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INTERDISCIPLINARY COOPERATION AND SURVEYING WORKS IN INVESTIGATIONS OF THE ROTUNDA LOCATED ON THE CASTLE HILL IN SIERADZ

People have been interested in the art of measurements from time immemorial. The oldest measuring document is the Babylon map drawn in 3800 B.C. on a clay tablet. Surveying was also known in Assyria and Egypt; it was applied for determining property borders of grounds.

As human development took place, the range of surveying works has been enlarged; they were applied to more complicated problems.

Nowadays, in the time of dynamic development of economy all over the world, a surveyor is not only a maker of plans and maps, but also a necessary participant of numerous works, for which surveying methods are considered to be more effective.

The Castle Hill in Sieradz, on which the rotunda has been discovered, is an example of a comprehensively investigated site. It has been an object of great interest for archeologists, historians, geographers, geologists, architects, geophysicists, and surveyors since 1956.

Additional biological investigations were used as auxiliary information; they included results of dendrological, carpological, and palynological investigations.

Data for map elaboration collected during field works by surveyors in the form of numbers, drawings, etc., were then elaborated, edited, and presented by cartographers in an easily understandable form. The final results of their work are maps of different types and purposes.

As the number of results of investigations of the Castle Hill in Sieradz increased, new problems emerged, which gave rise to a new range of research tasks.

The discovery of an aisle a presbytery made the managing staff of these investigations perform accurate surveying measurements within the rotunda.

The Institute of Photogrammetry and Cartography of Warsaw Technical University was commissioned by the Ateliers for Conservation of Cultural Property to perform all the works concerning surveying investigations and preparation of documents.
Two objects were to be investigated: the aisle and the presbytery.

Considering the location of the objects in a deep excavation and the limitations of field of vision caused by the roof, and the difficulties connected with these factors, it was decided that a commission should carry out a field inspection.

During the inspection the basic principles, directions of investigations, methods, and the range of surveying works were established.

The following representatives took part in the field inspection: Klemens Kaczorowski, M.Sc., the vice-director of the scientific and preservation department, Wanda Jeleniewicz, an architectural engineer, and Urszula Perlikowska, an archaeologist, from the Ateliers for Conservation of Cultural Property, and Jerzy Fellmann, assistant professor, the vice-director of the Institute of Photogrammetry and Cartography.

The following surveying works were suggested by the commission for further elaboration:

1. Testing the existing exploratory network on the emplacement of a medieval castle;
2. Ranging of a micropolygon around the rotunda (the aisle and the presbytery);
3. Combination of the micropolygon and the existing exploratory network;
4. Determination of the approximate centre of the rotunda;
5. Dislocation of an existing auxiliary bench mark into the relics of the rotunda;
6. Situational measurements of wall on five levels at the scale 1:20 with information on ordinates (under the assumption that one of projections will be elaborated for the ground floor, i.e., the zone of contact between the object and the ground);
7. Measurement of the entrance at the scale 1:10 with ordinates of particular points;
8. Preparing three characteristic cross-sections including one through the culmination of walls,
9. External measurement of walls at the scale 1:20 for particular levels;
10. Performance of the longitudinal profile along the approximate axis of the aisle and the presbytery;
11. Drawing the final sheet for five levels (for points 6 and 9):
   a) calculations of the micropolygon and combination with the network,
   b) levelling calculations,
   c) elaboration of cross-sections and profiles,
   d) preparation of the are network, mapping of point and drawing of particular profiles;
12. Elaboration of scientific report concerning implemented work, general criteria for performing works concerning similar objects.

Surveying investigations included the measurement of the rotunda (the aisle
and the presbytery) and their graphical presentation in order to enable performance of archaeological and architectural investigations, carried out on the Castle Hill in Sieradz.

After field testing of a theodolite, a levelling instrument and rods, the first goal was to test the existing are network on the Castle Hill; the micropolygon created as a network for measuring the aisle and the presbytery was to be controlled with the are network.

The field testing resulted in corrections smaller than ±0.04 cm; the side of the are network located in the South-North direction, the length of which was 10.03 m, was assumed for further measurements and the existing points of the network were marked as A and B. This are network was described on a plan which was delivered by the Ateliers for Conservation of Cultural Property. The following plane coordinates were assigned in this system to A and B:

<table>
<thead>
<tr>
<th>No. of point</th>
<th>coordinates of points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X axis</td>
</tr>
<tr>
<td>A</td>
<td>120.03 m</td>
</tr>
<tr>
<td>B</td>
<td>110.00 m</td>
</tr>
</tbody>
</table>

The next stage of work concerned determination of the approximate centre of the rotunda.

Point 8 was assumed to be the centre of the rotunda as a result of the applied method of succeeding approximations; it was included in the axis of the longitudinal profile by connecting it with the centre of the presbytery. This axis was fixed and the numbers 9, 7, 8, and 3 were assigned to particular points. The micropolygon was designed around the rotunda, the points were fixed and denoted as 1, 2, 4, 5, and 6.

In total, 9 points fixed; for this fixation timber piles were used with nails, which were driven in the centres of these piles.

The directional method with two positions of the telescope was applied for angular measurements; the Theo 030 Zeiss instrument of accuracy ±30″ was used for these measurements. The distance measurements were performed in both directions with the steel 20 m tape, the equation of which was as follows:

\[ L_t = L_{20} + 0.0115 \cdot 20(t - 20°) \text{ mm} \]

for our tape

\[ L_{20} = 20 \text{ m} + 2 \text{ mm}. \]

Air temperature during the measurements was approximately +10°C, the corrected length of the tape was equal:

\[ L_t = 20002 + 0.0115 \cdot 20(10° - 20°) \text{ mm} \]
\[ L_t = 20002 + 0.23 \cdot (-10) \text{ mm} \]
\[ L_t = 20002 - 2.3 = 19999.7 \text{ mm} \]
The tape length \( L_t = 20.000 \) m was assumed for the calculations. As a result of fixation the close polygon was obtained, the base of which was the A-B side of the existing are network.

This polygon was adjusted by means of the approximate method; for particular intervals of coordinates the following closure errors were obtained:

\[
f\Delta x = -0.01 \text{ m}; \quad f\Delta y = 0.00 \text{ m}
\]

Calculation of the linear correction for our micropolygon is following:

\[
f \Delta x \Delta y = \pm \sqrt{f^2 \Delta x + f^2 \Delta y} = \pm \sqrt{1^2 + 0^2} = \pm 1 \text{ cm},
\]

what is equal 1 : 6315 in terms of relative error of linear closure of the polygon.

The biggest allowable linear correction of the polygon, \( \max f_L \) can be calculated by means of the formula for average conditions (the 2nd class area), though this micropolygon was designed in very hard conditions (large altitude differences between particular points, difficult acces to points, etc.).

\[
\max f_L = 0.00035L + 0.0105 \sqrt{L} + 0.035,
\]

where:

\[
L - \text{the length of the polygon in meters and weight } \quad p = \frac{1000}{L}
\]

For our polygon:

\[
\max f_L = 0.00035 \cdot 63 + 0.0105 \sqrt{63} + 0.035 = \pm 0.15 \text{ m}.
\]

It can be stated that though more difficult conditions were assumed (the IIInd class area) the obtained error is 15 times lower than the allowable one.

The next stage of works concerning the creation of the situational and levelling network was transformation of heights to the fixed points of the micropolygon from the bench mark, the ordinate of which was 134.900 m.

The Rosenberg levelling instrument (sensitiveness of level tube per 1 division 30' / 2 mm) was used for technical levelling: the rods with 1 cm division were utilized.

The approximate method was applied for adjustment of the levelling network.

The following results were obtained:

<table>
<thead>
<tr>
<th>the closure error of levelling network</th>
<th>number of levelling stations</th>
<th>allowable correction according to the formula: ( m\Delta h_{m_o} = \pm 5 \sqrt{n} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2 mm</td>
<td>9</td>
<td>( \pm 5 \sqrt{9} = \pm 15 \text{ mm} )</td>
</tr>
</tbody>
</table>
After measuring the network, measurements of 4 characteristic profiles were started.

The profiles were performed along the longitudinal and transverse axis, through the entrance to the rotunda, through the hole in the walls, and through the wall culmination.

Relics of the walls were measured at all characteristic levels both inside and outside with simultaneous measurements of altitude of all points. All measurements are presented on 6 panels and on a sheet of tracing paper used for drawing the final results.

Particular relics of walls were presented on sheets 1–4 at the scale 1:20; the altitudes of points were also shown. Sheet 6 presents the entrance at the scale 1:10 and sheet 5 shows all of the profiles at the longitudinal and altitude scales 1:20.

Sheet 7 contains situation shown in the sheets 1, 2, 3, and 4; it is drafted on the tracing paper at the scale 1:20 as well.

A historian of art, an architect, and an archaeologist were consultants during field works and cartographic elaborations.

There are few objects which can be considered as typical ones in the field of measurements performed for the needs of preservation of architectural relics. The majority of them requires application of non-standard networks and special methods of measurements.

Sheet 1. Sieradz Castle, scale 1:20 (measurements made by J. Fellmann)
Sheet 2. Sieradz Castle, scale 1:20 (measurements made by J. Fellmann)

Sheet 3. Sieradz Castle, scale 1:20 (measurements made by J. Fellmann)
The success of our works often depends on results of cooperation with specialists representing particular branches, which will utilize surveying elaborations.

Readability of the final sheer is not explicit, either, since series of lines overlap and that makes interpretation more difficult.

A possibility of drawing lines of different width was considered; after commission considerations it was decided, however, to draw lines of the same width for the entire sheet.

It is necessary to use sheets 1 to 4 in order to elaborate particular elements of construction, because the construction elements can be easily recognized on these sheets.

General criteria for performing investigations concerning similar objects will be as follows:

1. Participation of a surveying engineer is necessary during a working conference concerning architectural and archaeological investigations.

2. The scales 1:10 and 1:20 which are used to present relics of constructions are not typical for surveying elaborations, so during measurements cooperation with an architect is necessary; he decides which fragments of the construction should be considered in detail and which of them can be generalized.
Sheet 5. Sieradz Castle, scale 1:20 (measurements made by J. Fellmann)

Sheet 6. Sieradz Castle, scale 1:10 (measurements made by J. Fellmann)
3. The points for distance measurements have to be marked, because measurements concern the relics of constructions.

4. For small and complicated objects only micropolygons can be measuring networks; for the scales 1:10 and 1:20 they ensure sufficient accuracy of the order 1:5000.

5. Field works should be performed in such a way that they can be presented cartographically in the form readable for a historian of art, an architect, and an archaeologist.

6. It is always necessary to determine shapes of objects, and altitudes of particular points, to create profiles, when the inventory for research and preservation purposes is to be performed. So points of networks should be assumed in such a way, that they could be utilized for further exploratory and preservation works.

7. Considering variety of local conditions, technical requirements, and types of objects, it should be stated that surveying works must be performed and elaborated separately for each object.

Relics of walls presented on successive sheets as well as the final sheet (the surveying documents) have one common feature: they are a fragment of environment which was created by man in order to fulfill his own spiritual needs.
The primary aim of surveying specification is to obtain accurate and explicit data; each of such surveying documents which is interpreted by various specialists testifies to a specific life-style and can explain the beliefs and custom of men who constructed it. It also allows to reproduce historical development of a particular object or groups of objects.

The surveying investigations performed on the Castle Hill in Sieradz are an example of cooperation between the humanities and exact sciences necessary to obtain the best possible results of complex scientific investigations.