Evaluation of Static and Dynamic Behaviour of Fibre Reinforced Concrete Incorporating Polypropylene Fibres

by

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Certificate of Authorship / Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in this thesis.

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Sydney, March 2012

ABSTRACT

This thesis represents a systematic study on the behaviour of special engineered concrete material and its behaviour in the structural elements. The approach of this research has been to create an innovative material which is beneficial to the improvement of the structures and infrastructure and at the same time produce an environmentally friendly concrete by using Fly ash and polymeric waste material. Using polypropylene (PP)fibre and Styrene Butadiene Latex (SB latex)polymer, different mix designs of fibre reinforced concrete (FRC), polymer modified concrete (PMC) and fibre reinforced polymer modified concrete (FRPMC) have been studied. At first stage of the project, material characteristics of each engineered concrete mix design is evaluated and tested. This initial study led to a comprehensive understanding of the behaviour of FRC, PMC and FRPMC using PP fibres and SB latex. Generally, using SB latex in the concrete mix without the addition of any anti-foaming agents or any other modifier, especially at higher percentages, lowers the mechanical properties of concrete. This phenomenon is of more attention where fibres are used together with the SB latex in the mix. In FRCs, the matrix mechanical characteristics are enhanced at specific percentages which led us to choosing some of the best mix designs for the structural studies. In terms of the dynamic properties of the concrete mix, for example the damping ratio, PMC and FRPMC showed good behaviour and as a result, from among many, one best mix has been chosen for the dynamic structural testings.

Two types of PP fibres have been used in this project namely the monofilament and fibrillated PP fibre with the length of 18 mm and 19 mm, respectively. Amongst the monofilament fibres, 0.25% volume of the mix showed promising results and between different percentages of fibrillated fibre, 1% fibre is chosen for the structural testing. Reinforced beams have been constructed to evaluate the structural behaviour under 4 point static loading and 3 point cyclic loading. Two types of mentioned FRCs as well as the two reference concrete mix designs were used for the static beam testing. With regards to the cyclic testing, again the two references as well as the two FRCs had been prepared and tested. At the same time a PMC beam and an FRPMC beam was prepared to be tested under the cyclic loading.

Results of the structural tests show that by adding higher percentage of the fibre to the mix, the ductility of the structural beam is enhanced more than in case of using lower percentages. In the cyclic tests, each cycle has been evaluated separately and also all cycles together. Results indicate that where elastomeric materials are present in the mix i.e. PP and SB latex, the damping ratio of the first cycles are much higher than the conventional concrete. This is beneficial due to the serviceability loading areas. The principal conclusion can be that by adding higher percentage of fibres, the structural behaviour of concrete beam can be enhanced in terms of both static and dynamic characteristics.

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Definitions and List of Notations

ζ_{eq}: Damping

ξ: Energy loss

A_s: area of the steel reinforcement

f_c': Characteristic compressive strength

f_{ct} : uniaxial tensile strength

$\mathrm{f_{ct.f}}$: flexural tensile strength

$\mathrm{f'_{ct.f}}$: characteristic flexural tensile strength

$\mathrm{f'_{ct}}$: characteristic uniaxial tensile strength

f_{600}^D: Residual strength at net deflection of L/600

f_y: Steel yield stress

I: cross sectional moment of inertia

LOP: Limit of Proportionality

M_n: Bending moment

P_{150}^D: Residual load at net deflection of L/150

P_{600}^D: Residual load at net deflection of L/600

$R_{T,150}^D$: Equivalent flexural strength

T_{150}^D: Area under the load vs. net deflection curve 0 to L/150

w_n: Fundamental frequency

AC: Air Content

ACI: American Concrete Institute

AS: Australian Standard

ASTM: American Society for Testing and Materials

CA: Coarse Aggregate

DMOE: Dynamic Modulus of Elasticity

EI: Bending stiffness

HWR: High Range Water Reducer

FA: Fly Ash

FRP: Fibre Reinforced Plastic

FS: Fine Sand

FRC: Fibre Reinforced Concrete

FRPMC: Fibre Reinforced Polymer Modified Concrete

L: Latex

LOP: Limit of Proportionality

MOE: Modulus of Elasticity

MOR: Modulus of Rupture

PP: Polypropylene

PC: Portland Cement

PMC: Polymer Modified Concrete

SDOF: Single Degree of Freedom

SB: Styrene Butadiene

SBR:Styrene Butadiene Rubber