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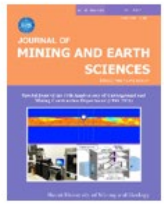

Application of steel fiber-reinforced concrete for slab lagging at underground mines in Quang Ninh

Phong Duyen Nguyen[1,*], Minh Tuan Tran[1], Thuc Van Ngo[2], Lam Van Tang[1], Tung Huu Trinh[3]

[1] *Hanoi University of Mining and Geology, Hanoi, Vietnam*
[2] *Mien Tay Construction University, Vinh Long, Vietnam*
[3] *Joint-Stock Investment and Construction Company No.34, Hanoi, Vietnam*

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ABSTRACT

Steel Fiber-Reinforced Concrete (SFRC) is an advanced material studied and used in some developed countries in the world in recent years. The characteristics of this concrete are intensive compression, high tensile and tolerance strength, higher repeated loads, and long-term durable stability. Steel fibers were used to manufacture SFRC because of their outstanding characteristics. The durability of SFRC should be improved and the disadvantages of traditional concrete should be reduced. To produce inserts in the support structure, SFRC must be applied. Because 60÷70% of tunnels are being constructed for underground coal mines of Vietnam National Coal and Mineral Group (TKV) currently use. SPV steel frame support in combination with reinforced concrete inserts steel. To increase the plaque's capacity and durability in the future, a study must be done to create new, very intense concrete materials. This study investigated how the ratio and compressive strength of steel fibers affected the flexural characteristics of SRFC. To achieve this, 30 MPa strength SFRC with 0.5%, 1.0%, and 1.5% fiber fractions were made and evaluated. This study's experimental results can be summarized as follows: according to the compression experimental results, the compressive strength and elastic modulus of SFRC were not considerably impacted by the steel fiber volume ratio; The experimental results from the bending tests show that for concrete with a strength of 30 MPa, the proportion of steel fibers of 1.0% has higher flexural strength and toughness than the proportion of steel fibers of 0.5% and 1.5%; A comparison of the test at 28 days of age with the (ACI 211.1-91, 1991) was completely satisfied.

*Corresponding author
E - mail: nguyenduyenphong@humg.edu.vn
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1. Introduction

Researchers have experimented with adding steel fibers to concrete mixes to boost the concrete's strength. The role of steel fibers in preventing brittleness and minimizing fractures caused by the high-intensity impact of the poor, which is a high density of silica, which is for the port of pool, has been researched by the author (Shah and Ribakov, 2011). (Uygunoğlu, 2008) have conducted the Investigation of microstructure and flexural behaviors of steel-fiber reinforced concrete. The flexural strength of SFRC increased with the concrete age and fiber volume fraction. (Köksal et al., 2008) have studied the effects of the Silica Fume (SF) and steel fibers on the characteristics of high-intensity reinforced steel. Concrete shows lower than the SF intensity. However, the use of steel fibers in concrete has created his weaknesses. Flexibility is a key factor in the relationship between the steel's itch component and the qualities of the substrate and steel fibers (Cao et al., 2019) have studied the flexural behavior of fiber-reinforced cemented tailings backfill under three-point bending: In this study, comprehensive laboratory work was carried out for better investigating the bending strength of fiber-reinforced CTB samples. Steel fibers as minimal shear reinforcement in reinforced concrete beams have been studied by (Jain and Singh, 2013), The failure modes of the beams with steel fibers as minimum shear reinforcement were comparable and similar to that of the beams detailed with the ACI Building Code and the Indian concrete code-recommended minimum shear reinforcement and shear strengths of the fibrous concrete beams although significantly lower than the measured strengths of the beams detailed with the code-specified web reinforcement were higher than the predicted values of 0.344 MPa and 0.4 MPa, respectively, from these design codes. (Ganesan et ala., 2013) has studied the Engineering properties of steel fiber reinforced geopolymer concrete. An attempt was made to obtain the relationship between the various engineering properties with the percentage of fibers to be added. According to the study by Ganesan et al., 2014, adding steel fibers to the HPC structural walls improves the first crack load, strength, initial stiffness, and energy dissipation capacity. High-performance fiber-reinforced cement concrete slender structural walls. (Shaikh and Taweel, 2015) has looked examined fiber-reinforced concrete's compressive strength and failure patterns under high temperatures. Compressive strength and failure behavior of fiber-reinforced concrete at high temperatures. (Areef et al., 2020) have investigated the flexural behavior of beams constructed of steel fiber reinforced concrete and copper slag as a partial replacement for fine aggregate. The load-deflection behavior of under-reinforced, normal, and copper slag concrete beams is seen to be similar with the exception of the increased values of ultimate failure loads and ultimate deflections at failure in steel fibred copper slag concrete beams. (Ali et al., 2020) has examined the impact of varied steel fiber content on strength and permeability characteristics of high-strength concrete with micro silica. Fibers have mixed effects on compressive strength (CS). The positive SF's effect on CS is observed only at low dosage. A large amount of SF negatively affects CS. MS improves the use of SF in developing the CS of concrete. The experimental study on the use of fly ash in underground construction concrete has been examined by (Dang et al., 2020). To investigate the effects of using fly ash for partial replacement of cement on making concrete insert plates for SVP steel frames in underground mines. This paper presents the effect of steel fiber replacement on the compressive strength and flexural strength of concrete with the slump and other fresh and hardened properties. A comparative cost analysis of making concrete for lagging of SVP steel frames in underground mines has been presented.

2. Materials and research methods

2.1. Material and scale

The mixture of high-intensity SFRC and normal is used in the study shown in Table 1 (ACI 211.1-91, 1991), (TCVN 12393:2018, 2018) and in Figure 1.

SFRC with a specific compression intensity of 30 MPa is prepared. The sand composition, cement, which is merged within 2 minutes in the concrete mixer, and the vibrating test system provided by Control to produce SFRC (Figure 2).

The sample casting process is supported by Controls concrete vibrator (Figure 3) (https://www.controls-group.com, 2015).

After that, within a minute, add the silica fume and fly ash to the sand and cement combination. It's roughly five minutes to the rock. Then it would take 3 to 5 minutes to add the water and extra plastic. Finally, steel fibers were added to the fiber volume that had previously been selected from 0.5%, 1.0% and 1.5% of steel fibers combined by volume of concrete composite. Here, the steel fiber is made of copper-plated micro-metallic steel, the mechanical properties of steel fibers are listed in Table 2.

Compression and bending tests were conducted for 28 days on SFRC with 30 MPa strength after casting. To evaluate the compressive properties of SFRC 150×150×150 mm cube samples were used (Figure 4).

Figure 1. Experimental material.

Figure 2. Control concrete mixer.

Figure 3. Controls concrete vibrating.

Figure 4. Form and maintenance.

Table 1. SFRC intensity ratio.

Mixture	Fiber volume fraction (%)	Unit weight (kg/m^3)						
		Water	Cement	Silica fume	Fly ash	Sand	Large aggregate	Steel fiber
NSFC-0.0	0.0	166.5	321.3	18.9	37.8	854.5	1017.5	0.0
NSFC-0.5	0.5	166.5	321.3	18.9	37.8	854.5	1017.5	5.0
NSFC-1.0	1.0	166.5	321.3	18.9	37.8	854.5	1017.5	10.0
NSFC-1.5	1.5	166.5	321.3	18.9	37.8	854.5	1017.5	15.0

Table 2. Mechanical Properties of Steel Fiber.

End type	Tensile strength (MPa)	Length (mm)	Diameter (mm)	Aspect ratio	Modulus of elasticity (GPa)	Specific gravity
Hooked-end	1.1	30	0.5	60	205	7.85

Controls Advantest 9 is an automatic compression and bending system of Controls with a compression module of 3000 kN and a bending module of 300 kN capacity (https://www.controls-group.com, 2015) (Figure 5).

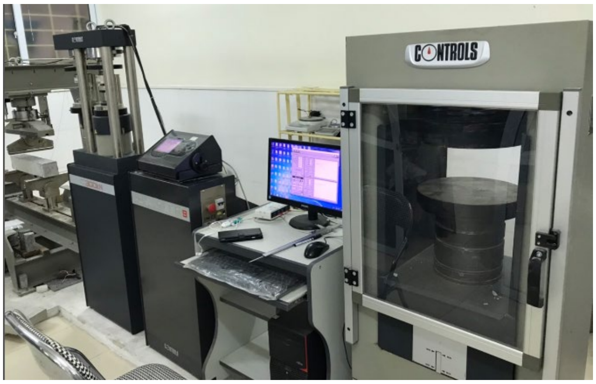

Figure 5. Advantest 9 Control system by Humg.

The cube samples were carried out according to the standard (ACI 211.1-91, 1991). The Controls Advantest 9 of 3000 kN was used in the test, which was carried out as shown in Figure 6(a), to apply load at a rate of 0.5 MPa/s. The axial strain measurement was performed by using two linear transform transducers (LVDT). Bending tests were performed by using a basic support beam method according to (ACI 544.4R-88, 1988). A Controls bending machine with a capacity of 300 kN and a speed of 0.5 mm/min was used for the test. The test setup for bending is shown in Figure 6(b). The deflection at the center of the beam is recorded by the LVDT on the machine.

2.2. Test Results and Discussion

A typical stress-strain curve for concrete and cube samples is shown in Figure 7 along with the connection between stress and compressive strain. The results show that the compressive strengths of the mixture of NSFC-0.5%, NSFC-1.0% and NSFC-1.5% are 41.01; 44.36; 46.64 MPa, respectively. As expected, the elastic modulus has similarly changed to the compressive strength. As a result, (Shaikh and Taweel, 2015) concluded from their existing experimental research on the influence of fiber volume fraction on compressive strength, that the volume ratio of steel fibers had minimal effect on the compressive strength of SFRC.

Figure 6. Effects of Compressive Strength on Flexural Toughness index of SFRC according to Steel Fiber Volume Fraction.

(a) Compressive strength of concrete test specimens; (b) Flexural strength of concrete test specimens.

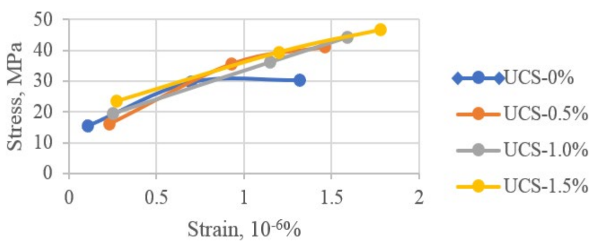

Figure 7. Relationship Stress-strain.

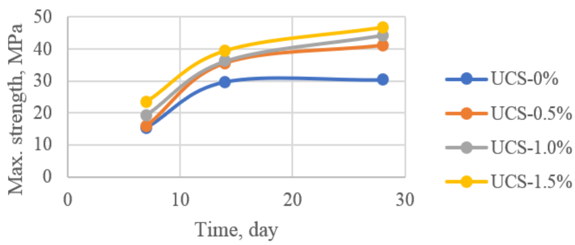

Figure 8. Relationship stress-age curve.

Relationship between compressive stress and age of concrete. The compressive stress-age curves of concrete with the volume composition of steel fibers are shown in Figure 8. These figures illustrate that the effect of steel fiber ratio in concrete does not have a significant influence on compressive stress. And their magnitude increases gradually with the ratio of steel wire 0.5% < 1.0% < 1.5%. A comparison of the test at 28 days of age with the (ACI 211.1-91, 1991) was completely satisfied.

Based on the compressive strength of the test sample, the research team created reinforced concrete inserts to withstand the furnace. With a length of 0.7 m, a width of 0.2 m and a thickness of 0.05 m. With the grade as in Table 1. From there, the relationship between the flexural strength and the age of concrete can be determined. The concrete's flexural strength-age curves with the volumetric composition of steel fibers are shown in Figure 9. These figures show that the maximum flexural strength is achieved at 1.0% steel fiber content.

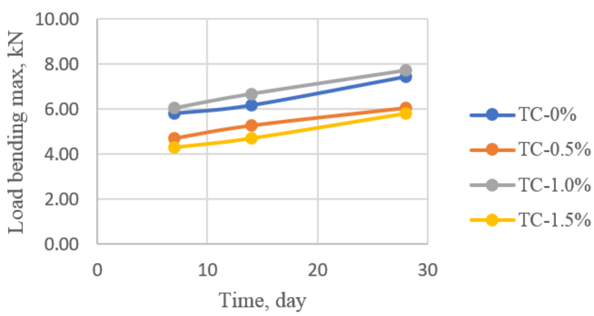

Figure 9. Relationship flexural strength-age curve.

Figure 10. Testing of reinforced concrete sheeting.

Testing the bending resistance of steel fiber concrete inserts by using Controls Advantest 9 automatic bending and compression system is shown in Figure 10.

3. Conclusions

This study investigated how the ratio and compressive strength of steel fibers affected the flexural properties of SRFC. For this purpose, 30 MPa strength SFRC with fiber fractions of 0.5%, 1.0% and 1.5% was created and tested. The experimental results from this study can be summarized as follows:

(1). According to the compression test results, the steel fiber volume ratio did not significantly affect the compressive strength and elastic modulus of SFRC.

(2). The experimental results from the bending tests steel fiber content of 1.0 percent in concrete with a strength of 30 MPa has stronger flexural strength and toughness than steel fiber content of 0.5 percent and 1.5 percent.

(3). Comparison of the test at 28 days of age with the (ACI 211.1-91, 1991) was completely satisfied.

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Author Contributions

Phong Duyen Nguyen - proposed the idea of research, wrote manuscripts; Minh Tuan Tran, Thuc Van Ngo - calculated the distribution, collected reference materials and processed experimental results; Lam Van Tang, Tung Huu Trinh - carried out experiments and edited the manuscript.

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