Laser scanning application possibilities in the engineering structures survey

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Abstract. The advantages of using laser scanning in the process of examining technically complex structures and deformations monitoring are shown on the realized objects example.

Introduction
The ground-based laser scanning has become widespread in the geodesic industry in the last decade. The development of technologies makes modern scanner models more accessible and compact. Currently, laser scanning capabilities allow this technology to be used in order to prepare the executive documentation, as well as to provide materials for BIM modeling. However, several key problems need to be solved in order to implement the laser scanning technology into an organization’s activities. First of all, specialists operating scanner systems should have experience in field work to ensure the quality results. In addition, for the effective laser scanning implementation in production activities, it is necessary to carry out the selection and development of application software for processing measurement results.

The realized experience analysis of using scanning systems during the structures inspection and the deformations monitoring production reveals the advantages of using scanner imagery in comparison with traditional geodetic methods of work. Let us consider in more detail some of them.

Scanning a Cultural Heritage Site
The specialists of the FSBEI HE PGUPS faced the task of performing measurement work and defining the deformations of the historical significance unique structure, the main facade of which is located in the center of St. Petersburg on the English Embankment in 2018 (Figure 1). The Anglican Church of Jesus Christ, an object of cultural heritage of federal significance, was built in the 1730s by the architect Giacomo Quarenghi.

As part of the survey and assessment of the technical condition of the building’s ground-based building structures, it was necessary to perform the measurement work, determine the building facades rolls and estimate the church hall ceiling accumulated deformations.

The church hall ceiling decoration has historical and artistic value, as a result of which the attic floor was not opened to ensure its safety. The ceiling beams are supported by the ends on the longitudinal bearing walls, in the beams span are suspended from the girders running along the entire hall. The runs are fastened with metal clamps to the wooden trusses’ racks.
A detailed examination of the ceiling revealed areas of its surface that are subject to deformation. Surveying the surface of the ceiling using an electronic total station would provide only a limited set of data without a full analysis of the deformation process. In addition, due to the ceiling painting historical value, it was impossible to fix the deformation marks and the work of the electronic total station in a non-reflective mode could entail significant errors comparable to the values of the detected deformations. Such measurements results would be too discrete, even with a large volume of observations. As a result, at the stage of reconnaissance, the possibility of using an electronic total station was excluded, and the scanner surveys became the only option for work.

According to the ceiling scanning results in a geographic information system, its surface was obtained, which clearly demonstrated local surface deformations (Figure 2). For control, a survey of longitudinal overlap runs, which confirmed the scan data validity, was performed.

The scan results also made it possible to establish the deformations in other structures. For example, the beams deflection above the body.

It is important to note that the use of a laser scanner at this site has helped to solve many related tasks in the survey:
- to restore the lost project documentation;
- identify facades rolls;
- set the deformations of structural elements.

The artificial structures scanning survey

Another striking example of the scanning use in the survey are the Phosagro Apatit JSC Kirov branch bridges. 8 man-made structures of Apatit JSC, many of which have been operated by the train for decades and are soon to be reconstructed were subject to a planned inspection.

The survey program of such artificial structures is fairly standard and in terms of geodetic works it includes surveying longitudinal and transverse profiles, determining deflections of the span structures beams and determining deviations of supports from the vertical.

The laser scanning use was due to a rigid time frame set aside for the inspection of structures: 4 days for 8 structures. To perform the work in a given time frame, it was decided to carry out the work on the superstructure of bridges using traditional methods and conduct a scaffolding space scan (Figure 3).

![Figure 3. The artificial structure scanning](image)

As a result, the field work was completed within the prescribed period, and most of the information was obtained during the office processing.

Clouds of the points of the podium space allowed to obtain the superstructures longitudinal beams profiles, to determine the piles of supports, to determine the characteristic points elevations, to obtain a sufficient amount of information for drawing up the schemes of structures (Figure 4).
Thus, a clear advantage of using laser scanning during the examination of artificial structures was a record reduction in the timing of field work compared to using traditional geodetic instruments.

**Laser scanning for determining accumulated surface deformations**

Another object of the study, where the scanner survey has found an actual application, is the federal highway M11 “Moscow - St. Petersburg”.

On the highway section near the town of Bologoye, Tver Region, in accordance with the initial project, a bridge was supposed to cross the river Kolomenka. However, at the stage of the pile foundation, it turned out that the soils do not provide the required bearing capacity. The design documentation was corrected, and the river bed and the bridge crossing were transferred to the zone with the weak soils’ lowest depth.

Strengthening of weak soil toes under the road embankment base was made according to an innovative, specially developed method of creating vertical sand drains using the energy of an explosion. This method involves the weak organic soils consolidation acceleration, as well as loose sand compaction, which is the road embankment basis.

Throughout the construction phase of the embankment at the construction site, work was underway to monitor the embankment deformations. Geodesic observations were made during explosions and in the process of stabilization of soils.

To obtain information about the deformations, the results of joint tachometric and in clinometric measurements were analyzed.

So, according to the established deformation marks, the planned-altitude displacements were determined by an electronic total station. Using the borehole inclinometer, the soil massif sliding boundaries are determined.

The deformations observations were carried out over a period of 2.5 years; in Figure 5, the constructed from the total accumulated values sediment surface is shown.

One of the tasks assigned to the embankment deformation monitoring organization was to determine the marks of its shoulders after each series of explosions, since it was in the zone of the shoulders that the ground soil was squeezed as a result of the base compaction. The complexity of the work on determining the marks of the shoulders was the real threat of dragging the lumber keeper into the quagmire when moving along the embankment side.

At that moment, the scanner shoulders application was not only effective, but also the only possible option for obtaining the necessary information.

As a result, the use of a laser scanner made it possible not only to monitor the current form and the road embankment marks, but also to estimate the volumes of imported sand on the surfaces created in the geographic information system.

**Summary**

The laser scanning systems introduction in the geodetic works production allows, in addition to three-dimensional visualization of the object, to solve non-standard problems arising in applied fields of science related to geodesy. For example, if necessary, perform repeated measurements to determine the accumulated deformations or calculate the building materials volume; also, if necessary, the maximum automation of work and the limited duration of work; to increase the effectiveness of
traditional geodetic methods and devices based on joint measurements. At the same time, there is still an obvious lack of scanning systems - the high cost of equipment and the need for qualified personnel to service them. Also, a particularly topical issue in the laser scanning work organization is the survey plan-and-height justification accuracy, the geodetic network design and the three-dimensional model accuracy assessment of the object obtained from the scan results.

Figure 5. Embankment surface as scanned

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