Steel Fibrous Cement Based Composites

Part one: Material and mechanical properties
Part two: Behavior in the anchorage zones of prestressed bridges

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Abstract

This PhD thesis is divided into two parts. Part one deals with the development of the material and the mechanical properties of Steel Fibrous Cement Based Composites (SFCBC) for improving bridge design and construction. It familiarizes the hydration mechanisms of the high performance concrete with the help of Powers´ and Jensen´s models. Concretes with different water-cement ratio were compared with each other with respect to degree of hydration and hydration products. This analysis showed that high performance concrete has higher strengths not because it has more gel solid, but due to it having less porosity and higher filler content compared to ordinary concrete.

A number of experiments were performed to achieve a mix design method for a SFCBC, which has good workability, high early and long-term strength and good durability characteristics. A Self-compacting and self-leveling fibrous composite, which has ultra high strengths (Compressive strength $f_c = 180 \sim 220\,\text{MPa}$ and flexural tensile strength $f_{flu} = 14 \sim 32\,\text{MPa}$ depending on the volume fraction of fibers) was produced. This composite was also tested under different curing conditions in order to investigate the effect of curing on hydration and self-desiccation shrinkage. These tests showed that SFCBC should not be water-cured under a long period and self-desiccation influences the compressive strength negatively. Test of scaling at freezing showed that SFCBC has very good durability characteristics.

Part two deals with the behavior of SFCBC in the anchorage zones of prestressed bridges. The prismatic composite specimens were tested for different volume fractions of fibers under different concentrations ratios of strip loading. The results of these tests showed that the ultimate strength of the SFCBC specimens was approximately twice that of ordinary concrete with the same size ($f_c = 60\text{MPa}$, reinforced with stirrups). Therefore, SFCBC has good possibility to replace the traditional rebars in the anchorage zones of prestressed bridges.

This composite has different behavior than the traditional concrete e.g. crack formation, failure criteria, effective strength and angle of friction. A vertical crack on the centerline was occurred while wedge developed under the loading plate. In contrast to ordinary concrete, the cracks could not reach to the bottom of the blocks.

The tests results gave the ideas of that this material acts like metals or plastics in the high fiber content. This material is neither very brittle as concrete nor very ductile as metals but it is somewhere between them.

Upper-bound plasticity solutions were utilized for modeling the bearing capacity of SFCBC. Predictions of this method are good enough to estimate the bearing capacity of SFCBC in the anchorage zones of prestressed bridges.

Keywords: Process improvement of bridges, Prestressed concrete, High performance concrete, Ultra high performance concrete, Hydration, Cement based composites, Fibers, Self-compacting concrete, Bearing capacity, Anchorage zones, Tests

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MATERIAL AND MECHANICAL PROPERTIES

Part two

BEHAVIOR IN THE ANCHORAGE ZONES OF PRESTRESSED BRIDGES