THE TENSION STIFFENING IN REINFORCED CONCRETE BEAMS AND SLABS

By

RAHIMAH MUHAMAD
B.E. (Hons) Civil Engineering, Universiti Teknologi Malaysia
M.Eng (Civil & Structural), Universiti Teknologi Malaysia

This thesis submitted for the degree of

Doctor of Philosophy (Ph.D)

THE UNIVERSITY OF ADELAIDE
AUSTRALIA

SCHOOL OF CIVIL, ENVIRONMENTAL AND MINING ENGINEERING

THE UNIVERSITY OF ADELAIDE, ADELAIDE
AUSTRALIA
JANUARY 2012
CHAPTER 3: APPLICATION OF THE STRUCTURAL MECHANICS MODEL

INTRODUCTION

This chapter focuses on the application of the developed generic structural mechanics models from the previous chapter. As discussed in Chapter 2, the developed mechanics based model is demonstrated and validated in this chapter.

The first paper Discrete rotation deflection of RC beams and slabs at serviceability focuses on the application of the developed structural mechanics models for predicting the deflection of reinforced concrete beams and slabs at serviceability. The discrete rotation at each particular crack is examined through the developed load slip relationships from Chapter 2. By knowing the slip, the rotation at a particular crack can be obtained and, subsequently, the deflection at that crack. Then, a summation of the deflection from each discrete rotation crack and the deflection in uncracked regions can be determined; the deflection in the uncracked regions is evaluated directly by integrating the curvature. These mechanics based models are compared with a set of experimental data of reinforced concrete beams and slabs and also with a code of practice. The results show a good agreement between them and suggests that this is an improved procedure which does not rely on an extensive empirical testing regime.

The second paper Simulating the deflection of RC flexural members with FRP reinforcing bars presents the application of the developed generic mechanics based model further into reinforced concrete with FRP reinforcing bars. Interestingly, this paper shows that this partial interaction moment rotation approach can be adopted for reinforced concrete beams and slabs for any range of reinforcement moduli and for any type of interface bond slip characteristic. This new approach brings an innovation in predicting the deflection of reinforced concrete beams and slabs as it allows the development of any new FRP product.
List of Manuscripts

Discrete rotation deflection of RC beams and slabs at serviceability
Muhamad, R., Oehlers, D.J., and Mohamed Ali M.S.
ICE Proceedings, Structures and Buildings 2011: accepted paper

Simulating the deflection of RC flexural members with FRP reinforcing bars
Oehlers, D.J., Muhamad, R., and Mohamed Ali M.S.
ASCE Composites for Construction 2011: submitted paper
Statement of Authorship

DISCRETE ROTATION DEFLECTION OF REINFORCED CONCRETE BEAMS AND SLABS AT SERVICEABILITY

**Corresponding author:**

**Professor Deric John Oehlers**  
School of Civil, Environmental and Mining Engineering  
The University of Adelaide  
Supervised research, provided critical manuscript evaluation and acted as corresponding author.  
I hereby certify that the statement of contribution is accurate

**Signed:** \[11/1/2012\]

---

**Rahimah Muhamad**  
PhD student  
School of Civil, Environmental and Mining Engineering  
The University of Adelaide  
Contributed to perform the analysis and provided equations.  
I hereby certify that the statement of contribution is accurate

**Signed:** \[11/1/2012\]

---

**Dr Mohamed Ali M.S.**  
School of Civil, Environmental and Mining Engineering  
The University of Adelaide  
Supervised development of work and assisted in manuscript evaluation.  
I hereby certify that the statement of contribution is accurate

**Signed:** \[11/1/2012\]

Proceedings ICE, Structures and Buildings: accepted paper

*Proceedings of the Institution of Civil Engineers, Structures and Buildings, Submitted manuscript*

NOTE:
This publication is included on pages 145-167 in the print copy of the thesis held in the University of Adelaide Library.
Statement of Authorship

SIMULATING THE DEFLECTION OF REINFORCED CONCRETE FLEXURAL MEMBERS WITH FRP REINFORCING BARS

Professor Deric John Oehlers
School of Civil, Environmental and Mining Engineering
The University of Adelaide

Prepared manuscript and supervised research.
I hereby certify that the statement of contribution is accurate

SIGNED:..........................................................DATE:........................./..1/2012..................

Rahimah Muhamad
PhD student
School of Civil, Environmental and Mining Engineering
The University of Adelaide

Contributed to perform the analysis and provided equations.
I hereby certify that the statement of contribution is accurate

SIGNED:..........................................................DATE:........................./..1/2012..................

 Corresponding author:

Dr Mohamed Ali M.S.
School of Civil, Environmental and Mining Engineering
The University of Adelaide

Supervised development of work and assisted in manuscript evaluation.
I hereby certify that the statement of contribution is accurate

SIGNED:..........................................................DATE:........................./..1/2012..................

Submitted to ASCE Composites for Construction

168
*ASCE Journal of Composites for Construction, Submitted manuscript*

**NOTE:**
This publication is included on pages 169-189 in the print copy of the thesis held in the University of Adelaide Library.
CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

In this thesis, generic structural mechanics models using a partial interaction approach were developed to predict the behaviour of reinforced concrete flexural beams and slabs at serviceability.

Partial interaction tension stiffening theory was used for quantifying, through closed form solutions, the serviceability behaviour of reinforced concrete prisms. The structural mechanics models for single and multiple cracks have been developed such as the load slip behaviour, crack spacing, crack width and load to cause a crack.

The outcome from the derivation of the closed form structural mechanic models is used in determining for the first time the deflection of reinforced concrete beams and slabs under serviceability limits state. Very good correlation was achieved with the current empirical code of practice and with various experimental researchers’ data.

The current empirical moment curvature approach implies no slip between the concrete and the reinforcement which does not occur in practice. On the other hand, this new generic method provides an accurate procedure that considers the occurrence of slip between the reinforcement and concrete for predicting the deflection of reinforced concrete beams and slabs. Hence, this generic structural mechanics approach has a major advantage as it will allow the development of new products without the needs for an extensive empirical testing regime.

It is suggested that further research is required on the study of reinforced concrete member deflections for long term loads by considering creep and shrinkage. Furthermore, closed form solutions that incorporate strain hardening need to be derived.