INVENTORYING THE SHAPE 0F A VELODROME TRACK BY SCANNING

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SUMMARY

The study of a structure's geometry can be done in order to assess the state of a structure both for its design, stability and safety. In the case of sports facilities, their geometrical parameters have a direct influence on the results achieved on the spot, at the same time the shape of a track creates specific conditions for the kinetics of objects moving on the track. The present article shows measurement problems connected with accurate rendering of the shape of a structure by contemporary geodesic techniques of measurement including laser scanning. Experiments like this may be used in precise measurements assessing shape imperfections of spatial structures and deformations of area structures.

1. VELODROME – BGŻ ARENA IN PRUSZKÓW

BGŻ Arena in Pruszków is a 250m wooden cycling track housed in a modern sports hall. The wood used to build the track was specially selected so that its thermal coefficient of expansion was the smallest possible. Geometrically, the track consists of two straight sections and an appropriate combination of circular bends. The very short straight sections of the track, as compared to other tracks of this type, make it one of the fastest cycling tracks in the world. Cyclists reach here the racing speed up to 90 km/h.

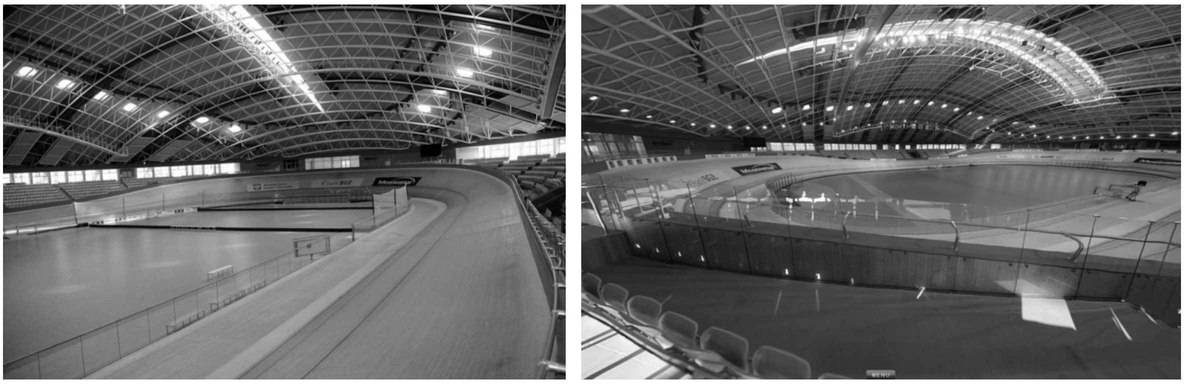

Fig. 1. General view of the velodrome.

2. METHODS OF MEASURING THE GEOMETRY OF THE TRACK

The inventory of a structure understood as the inventory of its shape can be carried out by different methods, using different measuring techniques. Among the contemporary methods used, one should include:

● traditional approach – electronic tacheometry,
● technique of non-reflector profiling,
● short-range photogrammetry,
● ground laser scanning,
● video-tacheometry.

Taking into account the complex form of the structure (track), measuring conditions and requirements for precise rendering of the space form of the structure, quite a new inventorying technology was chosen, namely video-tacheometry.

3. SCANNING WITH A VIDEO-TACHEOMETER

A TOPCON IS 03 was used to measure the track. Apart from polar measurements also images (digital photos) can be registered with two CCD cameras (external wide-angle and internal telescope-aided). The instrument can take individual tacheometric measurements or a whole series of observations in the scanning mode. In this way we obtain a point representation of the structure's surface in the form of a so-called "cloud of points". While scanning, firstly, photos of the scanned area are taken to be later joined together into a panorama, still at the initial processing stage in the instrument. The image obtained in this way can be an active element of designing the scanning process. The photographs can be later used to texture the areas created on the basis of " a cloud of points".

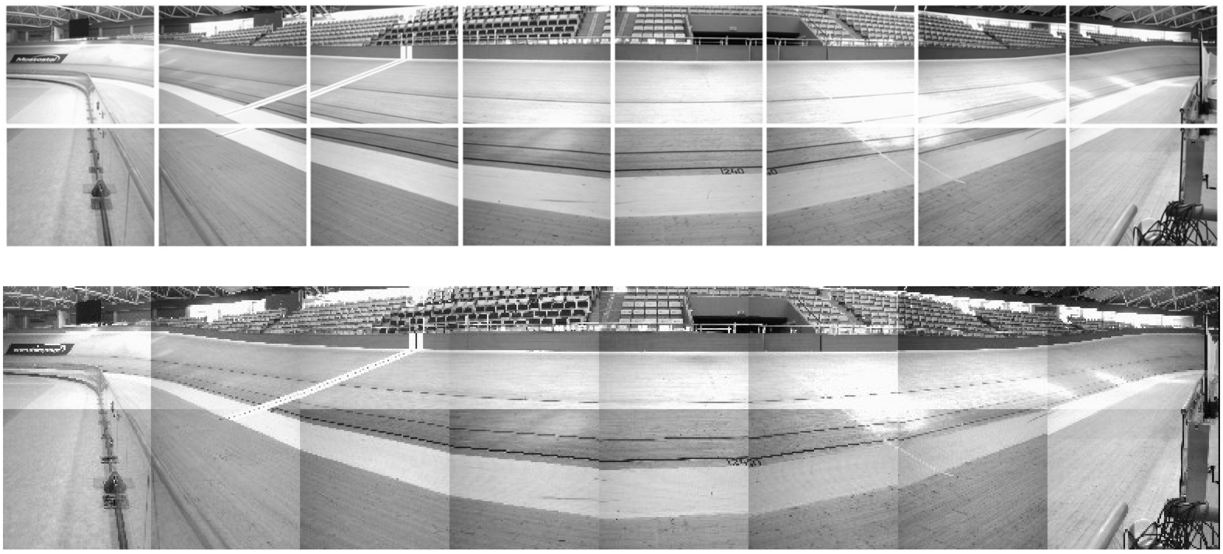

Fig. 2. Panorama consisting of photos taken with a video-tacheometer.

The effect of automatic combination of sets of photos taken with the IS 03 from one stand into a uniform panoramic image is presented in Fig. 2. It is a preliminary raster product to be next carefully processed during the so-called post-processing phase.

4. MEASUREMENT OF GEODETICCONTROL ENSURING A UNIFORM REFERENCE SYSTEM

The inventories of complex structures require rendering the whole structure in a uniform system of coordinates. Accuracy requirements concerning interrelationships between all points of a structure impose a high precision condition on space. It is an atypical geodetic construction both in terms of stability, location of points, network geometry and the measuring technology used.

A high-precision Leica TCRP 1201+ tacheometer was used to take this measurement, guaranteeing the highest accuracy possible of non-reflector measurements as well as those of the so-called certified reflexive foils

Measurements were taken from non-stabilized stations, placed on the track's arena with basic control points around the track. Such a distribution of control points ensures the best geometric conditions possible for defining the position of stations in terms of the "free station" technology. As a result of the adjustment of all angle-line observations, averaged point positions were obtained in the form of their X,Y,Z coordinates. Average errors of control point coordinates obtained did not exceed ± 1 mm. An outline of control and standard error ellipsis are illustrated for individual points in Fig. 3.
In order to ensure the fidelity of the measured structure, the whole track was measured in the surface scanning mode and processed in the Image Master system (Fig.4).
The most essential element of the track parameter is its inner edge line, determining the real length of the track. The measurement of this line was taken very carefully in the non-reflector mode. This measurement is a direct indication of real results obtained on the track.

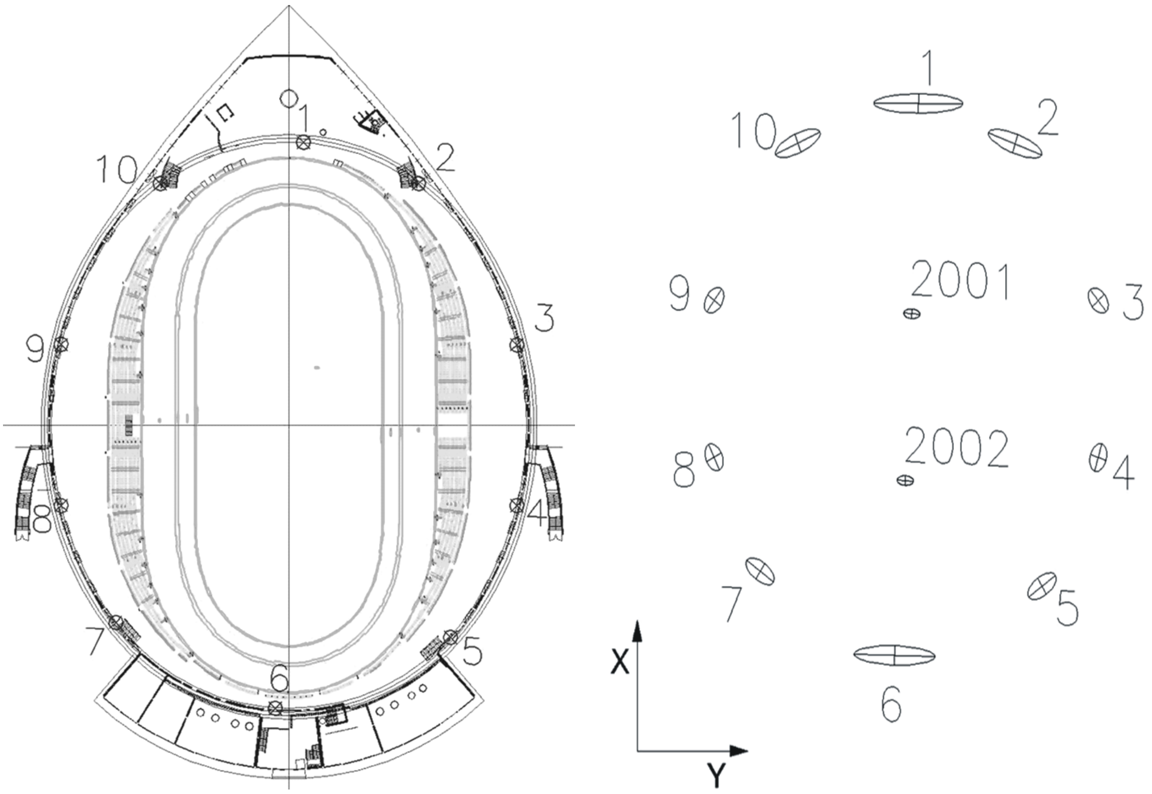

Fig. 3. View of control and accuracy characteristics in the form of standard error ellipsis.

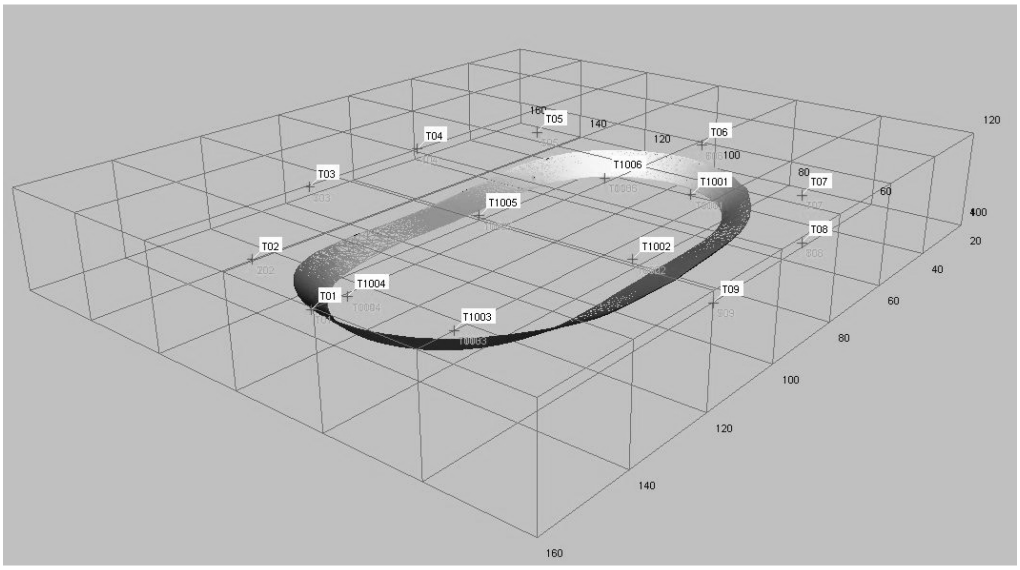

Fig. 4. View of the structure's model in the Image Master system.

5. INVENTORY MEASUREMENTS OF THE TRACK AND ITS MODEL CONSTRUCTION

The results of measurements taken directly in relation to the structure's surface are rife with certain deformations due to faulty distance measurement in the non-reflector mode. It is caused by the phase heterogeneity of a measured wave front during its reflection from an oblique reflective surface. Additional discrepancy between the telescope axis and the telemetric system results in further measurement errors. Hence there are result distortions, especially rife with an increased incidence angle.
It is confirmed by the results of experiments on the above phenomenon, being connected with a concrete instrument. Sample registrations of laser spots confirm individual eccentricities of laser beams.
A contour drawing shows the deformations of distance measurements for the TCRP1202 and TCRP 1201+ tacheometers (Fig.5).
During the measurement of the track's edge there was another element disturbing distance measurements, resulting from a considerable diversity of the reflection coefficient for different sections of the measuring spot. In order to check the influence of this element, an appropriate experiment was carried out. It showed the likelihood of maximum disturbance of the measured distance (25m) of as many as 10 to 20 millimeters. The measurement situation was graphically presented below. All these elements have a significant impact on geometrical features under study. The knowledge about the impact of all disturbances allows us to carry out the measurement avoiding or compensating for these negative effects.

Reflectorless dla 30m

Położenie pionowe

Stopnie	75	60	45	30	15	0	15	30	45	60	75
DELTA (mm)	-	5,1	0,9	-0,3	-0,1	0	-0,2	-0,1	0	1,7	-
ODCH. STRD. (mm)	-	0,201	0,148	0,097	0,637	0,121	0,067	0,103	0,25	0,179	-

Położenie poziome

Stopnie	75	60	45	30	15	0	15	30	45	60	75
DELTA (mm)	-10,6	-9,1	-6,9	-1,2	-0,6	0	0,4	2,2	-	-	-
ODCH. STRD. (mm)	0,087	0,145	0,095	0,088	0,141	0,053	0,076	0,088	-	-	-

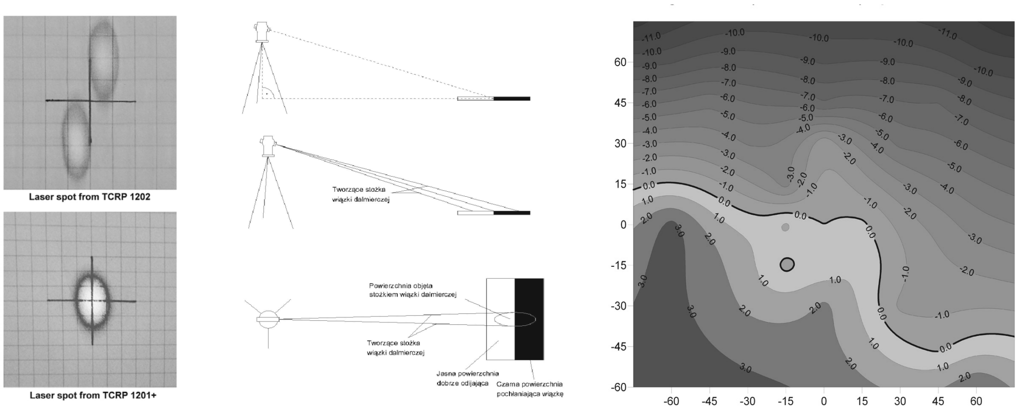

Fig. 5. Eccentricities of a laser beam for TCRP 1202 and TCRP1201+ and length changes caused by changes in the incidence angle for the TCRP 1202 tacheometer.

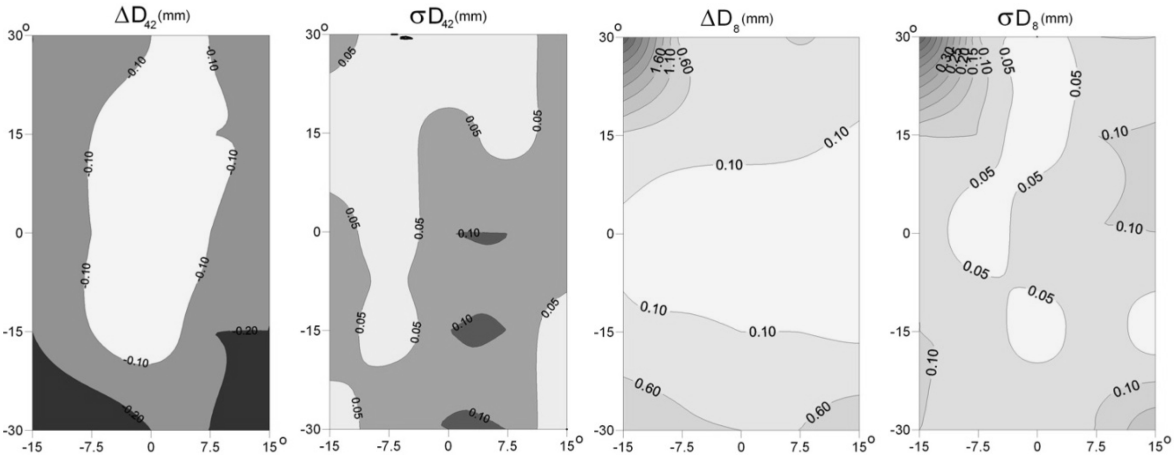

Fig. 6. Measurement results of distance changes caused by the incidence angle of a laser beam for 8 and 42 m for the TCRP1201+ tacheometer.

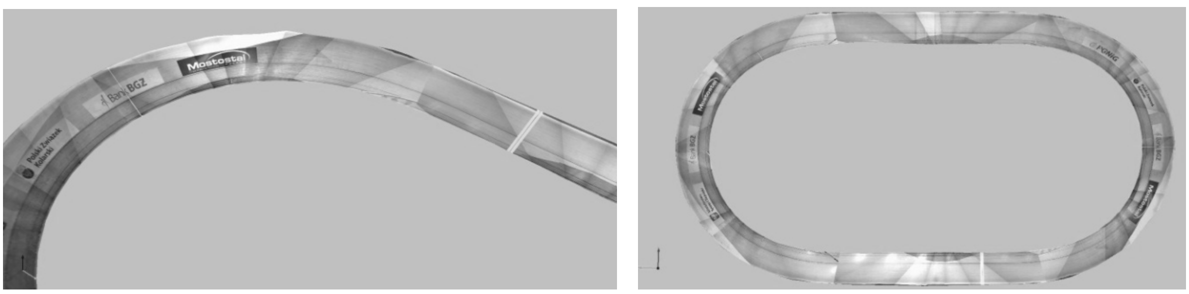

Fig. 7. Model of the racing track.

The construction of a model was started by combining the obtained data about the structure into a uniform system of XYZ coordinates. The "cloud of points" is a canvas, on which the pseudo-realistic surface of the structure is marked. Marking the surface by building a TIN network is automatically done by the Image Master system.

Due to its "smoothness" of shape, the track did not cause any problems in creating its model. The TIN network was covered with a raster made from photographs taken with an internal camera IS 03, producing a virtual model of the track.

6. FINAL CONCLUSIONS

Video-tacheometry is a new measurement technology, being a intermediate element between ground photogrammetry and ground laser scanning. It combines the merits of photographic images, i.e. information density and data objectivity, with accuracy of geodesic observations. It is especially suitable for the inventory of spatial area structures.
One should be aware of measurement errors which result both from observation errors themselves and their time-space synchronization.
In the case of photographic registration, we deal with errors concerning the measured values of internal and external camera orientation elements as well as features of their optical system.
The conducted experiments allow us to assess the real accuracy of measurements of this type and their practical usefulness.
Apart from the above, a number of studies were carried out to analyze the constancy of measurements of the wooden track from the point of geometry and the ensuing parameters of the cycling track. For this purpose an expansion coefficient study was carried out of the material, from which the track was made, as well as the atmospheric conditions prevailing on the velodrome.
The experiments show that to ensure full geometrical control of the velodrome it is required to monitor atmospheric parameters in the arena as these elements have a significant impact on the track's dimensions, and by the same token the sports results obtained.
The measurement techniques applied during the inventory studies were carefully analyzed and the results can be used to monitor the geometry of other sports facilities, ensuring both the reality of results and users' safety.

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