PREDICTION OF DEFORMATIONS IN POST-TENSIONED PRESTRESSED SUSPENDED SLABS IN TALL BUILDINGS

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B.E. Civil Engineering (Hons.)

A thesis submitted in fulfilment
of the requirements for the degree of
Master of Engineering

at

The University of Adelaide
(Faculty of Engineering)

July 2008

Declaration

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Acknowledgements

I would like to thank all those people who have assisted me throughout the preparation and completion of this thesis. In particular, I wish to extend my gratitude and appreciation to my primary supervisors; Dr. Togay Ozbakkaloglu and Dr Rudolf Seracino who guided me through my research and helped expand my knowledge, confidence and expertise. I am very appreciative of their help, guidance and constructive criticism in producing this thesis and associated papers. My appreciation is also extended to my secondary supervisors; Dr Daksh Baweja and Dr.William Kaggwa who supported this research with contributions in their specific fields of knowledge.

I am very grateful for the contribution to this thesis by both Built Environs Pt Ltd and Readymix, Rinker. The support supplied from these companies was vital for obtaining the vast amount of data required in this research as well as guidance and management from the concrete construction industry. My gratitude is also extended to Engineering Surveys Pty Ltd for completing the essential stage of accurately surveying the slab deformations.

I would like to thank the Civil, Environmental and Mining Engineering laboratory staff at The University of Adelaide. The laboratory training and guidance provided by the laboratory staff was a crucial requirement in the completion of this research.

Publications

The following three journal publications have been prepared from the research performed and displayed in this thesis. At the time of completion of this thesis the papers are still being finalised and hence are unpublished.

Vincent, T. J., Ozbakkaloglu, T. and Seracino, R. *Design and Construction Challenges of a Partially Prestressed Building*.

Vincent, T. J., Ozbakkaloglu, T. and Seracino, R. *Statistical Variance of Concrete Material Properties and their effect on Member Performance.*

Vincent, T. J., Ozbakkaloglu, T. and Seracino, R. *Advances in Predicting Concrete Member Deformations Accurately Under Service Loads.*

Abstract

The research presented in this thesis focuses on the accuracy of predicting deflections and cambers in partially prestressed suspended slabs. Precision in predicting this behaviour accurately is complex due to the large number of variables which affect the behaviour of suspended prestressed slabs. This level of complexity is particularly relevant for post tensioned slabs due to the numerous on site construction steps. Many of the variables are hard to determine accurately due to their tendency to be unique for each construction site. Variables such as ambient temperatures, concrete material properties, stressing times, applied loads, loading times, prop movement and humidity are all examples of these properties. Hence, when predicting the behaviour of post tensioned suspended slabs of a multi storey building there always remains a degree of uncertainty. The research presented in this thesis addresses crucial areas of this topic and ultimately aims to supply reinforced concrete designers and constructors with additional confidence when predicting this behaviour.

The requirement for this project surfaced during the design stages of 151 Pirie, a multistorey building constructed in Adelaide, Australia. The design project for 151 Pirie was particularly complex due to a very ambitious construction timeline. The strict construction timeline was imposed due to the contractual agreement of early occupancy of the top three floors (of a 9 storey building). The client purchasing the top floors required functioning office space within a matter of months. This contract created a construction priority of erecting the bare structural requirements up to and including the top three floors in the shortest possible time. Fittings and services to the top three floors was then the secondary priority. Fitting and services to the lower floors (which would usually be achieved before the upper floors) would be performed at a later date. Excessive deflection limits of the slabs due to the accelerated construction were a major concern for the client. The effect on the deformation performance due to the accelerated construction was difficult to predict for the designer. Therefore, this project was born to help supply confidence to the designer and concrete supplier for this construction scenario.

This research project was designed to assist in the close monitoring and recording of the construction process of 151 Pirie. Due to the nature of data collection, data from this construction site would be limited in its benefits for the current construction. However, the data obtained would be vital for future projects by providing a log of onsite slab performance data as well as explanations of delays or other general outcomes with the construction process. Therefore, the aim of this research is to present the issues that were faced, the methods used to overcome these issues as well as displaying the vast amounts of site specific data documented within this project for future reference.

In this research a wide range of concrete material properties were collected and monitored closely on site as well as in the laboratory. The experimental testing created large detailed database of concrete material properties as well as other relevant factors such as surveyed deflections and construction timing. Concrete material properties were the primary focus of this research due to their direct effect on member performance. The database was sufficiently large to allow a meaningful statistical data analysis to be performed on the compressive strength (f'_c), modulus of elasticity (E_c) and tensile strength (f'_t) of the concrete samples. This analysis supplied a detailed understanding of the statistical relationship between different concrete material properties.

A Monte Carlo simulation was performed, with multiple deflection and camber models, to create a statistical distribution of predicted deflections and cambers from the statistical distribution of concrete material properties. This statistical output is then critically analysed and compared to the surveyed data. Proposed improvements to the process of predicting deflections and cambers have been outlined. These improvements have then been utilised in the construction of a finite element style program.

Finally, the multiple predictions of column strip and mid panel deformation are compared to the short term surveyed deflections. It is summarised that the improvements suggested and implemented in the finite style analysis yield results with a higher degree of accuracy. The accuracy and benefits of the suggested improvements has been justified and proven by the application of multiple examples and a parametric study.

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α_E = factor to account for aggregate type (CEB-FIB, 1993)

β_{sh} = a factor representing the support conditions of the beam/slab (Warner et al. 1998).

Δ = member deflection

Δ_x = member deflection along strip x

ε = strain

ε_{sh} = strain due to concrete shrinkage

ε_s = compressive strain in steel reinforcement

μ = mean value

σ = standard deviation

σ = stress

Φ = member curvature

Φ_{sh} = member curvature due to shrinkage of concrete

ν = Poisson's ratio

A_{sc} = area of steel reinforcement in compression

A_{st} = area of steel reinforcement in tension

C_{ca} = factor to account for aggregate type (Iravani, 1996)

C_x = Member camber at point x

d = depth of slab to lower reinforcement

D = total depth of slab

D = concrete cylinder diameter

DEMEC = Demountable Mechanical Strain Gauge

e = eccentricity of applied prestressing force

E = modulus of elasticity

E_c = modulus of elasticity of concrete (typically at 28 days)

f'_c = characteristic compressive strength of concrete (typically at 28 days)

f'_t = characteristic tensile strength of concrete

f_c = compressive strength of a sample of concrete

f_{ck} = characteristic compressive strength of concrete at 28 days, typically assumed to be f_{cm} – 8 MPa

f_{cm} = mean compressive strength of concrete

f_t = tensile strength of a sample of concrete

FTS = flexural tensile strength of concrete

h = slab height

H = relative humidity of concrete

I = moment of inertia

$I_{average}$ = Weighted average moment of inertia with respect to length

$I_{sectional}$ = Sectional values of moment of inertia

I_{trans} = Transformed moment of inertia

l = member length

L_{ef} = effective member length

FTS = flexural tensile strength of concrete

I = moment of inertia

I_{cr} = moment of inertia of cracked section

I_{ef} = effective moment of inertia

I_g = gross moment of inertia

K1 = factor according to slab location (Warner et. al., 1998)

K2 = factor according to slab dimensions (Warner et. al., 1998)

k_c = a factor which accounts for volume-to-surface ratio (Collins and Mitchell, 1997)

k_{cs} = long term deflection multiplier

k_f = factor which accounts for lower creep of higher strength concretes (Collins and Mitchell, 1997)

l = length

L = span of member, to centre of each support

L_n = span of member, to face of each support or drop panel

M = maturity index

M_{cr} = applied moment to cause cracking

M_s = applied moment at service load

p = tensile reinforcement ratio (A_{st}/bd)

p_c = compressive reinforcement ratio (A_{sc}/bd)

P = Prestressing force

PPS = Partially Prestressed Suspended

RC = Reinforced Concrete

STS = splitting tensile strength of concrete

t = time

t_{28} = time at 28 days

T = indirect tensile strength of concrete cylinder

TD_x = Total Deformation of the member at point x

UDL = Uniformly Distributed Load

UTS = Ultimate Tensile Strength

w = applied uniformly distributed load

w_{eff} = effective width of slab

w_s = sustained uniformly distributed load

y = distance from neutral axis down to the member centroid