Flexural strengthening of RC beams via external prestressing

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ABSTRACT: External prestressing is a post-tensioning method in which the tendons are placed outside of the concrete members. It is an efficient way of strengthening existing reinforced concrete beams, particularly in flexure. This paper describes the ability of external prestressing in enhancing the flexural strength of reinforced concrete beams quantified by the flexural strengthening ratio. This ratio indicates the percentage increase in flexural strength in the strengthened beam. It is derived mathematically for beams with rectangular section behaviour, and determined explicitly for beams with *T*-section behaviour. The proposed analytical method was validated with experimental results available in the literatures. The predicted results agree well with the test results. In this study, it is also shown that the strengthening effect from external prestressing can be as high as 80% in flexure. As a result, a parametric study was carried out to study the effect of strengthening, in which the results provide some guidelines on the design for beam strengthening using external prestressing in the form of nomographs.

Key words: beam; flexure; prestressing; strengthening.

1 INTRODUCTION

External prestressing is a post-tensioning method where the tendons are placed on the outside of the concrete section. It is commonly used in new construction work of bridges particularly in segmental box girders and is also becoming popular in the strengthening of existing structures, both concrete and steel types. Flexural strengthening of reinforced concrete beams by external prestressing is an efficient method which involves little disturbance to the original beams.

Two of the reasons which lead to the complexity in the analysis of externally prestressed beams are stress increase in the external tendons which is dependent of the overall deformation of the member; and eccentricity variations of external tendons under load, commonly referred to as second-order effects (Trinh 1990, Alkhairi & Naaman 1993, Virlogeux, & M'Rad 1993, Mutsuyoshi et al. 1995, Tan & Ng 1997, Ng 2003). Therefore, the elongation of the external tendons is dependent of the total deformation of the structural member rather than being solely dependent of the critical section under consideration. As a result, most of the proposed methods of analysis for the behaviour of externally prestressed beams involve complicated numerical analysis.

This paper presents the concept of using external prestressing as a mean for strenthening of reinforced concrete beams. The analytical model for the externally prestressed beams is based on the "pseudo-section" analysis, which is fundamentally a cross-sectional analysis using bond reduction coefficient for the external tendons. The strengthening effect of external prestressing is assessed through a ratio defined herein as flexural strengthening ratio.

2 ANALYTICAL CONSIDERATIONS

2.1 Flexural strengthening ratio

In order to assess the flexural strengthening effect of external prestressing, a ratio relating the strength of the strengthened beam to the strength of the original or strengthened beam is defined herein, that is,

$$\text{Flexural Strengthening Ratio (FSR)} = \frac{M_u}{M_{un}} \qquad (1)$$

where M_u = ultimate flexural strength of strengthened beam; and M_{un} = ultimate flexural strength of unstrengthened beam.