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THE IMPORTANCE OF TOPOGRAPHY IN THE EXECUTION OF CIVIL CONSTRUCTION WORKS

M. A. PĂDEANU[1], Iosefina Laura ȘMULEAC[1], A. ȘMULEAC[1]

[1] University of Life Sciences "King Mihai I" from Timisoara, 300645, 119, Calea Aradului, Timisoara, Romania

Corresponding author: adrian_smuleac@usvt.ro

Abstract: *The civil construction works, which include topographic surveying of the land and marking out the structural elements, were carried out using modern equipment to ensure the required precision. The civil construction project in question involves an apartment building, consisting of an underground parking lot with over 50 spaces and a height regime of P+9 (ground floor plus 9 floors). The topographic surveys were conducted using a Stonex S10 GNSS GPS, which provided precise measurements thanks to its compatibility with multiple GNSS networks (GPS, GLONASS, Galileo, BeiDou). The marking of the structural elements was performed with a Stonex R35 total station, ensuring efficiency and accuracy. For determining levels and leveling, a Leica NA720 digital level was used, starting from the project's 0 level, which is defined by a specific value related to the Black Sea level, providing a well-established reference point. The obtained data were stored, processed, and organized in AutoCAD for a detailed and clear representation of the work performed on-site. The coordinate system used was Stereographic 1970, and the final data processing was carried out using the software suite provided by AutoCAD to ensure precise results. The results obtained are stored in digital formats (such as .csv, .gsi) and later accessed and printed in digital or analog form using AutoCAD software along with the auxiliary program TopoLT.*

Keywords: *GNSS, Stonex S10, Stonex R35, Leica NA720, AutoCAD, civil construction, industrial construction, Stereographic 1970*

INTRODUCTION

Topography plays a crucial role in civil construction, shaping how projects are designed, planned, and executed. It involves mapping and analyzing the natural and artificial features of a land surface, including elevation, slope, and landscape contours.

By understanding these features, engineers and planners can identify potential challenges, optimize the positioning of structures, and develop strategies to mitigate issues such as erosion, drainage, and stability. Accurate topographical data helps in determining the best locations for foundations, roads, and utilities, ensuring that the structures are both safe and sustainable. In essence, topography directly influences construction costs, environmental impact, and long-term durability, making it a fundamental consideration for any civil engineering project (Botnaru, 2024; Șmuleac et al., 2020; Popescu et al., 2016).

Additionally, topography contributes to resource optimization, ensuring that materials are used efficiently and reducing the risk of errors and costly adjustments during execution. Topographical measurements also allow the integration of construction into the existing landscape, minimizing environmental impact and ensuring harmony between the new project and the local ecosystem. Thus, the importance of topography in civil construction is not limited to the design phase but extends throughout the entire project, from land preparation to the monitoring and maintenance of the final structure (G Rusu, 2016; Pașcalau et al., 2020).

For the execution of civil constructions, in addition to all the topographical stages, the most modern equipment is also used, such as the Stonex S10 GNSS GPS, the Stonex R35 total station, and the Leica NA720 digital level. These tools were essential for building the apartment-style residential structure with 2 basements, a ground floor, and 9 stories (2S+P+9).

The Stonex S10 (figure 1) is a high-precision GNSS (Global Navigation Satellite System) receiver used in topography and geodesy, providing advanced solutions for measurement and data collection. The Stonex S10 is ideal for applications requiring high accuracy in civil construction, such as delineating property boundaries, monitoring road and rail alignments, establishing reference points, and documenting the topography of the land. Using this equipment enables faster and more efficient project execution with minimal errors, which is essential for staying within budget and meeting deadlines (Rusu, 2016; CC Mușat, 2006).

The Stonex R35 (figure 2) is an advanced total station used in topography, geodesy, and civil construction for precise and efficient measurements. The Stonex R35 is suitable for a variety of applications, from classic surveying to the precise layout of civil constructions such as buildings, roads, bridges, and urban infrastructure. It is especially advantageous for civil construction because it is designed to deliver extremely precise measurements, with an accuracy of up to 1 mm + 1 ppm for distances measured with a prism and 2 mm + 2 ppm without a prism (Șmuleac et al., 2017, 2022; Kennie, T. J., 2014).

The Leica NA720 (figure 3) is a high-precision optical level, known for its durability and performance in construction and surveying. The Leica NA720 is ideal for civil engineering tasks such as leveling foundations, road construction, layout of infrastructure elements, or precise topographic measurements. Its reliability ensures fast and accurate measurements, reducing time spent in the field and guaranteeing consistently high-quality results.

Fig.1 Stonex S10 GNSS

Fig.2 Stonex R35

Fig.3 Leica NA720

METHODS AND MATERIALS

The surveying process in civil construction consists of several essential stages, from measuring the land to integrating data into project planning and design. Here is an overview of the main steps in executing civil construction projects.

• **Designing Support Survey Networks** is an essential process for conducting topographic surveys and staking out. It involves establishing a system of control points, strategically distributed across the site, to provide precise references for measurements and layout of construction elements. Support networks are fundamental for achieving accurate measurements, regardless of terrain or project complexity (Botnaru, A., 2024).

• **Setting the +0.00 Elevation** represents a critical stage in construction execution, as this reference elevation defines the building's zero level, from which all other heights and depths are measured. Accurate establishment of the +0.00 elevation is crucial for the correct alignment of the foundation and other structural elements according to the design.

• **Calculating and Verifying Fill and Excavation Volumes** are essential activities in preparing and executing construction works, aiming to accurately determine the amount of material that must be excavated or added to bring the land to the specified project elevations. These calculations are necessary to optimize costs and ensure compliance in execution (Moldoveanu, 2004).

• **Staking Out and Verifying Construction Elements** are critical phases in project execution, ensuring the exact positioning of structures according to design plans. These processes guarantee that all construction elements are correctly placed, respecting specified dimensions and orientations, so the final structure is stable, safe, and functional (G. Rusu, 2016).

RESULTS AND DISCUSSION

In civil construction, particularly for residential buildings, the most modern surveying practices and advanced equipment are used, such as the Stonex S10 GPS, which was employed for conducting the initial topographic survey and establishing control points for the geodetic network (Pașcalau et al., 2021; Șmuleac et al., 2012; Moldoveanu, 2004).

In conducting the initial topographic survey, a detailed representation of the terrain was provided. The data collected, including elevations and configurations, was essential for adapting the project to the actual conditions of the land where the residential building would be constructed.

The process began by establishing six control points using the Stonex S10 receiver (fig. 4), configured in the Stereo 70 coordinate system. Measurements were taken with RTK (Real-Time Kinematic) corrections from ROMPOS fixed stations, achieving a precision of ±1 mm horizontally and ±2 mm vertically. Each point was observed for 20 minutes, recording 1,200 observations.

Fig.4 GPS Stonex S10 during use, for making the geodetic network

The next phase of construction involved excavation for the building's foundation and the underground parking, carried out as follows:

Calculating and verifying the volumes of fill and excavation are essential activities in preparing and executing construction work, aimed at precisely determining the amount of material to be excavated or added to bring the land to the specified project elevations. These calculations are necessary to optimize costs and ensure compliant execution.

The main stages in calculating and verifying fill and excavation volumes include:

1. **Creating an Initial Topographic Model**
   - **Topographic Survey:** A topographic survey of the existing land is conducted using a total station, GNSS (in this case, the Stonex S10, figure 4), or drones equipped with LiDAR technology. The data obtained is used to create a digital terrain model that reflects the actual surface configuration.
   - **Generating the Digital Model:** The topographic data is integrated into GIS or CAD software to create a 3D model of the land, which serves as a reference for volume calculations.
2. **Determining the Final Elevation and Plotting Work Volumes**
   - **Planned Elevation:** The final elevations for fill and excavation are defined by the technical project and specify the levels to which the land must be adjusted. The differences between existing and planned elevations determine the volume of material to be excavated or added.
   - **Work Zones:** Based on the digital model, zones requiring excavation or fill are defined, marking the boundaries of each operation to achieve an accurate volume estimate.
3. **Calculating Excavation and Fill Volumes**
   - **Volume Calculation Methods:** Volume can be calculated using cross-section methods, the trapezoidal prism method, or by comparing 3D models before and after work, providing an accurate volume estimate.

▪ **Cross-Section Method:** Cross-sections are drawn at regular intervals across the terrain, determining height differences between the initial and projected surfaces, then calculating the volume.

▪ **Trapezoidal Prism Method:** Used for detailed calculations in complex areas, determining the volume between successive models through interpolation.

o **Specialized Software:** Design software (e.g., AutoCAD Civil 3D) simplifies the calculation process and provides precise results, integrating data from the digital model and projected elevations (Casian et al., 2019; Kennie, T. J., 2014; Herbei et al., 2021).

4. **Verifying Calculated Volumes**

o **Comparing Calculations with Field Data:** After theoretical calculations, field checks are conducted (fig. 5) to confirm volume accuracy. Post-excavation or fill surveys are compared with the initial digital model to measure differences.

o **Balancing Excavation and Fill Volumes:** Depending on project specifics, volume optimization is attempted by reducing the need for transported material. This involves adjusting the terrain to minimize differences between excavation and fill volumes, reducing transportation and storage costs (figure 5).

Fig.5 Realization of the excavation, of the volume

Another important step in executing such a project is setting the +0.00 elevation, an essential stage in construction execution, as this reference elevation defines the building's zero level from which all other heights and depths are measured. Precise establishment of the +0.00 elevation is crucial for the proper alignment of the foundation and other structural elements according to the project (Herbei et al., 2013; Y Xu, S Zhao, J Fan, 2021).

The main steps in setting the +0.00 elevation include:

1. **Determining the +0.00 Elevation Based on the Project**

o The +0.00 elevation is defined in the building's technical plan, established as a reference for all subsequent work. Generally, this corresponds to the floor level (fig. 6) of the ground floor or a specified point designated as the zero reference. Depending on the terrain configuration and project requirements, it may be necessary to adjust the +0.00 elevation to a certain height relative to an existing natural or artificial benchmark.

Fig.6 Elevation 0.00 and the structural elements of the future residential building

2. **Marking the +0.00 Elevation on Site**
   - Once determined, the +0.00 elevation is marked on the site using leveling equipment, such as the Leica NA 720 optical level or a laser level. A stable reference point is chosen (usually an existing structure, a securely placed benchmark, or a geodetic marker) from which the +0.00 elevation is transferred to the necessary locations (figure 6).
3. **Transferring the +0.00 Elevation to Structural Elements**
   - After marking on the site, the +0.00 elevation is transferred to essential structural elements of the building, such as the edges of the foundation or formwork, to ensure a constant reference throughout the work. This allows the construction team to check at any time that built elevations align with the project.

4. **Periodic Verification of the +0.00 Elevation**
   - During construction, the +0.00 elevation must be periodically verified to prevent errors that can result from ground shifts, changes to formwork, or other external factors. This ensures that each level built is aligned with this initial reference (Y Xu, S Zhao, J Fan, 2021).
5. **Monitoring and Maintaining Reference Points**
   - To maintain the accuracy of the +0.00 elevation throughout construction, reference points need to be well-protected and maintained, with markings redone if they are damaged or accidentally relocated.

Proper establishment of the +0.00 elevation is fundamental to building a structure aligned with the project, preventing leveling issues and ensuring a solid reference base for all other construction work.

The next critical aspects in civil construction are marking and verifying construction elements, which are essential stages in executing a project. They ensure precise positioning of structures in line with design plans. These processes guarantee that all construction elements are accurately placed, respecting specified dimensions and orientations, so the final structure is stable, safe, and functional (MR Gridan, 2012; Mita et al., 2020; Șmuleac et al., 2020).

The main steps in marking and verifying construction elements are:

1. **Marking Construction Elements**

Marking involves transferring the project design onto the site by accurately marking the reference points and outlines needed for construction. This is done using measurement equipment such as total stations—specifically the Stonex R35 in this project—and GNSS technology with the Stonex S10 to ensure precise positioning (figure 7). Marking must adhere to the exact coordinates from the design to avoid deviations.

Fig.7 Plotting construction elements with the Stonex R35 total station

2. Marking the Foundation Outline and Other Structural Elements

Before the actual construction, the foundation outline and other main structural elements (walls, columns, openings) are marked using the Stonex R35 total station, which was used to complete these operations (figure 8). These markings serve as the basis for subsequent work. It is essential that these markings are thoroughly checked and rechecked to prevent deviations that could compromise the entire structure (Paunescu et al., 2020; CC Muşat – 2006).

3. Checking verticality and alignments

Once the structural elements start to be built, periodic checks are made, as can be seen in (figure 9, this was done during the construction of the 3rd floor of the building, to ensure that they are correctly placed vertically and aligned This stage involves the use of leveling equipment, plumb lines and construction lasers, to monitor possible deviations and correct any non-conformities. (Popescu et al., 2019; MR Gridan, 2012).

4. Control of dimensions and distances

During construction, dimensions and distances between elements are checked to ensure compliance with the project (figure 10). Each side, height and thickness is measured and compared to the design specifications to avoid errors that could affect the structural integrity or appearance of the construction.


Fig.8 Plotting the building's resistance columns (left)
Fig.9 Checking the verticality of the building during the construction of the 3rd floor (right)

Fig.10 Check axles

5. Verification of compliance with the project

At the end of each stage of construction, a general inspection is carried out to confirm that all elements have been built according to the original plan. This includes checking each drawn item, comparing it to the technical drawings and producing a compliance report for each section. Thus, any deviation is detected and corrected before continuing with the next stages of the project.

Through rigorous layouts and checks, construction teams ensure that every element of construction meets design requirements, contributing to the safety, stability and durability of the final design.

CONCLUSIONS

Surveying plays an essential role in the realization of civil constructions, providing a solid basis for the planning, design and execution of each project. Through accurate topographical measurements, vital information about terrain features such as relief, property boundaries, and the positioning of natural or man-made features in the area is obtained.

These data allow a correct assessment of costs, an efficient use of materials and an optimal location of the structure, contributing to the stability and safety of the construction. Topography is also essential in avoiding the risks of erosion, flooding and landslides, helping to prevent long-term problems. Thus, the importance of topography in civil constructions is indisputable, as it constitutes the foundation for sustainable and sustainable projects.

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