Determination of minimum CFRP pre-stress level for fatigue crack prevention in retrofitted metallic beams

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Roughly twenty-two percent of all European bridges are metallic, and nearly seventy percent of these metallic bridges are over fifty years old. With such old metallic bridges, fatigue crack safety and the ability to safely carry larger traffic loads (traffic loads greater than in the original design) is a major concern. After fifty years in service, most elements within a bridge function satisfactorily (having sufficient excess fatigue-capacity); however, there are often a few bridge elements that are approaching or have reached the end of their fatigue life. In this situation, bridge authorities often try to avoid replacing the entire bridge, in favor of more economical solutions such as localized retrofits.

One promising retrofit material for steel bridge applications is carbon-fiber-reinforced polymer (CFRP), which offers excellent fatigue performance and a high strength-to-weight ratio. Retrofit application of CFRP plates to metallic bridge beams can be done using bonded or unbonded (using mechanically anchored) systems. Often such CFRP systems employ a certain amount of pre-stress to increase performance; however, there is currently no analytical model to estimate the minimum pre-stressing level required for fatigue crack safety. This paper presents an analytical model for determining the minimum CFRP pre-stressing level required to increase the fatigue life of a fatigue prone element for a certain amount of additional cyclic load. In particular, the model gives the prestressing level by which there would be no fatigue cracking (i.e., theoretical infinite fatigue life) in an existing fatigue prone detail.