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DETERMINING THE RADIUS OF ROUND STRUCTURES BY A PHOTOGRAPHIC METHOD IN DETERMINING ITS GEOMETRIC PARAMETERS

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ABSTRACT

Theoretical foundations for determining the radius of round structures by a photographic method using digital cameras are considered. Formulas for calculating the radius are derived and an accuracy estimate is made. Examples are given. The need to determine the radii may arise when measuring structures that have the shape of a body of revolution: chimneys and ventilation pipes, cooling towers, distillation columns, granulation towers, pile drivers above mine shafts, water towers, radio and television antenna supports, silo towers, building columns, various reservoirs, domes of historical monuments, etc.

KEYWORDS:*Construction Shaped Body Of Rotation, Radius, Digital Camera, Error.*

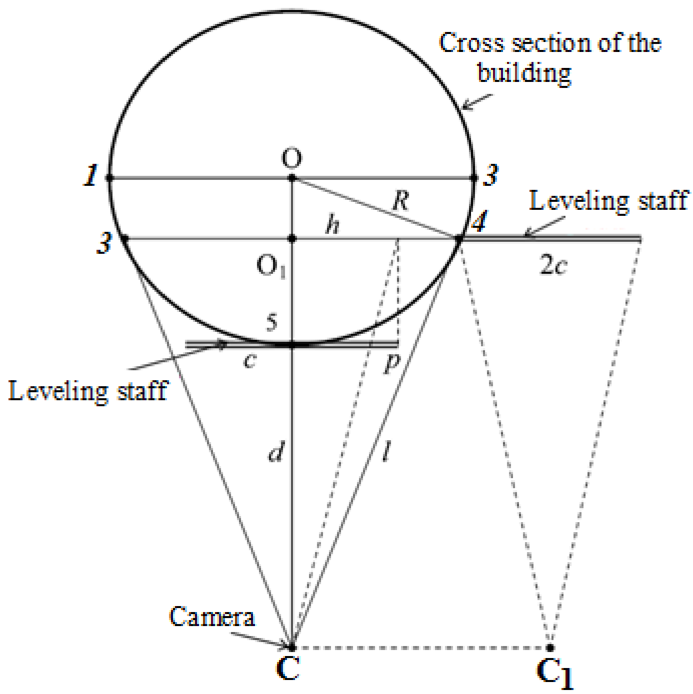
INTRODUCTION

The need to determine the radii may arise when measuring structures that have the shape of a body of revolution: chimneys and ventilation pipes, cooling towers, distillation columns, granulation towers, pile drivers above mine shafts, water towers, radio and television antenna supports, silo towers, building columns, various reservoirs, domes of historical monuments, etc. In addition, the radius is necessary to determine the coordinates of the center of the structure. There are various methods for determining the radii [1–4], which require significant amounts of accurate measurements and rather cumbersome calculations.

This article proposes a photographic method for determining the radii of round structures, the essence of which is illustrated in Fig. 1 and is as follows.

The structure is photographed with a leveling rod attached to it horizontally from point K, located at a certain distance KO=d. The leveling staff further serves to scale the image in order to obtain measurement results on it in the metric system.

It should be noted that the image of the imaginary chord 3–4 in the photograph does not correspond to the diameter 1–2 of the cross section of the structure, but is always smaller than it. Therefore, it is necessary to introduce an appropriate correction into the results of measurements on the image of the magnitude of this chord.



Rice. 1. Scheme for determining the radius of a structure by a photographic method

To determine the value of this correction, we introduce the notation: K– 4 = l,O_1–4=h. From the similarity of triangles OK4 and O_1K4 we have R/d=h/l, hence we express l = dh/R. Let's take d = nR(where n is the number of laying the radius in the distance KO=d), then l = nh. From triangle OK4 we find $R_2 = d_2 - l_2$. Let us substitute the values of d and l into this expression and after appropriate transformations we obtain the formula

$$R = \frac{h}{\sqrt{1-\frac{1}{n^2}}}. \tag{1}$$

In this formula, the unit divided by the square root represents the correction factor for the h value measured on the image (using a photographic image editingprogram such as ArchiCAD 11). For values of n equal to 1.5; 2; four; 6; eight; ten; 15 and 20 these coefficients were calculated, which turned out to be equal to 1.342, respectively; 1.155; 1.033; 1.014; 1.008; 1.005; 1.002; 1.001.

Analysis of formula (1) from the point of view of the "Theory of Errors" allows us to state that the accuracy of determining the radius of a structure by the proposed method mainly depends on the accuracy of measuring the chord 3–4 in the image, since the correction factor even for n = 2 is only 1.155 and with an increase in n tends to unity. At the same time, an increase in the photographing distance may adversely affect the accuracy of measuring chord 3–4. Therefore, in each specific case, it is necessary to choose the optimal ratio between the photographing distance and the measurement error of the image, which provides a given accuracy in determining the radius of the structure.

If the correction factor is expanded in a Taylor power series and limited to one term of this series, then we can obtain an approximate formula

$$R \approx h\left(1+\frac{1}{n^2}\right). \tag{2}$$

As for the scaling of the image along the leveling staff located at point 5 at a distance of $O_1 - 5$ from the chord 3–4, in this case, a correction of 2p must be introduced into its length 2c.

From the similarity of triangles, the relation $p/c = O_1 - 5\,/O_1 - K$ follows, therefore $p = cO_1 - 5\,/O_1 - K$. Let us find $O1 - 5 = R - \sqrt{R^2 - h^2}$, and after substituting the value of h from formula (1) into the radical expression, we obtain $O1 - 5 = R - \left(1 - \frac{1}{n}\right)$. In its turn $O_1 - K = d - \sqrt{R^2 - h^2}$, но $d = nR$, that's why$O_1 - K = R\left(1 - \frac{1}{n}\right)$.Substituting the obtained values into the expression for p, we obtain in the final form the correction formula

$$p = c\frac{n-1}{n^2-1}. \tag{3}$$

For the above values of n equal to 1.5; 2; four; 6; eight; ten; 15 and 20, the coefficients at c were calculated, which turned out to be equal to 0.400, respectively; 0.333; 0.200; 0.143; 0.111; 0.091; 0.062; 0.048. As follows from formula (3), the accuracy of determining the correction p depends only on the accuracy of n, i.e., on the accuracy of determining the distance d from the camera to the axis of the structure.

If it is possible to place the staff along the chord 3–4 and photograph it from the point K_1, then in this case the need to use the p correction disappears.

In conclusion, we note that the photographic method for determining the radius of round tower structures, then, of course, it is distinguished by its clarity, information content and has good prospects for its further development using video measuring devices based on charge-coupled device-matrices in combination with computer technology [7].

In conclusion, we note that the linear-angular method of determining the radius in combination with the method of directions makes it possible to determine the roll of round tower structures from one point of the total station simultaneously in two mutually perpendicular directions.

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