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Conceptual design of an off-site industrialization process for FRP-based transport infrastructure components

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Abstract

Fiber reinforced polymers (FRP) are used more and more in new construction structural components. Today already first transport infrastructures e.g. road and pedestrian bridges are built out of such components, using mainly manual and not automated manufacturing processes. In order to develop a cost-effective integrated construction process that will enable the maximum capability of automation of components for transport infrastructures using polymer based materials (carbon fiber, glass fiber, etc.) there is a need to industrialize the whole construction process of the FRP components.
Hence the main objective is the conception and development of an automated off-site industrialization process for producing modular FRP-based transport infrastructure components. This overall process will cover the whole production process from the procurement of raw materials up to the transport of the produced components, including the facility layout and the management of involved human resources.
This leads to the conceptual design of an off-site industrialization process for the most suitable highly flexible and agile production process at a high automation level as well as for coping different sizes and quantities of FRP components.
Within this paper different planning activities for the conceptual design of the off-site industrialization process are presented and a detailed description of each planning phase and their associated planning activities is given. To define a conceptual design of the off-site industrialization process, the components that should be produced and the needed manufacturing processes are shortly presented. As a result of this for each component of the bridge, a generic production structure can be assigned and evaluated.
Production areas, logistics as well as a rough layout for the factory have been analyzed and finally a variant for the possible final factory layout is presented.

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Keywords: Factory and Production Planning; Fibre reinforced polymers (FRP); Industrialization

1. Introduction and Problem Statement

Polymer composites, also known as Fibre Reinforced Polymers (FRPs), are commonly used for strengthening existing structures in concrete and steel in civil and building construction. Fiber reinforced polymers (FRP) are used more and more in new construction structural components. Today already first transport infrastructures e.g. road and pedestrian bridges are built out of such components, using mainly manual and not automated manufacturing processes. Potential capacity of these materials is not yet been exploited because of complex manufacturing processes for composites components in construction that currently are based either on inefficient manual processes or in processes unable of taking advantage of the full capacity of these materials [7].

In order to develop a cost-effective integrated construction process that will enable the maximum capability of automation of components for transport infrastructures using polymer based materials (carbon fiber, glass fiber, etc.) there is a need to industrialize the whole construction process of the FRP components.

Hence the main objective is the conception and development of an automated off-site industrialization process for producing modular FRP-based transport infrastructure components. This overall process will cover the whole production process from the procurement of raw materials up to the transport of the

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produced components, including the facility layout and the management of involved human resources.

The overall concept represents the systematization and structuring of all planning activities and their related planning objects. Different planning activities for the conceptual design of the off-site industrialisation process are presented and a detailed description of each planning phase and their associated planning activities is given. Based on that, production areas, logistics and a rough layout for the factory will be analysed and finally different variants for the possible final factory layout are presented.

The developed concept is a part of the European research project "New Industrialised Construction Process for transport infrastructures based on polymer composite components" (TRANS-IND – EU FP7-NMP) on innovative concepts and technologies to enable the maximum capability of industrialisation of components for transport infrastructures (road and pedestrian bridges, underpass, containing walls, acoustic and safety barriers) using polymer based materials.

2. FRP Structural Components

The next chapters concentrate on the product and the required manufacturing processes for this purpose. To establish the relationship between the product parts (components) and the manufacturing processes the product is presented first. Once the components are described, they can be assigned to the appropriate manufacturing processes according to the desired shape and characteristics. This forms the basis for later activities in order to create a precedence planning graph, describing what processes can run in series or parallel.

2.1. Beams

A beam is a structural element that is used to absorb load and resist bending. They are designed to carry horizontal (e.g. earthquake, wind) as well as vertical loads. Beams are characterised through their profile, their length and their material.

The profile of the beams can be open-shaped, closed-shaped and u-shaped [11]. The expected beams are 10-40 meters long and consist of the following components:

- Sheath
- Diaphragm- Modules

The assembled beam is mounted on two concrete columns. It is expected that a fabricated beam which has to stand on two columns therefore consists of a sheath and diaphragms. The number of diaphragms depends on the beam`s design (length and type of the beam). The aforementioned components can also be seen in Fig. 1 schematically, which shows the draft of the beam in an early planning phase.

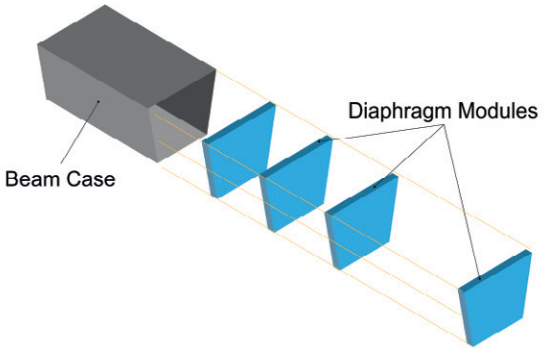

Fig. 1: Exploded drawing of a composite beam in an early planning phase.

2.2. Decks

A deck is a flat surface capable of taking weight and is designed for applications in vehicular and pedestrian bridges (see Fig. 2). The used materials to manufacture this deck are glass, epoxy resin and concrete. The deck components can be applied on different types of beams mentioned in the former section [11]. Two different types of decks can be produced: one made of thermoset material and another one made of thermoplastic material. These products have to pass other processes (e.g. pultrusion processes, cutting processes) until they can be shipped to their final destination.

2.3. Acoustic and Safety Barriers

For bridges made out of FRP structural components, two different types of barriers can be defined, acoustic barriers and safety barriers. An acoustic barrier is an element to protect sensitive land uses from noise pollution. They are the most effective method of mitigating roadway, railway and industrial noise. Within this work three topologies of acoustic barriers are considered to assure the most suitable solution for noise reduction: Simple acoustic barriers, acoustic barriers with vegetation, curved acoustic barriers. All these acoustic barriers systems consist of panels made of glass reinforced polymers (GFRP), supported by glass fibre H-shaped soldier piles [11]. A safety barrier is a component which prevents unwilled access to a locked or potentially deadly area. In traffic it is a guard, such as a fence, to keep the vehicle away from falling down e.g. a bridge or cliff.

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