Load-slip relationship of tension reinforcement in reinforced concrete members

Rahimah Muhamad, M.S. Mohamed Ali *, Deric Oehlers, A. Hamid Sheikh

School of Civil, Environmental and Mining Engineering, University of Adelaide, South Australia 5005, Australia

1. Introduction

The deformation of a reinforced concrete member as shown in Fig. 1(a) can be considered to comprise that from: the undisturbed or homogenous region as shown in Fig. 1(b) where there is no slip between the reinforcement and the concrete, i.e. full interaction exists and a linear strain profile can be used; and the disturbed regions at each individual crack as shown in Fig. 1(c) where a linear strain profile over the entire depth of the beam no longer exists and a discrete change of rotation $\theta$ occurs across the crack faces. The deformation of the reinforced concrete member can, therefore, be idealized as that due to the undisturbed region as shown in Fig. 1(b) and that due to the disturbed region as shown in Fig. 1(c) [1,2].

For the undisturbed region (Fig. 1(b)), a standard sectional analysis, which may be defined as a full-interaction analysis, can be used to determine the moment–curvature relationship. This can be used to derive the rotation that has a continuous variation by integrating the curvature along the member’s axis.

In a disturbed region surrounding any crack as shown in Figs. 1(c) and 2, the discrete change in rotation $\theta$ is due to rigid body rotations of the adjacent crack faces. The discrete change in rotation $\theta$ depends directly on the slip or slip displacement $\Delta$ between the reinforcing bar and the concrete at the crack face [3,4] which is equal to $h_{rb}\delta$ where $h_{rb}$ is the distance from reinforcing bars to the crack tip. The load–displacement relationship at the crack face $P–\Delta$ for each reinforcing bar and at each level can be derived; then for a given crack rotation, the reinforcement forces can be derived and consequently the moment. Hence once the $P–\Delta$ is derived, it can be applied to any type of reinforcement at any position such as externally bonded plates at position of $h_p$ where $h_p$ is the distance from externally bonded plates to the crack tip. The $P–\Delta$ relationship depends on the bond–slip $\tau–\delta$ properties at the interface between the reinforcement and concrete [3,5–11].

In this paper, closed form solutions are derived for the $P–\Delta$ relationships which are applicable to any type and shape of reinforcement. It is then shown how these closed form solutions can be conveniently used to derive the moment-rotation relationship at a crack.