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GEODETIC MONITORING METHODS OF HIGH-RISE CONSTRUCTIONS DEFORMATIONS WITH MODERN TECHNOLOGIES APPLICATION

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ABSTRACT

In article the analysis of the high-rise buildings and constructions deformation processes geodesic monitoring method is provided. The purpose of geodetic monitoring consists in surveying technology use including a processing and comparing algorithm of observations cycles results on the selected clusters and providing monitoring of the object deformed status on all it surface. The analysis and synthesis of domestic and foreign experience of high-rise buildings and constructions deformation processes geodesic monitoring was carried out. Advantage of the geodesic monitoring methods using a surface laser scanning technology allowing increasing safety in case of high-rise buildings construction and operation is shown.

Keywords: *High-Rise Buildings, Surface Laser Scanners, Deformation, Monitoring, Monitoring Methods, Technology.*

1. RELEVANCE

Now in Kazakhstan intensive development of the city space territory including underground is actively conducted. At the same time in connection with increase in the land plots cost a building density and a tendency of high-rise constructions is observed. In these conditions there is a need of these objects' deformation processes observations considering that they are most sensitive to environment state changes [3, 11].

All this leads to change of requirements to the determination accuracy of the buildings and constructions geometrical sizes and also to errors definition which arise at designs installation, laying the buildings and constructions foundation. [3].

At the same time the probability of a soil surface deformations emergence for large megalopolises what Almaty becomes the considerable. Deformations can be caused by both technogenic and quite natural factors: buildings and constructions pressure upon soil, large-scale multystoried construction, intensive development of underground space (the subway lines, different type's communications, etc.), increase of transport streams, change of ground waters level and so forth.

Especially considering that the southern and southeast Kazakhstan territory the Almaty district including, is one of the most earthquake zone in the CIS (Commonwealth of Independent States). On the geological basis added with elements of the latest tectonics and seismic dislocation, distribution of the largest earthquakes epicenters of the past and modern seismicity manifestation the purposeful choice of the areas for geodetic networks creation for the purpose of soil surface modern movements studying in various geological tectonic conditions is carried out.

Intensive development of the city space territory is conducted. At the same time in connection with increase in the land plots cost the tendency of high-rise constructions building is observed. In these conditions there is a need of supervision of these objects deformation processes, considering that they are most sensitive to an environment state changes [3], [11].

2. ANALYSIS OF EXISTING RESEARCH

Prerequisites for the solution of a problem of high-rise constructions deformations definition are in many respects put in the operating standard and

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methodical literature according to various engineering constructions deformations. In this regard the significant contribution to development of this geodetic works direction was made by the famous scientists: I.Yu. Vasyutinsky, V.N. Ganshin, Yu.P. Gulyaev, B.N. Zhukov, A.K. Zaytsev, A.A. Carlson, E.B. Klyushin, G.P. Levchuk, G.A. Shekhovtsov, etc.

Use of modern measurements technologies and their processing in relation to the considered subject is reflected in researches A.V. Komissarov, E.M. Medvedev, A.I. Naumenko, A.V. Seredovich, V.A. Seredovich.

Analyzing a scientists' research we will consider the geodetic monitoring methods according to the figure 5. The *direct leveling* method with the short collimating ray application a beam 3 to 25 m long is most widespread. The main advantages of this method are: high precision and speed of outreaching measurements on stations, a wide choice of exact levels, opportunity to carry out supervision in the constrained conditions of construction [11, 13].

Excess between points at distance of 5-10 m is possible to determine with an accuracy of 0,05-0,1 mm and at distance of hundreds of meters - with an accuracy of 0,5 mm. Marks of deformation points (deformation control benchmarks) for the entire supervision period determine rather Borros point or group of benchmarks. The received results equalize, estimate the actual accuracy of marks, on differences of marks in cycles build the schedules of settlements. In the course of supervision over settlements in each measurements cycle the control of vertical angle bench mark stability is carried out [3]. At the same time for determination of position level stability there is a number of widespread methods [6, 10], and the smaller attention is paid to planned stability. Besides, electronic (digital) levels with special bar code laths for which coding RAB and BAR codes [16] are used are successfully applied to supervision over deformations.

Full leveling process automation is reached due to reading of counting on a lath, fixing of horizontal distance to it, and also calculation of excess between points. Besides the minicomputer which is built in the device allows to keep data and also to often conduct their handling and equalization directly in the field. It is noted that possibilities of digital levels provide performance improvement for 50% in comparison with traditional optical-mechanical devices [1, 2]. In [7, 11] is specified that when conditions of a construction complicate application of direct differential leveling, for measurement a settlement of constructions use trigonometric leveling by short beams up to 100 m long. At the same time the corresponding instrument row shall include exact and high-precision theodolites with superimposed cylindrical levels or total stations [7].

Besides, for observations the conditions allowing reducing the vertical refraction influence [11] shall be chosen. The hydrostatic leveling based on use of liquid balance laws in communicating vessels is applied to measurement a points relative vertical movements under following conditions: inaccessibility of other methods of movements accounting; lack of visibility between brands; impossibility of the person in a workplace (observance of safe engineering). But if the building or a construction experiences dynamic loads, then the method of hydrostatic leveling isn't applied [7].

Instrumentally the method can be provided with figurative hose levels, stationary hydrostatic or hydrodynamic systems, for example [15]. However it should be noted that application of hydraulic systems is connected with considerable organizational and technological difficulties therefore cases of their use are single [17].

Use of *total stations* by production of land works is really comprehensive. These devices found the niche, including, when conducting geodetic monitoring of engineering objects, at the accounting of deformation processes. Certainly, it is promoted by considerable accuracy: angular measurements reach 0°00'0,5", distances - 0,5 mm + 1 mm/km (1 mm + 1 mm/km in the reflectorless mode).

Mass distribution was gained now by robotic tacheometers with the servo-drivers providing automatic rotation around an axis of the tool and rotation of the telescope. In such devices the possibility of uninterrupted tracking reflectors at huge distances is realized. At the same time special software automatically reads out receptions data of separate sessions and results possible movements of the purposes for the concrete time period.

The standard diagram of observations over engineering objects deformation processes with robotic tacheometers use agrees to [4, 21] is provided in a figure 1 and is summarizing to the following procedures:

- installation of the instrument in the stable place providing the wide review of an observations object and not subject to deformation influences.

In case of impossibility of these conditions observance it is possible to use control station in the form of reflective prisms concerning which the tacheometer position is defined by three-point method;

- fixing of special reflectors in ordinance-datum of an object;

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- periodic observation of reflectors position in a local coordinate system;
- comparing of observations cycles of spatial provision of reflectors ordinance-datum.

The main direction of total stations development is still the further robotizing reducing user functions to distant monitoring and control of the instrument operation . Also there is a tendency to equipment the instruments with GPS systems.

At the same time tacheometers in a combination with navigation receivers, digital levels and other instruments, and also the special controlling software (S) often form special automated geodesic monitoring systems (a figure 1).

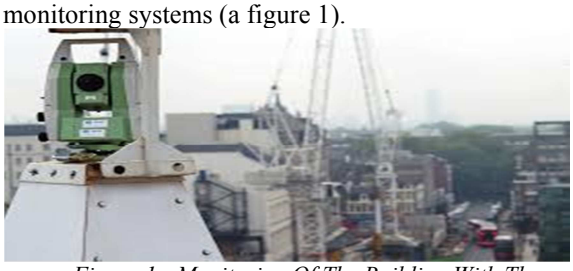

Figure 1 - Monitoring Of The Building With The Robotic Tacheometer Use

Factors of the global navigation satellite systems (GNSS) wide use are: a continuity of coordinates determination, an all-weather capability, efficiency of coordinates determination, high precision of the received results, small dimensions and weight of receivers, small power consumption, simplicity of operation and rather low cost.

Unlike many alternative methods which are carried out with a certain interval, various objects deformations monitoring with application of satellite methods can be continuous as in real time, and at a post-processing stage. At the same time possibilities of these methods are actively used at the accounting of deformation processes of various engineering objects.

In relation to high-rise constructions in [9] is noted that devices of GPS positioning allow to determine spatial coordinates of points with an accuracy of 1 cm that for high-rise structures with possible horizontal movements about several tens centimeters represent quite high precision. At the same time the exception of mistakes in case of measurements can be made in case of a supervision differential method.

Measurements should be carried out by means of two groups of receivers: established in controlled points of an object (rovers) and located in points with the known coordinates (base stations). The differential mode basic allows to fix not absolute coordinates of the rover stations, but their position referred to basic. It is noted that the accuracy of phase measurements reaches millimetric accuracy. In this regard, GPS systems can be the effective tool in case of dynamic indicators determination of high rise buildings fluctuations from wind impacts. The general scheme of similar monitoring carrying out is provided in figure 2.

Figure 2 - GPS Monitoring Of Wind Impact On The High-Rise Building

Now in the market there is a wide choice of the equipment on implementation of the satellite positioning technology having different appointment and differing in the characteristics. It is important to note that in case of all variety of a GNSS use method it isn't deprived of shortcomings among which the basic is the impossibility of passing of a signal to the receiver, its considerable misstatement or a delay (foliage of trees, big overcast, hindrances from land-based radiation sources, and also from magnetic storms).

The building of high-rise and unique constructions very urgent grows in the megalopolises of Kazakhstan therefore use of nonlinear laser systems at geodetic monitoring becomes of current interest. Supervision over the buildings settlement is a special type of geodetic monitoring and one of the constituting of engineering and geodetic researches. They are extremely important in construction case of high rise buildings or special unique constructions on complex soil for a guarantee of their use safety, especially in places of the subway passing. Also need of supervision can arise because of the long term of the building use and its strong deterioration.

As it was noted in [5, 14, 17, 18, 19] the essence of Surface Laser Scanning consists in measurement of the points set belonging to the studied object surface by means of the laser scanning system (the laser scanner or a lidar). Irrespective of the device type and attached Software the resulting data of field works and preprocessing is the three-dimensional dot model (the scan, a point cloud) of the studied

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object representing a set of points with the known coordinates X, Y, Z (figure 3).

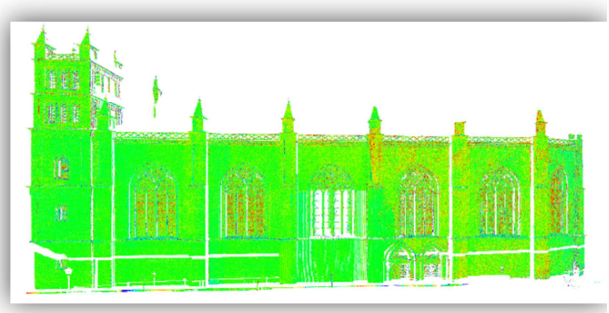

Figure 3 - Example Of A Point Cloud Of The Building Facade

Now surface lidars are provided by the models wide range differing in technical parameters, the action principle, overall dimensions and application methods. At the same time the main features defining possibilities of the instrument are range of action and accuracy [14, 19, 20].

In the context of Surface Laser Scanning application for collecting data about high-rise objects it is necessary to be guided by an instrument choice with high range of action and accuracy. The triangulation scanners realizing an intersection method of distance measurement to an object have accuracy from 50 microns to 0,3 mm in case of action range from tens of centimeters to 25 m. Traditionally ranges of these devices application are the mechanical engineering, medicine, etc. [19, 20]. The limited range of action insufficient for Surface Laser Scanning of high-rise objects excludes triangulation scanners from further reviewing.

In the course of scanning the direction of a laser beam distribution and distance to object points is fixed. The raster image – the scan which pixels values represent the vector elements with the following components: the measured distance, intensity of the reflected signal and the RGB-component characterizing real color of a point is a result of the scanner operation. And also gives the most complete and exact idea of constructive and technological elements on an object. For the majority of the Surface Laser Scanning models the characteristic of real color for each point it turns out by means of the nonmetric digital camera. The raw data of laser scanning in the form of "clouds" of points allow revealing in the automated mode deviations from the project in real time.

Pulse and phase reflectorless methods of distances measurement and also method of direct angular reamer (triangulation method) are put in a basis of the laser distance meter work used in scanners.

The difference of the output and input light waves phases is measured in a phase method for distance determination. Scanners where the similar technology is applied can provide data acquisition productivity to 1 million points a second with an accuracy of 1 mm, at the same time range of action reaches about 300 m. Time of a light impulse passing is measured in a pulse method for determination of distance. The scanner lets out short light impulses and measures time for which light reflected from a subject comes back. Usually such scanner provides the accuracy of measurements of 3 - 6 mm with a productivity about 100000 points a second. At the same time distance measured by these devices can make up to 6 km.

Thus general benefits of a pulse method over a phase one is high range of action in case of an impulse rather low capacity, unambiguity of the received result (the measured range is pro rata to time of a signal pass). Accuracy of measurements and performance of works belongs to method shortcomings smaller in comparison with a phase method.

Management of the land laser scanner operation is perhaps direct from the PC (laptop) through a special cable or wireless connection (Wi-Fi, Bluetooth).

The comparative analysis of a high-rise construction deformation geodetic monitoring use showed advantages and prospects of Surface Laser Scanning.

3. MAIN OBJECTIVE OF RESEARCH

The purpose of geodetic monitoring is timely identification of deformations critical sizes, establishment of their emergence reasons, drawing up forecasts of deformations development, development and taking measures for undesirable processes elimination.

Non-performance of geodetic monitoring or non-execution of surveyor's instructions leads to sad consequences (figure 4).

Figure 4 - Yield Of The Building Foundation

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Now for the solution of high-rise objects geodetic monitoring problems there is an impressive number of methods, including a possibility of the modern geodetic methods application connected with total station use, satellite positioning, and also a number of tool methods (figure 5).

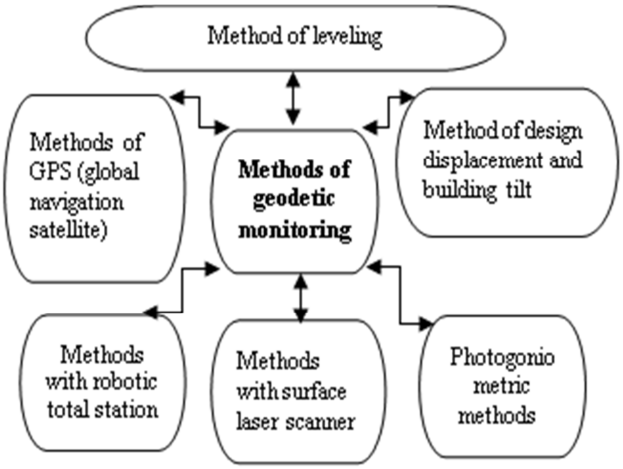

Figure 5 - Methods of geodetic monitoring

As the main methods of vertical displacements measurement depending on a accuracy class it is recommended: direct differential leveling, trigonometric leveling, hydrostatic leveling.

4. MAIN PART OF RESEARCH

The research main part is studying of the high-rise building and constructions Surface Laser Scanning method use.

As the main benefits of Surface Laser Scanning in case of the tasks solution connected with collection of geospatial information on engineering objects as it was noted in [12, 15, 17, 18, 19] is considered to be:

- high speed of work; high precision;
- noncontact method of data collection;
- completeness and detail of the received results;
- instant three-dimensional visualization;
- minimum influence of "a human factor".

The main shortcomings of technology are bound to the inventory high cost, lack of the regulatory base on works and the standardized technologies of measurements accuracy assessment. Besides topical issue of presence of the qualified specialists capable to perform field works on Surface Laser Scanning and cameral handling of its results.

As shown above the Surface Laser Scanning technology allows to gain the fullest and rather faithful impression about the space provision of a high-rise object and its parts.

The choice of a measurements method at geodetic monitoring of high-rise buildings, first of all, depends on solvable tasks and precision requirements. At comprehensive examination of buildings and constructions deformation by standard methods the main difficulty is presented by objects of unique construction, having the complex spatial structure.

When using reference geodetic surveying for creation of three-dimensional model the operator needs to perform pointed measurements on each element separately, to make a contour, to take the picture with the indication of the direction of a picture, its space situation, form, the size. On the basis of all this the handler can imagine an overall picture of an object, and it will be possible to judge observed datas only after their cameral processing.

Comparing characteristics of the measurements methods presented in table 1, levellings, tacheometries and GPS it is possible to claim that results of Surface Laser Scanning are more productive, than other methods.

Accuracy of surveying by Surface Laser Scanning technology method allows to carry out geodetic monitoring of many elements of unique construction. In case when precision parameters of the scanning system exceed by 0,2 times of the deviations size allowed in the registered norms and rules it is necessary to carry out measurements by more precision geodetic instruments. The comparative characteristic it is given below in table 1.

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Table1-Comparative characteristic of measurements methods

Referent criterion	Leveling	Tachymetry	GPS	Laser scanning
Standard error (SE) of location survey, m	in the plan, 0,010 on height, 0,002	in the plan, 0,250 on height 0,020	in the plan, statics 0,010 kinematics 0,020 on height, statics 0,010 kinematics 0,020	in the plan, 0,030 on height, 0,030
Terms of field works performance, 10 hectares /day	10 /15	10/7	10 / 5	10 /1
Terms of office operations performance, days	3	5	5	15
Performers, persons	3	2	1	1
Gauging speed	Single measurements (influence of a human factor)	Single measurements (influence of a human factor)	time:100 nanoseconds speed: 0.1 m/s	1 000 000 measurements/sec. (are completely automated)
Result	Creation of the topographic map 1:500	Creation of the topographic map 1:500	Creation of the topographic map 1:500	Creation of the topographic map 1:500 (a 3D creation possibility according to the obtained data)

It was widely assumed that the main works problem on technical condition monitoring of high-rise objects with use considered technologies is not so much surveying process which, in fact, is completely automated how many its results processing technique. Yes it is possible to agree with it, but there are not resolved issues on errors which come to light in the course of surveying. This is the scanner installation site, diameter of a laser bunch which depends on a corner and distance from the removed object.

5. CONCLUSIONS

Advantage of Surface Laser Scanning in comparison with traditional methods is shown, especially when conducting monitoring a high-rise buildings and constructions condition, the consisting of possibilities of quick data acquisition with the subject high density measurements.

In the context of Surface Laser Scanning application for acquisition about high-rise objects it is necessary to be guided by the choice of the device with high range of action and accuracy.

At the same time there are difficulties when processing results, especially it is shown at a stitching the images received from different places of objects scanning. It is caused by differences of measurement accuracy of various sites of a objects surface and depends on distance to the scanner and the scanning angle.

It should be noted, as in case of the building scanning from the same place because of distinction in distance from the scanner to the site of a surface and the scanning angle accuracy will also be various. In this regard there is a need for development a way of the place choice of the high-rise building and construction Surface Laser Scanning, providing its effectiveness at the greatest possible measurement accuracy.

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To reach a high precision when scanning the high-rise building it is necessary to define optimum distance from an object and the angle of scanning depending on building height.

Having resolved above the stated issues it is possible to claim that it is possible to apply Surface Laser Scanning technology to carrying out geodetic monitoring of deformations of high-rise constructions at construction and operation of various, including unique, engineering objects.

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