# Numerical investigation on shear strengthening of RC beams using Near Surface Mounted (NSM) FRP

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**Abstract**

A recent and promising method for shear strengthening of reinforced concrete (RC) members is the use of near-surface mounted (NSM) fiber-reinforced polymer (FRP) reinforcement. So far, numerical studies concerning the NSM FRP strengthening method have been rather limited. Moreover, virtually no comprehensive analytical research is available on the behavior of shear-strengthened beams considering NSM FRP. This paper illustrates a numerical research program on shear strengthening of RC beams with NSM reinforcement, aimed to investigate individual parameters effecting numerical analysis and capture the effect of important issues. The proposed numerical analysis is validated against published experimental results. Maximum load bearing capacity of proposed numerical models was shown very good conformity to experimental results. As a result, the behavior of the FRP systems predicted by the analytical modeling was slightly stiffer than the values recorded experimentally; probable differences in stiffness are discussed in this study. In general, comparison between the numerical predictions and test results shows desirable agreement.

**Keywords: Shear strengthening, Near Surface Method, FRP, Numerical analysis of RC beams.**

## 1. INTRODUCTION

Fiber reinforced polymer (FRP) based techniques for shear strengthening of reinforced concrete (RC) structures have been rapidly gaining popularity worldwide. Beside the most widespread use of externally bonded FRP laminates, near-surface mounted (NSM) FRP has been found to perform efficiently as shear strengthening technology for RC beams [1]. The NSM technique is based on fixing, by epoxy adhesive, FRP laminates into pre-cut slits opened in the concrete cover of lateral surfaces of the beams. Finite-element analysis is clearly the most powerful tool for simulating complex structural behavior. This method is useful to model FRP shear-strengthened beams, which is a more economical approach than conducting elaborate laboratory tests. Recently finite-element studies on shear-strengthened beams have been conducted by Santhakumar and chandrasekara[2], Elyasian et al[3], and Godat and Neal[4]. These analytical studies were focused on externally bonded (EB) shear strengthening. The available finite element investigations in the literature, on the scope of shear strengthening by FRP materials, do not considered NSM method. In this investigation, an analytical approach is developed, using ANSYS program, to predict the response of reinforced concrete beams strengthened in shear with NSM FRP composites, with a particular emphasis on the numerical modeling aspects. The proposed three-dimensional analysis is applied to various cases having different FRP strengthening configurations. Stiffness in various part of load deflection curves are compared with experimental values and the probable reasons for nonconformities are discussed. Maximum load carrying capacity of numerical models are calculated and evaluated with experimental quantities. General behavior of numerical models, such as cracking pattern, is also explored. The presented finite element model in this study can be considered as one of the pioneering models that gaining analytical behavior of NSM FRP in shear strengthening of RC beams. Useful recommendations for numerical modeling of reinforce concrete beams retrofitted by NSM FRP are available in conclusion. Predicted strain along the FRP sheet depth is also presented. The predicted results are shown to compare very well with published experimental data.