SURVEY FOR NEWLY BUILT SPORT FACILITIES

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INTRODUCTION

Currently, geodesic service for complex cubature structure requires the involvement of experienced surveyors and modern equipment [1][4]. During construction and after it's end, surveying is carried out according to Technical Standard G-3 [2]. However during the exploitation of buildings, you can use different, geodetic and non-geodetic survey methods described in [3]. The article presents selected surveying and construction problems on two newly built sports facilities in Gdansk: Multifunctional Sport-Entertainment Arena ERGO-ARENA Gdansk-Sopot, and football Stadium PGE Arena Gdansk. Were characterized terrain and soil and water conditions in places of location of these objects. The supporting structure together with the roof cover and the foundation hall and stadium was described. Particular attention was given to an organization, technology and the course of the surveying made during the realization of geodetic service by UH DIAZ from Gdansk in cooperation with the Gdansk University of Technology. The article contains selected results of surveying.

1.0. LOCATION OF SPORT FACILITIES IN GDANSK

A newly built hall ERGO-Arena is located at the administrative town border of Sopot and Gdansk, in the region of former allotment gardens, in the vicinity of electric railway station Gdańsk Żabianka and Sopot Racing and horse racing track (Fig. 1).

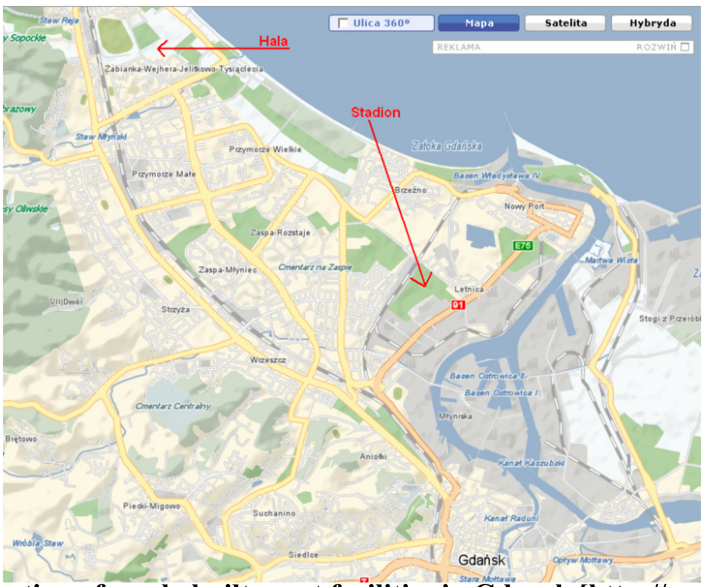

Fig. 1. Location of newly built sport facilities in Gdansk [http://www.zumi.pl]

Size of the built-up area is approximately of 15 hectares. The range of elevation is from approximately 11.000 m above sea level to about 4.30 m. Whereas, PGE Arena football stadium is located in the region of former allotment gardens with an area of approximately 35 hectares in the district of Gdańsk – Letniewo, in the neighbourhood of the Marynarki Polskiej street and Uczniowska street (Fig. 1).

In the location of the Hall ERGO-ARENA, there are moderately favorable ground-hydrous conditions, such as slightly and the mildly putrefied peat with a high compressibility and low shear resistance, organic aggradate mud, and bog lime occurring in a plastic state and high-plasticity, very fine sands and loamy sands. On the construction site, ground water level is placed on the elevation from H = 2.890 m to H = 4.310 m above sea level. Hall and back-up facilities are located in the regional cone of depression formed by the water intakes "Czarny Dwor" and "Zaspa" in Gdansk and "Bitwy pod Plowcami" in Sopot.

By contrast, in the ARENA PGE investment, there are sediments represented by Quaternary sands and gravels of various origins and clay, silts and peats (often appear from the ground surface). Under the layer of soil or earth embankment there is a continuous layer of Holocene alluvial-swampy tracks in a form of peat with an average thickness of up to 13.000 m. Locally, there are clusters of aggradate muds and interbedding of non-cohesive subsoils. The free and surface of ground water stabilizes at depths of 0.200 m to 2.100 m (0.000 m - 0.700 m). Due to poor parameters of the subsoil, within the range of earthworks it have been strengthened and replaced.

2.0. CONSTRUCTION AND FOUNDATION OF OBJECTS

Hall Entertainment - Sports *ERGO-ARENA* Gdansk-Sopot

Hall consists of two parts, the bottom is partially sunk into the ground, while the upper part is entirely visible in the form of a simple cylinder (Fig. 2). In the building of Hall, Main Arena with surrounding auditorium of approximately 11.000 seats, and back-up facilities is located. The sport hall serving as a place for warm-up, equipped with a movable rostrum adheres to the main building.

Fig. 2. View of Hall ERGO-ARENA under construction on the administrative border of Gdańsk and Sopot.

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Load-bearing structure of auditorium is a monolithic reinforced concrete slab made of concrete B37 and steel AIII N, based on the walls and pillars and binding joists. Whereas load-bearing structure roof of Hall constitutes a set of four pillars - the pylons with a diameter of 10.800 m and height of 25.000 m (Fig. 3), each of them is rigidly fixed in the pile foundation, articulated to the roof structure, and dilated from the rest of the structure of the object. A roof consists of spatial system of steel truss, supported on reinforced concrete columns, monolithically poured, covered with corrugated metal sheet. The spatial structure is characterized by dimensions of the axes: 70.600 m (length) x 66.600 m (width) x 5.600 m (height) and the axial distances of girders are 6.460 m and 6.060 m, with the technological platforms, attached to their lower flanges.

Fig. 3. View of the pylon and the girder of Hall.

The whole structure is connected to the pylons by bearings, what allows horizontal sliding at the distance 6 - 9 cm. Roof structure was made with contr-bending by reducing the length of individual cross braces. The roof of the hall is supported in four points (in the corners) by means of cranial bearings with teflon lining, allowing the free rotation in each of the supports and the movement in the three corners (in the directions described in the drawings). These bearings allow displacement of the structure resulted from temperature changes, and deflection of the structure. Despite the previously mentioned division, dilatations with the radial course, into eight sections was also anticipated.

Football stadium *PGE ARENA* Gdansk

Fig. 4. View of the girders from the side of the pitch - the second stage of assembly.

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The sport facility takes about 3.3 hectares, while the dimensions of the stadium are: length 236.000 m, width 203.000 m, height 45.000 m. The roof of the stadium consists of 82 girders weighing 66 tons each (Fig. 4 and 5), supported on independent bearings fixed in the ground parts of the object - a reinforced concrete structure by means of 8 anchors.

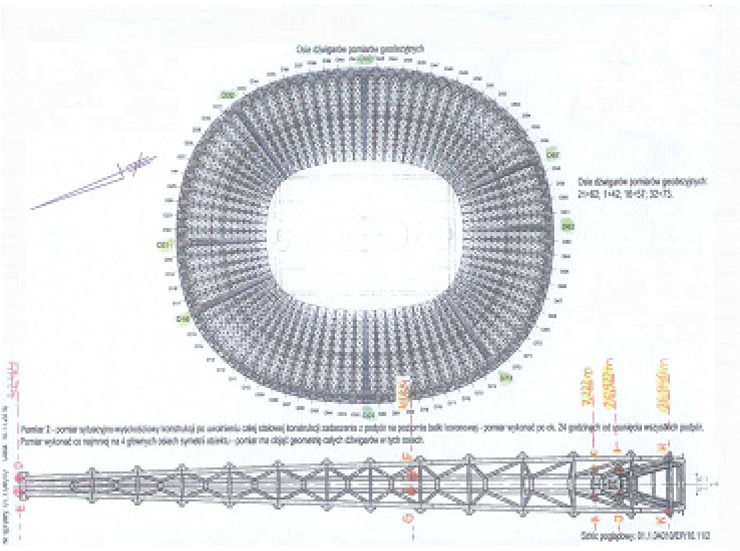

Fig. 5. Top view of the steel structure of stadium.

3.0. SURVEYING

3.1. Hall Entertainment - Sports *ERGO-Arena* Gdansk-Sopot

Complex geodetic service was provided by "DIAZ" from Gdansk. In the initial phase one team participated, and at the peak period of the works three teams conducted measurement. In the area of investment following networks were established:

- horizontal geodetic network in the coordinate system "Gdańsk 70 " (connection to the points of realization network established for the construction of the object - three points of the first order - signalized by geodetic prism and geodetic network of the second order signalized by reflective target ,

- vertical geodetic network in 1986 Kronstadt 86 bis six (bench-marks were established for geodetic service on construction-site and for the densification of network).

Marking out have been based on the network realization of 3rd class. Moreover, surveying was conducted during the assembly of structural elements of roof, during its installation and during the roof load test with water. For service and inventory measurements electronic rangefinder *Leica TCR803power* with the inner registration and levelling instrument ZEIZZ NI 2 were used.

For measuring the deflection of the roof structure six controlled points (Fig. 6) and three bench marks were established. Controlled points were signalized by reflective targets placed on the bottom surface of the supporting beam (visible from the pitch). Three concrete bench-marks were settled in reinforced concrete walls (A, B, C), from which

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height of controlled points of the roofing was defined (Fig. 7). Measurements started at September 30th 2008 and were conducted twice a day (at 8.00 and 14.00), subsequently once a day and at further step at the request of the client (Budimex Dromex). Calculations were being conducted systematically with the rangefinder software and C-GEO v.6.5.

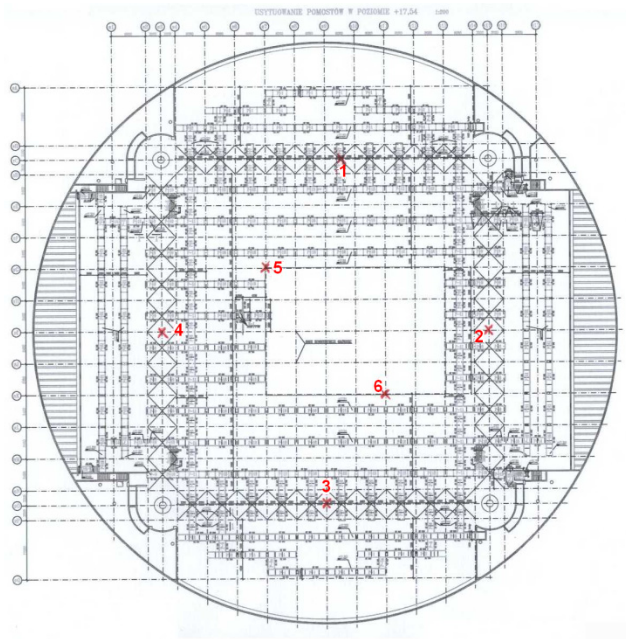

Fig. 6. Top view of construction – level of lower spar flange supported on four pylons.

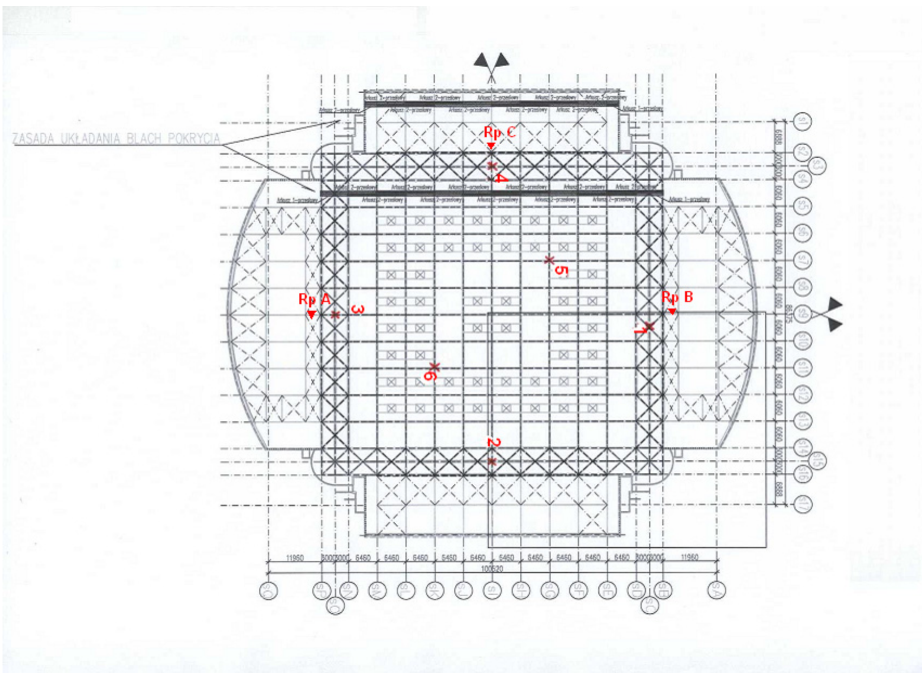

Fig. 7. Top view of construction - level of upper spar flange.

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3.1.1. Results of surveys

Cover construction
Survey of displacement - the deviation of the designed values: from 0 mm to 15 mm.
Roof load test: water (760 m^3) = 7.600 kN for one day.
Number of measurements: 4.
Differences of designed elevations:
- in the central point 16 mm,
- in side zones 10 mm,
- girder between the pylons 39 mm.

3.2. Football stadium PGE Arena Gdansk

Fig. 8. Staking out axis of heads of reinforcing subsoil piles by means of GPS.

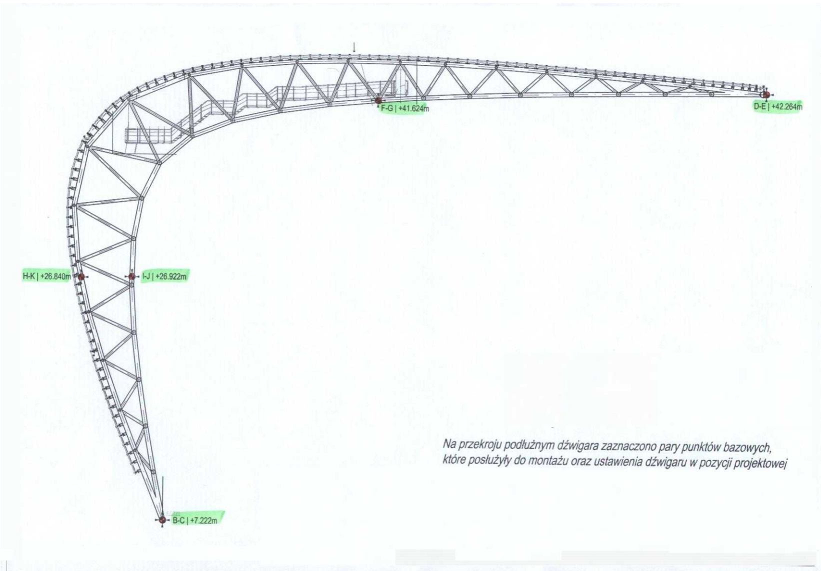

Fig. 9. Steel girder as load-bearing element of the roof.

Surveying at the stadium from the begining of the investment surveying at the stadium has been performed by "DIAZ" from Gdansk. At the culmination stage works in field

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there were 6 - 7 teams. Used instruments are: TCR400 and TCR800 and TCR1201 of Leica. In staking out the axis of the reinforcing subsoil piles GPS was used (Fig. 8).

At the final stage of construction the most of the work ~~is~~ was related to the assembly service of the roof of the stadium . Besides the basic requirements related to the assembly, after consultation with the Department of Geodesy (University of Technology in Gdańsk) and with the consent of the investor there were also observed displacements of steel girders, which are load-bearing structure of the roof (Fig. 9).

The basic geodesic network

Elements of network connected to the national network of 3rd class: 6 points - a geodetic prism affixed to the slab roof of surrounding tall buildings, 15 points - reflective targets on facades of buildings, a ground point - stainless steel bar settled in a concrete block in the middle of the pitch (Fig. 10). Deviations (dx and dy) of newly-assigned points do not exceed 4 mm with a maximum length of 800 m. Detailed geodesic network was the development and densification of the basic realization network and consisted of 80 points sygnalized by reflective targets. The accuracy of alignment of points is 1 - 2 mm.

Fig. 10. The central geodetic mark - located in the middle of the stadium plate.

Vertical geodetic network

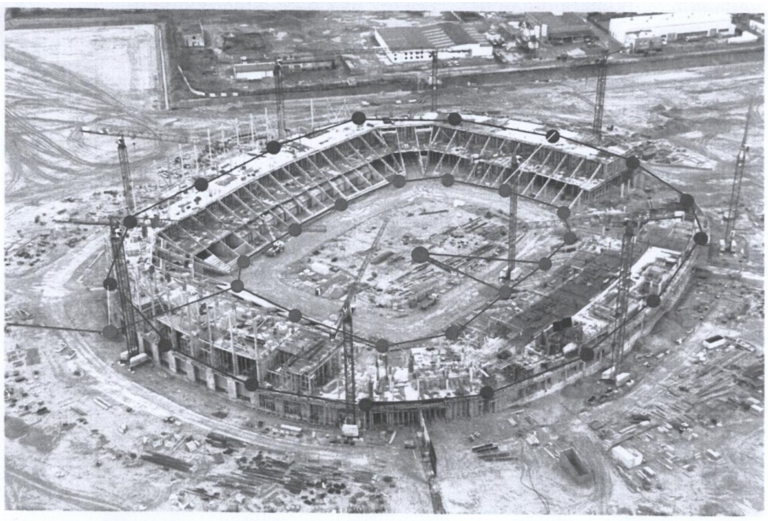

Fig. 11. Vertical geodetic network on the construction site of the stadium.

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Vertical geodetic network was designed as two ovals at two levels of the object with the height difference of 6.000 m (Fig. 11): horizontally at the base of foundation, vertically in reinforced concrete of roof and was connected to the national vertical geodetic network (three bench-marks at a distance of about 800 meters from the stadium). The construction project assumed that the settlement of construction should not exceed 100 mm, and the differences of settlement should not exceed 10 mm.

3.2.1. Results of steel structure of the roof

Horizontal geodetic network: coordinate system "Gdańsk 70".
Vertical geodetic network: local system.
Method of survey: free station – coordinate system, Leica TC1200.
The accuracy of measurement of the angle 1".
Distance measurement accuracy when reflectorless measuring 2 mm + 2 ppm.
Goal:
Internal Ring - 95 reflective targets and 57 reflectorless points (steel rings).
Girders: reflectorless points and reflective targets.
Calculation of the point coordinates was made by means of C-GEO.

Table 1

Displacement measurement of the ends of steel girders of the roof – overview of results

The values calculated from measurements of the 82 girders	Differences between designed values and values obtained in inventory before leaving the construction site			Differences between designed values and values obtained in inventory after leaving the construction site			Differences between the values measured before and after leaving the construction site		
	ΔX	ΔY	ΔH	ΔX	ΔY	ΔH	ΔX	ΔY	ΔH
Average	0.007	0007	0.065	0.008	0.012	-0.319	0.000	0.006	-0.385
Maximum	0.051	0.047	0.090	0.056	0.058	-0.233	0.014	0.035	-0.314
Minimum	-0.038	-0.033	0.038	-0.039	-0.039	-0.392	-0.015	-0.023	-0.451

4.0. CONCLUSIONS

Based on surveying performed for the two new sport facilities, which are the unusual large-size engineering objects, the conclusions are as follows:

- **surveying work on untypical construction sites should be performed by the experienced geodetic company**
- **Surveying teams should be equipped with modern surveying instruments, which were "tested" before on other constructions ,**
- **the number of surveying teams should ensure around-the-clock service,**
- **during investment realization it is necessary to control the geometry of prefabricated load-bearing elements at the stage of their production and before assembly,**
- **range of surveying and measurement should go beyond the traditional scope of work on typical building surveying,**
- **established networks and the measured points should be used for long-term observation of the load-bearings components,**

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conducted at both construction sites geodetic services using modern tools and technologies, including the assembly of prefabricated elements (steel and reinforced concrete) guaranteed the maintenance periods and required accuracy of the mounting structure,
displacement measurement results of the main elements of the described objects shows theirs stability so far.

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