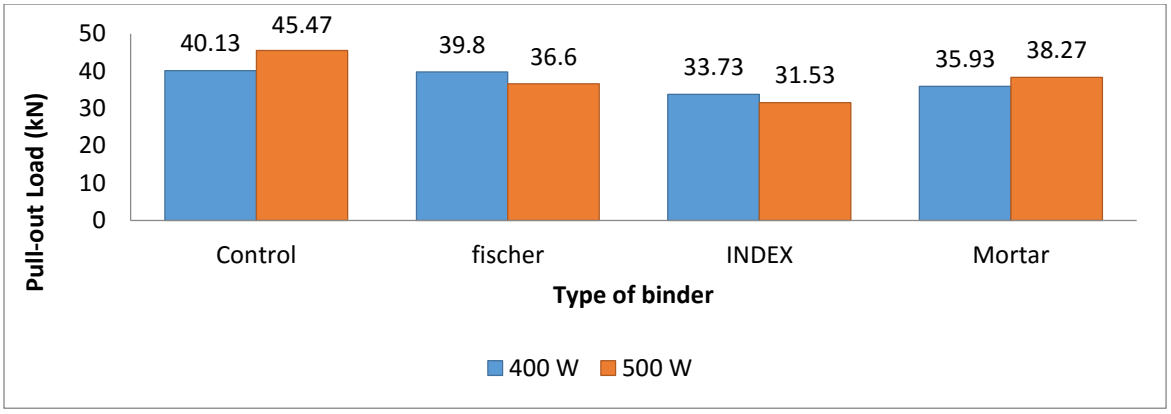

Figure 9: Capacity of bonded anchors using several types of adhesives (1:2:4)

It means that using fischer and INDEX adhesive is better for concrete with its reinforcement grade 400W. For using cement based binder (mortar) the average pull-out loads in post-installed 400W(B-PmR2G1) and 500W(B-PmR2G2) rebar samples are about 89.53% and 84.17% respectively of the cast in place pull-out load.

7. Conclusion

The pull-out load of control samples are higher than all other post-installed anchor samples where chemical adhesives are involving as bonding agent. Though the strength of post-installed anchor samples are lower than that of cast in place, it is sufficient to rehabilitation and strengthening work. For cast in place as well as mortar samples, it implies that the higher reinforcement grade and higher concrete strength, the higher the bond strength or the recordable pull-out load. The result show that the pull-out load values are higher for 400W rebar and mix proportion ratio 1:1.5:3 in concrete by applying fischer and INDEX chemical adhesive. If the mix ratio of aggregates are changed from 1:1.5:3 to 1:2:4, the pull-out load is decreased about 2% for both fischer and INDEX post-installed samples.

8. Recommendations

Based on the present study the following recommendations may be drawn for further study.

- Pre-existing structure can be used
- Holes diameter can be changed;
- Cavity height may be reduced for better prediction.

However, cost effectiveness and environmental considerations may be the guiding criteria on the choice of adhesives and cement based binder as a binding agent for post installed rebar concrete applications.

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