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MECHANICAL AND STRUCTURAL PROPERTIES OF POLYVINYL ALCOHOL FIBRE REINFORCED CONCRETE (PVA-FRC)

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Mechanical and Structural Properties of Polyvinyl Alcohol Fibre Reinforced Concrete (PVA-FRC)

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 the thesis.

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Amin Noushini

Sydney, August 2013

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LIST OF PUBLICATIONS BASED ON THIS THESIS

Journal Articles

1. Noushini, A., Samali, B., Vessalas, K. 2013, 'Effect of Polyvinyl Alcohol (PVA) Fibre on Dynamic and Material Properties of Fibre Reinforced Concrete', *Construction and Building Materials*, vol. 49, pp. 374-383
2. Noushini, A., Vessalas, K. and Samali, B. 2014, 'Rheological Properties and Compressive Strength Behaviour of Polyvinyl Alcohol Fibre-Reinforced Concrete', *Australian Journal of Structural Engineering (AJSE)*, vol. 15, no. 1
3. Noushini, A., Vessalas, K., Samali, B., Arabian, G., 'Drying Shrinkage Behaviour of Fibre Reinforced Concrete Incorporating Polyvinyl Alcohol (PVA) Fibres and Fly ash', *Magazine of concrete research* – under review
4. Noushini, A., Vessalas, K., Samali, B., 'Static Mechanical Properties of Polyvinyl Alcohol Fibre Reinforced Concrete (PVA-FRC)', *Magazine of concrete research* – under review
5. Noushini, A., Samali, B., Vessalas, K., 'Ductility and Damping Characteristics of Polyvinyl Alcohol Fibre Reinforced Concrete Beam Elements', *composite structures* – under review

Conference Papers

1. Noushini, A., Vessalas, K., Ghosni, N., Samali, B. 2013, 'Effect of Polyvinyl Alcohol Fibre and Fly Ash on Flexural Tensile Properties of Concrete', *Proceeding of the 22nd Australasian Conference on the Mechanics of Structures and Materials (ACMSM 22),* Sydney, Australia, pp. 1165-1170
2. Noushini, A., Samali, B., Vessalas, K. 2013, 'Flexural Toughness and Ductility Characteristics of Polyvinyl Alcohol Fibre Reinforced Concrete (PVA-FRC)', *VIII International Conference on Fracture Mechanics of Concrete and Concrete Structures (FraMCoS-8),* Toledo, Spain, pp. 1110-1121

3. Noushini, A., Samali, B., Vessalas, K. 2013, 'Effect of Polyvinyl Alcohol Fibre on Dynamic Properties of Concrete Containing Fly Ash', *Composite Construction VII (CCVII)*, Palm Cove, Queensland, Australia

4. Noushini, A., Samali, B., Vessalas, K. 2013, 'Damping Properties of Polyvinyl Alcohol Fibre Reinforced Concrete', *The Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13)*, Sapporo, Japan

5. Noushini, A., Samali, B., Vessalas, K. 2013, 'Influence of Polyvinyl Alcohol Fibre Addition on Fresh And Hardened Properties of Concrete', *The Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13)*, Sapporo, Japan

6. Noushini, A., Vessalas, K., Samali, B. 2013, 'Flexural and Tensile Characteristics of Polyvinyl Alcohol Fibre Reinforced Concrete (PVA-FRC)', *The Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13)*, Sapporo, Japan

ABSTRACT

Concrete is a brittle material that has low tensile strength and low strain capacity. In fact, many deteriorations and failures in the concrete structures are due to the brittle nature of this material (Hamoush et al. 2010). These disadvantages may be avoided by adding short discontinuous fibres to plain concrete which has been a major motivation for many research works in recent years (Wu & Sun 2003).

Fibres are added into a brittle-matrix composite to help improve three major aspects; toughness, ductility and strength (tensile) (Arisoy 2002). Fibres tend to increase toughness of the composite material by bridging the cracks and provide energy absorption mechanism related to de-bonding and fibre pull-out. Furthermore, they can increase the ductility of the composite by allowing multiple cracking. They may also help increase the strength by transferring load and stresses across the cracks.

Advancement of fibre reinforced concretes (FRCs) started in the 1970s. By that time, only glass fibre and steel fibre were investigated (Perumalsamy & Surendra 1992). Synthetic fibres have become more attractive in recent years as reinforcements for cementitious materials. This is due to the fact that they can provide inexpensive reinforcement for concrete and if the fibres are further optimized, greater improvements can be gained without increasing the reinforcement costs (Li et al. 1991; Wang et al. 1989). Moreover, unlike the steel fibre which is highly corrosive in nature, there is no corrosion concern regarding synthetic fibres in concrete.

During the past 20 years (since early 1990s), polyvinyl alcohol (PVA) fibre has been introduced in the production of cementitious composites (Li 1998; Redon et al. 2001; Shen et al. 2008; Sun & Wu 2008). PVA fibres act greatly in a cement based matrix with no coarse aggregates due to their surface formation and high strength (Li et al. 2001). The resulting composite, which exhibits a pseudo ductile behaviour, is called engineered cementitious composites (ECC).

Although many research works have been performed to date on the properties of PVA fibre reinforced ECC, there has not been much investigation on the mechanical and structural characteristics of PVA fibre reinforced concrete. Accordingly, the objective of this study is to experimentally observe the effects of adding PVA fibres to the conventional concrete to assess its mechanical and structural properties.

To achieve this aim, a comprehensive set of experiments were carried out to investigate the effect of PVA micro fibre addition on mechanical and structural properties of conventional concrete. Therefore, concrete mixes containing PVA fibres of varying lengths (6 and 12 mm) in different fibre volume fractions ranging from 0.125% - 1% were prepared and tested for their fresh and hardened properties. The optimum fibre contents in terms of FRC performance were then selected to cast several concrete beams. These beams have later been tested for 4-point monotonic and 3-point cyclic flexure, to assess their structural properties. Hammer test was also conducted to evaluate the dynamic characteristics of conventional and FRC specimens as well as concrete beams.

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NOTATIONS

The symbols used in this thesis, including their definitions, are listed below.

A_s	cross-sectional area of reinforcement
A_{sc}	cross-sectional area of compressive reinforcement
A_{st}	cross-sectional area of longitudinal tensile reinforcement
b	width of a rectangular cross-section
c	distance from the extreme compression fibre to the neutral axis
d	effective depth (the distance from the extreme fibre to the centroid of the tensile steels)
d'	distance from the extreme compressive fibre to the centroid of the compression steels
d_f	diameter of fibre
E_c	static modulus of elasticity of concrete
E_f	modulus of elasticity of fibre
E_s	modulus of elasticity of steel reinforcement
f_c	compressive strength of concrete – stress in concrete
f'_c	characteristic compressive (cylinder) strength of concrete
f_{ct}	uniaxial tensile strength of concrete
$f_{ct.sp}$	indirect (splitting) tensile strength of concrete
$f_{ct.f}$	flexural strength (modulus of rupture) of concrete
f_s	stress in tension reinforcement
f_y	specified yield strength of steel reinforcement
f_{sy}	yield strength of steel reinforcement
f_{su}	ultimate strength of steel reinforcement
$\mathrm{F_u}$	ultimate (maximum) load applied

h	overall height of a rectangular cross-section
I_g	second moment of area of the uncracked cross-section
I_{cr}	second moment of area of the cracked cross-section
L_f	length of fibre
M_{cr}	cracking moment
M_y	yield moment
n	modular ratio (E_s/E_c)
V_f	fibre volume fraction
ε_{cu}	strain at peak stress (compression) of concrete
ε_{cc}	concrete strain in compression
ε_{ts}	steel strain in tension
ε_s	strain in tension reinforcement
ε_{sy}	yield strain of steel reinforcement
ε_{su}	uniform strain at maximum stress, corresponding to the onset of necking
ρ_s	longitudinal tension reinforcement ratio (A_{st}/bd)
ρ'_s	longitudinal compression reinforcement ratio (A_{sc}/bd)
ξ	damping ratio (percentage of critical damping)
δ	logarithmic decrement
δ_y	yield displacement of reinforced concrete beam
δ_u	ultimate displacement of reinforced concrete beam
μ	ductility factor
$\O_{cr}$	curvature corresponding to the cracking moment (M_{cr})
$\O_y$	curvature corresponding to the yield moment (M_y)