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Stress Strain Relationship and Modulus of Elasticity of Normal and Steel Fiber Reinforced Concrete under Uniaxial Compression Pressure

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Abstract:- Steel fiber reinforced concrete's stress-strain characteristics and compression elastic modulus are key in structural analysis and design. The purpose of this research is to explore the stress-strain behavior and modulus of elasticity of steel fiber reinforced concrete (SFRC) and normal concrete (NC) in order to experimentally assess their compression-stress behavior. The SFRC was reinforced with straight steel fibers with a nominal length of (13 mm), diameter of (0.2 mm), and aspect ratio (length of the fiber to the diameter of the fiber) was about (65). For the purposes of this experiment, the volume fraction was fixed to 1%, and normal concrete was used as a reference. When fiber is added to concrete, the ultimate stress, ultimate strain, toughness, and the modulus of elasticity were increased. As shown in an experiment, the SFRC had a very high values of strain capacity which was about (74.51%) more than that for NC, indicating that it had high ductility. Also a comparison was carried out between the experimental resultsof modulus of elasticity and the pervious theoretical proposed equations for SFRC and NC,the test resultsshowed a good agreement compared with the results of the theoretical equations.

I. INTRODUCTION

Steel fibers may be added into normal concrete to increase its tensile and flexural strengths, as well as its impact and toughness. SFRC is a very interesting composite material for the structural applications. It is a very beneficial when it comes to avoiding sudden and explosive failure under static loads and absorbing energy under dynamic loads (ACI 544.4R, 1989) [1]. Nataraja and Gupta investigated steel-fiber reinforced concrete with compressive strengths ranging from 30 to 50 MPa experimentally in 1999 [2]. Where they employed a round crimped fibers with volume fractions of 0.5%, 0.75% and 1.0% to meet two distinct aspect ratios(55 and 82),they submitted a simple mathematical model may be used to generate both the rising and falling regions of the stress–strain curve.Francesco et al (2008) [3] presented compression test results on steel fiber-reinforced concrete and performed a critical analysis of the models used to quantify compressive stress –strain behavior. In the aforementioned trials, samples of plain and steel fiber-reinforced concrete were employed. Theoretical and experimental findings were compared for a variety of stress-strain relationships.Luiz et al (2010)[4]computed the stress-strain curve for SFRC with strengths of 40 and 60 MPa at 28 days analytically which give a good agreement compared with the experimental results. Suksawang et al (2018)[5] investigated the influence of discontinuous steel, polypropylene, macro-polyolefin, PVA, and basalt fibers on the elastic modulus of concrete. And they proposed a new formula to calculate the elastic modulus of FRC with a maximum volume percent of 10%, the results indicated that the fibers did not influence its elastic properties when the ratio of coarse to fine aggregate C/S greater than one but when coarse aggregate was absent or the C/S ratio was≤1, the elastic modulus decreased by an average of 20%.In 2019 Babaie et al [6] conducted to determine the effect of different fiber parameters on the performance of SFRC and polymer fiber reinforced concrete (PFRC), which are often utilized in tunneling practices.

The present research presented a comparison between NC and SFRC with steel fiber of 1% volume fractions, on the modulus of elasticity test, and stress-strain test.

II. MATERIALS

The materials which used in this study were Ordinary Portland-limestone cement type, the natural fine aggregate passed 4.75 mm sieve with fineness modulus of 2.73, rounded aggregate of maximum size 9.5mm, Straight steel fibers with a nominal length of (13 mm), diameter of (0.2 mm), aspect ratio of (65),tap water, and a Super plasticizer third generation admixture Sika ViscoCrete. The mix design of normal concrete was confirming to(ACI-211.1R-96) [7] to get a nominal compressive strength of concrete about (28-30) MPa after age 28-days, and the mix design of steel fiber reinforced concrete was confirming to(ACI-544.1R-96) [8]. Water cement ratio of 0.47 was adopted.

III. EXPERIMENTAL PROGRAMS

A. Stress-strain test

According to ASTM C-39 standards [9] at 28 days, three cylindersspecimens of (150×300)mmfor each type of concrete were tested.The test was conducted using universal compression testing machine with 1000 kN. To provide uniform loading faces and a constant height for all cylinders, the cast face was grinded and covered with a strong plaster. The load was applied at a very slow rate to perform the compressive test is shown in Figure (1), as a consequence of this test, it was determined that the compressive crushing mode was complete.The cylinder shortening andcompressive load readings were collected during the tests until the failure of the cylinder specimens. For measuring a shortening displacements of cylinders.A 50 mm dial gage and LVDTs was used to average the data from the specimen's two opposing sides. And thesedata were recorded and displayed in the computer by using a data logger. Strain calculations was found through dividing the average deformation ,for LVDT and the dial gage , on the original length for the specimen. The test system which is used in present study was as the system which used by Sabariman et al, 2018 [10].

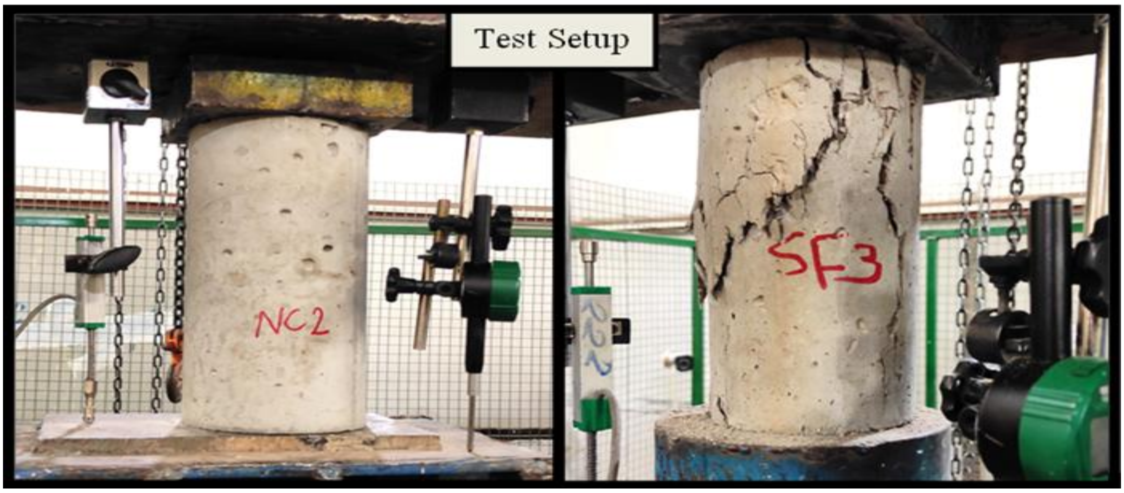

Fig. 1: Compression stress-strain test for NC and SFRC.

B. Test of Modulus of elasticity

Stiffness is characterized by the modulus of elasticity of a material of a solid material.By performing an experiment, the static modulus of elasticity of (150x300)-mm cylinder molds that could be used under compression testing machine with a capacity of 2000 kN. The static modulus of elasticity of (NC) was determined in accordance with ASTM C469-2002 [11], as shown in Figure (2). To calculate the modulus of elasticity of the NC material, an equation was used (1).

$$E = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} \quad (1)$$

Where S_2 =Stress level accounts for up to 40% of themaximal load (in MPa).

S_1 = Denotes the Stress accounts for a longitudinal strain, ε_1,of 0.00005, MPa.

ε_2 = Longitudinal strain correspondingto thestressS_2.

While the method which proposed byGilani (2007)[12] was used in this study to calculate the SFRC modulus of elasticity by using the slope of stress -strain curve between zero stress and (20 %) of the ultimate compressive capacity.

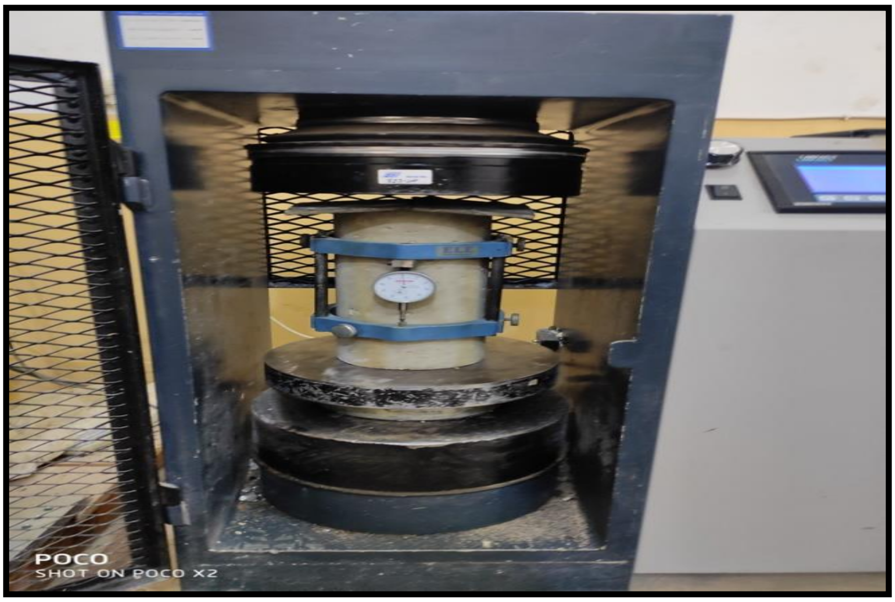

Fig. 2: Testing of static modulus of elasticity of NC.

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IV. EXPERIMENTAL RESULTS AND DISCUSSION

A. Stress- strain curves for NC and SFRC

The stress-strain curve for NC and SFRC were plotted. All samples were tested under uniaxial compression pressure. From test results can be concluded that the SFRC had avery high values of strain capacity which was about (74.51%) more than that for NC, demonstrating a highductility. As a result for that, toughness (energy absorption) of SFRC was enhanced as the area under the stress-strain curve grew, Figure (3). While the compressive strength of the SFRC was enhanced slightly by about (9.5%)compared with the compressive strength of NC. Also Figure (4) showed the mode of failure of SFRC and NC, from this figure it can be noticed that the failure mode of NC was crushing, and the steel fibers included in the concrete makes the cracks gets discontinued which provide ductility to the SFRC.

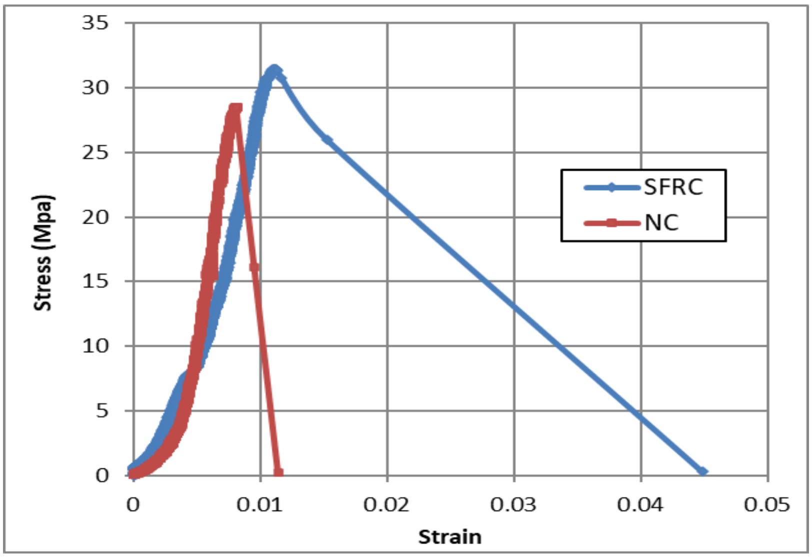

Fig. 3: Stress-strain curves for NC and SFRC.

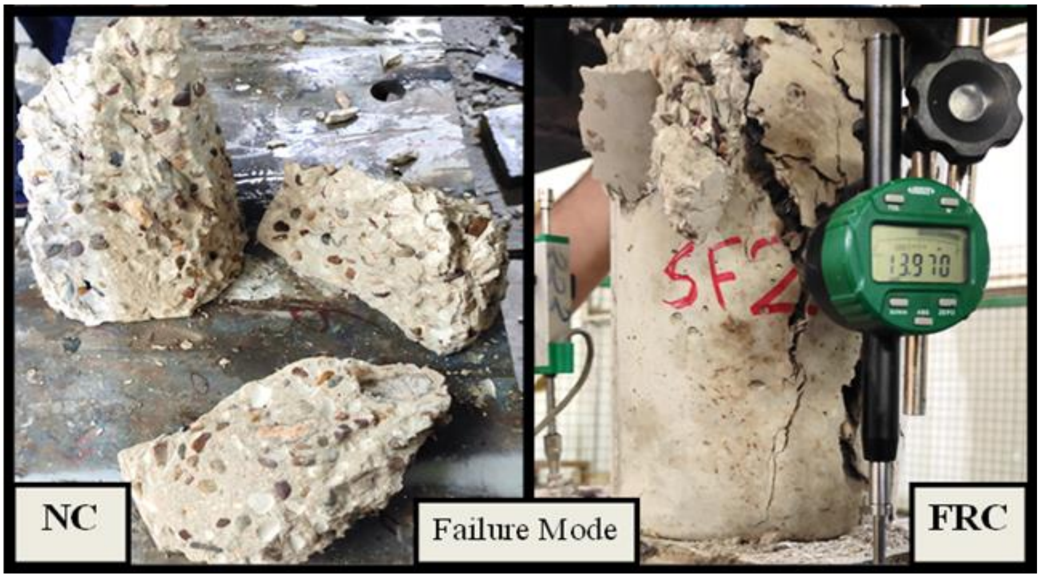

Fig. 4: Failure mode of NC and SFRC.

B. Modulus of elasticity for NC and SFRC

The obtained results showed in Table (5), which illustrated that the modulus of elasticity of SFRC was more than for the NC by about (4.9%). Also from this table it can be observed that the values obtained theoretically for NC using Equation (2) according to ACI 318-19.[13] were lower than the experimental results, and also were lower for SFRC compared with Equation (3) by (Suksawan et al,2018)[5], where (C/S=0.83 <1, and V_f=1%) in this study.

experimental results were higher than the

$$E_c = 4700\sqrt{f_c'} \quad (2)$$

$$E_c = 4700\,\lambda_{V_f}\sqrt{f_c'} \quad (3)$$

Where

$$\lambda_{V_f} = 1 \text{ for } C/S > 1$$

$$\lambda_{V_f} = \frac{1+0.7^{V_f}}{2} \text{ for } C/S \le 1$$

Type of concrete	Modulus of Elasticity,	Modulus of Elasticity, Theortical
Normal concrete (NC)	26731	26324
Steel fiber reinforced concrete (SFRC)	28107	27616

Table 5: Modulus of Elasticity Test Results for Concrete

V. CONCLUSION

The following are the study's most significant findings:

- From test results can be concluded that the SFRC had avery high values of strain capacity which was about (74.51%) more than that for NC, which mean high ductility, While the compressive strength of the SFRC was enhanced slightly by about (9.5%)compared with the compressive strength of NC.
- The area under the curve of stress -strainof SFRC wasmore than that for normal concrete and this mean that there was an enhancement in toughness when using steel fiber reinforced concrete.
- It can be noticed that the failure mode of NC was crushing of cylinder specimens,and the steel fibers included in the concrete makes the cracks gets discontinued which provide ductility to the SFRC.
- The modulus of elasticity of SFRC was more than for the NC by about (4.9%).
- It can be observed that the values obtained theoretically using pervious proposed equations by another research were lower than the experimental results which obtained in this study.

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