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THE INFLUENCE OF STEEL FIBER USED AT SHEAR BEAMS

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Abstract: *The use of fiber reinforced concrete (FRC) is becoming a widely accepted solution for tunnel shells, concrete sewer pipes, slabs of large industrial buildings and even for elements of concrete frames. A new approach is to use FRC for the optimization of the reinforcement for normal concrete structures. This paper presents a theoretic and practice view upon the usage of steel fibers for normal reinforced concrete subjected to shear force.*

Key words: *Steel fiber reinforced concrete, Fiber orientation, Beam, Shear force*

1. Introduction

Adding steel fibers transforms the quasi-brittle concrete into a ductile material. Whereas in this case the maximal tensile strength is hardly enhanced, the fiber-knitting through the crack allows stress transfer even at large crack openings.

It is shown that for one specific fiber type, higher fiber dosage involves higher residual flexural strength. Observations with specimens loaded in direct tension are presented by Rossi [1]. He made compression tests on cylinders with two different concrete mixtures and two fiber dosages (20 and 40 kg/m3). The presence of a fiber reinforcement involved a lower ultimate compressive strength compared to the unreinforced specimens.

However, ultimate strain increased with growing fiber content. In general, workability of the conglomerate represents an upper limit for fiber dosages.

Over the last decades, steel fibers in an amount of 20–60 kg/m3 were found highly useful as an alternative reinforcement in slabs on ground-construction. Due to the increasing evidence from previous research results, the 2008 ACI Building Code allows engineers to use steel fiber reinforced concrete (SFRC) to replace the conventional shear reinforcement (i.e. steel stirrups) even if the design shear force is greater than half of the concrete shear strength.

Though the new ACI provisions, marked a significant transfer from research to practice, beams constructed of steel fiber reinforced concrete are required to have a minimum amount of steel fibers of 0.75% in volume (60 kilograms per cubic meter) and compressive strength not greater than 40 N/mmp. The ACI provisions are primarily formulated on experimental studies on concrete beams and majority of them had a cylinder compressive strength less than 40 N/mmp. Results from these studies have indicated some beneficial effects provided by fibers in terms of improving the shear behaviour. However, as most of the shear design procedures have been developed from experimental

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results, there are reasons to suspect that these will prove to be insufficient, especially regarding the effect of the geometrical dimensions of the beams. The aim is to investigate the possibility of replacing conventional shear reinforcement, stirrups, with reasonable amounts of steel fibers, 1 % of volume or less.

2. Experimental Result and Theoretic Approach

The experimental tests were done in Luleå University of Tech., Div. of Struct. Eng. Sweden. The experiment consisted by several large scale beams, some with stirrups, and the other with 0.5-1% steel fibers Figure 1.

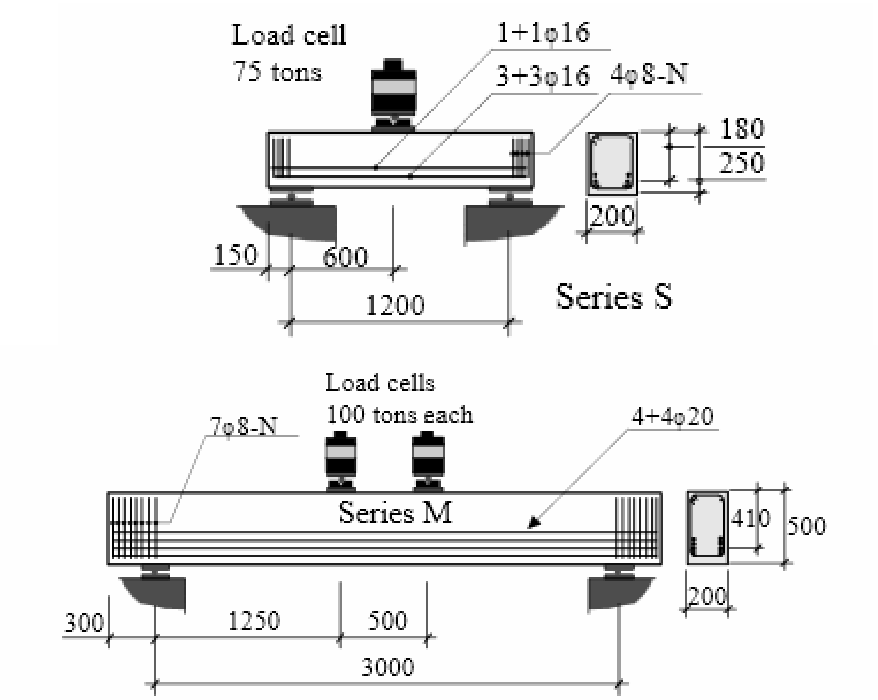


Figure 1. *Load setup and geometrical configurations of test specimens in series S, M*

2.1 Specimen and material details

The concrete mix was designed in order to reach an average cube compressive strength of about 120 MPa at 28 days of age. The cement quantity was 490 kg/qm, w/c ratio 0.32 and superplasticizer type peramineF 4,6l.

The fibers were of a drawn wire type. Two of them, 30/0.6 and 60/0.7, were hooked in the ends to provide good anchorage to the surrounding concrete whereas the third one, 6/0.15, was a straight fiber.

2.2 Testing steps

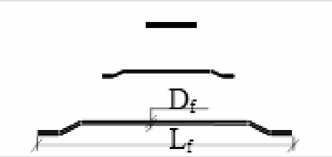
The testing was done on 2 different tipes of beams, some small beams (S) and some larger beams (M). The beams in the first series, S, were subjected to a midpoint load whereas the larger beams of series M were subjected to two point loads.

2.3. Shear force results

The shear force obtained on these different types of fiber reinforced concrete beams at the moment of fracture (peak)

Material and geometrical data on steel fibers Table 1

Types of steel fibers	Geometrical configuration	Aspect ratio (L_f/D_f)	f_y (MPa)
Dramix 6/0.15		40	2600
Dramix 30/0.6		50	1100
Dramix 60/0.7		86	2600



illustrates the differences between different quantities of steel fiber used in concrete at the two different scales of beams used in the experiment. The post cracking behavior is slightly different for the test beams. The best failure diagram is at the medium beam with two mixed fibers (a ductile collapse). This may be attributed to the ability of the fibers to bridge and carry load from one side of a crack to the other.

In the next table is shown the shear force at the cracking moment. Figure 3 shows the behavior of SFRC beam. As can be seen, compared to the RC beam, the first peak was significantly postponed due to the presence of steel fibers.

Results on small and medium beams Table .2

Beam Type	Shear Reinforcement	*fct* (MPa)	Shear force (kN)
S	None	4.15	210
S	Stirrups ϕ8	4.15	245
S	Hook 1%	4.98	255
S	Mix 1%	4.53	270
M	None	3.77	155
M	Stirrups ϕ8	3.77	330
M	Hook 1%	4.92	345
M	Mix 1%	3.97	365

What can be seen in this table is that as long as we approach the normal beam section and length the more exact we see the influence of stirrups. In this condition the best results should be obtained by using in the same beam some amounts of steel fibres with some stirrups so that one should help the strength of the beam and the other should improve the ductility of the shear beam.

2.4. Theoretic approach

In a beam the shear strength of an FRC with stirrups can be calculated like this:

$$v_j = v_{j,c} + v_{j,l} + v_{j,s} + v_{j,f} \tag{1}$$

Those here considered are: concrete contribution to shear strength, $v_{j,c}$, beam longitudinal reinforcement contribution to shear strength, $v_{j,l}$, stirrup contribution to shear strength, $v_{j,s}$, and fiber contribution $v_{j,f}$. In this case we need to take care of the $v_{j,f}$ position because this makes the difference in our case. If we consider the approach of Jiuru et al. from 1992 it is equal to:

$$v_{j,f} = 2 * \frac{l_f}{d_f} * \rho_f \tag{2}$$

where l_f is the length of the fibers, d_f is the diameter of the fibers and ρ_f is the volume fraction of fiber in the concrete mix. If we consider the approach of Russo and Summa (2002) it is equal to:

$$v_{j,f} = 5 * f_{yf} * \rho_f^{\ 4} \quad (3)$$

Where f_{yf} is the fiber reinforcement yielding strength, ρ_f is the volume fraction of fiber in the concrete mix.

In either way we should consider two situations, one with a type of fibers and another one with the mixed types. In this case we should make a share average between the volume fraction and yielding of both types of fibers.

3. Conclusions

The usage of steel fibres at shear beams can be useful if it is associated with stirrups because it gives a better ductility to the beam. Another advantage is the fact that in a beam-column node the usage of fibres give a better anchorage of the longitudinal reinforcement and prevents the initial cracking of concrete. The main disadvantage is that the control of segregation of the steel fibres can not be done easily and this is an aspect that greatly influences the final result. The usage of steel fibres makes the concrete to expensive in accordance with the results and this is another main disadvantage.

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- first name „title case" and name in capital letters, when there is a single author (ex. Ion POPESCU);
- initial of every author's first name and the name, in capital letters; they will be not separated through coma and may be written on 2 lines unless they fit within a single one.

Between the authors and the abstract, there will be left a free line (14 pt.).

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