Flexural Performance of HPFRC Plates using PPC and Variation of Steel Fiber Composition

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4th International Conference on Rehabilitation and Maintenance in Civil Engineering
Best Western Premier Hotel, Solo Baru, July,11-12 2018

Lay Out

1 Introduction

- Fracture toughness, ductility, durability, control of crack width, plate thickness reduction and increased permissible connection spacing are the advantages of the mechanical properties of HPFRC
- In order to meet the sustainability requirements of HPFRC material technology in the construction process, there is still the need to determine the right strategy to develop this kind of concrete technology.
- This study aims to investigate the improvement of flexural performance on HPFRC plates that utilize Portland Pozzolana Cement (PPC) with various compositions of steel fibers

2 Literature review

A one-way HPFRC plate with a line load at the center of the span, will bend in the perpendicular direction to its longitudinal axis.
The external load acting as the lateral load will be converted as the internal moment causing the tensile force at the lower side of the plate and the compressive force on the upper side of the plate.
The maximum moment in the member due to service loads M_a (N-mm) at stage deflection is calculated by the equation:

$$M_a = \frac{1}{4}\,P.l - \frac{1}{8}\,q\,l^2$$

The moment of inertia of the HPFRC plate section about a centroidal axis $\left(I_g\right)$ is

$$I_g = \frac{1}{12}\,b\,h^3$$

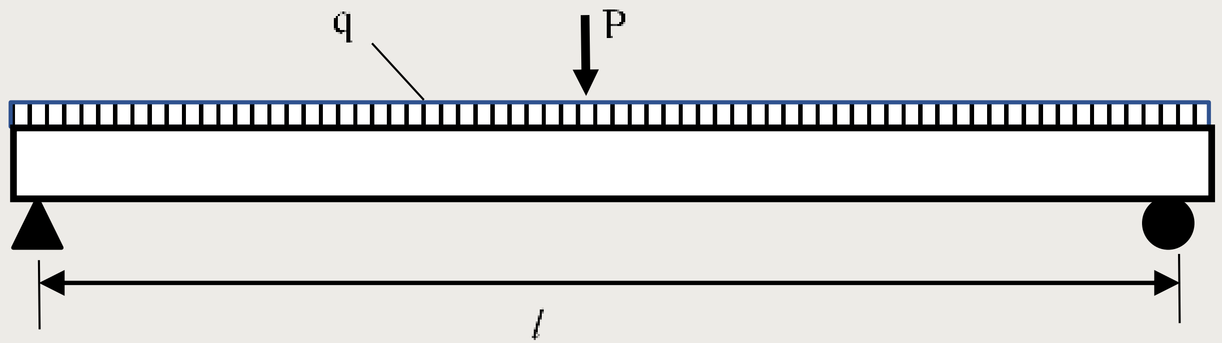

Fig. 1. The external line load acting on the one-way HPFRC plate.

2 Literature review

The cracking moment M_{cr} is $$M_{cr} = \frac{f_r\, I_g}{y_t}$$

After the crack occurs, the form of stress on the compression concrete will change shape as in figure 2.

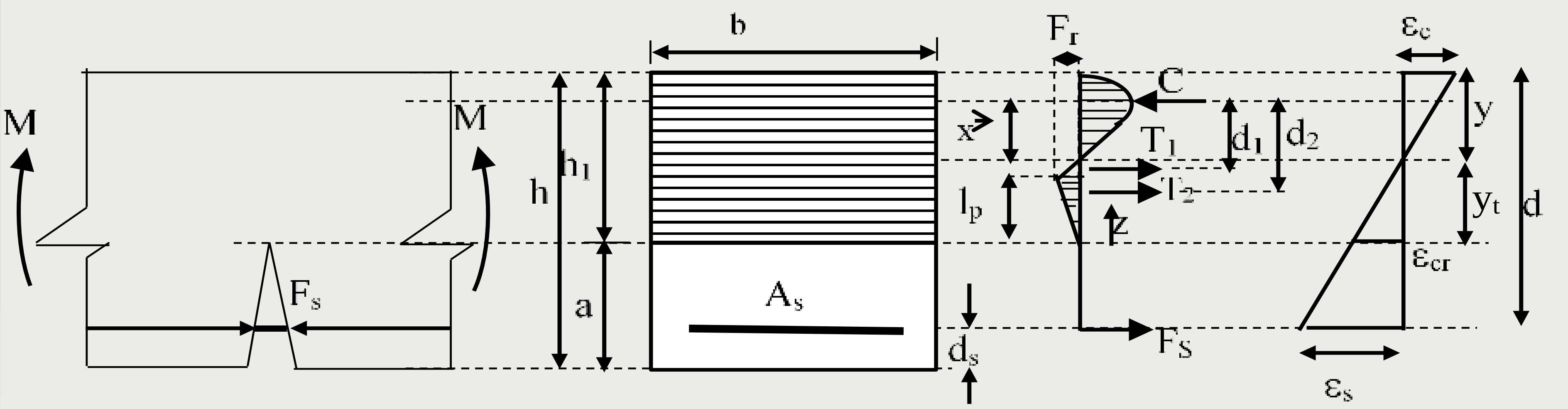

Fig. 2. The HPFRC plate element and variation of stress and strain across the plate depth [5].

The effective moment of inertia, I_e, is $$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr}$$

3 Materials and methods

- This research uses Portland Pozzolana Cement (PPC), gravel from the Malang area; Lumajang sand; water; silica fume; steel fiber; superplasticizer Sika® ViscoCrete®-7150.
- The mix design of the HPFRC uses the absolute volume method.
- The steel fiber Dramix @ 3D 80/60 BG is used varyingly from 0.2% to 1.0% from the HPFRC plates' volume.
- The HPFRC plates bending test is carried out using a center-point loading method or three-point bending method.
- The distribution of load on the plate width uses the IPE-100 profile.
- Measurement equipment used was a 20-ton load cell to measure the external load, a strain gauge and strainmeter for measuring strain on upper side concrete and lower the steel reinforcement, and a LVDT for measuring the deflection on the HPFRC plate.
- The load capacity of the HPFRC plates, deflection, and the cracking pattern are the objects observed.

3 Materials and methods

Table 1. Physical and mechanical properties of aggregate.

Properties of Lumajang sand	**Unit**	**Value**
Fineness modulus	-`	2.67
Humidity	%	2.80
Water absorption	%	0.30
Specific gravity	-	2.70
Finer material less than a 75-µm	%	0.00
Properties of gravel from Malang area	**Unit**	**Value**
Fineness modulus	-	7.05
Humidity	%	1.19
Water absorption	%	1.95
Specific gravity	-	2.69
Los Angeles abrasion value	%	18.65

Fig. 3. Material testing equipment. a) Material Testing System (MTS), b) Universal Testing Machine (UTM).

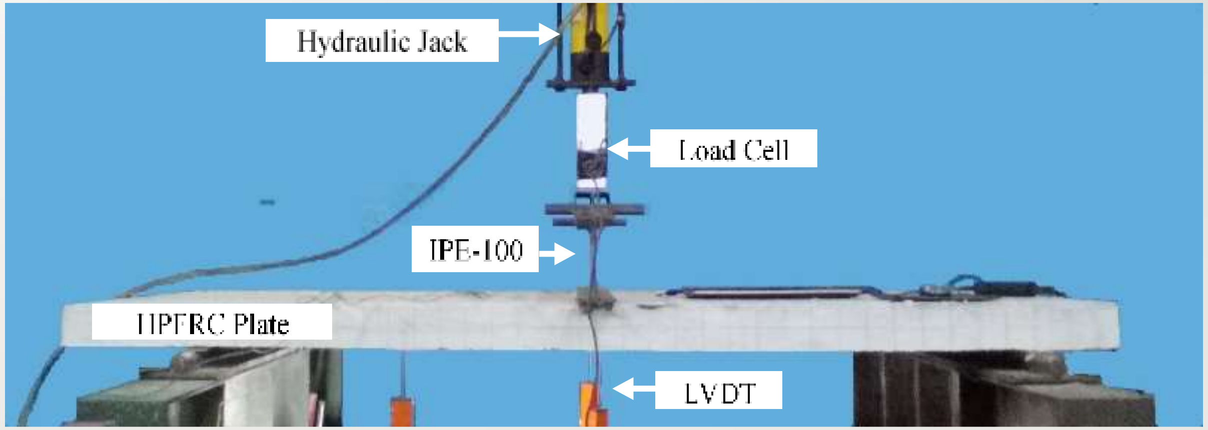

Fig. 4. The setting of flexural HPFRC plate experiment.

4 Result and discussion

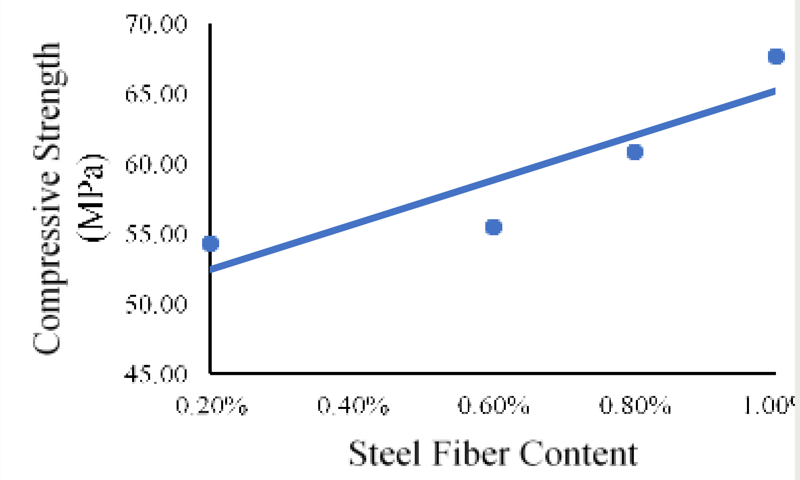

Fig. 5. Compressive strength of HPFRC plates with variation of steel fiber content.

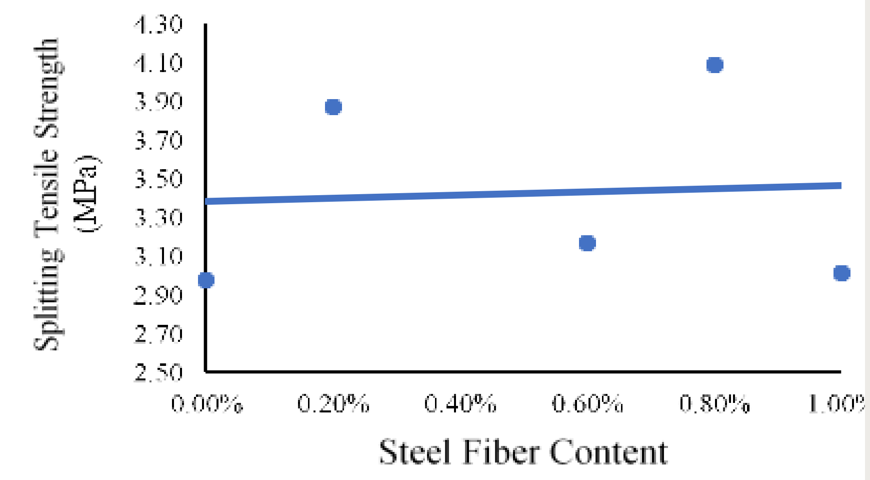

Fig. 6. Splitting tensile strength of HPFRC plates with variation of steel fiber content.

- The unit weight of the HPFRC material is 24.93 kN/m3.
- The compressive strength of the HPFRC plate shows an increase with ranges from 54.35 MPa to 67.67 MPa, and the average of the compressive strength is 59.59 MPa.
- The results of the splitting tensile test indicates that the optimal splitting tensile strength occurs in the composition of 0.8% of the steel fiber, about 4.09 MPa.

4 Result and discussion

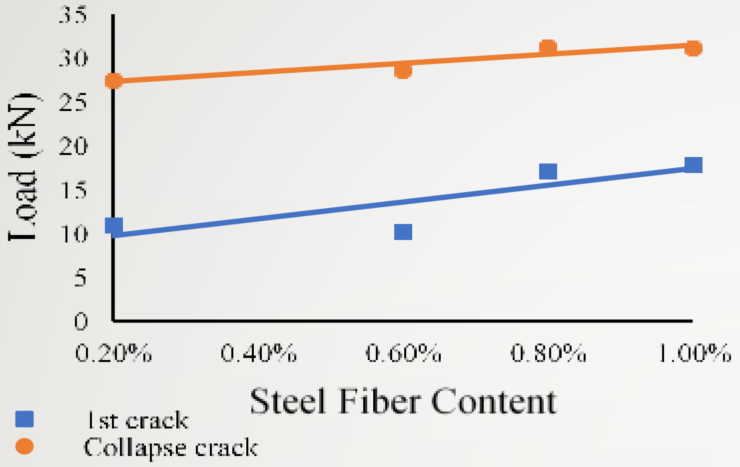

Fig. 7. Load capacity of HPFRC plates at the 1st crack and at the collapse crack.

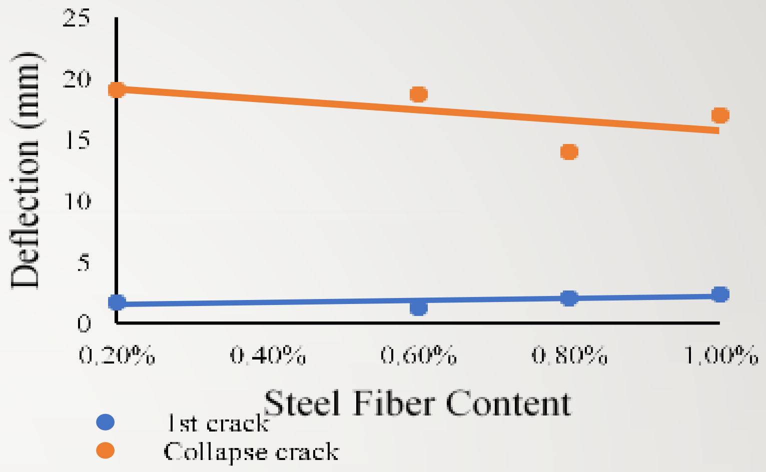

Fig. 8. Deflection of HPFRC plates at the 1st crack and at the collapse crack.

- The flexural load capacity tends to increase according to the steel fiber composition in the HPFRC plate.
- The deflection tends to decrease as the proportion of steel fiber increases.
- The test results in Fig. 8 show that the smallest deflection at the time of the HPFRC plate collapse occurred in the composition of 0.8% steel fiber. This is in accordance with the behavior of HPFRC material based on the results of the splitting tensile test in Fig. 6.

4 Result and discussion

Before the first crack occurs due to the internal tensile stress exceeding the tensile stress capability of the HPFRC matrix, the plate will be deflected linearly in an elastic state.

After the crack, the plate will have non-linear deflection, with the addition of a much larger deflection, until the load will not increase anymore when the HPFRC plate collapses.

After the load is reduced the deflection will decrease, but will not return to zero.

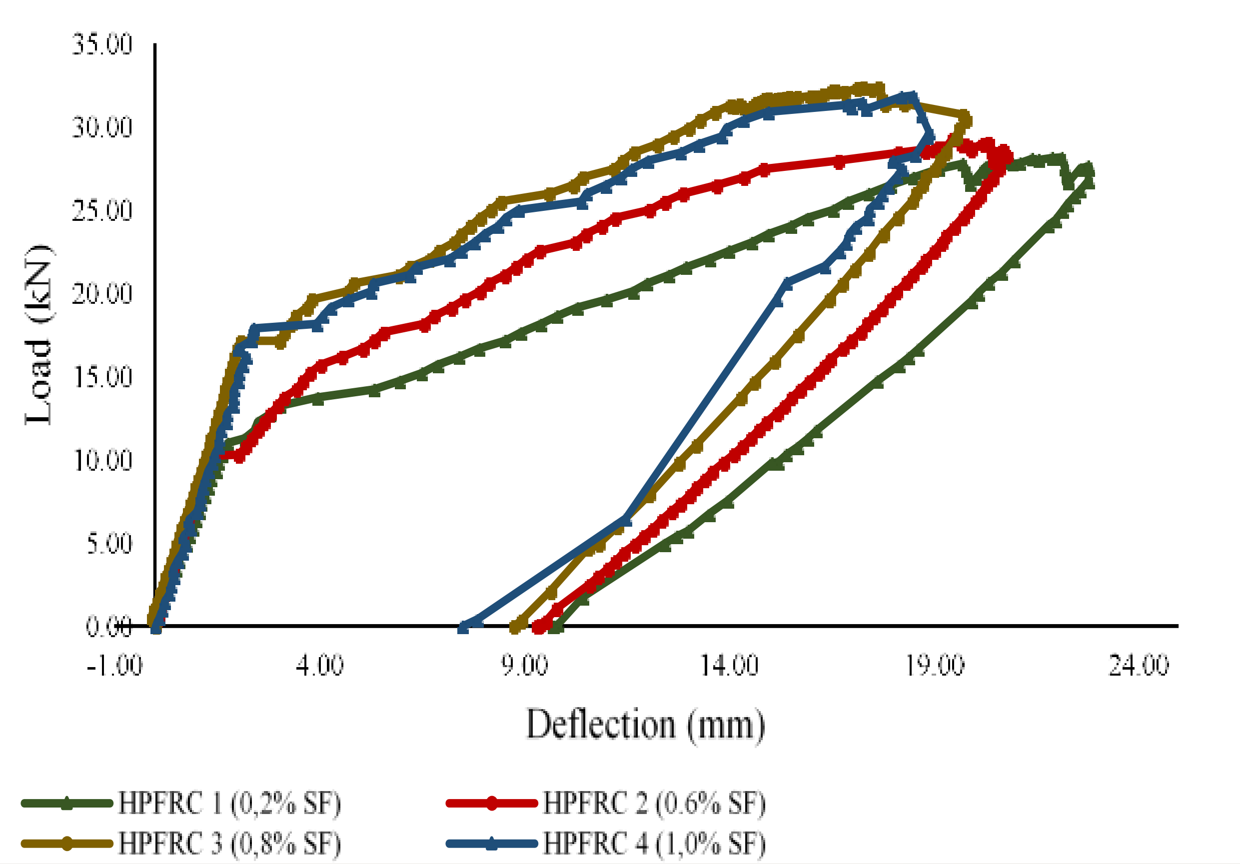

Fig. 9. Load-deflection correlation of HPFRC plate with a variety of steel fiber content.

4 Result and discussion

Prior to the crack, the addition of external loads caused the stress-strain relationship on each plate to behave linearly.

At the first crack, there is a considerable change in the tensile strain on the reinforcing steel on the lower side of the HPFRC plate, so that the diagram shows a horizontal line.

Next, the strain will behave non-linearly with a larger increment until the collapse of the HPFRC plate occurs.

The collapse of the plate is marked by no increase of the external load value acting on the HPFRC plate.

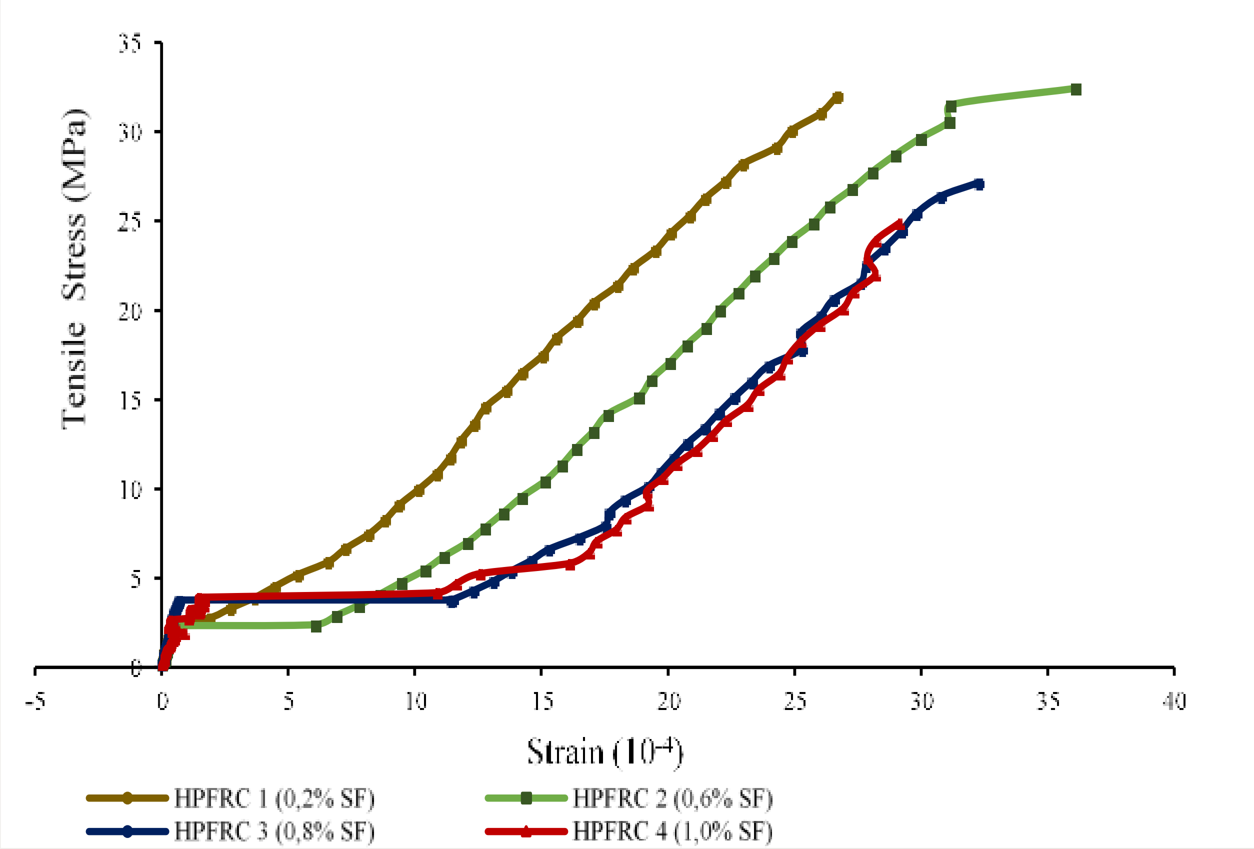

Fig. 10 Tensile Stress-Strain correlation of HPFRC plate with a variety of steel fiber content.

4 Result and discussion

- The crack is uniformly distributed on the lower side of the HPFRC plate between the plates' support.
- The crack distribution indicates that the HPFRC concrete matrix and the reinforcing steel have a good bond during loading after the first crack.
- When the flexural loads increase, it will increase the HPFRC plate tensile stress on the lower side of the HPFRC plate.
- When the HPFRC matrix tensile strength is surpassed, new cracks are formed on the lower side of the HPFRC plate, and then the tensile strength will be distributed to the reinforcing steel.

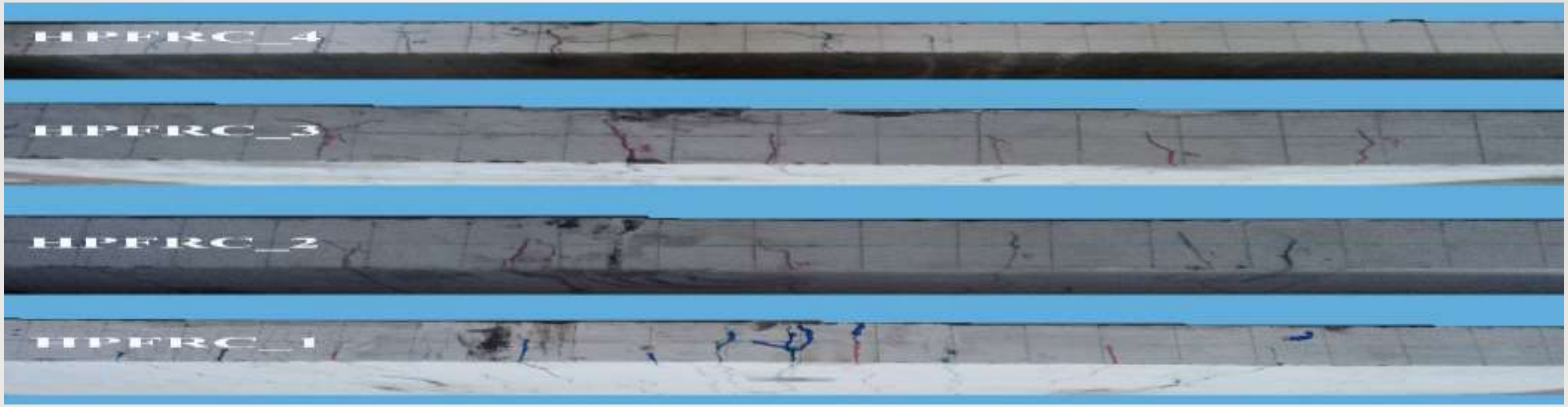

Fig. 11. HPFRC plates crack pattern.

5 Conclusion

- The composition of steel fiber is very influential to the improvement of the flexural strength at the 1^{st} crack and when the HPFRC plate collapses.
- The optimum bending strength of the HPFRC plate when the collapse occurs is obtained when the steel fiber composition is about 0.8% with an external load value of 31.76 kN and a deflection of 14.99 mm.
- The cracking pattern occurring on the lower side of the HPFRC plate showing the uniform distribution of cracks between the plate supports proves that the use of steel fiber can provide a good bond distribution between the HPFRC matrix and the reinforcing steel.

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THANK YOU