VERTICAL DISPLACEMENT DETERMINATION OF THE VERTICAL BUILDINGS SITUATED IN THE AREA OF GRUNWALDZKI SQUARE IN WROCLAW

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SUMMARY

The correct determination of displacements, mainly vertical ones, of the buildings and other building objects is necessary for the statement of changes in construction of these buildings and working out the security rules and forms, allowing for the avoidance of the building catastrophes.
The geodetic vertical displacement measurements ought to be performed with high accuracy.
For that reason, the most appropriate method of their determination is the precise geometric leveling. This method is characterized by not very long time of realization, but on the other hand there are some inconveniences, caused by doing works in unfavorable terrain conditions (road, vehicular and pedestrian traffic, variable lighting conditions).
As a consequence, it is advisable to use for displacement measurements the measurement equipment of high precision parameters, preferably with the automatic registration of the measured elements.
In this work there are presented the outcomes of the vertical displacement measurements for the five annual cycles of the Wroclaw University of Environmental and Life Science's buildings, situated in the area of Grunwaldzki Square. The measurements have been carried out between the years 2006-2010.
Because of the statement of abundant cracks of the walls of these buildings, the terrain works have been carried out there.
Taking into consideration the localization of the cracks in the area of the ice-marginal valley of the Oder River and their time formation, there has been assumed, that the floods in years 1997 and 2010 are the main reason for the cracks occurrence as well as earthworks associated with doing deep, wide-spatial pits of new building objects .
The terrain measurements are performed mainly by third-year students of land surveying in frame of the terrain classes within the Engineering Geodesy course.
The terrain data for computations have been prepared by students in frame of their master's thesis works under the authors' of this paper guidance.

1. INTRODUCTION

The conducting of work measurements, concerning the determination of changes in building foundations and other building objects, has the first-rank significance as far as

the settlement of risks is concerned, which result from permanent damages of these foundations.
The precise leveling is still the most practical and accurate measurement method for determination of shifts of controlled points, situated in the building foundations.
For the correct determination of the vertical displacements (as well as other deformations) it is necessary to fulfill several important measurement conditions:
- the appropriate settlement of reference benchmarks, resulting in the stability of the reference frame within the whole time period of the surveys,
- the sufficient amount and the appropriate settlement of the controlled points, ensuring the correct interpretation of the changes in the foundations of the surveyed buildings,
-the performance measurement with the same, tested measurement equipment, allowing for automatic registration of the measured data, carried out by the same well qualified measurement team, in possibly similar, generally comprehended measurement conditions ,
-the maximal short time necessary for doing and working out the next observation cycles, ensuring continuously the security of the surveyed object,
-the appropriate accuracy of the measurement works,
- the correct determination of the stability of the reference benchmarks,
-the correct computation of the values of displacements and the correct estimation of their accuracy.
The performance of the measurements in accordance with the above mentioned conditions gives a guarantee for the correctness of the received measurement results, not only in the precise leveling networks.

2. THE RULES OF THE PERFORMANCE MEASUREMENTS OF THE PRECISE LEVELLING NETWORK

In 2006, at the time of the beginning of the measurements, the research network consisted of the 23 national leveling benchmarks of the Wroclaw city and 120 controlled benchmarks.
Unfortunately, each year there have been damaged several benchmarks.
At least four of the controlled benchmarks (suitably six) are fixed on every surveyed object, so that it would be possible to determine the range and type of the changes in the foundations of these objects.
In the beginning, the measurements were carried out with the use of the Ni007 levelers; currently there have been used the DNA03 code levelers and the invar precise leveling staff. In one cycle there have been measured approximately 400 observation sites, twice observed while back and forth measurements.
Each year the measurement time is about 12-15 days. The outline of the measurement network shape of the year 2010 presents the leveling lines, measured in this cycle (fig.1).

3. THE INVESTIGATION OF THE STABILITY OF THE REFERENCE POINTS

To make a choice of the stable reference points, there has been conducted the analysis of the historical materials of the Wroclaw city national leveling, taken from three measurement cycles from the years 1920, 1960 and 1986. The elevations, computed for approximately 20 benchmarks and containing unfortunately only compensated ordinates, have been compared with the results of the first control measurement (from the year 2006).

As a consequence, there has been indicated four reference benchmarks: W-1471, W-1470,
W-284, W-469. The computed differences of the elevations for different combinations between benchmarks have not exceeded the value of 7mm.
The exact statistical analysis has not been carried out, because of the lack of the unambiguous and precise information about the accuracy of the performance of the historical measurements.

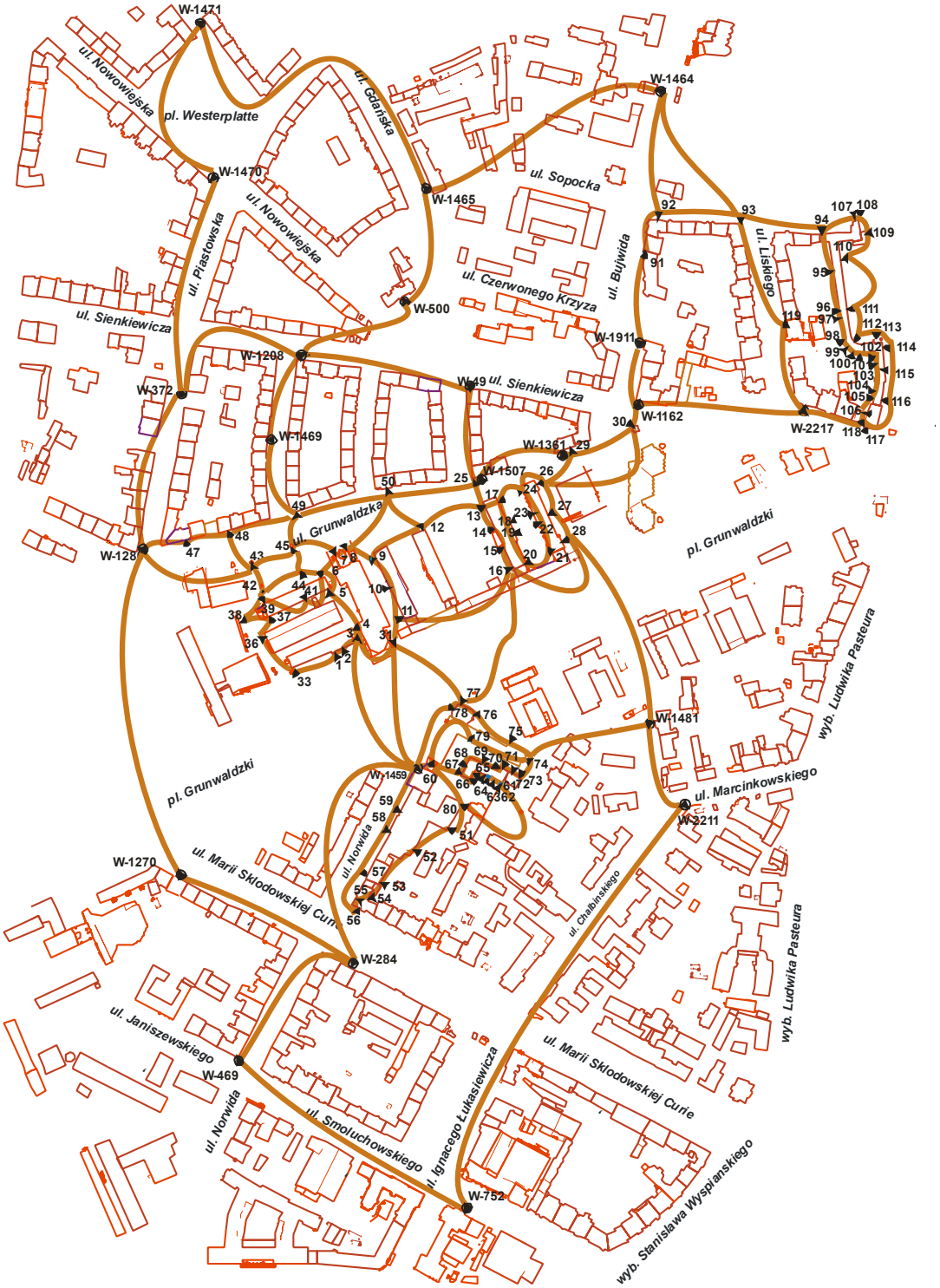


Fig. 1. The outline of the measurement network „Grunwaldzki Square" – the situation in the year 2010.

For the period of 2006-2010 there has been carried out the investigations of the stability of the reference benchmarks with the use of Hermanowski method (tab. 1-4). In the tables (tab. 1-4) there have been presented in numerators the measured differences of the elevations and in denominators the maximum ones.
The changes of the elevations, that do not meet the criterion of the stability of the reference points, have been presented in bold type.
In the time period of the analysis, there has been only one benchmark (W-469 from the year 2009), that has not met the required criterion.
For that reason, he has been excluded from the group of the reference benchmarks while performance compensation of the network from the year 2009.

Table 1 The investigation of the stability of the reference points

2006 – 2007				
$\Delta h'-\Delta h$ [mm] / $\pm 1{,}5\, m_o \sqrt{n'+n}$ [mm]	1471	1470	284	469
1471	X	-0,57 0,85	-1,62 2,40	-0,39 2,54
1470		X	-1,02 2,24	-3,55 2,40
284			X	-0,39 0,85
469				X

Table 2 The investigation of the stability of the reference points

2006 – 2008				
$\Delta h'-\Delta h$ [mm] / $\pm 1{,}5\, m_o \sqrt{n'+n}$ [mm]]	1471	1470	284	469
1471	X	0,27 0,85	-1,02 2,40	0,19 2,54
1470		X	-1,29 2,24	-1,10 2,40
284			X	0,19 0,85
469				X

Table 3 The investigation of the stability of the reference points

2006 – 2009				
$\Delta h'-\Delta h$ [mm] / $\pm 1{,}5\, m_o \sqrt{n'+n}$ [mm]]	1471	1470	284	469
1471	X	1,26 0,85	-0,24 2,40	-2,29 2,54
1470		X	-1,02 2,24	-3,55 2,40
284			X	-2,53 0,85
469				X

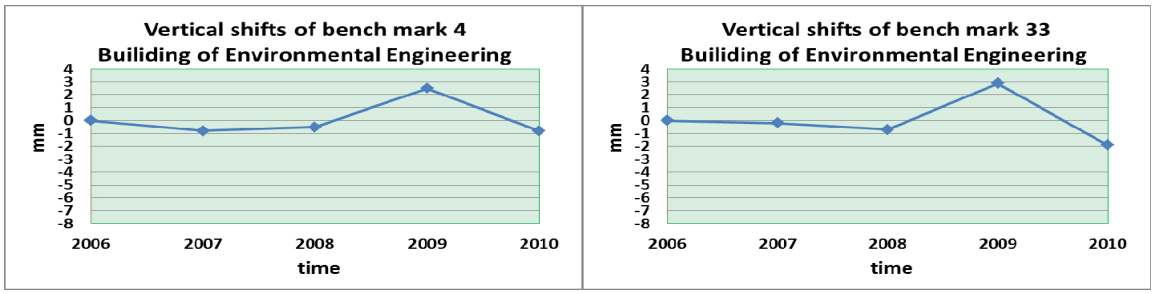
Table 4 The investigation of the stability of the reference points

2006 – 2010				
$\Delta h'-\Delta h$ [mm] / $\pm 1{,}5\, m_o \sqrt{n'+n}$ [mm]]	1471	1470	284	469
1471	X	0,90 0,85	-0,40 2,40	-0,36 2,54
1470		X	-1,30 2,24	-1,26 2,40
284			X	0,04 0,85
469				X

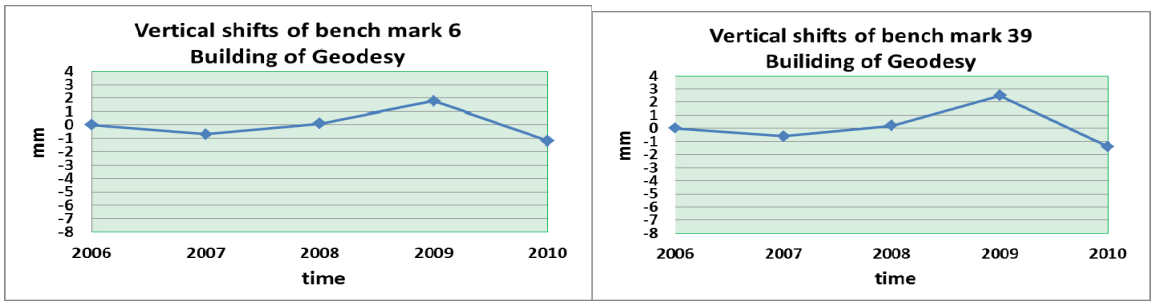
4. THE DETERMINATION OF THE VERTICAL DISPLACEMENTS OF THE CONTROLLED POINTS

The vertical displacements of the controlled points have been determined annually, after the verification of the stability of the reference benchmarks. For the computations there has been used the c-geo v.8. software. The received vertical displacement errors have not exceeded the value of 1 mm. For most of the controlled benchmarks, there has been registered small subsidence values, usually insignificant, from the point of view of the accuracy estimation of the measurements.

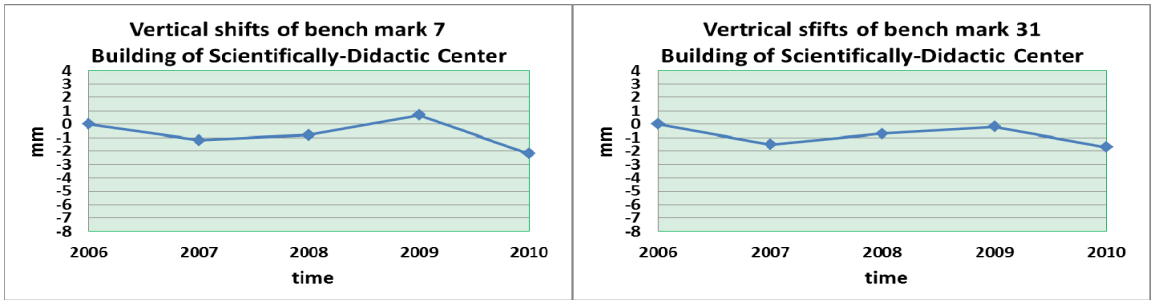
The graphs (fig. 2 -9) show the vertical shifts of the chosen controlled benchmarks with the characteristic course of these shifts for the surveyed objects.



Rys. 2. Vertical shifts of bench mark of building of Environmental Engineering.

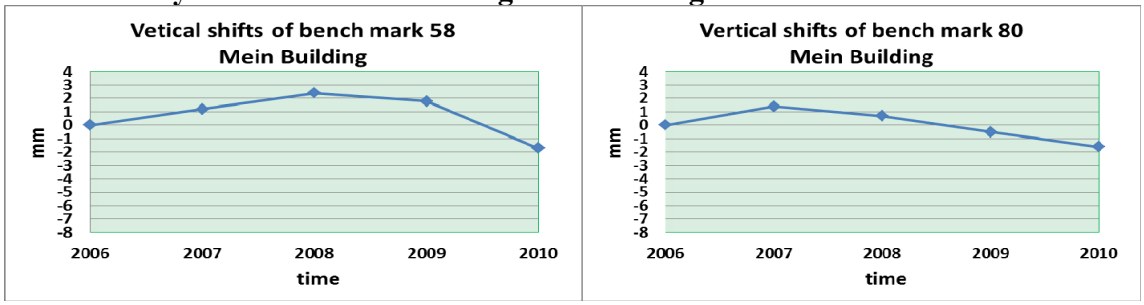


Rys. 3. Vertical shifts of bench mark building of Geodesy.

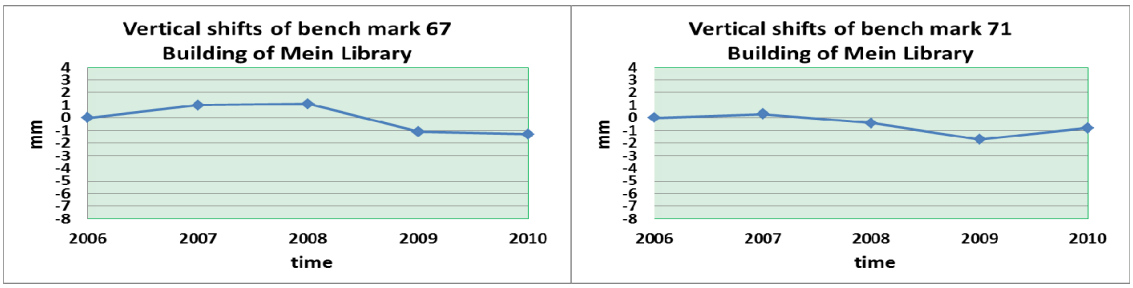


Rys. 4. Vertical shifts of bench mark building of Scientifically-Didactic Center.

The changes of the benchmark heights, observed on the Environmental Engineering and Geodesy buildings, as well as on the Didactic and Research Center building result most likely from the different level of groundwaters. The year 2009 was rather a dry year, whether in the year 2010 there was a significant rising of the Oder River Basin waters.

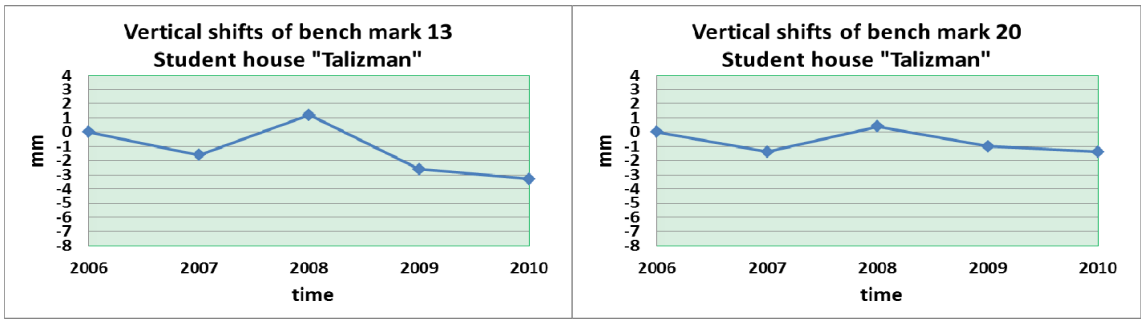


Rys. 5. Vertical shifts of bench mark of Mein Building.

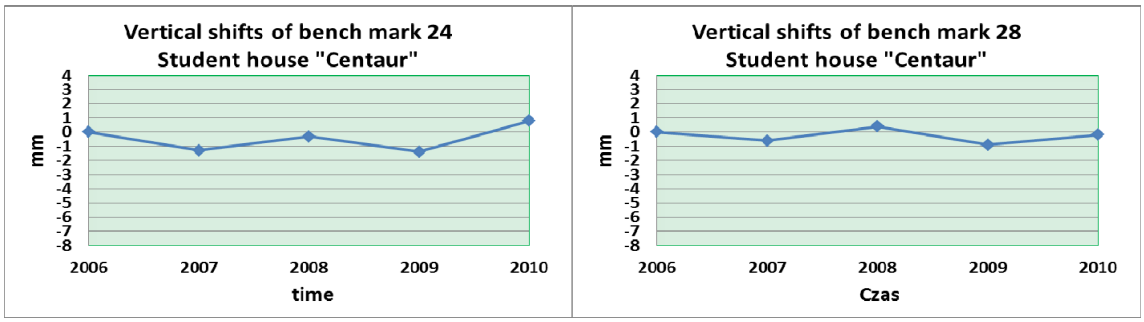


Rys. 6. Vertical shifts of bench mark.

The similar changes of the heights have been registered on the Main Building and the Main Library, where in the first time period of the investigations, there have been determined small uplifts and then subsidence's, that were caused by the raised groundwater level in 2010.



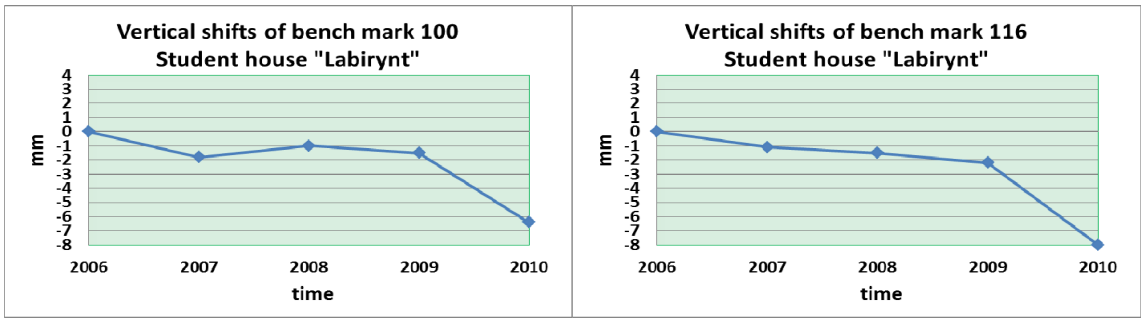
Rys. 7. Vertical shifts of bench mark student house "Talizman".



Rys. 8. Vertical shifts of bench mark student house "Centaur".

The height changes, registered on the buildings of the Talizman and Centaur dormitories are rather small; they are larger only for the benchmark 13. The reason for that is the localization of the benchmark, which is in direct proximity of the Grunwaldzka Street. Besides this, in 2007 there was introduced the through car traffic and the corner of the building is probably in direct proximity of the tenement houses, that were destroyed in 1945.

The evidence for that may be the significant and extensive crack of the walls in the rooms, situated over the benchmarks, on the ground floor. The crack is practically not present in other parts of the building.



Rys. 9. Vertical shifts of bench mark student house "Labirynt".

In the last period of time, between the measurements in the years 2009 and 2010, for the benchmarks, situated on the „Labirynt" dormitory building , there have been determined the subsidence's of the maximum value of 8mm. The reasons for that have been the excessive and the longer persistant ground damp, caused by the raising of the Oder River waters, in the period of time just before and even during the measurements in 2010.

On the basis of the presented graphs it could be stated, that the registered vertical displacements of the controlled benchmarks, situated on the building objects of the Wroclaw University of Environmental and Life Sciences are in most cases negligible, according to the geometric interpretation. At the same time, they could confirm the changes in the construction of the foundations of these buildings, revealing in a form of the cracks of the walls, particularly on the whole "Labirynt" dormitory building. The reason for these cracks might be the changes in groundwater level.

As far as the "Talizman" dormitory building is concerned, the cracks have been caused by the temporarily introduced excessive traffic on the Grunwaldzka Street.

The reason for cracks of the walls of the Environmental Engineering and Geodesy building has been the artificially caused groundwater level changes, associated with the formation of the deep pit under the Didactic and Research Center building.

The cracks of the walls of the Didactic and Research Center building have been resulted from the same phenomenon as it was during the erection of the Grunwaldzki Center building.

It is worth to mention, that the Didactic and Research Center building is covered by the special, extended research cycle, taking into consideration i.a. the course of the building processes, that occur in the near of this building object. It allows for more precise observations of the vertical changes in the structure of its foundation.

Until now, there have been carried out together 13 measurements. The initial measurement was conducted in April 2006 and the next control measurements in the following periods of time, October 2006- after determination of the cracks on the 4^{th} and 5^{th} floor of the building, March 2007 - before beginning of the earthworks under the Grunwaldzki Center building, April 2007- during the realization of the earthworks, June 2007 - after formation of the whole pit and the settlement of the lowered groundwater level, April 2008- after the end of the main building works of the Grunwaldzki Center building, August 2008, April 2009, November 2009, April 2010, June 2010- during the raised level of the waters in the near Oder Channel, October 2010, April 2011.

With reference to the figure fig. 10 there are presented the vertical shifts of the chosen benchmarks, fixed on the Didactic and Research Center building.

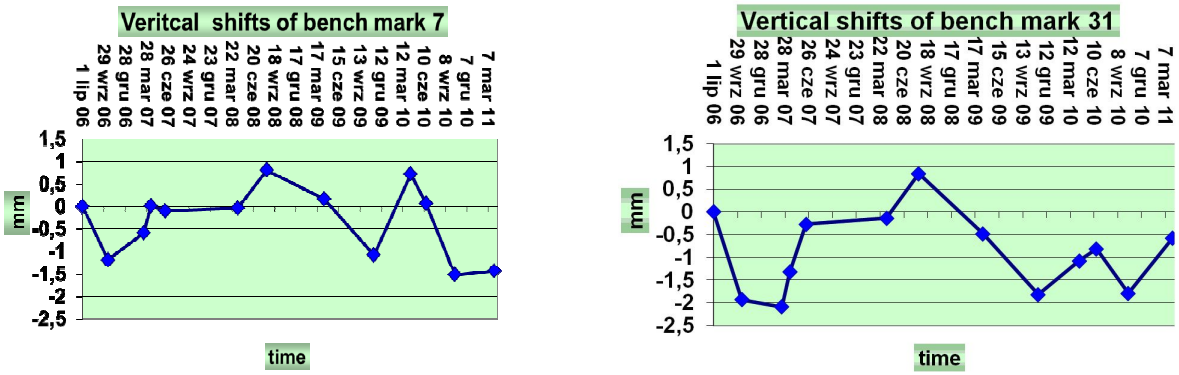


Fig. 10. Vertical shifts of the benchmarks 7 and 31.

According to the charts (fig. 10), there could be observed changes, resulted from the erection of the Grunwaldzki Center building: the first period of the subsidence's (autumn 2006), caused by the artificial lowering of the water level, connected with the realization of the deep, wide-spatial pit, and then the uplift period (spring 2007), resulted from the relaxation of the formation, after the creation the pit. There have been also observed the next two subsidence periods (autumn 2009 and autumn 2010), overlapping in the next two years. For most of the benchmarks there have not been observed any relevant height changes, caused by the rising of the Odra River Channel waters in summer 2010.

This could be resulted from the fact, that the controlled benchmarks of the object have been established to the reference benchmarks, which reaction for the raised level of waters has been like for the controlled benchmarks.

The undetection of these changes would not have any important influence on the eventually breach of the constitution of the foundations of the surveyed object. This is because of the fact, that if the changes have been occurred, their surface range has not covered most of the building objects of the university.

This has been confirmed by the values of the displacements of the benchmarks, situated on the „Labirynt" dormitory building, determined in 2010 (fig. 9), which have not been observed for the benchmarks, situated on the other buildings.

5. CONCLUSION

The conducting researches have an important meaning for the determination of the state of emergency of the building objects of the Wroclaw University of Environmental and Life Sciences. They are practically one of a few, possibly to determine evidences that could contribute to establish reasons for the formation of the abundant cracks and delineations of the walls of these objects. The surveys have been carried out since 2006 and in 2010 there was conducted the next 5th measurement cycle.

As far as the expense is concerned, there are approximately 500 man-hours each year for preparation and elaboration of the geometric interpretation of the results of the 100 man-hours. It gives together approximately 3000 man-hours for doing the whole executed task.

Besides essential values of the executed works, the didactic values could not be omitted. They concern the possibility for students to gain experiences of the realization of measurement and computing works. It is also of great importance, that students could take responsibility for the executed survey works.

The obtained results of the vertical changes of the controlled benchmarks confirm the pertinence of the establishment of the networks for their determination and indicate the need for further investigations.

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