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On the costly-effective application of FRP sheets to masonry arch railway bridge strengthening

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Abstract

This paper studies the minimum-cost strengthening of masonry arch railway bridges through optimal attachment of Fiber-Reinforced Polymer (FRP) sheets together with jacketing by reinforced concrete and shotcrete measures. For this aim, the Sahand-Goltappeh bridge, as a case study, is studied subjected to ordinary train pass. Finally, the strengthening cost is minimized pursuing following goals: i) the bridge's load-carrying-capacity is increased; and, ii) the response values of the bridge are reduced to a certain limit. The strengthening cost is estimated based on Iranian prices list for railway construction services. The results show that strengthening costs can be reduced by optimal utilization of FRPs.

Keywords: FRP sheet, cost minimization, bridge strengthening.

1. INTRODUCTION

Nowadays, masonry arch bridges, which may belong to past centuries, are crucial elements of the railway transportation network, worldwide. For example, almost 40% of in-service railway bridges in Europe are of this kind [1]. Hence, due to their socio-economic advantages they should be preserved from degradation. Such antique bridges may nowadays be expected to carry loads which are higher than those for which they were built. Because of this increasing demand, the train loads applying to the track system in each axle are increased. So, sufficient increase in their load-carrying-capacity should be provided via structural strengthening.

On the other hand, maintenance and repairing costs are ever-increasing, and therefore, such a strengthening measure should be accomplished with the minimum possible cost. To do so, suitable numerical optimization methods can be used to solve this kind of cost minimization problem. The use of numerical optimization methods in solving such a problem has not been paid attention in the literature. Moreover, the behavior, load-carrying-capacity and reliability level of these historic structures need to be assessed accurately.

It is current to apply numerical methods for solving engineering optimization problems. Metaheuristic algorithms constitute a well-known category of such methods. Genetic Algorithm (GA) [2], Particle Swarm Optimization (PSO) [3] and Harmony Search (HS) [4] are of famous optimization algorithms applied to various engineering optimization and reliability-based design problems [5-10].

In this paper, an efficient numerical optimization algorithm is applied to cost minimization of structural masonry arch railway bridge strengthening. The goal of this contribution is mainly to find the optimal locations in these bridges to attach FRP sheets. To do so, the Sahand-Goltappeh bridge (as a case study of historic masonry arch in-service railway bridge) is numerically investigated under ordinary train pass. Then, the numerical model of the bridge is structurally strengthened such that, the bridge's load-carrying-capacity is increased, and at the same time, the response values of the bridge are reduced to a certain limit. Meanwhile, the strengthening cost will be minimized as far as possible.

2. THE NUMERICAL OPTIMIZATION ALGORITHM

In this study, an efficient numerical optimization algorithm, namely HS-PSO [9], is used for cost minimization. In this algorithm, the harmony memory (HM) is created and improved using particle swarm optimization. On the other hand, the new off-springs generated by PSO, which can be considered as new