The Generic Simulation of Reinforced Concrete Beams with Prestressing and External Reinforcement

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ABSTRACT

This thesis presents a series of journal papers in which a new segmental moment-rotation (M/Θ) approach is developed for simulating the instantaneous and sustained loading behaviour of reinforced concrete (RC) beams with prestressing and external reinforcement. The M/Θ approach is formed on the fundamental Euler-Bernoulli postulation that plane sections remain plane, but not necessarily on the Euler-Bernoulli corollary of a linear strain profile. Further adaption of the well-established mechanics of partial-interaction (PI) theory introduces a fundamental baseline concept in which residual strains due to time-effects, thermal gradients and prestressing are accounted for in simulating the formation and gradual widening of cracks and the associated effects of tension-stiffening allowing for bond-slip. The effects of concrete softening are incorporated into the M/Θ approach through a size dependent concrete stress-strain relationship based on the mechanics of shear-friction theory which simulates the behaviour of a member once a concrete softening wedge forms. The approach is shown to be able to quantify segmental equivalent flexural rigidities for both instantaneous and time-dependent behaviour, thus removing the reliance on empiricism in quantifying the effects of concrete cracking and softening.

In defining the segmental equivalent flexural rigidities of RC beams with both post-tensioned and pre-tensioned reinforcement it is shown how the approach is used to quantify the load-deflection behaviour of the entire member through the application of conventional analysis techniques. The established M/Θ approach is then generically applied to RC beams with both prestressed fibre reinforced polymer (FRP) and steel reinforcement in quantifying the beams instantaneous and sustained loading behaviour through being able to accommodate any conventional method of quantifying the time-dependent parameters. Thus the broad application of the M/Θ approach provides a novel method of simulating, through mechanics, the full-range of behaviour of a prestressed beam, that is from prestress application through serviceability loading and to collapse. Moreover, the reliance on empiricisms, as typically relied upon in standard analysis methods, are removed with the only empirical components required being in defining the material properties.

Having established the M/Θ approach for the instantaneous and sustained loading of conventional prestressed beams, the approach is extended to simulate the behaviour of RC beams with unbonded post-tensioned FRP and steel tendons. Through understanding the individual segmental behaviour, a global approach is introduced in which the behaviour of the unbonded reinforcement can be quantified from the deformation based analysis. The approach is then further extended to incorporate the analysis of RC beams with mechanical-fastened (MF) FRP allowing for the PI behaviour at the fasteners. This extension forms the basis of a generic technique which can subsequently be used in the design of MF systems, with and without prestress, and therefore provide the foundation in developing design guidelines.

The universal application of the developed residual strain PI M/Θ approach provides a novel technique in simulating what is observed in practice for RC beams with prestressing and external reinforcement. The approach is a useful extension to the current analysis techniques in which the reliance on defining empiricisms through vast experimental testing procedures is removed.

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STATEMENT OF ORIGINALITY

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Daniel Knight Date

LIST OF PUBLICATIONS

Oehlers, DJ., Visintin, P,. Zhang, T., Chen, Y and Knight, D. Flexural Rigidity of Reinforced Concrete Members Using a Deformation Based Analysis. Concrete in Australia 2012, 38(4) 50-56

Knight, D., Visintin, P., Oehlers, D.J and Jumaat., M.Z. Incorporating Residual Strains in the Flexural Rigidity of RC members. *Advances in Structural Engineering*. DOI; 10.1260/1369-4332.16.10.1701. Nov 12, 2013b

Knight, D., Visintin, P., Oehlers, D.J., and Mohamed Ali, M.S. Short-term partial-interaction behaviour of RC beams with prestressed FRP and Steel. *Journal of Composites for Construction*, 10.1061/(ASCE)CC.1943-5614.0000408 (Jun. 26, 2013a).

Knight, D., Visintin, P., Oehlers, D.J., and Mohamed Ali, M.S. The time-dependent behaviour of RC beams with prestressed FRP and steel. Submitted to *Engineering Structures*

Knight, D., Visintin, P., Oehlers, D.J., and Mohamed Ali, M.S. Simulating RC beams with unbonded FRP and steel prestressing tendons. *Accepted to Composites B.* DOI;10.1016/j.compositesb.2013.12.039

Knight, D., Visintin, P., Oehlers, D.J., and Mohamed Ali, M.S. Simulation of RC Beams with Mechanically Attached FRP Strips. *Submitted to Composite Structures*

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