

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

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Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Date

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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 At the time of completion of this thesis the papers are still being finalised and hence are unpublished.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.

Table of Contents

Declaration.....	i
Acknowledgements.....	ii
Publications.....	iii
Abstract.....	iv
Table of Contents.....	vi
List of Figures.....	ix
List of Tables.....	xii
List of Notation.....	xiii
1. INTRODUCTION.....	1
1.1. The research topic.....	1
1.2. Research methodology.....	4
1.3. Structure of thesis.....	5
2. LITERATURE REVIEW.....	6
2.1. Introduction.....	6
2.2. History of Prestressing.....	6
2.3. Deflection and camber control of slabs.....	8
2.3.1. Past.....	8
2.3.2. Present.....	8
2.4. Material properties of concrete.....	12
2.4.1. Compressive Strength (f_c).....	13
2.4.2. Modulus of Elasticity (E_c).....	13
2.4.3. Tensile Strength (f_t).....	16
2.4.4. Shrinkage.....	19
2.4.5. Creep.....	21
2.5. Maturity of concrete.....	23
2.6. Effect of Construction methods on deflections.....	25
2.7. Applied Loads.....	26
2.8. Conclusion.....	28
3. EXPERIMENTAL PROGRAM.....	29
3.1. Introduction.....	29
3.2. Site Specific Details.....	29
3.2.1. The Site.....	29
3.2.2. 151 Pirie Slab Detailing.....	30

3.2.3.	Strength Specifications.....	31
3.2.4.	Concrete Mixes and Materials.....	32
3.2.5.	Concrete Placement and Levelling.....	33
3.2.6.	Experimental Testing Program.....	34
3.2.7.	Surveying Plan	37
3.3.	Concrete Material Properties Results	39
3.3.1.	Compressive Strength (f_c)	39
3.3.2.	Modulus of Elasticity (E_c).....	47
3.3.3.	Tensile Strength (f_t).....	52
3.3.3.1.	Splitting Tensile Strength (STS) test results	52
3.3.3.2.	Flexural Tensile Strength (FTS) conversion results.....	56
3.3.4.	Creep	58
3.3.5.	Shrinkage.....	59
3.3.6.	Summary of Acquired Material Property Data	59
3.4.	Analysis of Concrete Material Properties	63
3.4.1.	Introduction	63
3.4.2.	Compressive strength (f_c).....	63
3.4.3.	Modulus of Elasticity (E_c).....	66
3.4.4.	Tensile Strength (f_t).....	70
3.5.	Site Specific Recorded Data.....	74
3.5.1.	Cycle Time Monitoring.....	74
3.5.2.	The Effect of Concrete Performance on Member Performance.....	76
3.5.3.	Temperature Monitoring	77
3.5.4.	Slab Deformation Surveying.....	80
3.6.	Summary	82
4.	PREDICTION OF SLAB DEFORMATIONS	83
4.1.	Introduction	83
4.2.	Determination of Accurate Inputs for Deflection Prediction	84
4.2.1.	Post-tensioned Tendon Force Calculations	85
4.2.2.	Applied Loads Calculations	87
4.2.3.	Determining Accurate Moment of Inertia	88
4.3.	Analysis of Slab Deformation Prediction Methods.....	91
4.3.1.	Numerical Approach to Slab Deformation Prediction	92
4.3.2.	Monte Carlo Simulation of Slab Deformation Prediction.....	100
4.3.2.1.	Introduction of Monte Carlo Simulation Method	100

4.3.2.2.	Explanation and Justification of Monte Carlo Simulation	101
4.3.2.3.	Results of the Monte Carlo Simulation	104
4.3.2.4.	Summary of Monte Carlo Simulation.....	111
4.3.3.	Finite Element Method to Slab Deformation Prediction	112
4.3.3.1.	Introduction to Finite Element Method	112
4.3.3.2.	Explanation of Finite Element Method.....	113
4.3.3.3.	Finite Element Method Results	123
4.3.3.4.	Summary of the Finite Element Method	127
4.3.4.	Summary of Deformation prediction methods	127
4.4.	Comparison of Deformation Predictions to Surveyed Values.....	129
4.5.	Limitations of Accuracy	135
5.	CONCLUSION AND RECOMMENDATIONS	138
5.1.	Research Conclusion	138
5.2.	Recommendations for future research	139
	References.....	140

APPENDICES

- Appendix A - Long Term Deflection Prediction Method Proposed by Hwang and Chang (1996).
- Appendix B - Examples of modelling construction effect of propping and back propping by the use of load factors (k) from J.F.M.A. Prado et al (2003).
- Appendix C - 151 Pirie Slab Structural Plans Incorporating Photos of Slab Details.
- Appendix D - Concrete Mixtures and Slab Pour Details.
- Appendix E - Concrete Compressive Strength (f_c) Results from the Experimental Analysis.
- Appendix F - Concrete Modulus of Elasticity (E_c) Results from the Experimental Analysis.
- Appendix G - Detailed Outcomes of Data Analysis.
- Appendix H - Results of Deformation Prediction Methods.

List of Figures

<i>Figure 1-1 Examples of concrete compressive strength gain</i>	2
<i>Figure 2-1 Growth of prestressed concrete industry in United States and Canada.</i>	7
<i>Figure 2-2 Mid panel deflection prediction methods</i>	10
<i>Figure 2-3 Comparison of Modulus of Elasticity (E_c) Models.</i>	15
<i>Figure 2-4 Typical instantaneous stress strain response and associated slope, E_c.</i>	16
<i>Figure 2-5 Typical long term stress strain response and associated slope, E_c.</i>	16
<i>Figure 2-6 Comparison of Splitting Tensile Strength Models</i>	18
<i>Figure 2-7 Comparison of Flexural Tensile Strength Models</i>	18
<i>Figure 2-8 Relationship between STS and FTS for NSC (Narrow and Ullberg, 1963)</i>	19
<i>Figure 2-9 Creep and shrinkage effects under constant sustained stress (Warner et al. 1998).</i>	21
<i>Figure 2-10 Time-Temperature relationships of curing concrete</i>	23
<i>Figure 2-11 Dead end Failure in a prestressed slab (Choong J, 2003).</i>	24
<i>Figure 2-12 Load and deflection histories for partially prestressed members (Warner et al, 1998)</i>	27
<i>Figure 3-1 151 Pirie Construction (mid 2005)</i>	30
<i>Figure 3-2 151 Pirie Completed (June 2006)</i>	30
<i>Figure 3-3 Examples of concrete compressive strength gain</i>	31
<i>Figure 3-4 Compressive strength gain of N32 and N40 concrete mixes</i>	32
<i>Figure 3-5 Concrete placement and finishing techniques used for the PPS slabs at 151 Pirie</i>	34
<i>Figure 3-6 Curing conditions of concrete cylinders</i>	36
<i>Figure 3-7 Long Term Deflection Prediction Plot from Initial Design Stages using RAM Concept</i>	38
<i>Figure 3-8 Surveying Grid Established based on Long Term Deflection Predictions</i>	38
<i>Figure 3-9 Experimental testing apparatus at the University of Adelaide Annex Laboratory.</i>	39
<i>Figure 3-10 Premature failure of early age concrete compression tests.</i>	40
<i>Figure 3-11 Premature failure due to eccentric loading</i>	41
<i>Figure 3-12 Comparison of Strength results from Readymix and Adelaide University laboratories.</i>	42
<i>Figure 3-13 Example f'_c gain for differently cured N32 and N40 concrete.</i>	43
<i>Figure 3-14 A summary of experimentally tested f'_c.</i>	44
<i>Figure 3-15 Compressive strength performance of the N32 and N40 mixes.</i>	45
<i>Figure 3-16 f_c performance of the N32 and N40 mixes for Readymix's samples.</i>	46
<i>Figure 3-17 Modulus of elasticity two ring test rig.</i>	47
<i>Figure 3-18 Data acquisition process for f_c and E_c</i>	48
<i>Figure 3-19 Example E_c gain for differently cured N32 and N40 concrete.</i>	49

Figure 3-20 A summary of experimentally tested E_c .	50
Figure 3-21 Modulus of Elasticity performance of the N32 and N40 mixes.	51
Figure 3-22 The Splitting Tensile Strength (STS) testing rig	52
Figure 3-23 An example of a failed specimen from the STS test.	53
Figure 3-24 Australian Standards testing rig requirement for obtaining STS (AS 1012.10, 1985)..	53
Figure 3-25 A summary of experimentally tested STS values.	55
Figure 3-26 A summary of experimentally tested FTS values.	57
Figure 3-27 Creep rig arrangement	58
Figure 3-28 Material Property testing schedule for 151 Pirie.	60
Figure 3-29 Material Property testing schedule for 151 Pirie continued.	61
Figure 3-30– Compressive strength variability (Warner et al. 1998).	65
Figure 3-31 Modelling E_c from experimental values of compressive strength.	67
Figure 3-32 Simplified E_c Model.	68
Figure 3-33 Scatter of E_c values from the obtained model.	69
Figure 3-34 Determination of E_c model's dependence on f_c	69
Figure 3-35 f_t modelling from the experimental data.	72
Figure 3-36 Scatter of f_t values from the obtained model	72
Figure 3-37 Determination of the STS prediction model's dependence on f_c	73
Figure 3-38 Cycle times experienced at 151 Pirie	75
Figure 3-39 RAM Concept's model of tensile strength	77
Figure 3-40 Thermocouple equipment and arrangement on site	78
Figure 3-41 Thermocouple readings obtained from 151 Pirie.	79
Figure 3-42 Surveyed grid on each slab.	80
Figure 4-1 Labelling of the 2 bay grid points as well as the mid and column strips.	84
Figure 4-2 Prestressing arrangement under analysis for the 2 bay grid (measurements are in mm)	86
Figure 4-3 Prestressing stress for each strand in tendons situated in North-South direction	86
Figure 4-4 Prestressing stress for each strand in tendons situated in East-West direction.	86
Figure 4-5 Factors considered in determining effective width (Oehlers and Bradford, 1999).	89
Figure 4-6 Factors considered by Eurocode 4 (1994) in determining effective width (Oehlers and Bradford, 1999).	89
Figure 4-7 Graphical representation of the deformations predicted via numerical analysis	98
Figure 4-8 Flow diagram of numerical serviceability behaviour prediction.	101
Figure 4-9 Flow diagram of statistical approach to serviceability behaviour prediction.	101
Figure 4-10 Flow diagram of the Monte Carlo Simulation.	102

<i>Figure 4-11 Justifying the accuracy of statistical array of compressive strengths</i>	<i>103</i>
<i>Figure 4-12 Justifying the accuracy of material property models</i>	<i>103</i>
<i>Figure 4-13 Results of Monte Carlo simulation for predicting slab deformations.....</i>	<i>105</i>
<i>Figure 4-14 Definition of slab strip and point labelling</i>	<i>108</i>
<i>Figure 4-15 Mid point deformations utilising the complete Collins and Mitchell (1997) method ..</i>	<i>110</i>
<i>Figure 4-16 Creep data from Eblen et al. (2004)</i>	<i>115</i>
<i>Figure 4-17 Graphical representation of accurate determination of E_c under sustained loads</i>	<i>118</i>
<i>Figure 4-18 An example of E_c values for camber and deflection</i>	<i>120</i>
<i>Figure 4-19 Sample output from the First Principle Approach Program.</i>	<i>121</i>
<i>Figure 4-20 Comparison of deformation profiles utilising I average and I sectional.</i>	<i>122</i>
<i>Figure 4-21 Results of First Principles Approach for predicting slab deformations</i>	<i>123</i>
<i>Figure 4-22 Comparative summary of deformation predictions and surveyed values.</i>	<i>130</i>
<i>Figure 4-23 Experimentally measured E_c scatter</i>	<i>136</i>
<i>Figure 4-24 Simulated 28 day E_c scatter</i>	<i>137</i>
<i>Figure 4-25 Simulated 7 day E_c scatter</i>	<i>137</i>

List of Tables

<i>Table 2-1 Expressions for predicting slab deflections exposed to UDL loadings.</i>	9
<i>Table 2-2 Expressions for predicting slab camber.</i>	11
<i>Table 2-3 Factors which affect deflections in PPS Slabs</i>	12
<i>Table 2-4 Expressions for Modulus of Elasticity (E_c)</i>	14
<i>Table 2-5 Expressions for Tensile Strength</i>	17
<i>Table 2-6 Expressions for Curvature caused due to Shrinkage</i>	20
<i>Table 3-1 Concrete mix details</i>	33
<i>Table 3-2 Summary of testing cylinders for each pour.</i>	36
<i>Table 3-3 Statistical arrangement of 7 day f_c from separate laboratories.</i>	64
<i>Table 3-4 Summary of statistical arrangement of 7 day f_c values.</i>	64
<i>Table 3-5 Statistical arrangement of 28 day f_c from separate laboratories.</i>	64
<i>Table 3-6 Summary of statistical arrangement of 28 day f_c values.</i>	64
<i>Table 3-7 Models for obtaining E_c from 28 day values of compressive strength.</i>	66
<i>Table 3-8 Modelling 28 day values of E_c from f'_c.</i>	67
<i>Table 3-9 Final Outcomes of Modelling E_c from f'_c</i>	70
<i>Table 3-10 A comparison of modelled values of STS to measured values.</i>	71
<i>Table 3-11 A comparison of modelled values of FTS to converted values of FTS from STS values.</i>	71
<i>Table 3-12 Final outcomes from modelling f_i from f_c.</i>	73
<i>Table 3-13 Comparison of survey deformations to initially prediction deformations.</i>	81
<i>Table 3-14 Surveyed deformation values at column points</i>	82
<i>Table 4-1 Summary of Accurate Material Properties</i>	85
<i>Table 4-2 Prestressing summary for each column strip and middle strip</i>	87
<i>Table 4-3 Applied Loads utilised in 151 Pirie's deformation analysis</i>	88
<i>Table 4-4 Comparison of Column Strip Moment of Inertias</i>	90
<i>Table 4-5 Example comparison of I_{gross} to I_{trans} for the PPS slab.</i>	91
<i>Table 4-6 Expressions for predicting slab deflection and camber for use in numerical analysis.</i>	93
<i>Table 4-7 Initial comparison of Camber and Deflection equations for short and long term loading</i>	94
<i>Table 4-8 Comparison of deflection and camber predictions with altered material property inputs</i>	97
<i>Table 4-9 Percentage of full creep for application of prestress</i>	115
<i>Table 4-10 Summary of input for first principle style analysis</i>	116

List of Notation

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

$I_{\text{sectional}}$ = 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