DEVELOPMENT OF THE 3D MODEL OF THE HISTORIC BUILDING WALL WITH THE USE OF REFLECTORLESS ELECTRONIC TACHEOMETER

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SUMMARY

The main objective of this paper was to create the 3D model of the historic building wall with the use of reflectorless electronic tacheometer. The contour survey method has been applied as the method of measurement. In the article, the influence of the material, from which the building was made, on the measurement of distance taken by a laser rangefinder was estimated as well; the results have been compared to the results obtained from the angular intersection method and the contour survey method.
Key words: wall flatness, reflectorless tacheometer, contour survey method, angular intersection method

INTRODUCTION

Wall flatness surveys are made to determine possible wall deformation. Obtained values allow to represent buildings deformation, perform deviation of protecting walls tests and prevent threats of bearing elements deformation.
The use of modern geodetic instruments equipped with laser rangefinders is becoming more and more popular with scientists. (among them: Pawłowski Przewłocki 1997, Suchocki Wasilewski 2009). In order to perform the task the contour survey with the use of reflectorless measurement was chosen. The wall of an old boiler house situated in Olsztyn was used as the subject of the scientific study. The wide surface of the wall enabled to take the multi-punctual flatness measurement. Elevation of the building is made from burnt brick, which allowed to plan the point net without stabilization. In the work of Kowalczyk & Kuczyńska (2009) the model of a roadside shrine measured with the use of reflectorless total station, with the help of the photogrammetric software, was created. In this paper, performing of the wall flatness measurement of the historic building with 3D model visualization, constituted the main objective.

1. SURVEY PREPARATION

The old boiler house in the campus of Kortowo has been selected as the object for measurement. The distinguishing feature of this building was its wide surface of the wall. This, it turn, made it easier to design the multipunctual, almost regular net reflected on the wall surface (7 x 20 m) and to set the measurement base (Fig. 1.).

Fig. 1. Designed almost regular grid of squares.

To take the measurements, an electronic tacheometr GPT 7000i was applied. This tool allows to take the measurements in the reflectorless mode and, what is more, it has a built-in digital camera that enables to track the already measured points on the tacheometr screen (Fig. 2.). Total station has been equipped with the instruments enabling the precise measurement of an angle 1" / 3 ^{cc} and a distance measurement without a prism +/ - 5mm.

Fig. 2. The presentation of the points from the LCD Total station screen.

The wall of an old boiler house is entirely made from the classic burnt brick. The points composing the survey net have been designed in the corners of the individual bricks. The proposed distance between the points amounted to 1,2 m; it was about 5 bricks across horizontally and 20 bricks perpendicularly.
On account of the windows situated inside the wall, the proposed network could not have been realized as regular one. The points which had inconvenient location were moved so as not to destroy the net geometry and simultaneously, not to skip the measured area (Fig.1.). 108 points were designed on the surface.

The measuring base has been located 20 meters from the building. A built-in camera inside the tacheometer allowed to observe the highest points. A technical leveling was performed between the base spots.

2. MEASUREMENT OF THE NEARLY REGULAR NET OF SQUARES

In order to check the possibility of refletorless tacheometer application for this measurement, the following methods had been chosen:
- Spatial angular intersection
- Tacheometer measurement
Before performing the task, a thirty-time measurement of the same direction and distance was estimated on the basis of an average measurement error of a single direction m_k= 2,1 cc and single distances m_d=5 mm. The observations were carried out from the points of the stabilized base. The calculation of the coordinates was conducted through an observation of vertical and horizontal directions in one series and reflectorless measurement of the distance of measured points.
The values of the angles registered at two positions were used to calculate the coordinates with the use of angular intersection method, applied as a reference to some new ways of measurement. In addition, these observations conducted on each position (two angles and distance) constituted a base for the double determination of coordinates, with the use of reflectorless tacheometery. Thus, three data sets were obtained, which were later on subjected to the further estimation.

To make the obtained coordinates represent the inclination of the wall, a transformation of the coordinates from the base arrangement to the wall arrangement with the use of Helmert transformation was performed. As the adjustment points, the extreme bottom points of the measured area were chosen. The wall arrangement was created in such a way that the values of X coordinate depicted the size of an inclination from the theoretical surface. The coordinates obtained as a result of application of angular intersection method, constituted the representative values, with regard to which the usefulness of the reflectorless techeometry was assessed.
In order to verify the usefulness of the applied methods, the differences of coordinates between the methods, was estimated. Thus, two variants were obtained. For a better depiction, the differences of X coordinate were shown on Fig. 3. and Fig. 4.
- Variant 1- Differences in inclination determined with the use of angular intersection and tacheometer methods taken from the first workstation (Fig. 3.).
- Variant 2- Differences in inclination determined with the use of angular intersection and tacheometer methods taken from the second workstation (Fig. 4.).

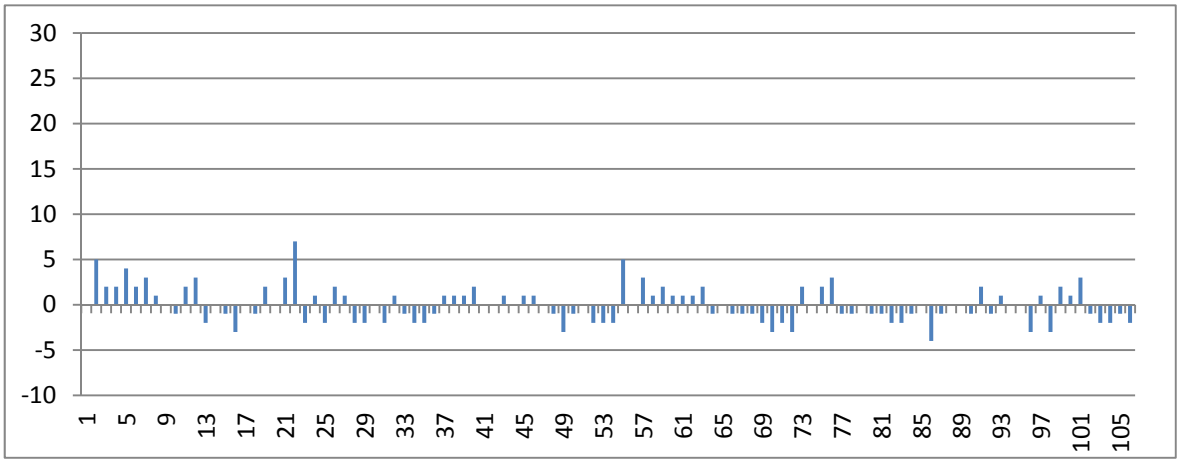

Fig. 3. Differences in inclination determined with the use of angular intersection and tacheometer methods taken from the first workstation [mm].

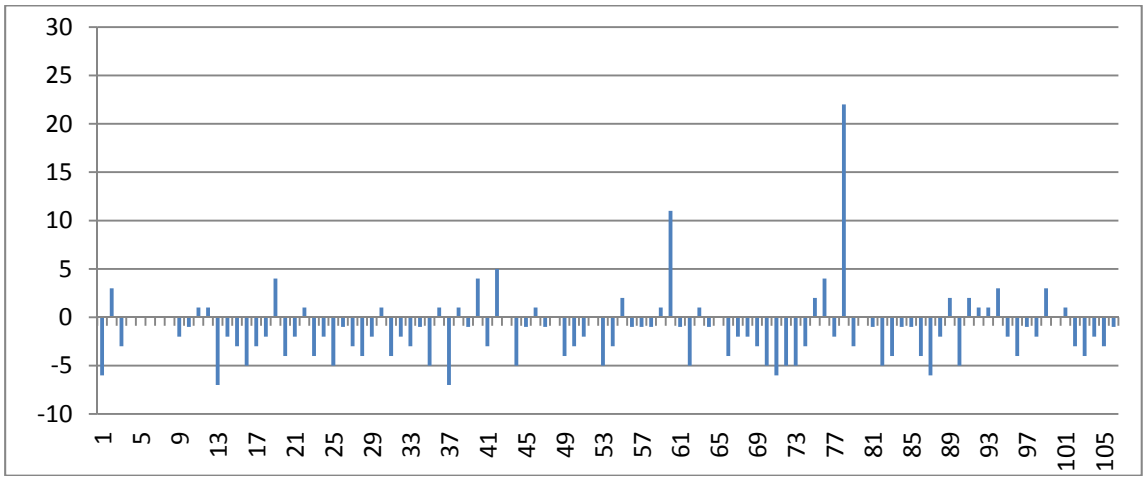

Fig. 4. Differences in inclination determined with the use of angular intersection and tacheometer methods taken from the second workstation [mm].

In the first variant, the average coordinates differences fluctuate from 4 mm to -4 mm. In the second variant from 5 mm to -5 mm. In both variants, there appear higher single differences than given ranges. In the second variant a single diverging value three times exceeding the average difference has been removed in the statistical estimation.

The obtained sets were subjected to the verification of statistical hypothesis. These hypothesis were applied in order to test the following conditions:

- whether the average significantly diverges from 0, from the statistical point of view
- whether the alternation is crucial from the statistical point of view
- whether the methods have equal or different alternations

To check these conditions, statistical tests taken from the work of Shrestha et al. (1993). From the conducted tests it can be concluded that none of the sets has major errors, and that they have equal alternations, and that both variants give representative results.

3. AN ATTEAMPT TO DETERMINE THE INFLUENCE OF THE BUILDING MATERIAL ON THE ACCURACY OF DISTANCE SYRVEY

In order to check the material from which the building of an old boiling house was made, the survey tests were conducted. To perform that, a handle with a brick was located on the ranging pole, so as the surface of the brick coincided with the centre of the pole. A rangefinder reflector joined to the pole's handle was attached directly below it according to the Kowalczyk's idea (Fig. 5).

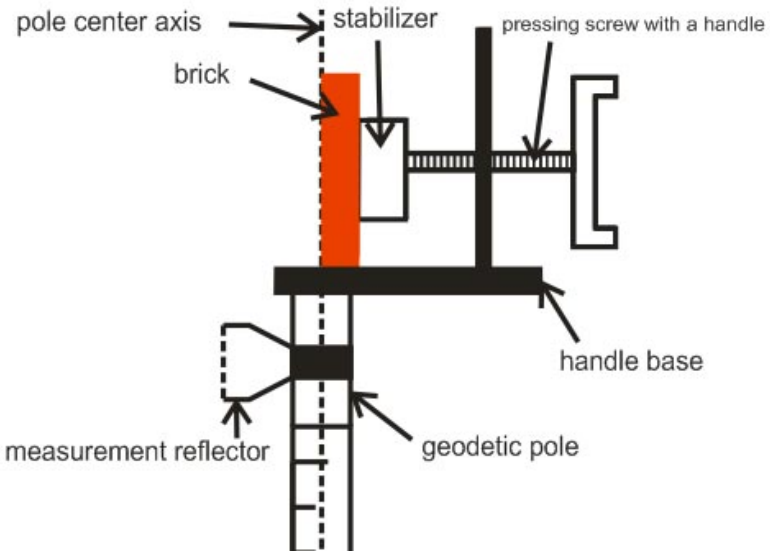

Fig. 5. Testing instrument construction.

The testing surveys of the distance of 150 m with a 1 meter interval were conducted. The distance differences of a survey from the mirror to the brick, are shown in Fig. 6.

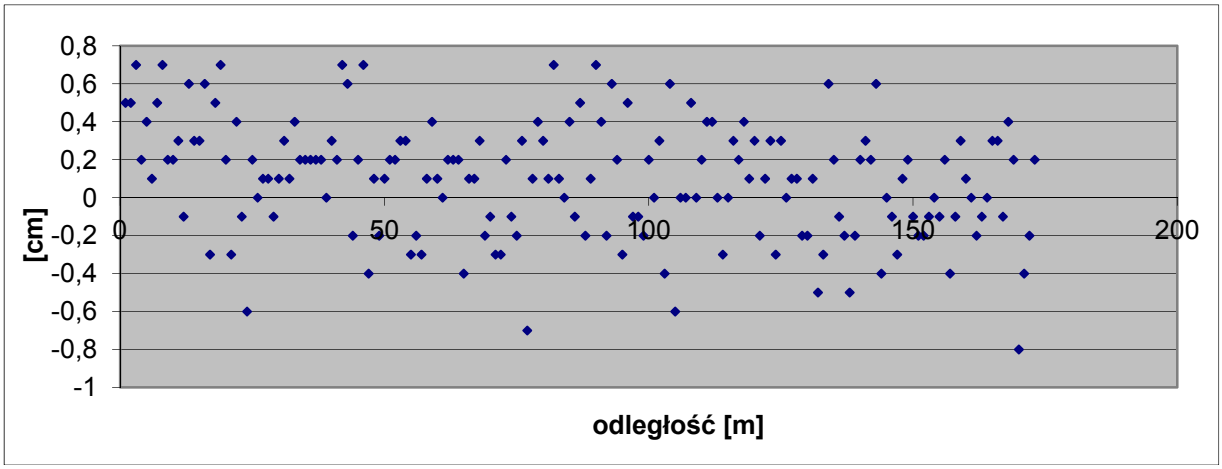

Fig. 6. Differences of a survey taken from the mirror to brick.

As it can be seen in Fig. 6., as far as the relation between the measured distance and the material used is concerned, there is no observed regularity. The differences fluctuate from -0.8 mm to 0.8 mm. However if one take into consideration sensitivity of a level tube and construction of testing instrument it can be noticed that differences could be caused by this factors.

4. WALL VISUALIZATION

In order to visualize the model of the wall of a historic boiler house, the data from the reflectorless tacheometer were used. Program Surfer 10 was applied as a visualizing instrument. The use of such software allowed to work out the models from values obtained as a result of application of different interpolation methods. 3D visualizations where created with the use of twelve algorithms from which three showed the highest accuracy and most precisely depicted the real appearance of the measured object. Among the methods of interpolation that had been chosen are kriging, natural neighbor method and triangulation with linear interpolation. 3D model obtained in the process of kriging is shown in the Fig. 7.

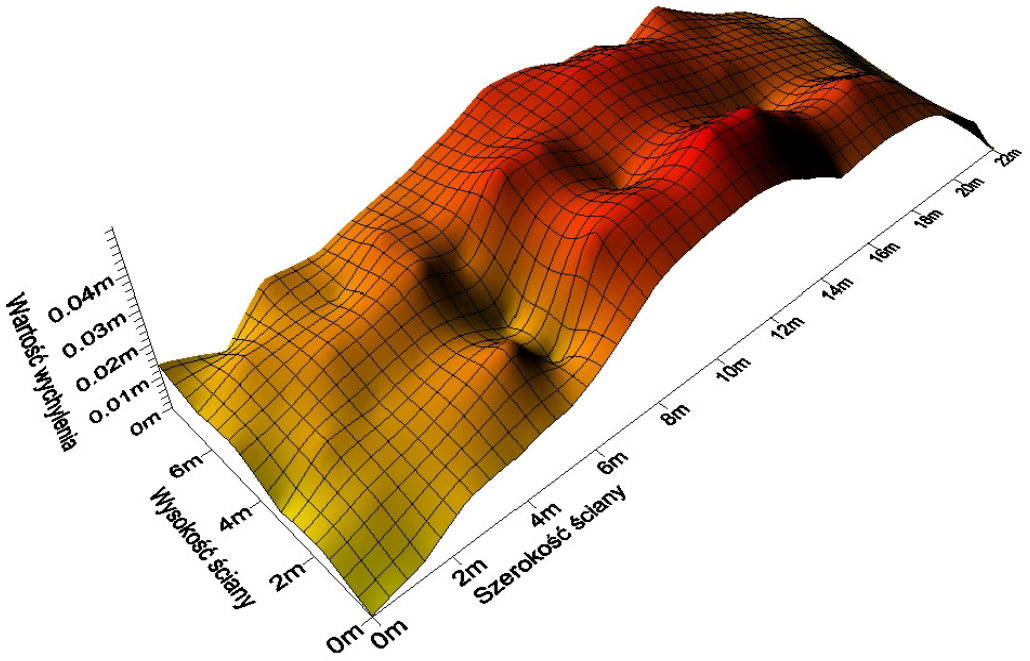

Fig. 7. 3D model of measured building wall obtained in the process of kriging.

The model created through natural neighbor interpolation is shown on Fig. 8.

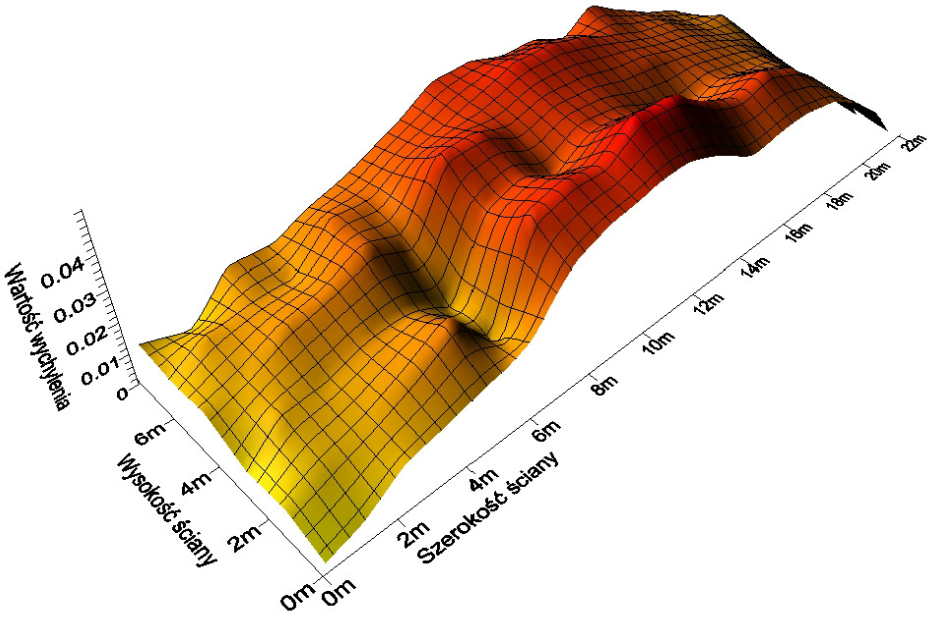

Fig. 8. Model of measured building wall created through natural neighbor interpolation.

Model obtained through triangulation with linear interpolation was presented on Fig 9.

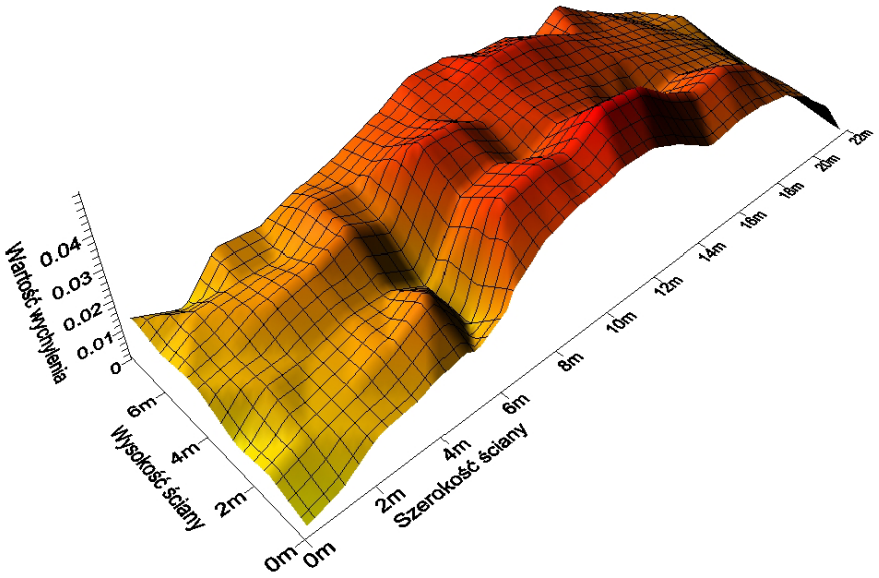

Fig. 9. Model of measured building wall obtained through triangulation with linear interpolation.

The models differ in contour sharpness and thus the choice of the interpolation method depend on the target need. In order to estimate the quality of the 3D model calculation of residuals and root-mean-square error were conducted. From the statistical point of view the average error of the model adjustment calculated on the basis of residuals accounted to 0,1 cm from each of the preformed interpolations. It proves that the models where well adjusted to the measured data.

5. CONCLUSIONS

On the basis of the conducted research, it can be concluded that the reflectorless measurements, taken with the use of tacheometer GPT 7000i, are suitable for the wall flatness survey. The application of the tacheometer method is legitimate in this case on due to the fact that it required less labour intensity for this survey. There is no need to stabilize the survey base when one does not expect to perform the further surveys in order to determine the kinematic change. Moreover, there is no need to mark the points on the measured wall as well. The use of the tacheometer with the build in camera allows to measure the points situated on the higher levels even if the distance form the work station to the wall is smaller. There is no distinct relation between the type of the building material and the distance measurement.

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