THEORETICAL PREDICTION OF SHEAR CAPACITY IN STEEL FIBRE RC BEAM WITHOUT STIRRUPS AND VERIFICATION BY OPTICAL ESPI METHOD

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1. Introduction

Steel fibre reinforced concrete is a composite material made from mixing normal concrete and steel fibres typically to a maximum of 2% content. Recent investigations have shown that steel fibres increase shear resistance in rc beams. Utilisation of this structural capacity has however, been limited by lack of design guidelines for potential structural design applications such as in shear reinforcement design. Furthermore there exists no unified expression for the complete characterization of shear strength and ductility in s.f.r.c beams. Fundamentally, steel fibres contribution should be considered based on stress transfer mechanism, augmented by concrete and dowel action of the rebars in unified manner. Theoretical and ESPI experimental comparisons results showed that the model predicted well the shear capacity in s.f.r.c beam.

2. Proposed theoretical model

The model was developed based on the considerations shown in Fig.1. Steel fibres, concrete and Re bars contribution were all considered based on equilibrium of forces and stress transfer mechanism. In the derivation, the expressions for the various forces acting to resist the shear stress (Fig.1(iii)) were first determined.
The the following assumptions were made;

(i) shear Plane sections remain plane
(ii) shear crack occurs at an angle α
(iii) fibres are elastic and perfectly bonded to concrete
(iv) fibres strain but eventually fail by pulling out
(v) dowel action of Re bars contribute to the shear

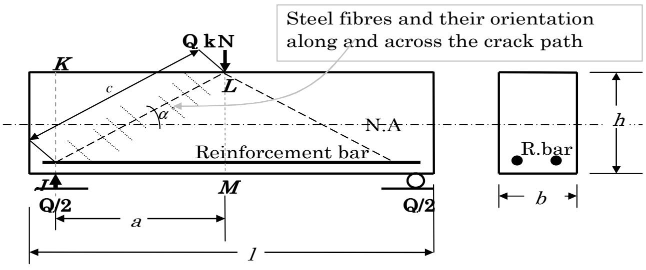
Finally equilibrium conditions between the internal forces and the applied external shear load were evaluated to arrive at a unified strain ratio dependant shear predictive relation given in eq. (1).

$$\tau_{xy} = v_{fc} + v_c + v_d \quad \text{..........................(1)}$$

Where

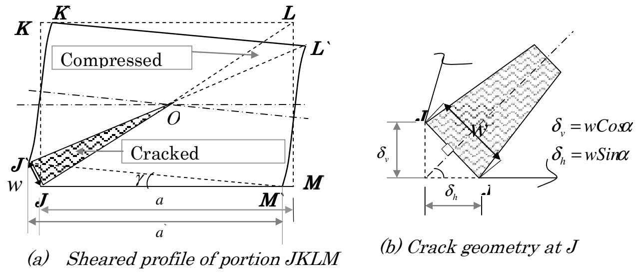
$$V_{fc} = \frac{k_1}{3\cos^2\alpha}\left\{3 - \left(\frac{\gamma_y}{\gamma}\right)^2 - \left[\frac{k_1}{\sigma_c}\left(2 - \frac{\gamma_y}{\gamma}\right) + \frac{\sigma_{ct}}{\sigma_c}\right]\left[\frac{3\sigma_{ct}}{2k_1} + 3 + \left(\frac{\gamma_y}{\gamma}\right)^2 - 3\frac{\gamma_y}{\gamma}\right]\right\}$$

(fibre concrete contribution)

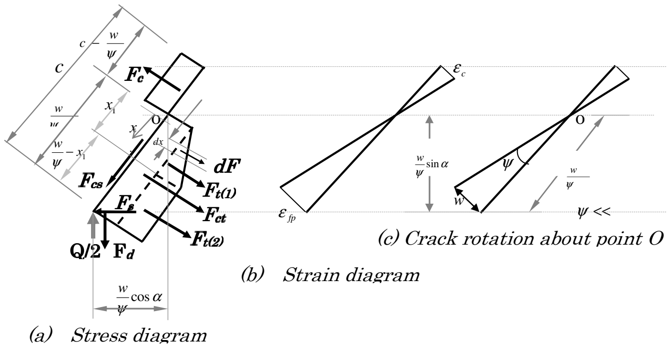


General details of the Model beam

(i) Model beam

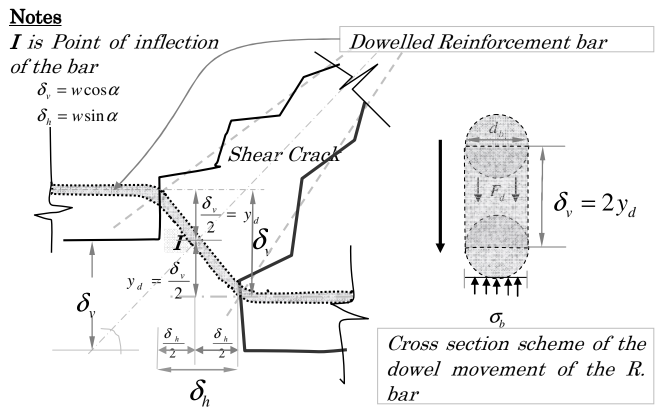


(ii) Shear deformation at JKLM



Assumed stress and strain diagrams along the shear crack path

(iii) Assummed stress strain profiles



Relative deflection of Reinforcement bar and the crack faces

(iv) Dowel of re bar at the crack face

Key word: Fibre Concrete; R.C beam; Shear Strength; Strain ratio; Theoretical model

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Fig 1: Model details

$k_1 = \frac{E_f V_f \varepsilon_{fp}}{\pi}$, $\frac{\gamma_y}{\gamma}$ = the shear strain ratio

σ_c, σ_{ct} is concrete compression and tenilse strengths

$$v_c = \frac{\sigma_{ct}}{2\cos^2\alpha} \quad \text{(concrete contribution)}$$

$$v_d = \frac{h}{a}\sqrt{\rho\frac{1}{\pi A_c}}\left(k\varepsilon_{fp} l_f^{ef}\frac{\gamma}{\gamma_y}\cos\alpha + 2\pi\tau_b l_a^{ef}\tan\alpha\right)$$

(Rebars dowel contribution)

3. Experimental programme

Specimens consisted of four 400×100 ×100mm beams and twelve number cylinders, 200mm diameter by 200mm height made from variably steel fibre reinforced concrete (38MPa). Tests on the beams and the tensile strength specimens were done using a 300kN capacity universal testing machine. Controlled loading was applied on the specimens while the full field strains were monitored and recorded using a set of optical measurements equipment system (ESPI) comprising a Desk top computer and CCD camera (2D sensor type). Four point bending test was carried out on the beam with a constant shear span to depth ratio of 1. The cylinders were tested in compression and tension for material control and property determination.

4. Results and discussions

Theoretical predictions from equation 1 were compared with experimental results from optical ESPI measurements. Fig 2 and 3 shows the theoretical and experimental results results obtained from equation 1 and ESPI repectivelly. Fig.4 depict these theoretical values in comparison with the experimental results for 0.5 to 1.5% steel fibre content.

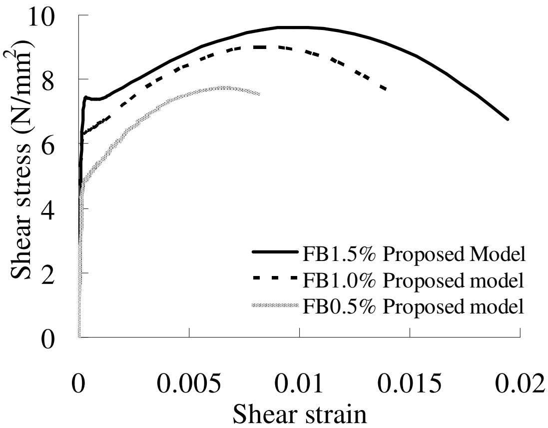

Fig 2
Theoretical shear strength prediction (Eq.1)

It is observed in these figures that both pre and post yield behavior up to including the ultimate limit and beyond in which the ductility property is represented has been predicted well by the model (Figs 2 and 4). The improvement in the ductility is attributed to the influence of the steel fibres and the re bars. Athough the the increase in the post yield shear capacity could also be due to the arch action, it is observed that for the same beam geomentry and rebar an increase in strength is also realised with increase in the fibre content. This confirms the positive effect of the fibres on shear strength.

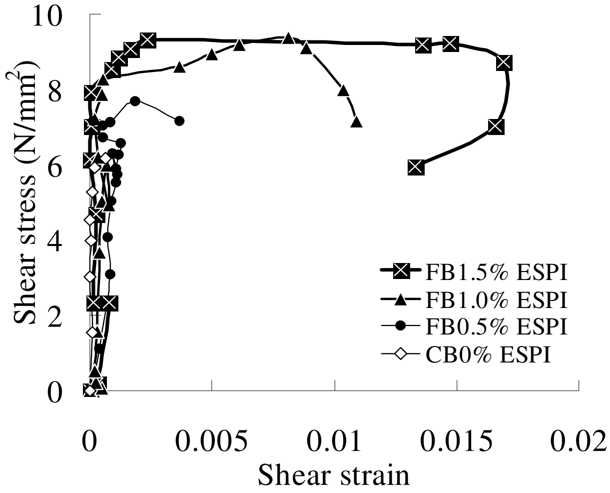

Fig 3 Experimental results

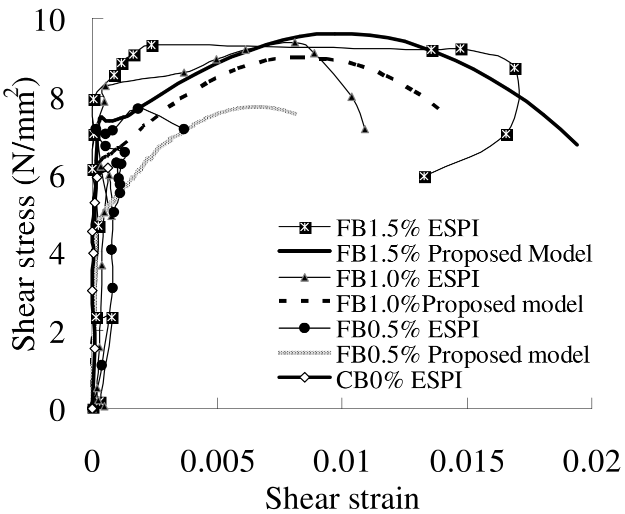

Fig 4 Theoretical and Experimental comparisons

5. CONCLUSIONS

The proposed model is quite versatile and can be used to predict the complete shear strength evolution in steel fibre reinforced concrete beams failing in shear. Quantification of the ultimate strength can also be computed based ultimate value of the strain ratio

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