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Use of Aluminium Alloys in Retrofitting Ancient Suspension Bridges

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Summary

The retrofitting of suspension bridges can take profit of the specific aluminium alloy characteristics for obtaining the maximum structural effectiveness, particularly if compared to classical solutions based on the use of steel. This paper also emphasizes how different structural materials can optimally co-operate in the suspension bridge scheme, thus characterizing the rehabilitated structure as a particular composite construction. The above aspects are discussed with reference to some case studies.

1. Introduction

During the seventies a rehabilitation program of ancient suspension bridges, constructed between the end of the 19th century and the beginning of the 20th century, has been developed in France. The old structures were made of wooden deck, masonry piers, steel girders and steel suspension chains. The adoption of aluminium alloy floor girders in the retrofit project of three bridges (the Montmerle and the Trevoux bridges on the Saone river; the Groslée bridge on the Rone river), allowed for conserving as much as possible some of the old structural elements, and brought to very effective solutions, both from the cost and the structural performance points of view.
In the Montmerle bridge (two 80 m bays), the use of aluminium both for the two truss beams with bolted connections, and for the deck slab, led to the possibility of increasing the weight of the road vehicles, while preserving both the existing cables and piers without significant strengthening. In the retrofit of the Groslée bridge (a single 174 m long bay) the floor structure is made of three longitudinal aluminium truss girders, connected to a light reinforced concrete slab. In this scheme a remarkable example of co-operation among different structural materials, each of them utilised in an optimum working condition, can be observed: the old masonry piers, the harmonic steel suspension cables, the stainless steel suspension ties, the aluminium alloy reticular girders with high strength steel bolted joints and the light reinforced concrete slab floor.

2. Pre-requisities of aluminium structures

The aluminium alloys can be considered as a family of materials which exhibit a wide range of mechanical properties depending on the type of alloy and the technological treatments [1]. Therefore it is possible to identify alloys which have strength comparable to the common structural steel, and, at the same time, a weight which is one third of the steel one. Due to this specific combined characteristics a high structural effectiveness can be obtained through the use of aluminium alloys. In addition, in the special case of retrofitting suspension bridges, the lightness of the material adopted for the girders allows for reducing the stress both in the steel cables and in the old masonry piers, thus allowing for the maintenance of these existing structural elements. As a further consequence of the reduced structural weight, i.e. of the dead loads, an increase of the live loads, i.e. of the maximum weight of vehicles which the bridge can sustain, can be obtained. Finally the corrosion resistance of the aluminium leads to avoid any surface protections, even in the case of bridges crossing rivers, thus reducing both the initial and the maintenance costs.

3. Advantages of aluminium versus steel

For the Montmerle and the Groslée bridges, extensive structural analyses of the actual retrofit aluminium solution and of an alternative steel solution, both subjected to several load conditions, have been carried out in [2], in order to examine the structural behaviour in the two cases and to point out the reasons which suggested the choice of the aluminium solutions instead of the steel ones. The comparison between the results obtained for the steel and aluminium solutions in both cases substantially showed that: bending stresses in the girders are less in the aluminium solution than in the steel one, axial stresses in the suspension cables are approximately equal in the two solutions and deformations in the floor girders are lightly larger in the aluminium solution, as expected due to the lower Young modulus of the material, but the values of the absolute displacement are still in an allowable range.

In addition to the numerical analyses of these particular case studies, a wide parametric analysis has been carried out in [3] on a simplified structural model of suspension bridge, accounting for second order effects. The main geometrical and mechanical parameters have been varied in a wide range, in order to point out their influence on the distribution of stresses and deformations among the different structural components, and therefore to show under which conditions the maximum benefits can be obtained through the use of aluminium structural elements. It has been observed in [3] that the detrimental effect of the larger deformability of aluminium is significantly reduced by accounting for second order effects in the structural analysis model.

4. A new proposal

A structural retrofit project of the oldest Italian suspension bridge, the "Real Ferdinando" bridge on the Garigliano river, based on the use of aluminium alloy girders, has been recently proposed in the context of a wider rehabilitation program of the zone [4]. The original bridge had a single 85 m bay scheme and the suspension system consisted of two pairs of steel chains, connected to steel ties which sustain the two steel longitudinal truss girders and the wooden transverse beams and floor slab. The proposed project, designed in order to satisfy the requirements of: (a) historic preservation, (b) stiffening of the floor structures, and (c) adoption of innovative technologies and materials, is based on the use of aluminium alloy girders, allowing for the conservation of the original geometrical configuration and appearance. The comparison between the results of structural analyses showed the following advantages of the aluminium with respect to an alternative steel solution: significant reduction of the dead loads; reduction of the required section area of the suspension cables; elimination of the costs necessary for corrosion protection treatments; reduction of repair and strengthening measures required for the masonry piers; easier and less expensive transporting and erection operations due to the lightness of the structural elements.

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