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Behaviour of over reinforced HSC helically confined beams

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BEHAVIOUR OF OVER REINFORCED HSC HELICALLY CONFINED BEAMS

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BY

NURI MOHAMED ELBASHA, B.E., M.ENG (First class)

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DECLARATION

I hereby declare that the research work described in this thesis is my own work and the experimental program was carried out by the candidate in the laboratories of Civil, Mining and Environmental Engineering, University of Wollongong, NSW, Australia. This is to certify that this work has not been submitted for a degree to any university or institute except where specifically indicated.

Nuri Mohamad Elbasha

December 2005

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LIST OF PUBLICATIONS

List of relevant journal and conference papers published during Ph.D candidature.

Elbasha, N. M. and Hadi, M. N. S. (2005). "Experimental testing of helically confined HSC beams." Structural Concrete Journal (Thomas Telford and *fib*), 6(2), 43-48.

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Hadi, M. N. S. and Elbasha, N. M. (2004). "A New Model for Helically Confined High Strength Concrete Beams." 7th International Conference on Concrete Technology in Developing Countries. Modelling and Numerical Methods for Concrete Materials. 5-8 October 2004. Kuala Lumpur, Malaysia. University of Technology MARA. pp. 29-40.

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ABSTRACT

The technology of high strength concrete and high strength steel have improved over the last decade although high strength concrete is still more brittle than normal strength concrete. As this brittleness increases, particularly with the use of over-reinforced sections, they may, suddenly fail without any warning.

The research reported in this thesis deals with the installation of helical confinement in the compression zone of over-reinforced high strength concrete beams. This study is divided into three parts as follows:

1) State of the Art & Literature Review

This part deals with state of the art and literature review. Helical confinement is more effective than rectangular ties, compression longitudinal reinforcement and steel fibres in increasing the strength and ductility of confined concrete. Helical reinforcement upon loading increases the ductility and compressive strength of axially loaded concrete due to resistance to lateral expansion caused by Poisson's effect. Based on this concept helical reinforcement could be used in the compression zone of over-reinforced high strength concrete beams. The effectiveness of helical confinement depends on different important variables such as helical pitch and diameter. Thus there is a need for an experimental programme

to prove that installing helical confinement in the compression zone of an over-reinforced concrete beam enhances its strength and ductility and to study the behaviour of over-reinforced high strength concrete beams subjected to different variables.

2) The Experimental Programme & Test Analysis

This part deals with an experimental programme and analysis of test results. Extensive experimental work was done because the beams should be full size in order to accurately represent real beams. Twenty reinforced concrete beams, 4 m long × 200 mm wide × 300 mm deep were helically confined in the compression zone and then tested in the civil engineering laboratory at the University of Wollongong. In this programme the following areas were studied: the effect of helical pitch, helical diameter, concrete compressive strength and longitudinal reinforcement ratio, on the behaviour of over-reinforced HSC helically confined beams.

3) Analytical Models to Predict the Strength & Ductility

This part deals with the analytical models used to predict the strength and ductility of over-reinforced high strength concrete beams based on the findings of this study. A comparison between the experimental and predicted results shows an acceptable agreement.

This study concludes that helical reinforcement is an effective method for increasing the strength and ductility of over-reinforced high strength concrete beams.

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A_c	cross-section area of the concrete core, in mm^2
A_g	gross area of the section, in mm^2
A_h	cross-section area of helix bar, in mm^2
A_{sh}	total cross-section area of rectangular ties, in mm^2
A_s	area of longitudinal tensile reinforcing steel, in mm^2
b	width of the cross-section of the beam, mm
C	compressive force, N or kN
d	effective depth of the cross-section, mm
d_{co}	effective depth of the section excluded the concrete cover, mm
d_h	helix bar diameter, in mm
d	effective depth of a cross-section, mm
D	the concrete core diameter, in mm
E_c	modulus of elasticity of concrete, in MPa
E_s	modulus of elasticity of reinforcement steel, in MPa
f_c'	concrete compressive strength, in MPa
f_{cc}'	axial compressive strength of confined concrete, in MPa
f_R	modulus of rupture, in MPa
f_t	tensile splitting strength, in MPa

f_{sy}	yield strength of tension reinforcement, MPa
f_{yh}	yield strength of helical reinforcement, in MPa.
h_c	maximum unsupported length of rectangular hoop, mm
K_s	ratio of the confined strength of concrete to the unconfined compressive strength of concrete
K_u	neutral axis parameter
M_u	ultimate moment capacity of a beam, in kN.m
M_{ud}	calculated moment by assuming the concrete strain at the extreme compression fibre is 0.003 of an over-reinforced concrete beam, in kN.m
P	lateral pressure on the confined concrete in MPa.
T	tensile force in longitudinal steel, N or kN
W_c	unit weight of concrete, kg/m^3
μ_d	displacement ductility factor
μ_e	strain ductility factor
μ_ϕ	curvature ductility factor
ρ_h	total volumetric ratio of helices
ρ	longitudinal reinforcement ratio
ρ_c	compression steel ratio
ρ_b	balanced reinforcement ratio
ρ_{max}	maximum reinforcement ratio

Δ_u	midspan deflection at ultimate load, in mm
Δ_y	midspan deflection at first yield of tensile steel, in mm
β	ratio depth of the rectangular stress block to the neutral axis
α	factors for intensity of stress in a rectangular stress block
φ	capacity reduction factors
ϕ_u	ultimate curvature
ϕ_y	yield curvature
ε_u	sustainable strain in concrete
ε_y	yield strain in concrete
ε_{con}	ultimate confined compressive strain
ε_{cu}	compressive strain at extreme compression fibre of confined concrete at ultimate load
ε_o	strain at top surface of the beam
ε_{st}	average steel strain