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Behavior of Confined Concrete using Prestressing Skew Bars

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Abstract: ***This paper presents the results of an experimental study on the biaxial compression behavior of concrete prism confined using pre-stressed bars. The pre-stressed bars could provide passive confinement stress, that preventing the lateral strain of the prism from increasing leading to an increase in both the initial modulus of elasticity and prism compressive strength. The confined concrete had a higher compressive strength that was directly proportional to the confinement bar pressing force and lower ductility than the plain prisms. The concrete initial modulus of elasticity is directly proportioned to the confinement lateral pressure of the prestressing bar and inversely proportion with the spacing between prestressing bars. It was simple to find out that the best pre-stressing stress was 10 N/mm2, also the compressive strength of the confined concrete with pre-stressed skew bars was greater than the compressive strength of the unconfined concrete by more 3.3 times.***

Keywords: ***Compressive Strength, Confined Concrete, Prestressing Skew Bars, Prestressing Stress.***

I. INTRODUCTION

Concrete is the most used building material, increasing the lateral confinement of concrete was a common solution to increase the strength and ductility of concrete members in compression Mander et al [2]. The lateral confinement could be divided into two main types either passive or active confinement, depending on whether lateral external confinement stresses were applied on the concrete member subjected to compression load. The lateral pressure of passive confinement is caused by restraining the lateral strain expansion of concrete during compression loading. Fig. 1 showed the profile stress diagram for both types of confinements. Kupfer [1] et al showed that the ultimate compressive strength of concrete increased by approximately 25 percent when laterally confined with half the uniaxial ultimate compressive strength, the increase was reduced to 16 percent when increasing the confinement stress to the uniaxial ultimate compressive strength as shown in Fig. 2.

The way to achieve a proper passive confined for concrete was based on the introduction of transverse reinforcements. Many researchers studied the behavior of concrete confined with diverse types of transverse reinforcements. But there were few relevant studies on active confined concrete, the existing research used active confinement forms includes Shape Memory Alloy (SMA), pre-stressed steel strand, and pre-tensioned FRP. Gamble [3] and Saatcigolu [4] attempted to retrofit Reinforced Concrete (RC) columns using pre-stressed steel strands. Hussain [5] conducted experimental tests on actively confined concrete using steel hollow section collars.

Other investigations on the behavior of RC columns using pre-tensioned FRP belts [6], Shin et al [7] showed that SMA and pre-stressed steel strand confined concrete could provide lateral pressure at the initial stage of loading that solving the problem of stress lag.

Applying active confinement through the pre-stressed steel strands required more labor and mechanical equipment and the confined concrete may be destroyed, SMA or pre-stressed steel strands might penetrate the concrete, resulting in stress loss [8,4]. Fakharifar [9] proposed lightweight pre-stressed steel jackets for rapid repair of the damaged circular reinforced concrete piers.

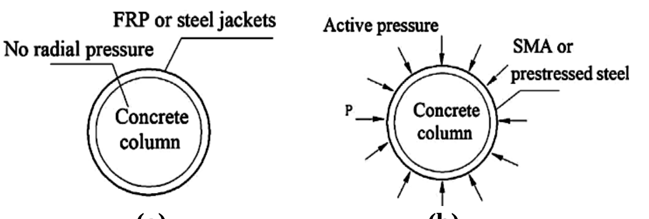

Fig.1 (a) passive and (b) active confinement on concrete cross-sections [2]

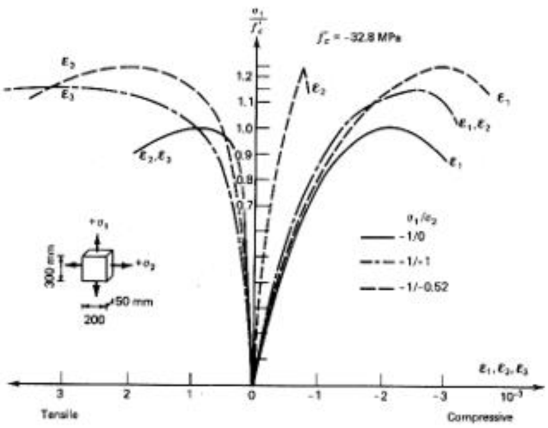

Fig.2 stress-strain relationships of concrete under biaxial compression test [1].

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It was composed of pre-stressed steel tendons and thin steel sheets restrained by these strands,

This research used pre-stressed skew bars to confine the concrete. Finally, the active confinement of the pre-stressed bars could solve the problem of passive confinement stress lag.

II. EXPERIMENTAL PROGRAM

To investigate the biaxial behavior of concrete, sixty square cross-sectional concrete prisms were uniaxially tested in compression with different slenderness ratios 0.5, 1, 1.5, and 2 respectively, and with different lateral confinement levels.

A. Test specimens

To obtain uniform lateral confinement on the prism sides two skew ducts were implemented at the prism middle half height. The prisms were divided into five separate groups, each group consisted of twelve prisms, four groups had two skewed ducts of 22 mm diameter spaced 50mm, 100mm, 150mm, and 200m respectively, while the last group was the control that had no ducts. All prisms had a constant square cross-section 200 x 200 mm with a variable different total height of 400mm, 300mm, 200mm, and 100mm, with different H/D ratio of 2.0, 1.5, 1.0 ,0.5, respectively, as shown in Fig. 3. The active confinement stresses were produced using two skewed pre-stressed 20mm diameter bars with grade 10.9. Different prestressing forces (PS) were applied to the bars 62.5, 112.5, 162.5 and 200 KN, using a calibrated torque meter that produced 250, 450, 650 and 800 N.m on the bars, respectively. Table 2 showed the summary of experimental investigation specimen's data.

B. Material properties

The characteristics of the materials used in this research were shown in Table 1. The design concrete mix was designed to produce characteristic strength after 28 days of 20 N/mm2.

Table- 1: The concrete mix proportions used for prisms casting.

Mix Proportions (Kg/m3)					Superplasticizer (% from Cement)	Slump (mm)
Cement	Dolomite	Sand	Silica Fume	Water		
215	1080	685	43	129	3.06	60

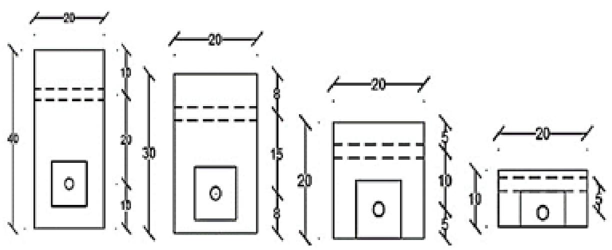

Fig. 3. Prisms concrete dimension

Table- 2: The Summary of Concrete prisms used in the experimental investigation.

Symbol	Torque	P.S FORCE	Hight	CONFINEMENT STRESS
	KN.mm	KN	mm	N/mm2
PC100H	0	0	100	0.00
PC200H	0	0	200	0.00
PC300H	0	0	300	0.00
PC400H	0	0	400	0.00
PC1025	250	62.5	100	3.13
PC2025	250	62.5	200	1.56
PC3025	250	62.5	300	1.04
PC4025	250	62.5	400	0.78
PC1045	450	112.5	100	5.63
PC2045	450	112.5	200	2.81
PC3045	450	112.5	300	1.88
PC4045	450	112.5	400	1.41
PC1065	650	162.5	100	8.13
PC2065	650	162.5	200	4.06
PC3065	650	162.5	300	2.71
PC4065	650	162.5	400	2.03
PC1080	800	200	100	10.00
PC2080	800	200	200	5.00
PC3080	800	200	300	3.33
PC4080	800	200	400	2.50

III. TEST SET UP AND LOADING PROCEDURE

Concrete prisms were tested in the laboratory after 28 days of curing using a 3000 KN compression testing machine. The test setup at the compression test machine and the failure mode of the prism were shown in Fig.4.

Fig.4: Test setup at the compression testing machine and prism failure.

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IV. RESULTS AND DISCUSSION

All prisms test results were recorded to the nearest 0.01 N/mm2 and the results were analyzed as followed.

A. Relationships between compressive strength and Confinement stress

Table (3) shows the summary of the test results for both prism compressive strength and applied lateral confinement stress of all prisms. It was clear that the compressive strength increased with increasing the lateral confinement stress. Fig. 5 shows the relationship between the prism compressive strength and the different lateral confinement stress for the height of the different prisms100mm, 200mm, 300mm and 400mm and with different lateral prestressing skew bars spaced 50mm,100mm,150mm, and 200mm, respectively.

From Fig.5. The prism compressive strength was directly proportions with the confinement lateral pressure, the prestressing bar spaced 200 mm and 150 mm produced maximum lateral confinement of 2.5 N/mm2 and 3.13 N/mm2 respectively, that increased the prism compressive strength by 53% and 56% respectively. While prestressing skew bars spaced 100mm and 50 mm produced maximum lateral confinement of 5 N/mm2 and 10 N/mm2 respectively, that increased the prism compressive strength by 162% and 229% respectively. As shown in Fig.6. it was clear that applying lateral prestressing force in the bars increased the percentage of prism compressive strength, since for prestressing bar spaced 200 mm and 150 mm, the prism compressive strength increases by 42% up to 53% and by 47% up to 56% respectively, with increasing the confinement lateral stress. But for prestressing bars spaced 100mm and 50 mm the confinement lateral stress was directly proportionated with the prism compressive strength since for prestressing skew bars spaced 100 mm the prism compressive strength increases by 70% up to 162% with the confinement lateral stress and for prestressing bar spaced 50 mm the prism compressive strength increases by 97% up to 229% with the confinement lateral stress.

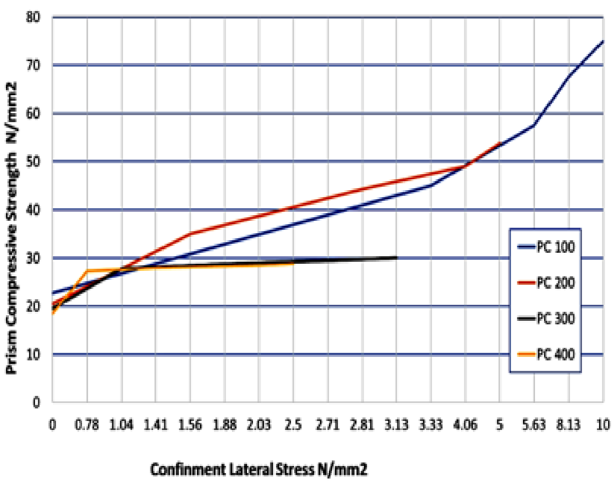

Fig. 5: Relationship between prism compressive strength and confinement lateral stress.

Table- 3: The Summary of Concrete prisms test results.

Symbol		COMPRESSIVE STRENGTH N/mm^2	CONFINEMENT STRESS N/mm2
PC100	PC100H	22.75	0.00
	PC1025	45.00	3.13
	PC1045	57.50	5.63
	PC1065	67.50	8.13
	PC1080	75.00	10.00
PC200	PC200H	20.50	0.00
	PC2025	35.00	1.56
	PC2045	44.25	2.81
	PC2065	49.00	4.06
	PC2080	53.75	5.00
PC300	PC300H	19.50	0.00
	PC3025	27.75	1.04
	PC3045	28.75	1.88
	PC3065	29.50	2.71
	PC3080	30.00	3.33
PC400	PC400H	18.50	0.00
	PC4025	27.25	0.78
	PC4045	28.00	1.41
	PC4065	28.50	2.03
	PC4080	28.88	2.50

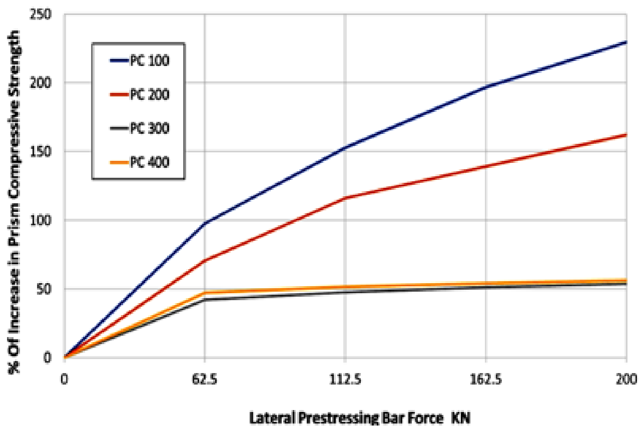

Fig. 6: Relationship between the lateral prestressing bar force and the percentage of increase in prism compressive strength.

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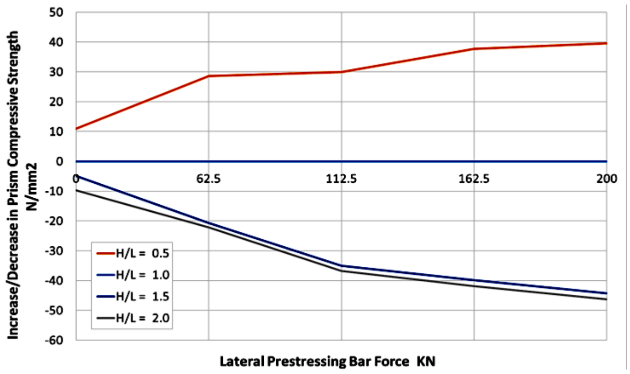

Fig. 7: The effect of prism slenderness on the change in prism compressive strength and the lateral prestressing bar force.

B. Prism Slenderness

The effect of prism slenderness H/L on the change in prism compressive strength either increased or decreased and the lateral prestressing force in the bar, compared to the 200 mm cube compressive strength (H/L equal one) was shown in Fig. 7. Where (H) the total prism height and (L) prism width which was identical for all prisms equal to 200 mm. It was clear that reducing the prism slenderness below the cube size increases the prism compressive strength for all the used lateral prestressing bar force while increasing the prism slenderness above the cube size decreased the prism compressive strength for all the used lateral prestressing bar force.

C. Stress Strain relationships

Fig. 8 shows the relationship between the concrete compressive stress and strain for both unconfined prisms PC100H, PC200H, PC300H, and PC400H and the maximum confined prisms PC1080, PC2080, PC3080, and PC4080, respectively. The concrete initial modulus of elasticity decreased with the increase of the prism height for both confined and unconfined prisms and the distance between prestressing skew bars, but it was clear that the initial modulus of elasticity for the maximum confined prism increased by more than ten times that of the unconfined prism with the same prism height.

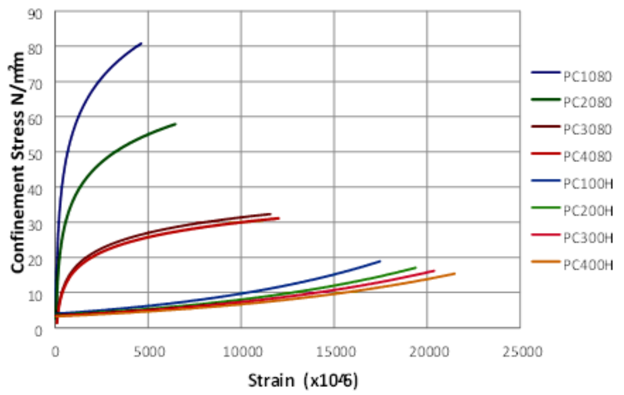

Fig. 8: The relation between the compressive confinement stress and strain of both maximum confined prestressing and unconfined prisms.

Also, the concrete strain decreased with decreasing the confinement space between the prestressing skew bars while the concrete compressive strength decreased with increasing the space between bars at maximum confinement stress.

From the relationship between the compressive strength and the confinement Stress of the prisms, it was simple to find out that the best pre-stressing stress was 10 N/mm2, also from the relation between stress and strain it was found that the compressive strength of confined concrete with pre-stressed skew bars act as a transverse reinforcement and increase concrete strength by more than 3.3 times that of the compressive strength of unconfined concrete.

V. CONCLUSIONS

From the previous discussion, the following could be concluded:

1- The prism compressive strength is directly proportional to the confinement lateral pressure of the prestressing bar and inversely proportional to the spacing between prestressing skew bars.
2- The concrete initial modulus of elasticity is directly proportioned with the confinement lateral pressure of the prestressing bar and inversely proportion with the spacing between prestressing skew bars.
3- Reducing the prism slenderness below the cube size increase the prism compressive strength for all the used lateral prestressing bar force. while increasing the prism slenderness above the cube size decreases the prism compressive strength for all the used lateral prestressing bar forces.
4- The maximum pre-stressing stress was found to be 10 N/mm2, which produces compressive strength of confined concrete with pre-stressed bars as a transverse reinforcement is more by 3.3 times than the compressive strength of unconfined concrete
5- Prestressing skew bars act as lateral reinforcement to the concrete prisms for all spacing between skew bars and for different prestressing forces.

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