Comparing the behavior of confined HSC beams with AFRP sheets under bending

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Abstract

By increasing the use of FRP composites in civil engineering, they seem highly essential to be studied. The purpose of the study is comparison of the behavior of steel reinforced HSC beams which confined with AFRP sheets under bending. 12 steel reinforced HSC beams which confined with AFRP sheets (with different number of laminates) have been modeled. In addition three simple steel reinforced HSC beams have been modeled as the base of comparison. At the end behavior of aforementioned beams has been compared and corresponding graphs have been sketched. It concluded that maximum deflection in HSC beams reinforced with AFRP is higher than HSC beams reinforced with steel bars. Failure force of AFRP reinforced and covered HSC beams are much higher than steel reinforced.

Key words: HSC beams, AFRP sheets, Bending, Modeling

1. Introduction

Fiber-reinforced polymers (FRP) are using in the form of sheets or laminates to confinement and bars to reinforcement the concrete members. In both they have some advantages to steel jackets and steel bars. Steel is an isotropic material and its modulus of elasticity is high, thus the steel jackets stand the great part of axial forces which lead to buckling of steel. On the other hand Poisson ratio of steel is greater than concrete, thus the two materials act separately (Hoseini and Fadayi, 2004). Although using the FRP bars as the main reinforcement isn't common yet, it seems they will play an important role as a main reinforcement soon. Fiber-reinforcement polymers (FRP) in the form of bars or sheets, usually made from one of the three basic types of fibers such as Aramid (AFRP), Carbon (CFRP), and glass (GFRP), represent one of the most promising new developments in the area of structural concrete. High strength, but lightweight fibers encapsulated in a polymer matrix possess non-corrosive, non-conducting, and nonmagnetic purpose structures. The non-corroding characteristics of FRP reinforcement could also significantly increase the service life of ordinary concrete structures (Vatani, 2004; Rashid, 2005). In the case of flexure, the very high strength FRP bars, which exhibit elastic response up to failure, could perhaps be effectively used in combination with high strength concrete (HSC). However the majority of reported research works (Cosenza et al., 1997; Toutanji and Saafi, 2000) dealt only with normal strength concrete (f'c≤41MPa),while some other (Benmokrane et al.,1996; Masmoudi et al.,1998; Grace et al.,1998) considered concrete with maximum compressive strength (f'c) of up to 70 Mpa. Only Theriault and Benmokrane (1998) used concrete with (f'c) as high as 100 Mpa. Some other researchers worked on the effect of confinement of RC beams (Dathinh et al., 2004). In this study behavior of HSC beams reinforced and confined with AFRP under bending have been compared. ANSYS 9 has been used for modeling the beams.

2. Data and Material

Between more than 100 elements exist in the software, concrete 65; link 8 and solid layer 45 have been used for modeling of concrete, bars or stirrups and sheets respectively (Fig. 1) (Zareinezhad and Gorjinezhad, 2000).

3. Research Methodology

18 HSC beams all 3 meters length (Fig. 2) have been modeled. Three beams are in first group AF2, AF3, and AF4. In these beams tensile bars are AFRP bars but compressive ones are steel because compressive strength of AFRP is less than 20% of its tensile strength. The number in the names determines the number of tensile bars. As supplied by manufacturer the tensile strength and the modulus of elasticity of AFRP bars are 1760 Mpa and 53 Gpa, respectively. More properties of these beams are shown in Table 1.Second group has three beams too; ST2, ST3, and ST4. They have steel tensile bars and the number in the names determines the number of tensile bars. This group is the base group and the other groups' beams have been compared with these beams. Tensile strength and modulus of elasticity of steel are 533 Mpa and 2.1×105 Mpa respectively. More properties of these beams are shown in Table 2.
The last group has twelve beams which have steel tensile bars and AFRP sheet(s) attached at the bottom of the beams. The tensile strength and modulus of elasticity of AFRP sheets are 2900 Mpa and 120 Gpa respectively. The third group name is SmCn. S and C imply Steel and Confine and m and n are two numbers that determine number of tensile bars and number of AFRP sheet layers respectively. More properties of these beams are shown in Table 3. All layers of AFRP have 0.3 mm thickness. All the compressive bars are steel. 26 steel stirrups have been distributed monotonously along the beams. Compressive strength of concrete (f'c) has been considered 84.5 Mpa in all beams. More details are shown in Fig. 2.
Before modeling of main beams, two experimental results of beams compared with ANSYS results. It can help to check the software. AF-control beam is a represent of first group. It has AFRP bars as tensile bars and its experimental results have been shown by Rashid et al. (2005) (DF3T1).
Fig. 3 compares the results of experimental and modeling beams. After the formation of great cracks, the software couldn’t coverage the equations and couldn’t continue up to complete failure. STC-control beam is a represent of third group. It has steel tensile bars and a layer of FRP attached at the bottom. Its experimental results have been shown by Sadr-Momtazi et al. (2006) (G1). Fig. 4 compares the results of experimental and modeling beams.

4. Results and Analysis

HSC beams which reinforced with AFRP exhibit elastic response up to failure. Fig. 5 compares the response of AF2, AF3, and AF4 (First group). HSC beams which reinforced with STEEL exhibit nonlinear behavior after yielding. Fig. 6 compares the response of ST2, ST3, and ST4 (second group). Comparing the behavior of third group beams is shown in Figs. 7, 8, 9, 10 which show third beams with one, two, three and four AFRP covering layers respectively.
Figs. 11, 12 and 13 show the comparing of beams with 2, 3 and 4 tensile bars respectively.

5. Conclusions

1. Maximum deflection in HSC beams reinforced with AFRP is higher than HSC beams reinforced with steel bars.
2. Failure force of AFRP reinforced and covered HSC beams are much higher than steel reinforced.
3. HSC beams with AFRP covers have higher ductility than uncovered beams (second group). Ductility factor (μ) increases by increasing the number of AFRP covers.

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Table 1. First group properties.

Name	AFRP bars properties		Compressive steel bars properties		Concrete properties		
	Tensile strength(Mpa)	Modulus of elasticity(Mpa)	Yielding strength(Mpa)	Modulus of elasticity(Mpa)	Compressive strength(Mpa) f'_c	Modulus of elasticity(Mpa)	Tensile strength(Mpa)
AF2	1760	53000	533	2.1×10^5	84.5	45962	5.05
AF3	1760	53000	533	2.1×10^5	84.5	45962	5.05
AF4	1760	53000	533	2.1×10^5	84.5	45962	5.05

Table 2. Second group properties.

Name	Steel bars properties		Concrete properties		
	Yielding strength(Mpa)	Modulus of elasticity(Mpa)	Compressive strength(Mpa) f'_c	Modulus of elasticity(Mpa)	Tensile strength(Mpa)
ST2	533	2.1×10^5	84.5	45962	5.05
ST3	533	2.1×10^5	84.5	45962	5.05
ST4	533	2.1×10^5	84.5	45962	5.05

Table 3. Third group properties.

Name	AFRP bars properties			Steel bars properties		Concrete properties		
	Number of layers	Modulus of elasticity (Mpa)	Tensile strength (Mpa)	Yielding strength (Mpa)	Modulus of elasticity (Mpa)	Compressive strength(Mpa) f'_C	Modulus of elasticity (Mpa)	Tensile strength (Mpa)
S2C1	1	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S3C1	1	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S4C1	1	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S2C2	2	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S3C2	2	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S4C2	2	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S2C3	3	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S3C3	3	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S4C3	3	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S2C4	4	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S3C4	4	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05
S4C4	4	12×10^4	2900	533	2.1×10^5	84.5	45962	5.05

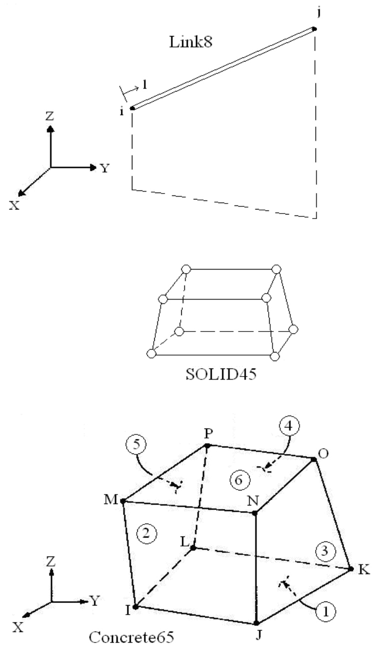

Fig 1: Used elements.

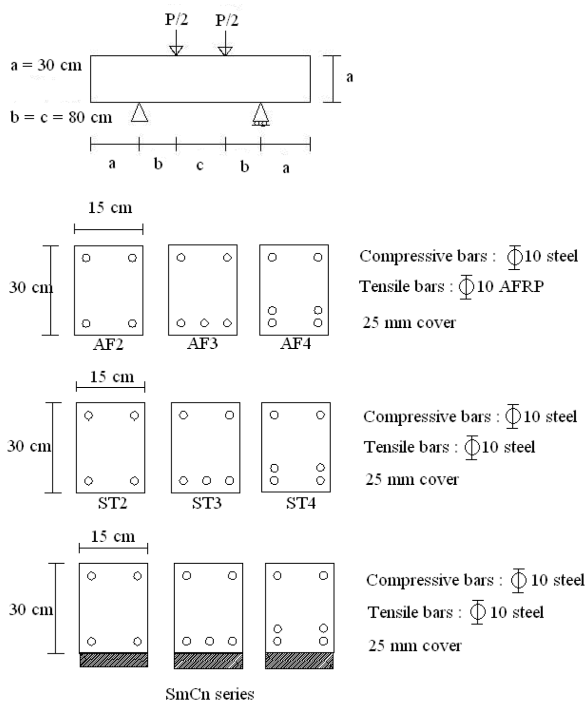

Fig 2: Modeled beams.

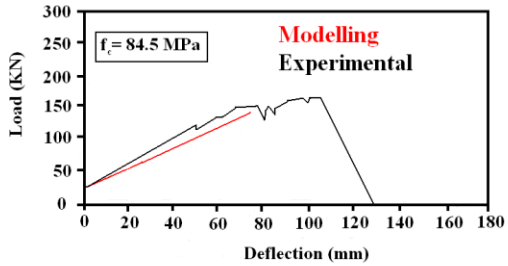

Fig 3: AF control beam.

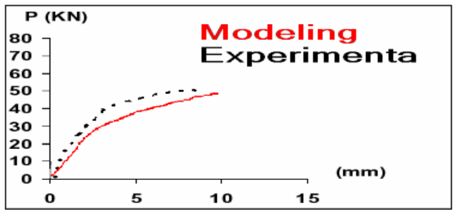

Fig 4: STC control beam.

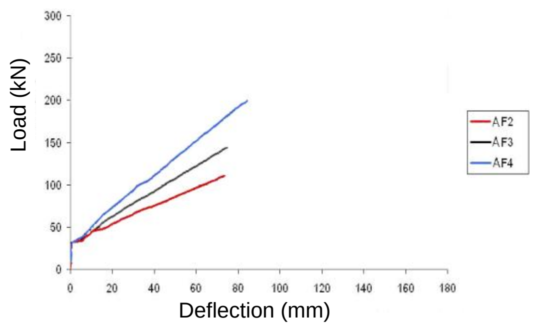

Fig 5: First group beams.

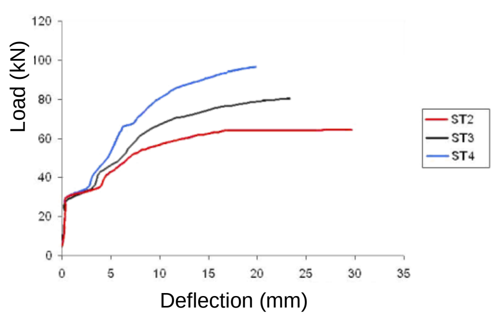

Fig 6: Second group beams.

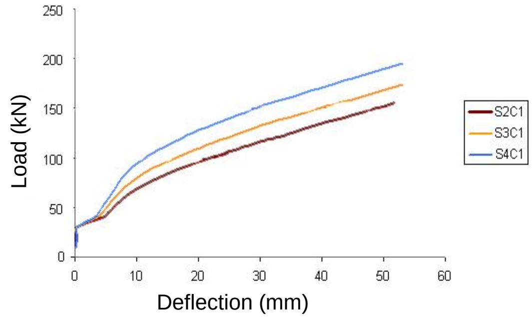

Fig 7: Third group with one layer.

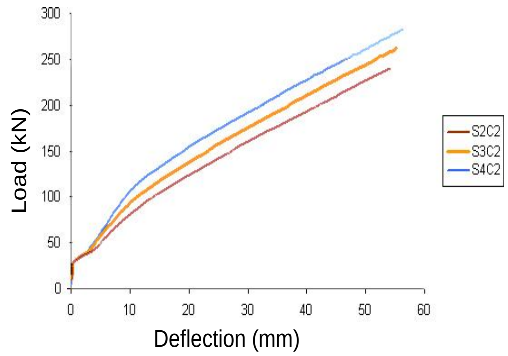

Fig 8: Third group with two layers.

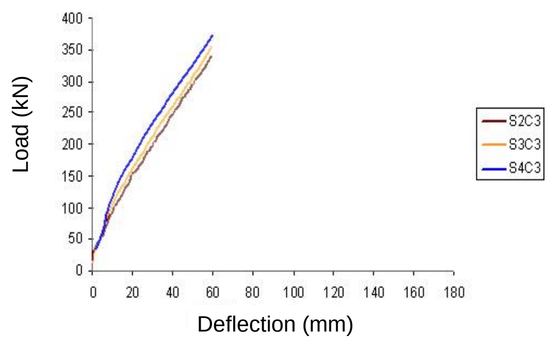

Fig 9: Third group with three layers.

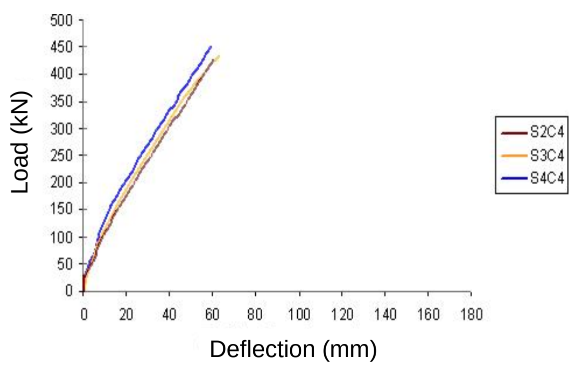

Fig 10: Third group with four layers.

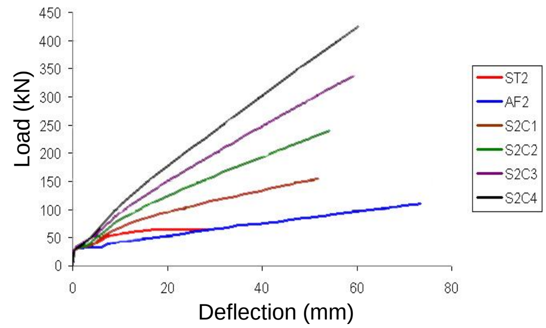

Fig 11: Beams with two tensile bars.

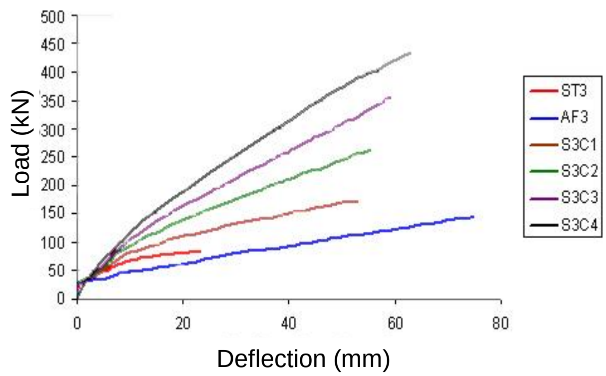

Fig 12: Beams with three tensile bars.

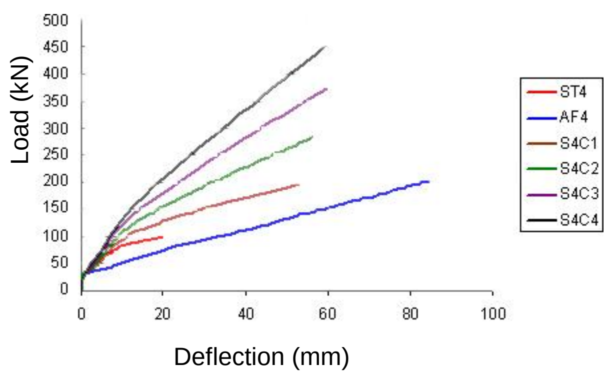

Fig 13: Beams with four tensile bars.