

# Didactic VR Model in Bridge Construction



Alcinia Z Sampaio, Luis Viana  
University of Lisbon, Dep. Civil Engineering and Architecture  
Portugal  
[zita@civil.ist.utl.pt](mailto:zita@civil.ist.utl.pt), [luis.viana7@gmail.com](mailto:luis.viana7@gmail.com)

**ABSTRACT:** *In the execution of bridge or overpass decks several construction processes are applied. A geometric model 4D (3D + time) in a Virtual Reality (VR) 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 followup and the type and mode of operation of the required equipment were initially examined, in detail. Based on this study, the 3D geometric modelling 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. The VR application is currently used to support Bridge classes.*

**Keywords:** Bridge Construction, Interaction, Education, Virtual Reality

**Received:** 1 December 2014, Revised 2 January 2015, Accepted 5 January 2015

© 2015 DLINE. All Rights Reserved

## 1. 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 allow 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].

Currently, the information related to the construction of buildings is based on the planning of action to be taken and on the log of completed work. It is also applied in education. The capacity to visualize the construction activity can be added through the use of three-dimensional (3D) models which facilitate the interpretation and understanding of process sequence of construction and, furthermore, the possibility of interaction with the geometric models can be provided through the use of Virtual Reality (VR) technology. The developed VR models can be considered as useful computer tool with advanced visualization capacities in the education and construction fields. The interaction with the construction steps visualization allowed by the models turn these applications simple and direct to be used in an educational perspective. The VR technology is actually used in areas like education as a teaching support tool or in planning processes concerning industry as a collaborative tool. In architectural design studio, Abdelhameed [4] applies micro-simulation function, inside a virtual reality environment, using the VR Studio program, in order to provide the students with an effective tool to select and visualize a structural system and its construction process. Sampaio and Martins [5] present didactic VR models applied to the construction of bridge field, and developed a set of learning activities for students, in the Engineering Graphics subjects, in order to acquire, develop and improve their levels of spatial skill and, for that purpose; they have structured training with VR and Augmented Reality (AR) technologies. Fillatreau et al. [6] develop a framework for immersive industry checklist-based project reviews, combining immersive navigation in the

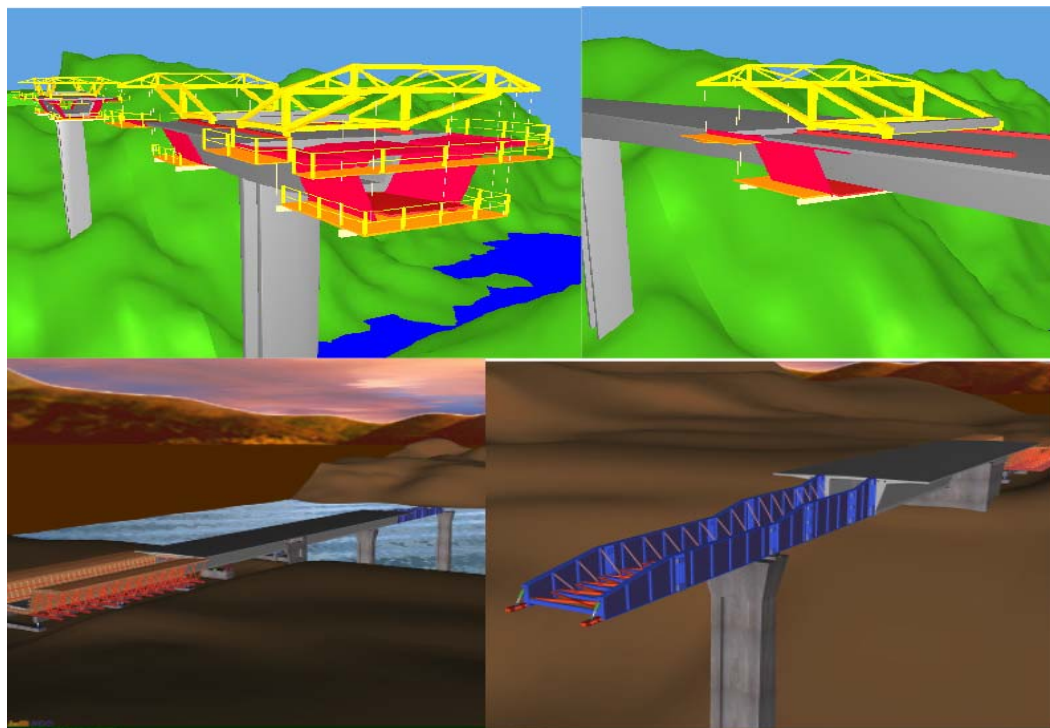


Figure 1. Didactic virtual models of bridge deck construction

checklist, virtual experiments and multimedia update of the checklist, relied on the integration of various VR tools and concepts, in a modular way, and Menck et al. [7] uses VR as a tool for collaboration to exchange information and data has increased significantly over time in production-related areas.

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 [8].

## 2. 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. 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.

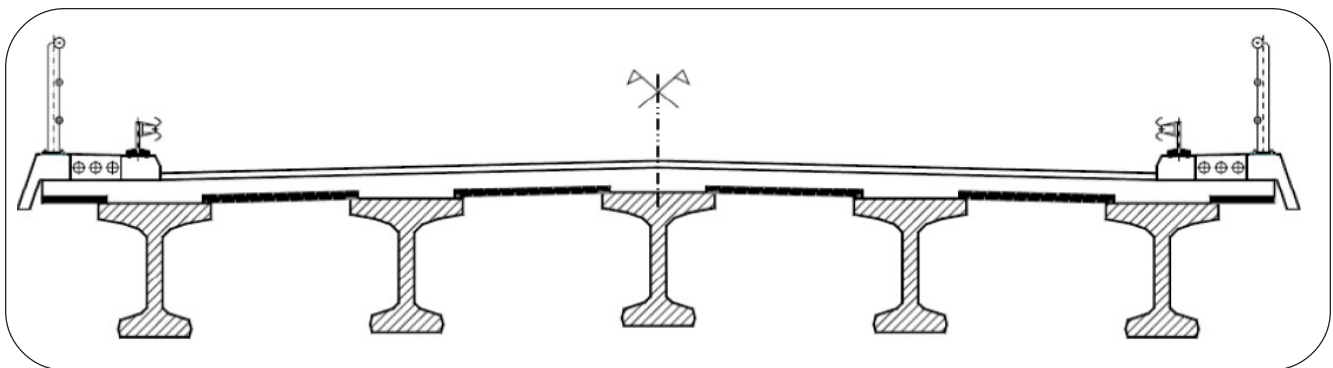


Figure 2. Cross section of a bridge with “I” beams [9]

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).

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.

### 2.1 Geometric Modelling and Equipment

After different kinds of bridge deck construction methods had been analysed, a commonly used model was chosen for the implementation of the 4D (3D + time) virtual model [11]. 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 modelling of all elements necessary to the implementation of the desired visual simulation was created. The example modelled corresponds to a bridge with the highway profile composed by five spans with the extension of 30m (central) and 24m (lateral) [12]. The cross-section of the bridge deck consists of 4 precast beams (Figure 2).

The 3D modelling 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.

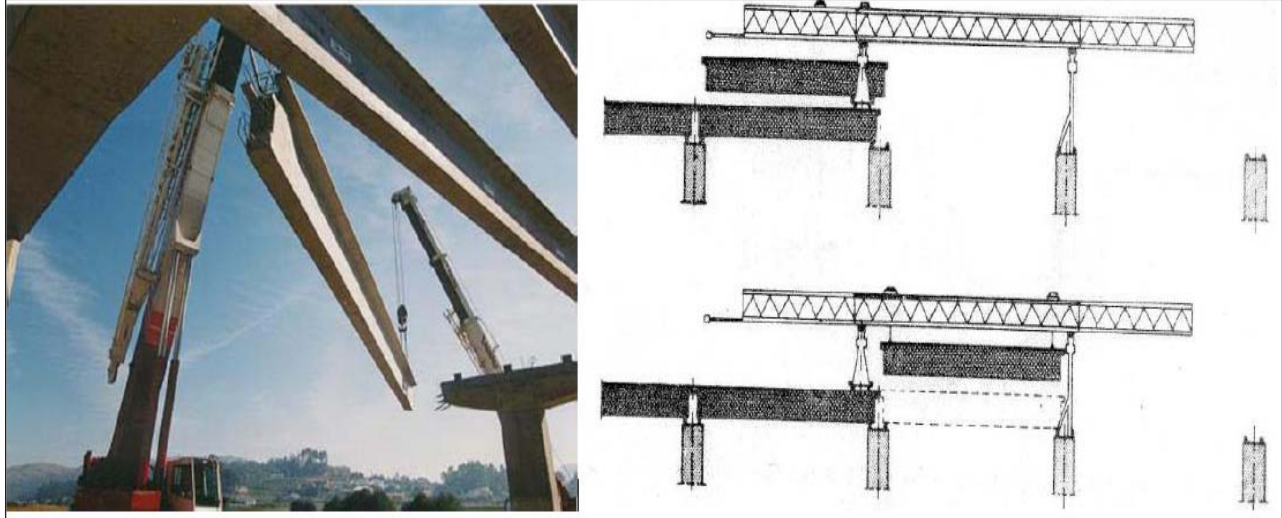


Figure 3. Placing of precast beams on the pillars [10]

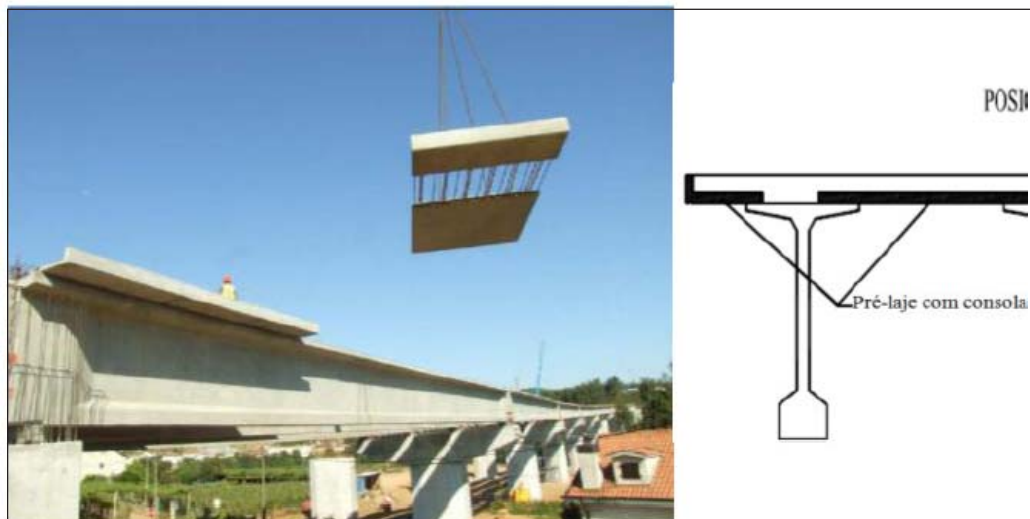
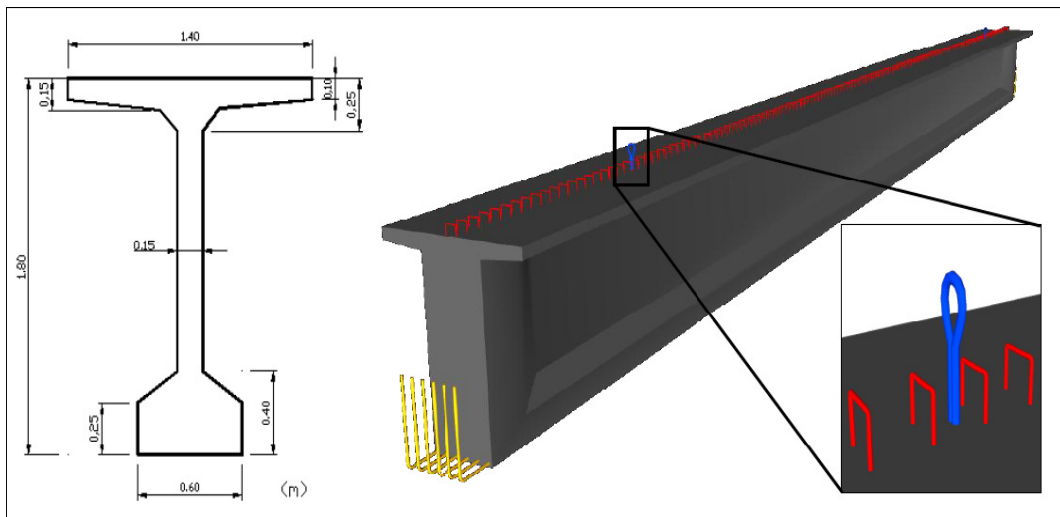


Figure 4. Cross-section and prefabricated beam model and placement and position of pre-slabs on the deck



Figure 4 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 crosssection: type 1, between beams or type 2, in the console. **Error! Reference source not found.** 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 5 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.

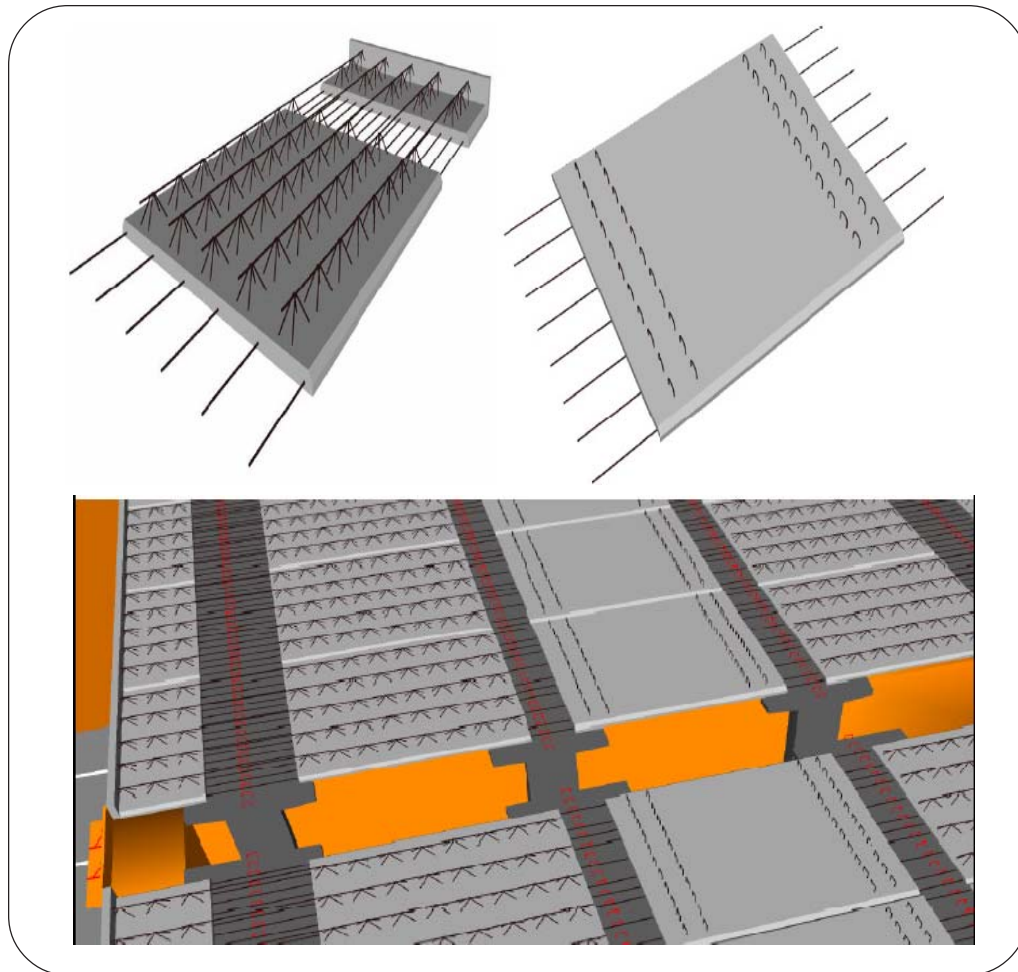


Figure 5. 3D models of the pre-slabs

## 2.2 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](http://www.eonreality.com)). In accordance with the established 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 6).

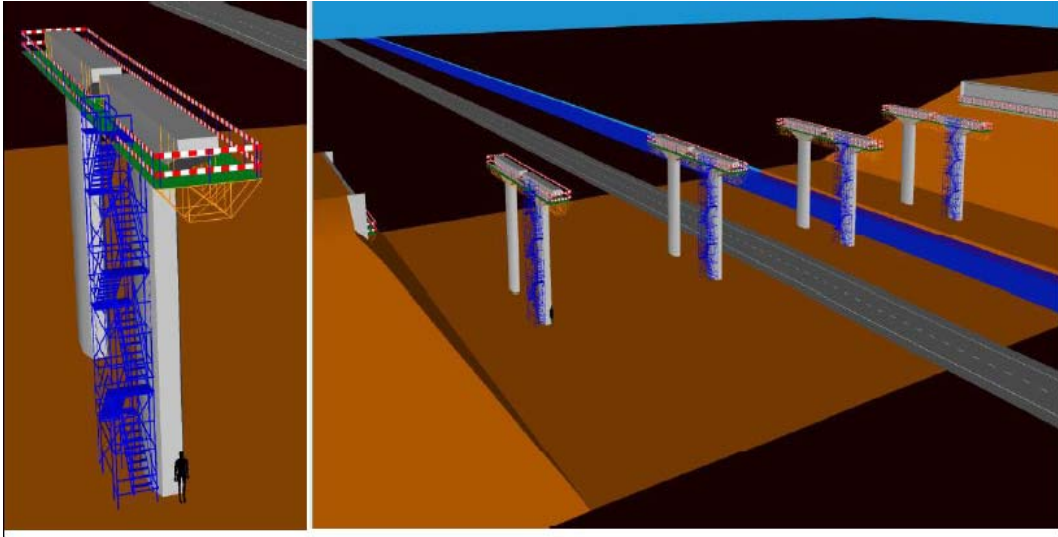


Figure 6. Display stair towers and work platforms

- 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 7);
- Each beam is raised by two cranes and placed on the temporary support devices (Figure 7);

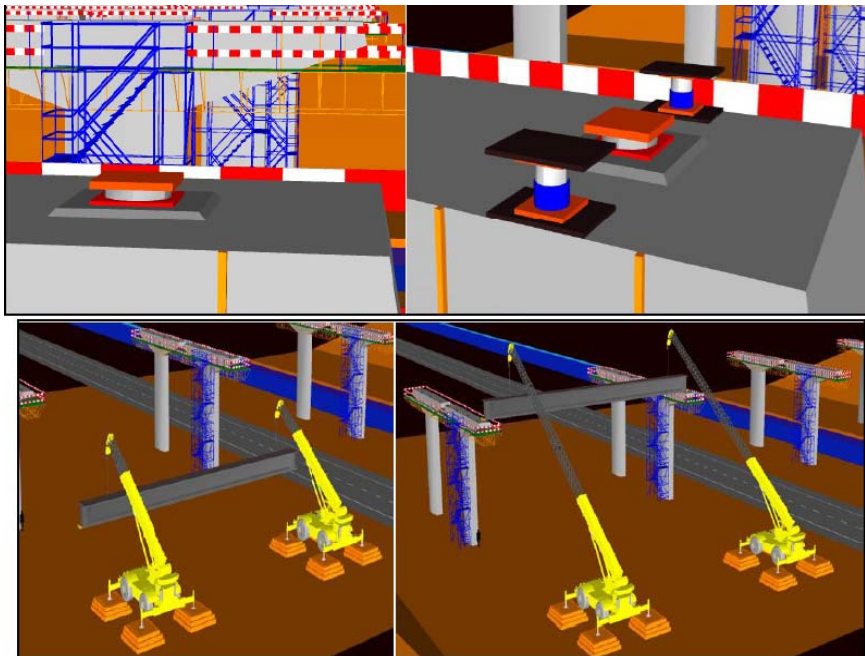


Figure 7. Placing of definitive and provisional support and the prefabricated beam

- The simulation of construction process proceeds with the placement of the pre-slabs on the prefabricated beams (Figure 8);
- At this stage, it was found that due to the large amount of reinforcements set in the pre-slabs (Figure 3), 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;

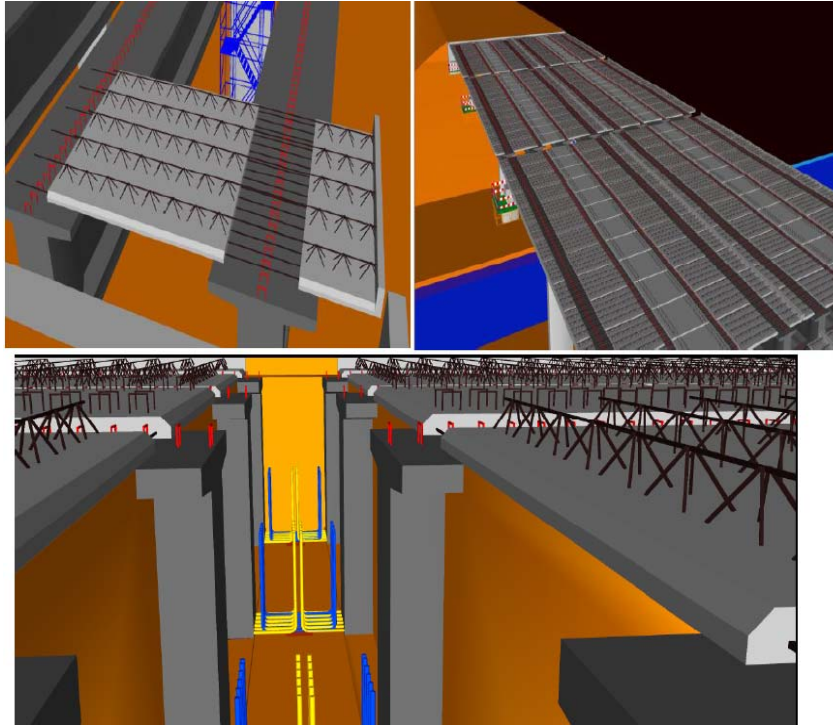


Figure 8. Placement of pre-slabs and concrete transversal beam and slab and large amount of reinforces set in the pre-slabs

- Then, the reinforcement of the slab is placed over the pre slabs and the deck slab is concreted (Figure 9);
- Next, the transversal beams are concreted. Figure 9 illustrates the reinforcements, the 3D model and the placement of the formwork and reinforcement of one of the transversal beam;

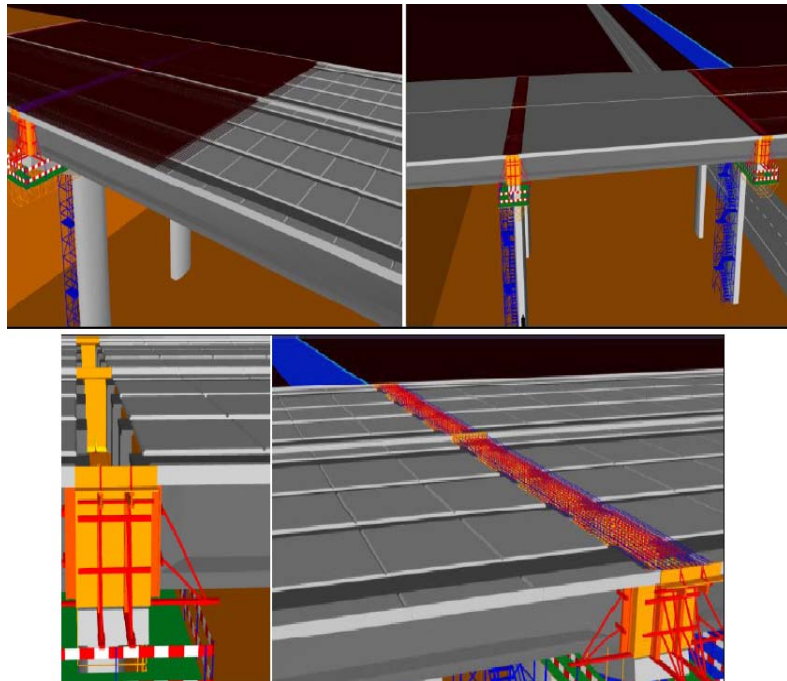


Figure 9. Placing reinforcement and concreting the deck slab and concreting one of the transversal beam.

- After the completion of the construction of the deck the provisional support devices are removed (Figure 10);

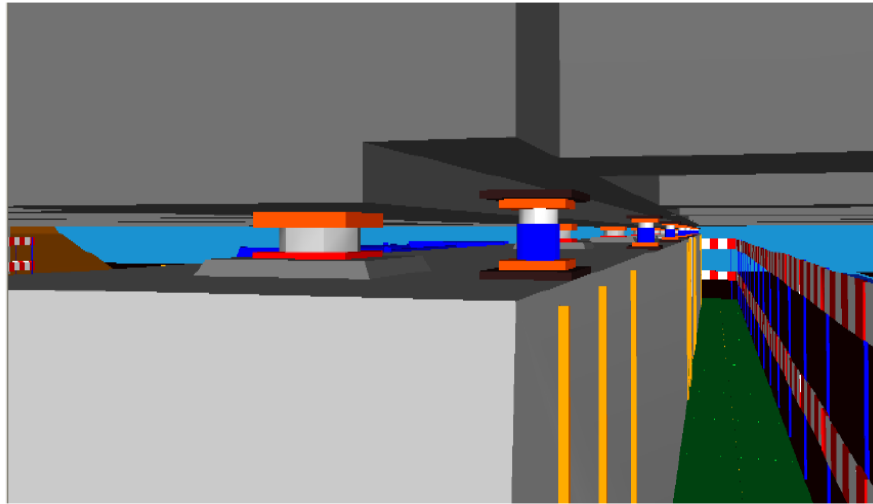


Figure 10. Removing the provisional support devices

- Finally all complementary elements necessary for the road traffic were inserted into the top of the deck (Figure 11).
- The complete bridge can now be observed from any point of view (Figure 11). The model allows the user to use the zoom sufficiently well in order to understand the final configuration of the bridge.

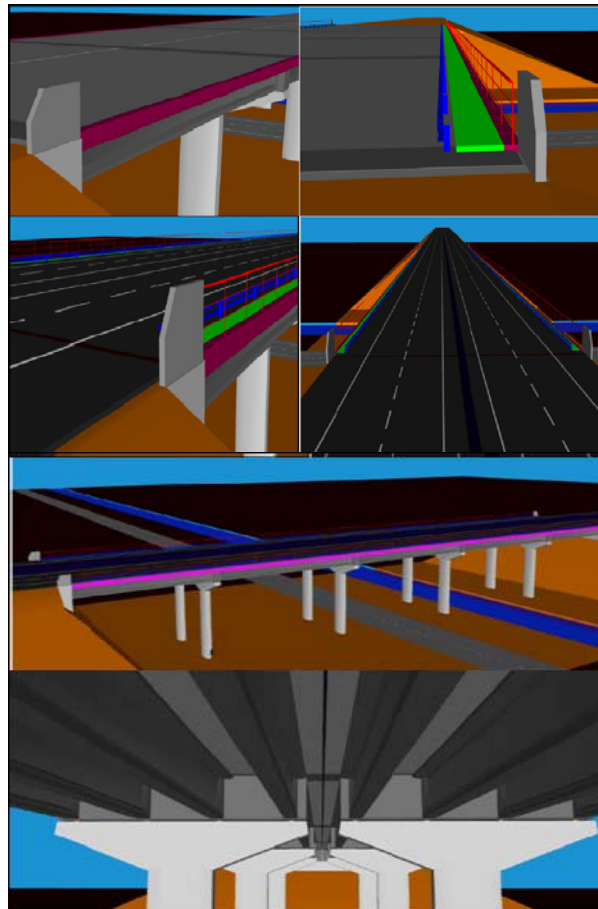


Figure 11. Placing the complementary elements and views of the complete deck



### 3. DIDACTIC ASPECTS

The main objective of the practical application of this didactic model concerning a bridge construction process is to support class-based learning and in distance learning using e-learning technology. A didactic application to be used as an e-learning tool must meet the following requirements: reusability, accessibility, durability and interoperability [13]. Thus, it seeks the same educational database for be used by the international community through different learning software. Furthermore, it is necessary employ an accepted format with the aim of facilitate communication between different databases of several areas of knowledge. Also another important point to be considered is those models in e-learning institutions should be independent of country, language or any other regional circumstances in the process of creation the didactic models.

The use of the EON software, a system of virtual reality technologies, on the development of the didactic model, which can be free downloaded, enables the VR application to be used for a multitude of handlers. For that, the user should download the EON Viewer application available at: <http://download.eon-reality.com>. Through direct interaction with the models, it is possible to monitor the progress of the construction process of the bridge. The objective is not to replace current training methods but to position accurate as an additional teaching method. To do so, there were developed immersive 3D models that were based on an actual method of teaching. The model is currently being used in face-to-face classes of bridge discipline and the understood achieved by the students is related by the bridge's teacher as substantially increased.

### 4. Conclusions

This paper analyses 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.

### References

- [1] Câmara, J. N. (2001). Prefabrication of bridges and viaducts, National Meeting of Prefabricated Structures, Prefabricated Company Castelo, Lisbon, Portugal, January.
- [2] Woksepp, S. (2007). Virtual Reality in Construction. Tools, Methods and Processes, PhD thesis in Civil Engineering, Luleå University of Technology, Sweden.
- [3] Sampaio, A. Z., Henriques, P. G. (2008). Virtual Reality Technology Applied to the Visual Simulation of Construction Activities, The Open Construction & Building Technology Journal, Mathew Honan, Editorial Director, Bentham Science Publishers Ltd., 2, p. 7-14.
- [4] Abdelhameed, W. A. (2013). Virtual Reality Used in Architectural Design Studios: A Case of Studying Structure And Construction, Procedia Computer Science, 25, 2013, p. 220-230.
- [5] Sampaio, A. Z., Martins, O. P. (2014). The Application Of Virtual Reality Technology In The Construction Of Bridge: The Cantilever And Incremental Launching Methods, Automation in Construction, 37, January, p. 58-67.
- [6] Fillatreau, P., Fourquet, J.-Y., Cailhol, R. M., Le Bolloc'h, S., Datas, A., Puel, B. (2013). Using Virtual Reality And 3D Industrial Numerical Models For Immersive Interactive Checklists, Computers In Industry, 64 (9), Dec. 2013, p. 1253-1262.
- [7] Menck, N., Weidig, C., Aurich, J.-C. (2013). Virtual Reality as a Collaboration Tool for Factory Planning Based on Scenario

Technique, Forty Sixth CIRP Conference on Manufacturing Systems 201, *Procedia CIRP*, 7, p. 133-138.

[8] Sampaio, A. Z., Henriques, P. G., Studer, P., Luizi, R. (2005). Interaction with Virtual 3D Models in Order to Access the Construction Processes of a Wall and a Bridge, CC-2005, The 10<sup>th</sup> Int. Conf. on Civil, Structural and Environmental Engineering Computing, ed. B. Topping, Rome, Italy.

[9] Sousa, C. F. F. (2004). Structural Continuity in Bridge Decks Built with Prefabricated Beams. Solutions with Reinforced Concrete Connection. MSc thesis in Civil Engineering Structures, FEUP, Porto, Portugal.

[10] Leonhardt, F. (1982). Basic Principles of the Construction of Concrete Bridges, 6, Interciencia, Rio Janeiro, Brasil.

[11] Viana, L. F. (2012). Simulation of the Construction of the Bridge Deck Composed of Prefabricated Beams Based on Virtual Reality Technology. MSc thesis in Civil Engineering Structures, IST, Lisbon, Portugal.

[12] Reis, A. J. (2006). Bridges, Didactic text, ed. AEIST, Lisbon, Portugal.

[13] Birzina, R., Fernate, A., Luka, I., Maslo, I., Surikova, S. (2012). ELearning as a Challenge for Widening of Opportunities for Improvement of Students' Generic Competences, *journal ELearning and Digital Media*, 9 (2).