

Virtual Simulation of the Construction Activity

Bridge Decks Composed of Precast Beams

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Abstract— In the execution of bridge or overpass decks several construction processes are applied. A geometric model 4D (3D + time) in a Virtual Reality environment which simulates the construction of a bridge deck composed of precast beams was implemented. The model allows viewing and interaction with the various steps and the main elements involved in the construction process. In order to develop the virtual model, the components of the construction, the steps inherent in the process and its follow-up and the type and mode of operation of the required equipment were initially examined, in detail. Based on this study, the 3D geometric modeling of the different elements that make up the site was created and a schedule that would simulate an interactive mode of construction activity was established. As the model is interactive, it allows the user to have access to different stages of the construction process, thus allowing different views in time and in space throughout the development of construction work, thereby supporting understanding of this constructive method. Since the model is didactic in character it can be used to support the training of students and professionals in the field of Bridge Construction.

Keywords - Bridge construction; interaction; simulation; virtual reality.

I. INTRODUCTION

In Civil Engineering, there are several construction methods for the execution of bridge decks. This study analyses the constructive method applied to bridge decks using precast beams. In Civil Engineering prefabricated elements are frequently used, because they offer several advantages in urban areas, in works over railway lines, and in general in areas where the placement of trusses is difficult, as this allows quick and economical construction without generating significant local constraints.

Using prefabrication in bridges presents several advantages, such as: the good quality of the concrete of the components produced; economic benefits that result from the use of optimized and standard solutions, which can be used repeatedly throughout the whole process; reduction of congestion on the construction site and the shortening of time-limits for construction, and finally, greater security because it reduces the number of tasks to be carried out on site [1].

This present work aims to contribute to the dissemination of this methodology of construction through a visual

simulation created in a virtual environment and to draw attention to its usefulness as a teaching tool, supporting, as it does, the in-depth understanding of this process. For the creation of a visual simulation application Virtual Reality (VR) technology was applied. This technology offers advantages in communication allowing the user to interact with the 4D model as it allows access to different modes of viewing the model in space and time [2].

In order to create models, which could visually simulate the progressive sequence of the process and allowing interaction with it, techniques of virtual reality were used.

When modelling 3D environments there must be a clear idea of what should be shown, since the objects to be displayed and the details of each must be appropriate to the goal the teacher or designer wants to achieve with the model. The use of virtual reality techniques in the development of these didactic applications is, also, generally beneficial to education in that it improves the efficiency of the models in the way it allows interactivity with the simulated environment of each activity. The virtual model can be manipulated interactively allowing the teacher or student to monitor the physical evolution of the work and the construction activities inherent in its progression. This type of model allows the participant to interact in an intuitive manner with 3D space, and to repeat the sequence or task until the desired level of proficiency or skill has been achieved always performing in a safe environment. Therefore, it can be seen that this new concept of VR technology applied to didactic models brings new perspectives to the teaching of subjects in Civil Engineering education [3].

The model discussed here follows other VR models developed within the Technical University of Lisbon at the Department of Civil Engineering, concerning construction works (Figure 1): The models relate to the cantilever process and the incremental launching method of bridge deck construction [4].

II. CONSTRUCTIVE PROCESS OF BRIDGE DECKS

The construction of bridge decks composed of prefabricated beams uses an equidistant distribution of isolated elements placed side by side, complemented by a slab that establishes continuity on the surface of the deck.

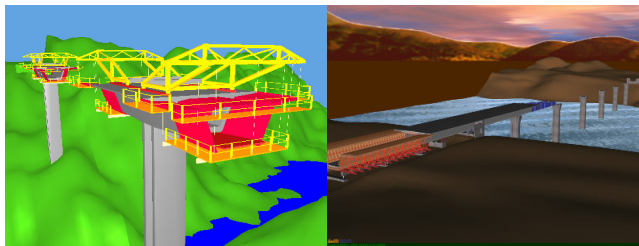


Figure 1. Didactic virtual models of bridge deck construction.

The prefabricated beams are usually built with a length equal to the bridge spans, each consisting of several beams connected from above by a slab concreted “in situ”, and crosswise by transversal beams located on the support. The slab can be made “in situ” using a false-work or pre-slabs, which can contribute to structural strength or assist only as formwork while the slab of the deck is concreted. The most common cross sections in these types of beams are I- shaped (Figure 2) or, sometimes, U-shaped. The shape of the section is determined by various constraints, such as: the procedure of manufacture; the pre-stressing system used (pre- or post-tensioned); transport and assembly; the construction method of the bridge deck slab.

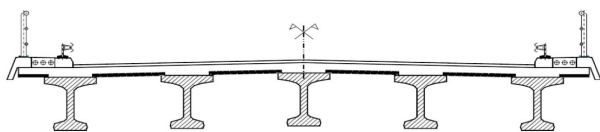


Figure 2. Cross section of a bridge with "I" beams [5].

The constructive method applied to bridges with prefabricated beams can include differences in placement of prefabricated beams, or the type of connection between elements and execution of slabs. The first step consists of placing the prefabricated beams, which can be carried out by means of cranes a launcher (Figure 3).

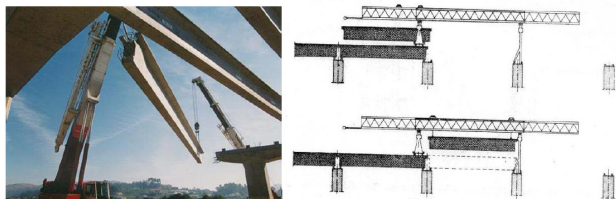


Figure 3. Placing of precast beams on the pillars [6].

The constructive method applied to bridges with prefabricated beams can include differences in placement of prefabricated beams, on the type of connection between elements and implementation of slabs. The first step consists in placing the prefabricated beams, which can be effected by means of cranes or by means of a launcher. After placing the prefabricated beams in its final position, can be used several solutions of connection between these elements and structure: isostatic spans (consist of separate sections, separated by expansion joints, simply supported on the pillars); isostatic spans with solid slab over the joints (prefabricated beams are assembled on supports in an independent way, and a slab in concreted over the joints

defining the continuity of the overall deck); hiperstatic solid spans with ordinary reinforcements (continuity is performed by placing the longitudinal slab continuous reinforcements, on the supports, and the space between beams is concreted).

After placing the prefabricated beams in their final position, the connection between these elements is performed using pre-slabs: This method consists of replacing the shuttering and supporting structure of the previous solution for reinforced concrete or pre-stressed slabs with a thickness that usually varies between 6 cm and 10 cm. These pre-slabs can be used as lost shuttering, - in construction they can be used only to support the concrete slab or as bi-functional formwork, that is, functioning as formwork during the constructive phase, but as reinforcement during service.

III. GEOMETRIC MODELLING AND EQUIPMENT

After different kinds of bridge deck construction methods had been analyzed, a commonly used model was chosen for the implementation of the 4D (3D + time) virtual model. The deck is composed of beams with I-shaped cross section, lifted by cranes and supplemented with composite pre-slabs. Initially, three-dimensional (3D) geometric modeling of all elements necessary to the implementation of the desired visual simulation was created. The example modeled corresponds to a bridge with the highway profile composed by five spans with the extension of 30m (central) and 24m (lateral) [7]. The cross-section of the bridge deck consists of 4 precast beams (Figure 4).

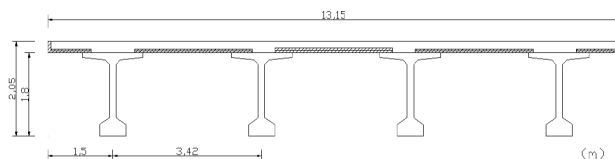


Figure 4. Cross section of the deck.

The 3D modeling process is initiated with the generation of the surroundings of the working place, followed by the pillars, stair towers, worker platforms, provisional and definitive supports and two cranes needed to lift the precast beams.

Figure 5 represents the configuration of the cross-section of the prefabricated beam used and the respective 3D model. In the projection it is possible to see: the running boards (red), protruding out of the beam, which serve to provide resistance and support for the connection of concrete of different ages of the deck slab; the reinforcements connecting precast beams (yellow); other reinforcements needed for lifting the beam (blue).

For the execution of the slab composite pre-slabs were chosen. The dimensions applied in creating the 3D model of the pre-slabs were established based on the drawings of the design of Beira Interior viaducts. Differentiation can be made between pre-slabs, depending on their location on the cross-section: type 1, between beams or type 2, in the console.

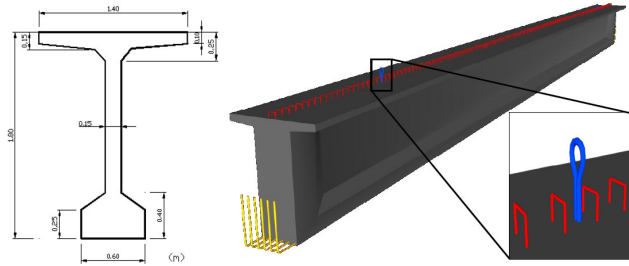


Figure 5. Cross section and prefabricated beam model.

Figure 6 shows a picture of the placement of both types of pre-slabs. The virtual model includes two types of pre-slabs: central and cantilever.

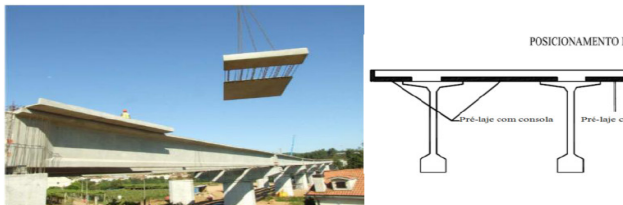


Figure 6. Placement and position of pre-slabs on the deck.

Figure 7 illustrates the geometric model of two kinds of pre-slabs used in the virtual model. The pre-slab in the console is placed in the side of the deck cross-section and the central pre-slab is placed between beams.

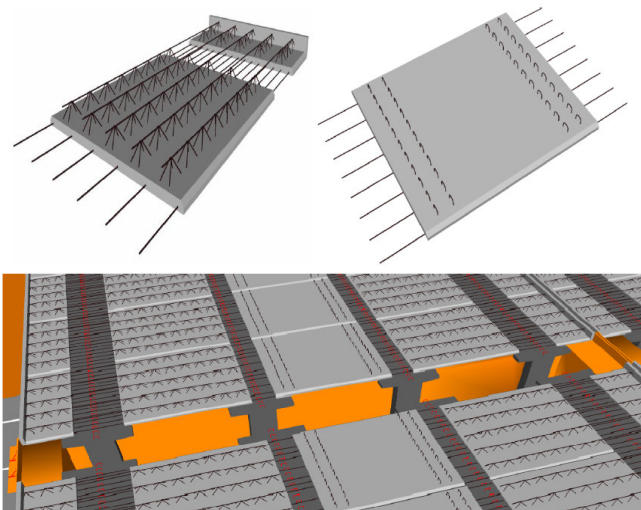


Figure 7. 3D models of the pre-slabs.

IV. THE CONSTRUCTIVE PROCESS ACTIVITY

The visual simulation of the construction was accomplished using software based on the Virtual Reality (VR) technology, the Eon Studio (www.eonreality.com). In accordance with the programmed sequence of the construction:

- The virtual simulation starts with the presentation of the work place environment;

- The simulation of the construction activity continues with the insertion of additional elements, such as the stair towers (for access to the top of the pillars) and the work platforms (which allow the workers to move around and complete their tasks) (Figure 8).

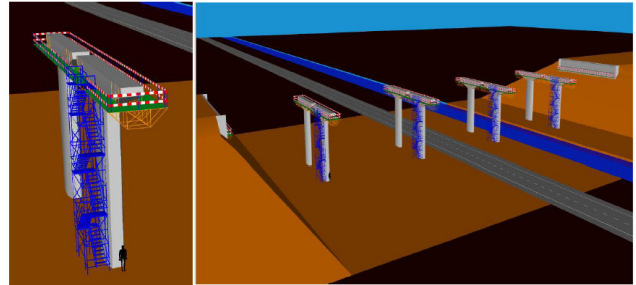


Figure 8. Display stair towers and work platforms.

- In the virtual space the placing of the definitive support device is simulated, followed by the placement of the temporary support, on the top of the pillars (Figure 9);

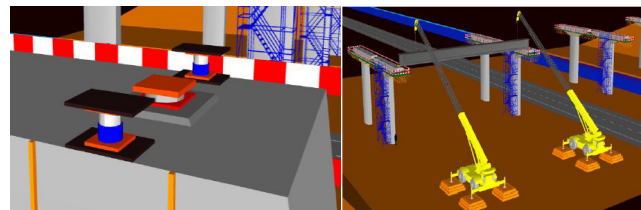


Figure 9. Placing of definitive and provisional support and the prefabricated beam.

- Each beam is raised by two cranes and placed on the temporary support devices (Figure 9);
- The simulation of construction process proceeds with the placement of the pre-slabs on the prefabricated beams (Figure 10);

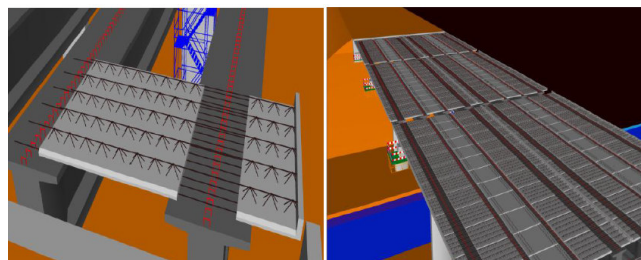


Figure 10. Placement of pre-slabs and concrete transversal beam and slab.

- At this stage, it was found that due to the large amount of reinforcements set in the pre-slabs (Figure 11), the movement of the camera (from the point of view of the user) through the virtual environment was very slow because the drawing file was already too heavy. It was, therefore, decided not to display 3D model of the pre-slab reinforcements and also the brackets from prefabricated beams;

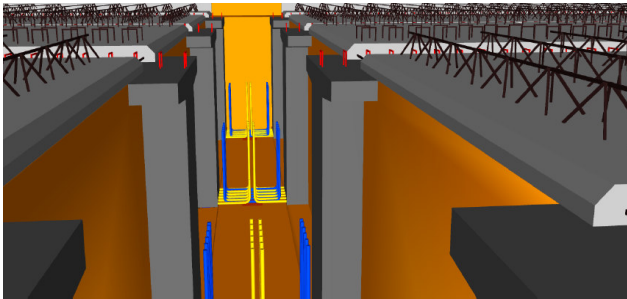


Figure 11. Large amount of reinforces set in the pre-slabs.

- Then, the reinforcement of the slab is placed over the pre slabs and the deck slab is concreted (Figure 12);

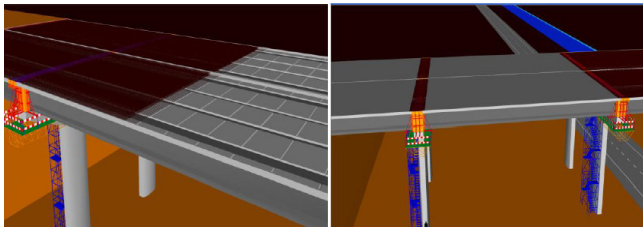


Figure 12. Placing reinforcement and concreting the deck slab.

- Next, the transversal beams are concreted. Figure 13 illustrates the reinforcements, the 3D model and the placement of the formwork and reinforcement of one of the transversal beam;

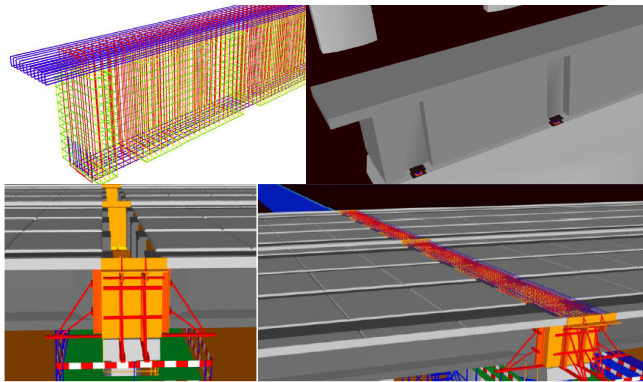


Figure 13. Concreting one of the transversal beam.

- After the completion of the construction of the deck the provisional support devices are removed (Figure 14);

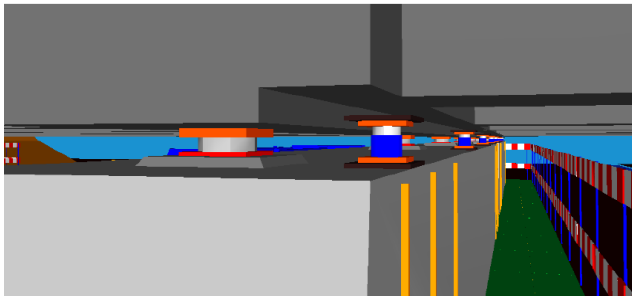


Figure 14. Removing the provisional support devices.

- Finally all complementary elements necessary for the road traffic were inserted into the top of the deck (Figure 15).

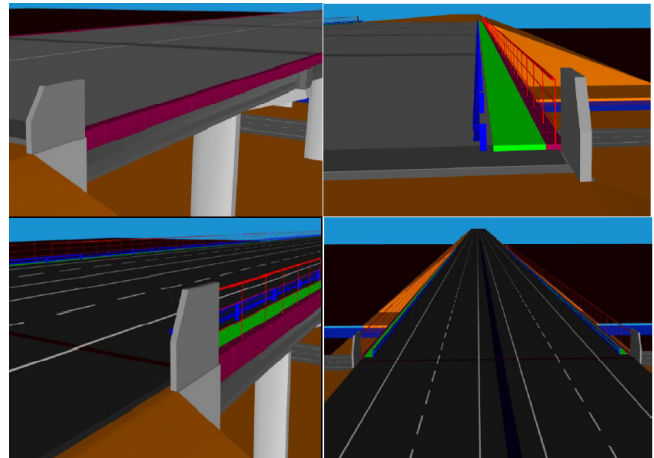


Figure 15. Placing the complementary elements.

- The complete bridge can now be observed from any point of view (Figure 16). The model allows the user to use the zoom sufficiently well in order to understand the final configuration of the bridge.

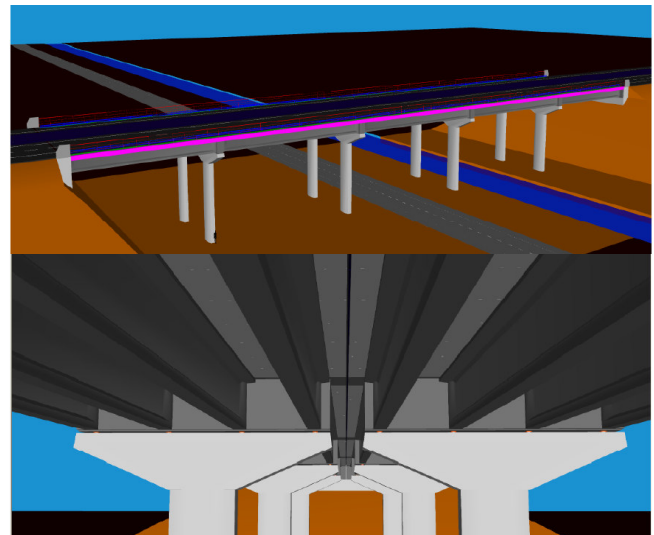


Figure 16. Views of the complet deck.

V. EDUCATIONAL ASPECTS

The virtual model is currently used in the discipline of Bridges. The introduction of the topic on the construction processes used in bridges, in particular, the methods related to bridges composed of precast beams is supported with the visual and animated simulation of the modeled construction deck. The teacher of bridges, which refers to the use of the virtual classroom model, verifies that the student is quite observant with the lively presentation of the entire process of construction of the bridge. All constructive and the sequence type and geometric form of constructive elements required in

the execution of the deck are presented in the virtual model with enough clarity.

The model was implemented with great accuracy in terms of scientific content in order to obtain a correct model technically and so is effective as a teaching model. The target student of the virtual application is the student of the last year of the course of Civil Engineering, in particular of the area of Structures, as is the branch that is more related to the general theme of bridges. The constructive process of bridges is a theme that is fundamental in the teaching of design and types of bridges. This model and other previously performed (incremental method and method of advances [4]) composes together with this virtual model, a set of educational tools, based on IT (information technology) and VR (virtual reality), which serve as support for the discipline of Bridges. The models were made available to students in the www sites of Bridges and research related to masters' theses. There request and manipulation are made available to any student.

VI. CONCLUSIONS

This paper analyzes some constructive processes concerning bridge deck formed of precast beams and describes the implementation of an interactive model that simulates the construction work activity. The virtual application shows one of the methods most often applied in the construction of this type of Deck Bridge. In the creation of the model software based on the RV technology was used.

Virtual Reality allows, through interaction with 3D models of the environment, representing building components and equipment, the creation of the constructive sequence in time and space by simulating the progression of the construction of the deck, which allows a good understanding of the whole process.

The model 4D (3D + time) offers several advantages, allowing a deeper awareness of the relationship of the components of the building and the phasing of the work, leading to a better understanding of the spatial movement of equipment and of the component placement in work. Since the traditional designs of graphic documentation of the construction project are sometimes more difficult to understand, it can be seen that this model is clearly didactic in character and as such can be used to support the training of students and professionals in the field of Bridges.

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