Finite Section Analysis of RC Beams Prestressed with External Tendons at Ultimate Limit State

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INTRODUCTION

The flexural behaviour of RC beams prestressed with external tendons is dependent of the whole structural member deformation, leading to the complexity in the analysis of the member. Another factor which contributed to the complexity in the analysis is the variation in eccentricities of the external tendons termed as second-order effects. Therefore, analytical study on the flexural behaviour of externally prestressed beams is scarce.

The present paper presents an analytical model for the ultimate limit state of externally prestressed beams, which is defined as the finite section analysis. As the name of the method suggests, a beam is divided into several sections with a constant segment length. Each section is then analysed for strain compatibility, force equilibrium and moment equilibrium. The strain increase in external tendons is then calculated based on the total elongation of the concrete at the tendon level. Deformation of the beam member is calculated based on moment-area method and variation in tendon eccentricities are calculated at each section. This analytical model requires an iterative process to achieve strain compatibility, force equilibrium and moment equilibrium at every section, including convergence of the member deformation. Some experimental results from other literatures were used to validate the analytical model and the theoretical predictions were found to agree well with the test results.

Keywords: analysis, beam, section, stress, tendon, ultimate

BACKGROUND

Several methods have been developed to analyse the behaviour of concrete structures with external tendons. However, most of these studies have limitations. Member approach analysis such as finite-element method is more general and complicated [1-4]. However, it is difficult to represent beam member with material nonlinearity, geometric nonlinearity and slip at deviators. Among these researches, Fenves [1] considered material nonlinearity but ignored geometric nonlinearity, and Ramos and Aparicio [4] and El-Habr [2] investigated on structural behaviour of externally prestressed precast segmental beam.

Alkhairi and Naaman [5] then proposed that shear deformations has significant effect on the increase in the ultimate tendon stress. The effect of shear deformation was considered based on the concept of truss mechanism (strut-and-tie model). However, Gauvreau [6] had verified that the consideration of shear deformation in a strut-and-tie model has no significant effect on the external tendon stress, due to the unbonded nature and unrestrained movement of external tendons.

The earlier development on external prestressing had been associated with internally unbonded prestressing, in which the span-depth ratio was reported to have a significant effect on tendon stress at ultimate. Motjahedi and Gamble [7] conducted an experimental study on simply-supported beams, continuous beams and continuous slabs prestressed with unbonded tendons. An analytical model of a conceptual triangular truss comprising two symmetrical compressive members and a tie to simulate a cracked beam prestressed with unbonded tendons was also developed. From the observed experimental results and theoretical analysis, it was concluded that the span-depth ratio has a significant effect on the ultimate tendon stress. Based on their findings, ACI Building Code [8] adopted the effect of span-depth ratio, and the ultimate tendon stress for unbonded tendons is given as