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Review

Flexural fatigue performance of metal steel fibre reinforced mortar – Influence of fibre aspect ratio and type

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HIGHLIGHTS

- This study presents the experimental results of flexure fatigue.
- Two different methods of reinforcement.
- The results presented, in the *S*/*N* curves – progression of the deflection, as a function of N – followed by cracking.

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ABSTRACT

This study presents the experimental results of flexure fatigue tests carried out on mortar reinforced of the matrix, leading to two different methods of reinforcement.

Data from 64 fatigue tests and 42 complementary static loading tests are presented both as *S*–*N* relationships.

Following a phenomenological analysis, it appears that to define performance in terms of fatigue strength, the characteristics at the elastic limit obtained with static loading seem to be the best reference. The results presented, in the *S*/*N* curves – progression of the deflection, as a function of *N* – followed by cracking, allow comparisons to be made between the tested materials.

It notes that the steel fibres have a better response to fatigue than traditional mortar, which can make it more attractive for some composite applications. The presence of fibres makes it possible, in the most favourable cases, to raise the reference threshold (fracturing threshold), which means that there is more stress for a given life expectancy and, also, makes it possible to raise fracture toughness under cyclic loading, while prolonging the life of specimen after cracking (with the slow development of multi-cracking in specimen). For satisfactory fatigue strength, at a constant percentage of fibres, it is preferable to use fibres that can be dispersed in large numbers, rather than more compact fibres with larger aspect ratios.

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1. Introduction

Cyclic actions have to be taken into account in many situations, for example with airports, marine and offshore construction, and structures which may have to withstand earthquakes. A comparative experimental study was carried out with the aim of evaluating possible improvements in the fatigue behaviour of traditional construction materials (concrete, mortar) reinforced by the addition of dispersed fibres in the matrix. The results of the study are presented in this article. The fatigue behaviour of the material is studied in flexure.

The results of the fatigue tests may be presented simply in the form of *S*/*N* curves derived from the Wöhler diagram. The analysis of propagation of crack is carried out by using the principles of fracture mechanics. Finally, the results have a bearing on concepts of safety, in that they deal with the notion of the probability of total failure. These approaches are complementary, and both are necessary to the study of composite materials.

It is important to establish whether there exist any real fatigue limits for a composite which contains fibres in sufficient quantity. Such limits would mean that for certain applications of fibre mortar would be more suitable than plain mortar, which seems to have limited fatigue limit. On reading the literature, however, it appears that the notion of "fatigue limit" is difficult to define, for fibre mortars [9]. Although longstanding harmful and destructive consequences of cyclical variable actions have been identified, the rules used at present to predict the response of a building such actions take little account of the specific behaviour of materials that type of stress. If the notion of real fatigue limits seems difficult to transfer to rigid matrix composites, it is nevertheless important to estimate if for expected life of a structure, fatigue damage can manifest.

Furthermore, the materials tested in the previous studies were under relatively smaller number of cycles [3,4,7,9,10,12,13,15]. In order to define the notion of limit of strength, it is important to analyse phenomenologically the process of total failure, and to bring out the parameters which are likely to influence these processes. This remark should serve as a guide to the approach used for the interpretation of the results.

2. Materials and methods

This investigation of the flexural fatigue behaviour of steel fibre reinforced mortar involved six different mix proportions, including a control mortar without fibres. The parameters of the fibres, such as fibre type and length, were varied. For the geometrical characteristics of the fibres, it was decided to take the product of fibre length and external area, divided by volume, instead of the fibre aspect ratio. Using this approach, it was a simple matter to compare cylindrical fibres and ribbons [5]. The fibre parameters are shown in Table 1. The volumetric fibre content remained constant, at 1%.

Two types of metallic fibres were tested: one fibre steel (mild steel hardened) which presented in cylindrical form and fitted with hooks at the ends (noted HE), the other one fibre amorphous iron: they are in the form of very thin flexible ribbons of lengths and widths (noted SS). Thus, two very different methods of matrix reinforced are compared.

The mortar matrix chosen comprised of 3.15 mm sand aggregate from the Saône River (air-dried prior to batching) and 665 kg/m^3 of CEM1 55 cement with conventional water-reducing. The W/C weight relation was equal to 0.42. In the mix proportions the volume of inert material, sand plus fibre, was kept constant. We formulated mixtures with a similar criterion of cohesiveness to the freshly mixed quantity of mortar, measured on LCL mortar workability (The workability of the mortar was controlled between 10 and 15 s for all the mixtures). So the formulation with constant workability was obtained with an fitted quantity of superplasticizer. The amounts superplasticizer were 0.25–0.32% by weight of cement for composite with HE fibres and 0.62–0.72% for composite with SS fibres.

Beam specimens, 120 × 10 × 5 cm, were cast in steel moulds compacted on a vibration table and vibrated for 5–10 s. The specimens were de-moulded after 24 h and stored in a curing room (20 °C, 98% relative humidity). The cement, which had a very high degree of fineness, yielded high early age strength. At 7 days, fifteen beams of every mix proportion were tested, six for static flexure, six for flexural fatigue, and three for creep. The table presents the six tested mortar.

A four-point loading configuration was adopted, and the mid-point deflection was measured using an inductive transducer with a least-count of 0.01 mm. Triangular waves were used for cyclic loading, with constant amplitude and frequency (Fig. 1), the applied force was never unloaded at each cycle with a minimum applied load of 0.5 KN. The cycle frequency was 1.8 Hz. The load and deflection of each cycle were recorded as a function of time, which gave the time evolution of the load/deflection curve directly.

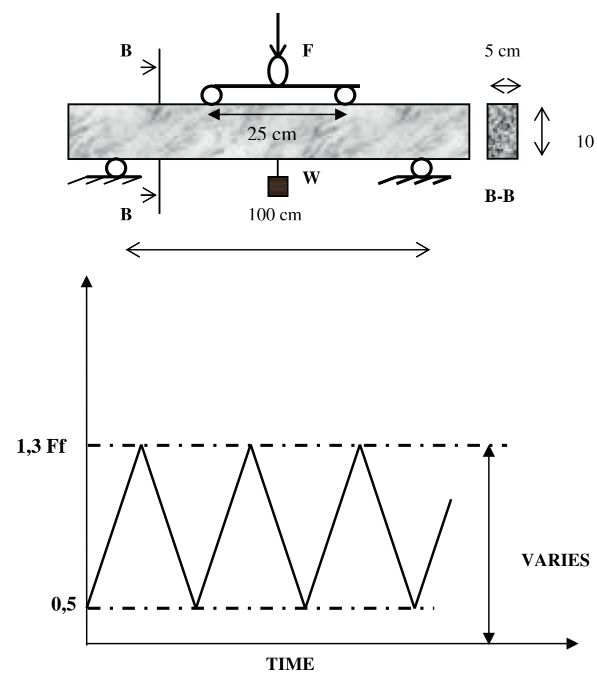

Fig. 1. Loading scheme and parameters (beam dimensions in cm). Ff: Flexural strength first crack.

Table 1
Fibre parameters.

Fibre parameter			Tested mortars		
Size (mm)	Type	Aspect ratio	Reference	Fibre volume (percent)	Compressive strength 16 × 32 cm (7 days) MPa
0	–	0	WF	0	44.03
15 × 1 × 0.03	SS	900	SS15	1	39.23
30 × 1 × 0.03	SS	18,000	SS30	1	36.80
60 × 1 × 0.035	SS	2600	SS60	1	35.97
30 × 0.5	HE	240	HE30	1	40.05
60 × 0.8	HE	340	HE60	1	42.18

HE: circular in cross section with hooked ends (Bekaert).
SS: flexible ribbon (Fibraflex).

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