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Flexural response of multi-stiffened aluminium beams in dock platforms

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ABSTRACT

In this paper, the flexural response of extruded wrought aluminium girders is presented. This structural element is intended for usage in marine structures such as light docks, marinas and yacht ports. Ease of use, durability, reduced weight, manoeuvrability and the potential development of bespoke sections are appealing properties in such structures that are fulfilled satisfactorily by this type of aluminium elements. Both experimental and numerical analyses are presented. Experimentally, modules of the girders are tested with loading about both minor and major axes. Numerically, the tests are satisfactorily reproduced for the sake of validation and a subsequent exploitation of the model is addressed for further study of the structural response of the girders. A discussion of the results is presented with some design recommendations of these particular structural elements.

1. Introduction

Extruded wrought aluminium stiffened beams are appealing structural elements with particular interest for marine structures such as marinas, yacht ports and docks due to their reduced weight, durability, corrosion resistance, ease of maintenance and operability with small- to medium crafts. The extrusion process facilitates the design of bespoke cross-sections in which both stiffening and geometrical needs related to operability can be matched in a single element with little- to no need of welding. Research related to the structural response of aluminium elements dates back to 1940 [1] and since then, a considerable amount of experimental and numerical investigations has been published. In particular, for the case of flexural response of I-shaped aluminium beams, several studies related to cross-sectional classification [2], compactness [3,4], local buckling including concentrated loads [5,6] and lateral stability [7] are available. For other types of cross-sections such as Channel, Square Hollow and Rectangular Hollow Sections (C, SHS and RHS respectively), the deformation-based design has been proposed [8–10] similarly to other nonlinear metallic materials with pertinent validations using experimental and numerical investigations. Research related to other arbitrary shapes of extruded sections is primarily devoted to the extrusion process and its effect on the final product [11,12]. Durability reports related to inspection, testing and exfoliation of aluminium structural elements are also available [13,14].

Moreover, the structural behaviour of aluminium structural elements has been particularly studied in the marine environment for the case of stiffened plates used as parts of hulls and decks [15–17] in crafts. Durability, corrosion resistance and the ease of weld (using for instance friction stir welding) are appealing properties for the use of such material as part of on-

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and offshore marine structures. The structural applications in the marine environment are thus hulls and decks in high-speed boats, catamarans and superstructures for ships, box-girder bridges in corrosion-prone atmospheres, and walls and floors in offshore modules and containers.

This investigation focuses on the static structural analysis of extruded aluminium beams that are primarily designed as resisting elements in light docks. These structures are presently used along the Spanish littoral in marinas and yacht ports. Considerable aesthetic appeals as well as maintenance, weight and operation advantages provide these elements a promising use as marine light structures. These structures typically include a 3D structural arrangement in which the aforementioned extruded stiffened elements act as longitudinal main girders. On the other hand, transverse and diagonal RHS elements provide an overall structural behaviour. As a result, the design consists of a planar truss whose both lateral chords are the extruded elements whereas diagonal and additional horizontal members act as a platform for the deck. This platform may be built with light materials such as cellular ceramic slim floors, wood, plastic or similar materials. Fig. 1(a) displays a general panoramic view of a platform in the Spanish littoral with mooring lines and small- to medium crafts. Fig. 1(b) shows an aluminium platform in a modular form that may be coupled sequentially for different dock lengths of such marinas. Fig. 1(c) displays a real platform in which the truss is highlighted and Fig. 1(d) shows details of the beam with bespoke joints and shapes which are needed in such elements.

The flexural response of an extruded multi-panelled, stiffened cellular girder is studied both experimentally and numerically. Section 2 describes a set of tests performed at the Laboratory of Structural Technology of UPC. Two extruded aluminium girders with realistic depth proportions were tested to bending for both major and minor axes. The length of the girder was 4,0 m in accordance with the laboratory facilities. The former test (bending about minor axis), is related to lateral loads that may be generated by the crafts whereas the latter (bending about major axis) is related to gravity loads acting on the overall structure. Subsequently, section 3 describes a numerical reproduction of such tests for the sake of validating the computational tool used in the study. Thus, numerical vs. experimental comparisons of the results are provided. Finally, section 4 describes a parametric study in which the numerical tool is used systematically in order to evaluate different design situations to which the extruded girder may be subjected to. The characterising methodology shows ultimate loads, failure modes and deformation capacity of the aluminium elements for different situations which gives hints about their flexural response in bending and about their potential weak areas that control these failure modes. It is important to note that other identified potential loading cases such as dynamic impact loading in both wide or concentrated areas are out of the scope of this piece of research.

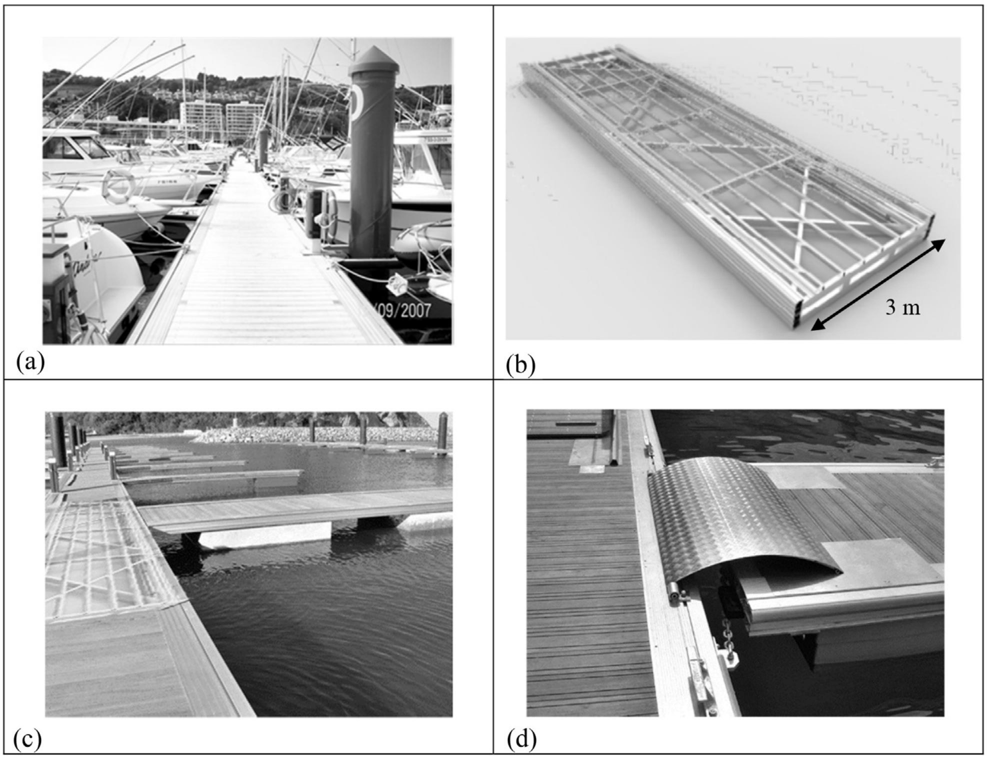

Fig. 1. (a) Panoramic view of the dock (b) Aluminium truss platform model (c) View of the location of the truss in a real platform and (d) Detailing in bespoke sections [23].