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Review

A review of the fire behaviour of pultruded GFRP structural profiles for civil engineering applications

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ABSTRACT

Pultruded glass fibre reinforced polymer (GFRP) profiles are finding increasing applications in civil engineering structures, owing to the several advantages they offer over traditional materials. However, due to the combustible nature of their polymer matrix, there are well-founded concerns about their behaviour at elevated temperature and under exposure to fire. These concerns are hindering the widespread acceptance of GFRP profiles, particularly in buildings, which need to comply with relatively strict requirements in terms of fire reaction and fire resistance behaviour. This paper presents a review about the fire performance of pultruded GFRP profiles. It first addresses the effect of elevated temperature on the thermophysical and thermomechanical properties of the pultruded GFRP material. Then the fire reaction properties of pultruded GFRP profiles and the effects of different fire protection measures on those properties are discussed. Next comes a section reviewing previous experimental and modelling studies about the fire resistance behaviour of different types of GFRP structural members. The final part of the paper provides a summary of the design guidance set out in the most relevant guidelines and codes applicable to pultruded GFRP structures. The most pertinent research needs for the various fire behaviour aspects addressed are also identified.

Contents

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1. Introduction

Glass fibre-reinforced polymer (GFRP) composites are being increasingly used in bridge and building construction thanks to the advantageous properties they can offer compared to traditional materials [1,2]. Among the many processes that can be used to manufacture GFRP load-bearing components, pultruded profiles are the most frequently used in civil construction. Typical pultruded GFRP cross sections mimic steel construction, while more complex multicellular shapes are also available, being assembled using adhesive bonding to form bridge decks (Fig. 1). The usual fibre architectures of pultruded plates comprise alternating unidirectional roving and fabric/mat layers (Fig. 2). Since the content of the rovings normally outweighs that of the fabrics (with fibres transverse to the pultrusion direction), the mechanical behaviour of the profiles is anisotropic – shear stiffness and strength are therefore comparably low, although the total fibre content is high compared to other manufacturing processes.

Today, pultruded GFRP profiles are mainly used in bridge construction for pedestrian bridges or decks of road bridges [3]. Since the cross-sectional height and thus the span of the beams is limited, truss or cable-stayed systems are used in pedestrian bridges to achieve larger spans. These systems basically work in axial tension and compression and less in bending and shear, and are thus well adapted to the anisotropic properties of the profiles. In bridge decks, the profiles are normally arranged in the transverse direction and act as one-way slabs; the limited span of 2–3 m (depending on the system) determines the spacing and number of the main (longitudinal) girders.

In building construction, GFRP profiles are well suited for structures in corrosive environments (e.g., wastewater treatment, indoor swimming pools, cooling towers). The use of GFRP profiles in housing and office buildings is less successful, although they can offer significant advantages such as low weight in the rehabilitation or transformation of existing buildings. The tallest building with a primary load-bearing structure composed of pultruded GFRP profiles is shown in Fig. 3. Since it is a mobile building, which can be (and was already once) dismantled and re-erected, the low weight of the profiles is a significant advantage. Furthermore, due to their low thermal conductivity, GFRP profiles are used as an architectural element in the facade without creating inadmissible thermal bridges. Since the building has a sprinkler system the profiles are not fire protected.

The main barrier to the application of GFRP pultruded profiles in building construction is indeed the sensitivity of the mechanical properties to elevated temperature and fire. The fire conditions in closed rooms of buildings are much more severe than outdoors on bridges where heat can easily escape. This is demonstrated by the

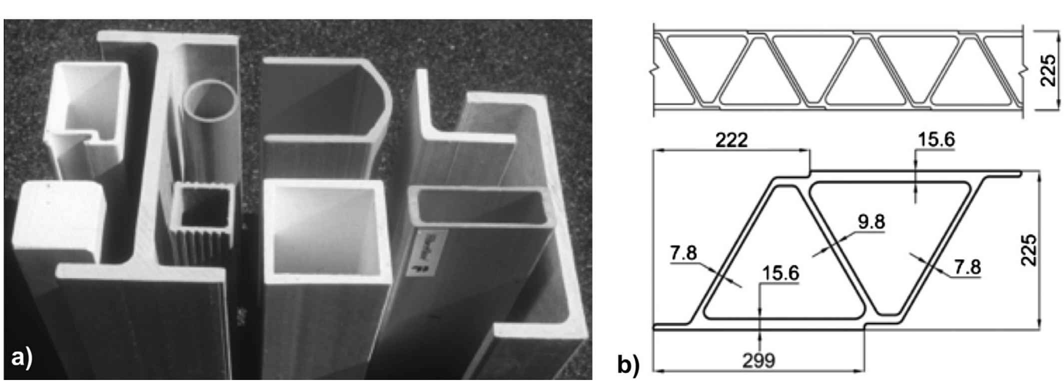

Fig. 1. Typical pultruded GFRP profiles (left) and pultruded GFRP bridge deck system with triangular cell configuration (right).