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Procedia Engineering 65 (2013) 100 – 106

Procedia Engineering

www.elsevier.com/locate/procedia

Concrete and Concrete Structures 2013

Optimization of Fibre Reinforced Concrete Structural Members

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Abstract

The aim was improvement of function and performance of the construction members by using fibre reinforced concrete (FRC) instead of ordinary reinforced concrete and to transfer innovative technologies from laboratory in academic sphere into real industrial production which is cost-effective and brings about savings of labour and material. The paper discusses complexity of the FRC design for structural use related to optimization of FRC properties and consequently the design of FRC mixture according to demands on performance of the structural member. Case studies on some applications showed aspects that can reduce demandingness of the process. A series of tests involved performance and load carrying capacity of members were performed. The results of tests are presented and discussed.

Selection and peer-review under responsibility of University of Zilina, Faculty of Civil Engineering, Department of Structures and Bridges

Keyword: fibre reinforced concrete; multi criteria optimization; design of FRC structural members;

1. Introduction

Fibre reinforced concrete is increasingly used in precast industry after the successful applications in industrial floors and shotcrete. The basic idea is partial or total substitution of conventional reinforcement (rebars or welded mesh), which could be economically profitable since higher cost of FRC material is compensated by reduction in labour cost of manipulation and storage of conventional reinforcement. Moreover, there are a lot of small or thin concrete elements that are not subjected to significant loads, where rebar reinforcement is required to prevent a brittle failure due to accidental contacts and shrinkage cracking. In these cases fibres are very suitable, because

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Selection and peer-review under responsibility of University of Zilina, Faculty of Civil Engineering, Department of Structures and Bridges
doi:10.1016/j.proeng.2013.09.018

production process of elements without rebars is easier and quicker and moreover placing of rebar reinforcement in such tiny element is very demanding and labour-consuming.

In the last decade rapid development in the sphere of structural concrete run up including introduction of progressive technologies and applications of innovative materials like various types of fibre reinforced concrete. Fibres affect resulting properties of concrete composites to the great extent and enable innovative procedures to be introduced into technology and production of concrete members and structures. Significance of fibres in fibre reinforced concrete is not only in improvement of the performance of FRC in comparison to the plain concrete but also in application in reinforced concrete structures, high strength and ultra high strength concretes. For application of FRC in structural members it is necessary to ensure both appropriate technique for production and adequate guidelines for design. Material properties of FRC have been investigated since 70´s and benefits of FRC are beyond all doubt. Lately utilisation of FRC in structural elements has been focused, as fibres in a structure improve structural behaviour under service load, fatigue resistance, enhance service life and provide advantageous failure mechanism due to higher ductility. It is also proved that thanks to fibres the amount of shear reinforcement may be reduced. For extension of FRC utilisation more investigations of structural behaviour have to be provided. Research presented in this paper intends to be a contribution to the structural FRC development.

1.1. Fibre concrete and sustainable structural design

Optimisation of a structural design could be achieved by use of material that covers all demands stated for particular structural member. Dispersed fibres in a concrete mixture improve material properties and structural behaviour. Fibre concrete members are more ductile, have favourable layout of cracks; some kind of fibres enhance tensile strength of the basic material, other fibres prevent cracking due to shrinkage and volume changes. Enhanced performance of the fibre concrete structure enables decrease of dimensions of the element and decrease of amount of conventional rebar reinforcement. Lower consumption of materials signifies lower environmental impact and cost savings at the same time. To achieve successful utilisation of FRC, that would really lead to savings and decrease of material and energy consumption, a suitable material for particular application must be designed. Theoretical and experimental investigations of the FRC behaviour performed for four decades brought about much experience and results of test in the archive database are the basis of prosperous application of fibre concrete together with convenient structural analysis. A simple transparent design procedure was established and verified in several applications of FRC in a structural element. Here follows a description of the design process in subsequent steps and an example of its use.

Effective application of FRC in structure is based on the following aspects: choice of such a member, where FRC is a benefit; the second step is simple elastic analysis where the stress state of the element is determined and sections with extreme strain found; design of suitable FRC mix according to the loading and stresses, desired properties and behaviour of the element follows accompanied by material tests and the last step is verifying of material properties, technology and testing of the fibre concrete member.

1.2. Structural analysis of FRC members

Generally, the FRC characteristics for tension largely influence the bending resistance and the shear resistance properties of the structure. By estimating tensile characteristics adequately, it is encouraged to produce the structure with efficient safety and also with the economical rationality.

Prior to proposing a suitable methodology for FRC structures design, demands on FRC analysis should be stated. Designing of FRC elements must be compatible to concrete structures analysis. Benefits of fibre reinforced concrete must be taken into account. A general routine for FRC member is not standardized yet. There are many types of fibres and concretes with diverse behaviour. These are the reasons to find methodology as simple and as low-cost as possible.

Analysis of any structure must be based on realistic material properties and suitable material model. The basic material characteristics shall be determined in common laboratory tests: compression test, tension test, flexural test and additional.