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A Study and Comparison on Compressive Strength, Tensile Strength and Elastic Modulus of Confined Self-Compacting Concrete (SCC) by Polymeric Material GFRP Investigation of Self Compacting Concrete Confined

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Abstract

Self-compacting concrete does not have problems associated with conventional concrete construction, including the inability to fill the mold, inability to completely surround the reinforcement in reinforced concrete structures, vibration equipment performance and noise caused by their. Using reinforced polymer sheets became conventional from mid-1980s and replaced of polymer sheets in order to overcome the disadvantages caused by reinforced with steel sheets. Unlike steel sheets, it was not being under corrosive agents and it is resistant against harmful effects caused by acids, salts and other environment corrosive. Many of the proposed relationships for estimating the compressive strength of confined concrete and similar strain have been obtained based on the experimental results and they possess a lot of diversity, this shows the behavioral complexity of confined concrete and its dependence on the various parameters. In this paper, experimental results are presented concerning the behavior of self-compacting concrete enclosed as single-layer and double-layer by polymeric material GFRP. Cylindrical specimens of self-compacting concrete are used with dimensions of 150 × 300 and 100 × 200 mm for testing compressive strength, tensile strength and modulus of elasticity.

Key words: Self-compacting concrete (SCC), GFRP, compressive strength, tensile strength, modulus of elasticity

1 Introduction

In the early 1900s, the first studies were performed on the effect of concrete confinement in improving its bearing [www.seismosoft.com]. These studies showed that the lateral pressure on the concrete will increase its bearing characteristics.When column loading, these uniforms prevent from lateral expansion of the concrete caused by crack creating and developing and thus, a passive pressure are applied to the median concrete. Many of the proposed relationships for estimating the compressive strength of confined concrete and similar strain have been obtained based on the experimental results and they possess a lot of diversity, this shows the behavioral complexity of confined concrete and its dependence on the various parameters [Talaiekhozan and et al].

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2 The diagram of stress-Strain concrete confined by FRP

The results of experimental studies on the behavior of confined concrete columns with FRP composites suggest that the curve figure of confined concrete stress - strain changes is dependent on the amount of confining concrete and their figures would be like one of the three plotted curves in Figure 1 [Lam & Teng].

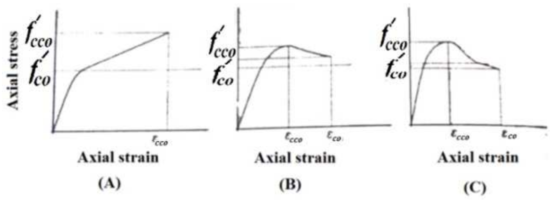

Figure 1: Different charts of stress - strain concrete confined by FRP.

If the lateral stiffness of FRP wrapping which is influenced by its thickness and elastic coefficient, is sufficiently high, it will be as figure (1 - a). If for some reasons, such as the little lateral stiffness of the bolts, the amount of compressive stress confining FRP bolt were insufficient, the chart of concrete compressive stress - strain confined by FRP will become like (1 - B) figure and may be due to weak confinement as figure (1 - c), failure stress also become less than unconfined concrete compressive strength. So far, many models have been proposed for presenting concrete stress-strain variation confined by FRP [D'Aloia and et al].

2.1 Lam model

Furthermore, this model has been developed according to the pressure testing on cylinder concrete samples and encapsulated with polymer composites. The chart of confined concrete stress - strain in this model like the figure (2), is two-part and ascending [Lam & Teng].

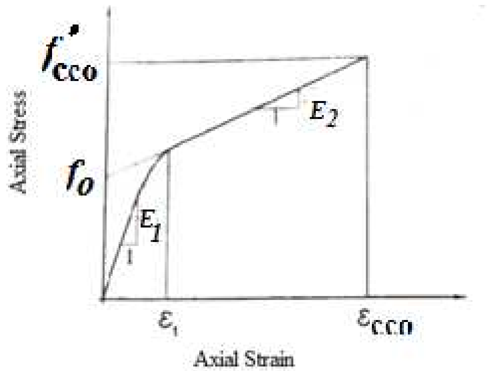

Figure 2: Changes of the confined concrete stress – strain in lam model.

To express this model, two line equations according to the following relationships are used:

$$\left\{ f_{cc} = E_1\varepsilon_{cc} - \frac{(E_1 - E_2)^2 \varepsilon_{cc}{}^2}{4 f_0} \qquad 0 < \varepsilon_{CC} \le \varepsilon_1 \right.$$

$$\left\{ f_{cc} = f_0 + E_2\varepsilon_{cc} \qquad \varepsilon_1 < \varepsilon_{cc} \le \varepsilon_{cco} \right.$$

f_{cc} and ε_{CC} are stress and strain of confined concrete variable in this relationship. f_o also according to Figure 2, is the amount of tension in the focus of the second zone along the curve with the axis of tensions. E_1 and E_2 are modulus of elasticity in two areas.

The strain ε_1 that is the breakpoint of two parts of two above equations is computed as follows:

$$\varepsilon_1 = \frac{2 f_0}{(E_1 - E_2)}$$

f_0 in the above equation, is the amount of tension in the focus of the second zone along the curve with the axis of tensions that is calculated as follows:

$$f_o = 0.872 f'_{co} + 0.371 f_{lfrp} + 6.258$$

The first part of the confined concrete stress - strain curve is nonlinear in this model that is the tangent slope on it at the initial point is equal to unconfined concrete elastic coefficient and is calculated from the following equation:

$$E_1 = 4730 \sqrt{f'_{co}}$$

The slope of the second linear region is also obtained by the following equation:

$$E_2 = \frac{f'_{cco} - f_0}{\varepsilon_{cco}}$$

In this modeling, the compressive strength of the confined concrete and the ultimate strain are calculated from the following relationships:

$$f'_{cco} = f'_{co} + 3.3 f_{lfrpu}$$

$$\varepsilon_{cco} = 1.75\varepsilon_{co} + 12\left(\frac{f_{lfrpu}}{f_{co}}\right)\left(\frac{\alpha_{frp}\varepsilon_{frpu}}{\varepsilon_{co}}\right)^{0.45}$$

In recent relationships f_{lfrpu} the maximum of confining stresses is due to FRP wrapping. Furthermore, the amount of α_{frp} is FRP ultimate strain reduction coefficient and is equal to 586%.

3 Self-compacting concrete

According to our need to mix design for achieving the technology of self-compacting concrete construction that the type of used materials and the amount of water and the cement grade give a correct answer in this mix design. Therefore, different designs were tested to find the appropriate mix design [Chabib and et al].

3.1 Slump flow test

Slump flow was considered as the initial test because in terms of mobility and investigation of grains separations which are the two key elements in the construction of self-compacting concrete, is a convenient and simple test. The diameter of self-compacting concrete should be between 65 and 80 cm in the slump flow [RILEM TC116-PCD, 1999]. According to figure (3) that shows the performance of the test, the measured diameter was 70 cm.

Figure 3: How to carry out the slump flow test

3.2 U-shaped box test

The about changes of the amount should be between 0 and 30 cm in this test. According to figure (4) that shows how to perform the test, the about changes was 6 cm in this experiment.

Figure 4: How to carry out U-shaped box test

3.3 V funnel test

The about changes of the amount should be between 6 and 12 seconds in this test. According to figure (5) that shows how to perform the test, the about changes was 6 seconds in this experiment.

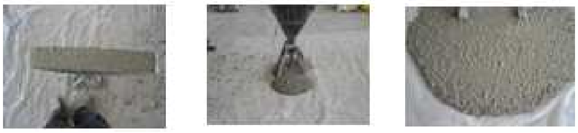

Figure 5: How to carry out v funnel test

According to the process of conducted experiments, the mix design of self-compacting concrete for stere in accordance with Table (1) is provided as following.

Table 1: The mix design of self-compacting concrete for stere

Concrete Type	Ultra Lubricant	Cement	Micro Silica	Stone powder	water	Gravel	Sand
The original design	8	450	50	73	225	657	852

3.4 The test of confined and unconfined self-compacting concrete

In this study, the self-compacting concrete with the strength of about 30 MPa and polymer material GFRP is used as single-layer and double-layer for confining [Saafi].

3.5 Mechanical properties of GFRP composite

The confinement of cylindrical specimens is done with GFRP fibers. According to manufacturer's report, the specifications of fibers are presented in Table (2).

Table 2: The used FRP properties

The final strain(%)	Modulus of elasticity (MPa)	The final Resistance (MPa)	Width (mm)	*Thickness (mm)*	Type of fiber
2.2	77	1700	-	0.3	GFRP

3.6 Compressive strength test

The numbers of cylindrical specimens of 150 × 300 and 100 × 200 mm are as follows:

- 25 samples of unconfined self-compacting concrete (control)
- 25 samples of confined self-compacting concrete as single-layer with polymer material GFRP
- 25 samples of confined self-compacting concrete as double-layer with polymer material GFRP

According to figure (6), How to perform the test and Tables (3) and (4) Feshelry resistance are offered briefly

Figure 6: compressive strength

Table 3: 28-Day compressive strength of cylindrical samples of 150 × 300 mm

The Compressive Strength of Cylinder Sample of 150 × 300 mm (MPa)						
Concrete Type	1	2	3	4	5	6
SCC	29.71	29.43	29.16	29.09	29.02	29.94
SGF1	36.37	36.19	36.13	35.85	35.90	36
SGF2	47.02	47.55	46.95	47.70	47.45	47.87

Table 4: 28-Day compressive strength of cylindrical samples of 100 × 200 mm

The Compressive Strength of Cylinder Sample of 200 × 100 mm (MPa)						
Concrete Type	1	2	3	4	5	6
SCC	30.40	30.19	30.56	30.51	29.70	29.90
SGF1	36.33	36.86	36.23	35.80	36.39	35.38
SGF2	54.67	54.13	53.80	54.20	54.43	54.66

That in which SCC is unconfined self-compacting concrete, SGF1 is confined self-compacting concrete as single-layer and SGF2 is confined self-compacting concrete as double-layer.

A study on compressive strength of SCC with SGF1 and SGF2 in cylindrical specimens of 150 × 300 mm

In this test, the polymeric materials GFRP showed their effective roles in compressive strength toward unconfined self-compacting concrete.

According to figure (7), the compressive strength is shown respectively 29, 38 and 60 MPa at the three modes of SCC, SGF1 and SGF2. Growing of compressive strength in the samples that were surrounded by polymeric materials GFRP as single-layer has 24.13 percent increase towards unconfined self-compacting concrete and in the samples which are enclosed by polymeric materials GFRP as double-layer has 62.06 percent increase of compressive strength towards unconfined self-compacting concrete.

A study on compressive strength of SCC with SGF1 and SGF2 in cylindrical specimens of 100 × 200 mm

In this test, polymeric materials GFRP indicated their effective roles in compressive strength towards unconfined self-compacting concrete.

According to figure (8), the compressive strength is shown respectively 30, 36 and 54 MPa at the three modes of SCC, SGF1, SGF2. Growing of compressive strength in the samples that were surrounded by polymeric materials GFRP as single-layer has 20 percent increase towards unconfined self-compacting concrete and in the samples which are enclosed by polymeric materials GFRP as double-layer has 80 percent increase of compressive strength towards unconfined self-compacting concrete.

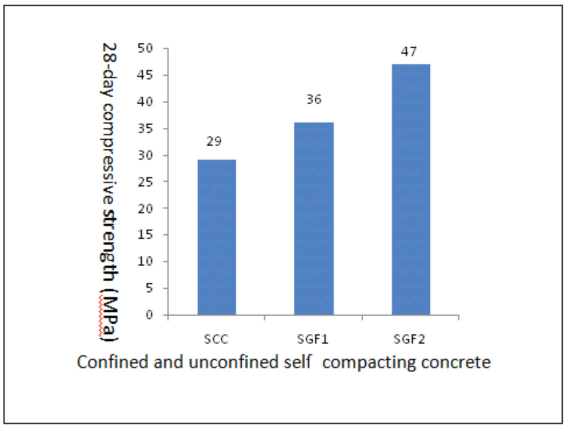

Figure 7: Compressive strength of SCC, SGF1 and SGF2

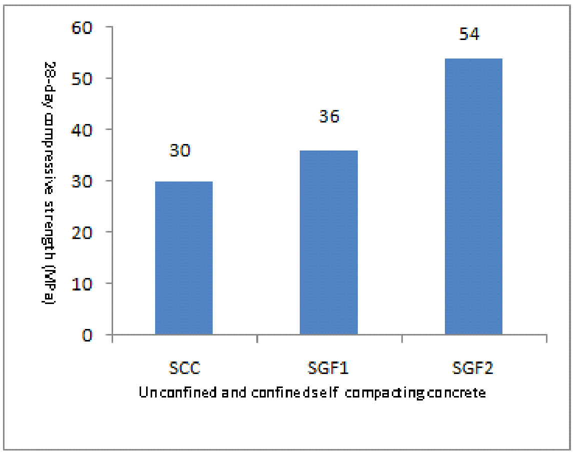

Figure 8: Compressive strength of SCC, SGF1 and SGF2

3-7- Tensile strength test

The numbers of cylindrical specimens of 150 × 300 mm are as follows:

- 20 samples of unconfined self-compacting concrete (control)
- 20 samples of confined self-compacting concrete as single-layer with polymer material GFRP
- 20 samples of confined self-compacting concrete as double-layer with polymer material GFRP

According to figure (9), How to perform the test and Table (5) tensile strength are offered briefly.

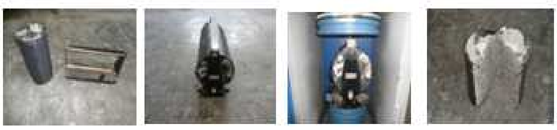

Figure 9: How to carry out tensile strength test

In this test, polymeric materials GFRP indicated their effective roles in tensile strength towards unconfined self-compacting concrete.

Table 5: Tensile strength of 28-day cylindrical samples of 150 × 300 mm

The Tensile Strength of Cylinder Sample of 150 ×300 mm (MPa)						
Concrete Type	1	2	3	4	5	6
SCC	3.10	3.11	3.15	3.9	3.19	2.95
SGF1	3.51	3.60	3.59	3.61	3.68	3.55
SGF2	4.11	4.13	4.19	4.23	4.30	4.12

According to figure (10), the tensile strength is shown respectively 3.10, 3.51 and 4.11 MPa at the three modes of SCC, SGF1, SGF2. Growing of tensile strength in the samples that were surrounded by polymeric materials GFRP as single-layer has 13.48 percent increase towards unconfined self-compacting concrete and in the samples which are enclosed by polymeric materials GFRP as double-layer has 32.80 percent increase of tensile strength towards unconfined self-compacting concrete.

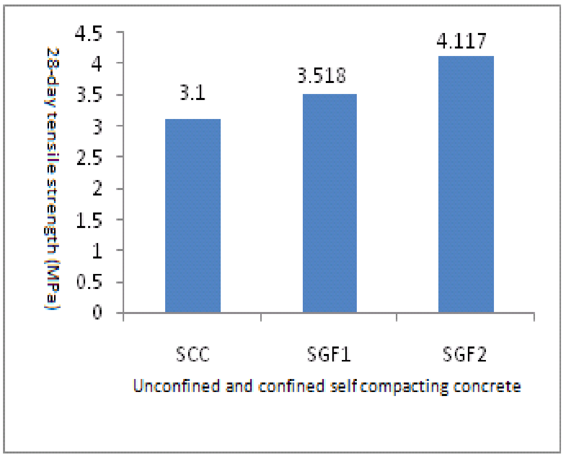

Figure 10: Tensile strength of SCC, SGF1 and SGF2

• The relationship between compressive strength and tensile strength provided by ((ABA)) [Tahuni, 2006] is as follows:

$$F_t = 0.55\sqrt{F_C}$$

Where F_t is tensile strength and F_c is compressive strength of ordinary concrete.

• In the unconfined self-compacting concrete, according to obtained compressive strength and tensile strength from the test, the following equation is recommended:

$$F_t = 0.575\sqrt{F_C}$$

Where F_t is tensile strength and F_c is compressive strength of self-compacting concrete.

• In the confined self-compacting concrete by polymeric material GFRP as single-layer, the following equation is proposed:

$$F_t = 0.586\sqrt{F_C}$$

Where F_t is tensile strength and F_c is compressive strength of confined self-compacting concrete as single-layer by polymeric material GFRP.

• In the confined self-compacting concrete by polymeric material GFRP as double-layer, the following equation is proposed:

$$F_t = 0.600\sqrt{F_C}$$

Where F_t is tensile strength and F_c is compressive strength of confined self-compacting concrete as double-layer by polymeric material GFRP[Esfahani and et al].

3.8 Modulus of elasticity test

The numbers of cylindrical specimens of 150 × 300 mm are as follows:

- 10 samples of unconfined self-compacting concrete (control)
- 10 samples of confined self-compacting concrete as single-layer with polymer material GFRP
- 10 samples of confined self-compacting concrete as double-layer with polymer material GFRP

According to figure (11), how to perform the test and Table (6) modulus of elasticity are offered briefly.

Figure 11: How to carry out modulus of elasticity test

Table 6: 28-Day modulus of elasticity of cylindrical specimens 150 × 300 mm

The Tensile Strength of Cylinder Sample of 150 ×300 mm (MPa)				
Concrete Type	1	2	3	4
SCC	27378	27550	27690	27770
SGF1	28455	28830	28685	28582
SGF2	30633	30819	30760	30690

A study on elastic modulus of SCC with SGF1 and SGF2 in cylindrical specimens of 150 × 300 mm, polymeric materials GFRP indicated their effective roles in increasing modulus of elasticity towards unconfined self-compacting concrete.

According to figure (12), the modulus of elasticity is shown respectively 27378, 28455 and 30633 MPa at the three modes of SCC, SGF1, SGF2. Growing of modulus of elasticity in the samples that were surrounded by polymeric materials GFRP as single-layer has 3.93 percent increase towards unconfined self-compacting concrete and in the samples which are enclosed by polymeric materials GFRP as double-layer has 11.88 percent increase of modulus of elasticity towards unconfined self-compacting concrete.

• The relationship between modulus of elasticity and compressive strength provided by ((ABA)) [4] is as follows:

$$E = 5000\sqrt{F_C}$$

Where E is modulus of elasticity and F_c is compressive strength of ordinary concrete.

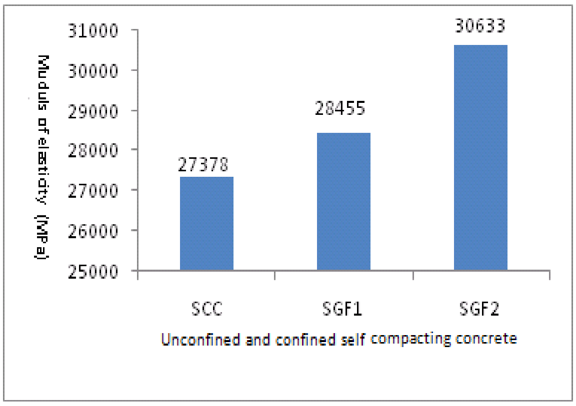

Figure 12: Modulus of elasticity of SCC,SGF1 and AGF2

• In the unconfined self-compacting concrete, according to obtained modulus of elasticity and compressive strength from test, the following equation is recommended:

$$E = 5084\sqrt{F_C}$$

Where E is modulus of elasticity and F_c is compressive strength of self-compacting concrete.

• In the confined self-compacting concrete by polymeric material GFRP as single-layer, the following equation is proposed:

$$E = 4742\sqrt{F_C}$$

Where E is modulus of elasticity and F_c is compressive strength of confined self-compacting concrete as single-layer by polymeric material GFRP.

• In the confined self-compacting concrete by polymeric material GFRP as double-layer, the following equation is proposed:

$$E = 4248\sqrt{F_C}$$

Where E is modulus of elasticity and F_c is compressive strength of confined self-compacting concrete as double-layer by polymeric material GFRP.

4 Conclusions

1- The compressive strength in cylindrical specimens of 150 × 300 and 100 × 200 mm that was encapsulated with polymeric material GFRP as single-layer has respectively 24.13 and 20 percent increase and in the examples that were encapsulated as double-layer has respectively 62.06 and 80 percent increase of compressive strength.

2 - Tensile strength in cylindrical specimens of 150 × 300 mm which were surrounded by polymeric material GFRP as single-layer and double-layer, has respectively 13.48 and 32.80 percent increase of tensile strength.

3 - Modulus of elasticity in the samples of 150 × 300 mm that were surrounded by polymeric material GFRP as

single-layer and double-layer, has respectively 3.93 and 11.88 percent increase of modulus of elasticity.

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