THE USE OF BIM (BUILDING INFORMATION MODELING) IN PAVING AS A PROCESS FACILITATOR.

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Abstract. Industry and construction engineering professionals have increasingly sought innovation so that they become competitive in today's marketplace. We have as an example the use of technologies of Augmented Reality and virtual reality for construction as attractive for clients. This work aimed to evaluate the use of the BIM (Building Information Modeling) methodology in road works as a facilitator of the construction and maintenance process. Initially research was carried out on BIM in paving works. With the use of software, such as AutoCad Civil 3D, the benefits generated in the design phases, the optimization in the work of quantitative survey and for the optimization in earthmoving calculation work. The obtained results indicated a greater control of the materials used during the execution of the work, reduction of the time of execution of repetitive tasks and a better general vision of the project of the work in its real conception geography and in 3D which favors both its study and its execution.

Keywords: Paving, Innovation, BIM

1 Introduction

In a capitalist and globalized society, increasing business competitiveness has increasingly motivated the pursuit of innovation as a strategy to leverage the productive sectors in the midst of so much competition. Thus, in the construction market, one of the areas of innovation that has been most widely expanded among engineering and architecture professionals is augmented reality technologies and virtual reality for construction, which aim to improve the quality of projects and works, as well as reducing costs and improving project transparency [1][2][3].

Among these technologies is Building Information Modeling (BIM), which enables the creation of virtual 3D models, brings together all projects of a work and organizes information about the work in an automated and accurate way, providing more efficiency. control and management processes [4]. In addition, the system of a BIM platform is parametric, meaning any changes made automatically update all other projects in real time [5]. Thus, this technology represents an important milestone in engineering, as it makes it possible to make all the projects involved in a project compatible in an easy and agile way, minimizing design and work errors and generating less rework and less cost [6].

Given the many advantages generated by the use of BIM in construction, its use has been increasing worldwide, accompanied by a movement of public incentives through legislation [7]. In Brazil, Decree No. 9,377 was sanctioned in 2018, in order to foster the dissemination of BIM in the country, which requires from 2021 the use of the methodology in all engineering and architecture projects [8]. However, despite the public effort, there is a fractionation regarding the application of BIM, since the main areas where it has been implemented are related to construction and sanitation, while application to infrastructure and paving is still incipient [9].

Given the importance of BIM for the efficiency of engineering projects and the fact that the application of this technology has been little applied in road works, this paper aims to evaluate the use of the BIM methodology in road works as a facilitator of the process. construction and maintenance.

Thus, at first, BIM is presented and its benefits. In a second moment, we discuss about the use of BIM in the geotechnical area and in road projects. In a third moment, we expose the main engineering software that supports BIM, such as Civil 3D. Subsequently, the case reports of the application of BIM application in road works in several countries are described.

2 Methodology

The research method used in this work is a descriptive research obtained through secondary research source, in order to enable a conceptual study on the subject. According to Gil [10], the descriptive research aims, primarily, to obtain descriptive data about the characteristics of certain phenomena and to establish a relationship between the variables.

Aiming to confront the researched theoretical view with the real case reports of the application of BIM in road works, the research design was traced by adopting the bibliographic and documentary research as a procedure for data collection as proposed by Gil [10], and the empirical analysis of the data as qualitative.

3 Building Information Modeling (BIM)

Building Information Modeling (BIM) refers to the representation of the physical and functional characteristics of a built object, about which the information model serves as a shared knowledge resource for information, creating a reliable basis for decisions during the lifecycle of the facility [11]. In this context, BIM definition goes beyond the usage of a software, since it is considered the process of planning, designing, constructing and managing using digital models that are combined with multiple data sources [12].

Even though literature shows that there can be some reasons against the use of BIM, almost all of them refer to the training of personnel and the cultural aspects. In addition, implementing BIM can impact positively both the organization responsible for the construction and the community [13]. The benefits of BIM implementation for the project include a better information flow between the stakeholders, an improved design visualization, a more precise estimated cost and reduced construction costs. This last advantage is, among other things, due to the fact that the usage of BIM augments the precision of the construction, reducing the need for changes made in the field or for redoing an specific work [12]. Another contributor for this cost reduction can be the less amount of time spent during the designing phase [13]. Moreover, beyond the outcomes already mentioned, BIM usage can contribute to the betterment of communities by improving the efficiency of the construction and by providing continuous information which can be used as basis for decision making within the community [14].

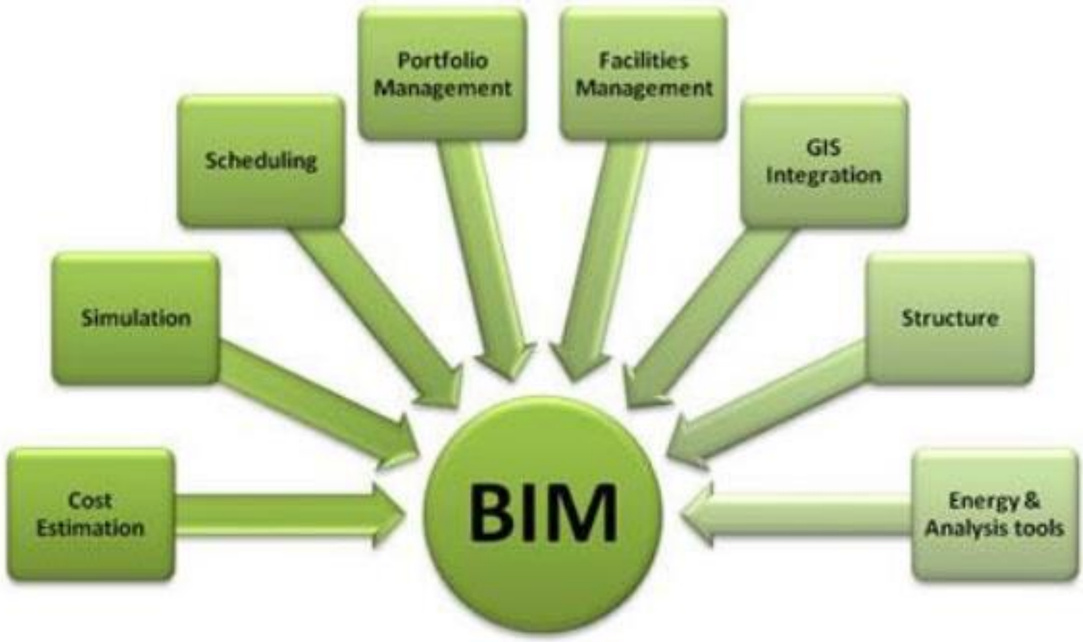

Figure 1. BIM environment. Source: A. Boukara and A. Naamane [12]

Therefore, in order to apply BIM technology to a project, it is important that it exists constant communication among team members, given that the process is collaborative and all the information needs to be always updated and available to everyone involved. This exchange of information is only possible through an standardization of software used that allows the interchange of information among different software systems [15].

As the concept of BIM grows and changes, along with its vast applicability, it emerges the idea of dimension, which refers to the adding of a certain variable to the model. Thus, the 3D model is the first stage of the project and it represents its three dimensions - height, length and width - and contains the basic information to comprehend the spatiality, geometry and geography of the object. When the time factor is added it becomes a 4D BIM, that allows the visualization of the schedules and, therefore, improves the project management. In addition to that four-dimension model, the fifth information that can be added is the budget data, creating a 5D model that enables an improved financial planning and resource control. Also, management, sustainability and safety are other factors that can be included to generate (in order) a 6D, 7D and 8D modeling [15] [16].

3.1 BIM technology in geotechnical engineering

When creating a 3D geotechnical model, the soils has to be previously studied for proper data collection. To do so, the goal of soil investigation, type of construction and geotechnical category have to be defined in advance, followed by the definition of the method of investigation, its execution and the samplings' laboratory tests. After all the needed data is collected and processed the modeling of the different layers of is created though the interpretation of the data of all boreholes. These models can be used for a lot of different purposes including volume and cost calculations and also for estimating the terrain's future behavior [17] [18].

3.2 BIM usage in road design, construction and maintenance

BIM is more frequently used for building than for infrastructure projects, but its usage has been increasing recently [19]. In this scenario, even though there are some similarities regarding the applicability of BIM within these two different sectors of civil engineering, the benefits for each type of construction are different. This affirmation is based on the fact that building modeling provides a better clash detection, clearer information and better visual data during the design stage, while for a road project these cited outcomes have no real impact on the efficiency of the project. On the other hand, the benefits of BIM utilization in infrastructure projects are related to the "non-graphic" data available, often used during pre-construction and construction phases [20].

Figure 2. BIM in Infrastructure. Source: Autodesk Infrastructure

There are multiple ways in which BIM can be beneficial to road projects in all its stages. During the design phase, the generated models are used to better comprehend the field, to simulate behavior, to improve time and material management. Moving forward to the construction stage, BIM can be employed to manage human and material resources, to anticipate locations with safety hazards and to support the builder on site in making construction decisions. After the project is finished, this technology still optimizes the maintenance activities required by providing the constructive history of the object, comparing post-construction performance with the designed one, simulating the cost of any future changes and providing information to make informed decisions regarding traffic flow or in case of an emergency [21].

4 Case studies in literature

The Table 1 resumes the cases studies in this paper.

Table 1. Cases studies

N.	Case	Local
1	Public underground parking lot	Lisbon, Portugal
2	Upgrade of existing highway	Australia
3	New four-lane road	Shanghai, China

4.1 Public underground parking lot in Lisbon, Portugal

This case study was reported in the paper “Study of BIM applied to Geotechnical Project” by Gondar et al. and the project is about the construction of a four-stage parking lot. Some of the obstacles for the construction were related to the surrounding area since the parking space was to be located underground and the excavation could cause damage if it was not controlled. Because of that it was used contiguous flight piles and king-post walls as solutions for the retaining structure that needed to be built.

For the soil data collecting, it was carried out four Standard Penetration Tests (SPT) and piezometer, which allowed the creation of a 3D surface model. The infrastructure of the surrounding areas was also studied, as well as the modifications in traffic and services troubled by the construction.

Regarding the usage of BIM software, the one chosen was the Autodesk Revit 2018, with which a 3D model was created and then the time factor was added, allowing the utilization of a four-dimension BIM technology. That extra feature allows the association of every phase of the project with its own quantity take-off and graphic elements. Also, cost and suppliers related data were then linked to that existing 4D model and generated a 5D model, which allowed a better budget administration. Furthermore, an important addition brought by the fifth dimension is the ability to study the consequences of modifications made to the project by comparing the two different models and their measurements and respective costs [15]

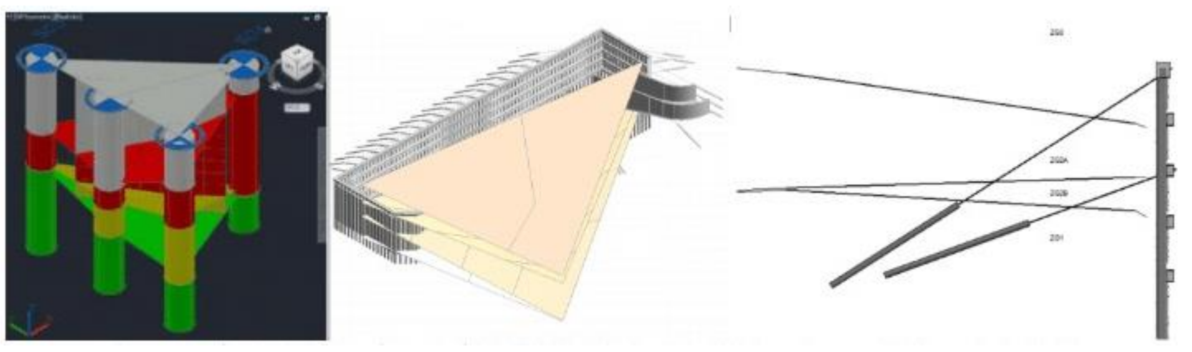

Figure 3. Geotechnical surfaces in Civil 3D (left), in Revit (middle), and compatibility analysis (right). Source: Gondar, J., Pinto, A. and Sampaio, Z. [18]

4.2 Upgrade of existing highway in Australia

This case study was presented by Chong et al. in their work “Comparative Analysis on the adoption and use of BIM in Road Infrastructure”. For this project the aim was to upgrade the highway capacity by increasing it by 70%, which would consequently improve the access to the areas around the road, as well as provide safety to its users. The project was carried out, from the creation of the model, applying BIM technology such as Autodesk AutoCAD Civil 3D, Navisworks, 12D model and Bentley MXRoad.

Regarding the preconstruction phase, some of the benefits to which the authors draw attention to are the accuracy of the models' visualization and the creation of a site layout that would avoid probable complications during the construction. Also, positive outcomes provided by the use of BIM were observed during the construction portion of the project. For instance, the earthwork was aided by the coordinates found in the model, creating a more precise work on site by, for example, making the contractor aware about the areas that should not be excavated [21].

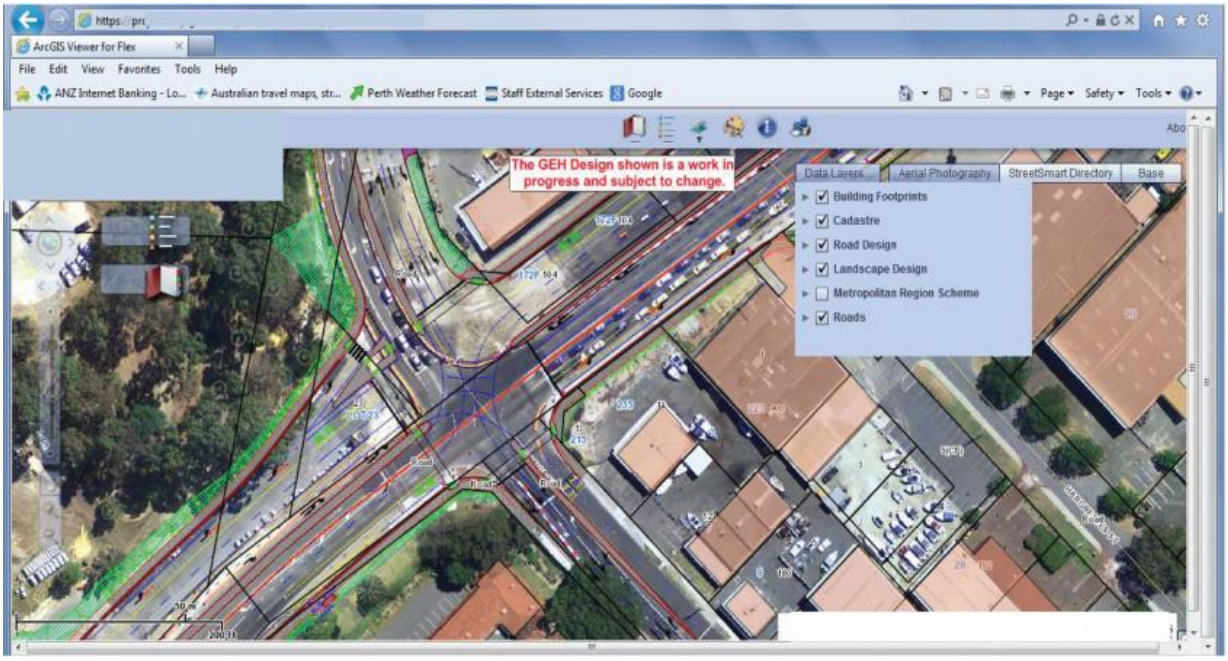

Figure 4. Web-based interface screenshot. Source: Chong, H. Y., et al. [21]

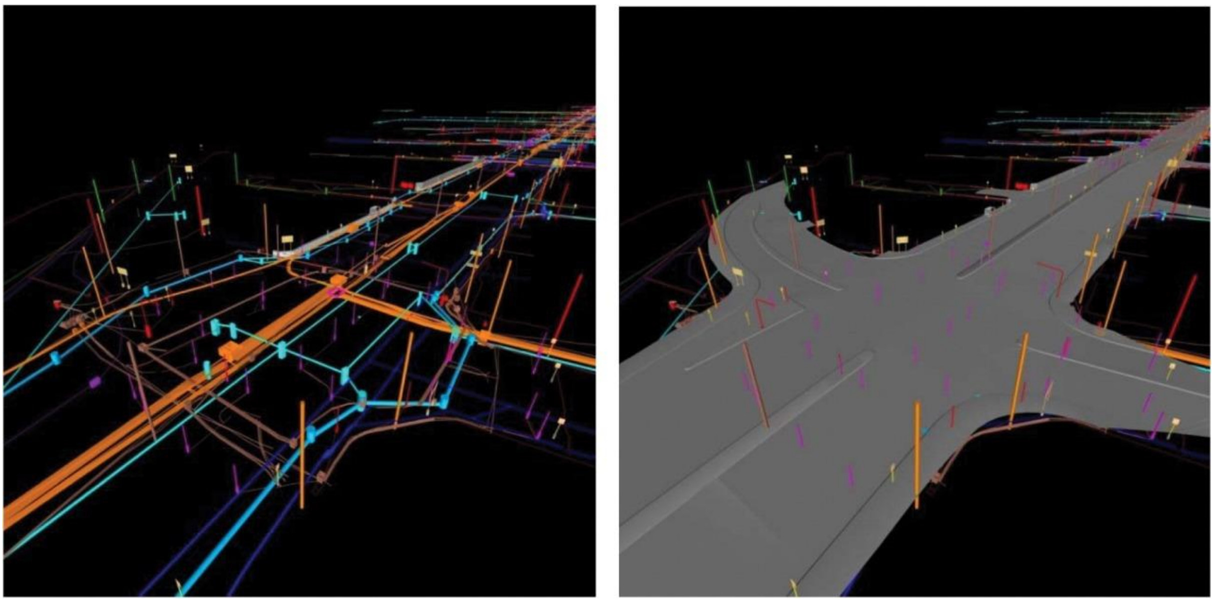

Figure 5. Different levels of screenshot detail in BIM from the engineering analysis and the results of clash detection. Source: Chong, H. Y., et al. [18]

4.3 New four-lane road in Shanghai, China

This case, as the previous one, is part of the article “Comparative Analysis on the adoption and use of BIM in Road Infrastructure”. The project is a four-lane road that measures 500 (five hundred) meters, for which the construction had some attention demanding issues, such as the obstacles on site crated by the existence of an adjacent road and the interruptions that the construction would cause to the traffic flow in the surrounding areas. It can be added that the BIM technology chosen for this case study were Autodesk Revit, Navisworks, Robot Structural, Ecotect Analysis and Infrastructure Modeler.

Before construction, the designing was facilitated by the usage of Autodesk software tools, which allowed to better coordinate the team members. In addition, the geotechnical data was included to the model, aiding the better comprehension of the relationship between the construction and its environment. Also, the simulations provided by the Autodesk Revit allowed the verification of safety requirements during preconstruction phase [21].

During the construction, an interesting feature of an automated theodolite system was combined with the BIM model designed and was used to better visualize the setting out points. Besides, in order to control the process, Autodesk Navisworks and Infrastructure Modeler were used in a complementarily manner, along with multiple cameras, which improved the tracking of the procedures as well as the communication among stakeholders. Furthermore, another tool added to the project was a laser scanner that could detect deviations from the beginning to the end of the construction process [21].

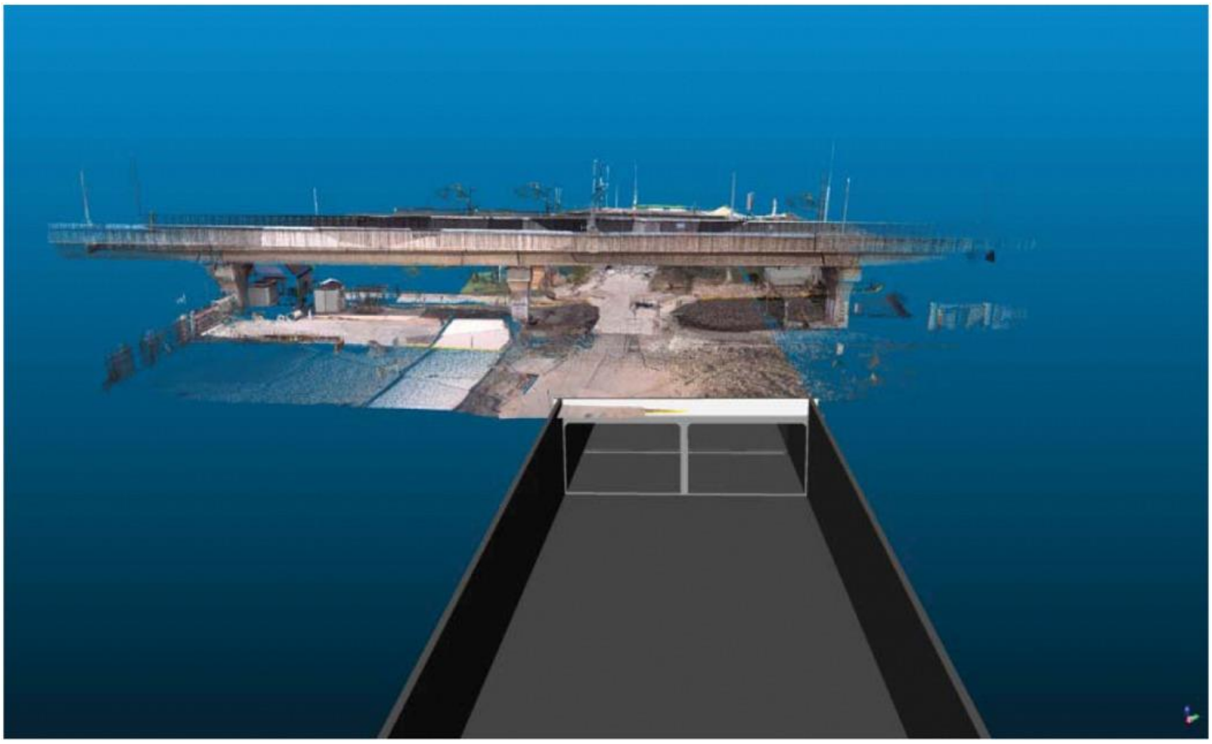

Figure 6. Laser scans for deviation detection screenshot. Source: Chong, H. Y., et al. [21]

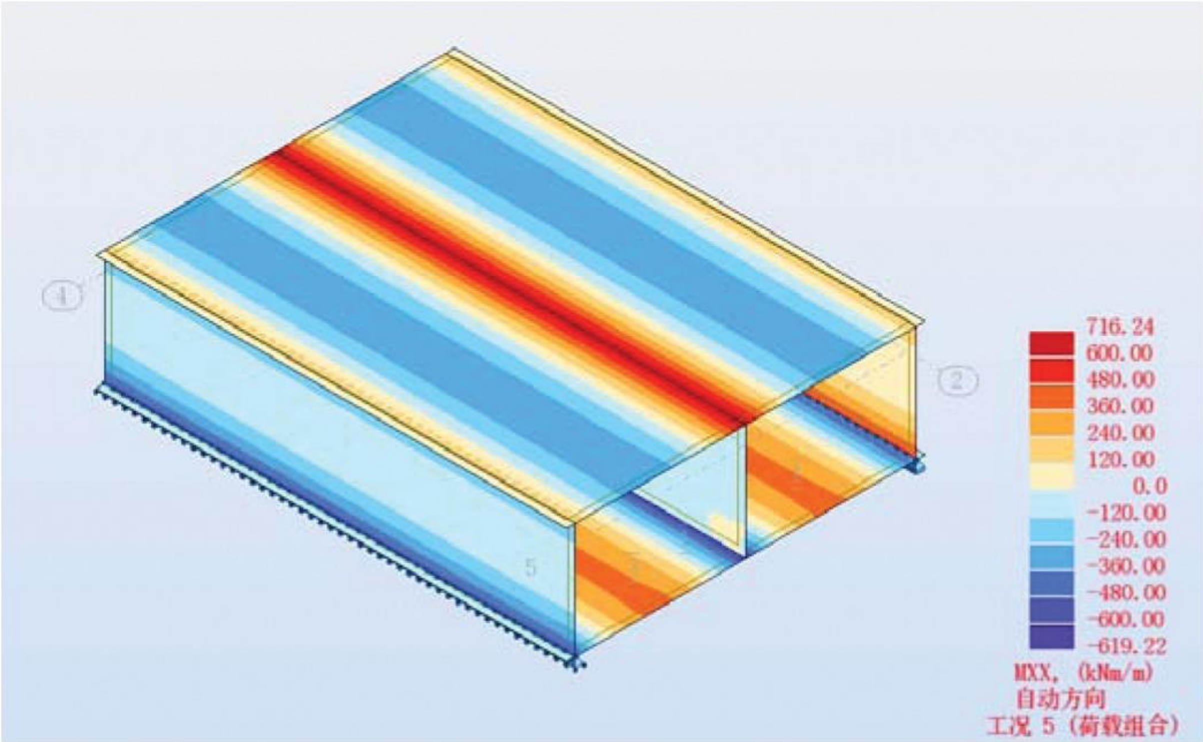

Figure 7. Live and dead load structural analyses screenshots. Source: Chong, H. Y., et al. [21]

5 Conclusions

To conclude, using BIM not only provides a better understanding of the disciplines surrounding pavement construction, but also allows a better visualization of the construction processes and road design by the software usage. Also, after the analisys of the case studies, it can be said that the BIM philosophy facilitates the transparency of activities, as well as greater consistency of activities, which can be carried out with the stipulated schedule and budget. It can also be added that GIS programs ads to the model by providing a closer geographical conception of the reality of the work. Finally, BIM's streamlined processes reduce the need for rework, favoring the schedule, bringing it closer to the time it was designed.

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