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Study on the effect of steel fiber on the crack opening ability of high-quality concrete

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ABSTRACT: Concrete during the curing process will appear micro-cracks inside, which will grow and be joined together to form obvious cracks due to changes in loads and environmental conditions during mining exploitation use. With crack propagation occurs abrupt fractures can occur for concrete structures. This study uses steel fibers to limit and prolong the crack resistance of concrete. Besides, to increase the strength of concrete, it is necessary to add mineral additives and plasticizers to reduce the amount of water and increase the ability to solidify the concrete. This paper uses a three-point bending test of slotted beam samples as recommended by Rilem. Rilem method uses a crack control device, here the team uses a CMOD device manufactured by Controls.

KEYWORDS: steel fiber, crack opening ability, high-quality concrete.

I. INTRODUCTION

Since concrete was used until now, the use of concrete for construction works has been increasingly focused. Research to reduce structural cross-sections based on bringing advanced technology and materials with higher material properties [1]. With the increase in compressive strength, the post-cracking of concrete becomes worse. Fiber-reinforced concrete (FRC) has been successfully used in many horizontal and vertical structures as well as non-structural elements [2]. To reduce crack propagation and displacement of concrete slabs such as industrial floors when using fiber reinforcement together with traditional reinforcement [3]. In buildings and bridges in seismic areas, fiber reinforced concrete improves the performance of structural elements such as columns, beams, or walls [4], Ali et al [5] showed the effect of fiber and silica fume on the mechanical performance and strength of concrete on reducing the permeability of the material. The benefit of using high-quality fiber-reinforced concrete is sustainable resource management, a case study [6] has researched and manufactured concrete significantly reducing the volume of materials.

To understand the performance of HPC and UHPC as well as concrete in general with the participation of fiber reinforcement, experimental research methods have been published recently. [7]. Typical fibers such as steel thread [8], carbon fiber [9], or polymers [10]. Materials analysis focuses on the combination of concrete and fiber reinforcement [11]. The results of the experimental tests to be carried out are based on the fiber anisotropy in the concrete substrate [12]. The location of the deformation and the location of the crack can lead to difficulties in the inspection process [13]. By using a clip gauge to measure the crack mouth displacement (CMOD) [14], [15].

The aim of the study was the effect of steel fiber addition on the properties of high-quality concrete. As with other claims, the addition of steel fibers does not always have a positive effect on mechanical properties. Therefore, in this study, the authors propose to consider the influence of steel fibers on the crack opening ability and mineral additives as well as superplasticizers to recommend users to use fabrication materials when concrete mix design.

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In recent years many researchers have described the elongation resistance of concrete through typical R and Kr curves [16].

II. MATERIALS AND EXPERIMENTAL METHODS

2.1. Material

In this study, materials are used including (1) Binding agent (BA) including Portland cement PC40 "But Son" by TCVN 2682:2009, fly ash class F of the thermal power plant. Vung Ang electricity (Vietnam) meets the requirements of TCVN 10302:2014, ASTM C618-03, Silicafume SF-90 of Vina Pacific by TCVN 8827:2011. (2) Large aggregate using basalt is selected from Sunway - Hoa Binh quarries following TCVN 7570:2006 and ASTM C33. (3) Fine aggregates using Viet Tri yellow sand were analyzed and found to be consistent with the standards of TCVN 7570: 2006 and ASTM C33. (4) Superplasticizer SR 5000 F "SilkRoad" (Hanoi-Korea co., Vietnam) has a density of 1.1 g/m3 at 25°C. This is a high-range, third-generation water-reducing additive with a composition based on Polycarboxylate radicals following TCVN 8826:2011. (5) Clean water is used to make water for mixing concrete mixes and for curing test samples, meeting the standard TCVN 4506:2012. (6) Steel yarn used by BeKeart Germany has a factory located in Shanghai, China. Dramix type steel thread, symbol OL13-20, has a diameter of D = 0.2 mm; length L = 13 mm; yield strength is 2,000 MPa of high-quality grade. Steel yarn is fabricated following ISO 9001 and meets TCVN 12392-1:2018, ASTM A820/A820M-16.

Dramix Steel fiber

2.2. Concrete mix design

Design of concrete mix composition. The concrete mix composition is calculated and designed according to the absolute volume method according to ACI 211.4R-08 and combined with experimental adjustment (Table 1).

Table 1. Calculation results of concrete composition using steel fiber

SAMPLE	SAMPLE	CONCRETE MIX MATERIALS								W/AA
		C	FA	SF	S	LA	SP	W	F	
ID1	D0.0	321.3	37.8	18.9	854.5	1017.5	1.61	166.4	0.0	0.4
ID2	D5.0	321.3	37.8	18.9	854.5	1017.5	1.61	166.4	5.0	0.4
ID3	D10.0	321.3	37.8	18.9	854.5	1017.5	1.61	166.4	10.0	0.4
ID4	D15.0	321.3	37.8	18.9	854.5	1017.5	1.61	166.4	15.0	0.4

Note: ID - sample symbol; D0.0 - 0% steel fiber beam sample (control); D5.0 - Sample beam 5% steel fiber; D10.0 - Sample beam 10% steel fiber; D15.0 - Sample beam 15% steel fiber; C - Cement (kg/m^3); FA - Fly ash (kg/m^3); SF - Silica fume (kg/m^3); S - Sand (kg/m3); LA - Large aggregate (kg/m^3); SP - Super-plasticizer (liter/m^3); W - Water (liter/m^3); F - Fiber (Steel fiber) (kg/m^3); W/AA - Ratio Water/Adhesion agent.

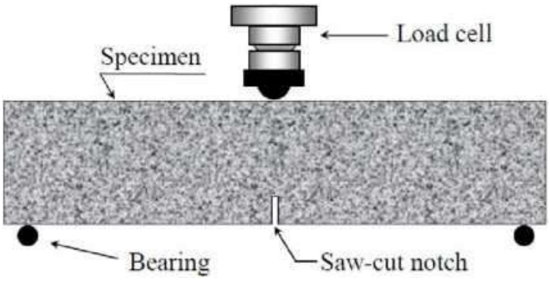
2.3. Producing concrete samples

Mix large aggregate with small aggregate in a mixer, then cement is added to the mixing process. Steel fibers are added during mixing with pre-calculated concentrations. The mixture of water and plasticizers is kneaded and added to the concrete mix.

The samples were fabricated and tested at the Construction Laboratory, the Department of Underground and Mine Construction, the Faculty of Construction, the University of Mining and Geology.

Study using three-point bending test of knurled beam samples to determine the fracture characteristics of concrete according to Rilem recommendation [16]. The concrete specimen used in the three-point bending test was a prism measuring 600×150×150 mm with a notch 2 mm wide. The groove depth is 25 mm and the ligament area is 150×125 mm^2 (Figure 2).

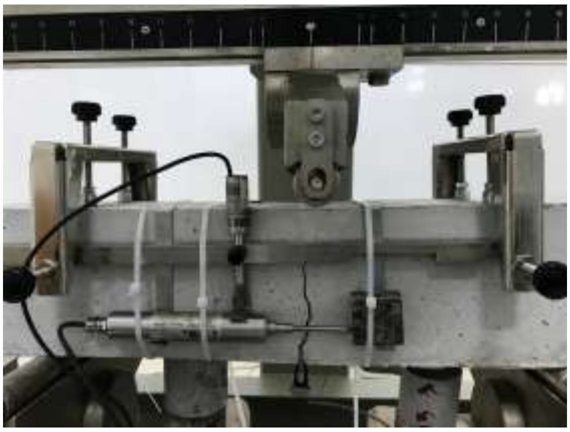
All notches are cut on a surface perpendicular to the top of the specimen during molding. The test beams after 28 days will be grooved on the 21st day. After that, the samples are cured until the day of testing.



Three-point bending test of beam specimen

2.4. Experimental methods

The test with a three-point bend beam with primer cracking is used to determine the fracture parameters of the concrete, and the test is depicted as shown in Figure 3. The fracture test is not the same as the strength test or other tests. With other mechanical properties, load control is not used but instead by controlling displacement or cleft displacement in the specimen. All three-point bending tests were performed under closed-loop conditions, using an automatic compression-bending machine system supplied by controls for testing. The parameters measured during the test are load, beam displacement (LVDT), crack opening width (CMOD) measured, and experimental equipment arranged as shown in Figure 3.



Three-point bending test of high-quality concrete samples using steel fibers

As recommended by Rilem [16], it is necessary to conduct experiments so that the rate of increase of mid-span displacement is a constant of 0.2 mm/min. However, the study suggests a small change could be made to this requirement. Instead of performing the experiments in mid-span displacement control, the experiments were performed in the crack mouth widening displacement (CMOD) control.

2.5. Results and Discussion

- Effect of steel fiber content on load relationship and crack opening width

The P-CMOD curve of steel fiber-free concrete has a significant slope after peaking (Pmax), the force value decreases rapidly when the CMOD is very small. When adding steel fiber to concrete at the rate of 5%, 10%, and 15%, the obtained P-CMOD curve changes markedly. In the first stage, concrete is still in the elastic stage; All sample curves have the same tendency to develop, as shown in Figure 4. The difference begins to appear at the point when the curve is nearing its maximum, the curve peak of the concrete using the steel fiber is higher. unused concrete. It can be understood simply that the tensile strength of the concrete using steel fibers is higher than that of the unused concrete.

- Effect of steel thread on the relationship between load and deflection (P-δ).

The relationship between load and deflection (P-δ) of high-performance concrete with the percentage of additional steel fibers is shown in Figure 5. For steel fiber concrete, the P-δ curve is thicker, the nonlinear

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phase of the curve becomes longer, and the load decreases more slowly.
Maximum span displacement (δmax) of the three-point bending test on concrete beams, based on Figure 5, it can be seen that δmax increases when comparing samples using steel fibers from 5%, 10% to 15% of the control sample (0% steel fiber).

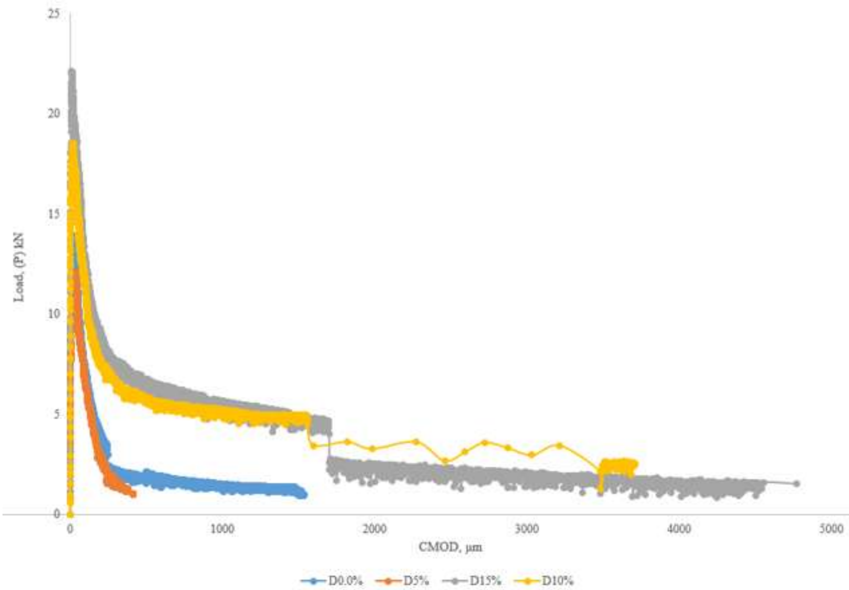

Diagram of the relationship between the load and the displacement of the crack mouth

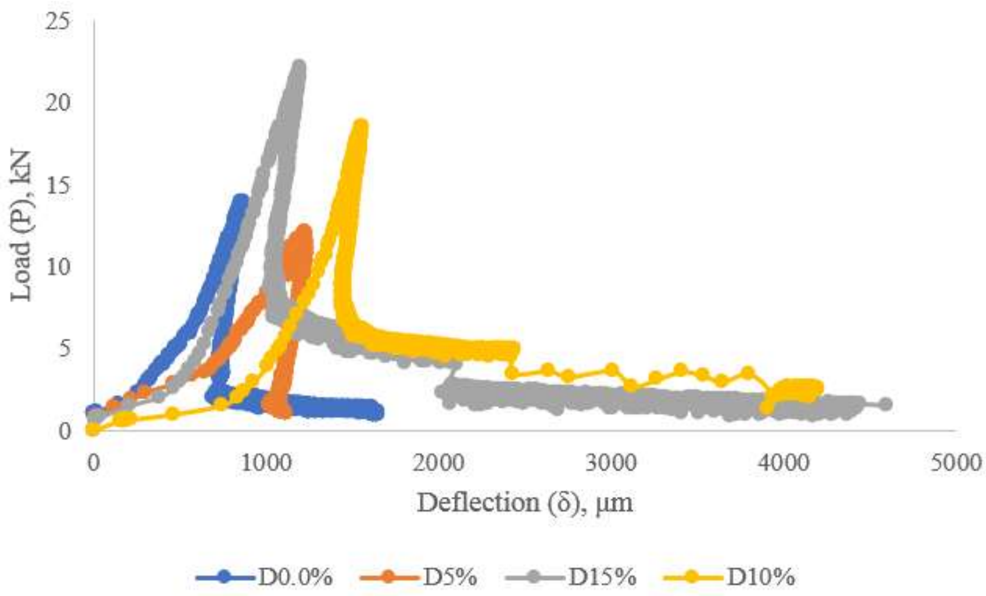

Diagram of the relationship between load and deflection

III. CONCLUSION

The fracture characteristics of high-strength concrete were investigated by changing the steel fiber content. Using steel fibers in high-strength concrete improves the fracture energy and toughness of high-strength concrete. The results show that the degree of fracture characterization is significant, with the percentage of steel fibers used is 15%.

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Underground and Mine Construction, The University of Mining and Geology, Vietnam has created research and experimentation.

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