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Structural Performance of Grouted Sleeve Splice Connectors with Grooves Under Axial Tensile Load for Precast Concrete Structure

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Abstract : This study explains the performance of the proposed grouted sleeve connector with internal Grooves within the sleeve beneath incremental tensile load until failure. In this study, a series of twelve grouted sleeve splice with grooves (GSSG) were tested experimentally beneath incremental tensile load until failure to determine their feasibilities. The connector utilized mild steel pipe as sleeve where the sleeve comprises internal grooves with differing height and width .The mild steel pipe and the grooves are utilized to confine and strengthen the grout and the two dis continued bars joined end-to-end configuration within the sleeve. The specimens are studied and evaluated based on two major aspects; (a) ultimate tensile capacities, whether it is higher than 125% of the specified yield strength, (b) failure modes, The test shows up that, there are two modes of failure which were bar to grout failure and bar broken outside the sleeve. Sex examples out of twelve shows up palatable comes about since it failed due to bar broken outside the sleeve and fulfill palatable ultimate tensile capacity. The stiffness and the ductility of the connectors additionally fulfill. It is found that the grooves on the sleeves are essential to interlock with the confined grout, resisting it from slipping out of the sleeve. The test appears that the performance of the grouted sleeve connector with grooves was represented by grout-bar bond, anchorage length and control action given by the sleeve and the grooves . Possibility consider for tried grouted sleeves detailing their adequacy in agreement with the code arrangements of ACI 318-14 and ECP 203-2018 is displayed. Besides, design equations capturing the parameters influencing the bond strength, the confining pressure, grooves , and the specified embedment length are determined.

Keywords: Precast conc rete; Grouted splice; Mechanical Splice; Confinement action; bar splice; Bond; bar embedment length.

I. INTRODUCTION

Precast concrete buildings have gained popularity around the world, see Fig. 1. Buildings which were already constructed with cast-in-situ concrete can be constructed with precast concrete components prefabricated within the factories. These ready-made loose components such as precast concrete wall panels are introduced on site.

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To facilitate the method of installation, connections such as uncommon strengthened bar splicing systems are needed to connect the free precast concrete components together.

Too, the association can extend the structural integrity of precast concrete components. A grouted splice could be a type of mechanical connectors that utilized as the connections for precast concrete structures. Figure 2 appears a few common applications of mechanical splices in precast concrete structures, where they can be utilized as the column-to-base, wall – to - wall, column – to - column, beam-to-beam connections. Splice connectors are cast along with precast components some time recently transported to the construction sites. In order to assemble the precast elements, the steel bars projecting from them are inserted and grouted within the connectors embedded within the other components. The preferences of splice connectors include ease of installations that speed up the construction pace, way better bond efficiency under proper confinement that leads to shorter required bar development length and others.

Fig.1 : Precast Concrete Building

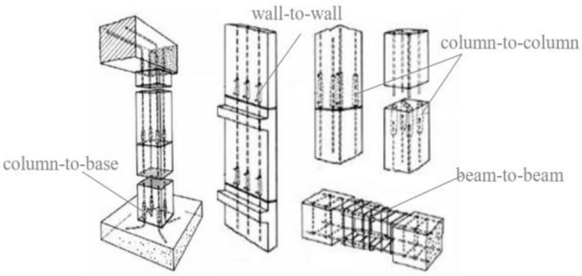

Fig.2 : Application of mechanical Splice

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II. LITERATURE REVIEW

The structural performance and durability of reinforced concrete individuals are exceedingly subordinate on the bond strength between strengthening steel bars and the encompassing concrete. Bond strength may be a work of the confinement given by the concrete itself and transverse reinforcement that encompasses reinforcing steel bars. Transverse confinement plays a basic part in deciding the specified improvement length and/or splice length. The taking after segment shows up a study of the explore work accessible inside the composing, examining the mechanical behavior of the sleeves beneath tensile load. Bond between steel and concrete is basic for the judgment of any strengthened concrete structure. Nevertheless, bond could be a complex issue and depends on numerous parameters. Due to its significance for practical design, the think about of bond between steel and concrete has continuously been a popular issue in the field of research.

According to Untrauer and Henry [15], bond can be defined as the adhesion of mortar to reinforcement bar or to other surfaces against which it is set. Bond strength between the steel and concrete increases in degree to square root of ordinary pressure and mortar strength. Normal pressure was connected to the faces of concrete specimens subjected to tensile forces. Lutz [10], and M.K[11]. Thompson [14]talk about the principles of bond, where the bond between steel bar and mortar is contributed by three major variables, to be particular chemical adhesion, friction, and mechanical interlocking between bar ribs and mortar keys, of which for the foremost portion concurred that the mechanical interlocking mechanism is for the most part more critical. Soroushian [13], who explored the local bond stress behavior of deformed bars in confined mortar, concluded that the bond strength diminished linearly as the bar diameter increased. In order to assess the performance of mechanical connectors, the specimens are commonly tested experimentally beneath incremental tensile loads, such as already conducted by Einea [8], Coogler [5], and Jansson [9]. A satisfactory splice is recognized based on their failure modes, where the spliced steel bars ought to fracture outside of the sleeve, indicating palatable bond strength that outperforms the tensile strength of steel bars.

Einea et al. [8] surveyed the bond strength of strengthening bars as a work of grout compressive strength and the level of confinement by considering the variables that impact the bond strength of rein forcing bars limited with steel channels. They point by point that a advancement length as short as seven time the bar diameter can be fulfilled by confining the high quality grout encompassing the bars. In terms of ultimate tensile performance, relevant codes , such as ACI. 318 [2]and ECP [7], indicate that an satisfactory mechanical splice should be able to offer the connection strength at least 25 percent higher than the specific yield strength of the spliced bars. Dar win et al. [3] concluded that the fourth root of the concrete strength given an exact representation of the effect of concrete strength on bond strength, and the yield strength of transverse reinforcement plays no basic part in choosing the improvement length. Einea et al. [8] inspected the behavior of spirally confined lap splices of deformed reinforcing bars in concrete. They concluded that joins with two lapping bars joined to the main bars appeared the most excellent performance. Moreover, they detailed that the A. C. I. [2] condition overestimates the desired lap length by at slightest 76%. They suggested to postpone the 12 in. constrain on least length of a lap join and increment the constrain on the confinement term to 4 instead of 2.5.

AbdAllh [1] study divers sleeve size and configuration and derived equations that could be used to determine the embedded length taking into consideration the grout compressive strength , bar diameter, confining strength, sleeve inner diameter and the sleeve wall thickness. Equation 1,2 and 3.

$$tbi = 0.75\sqrt{fg}$$

$$\frac{Ub}{\sqrt{fg}} = 0.0064 * ds\,in + 0.1871 * ts + 0.0648\,db - 0.006 * Lb$$

$$\frac{Ub}{\sqrt{fg}} = 1.747 - 2.45*10^{-3} * ds\,in + 0.05976 * ts + 8.475*10^{-2} * db - 8.84*10^{-3} * Lb$$

(1)

(2)

(3)

$$P_t = P_s + P_{gr}$$

$$P_s = f_n\, \pi\, d_{si}\, (l_d - h_{gr}\, n_{gr})$$

$$P_{gr} = (\mu_g f_n + \nu_g)\, d_{si}\, h_{gr}\, n_{gr}$$

Where:

fg = grout compressive strength (MPa)

tbi = initial bond strength (MPa)

Ub = bond strength of bar - to - grout (MPa)

ds in = inner diameter of (mm)

ts = sleeve wall thick ness (mm)

db = spliced bar diameter (mm)

Lb = spliced bar embedded length (mm)

Belal [4] derived equation to evaluate the minimum numbers of grooves which can prevent the grout to sleeve bond failure equation 4,5 and 6.

(4)

(5)

(6)

Where:

Pt = Total force resisted by the grouted splices (N)

Ps = Force resisted by the grout-sleeve bond action (N)

Pgr = Force resisted by the grooves (N)

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μs = Coefficient of friction between the sleeve and grout = 0.05
ld = bar embedded length (mm)
hgr = Height of the grooves (mm)
ngr = Number of grooves per embedded length
μg = Shear friction coefficient of the grout (monolithically cast) = 1.4
fn = Confinement stress as per Eqn. (4.4) (N/mm2)
vg = shear strength of the grout (N/mm2).

III. OBJECTIVE

The most objective of this investigate is to investigate the impact of grooves on the mode of failure of the splice association beneath incremental tensile force and drive a modern equation that can be utilized to design spliced sleeve associations with inner grooves considering all the para meters influencing the joint and accomplish all the code necessities for splicing steel bars.

IV. EXPERMENTAL PROGRAM

In this think about, 12 examples of grouted sleeve splice with inward grooves (GSSG) were tried beneath direct tensile load where their tensile performance and failure modes were examined to secure the components that oversee the performance of the connectors.

A. DESCREPTION OF SPECIMENS

Two arrangement with a add up to number of 12 examples of grouted splice sleeve connectors were arranged to be tried within the test think about. Each arrangement varies from the others in a few parameters such as the spliced bar diameter, the bar embedment length and the number of grooves. All the examples where made up of accessible commercial channels and grouts. The example comprises of 3 parts as appeared in Fig.3. To begin with portion ASTM. pipe [3] as a sleeve having a least yield strength of 240 MPa, we utilize as it were one sleeve SL 88 with external breadth 88.9 mm, interior breadth 77.92mm and divider thickness 7.62 mm moreover we made grooves interior the sleeve with height 5 mm and width 4 mm. Second portion is the joined bars in this investigate 18 mm and 25mm grafted bars were utilized with yield stress 360 MPa and ultimate Stress 520 MPa. Third portion is the filling fabric the commercially accessible grout utilized in this investigate work were SIKA grout ® 200 (G200) [12]. The compressive strength of the grouts was measured at the age of 7 days to discover out the creating of the grout strength till the testing day of the examples. Too, it was measured on the testing day utilizing standard 50×50×50 mm cubes. The whole connection was named concurring to the association parameters influencing the behavior of each sleeve. For case, example G200-D18-160-SL88-G-2 stands for a grouted join sleeve connector made from a Sleeve SL88 and filled with grout G200. The D18 image stands for the diameter of the joined bars and G stands for examples upgraded with inner grooves. Too, the number 160 within the center title of the example presents the embedment length of the joined bars. the last number within the Example title alludes to the number of grooves at each end of the sleeve. Table I speaks to list of examples and their description.

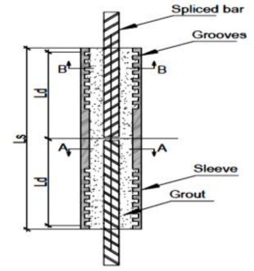

Fig.2 details of grouted spliced specimen with internal grooves

Table- I: list of specimens and their description

ID	Name	Grout	diameter	embedded length	sleeve				Grooves		
		Mpa	mm	mm	D out	D in	ts	length	Hight	WIDE	NUMBER
GSSG 1	G200-D18-160-SL88-G-2	G200	18	160	88.9	73.66	7.62	340	5	4	2
GSSG 2	G200-D18-160-SL88-G-3	G200	18	160	88.9	73.66	7.62	340	5	4	3
GSSG 3	G200-D18-160-SL88-G-4	G200	18	160	88.9	73.66	7.62	340	5	4	4
GSSG 4	G200-D18-180-SL88-G-2	G200	18	180	88.9	73.66	7.62	380	5	4	2
GSSG 5	G200-D18-180-SL88-G-3	G200	18	180	88.9	73.66	7.62	380	5	4	3
GSSG 6	G200-D18-180-SL88-G-4	G200	18	180	88.9	73.66	7.62	380	5	4	4
GSSG 7	G200-D25-170-SL88-G-3	G200	25	170	88.9	73.66	7.62	360	5	4	3
GSSG 8	G200-D25-170-SL88-G-5	G200	25	170	88.9	73.66	7.62	360	5	4	5
GSSG 9	G200-D25-170-SL88-G-6	G200	25	170	88.9	73.66	7.62	360	5	4	6
GSSG 10	G200-D25-190-SL88-G-3	G200	25	190	88.9	73.66	7.62	400	5	4	3
GSSG 11	G200-D25-190-SL88-G-5	G200	25	190	88.9	73.66	7.62	400	5	4	5
GSSG 12	G200-D25-190-SL88-G-6	G200	25	190	88.9	73.66	7.62	400	5	4	6

B. PREPRATION OF SPECIMENS

The GSSG examples were arranged in a few stages: Organize 1- cutting the ASTM pipes[3] to the desired lengths as appeared in Fig.3. Organize 2 - making grooves interior ASTM pipes[3] as appeared in Fig.4. Organize 3- introduce the bars to be joined at that point pour the mortar to grout the sleeves as shown in Fig.5 The grout was blended employing a blender concurring to the detail as expressed. The grouting handle was done by pouring the grout into a cone interfacing to the pipe. The cone was used to speed up the grouting prepare as the full grouting prepare must be done inside half an hour to avoid the grout from solidify. The 50*50*50 mm grout cubes were arranged to be tried afterward to discover out the genuine compressive strength of the grout. Moreover, steel bar tests were cut to be tried afterward to discover the real steel yield and ultimate strength.

Fig. 3 Cutting the ASTM pipes

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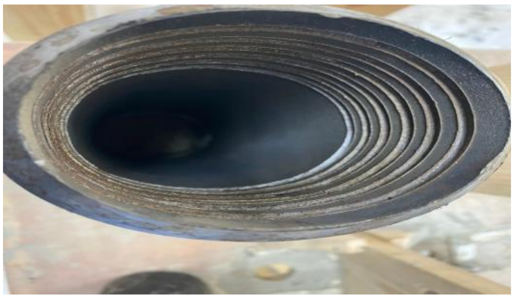

Fig. 4 Making grooves inside ASTM Pipes

Fig. 5 Grouted sleeve connectors prepared for grouting procedure

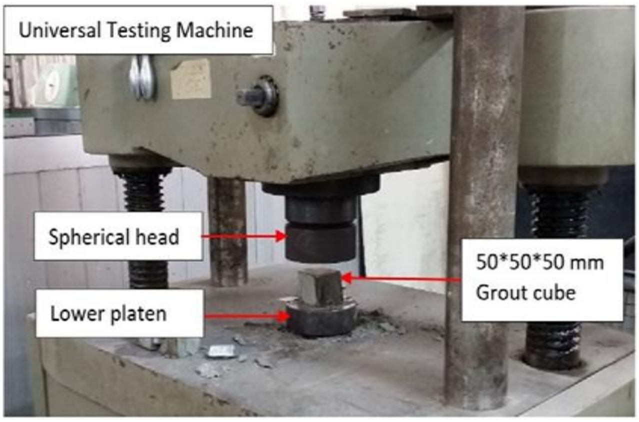

Fig.6 Compressive strength test of the grout cubes.

Fig. 7 Tensile strength test for steel bars.

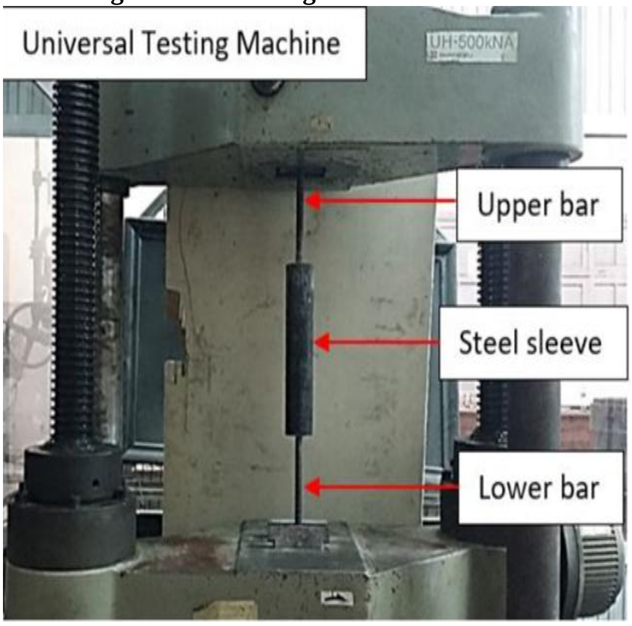

Fig. 8 Tensile test setup

C. TESTING SPECIMENS

The GSSG examples were tried to examine the mechanical behavior of the joins and the impact of the association parameters on the bond behavior. To begin with the grout cubes were tried utilizing universal testing machine as appeared in Fig.6 to survey the real grout compressive strength. Moment the steel bars were tried beneath axial tensile load to urge the genuine yield and extreme stress as appeared in Fig.7. All the examples were loaded with expanding axial force to failure, see Figure 8. The tensile tests were carried out after 28 days, to permit the grout to attain the target strength. The most extreme applied load up to the point of failure was recorded employing a computer, and the mode of failure was watched and reported.

V. RESULTS AND DISSCUSION

A. RESULTS OF TESTED GROUTED SPLICE SLEEVE SPECIMENS

The test comes about of the examples are given in Table II.

ID	Name	Tensile Force (KN)	Tensile strength (MPa)	Mode of Failure
GSSG 1	G200-D18-160-SL88-G-2	148.3	583.1	Bar- Grout bond failure
GSSG 2	G200-D18-160-SL88-G-3	152.2	598.4	Bar Fracture
GSSG 3	G200-D18-160-SL88-G-4	154.2	606.3	Bar Fracture
GSSG 4	G200-D18-180-SL88-G-2	150.4	591.3	Bar- Grout bond failure
GSSG 5	G200-D18-180-SL88-G-3	155.7	612.2	Bar Fracture
GSSG 6	G200-D18-180-SL88-G-4	162.2	637.7	Bar Fracture
GSSG 7	G200-D25-170-SL88-G-3	188.4	384.0	Bar- Grout bond failure
GSSG 8	G200-D25-170-SL88-G-5	232.7	474.3	Bar- Grout bond failure
GSSG 9	G200-D25-170-SL88-G-6	258.5	526.9	Bar- Grout bond failure
GSSG 10	G200-D25-190-SL88-G-3	246.2	501.8	Bar- Grout bond failure
GSSG 11	G200-D25-190-SL88-G-5	271.2	552.8	Bar Fracture
GSSG 12	G200-D25-190-SL88-G-6	279.2	569.1	Bar Fracture

The grout compressive strength, the extreme tensile capacity, and the mode of Failure are recorded. The comes about report that the proposed grouted splice sleeve examples given with inward grooves either fizzled due to bar-to-grout bond Failure or bar fracture.

B. ANALYSIS OF EXPERIMENTAL TEST RESULTS

- **MODES OF FAILURE**

Two modes of Failure were recognized for the examples within the test program, to be specific: bar-to-grout bond Failure as appeared in Fig. 9, and bar fracture as appeared in Fig. 10.

Fig.9 Bar to Grout Bond Failure

Fig.10 Bar Fracture Failure

The bar-to-grout bond failure mode occurs when the bond capacity between the joined bars and the grout cannot stand up to the tensile load. This may well be credited to an inadequately bar inserted length whose required regard is impacted by diverse parameters. Differing values of the tensile capacity of the cases were point by point for bar-grout bond failure mode and they changed due to particular setups of the sleeves affecting the confinement, or particular bar . embedded lengths. This mode happened in a couple of cases such as GSSG1, GSSG4, GSSG7, GSSG8, GSSG9, and GSSG10 with tensile capacities of 148.3 kN, 150.4 kN, 188.4 kN, 232.7 kN, 258.5 kN, and 246.2 kN, respectively. Bar fracture occurred when both bar-to-grout bond capacity and grout-to-sleeve bond capacity were palatable and outperformed the bar tensile capacity. In such joins, the ductile failure mode is ensured since of yielding of the joined bars a few times as of late the failure of bond. This pliable Failure

- **EFFECT OF STUDIED PARAMTERS**
  - DIAMETER OF SPLICED BAR

The comparison showed up in Fig.11 shows that expanding the bar diameter from 18 mm to 25 mm made a striking increase inside the tensile capacity of the grouted join sleeve connectors. Usually regularly due to two reasons: As the bar diameter increases, the embedded circumferential zone increments. Besides, as the bar diameter increases, the grout volume encompassing the bar reduces, along these lines, the bar is more restricted. The higher the confining stress on the grout, the greater the tensile capacity regard of the grouted join sleeves.

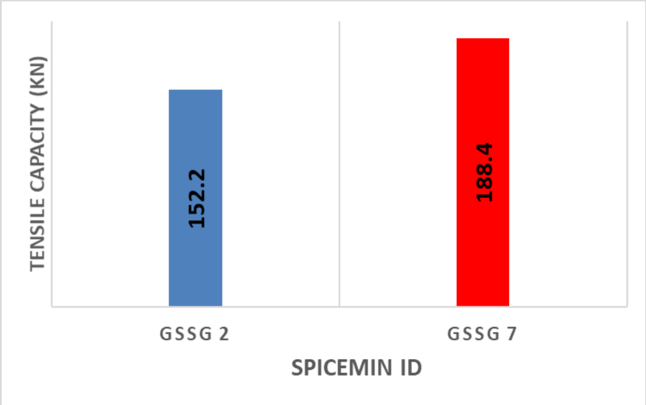

Fig. 11 Effect of increasing bra diameter on tensile capacity.

- **BAR INSERTED LENGTH**

The comparison showed up in Fig.12 reports that the tensile capacity increases as the bar inserted length increases. Extending the bar inserted length suggests increase of the number of shear keys along the interface of the joining bars with the encompassing grout and the bar circumferential zone moving forward the bond capacity. This comes almost in a basic increase inside the tensile capacity. Amin Einea [10], concluded that the lap splice or inserted length as brief as seven times the bar diameter can fulfill bar enhancement when the fitting grout compressive strength and confinement are given

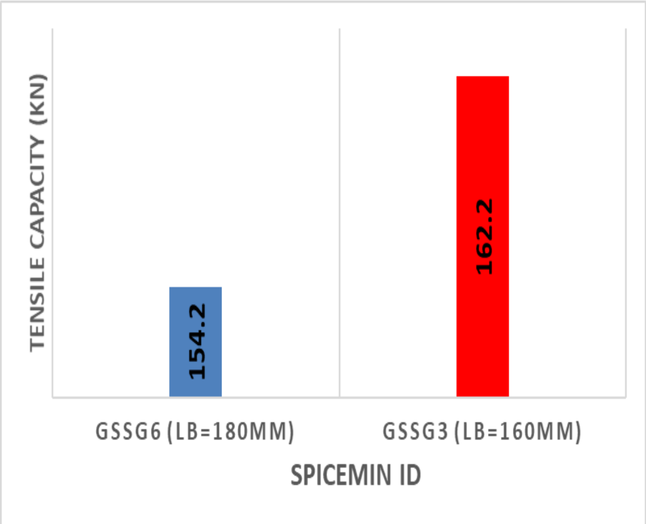

Fig.12 Effect of increasing embedded length on tensile capacity.

- **NUMBER OF GROOVES**

Examples with grooves cut inside the sleeve wall clearly show up the effect of sleeve setup on the pliable capacity of the grouted splices. Displaying grooves to the sleeve wall infers interlocking the grout along the bar inserted length by grout shear keys insides the grooves. This expanded grout-sleeve bond strength and extended the confining action on the grout, hence, extending the bond strength. Fig13. portrays the effect of the groove's numbers on the tensile capacity of the join.

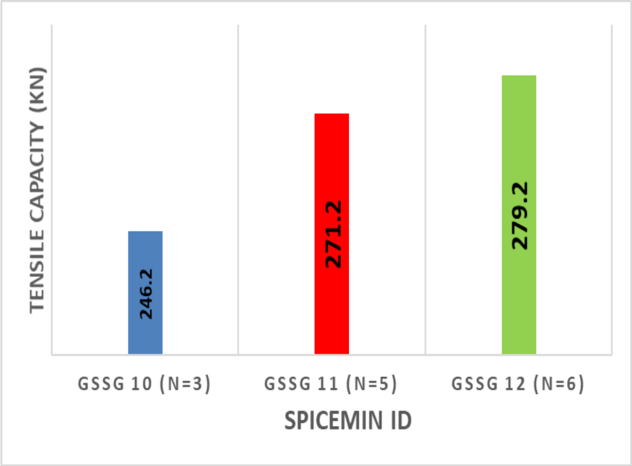

Fig. 13 Effect of increasing the number of grooves

- **DETERMINING THE Ampleness OF Tried Examples Agreeing TO ACI 318-14 (2014) AND ECP 203-2018.**

To check the ampleness of the tried examples, the yield ratio, *R*y, and the ultimate ratio, *R*u, were calculated and point by point in Table- III. The yield ratio, *R*y, can be characterized as the ratio of the tensile stress of the example and the yield strength of the bar. The ultimate ratio, *R*u, can be characterized as the ratio of the tensile stress of the joined bars. For these purposes, as it were examples with ultimate ratio, *R*u, more prominent than or rises to to 1 should be satisfactory for type 2 mechanical joins. Clearly, all the bar-fractured examples are considered palatable concurring to ACI 318-14 type 2 where the ultimate ratio, Ru, values extended from 0.74 to 1.23 arrangements for type 2 mechanical joins. Moreover, the examples with Ry extending from 1.32 to 1.77 are satisfactory with regard to the ACI 318-14 sort 1 and ECP 203-2018 arrangements for mechanical joins.

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Table III: Yield ratio Ry and Ultimate ration Ru

ID	Tensile strength(MPa)	Ry	Ru
GSSG 1	583.1	1.62	1.12
GSSG 2	598.4	1.66	1.15
GSSG 3	606.3	1.68	1.17
GSSG 4	591.3	1.64	1.14
GSSG 5	612.2	1.70	1.18
GSSG 6	637.7	1.77	1.23
GSSG 7	384.0	1.07	0.74
GSSG 8	474.3	1.32	0.91
GSSG 9	526.9	1.46	1.01
GSSG 10	501.8	1.39	0.97
GSSG 11	552.8	1.54	1.06
GSSG 12	569.1	1.58	1.09

$$Pd = Pt * \beta$$

C. PROPOSED COMPREHENSIVE DESIGN PROCEDURES

Based on the comes about of the exploratory program, the taking after design equations show a straightforward equation employing a linear regression strategy to assess the tensile force , Pt, as a function of grout compressive strength, fg, bar inserted length, Lb, bar to grout bond strength, Ub, groove height, hgr, and the number of grooves, Ngr (Eq. 7) GSSG examples.

(7)

Where:

Pt = Tensile force (KN)

Lb = Bar embedded length (mm)

fg = grout compressive strength (MPa)

Ub = bar to grout bond strength from Eq (2) (MPa)

hgr = groove height (mm)

Ngr = Number of grooves at each end of the sleeve as shown in Fig.2

- **VERIFICATION OF PROPOSED EQUATIONS**

For confirmation purposes, the comes about of the tried examples are compared to the anticipated values of the proposed equations all through substituting the values of the considered parameters of the tried examples into these equations. The anticipated values of tensile Force are compared to the test values. It was found that the proposed equations provide great dependable values for tensile drive

Pt, as appeared in Table- IV.

The strength ratio, *R*, can be calculated by dividing the pliable force of the tried GSSG examples by the tensile force calculated concurring to Eq. (7) as appeared in Table- IV. The strength ratio, *R*, for GSSG examples extended from 0.88 to1.11. These values show that the proposed equation provides dependable values with an error shifting between +11% and – 12 %. Based on the confirmation of the proposed condition and the strength ratio, *R*, a lessening factor to be specific tensile force lessening factor, β, was set to be 0.89 as appeared in Eq. (8). The application of such a calculate implies that the values of the tensile force decided by the propose design Eq. (8) are continuously less than those obtained experimentally.

$$Pt = 0.86 * Lb + 0.9 * fg + 14.4 * Ub + 2.27 * hgr * Ngr - 85.39$$

(8)

Where:

Pd : Design tensile force (N)

Pt : Tensile force Eq (7) (N)

β : Tensile force reduction factor

Table VI: The calculated value of tensile force Eq (7) versus the experimental value.

ID	Pt (act)	Pt calc	R
	N	N	
GSSG 1	148300	133869.57	1.11
GSSG 2	152200	145207.52	1.05
GSSG 3	154200	156545.47	0.99
GSSG 4	150400	151120.57	1
GSSG 5	155700	162458.52	0.96
GSSG 6	162200	173796.47	0.93
GSSG 7	188400	213995.25	0.88
GSSG 8	232700	236671.15	0.98
GSSG 9	258500	248009.1	1.04
GSSG 10	246200	231246.25	1.06
GSSG 11	271200	262953.47	1.03
GSSG 12	279200	283322.75	0.99

VI. CONCLUS IONS

In this think about, twelve grouted sleeve splices with grooves were experimentally tried beneath incremental direct tensile load. It permits stress to be transferred between the bar, grout, and the sleeve, moreover beneath the condiment given by the sleeve, way better bond performance is guaranteed. The finding is based on direct tensile load conducted on bar with 18 mm and 25 mm diameter as it were. So, the finding is pertinent for theses bar diameter as it were for the time being. The test comes about appear that

- The mode of failure watched in this think about were bar grout bond failure and bar fracture. Bar slipped from the connectors due to lacking bond strength whereas bar fracture due to bond strength higher than the ultimate tensile quality of the reinforcement bar.
- Presenting grooves to the sleeve wall implies interlocking the grout along the bar embedded length by grout shear keys interior the grooves. This increased grout-sleeve bond strength and expanded the confining action on the grout, so, increasing the bond strength.
- The tensile strength increasing with increasing of the number of grooves.
- The minimum number of grooves to achieve the fracture failure are 3 grooves for 18 mm bar diameter and embedded length 160 mm.
- The minimum number of grooves to achieve the fracture failure are 5 grooves for 25 mm bar diameter and inserted length 190 mm.

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- Increasing the inserted length increase the tensile force.
- The comes about of the tried examples were compared to the anticipated values of the bar-to- grout bond strengths calculated from the proposed equations. It was found that the proposed equations deliver great dependable values for the bar-to-grout bond strength.

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