Proceedings of the XVIII ECSMGE 2024
GEOTECHNICAL ENGINEERING CHALLENGES
TO MEET CURRENT AND EMERGING NEEDS OF SOCIETY

ISBN 978-1-032-54816-6
DOI 10.1201/9781003431749-79

ECSMGE 24
XVIII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

Use of BIM methodology in Geotechnical Projects – Construction of underground reservoirs

L'utilisation de la méthodologie BIM dans les projets géotechniques - Construction de réservoirs souterrains

A. Henriques*, N. Silva, M. Lopes
JET$_{SJ}$ Geotecnia Lda, Lisbon, Portugal

**ahenriques@jetsj.com*

ABSTRACT: Building Information Modelling (BIM) is a digital technology-based methodology that is widely used in the Architecture, Engineering, and Construction (AEC) industry. The application of BIM to geotechnical projects can provide significant benefits. This paper aims to present the use of this methodology in the geotechnical and structural design of two reservoirs inserted in Belo Horizonte's Flood Control System. These reservoirs are comprised of three 40 m diameter secant circular shafts around 35 m deep, in an area of approximately 3500 m^2. The geotechnical and structural design was conducted in a PLAXIS 3D model generated by importing an IFC with geological surfaces defined in GEO5 with the interpolation of boreholes results. Also, a geometrical model was developed in REVIT which allowed a better visualization and interpretation of the construction stage planning, interaction and clashing between different structures before construction and accurate quantities estimation of all elements. All steel rebars were modelled and detailed using REVIT or TEKLA, which improved the accuracy of rebar placement and design, and reduced error and omissions during the construction. This case study allowed us to conclude that the integration of specialized software in a unique collaborative environment can have several advantages leading to a better project and construction outcome.

RÉSUMÉ: La Modélisation des Informations du Bâtiment (BIM) est une méthodologie basée sur la technologie numérique largement utilisée dans l'industrie de l'Architecture, de l'Ingénierie et de la Construction (AEC). L'application du BIM aux projets géotechniques peut offrir des avantages significatifs. Cet article vise à présenter l'utilisation de cette méthodologie dans la conception géotechnique et structurelle de deux réservoirs. Ces réservoirs sont composés de trois puits circulaires sécants d'un diamètre de 40 mètres, d'une profondeur d'environ 35 mètres, sur une superficie d'environ 3500 mètres carrés. La conception géotechnique et structurelle a été réalisée dans un modèle PLAXIS 3D généré en important un fichier IFC avec des surfaces géologiques définies dans GEO5 grâce à l'interpolation des résultats de sondages. De plus, un modèle géométrique a été développé dans REVIT, permettant une meilleure visualisation et interprétation de la planification des étapes de construction, des interactions et des conflits entre différentes structures avant la construction. Toutes les armatures en acier ont été modélisées et détaillées à l'aide de REVIT ou TEKLA, améliorant la précision du placement et réduisant les erreurs et les omissions pendant la construction. Cette étude de cas nous a permis de conclure que l'intégration de logiciels spécialisés dans un environnement collaboratif unique peut présenter plusieurs avantages pour le projet et la construction.

Keywords: BIM methodology, 3d analysis, deep excavations, diaphragm walls.

1 INTRODUCTION

In this article, the application of the BIM methodology for the execution and construction of the "Nado 1" and "Vilarinho 2" reservoirs is presented. This project is part of the restructuring of the drainage system of the city of Belo Horizonte, state of Minas Gerais, Brazil (Figure 1).

The city has approximately 90 risk areas, classified according to the number of points per municipality, with the Venda Nova region, where both reservoirs are located, being the region with the highest incidence of flood records, with approximately 20 classified points (Cistini, 2018).

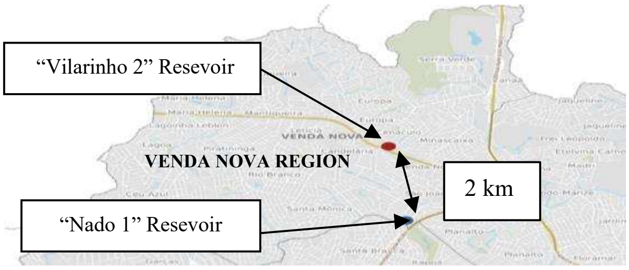

Figure 1. Site identification.

The construction of two large reservoirs with approximately 3500 m^2 and a considerable depth of about 35 m), situated in a densely populated region of the city of Belo Horizonte, results in a complex process marked by complex soil-structure interaction, influenced by various factors such as structural symmetry, geological-geotechnical asymmetry, flow analysis, stability of the excavation bottom (hydraulic failure) through permeable formations, construction phasing, and demanding control of settlements in the surrounding space. In this context, three-dimensional analyses were conducted to obtain results with greater reliability, capturing the soil-structure interaction appropriately. These analyses were made through the use of the BIM methodology by the creation and integration of geotechnical, numerical, and geometrical models of the reservoir's elements and structures in the Vilarinho area (Figure 2) and Nado area (Figure 3).

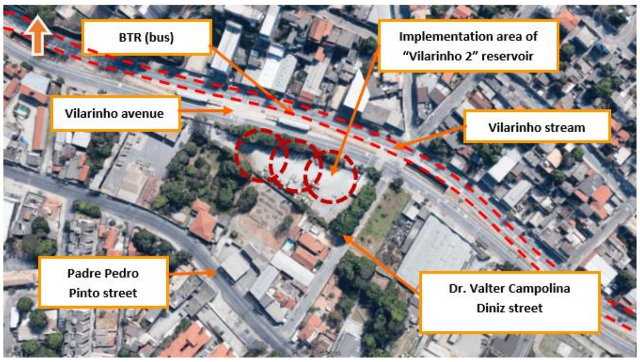

Figure 2. Vilarinho reservoir.

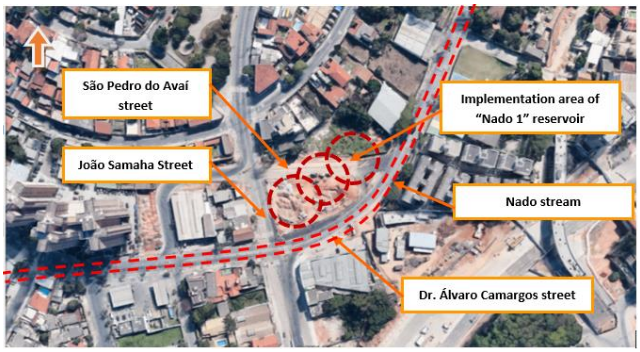

Figure 3. Nado reservoir.

2 STRUCTURAL SOLUTION

The main concept for the project aimed at controlling deformations in the influence area of the excavation, with the goal of minimizing its impact on existing infrastructures as well as neighboring buildings. Given the substantial depth of the planned excavation and the nature of the geological formations encountered, a solution in diaphragm walls was chosen, materialized by three intersecting circular shafts. At the intersection points, the execution of two reinforced concrete frames is designed, materialized by a set of columns and struts braced at various levels to reduce their respective bending lengths.

To ensure the proper functioning of the retaining structure when existing possible deviations from the verticality of the diaphragm wall panels, various bracing rings were designed along the perimeter of the wall. These rings are responsible for transmitting axial loads to the different levels of struts of the frames (Figure 4).

The regulatory soil pressures and overloads acting on the face of the diaphragm walls are, in turn, transmitted by bending/shear to the rings and, equally, by axial forces from the rings to the two reinforced concrete frames.

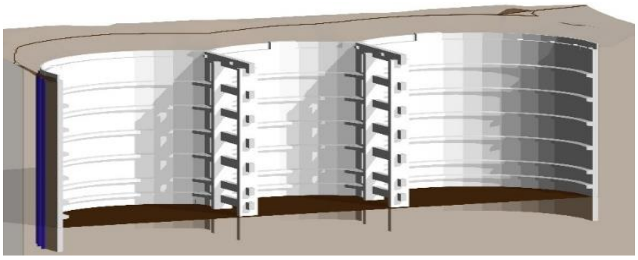

Figure 4. Excavation structure of the reservoirs.

The structure of the reservoir cover essentially consists of pre-slabs supported by prefabricated beams, which in turn are supported on reinforced concrete columns with a height equal to that of the reservoir (Figure 5).

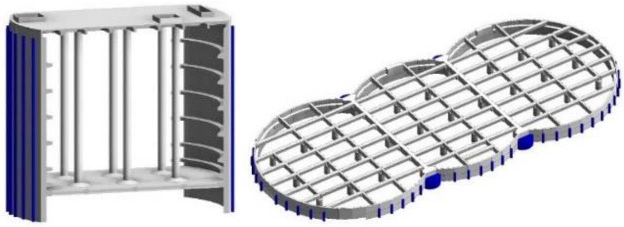

Figure 5. Cover structure of the reservoirs.

3 USE OF BIM TOOLS

3.1 Introduction

Considering the development and importance of using BIM tools in civil construction, especially in geotechnical projects (Vaníček et al, 2021), the decision was made to carry out this project in a collaborative environment, integrating and coordinating the geometry of the reservoir structure and associated structures with its reinforcement, and ensuring compatibility between the structure and the surrounding geological-geotechnical environment. The development of the project through this methodology also allowed for the identification of various incompatibilities among the different constituent structures of the reservoir, which were timely corrected in the design phase, prior to construction phase.

3.2 Geotechnical modeling

In order to identify the geological formations to be intersected by the excavation, geologic-geotechnical campaigns were conducted at both locations. These campaigns included mechanical drilling, geophysical surveying and in-situ and laboratory tests.

It is observed that the local geological environment generally involves a superficial layer of modern anthropogenic, alluvial, and colluvial materials, referred to as "fill deposits" and "alluvial/colluvial deposits," respectively. Underlying these formations there is a substratum dating from the Archean, representing the lithostratigraphic unit designated as the "Belo Horizonte Complex", composed superficially of residual soils/saprolites covering a gneiss rock mass with a degree of weathering ranging from sound to highly weathered.

In order to make a more accurate assessment of the materials intersected by the diaphragm walls (Tawelian et al, 2016), as well as to determine the various excavation volumes of these materials and the position of the existing water table, a three-dimensional modeling of the geological structure was carried out based on the information provided by the extensive geologic-geotechnical plan.

This model was developed using the Stratigraphy tool in the GEO5 software, which allows, through the input of various point field test data (drillings, wells, CPT, DPT, SPT, DMT, and PMT) and topographic surveying, to interpret and generate a geological model consisting of a set of transition surfaces between the various formations that constitute the terrain in the reservoir areas (Figure 6). The creation of this model was done iteratively, through the interpretation and analysis of the model until it aligned with the geological-geotechnical study results.

All this information was input into the program through georeferencing points with X, Y, and Z coordinates, allowing for subsequent export to the numerical and geometrical modeling program in the universal IFC format.

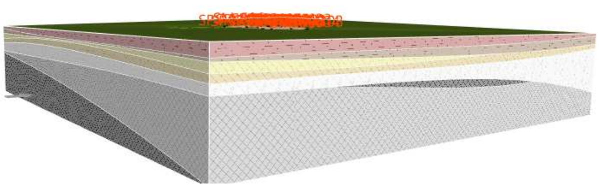

Figure 6. Stratigraphy generated by GEO5 after inputting geotechnical test data.

3.3 Numerical modeling

In an effort to assess the impact of geological-geotechnical asymmetry, structural asymmetry and the presence of neighboring structures and infrastructure, and thereby estimate the forces and deformations on the structure, three-dimensional finite element analyses were conducted using the PLAXIS 3D software, simulating the key construction phases (Figure 7).

The geometry of the numerical calculation models, particularly concerning the spatial definition of the geological structure, was based on the three-dimensional geological models presented in the previous chapter.

To achieve this, aiming to generate suitable finite element meshes, geotechnical boundary points (generated in the GEO 5 model) were first imported into AutoCAD 3D. Subsequently, Non-Uniform Rational Basis Spline (NURBS) surfaces were created at the transition between the various formations constituting the terrain in the reservoir areas. Finally, these surfaces were imported into the PLAXIS 3D numerical calculation program. This entire process was carried out iteratively until a finite element mesh with sufficient quality for the analysis of all structural elements and neighboring infrastructure was generated.

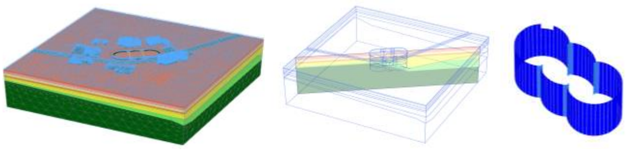

Figure 7. Geometry and finite element mesh of the three-dimensional calculation model of a reservoir and its structural elements (PLAXIS 3D).

3.4 Geometric modeling

Based on the structural preliminary design drawings created in AutoCAD, the decision was made to do the geometric modeling of the reservoir structure and adjacent structures in REVIT.

To make the project more comprehensive, enhance the understanding of all constituent elements of the models, and facilitate the extraction of material quantities from various components of the reservoir, including formwork, concrete, and reinforcements, various construction phases were created to simulate the reservoir's construction process (Figure 8)

It is also noteworthy that creating the model using these phases was crucial for all stakeholders involved in the construction of the reservoirs (designers, builders, inspectors, and the owner) to have a clear understanding of the planning and execution of the project.

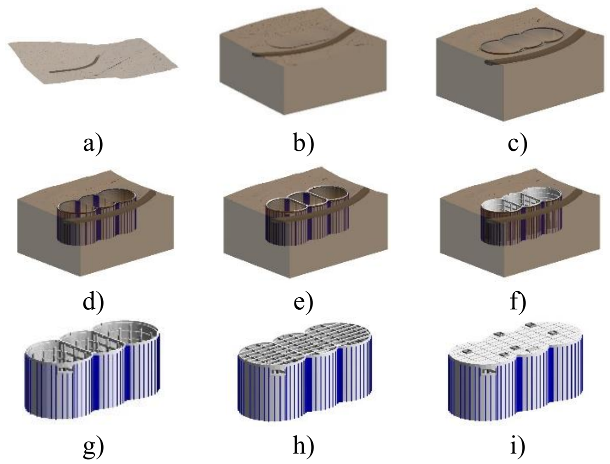

Figure 8. Phases for the execution of the structure: a) existing; b) excavation; c) guide wall; d) panels and jet grouting; e) first beam; f) rings and struts; g) structural columns; h) cover beams; i) roof slabs.

3.5 Rebar modeling

The reinforcement rebars of the elements of the reservoir were modeled in REVIT and TEKLA software to ensure that, during the construction phase, there were no doubts or errors in the assembly of the reinforcements.

Modeling of simpler and longer-developed elements such as the panels of the diaphragm wall, was carried out in REVIT (Figure 9), while modeling of more complex elements, such as beams and slabs of the cover, was performed in TEKLA (Figure 10).

Figure 9. Modeling the reinforcements' panels and assembling them on-site.

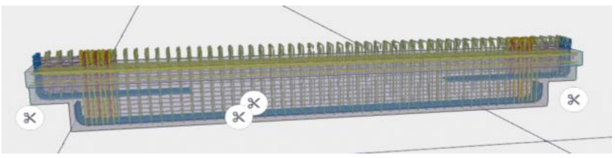

Figure 10. Modeling the reinforcements of the cover beams.

Despite being time-consuming, this modeling approach offers numerous advantages for geotechnical projects, particularly for designers and builders, including th reduction of steel wastage on the construction site, reduction of time spent on presenting and measuring reinforcements compared to traditional CAD methods, correction of errors and incompatibilities between reinforcements in a preliminary phase and evaluation of all necessary details for proper execution.

4 FINAL REMARKS

The present article addressed the use of the BIM methodology for the design and construction of two underground reservoirs with approximately 35 m of depth, integrated into the flood control system of the city of Belo Horizonte, Brazil.

The geological-geotechnical models, along with their iterative integration with numerical and geometrical models allowed for a better visualization and more comprehensive analysis of geotechnical data. This led to a correct simulation of the soil-structure interaction and, consequently, more realistic and optimized solutions.

The application of the BIM methodology in this geotechnical project facilitated coordination among different disciplines and structures involved. It has provided a better and more effective interpretation of different construction phases from the early design stage, avoiding coordination errors during the execution phase. Thus, this methodology represents a significant evolution in the approach to geotechnical projects and in their execution in a more efficient way.

ACKNOWLEDGEMENTS

The authors express gratitude for the authorization from SUDECAP and the CME consortium for the publication of this article and for their collaboration and willingness in providing the necessary data for the document's preparation.

REFERENCES

Cristini F. (2018) "*BH tem quase 90 áreas sujeitas a inundações; saiba onde ficam*" Available at https://g1.globo.com/mg/minas-gerais/noticia/2018/09/27/bh-tem-quase-90-areas-sujeitas-a-enchentes-saiba-onde-ficam.ghtml, acessed 26/02/2024.

Vaníček I., Jirásko D. and Vaníček M. (2021), "*Role of Geotechnical Engineering in BIM process modelling*" in 14th Baltic Sea Region Geotechnical Conference (2021), Helsinki, Finland. Doi: 10.1088/1755-1315/727/1/012007.

Tawelian L. and Mickovski S. (2016), "*The implementation of Geotechnical Data Into the BIM Process*", ProcediaEngineering Volume143, Pages734–741, Doi: https://doi.org/10.1016/j.proeng.2016.06.115.