1. INTRODUCTION

A measuring work carried out in engineering surveying for construction industry purposes apply to building facilities within the meaning of the Act, "Construction Law" [1], in the following situations:

a) at the construction stage - as-built and post-completion surveying (Art. 43 [1]);

b) during their use - mainly for specialized expertise performed under a periodic assessment of technical status of the object (Art.62 [1]) or when symptoms such cracks, scratches, excessive deflection or buckling of structural elements which pose a threat to its safe use,

c) surveying of objects in whose vicinity works are carried out (ground works or assembly) towards their development, which may pose a threat to the stability of their geometrical structure, particularly concerning objects situated on weak and / or heterogeneous soil.

This article represents methodical and technical documentation of works aimed at periodic registration of the geometrical structure of the Academy of Fine Arts building in Łódź in the situation referred in points b) and c) above .According to the experts, observed cracks of its construction called for conducting the surveying, the results of which could help, over time, to identify causes of the situation. In the immediate vicinity of this building a development of the university campus has commenced, involving massive excavation works followed by construction and assembly stages. The results of measurements taken before the expansion, and also carried out periodically during its works, are a vital source of information for the investor and construction company about the geometry of the building, which is subjected to a specialized expertise regarding the safety of its use.
2. ORGANIZATION AND IMPLEMENTATION OF MEASURING TASKS

Defining of measurement tasks, in particular their scope, was initially the result of agreements with the building's technical supervisor; at later stage also with the building contractor. The above tasks, intended to be specifically scheduled, were aimed at:

a) registration of vertical displacements of the building; this is due to a diverse vertical profile of the plot and likelihood of it being a former landfill,

b) registration of x, y, z coordinates of controlled points, designated on construction elements at the top floor, where cracks and fissures were observed.

Performance of such measurement tasks with the use of modern measuring equipment is not usually a methodological or technical problem. However, in some cases there is a serious problem with access to the object, particularly affecting the second of the above tasks. The first of above tasks represents the most common measurement assignment performed by surveyors for many years and on many types of buildings and structures. For the ASP building a measurement grid has been established: four reference points and ten controlled points (Figure 1).

Figure 1: Schematic of measurement grid for vertical displacements.
At the planning stage of this task, having determined the location of grid points (Fig. 1) and selection of measurement method - geometric levelling, the analysis turned to the accuracy and frequency of measurements. These issues have clear recommendations contained in the latest Technical Guidelines G-3.1 titled "Pomiary i opracowania realizacyjne" [2] [Measurements and development documentation]. Section §32 stipulates that the average error of measurement, used for defining measurement methods and tools, should be defined according to the following formula:

\[ t_p \leq \frac{D_g}{3.3R} \]  ……………… (1)

where:
\[ D_g \]  vertical displacement limit, which may not be exceeded without negative consequences for a proper usage of a building,
\[ R \]  coefficient of accuracy, depending on method and purpose of measurements may take value of 2 (with automatic signalling of dangerous conditions of the object), 3.3 (for measurements aimed to determine, if maximum displacement has been exceeded) and from 10 to 100 (for research measurements).

The guidelines [2] shows that displacement limit is specified in the draft of the construction or users' operations instructions, while the accuracy coefficient is agreed with the designer or construction manager. The above information is clear, but probably taken arbitrarily by the authors of the guidelines [2], since in practice the displacement limit, for a vast majority of buildings, are not stipulated in their projects, or operating instructions, similarly the safety factor.

Frequency of measurements also relates to vertical displacement threshold \( D_g \) and accuracy coefficient \( R \). According to the guidelines [2], the time interval between consecutive periodic measurements should be selected so that a predicted change in displacement \( \Delta_p \) was in range:

\[ 5M_p : \Delta_p : 2M_p \]  ……………… (2)

where:
\[ M_p \]  error of measurement (or rather: of determination) of displacement \( D_g/R \)

In case of the ASP building no data on \( D_g \) and \( R \) meant that stipulations contained in the guidelines [2], could not serve for optimal selection of a leveller, because geometric levelling was beyond any doubt in view of the terrain and experience of the surveying team. In this situation the organization of surveying task and its implementation as periodic measurements, as well as work on their outcomes has been carried out along the lines of internal instructions issued by Geoprojekt [3]. This manual, used by professional surveyors for years, adopts the following as accuracy parameters:
a) average error $m_0$ of single measurement of the difference in height after levelling,

b) average error $m_p$ of vertical displacement of any benchmark (for ASP building this was the farthest from the reference benchmark).

For measurement grid (Figure 1) periodically observed by geometric levelling and using leveller with Ni007 and 1.8 m invar staff, these parameters take values as shown in Table 1, against observed vertical displacements.

Observations from VII onwards were performed while construction works were being carried out in the immediate vicinity of the ASP building. Their frequency and accuracy meet expectations of the technical supervision of the investor.

Table 1: Description of measurement accuracy and detected vertical displacements

<table>
<thead>
<tr>
<th>OBSERVATION PERIOD</th>
<th>OBSERVATION DATE</th>
<th>$m_0$</th>
<th>$m_p$</th>
<th>VERTICAL DISPLACEMENT [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>February 2009</td>
<td>± 0.20</td>
<td>± 0.35</td>
<td>from - 0.1 to 0.9</td>
</tr>
<tr>
<td>II</td>
<td>May 2009</td>
<td>± 0.08</td>
<td>± 0.13</td>
<td>from 0.0 to 1.4</td>
</tr>
<tr>
<td>III</td>
<td>September 2009</td>
<td>± 0.18</td>
<td>± 0.30</td>
<td>from - 1.5 to 0.0</td>
</tr>
<tr>
<td>IV</td>
<td>December 2009</td>
<td>± 0.12</td>
<td>± 0.20</td>
<td>from - 2.0 to 0.6</td>
</tr>
<tr>
<td>V</td>
<td>April 2010</td>
<td>± 0.08</td>
<td>± 0.13</td>
<td>from - 2.1 to 1.0</td>
</tr>
<tr>
<td>VI</td>
<td>July 2010</td>
<td>± 0.17</td>
<td>± 0.28</td>
<td>from - 3.1 to 0.6</td>
</tr>
<tr>
<td>VII</td>
<td>October 2010</td>
<td>± 0.12</td>
<td>± 0.24</td>
<td>from - 0.2 to 2.3</td>
</tr>
<tr>
<td>VIII</td>
<td>December 2010</td>
<td>± 0.20</td>
<td>± 0.32</td>
<td>from - 1.2 to 8.2</td>
</tr>
<tr>
<td>IX</td>
<td>February 2011</td>
<td>± 0.12</td>
<td>± 0.20</td>
<td>from - 1.2 to 9.9</td>
</tr>
</tbody>
</table>

The second task is to periodically register location of controlled points designated on the top floor of ASP building. In the context of selecting the method of spatial intersections this task can also be regarded as one of the most common tasks of surveying in engineering. Individual groups of controlled points created so-called controlled profiles according to the concept shown in Figure 2.

A and B free stadia of electronic total station determining measurements reference (primary) - x, y, z for points observed using spatial intersection method,

$D_L$ & $D_P$ points located on a wall of the building at the ground level, indicating the secondary set X, Y, Z, in which are made comparisons of coordinates of controlled points obtained from periodic observations,

$G_1$, $G_2$, $G_3$ points located on the top floor will function as controlled points in the set X, Y, Z.
It is assumed that observations to be conducted according to the diagram in Figure 2, of each of the seven control profiles (Figure 3) will be performed from an independent measurement base. This was, among others, subject of consultations with the technical supervision and a building construction expert.

Figure 2: Schematic of observation of a control profile using spatial intersection method.
In this situation, such scheduled task was to register any changes in position of points located on the top floor ($G_2$, $G_3$ ... Figure 4) in the reference system, independently specified for each control profile through points $D_L$ and $D_P$. In all controlled points special targets have been installed intended for observation using spatial intersections method from free observation positions $A$ and $B$. The decision to resign from permanent stabilization of $A$ and $B$ points, resulted primarily from intensive use of ASP land and subsequent construction works.

In the adopted concept of measuring task the following needs to be considered:

a) existing difficulties due to such a location of measuring stations $A$ and $B$ at which a proper geometry of intersecting lines would be maintained, assuming achieving of expected accuracy of determining $\Delta X$, $\Delta Y$, $\Delta Z$ (Figure 4) points $G_1$, $G_2$ ..., at 2 - 3 mm level,
b) gauge maintaining stability of reference points $D_L$ and $D_P$ limited to assessing their mutual horizontal distance and their difference in height, calculated each time from coordinates of these points in the measurement system $A - B$

![Figure 4: Location of controlled points of a sample control profile.](image)

An alternative to the method of spatial intersections, in case of cyclic observations can certainly be a 3D polar method using a mirror-less tacheometer. However, this requires establishing appropriate measurement grid and protecting it from physical damage, which is not always possible in densely built-up areas and pending construction work.

3. CONCLUSION

Presented measuring tasks are examples of surveying works for building construction industry. In most cases the objective of these works is ongoing registration of selected geometrical features of construction objects in the context of specialized expertise concerning ensuring the safety of their use. This is related to diagnostics of buildings threatened by a failure of intensive construction work carried out in their surroundings.

In measurement tasks involved in the diagnostics of buildings typical methods of surveying engineering are applicable. Such methods include: geometric levelling with increased
accuracy to register vertical displacements or 3D polar method or spatial intersections to register changes in location of points inaccessible for direct measurements.

A choice of measuring instruments available is currently very wide, and the fundamental criterion should be meeting expectations of building designers, both as to the accuracy and scope of designated geometrical features.

REFERENCES


Internal Instructions: GB-2. “Geodezyjne wyznaczenie pionowych przemieszczeń metodą niwelacji precyzyjnej” [Geodetic determination of vertical displacements by precise levelling], Warsaw 1976, - GEOPROJEKT.