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Optimum strengthening of steel-concrete composite beams using pre-stressed FRP plates

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Abstract

This paper suggests an analytical procedure using exterior penalty approach to gain the optimum pre-stressing amount in FRP plates which is attached to tensile flange of a steel-concrete beam. Object of this study is viewing effect of pre-stressing on reduction of demanded FRPs which doesn't pre-stress. Finally a parametric study to demonstrate effect of pre-stressing on various types of the FRPs is conducted.
Keywords: Pre-stressed FRP plates, strengthening, optimization, steel-concrete composite beams.

1. INTRODUCTION

In recent applications, the use of pre-stressed laminates has been explored both in laboratory tests [1, 2]and in field applications on bridges [3] and other types of structure [4]. By pre-stressing the laminate, the ultra-high tensile strength of the composite material can be better utilized, which gives a more effective strengthening scheme. In concrete structures, the compressive stresses induced by pre-stressing will close existing cracks, reduce crack widths and delay the onset of new cracks in the strengthened structure. Yoo et al. [5] performed flexural experiments on RC beams with various pre-stressing levels of 0%, 20%, 40%, 60% and 70% of the tensile strength of CFRP plates. They reported that pre-stressing CFRP reinforcement method increased the cracking stress, yielding stress, and ultimate strength based on the pre-stressing level, while it reduced the displacement of the member during final failure. Sang-Kyun Woo et al.[6] carried out an experimental and analytical work for development of the flexural capacity of RC beams which were reinforced by pre-stressed CFRP plates. They reported surface bonding with a CFRP plate without pre-stressing increases the ultimate load of a specimen as much as 20.6%, and strengthening with pre-stressed CFRP plate increases the ultimate load as much as 46.7%-243.0%. They also found that in both aspects of ductility and flexural capacity of members, a pre-stressing level of 0.6% CFRP strain is considered as most effective and appropriate. For reasonable pre-stressed CFRP plate strengthening, it is also important to decide the proper pre-stressing level required for the anchor-bolt length or reinforcement length. Also in steel structures, compressive stresses introduced to the tension flange of a steel beam, for instance, will improve fatigue resistance of the steel beam [2]. The strengthening effect obtained when pre-stressed laminates are employed will not only be limited to additional imposed loads on the strengthened structure, but will also participate in carrying a portion of the dead load. Pouya zangeneh et al. [7]conducted a FE model to predict the flexural behavior of steel-concrete composite beams strengthened with pre-stressed CFRPs, they showed increase in the ultimate and yield loads as the pre-stressing percentage increases, whilst the ductility index tends to decrease.

However, capacity of FRPs can be completely utilized by pre-stressing. It can be important in economic aspects. In this paper we study minimum FRP thickness in strengthening of steel-concrete composite beams for a given ultimate moment resistance, In other words, proper pre-stressing level which require optimizing strengthening design will be provided. The elements considered consist of an existing steel-concrete section which is reinforced with pre-stressed unidirectional FRP plates bonded externally on the tensile flange with an epoxy adhesive. Object is minimum thickness of FRP and pre-stressing strain subjected to some constraints include available material, analysis and strength requirements. Exterior penalty approach as a non-linear optimization technique is employed to solve this problem. Crushing of the concrete and FRP rupturing are considered as two modes of failure in this study. Debonding between FRP plate and steel face isn't occurred to account for presence of anchorage at both ends of the plate.