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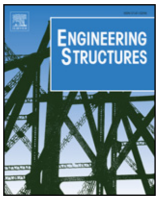

Structural behaviour of aluminium bridge deck panels

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ABSTRACT

The use of lightweight bridge decks made of FRP composites or aluminium alloys is particularly effective for replacing deteriorated bridge decks. Therefore a research program has been undertaken to develop and implement an innovative aluminium bridge deck system, which would be applicable and realizable in domestic conditions. Several service load and ultimate load tests have been carried out on the prefabricated 2.10 × 3.20 m deck panels, in order to examine and evaluate the panel behaviour under standard truck load, and when loaded to failure. The results of the service load study indicated adequate strength and stiffness of the deck panel. Two ultimate-load tests were conducted to further investigate the failure mechanism. The study clearly demonstrates that an aluminium bridge deck panel is a feasible alternative to RC decks from the standpoint of stiffness, strength and load carrying capacity.

1. Introduction

The most vulnerable element of a bridge is its deck. Bridge deck deterioration of older bridges is a significant problem in aging of the highway system. Therefore, RC bridge decks must be replaced every ten to fifteen years. Use of an advanced material bridge deck system is viewed as a potential long-term solution for the concrete deck deterioration problem. The recently developed redecking systems can be grouped according to the material used. The groups are: (1) conventional materials as concrete, steel and timber and (2) modern advanced materials such as engineered cement composite, glulam timber, aluminium alloys and FRP composites. The contemporary progress of metal engineering, which led to the development of new generation aluminium alloys with excellent strength and durability, had led to wider utilisation of this material in civil and transportation engineering [1]. Particularly effective is the use of aluminium alloys in bridge redecking, see Höglund [2], Matteo [3], Okura et al. [4], Soetens and Van Straalen [5]. The removal of a deteriorated heavy RC deck and the replacement with a lighter one, engineered with aluminium, make possible to avoid the strengthening of the superstructure and substructure and thus cut the total cost of modernization. Furthermore the excellent corrosion resistance of aluminium alloys brings the saving of cost, spent for maintenance during service life of a bridge, eliminating also during that time a lot of environmental issues due to painting for corrosion protection. Additionally the application of aluminium deck shortens the closing time of the bridge, needed for carrying out the rehabilitation works. It also reduces the social costs caused by traffic congestions [6].

Recognizing the potential benefits that aluminium could offer the transportation industry, the Department of Roads and Bridges at RUT has undertaken a research program to develop and implement an aluminium bridge deck system, which would be realizable and applicable in domestic conditions. The first phase of this study was to design aluminium extrusions and panels, suitable to bridge decks. On the basis of existing solutions, see Höglund [2], Matteo [3], Okura et al. [4], Soetens and Van Straalen [5], the geometry of extrusion's cross-section has been elaborated and optimized for domestic requirements and production possibilities, and the bridge deck panel made of those extrusions has been designed. The multicriterion analysis carried out according to [7] has showed that the best solution is multi-voided deck with triangle holes. The limit state code checking for the designed aluminium panel has revealed the required capacity, stiffness and safety level, when checked according to Eurocode 9 [8].

The second phase of the study, which is partially reported here, involves the experimental evaluation of the deck panel. Several service load and ultimate load tests have been carried out on the prefabricated 2.10 × 3.20 m deck panels, in order to examine and evaluate the panel behaviour under standard truck load and when loaded to failure. Phase three of the study will focus on the structural and environmental durability of a deck panel on the basis of fatigue testing in the laboratory and corrosion testing in the bridge environment. At the same time, the durability of the wearing surface will be assessed. The last, fourth phase of the study will involve a field evaluation of the deck system, which will replace a deteriorated RC deck. The final results of these tests are expected to be published soon.

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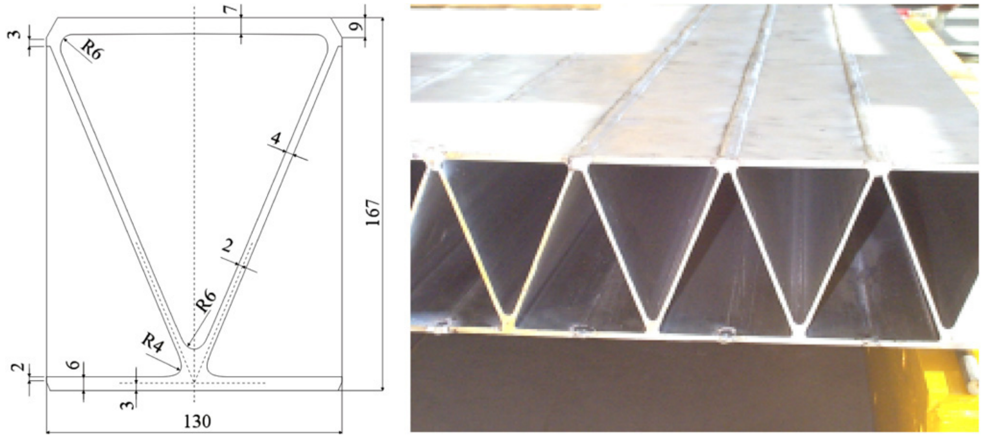

Fig. 1. Cross-section of the aluminium deck extrusion, dimensions in mm.

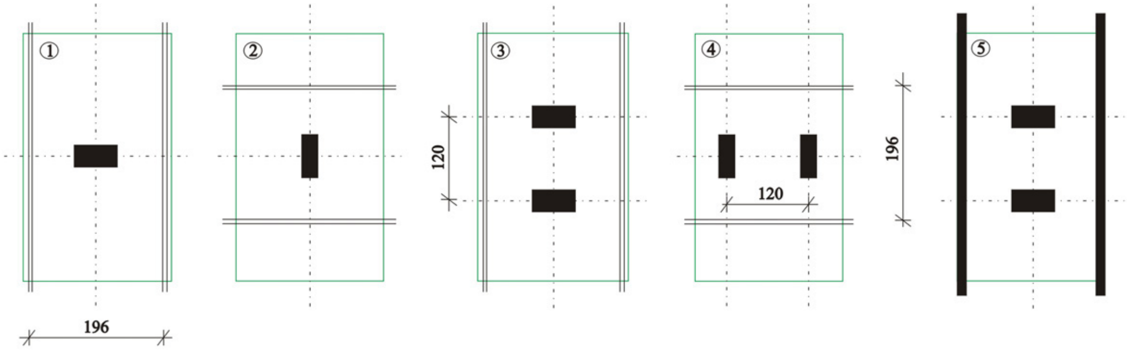

Fig. 2. Panel boundary conditions and service load configurations, dimensions in cm.

Table 1
Material properties of the AW 6005A-T6 aluminium alloy.

Parameter (mean values)	Aluminium alloy AW 6005A-T6	
	Parent metal	Metal in HAZ
Proof strength $f_{0.2}$ (MPa)	250.74	162.98
Ultimate tensile strength f_u (MPa)	280.42	182.27
Minimum elongation A_5 (%)	5.69	3.70
Brinnel hardness HB (kg/mm^2)	94.4	66.7
Modulus of elasticity E (GPa)	74.60	
Shear modulus G (GPa)	27.0	
Poisson's ratio ν	0.3	

2. Bridge deck panel description

The aluminium deck panel consists of hollow extrusions with a cross-section as shown in Fig. 1. On the basis of analysis of the similar deck extrusions, see Matteo [3], a triangular one-voided section of profiles with the height of 0.16 m and the width of 0.12 m was accepted. These dimensions were limited by the capability of the aluminium extruder, which could fabricate extrusions with the section inscribed in a circle with the 0.2 m maximum diameter of piston at that time. After a comprehensive material a study, the AW 6005A-T6 aluminium alloy was chosen for extrusions, because of its excellent mechanical and anticorrosive properties – see Siwowski [9]. Material properties of this alloy obtained from uniaxial tests are given in Table 1 for both patent material and material in HAZ (heat affected zone), i.e. along the centerline of the butt welds. As could be seen in the table the aluminium alloy used in the study has the mean proof strength of 250 MPa and the mean ultimate tensile strength of 280 MPa.

The tests were carried out on the deck panel 2.10 m wide and 3.2 m long, which comprised 16 extrusions welded together with MIG butt welds. The AW 5356 aluminium alloy was used as the filler metal. The dimensions of the individual panel were accepted with the assumption of its use in the bridge to be redecked in the fourth phase of the study. A linear support of the panel on steel beams was arranged in the experiment. The spacing of supports was equal to about 2.0 m, what suits the most frequently applied spacing of the main girders (or stringers) in the existing deck-beam or through truss bridges. Although the resulting deck is geometrically orthotropic, the panel is typically oriented with extrusions parallel to the supporting girders (stringers) and the direction of traffic. The deck constructed in this way cooperates very well with supporting beams, creating a composite system. When installed in this manner, stresses developed under loading can be generated by three different mechanisms, namely (a) longitudinal bending of composite girder — system I stresses; (b) transverse panel bending between beams — system II stresses; (c) transverse bending of panel top plate — system III stresses [10,3].

3. Experimental tests under service load

The main goal of static load tests was to obtain two basic sets of physical parameters: i.e. strains and displacements, to be generated under service load conditions and when loaded to failure. Instrumentation consists of 20 strain rosette gauges installed in strategic locations on the bottom surface and 25 rosette gauges installed on the top surface of the panel. More gauges were used on the top surface due to the presence of the load patch, which was expected to introduce localized stresses. Seven deflection gauges were connected to the bottom surface to record displacement data. All together 52 discrete channels recorded the data.

Five service load tests with the same wheel load magnitude were performed (Fig. 2). However, they used different boundary