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FIBRECONCRETE IN OUR COUNTRY AND ABROAD – STATE OF THE ART

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Abstract

A short essay about composite materials with dispersed fibres, positives and possibilities of progress and further development in fibreconcrete topic.

Keywords: fibreconcrete

1 Introduction

A considerable progress in technology of concrete with dispersed reinforcement, a lot of producers, who offer various sorts of fibres of different types and behaviour, caused extension of use of fibreconcrete from presently common use in pavements, airport runways, bridge decks, floor slabs and shotcrete lining of tunnels to applications in precast elements, prestressed structures and other structural elements.

Application of dispersed fibres in concrete brings economic profit related to better structural behaviour and savings concerning lately focused topics of Life Cycle (LCA, LCC).

2 Fibreconcrete overall

Up to now observations and experience have shown that fibres may replace conventional shear reinforcement, fibreconcrete element has higher load-bearing capacity if compared to reinforced concrete element, higher ductility and energy dissipation, better structural behaviour; fibres bring along confinement and better bond of concrete and rebar reinforcement. Enhancement of structural behaviour permits reduction of transverse reinforcement in joints in seismic areas.

With proper choose of fibres type and dosage the behaviour of fibreconcrete is more advantageous than RC element behaviour with respect to SLS (favourable layout of cracks) and ULS – residual tensile strength contributes to increase of the ultimate load and advantageous behaviour of element at failure.

The fundamental profit of fibreconcrete is tensile behaviour. Nevertheless the compressive behaviour has also benefits in comparison with reinforced concrete thanks to confinement of fibres.

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A growth of shear resistance of beams with fibres or a change of failure mode has been observed. According to present codes beams must have at least minimal shear reinforcement. It has been proved in experiment that in fibreconcretes with dosage from 0,5% to 2% the fibres act as effective shear reinforcement. We may assume that beams could be designed without conventional shear reinforcement or that spacing of links could be higher. Here further research and proper quantification of fibre contribution according to specific material, shape and dosage of fibres is necessary.
As far as bending is concerned the observing has similar results – fibreconcrete members have higher resistance and ductile mode of failure. Nevertheless applications of fibreconcrete in flooring systems are rare; existing uses are more or less exceptional efforts to establish innovative technology and material.
As examples of these innovative structures two examples let be mentioned. There are several attempts of use of fibreconcrete in a floor system with decrease of conventionally used rebar reinforcement (TabSlab [1]).

A partially precast frame system from SIMCON (Slurry Infiltrated Mat Concrete) where beams are created from SIMCON shuttering filled by lightweight fibreconcrete and steel columns are wrapped into SIMCON and infiltrated with a flowable cement-based slurry. Frame is assembled in a site by screwing. This frame is profitable in earthquake areas. Possible damage caused by earthquake is simply reparable [2]. This material could be included into advanced composites denoted as HPFRCC (High Performance Fibre Reinforced Cementitious Composites).

Fig. 1 SIMCON: Continuous fibre-mat; SIMCON stay-in-place formwork.

3 High performance cementitious composites with ultra high strength

In the design of structures accent is put on new topics lately. In code specifications there are demands to check durability of structures and analyse life cycle of the structure (LCA, LCC). These tighter specifications on durability could be prosperously met by fibreconcrete. For example HPFRCC (High Performance Fibre Reinforced Cementitious Composites) have substantially higher strengths, seismic resistance, ductility, durability, can resist extreme temperatures, dynamic loading, chemicals and fatigue loading and they are also faster and more cost-effective to construct than conventional materials.

Maintenance cost of reinforced concrete structures has been growing steadily. With more durable structures from fibreconcrete maintenance period will be longer. Nowadays fibreconcrete is used for repair, reconstructions and rehabilitations.

Favourable layout of cracks and thus smaller width of cracks leads designer to use of fibreconcrete in structures with severe SLS restrictions. Fibreconcrete has been used in tanks for frozen liquid gas [2] and radioactive waste [3].

In the point of view of fire resistance benefits of polymer fibres have been discovered. In this field mainly polypropylene fibres are inquired into. In high temperatures polypropylene fibre escape and created pores prevent spalling of cover and surface layers. In addition consequent repair after fire is not so demanding.

There is an endless number of different fibreconcretes and new types of fibreconcretes with new properties are blended steadily. Fibreconcretes with new fibres or cocktails of known fibres are examined. Combination of two or more types of fibres in one mixture should take advantage of both (all) different fibres. E.g. to restrict cracking for different loads fibres with different length and different Young moduli are used. In the scale of new material hybrid and high-performance fibre-reinforced cementitious composites should be mentioned [4], for example ultra-high performance concretes with exceptional characteristics e.g. ECC (Engineered Cementitious Composites) also called “bendable concrete”. This material is mostly used in repair and refit of structures.

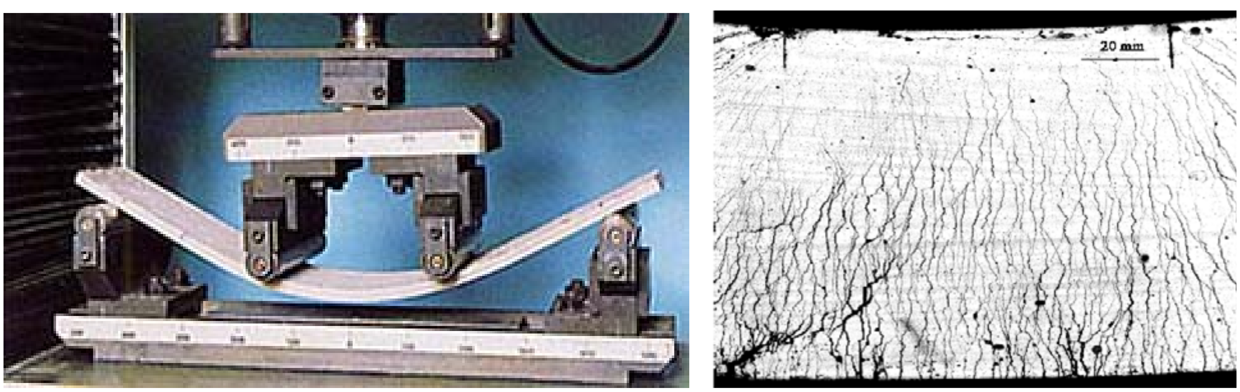

Fig. 2 Bendable concrete ECC [6]; multiple cracking pattern in ECC beam midspan around peak load [5]

An other example of use of the innovative material in structure is Shawnessy Light Rail Transit Station in Calgary, Canada - the *fib* Award Winner for Outstanding Concrete Structure. The rail station is made from Ductal thin-shelled canopies. Ductal is a cement-based composite which uses materials commonly found in concrete: cement, silica fume, sand, superplasticizer and water as and high carbon metallic or poly-vinyl alcohol (PVA) fibres. The combination of all these materials, using an optimized gradation theory, results in a material that provides a unique combination of ductility, durability, aesthetics and strength; compressive strengths range between 130 to 200 MPa and flexural strengths range between 20 to 50 MPa. The material's unique combination of superior properties and design flexibility enabled creating of the attractive, curved canopies with dimensions 5.1 m x 6 m and just 20 mm thick. The precast canopy components were individually cast and consist of half-shells, columns, tie beams, struts, and troughs.

Fig. 3 Structure of Shawnessy Light Rail Transit Station

Fig. 4 Structure of Shawnessy Light Rail Transit Station

4 Fibreconcrete at CTU

The team from the department of concrete and masonry structures has been dealing with fibreconcrete from seventies. Staff of the department experimented with various fibres, possibilities of mixture design, effect of different fibres on growth of tensile strength and ductility of the material. For years they have been taken actions to establish fibreconcrete use in structural elements and take advantage of the behaviour of the behaviour for example in precast members. They have encouraged cooperation with other research centres – universities in Czech Republic and abroad and research institutes.

From the early beginning when mainly behaviour of the material was focused, the team afterwards dealt with ways of the structural analysis. In collaboration with research institute VÚPS a guideline for SFRC was composed [10]. Lately ways of structural design by means of computer simulation and modelling are inquired into and verified in experiments performed in the scope of research tasks dealing with fibreconcrete in precast elements, lightweight fibreconcrete products or fibreconcrete in pre-stressed members.

While at the department of concrete structures the material is understood as a composite and the material model is sought for the material as such; the department of mechanics inspect the material from the microscopic point of view [11].

Potential of the fibreconcrete exploitation in terms of sustainable development is studied in research focused on concrete with recyclables.

5 Conclusions

Proper choice of structural material is very important in analysis of good function and efficiency of the structure. Fibreconcrete meets demands on load-bearing capacity and reliability of the structure; furthermore it satisfies requirements of serviceability and life cycle assessment. Use of fibreconcrete with fibres of different properties or an engineered composite material extends ranges of materials on the cementitious basis and thus possibilities of structural engineering.

Acknowledgements

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