ME THESIS

Long-term Performance of Timber-Concrete Composite Flooring Systems

A thesis submitted in partial fulfilment
of the requirements for
Master of Engineering by research

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CERTIFICATE OF ORIGINAL AUTHORSHIP

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.

Production Note:
Signature removed prior to publication.

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TO MY WIFE NEBYAT

&

MY DAUGHTER MIKAL

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List of journal papers

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List of conference papers

Hailu, M., Gerber, C., Shrestha, R., Crews, K., 2012, "Long-term behaviour of Timber-Concrete Composite beams", in "12th WCTE, Proceedings of the World Conference on Timber Engineering, New Zealand, Auckland.

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LIST OF NOTATIONS

Δ	Deflection (mid-span deflection)
ρ	density
Δ	elastic deflection of the system
δ	deflection
b	floor width
B_c	width of concrete topping
CO_2	carbon dioxide
d	diameter of the shear connector
D_C	theoretical full composite deflection
D_I	measured partial composite deflection
D_N	theoretical fully non-composite deflection
D_w	depth of LVL web
E	modulus of elasticity; efficiency of composite
E_{cj}	mean MOE of concrete at the appropriate age
EI	flexural stiffness
$(EI)_{eff}$	effective bending stiffness
E_x	mean modulus of elasticity of LVL in x-direction
F, P	point load
f'_b	characteristic bending strength
f'_c	characteristic compression strength parallel to grain
f'_p	characteristic compression strength perpendicular to grain
f'_s	characteristic shear strength
f'_{sj}	characteristic shear strength at joint details
f'_t	characteristic tensile strength
f_b	mean bending strength
f_c	mean compression strength
f_{cm}	mean value of the compressive strength of concrete at the relevant age
f_t	mean tensile strength
f_v	mean shear strength

g	acceleration due to gravity (9.81 m/s^2)
G	shear modulus
I	moment of inertia
k	stiffness
$K_1,K_4,k_6,K_7,K_9,K_{11},K_{12}$	Modification factors for timber as per AS/NZS 1720
$k17$	factor for multiple nailed joints
K_{serv}	serviceability limit state stiffness
K_u	ultimate limit state stiffness
L, l	span
L_b	shear-free span between load points
m	mass of the floor ; mass per unit length; mass per unit area
M_i	initial mass of moisture content test piece
M_o	dry weight of moisture content test piece
N^*t	Axial force on timber
M^*	Design bending moment
M^*t	Design bending moment on timber
φN_R	Resisting tensile strength
φM_R	Resisting bending moment
Q_k	strength of shear connectors
s_e	spacing of the shear connectors at the ends of the beam
S_{eff}	effective constant spacing of the shear connectors
s_m	spacing of the shear connectors in the middle of the beam
S_{min}, S_{max}	Minimum and maximum spacing of the connectors
T_c	thickness of concrete topping
T_f	thickness of LVL flange
T_w	thickness of LVL web
W	effective weight of the floor
V^*	Design shear force
w	maximum short-term deflection; uniformly distributed load per unit length (Chapter 7)
$g_{\bullet c}$	Partial safety factor for concrete

γ_m	Partial safety factor for timber
γ_{con}	Partial safety factor for connection
γ	reduction factor (gamma)

LIST OF ACRONYMS

BM	bird-mouth
CA	composite action
CoV	coefficient of variation
MOE	modulus of elasticity
FE	finite element
FEA	finite element analysis
FEM	finite element model
Glulam	glue laminated timber
LVDT	linear variable differential transformer
LVL	laminated veneer lumber
LWC	Light weight concrete
MC	moisture content
NS	normal screw
NZ	New Zealand
B-NS	Beam with normal screw connector
B-4N	Beam with four notch and with coach screw connector
B-6N	Beam with six notch and with coach screw connector
B-SFS	Beam with SFS screw as connector
Pty Ltd	proprietary limited
PSL	Parallel stranded lumber
RH	Relative air humidity
SCC	steel-concrete composite
SLS	serviceability limit state
STIC	structural timber innovation company
TCC	timber-concrete composite
TTC	Timber-timber composite
ULS	ultimate limit state
UTS	University of Technology Sydney

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Abstract

Timber concrete composites (referred to as TCC beams here onwards) consist of a concrete slab integrally connected to the timber joist by means of a shear connector. The coupling of a concrete layer on the compression side and timber on the tension side of cross-section results in efficient use of both materials. As the timber joist is mainly subjected to tension and bending while the concrete flange is mainly subjected to compression. The connection plays an important role for the composite action in determining the structural and serviceability performance of the system. Use of stiff and strong connection system contributes to a suitable bending strength and stiffness of the TCC together with other mechanical properties..

Design of timber-concrete composite systems requires verification of serviceability and ultimate limit states. With the increasing trend in long span and light-weight construction, design of these floors may be governed by serviceability limit states and deflection under long-term load is one of the serviceability criteria that need to be addressed.

The long term behaviour of timber-concrete structures depends on a number of phenomena taking place in its components. Phenomena such as creep and shrinkage effects in concrete, creep, shrinkage or swelling effects in timber and creep in connection affect long term strength, stiffness and deflection behaviour of timber-concrete composites. Creep due to variation in the moisture (mechano-sorptive creep) plays a major role in the long term behaviour of TCC floors. Few long-term experimental tests conducted so far have been reported in the literature.

The objectives and scope of this study are to conduct long–term experimental test on timber-concrete composite beams, analyse the results to determine the creep coefficient of the composite system and compare the experimental results with the analytical solutions in accordance with Eurocode 5, in which the effective modulus method is used to account the effect of creep.

To achieve the aforementioned objectives, a long-term laboratory investigation was started in August 2010 on four 5.8m span TCC beams with four different connector types. The specimens have been under sustained loads of 1.7kPa and subjected to a cyclic humidity conditions whilst the temperature remains quasi constant (22 °C). During the test, the mid-span deflection, moisture content of the timber beams and relative humidity of the air are continuously monitored. The long-term test is still continuing, two TCC beams were unloaded and tested to failure after 550 days, while the other two TCC beams are still being monitored and this report included experimental results up to the first 1400 days only. The long-term investigation on the two timber only composite floor beams commenced on March 2013 and the results are reported for the first 800 days from their commencement.