About research of building subsidence using sedimentary marks

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SUMMARY

The main task of geodetic observations within the monitoring of buildings is to identify changes in the spatial position of the load-bearing structures of buildings. Such monitoring makes it possible to determine the condition of the building and prevent accidents, destruction and ensure human life. The method of monitoring vertical displacements of building constructions is offered and tested in the work. 13 cycles of geodetic observations of the sedimentary marks were carried out in the building of the shopping complex on two floors, and the conditional heights of the sedimentary marks were determined. The difference of certain heights of the same marks for a certain period of time allows us to determine the number of vertical displacements. Excess between marks was determined by the method of II class geometric leveling. Measurements was performed at two horizons of the level, in the forward and reverse directions. The results of measurements were balanced by the nodal point method, and the leveling line was closed on each floor. As a result, we obtained the heights of sedimentary marks and the root mean square errors of their determination. The obtained results suggest that such observation technique can be recommended to determine the vertical displacements at similar objects.

Keywords: leveling, deformations, deformation monitoring of buildings, precise measurements
Introduction

The main tasks of the geodetic observations for monitoring of buildings are to identify changes in the spatial position of load-bearing structures (vertical and horizontal displacements) to assess risk of structures destruction, dismantling unstable structures, forecasting accidents.

In geodesy it is accepted to consider deformations as changes of one object positions concerning some other object (Brusak & Tretyak, 2020; Fys et al., 2020). Observation of landslides, subsidences and deformations of building have great importance for determining the stability and strength of the building to prevent its destructions or give signal in timely manner of an emergency, which can become vital. The main task of geodetic observation for buildings monitoring is to identify changes in the spatial position of structures for the timely implementation of measures to eliminate undesirable processes (Galinsky et al., 2010; Ratushniak et al., 2014; Savchyn & Zyhar, 2020; Kubrak et al., 2021).

During building’s deformations monitoring, measuring network is mostly used, which consists of the following geodetic points: benchmark - geodetic point that fixes the point of the leveling network (the height position of this point is almost unchanged during observations of deformations); mark - a rigidly fixed point on the building, which changes its height and planned position due to deformation of the building; reference point - practically motionless point in the horizontal plane, relative to which the displacements of building are determined (Ishutina, 2015; Isaev et al., 2013). In this paper we offered to carry out monitoring by a method of high-precision geometrical leveling on the established geodetic marks, according to one scheme with constant points of devices installation.

Method and Theory

Most effective method of observing the deformations of the building is monitoring by the method of high-precision geometric leveling (Dzhuman & Zablotskyi, 2020) on the established geodetic marks, according to one scheme with constant points of devices installation (Kubrak et al., 2021). Approbation of this technique was carried out on the example of the «Shuvar» mall building (Lviv).

Tectonically, the region is located on the border of the Eastern European (ancient) and Western European (young) platforms, the boundary between which runs along the Novovolynsk and Radekhiv-Rohatyn-Monastyrsky faults, which are part of the trans-European suture zone (Teisseira-Thornquist zone). The territory of Lviv is actually located on the edge of the Lviv Paleozoic Depression in the area of the Rava-Rusky deep fault (Fig. 1). Such tectonic location can cause horizontal and vertical tectonic movements and landslides. It should also be noted that in the territories of industrial and urban agglomerations, which are the territories of large cities, the karst process is intensified due to man-made factors (Information yearbook, 2013; Information yearbook, 2020; Gerasimov et al., 2004).

In addition, the territory of Lviv belongs to the area of influence of the Vrancea seismic zone, which can cause earthquakes for this area with a maximum magnitude of 5-6. In order to determine the vertical displacements of sedimentary marks of the «Shuvar» mall building, we carried out 13 cycles of II class leveling. The works have been performed since March 2009.

To determine the vertical displacements of the object under study we laid three wall benchmarks before the observations: Rp1 (directorate building of «Shuvar» mall), Rp2 (nine-story building on the right side of the entrance to the directorate) and Rp2 (column of a twelve-story building on the left side of the entrance to the directorate) (Fig. 2).

To perform a detailed determination of the building deformation, namely its sediment on two floors, we laid in the floor on the first floor 70 marks, and on the second floor 41 marks. Stamp numbering is indicated by a three-digit number. For the first floor the first digit 1 + mark number (for example 101), for the second floor the first digit 2 + mark number (for example 201). The system of heights is
accepted conditional. Rp3 was chosen as the original benchmark, for which the height $H = 100.0000$ mm was taken. In all cycles to obtain vertical displacements of the building for the initial mark was taken sedimentary mark № 106, the height of which was determined each time from Rp3 using double leveling. The heights of the other marks were obtained in relation to it. The results of geometric leveling were equilibrated by the nodal point method, and the leveling lines was closed on each floor, so the equilibrating was performed separately for each floor. As a result, the heights of sedimentary marks and the root mean square errors of their determination are obtained.

**Figure 1** Tectonic zoning of the studied region (Krupskyi, 2014): 1 - the boundary of the Lviv Paleozoic depression; 2 - the boundary of the Pre-Carpathian Depression; 3 - Novovolynsk and Radekhiv-Rohatyn-Monastyry faults (Teisseira-Thornquist zone); 4 - the main faults of the north-western direction (3-3 - Gorodotsko-Kapusk; 4-4 - Rava-Ruska), 5 - the main faults of the north-eastern and sublatitudinal direction

**Figure 2** Location of wall benchmarks

The schedule of heights change of the chosen marks of the first floor within 11 cycles is constructed (fig. 3). As we can see from Figure 4, the heights of marks from 1 to 9 cycles were almost unchanged, except marks 161 and 162, whose heights gradually increased from 6 to 8 cycles, slightly decreased to 10 cycle and increased again from 10 to 11 cycles, but these changes occurred within 2.5 mm. Marks 114, 138 and 199 changed their height up to 1 mm during the whole period, i.e., they are the most stable. All other selected marks up to 9 cycles remained almost unchanged, from 9 to 10 cycles rose (within 2 mm), and from 10 to 11 fell (within 2 mm). That is, in general, all marks, on which regular observations were made, did not experience critical uplift or subsidence.
Figure 3 The schedule of heights change of the chosen marks of the first floor during 11 cycles.

Fig. 4. shows a graph of displacements of marks between the 13th and 1st cycles, and the 13th and 12th cycles of observations on the first floor of the building. As we can see from the graph, most marks have been subsided. The mark № 133 subsided the most on about 12 mm, the other marks shifted to -5 mm. Marks 107, 120, 122, 125-130 were raised, the highest value was reached by the mark №130 up to 3 mm. Between the 13th and 12th cycles, the displacements acquired mainly negative values (subsidence) up to 1 mm, mark №133 has the maximum by -1.8 mm, small positive values of displacements (lifting) have marks 130 (+2.5 mm), 159 -166 (up to +0.5 mm).

Figure 4 Graph of shift of marks between 13 and 1 cycle, and 13 and 12 cycle of observations on the first floor of the building

Conclusions

The tectonic location of Lviv on the border of the Eastern European and Western European (Hercynian) platform (Krupskyi, 2014), on the edge of the Lviv Paleozoic trough in the zone of the Rava-Ruska deep fault can cause small horizontal and vertical tectonic movements and landslides. And since the territory of Lviv belongs to the influence of the Vrancea seismic zone, which suggests the possibility of seismic events with a magnitude of 5-6, the observation of the stability and deformation of large buildings is extremely important. It should also be noted that in the whole Lviv region, as well as in Lviv, rocks are widespread capable of karstification, and in the territories of large cities the karst process is additionally intensified due to man-caused factors, which is especially dangerous (Gherasimov et al., 2004; Map, 2016). Therefore we believe that the proposed method of monitoring buildings by high-precision geometric leveling on established geodetic marks, according to scheme with constant points of devices installation, which is tested on «Shuvar» mall (Lviv), can be proposed for using on such buildings, as it gives detailed and reliable results, and in comparison with other methods allows to observe the laid marks with lower costs, gives more complete and detailed information about the deformation condition of the building.

References


