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CFRP strengthening system to increase fatigue resistance of bridges

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1 Abstract

Carbon fiber reinforced polymers (CFRP) laminates externally bonded with epoxy resins are an often used strengthening technique of aged and overloaded structures, e.g. bridges. A well-known, though not commonly discussed, problem is the stiff bond behavior of the used adhesives. Their use leads to stress concentrations in the CFRP and concrete at the location of cracks and an uneven strain distribution of internal and external reinforcement. On that basis, the usage of such a strengthening technique for components subjected to dynamic loads is limited or almost impossible due to premature debonding of the CFRP.

The present paper focuses on numerical analysis of reinforced concrete bending beams strengthened with CFRP using the finite element method. In our analysis we focus on contact modelling techniques. The effect of differing adhesives on the overall behavior of the strengthened beams and strain distribution of internal and external reinforcement is shown. Numerical investigations demonstrate the relevance of the used adhesive on the static and fatigue behavior of the strengthened component. Modified and optimized material properties of the adhesive lead to a strengthening system which is even capable of carrying dynamic loads.

Keywords: CFRP, strengthening, RC structures, adhesive, fatigue

2 Introduction

The need for strengthening existing structures is attributable to the increase of loads (changing the load class of a bridge), damage, corrosion, or ageing. A commonly used strengthening technique of reinforced concrete (RC) structures is externally bonded (EB) reinforcement, mostly made of CFRP, bonded with epoxy resins. Unfortunately, there are some limitations in the practical use. The usage of stiff adhesives leads to stress concentrations, limited stress transfer from CFRP to concrete at intermediate cracks and therefore to premature debonding at those locations. [1] Furthermore, the differing bond behavior of embedded and EB reinforcement leads to an uneven strain distribution especially at service limit state (SLS). [2, 3] These points lead to the aforementioned limitations for components subjected to dynamic loads (small permissible stress ranges), since bond damage occurs at small crack widths of 0.04 mm. Some authors reported positive effects on the behavior of strengthened elements by the use of softer adhesives, such as reduction of mid span

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