MONITORING OF CONSTRUCTION SHAPE CHANGES USING REFLECTORLESS TECHNIQUES

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1. ABSTRACT

New total stations are equipped with two types of distance meters: IR (infra red) and RL (reflectorless). The option RL helps monitor the shape measurements of controlled surface of dozens of control points. It is possible to measure the distance directly to the object.
The accuracy effects of using this system in precise measurements were controlled in laboratory and field conditions for reflective targets at different incidence angles.
This paper presents the testing results and investigation conclusions concerning Leica TCRP 1202 and TCR 407 instruments.

2. 3D MEASUREMENTS

The geodetic control measurements of changes in an object's geometry are necessary to ensure the safety of an object and the evaluation of its imperfections.
The measurements should satisfy high accuracy and reliability requirements.
New Total Stations are very often equipped with two function modes of distance meters: infrared and reflectorless. The RL mode is very convenient in monitoring the shape of a wall and that of amorphous objects. Elaboration observations and graphical presentation can be made using CAD systems, for example SURFER (Fig.1,2).

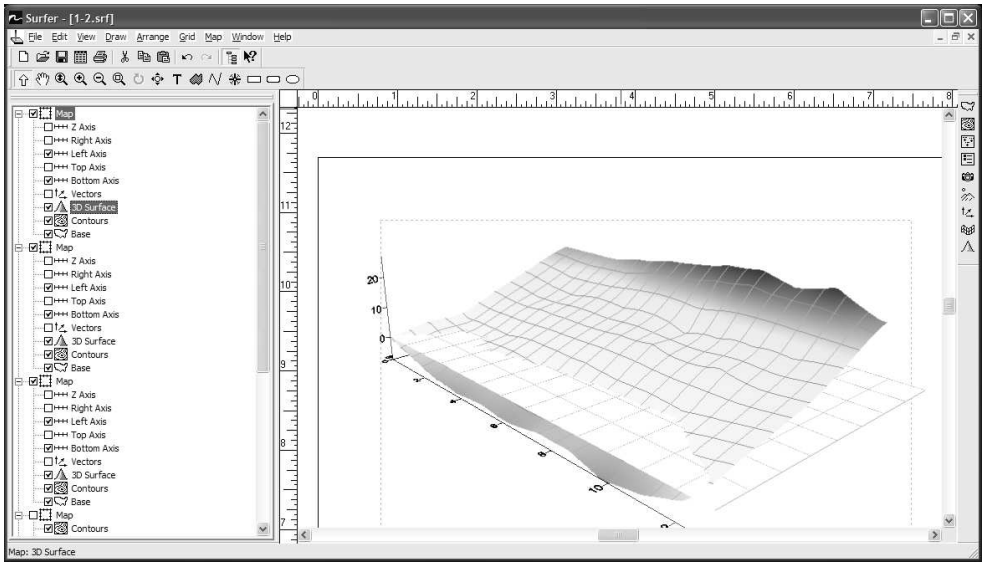

Fig. 1. The presentation of the results of geodetic measurements of the wall in SURFER.

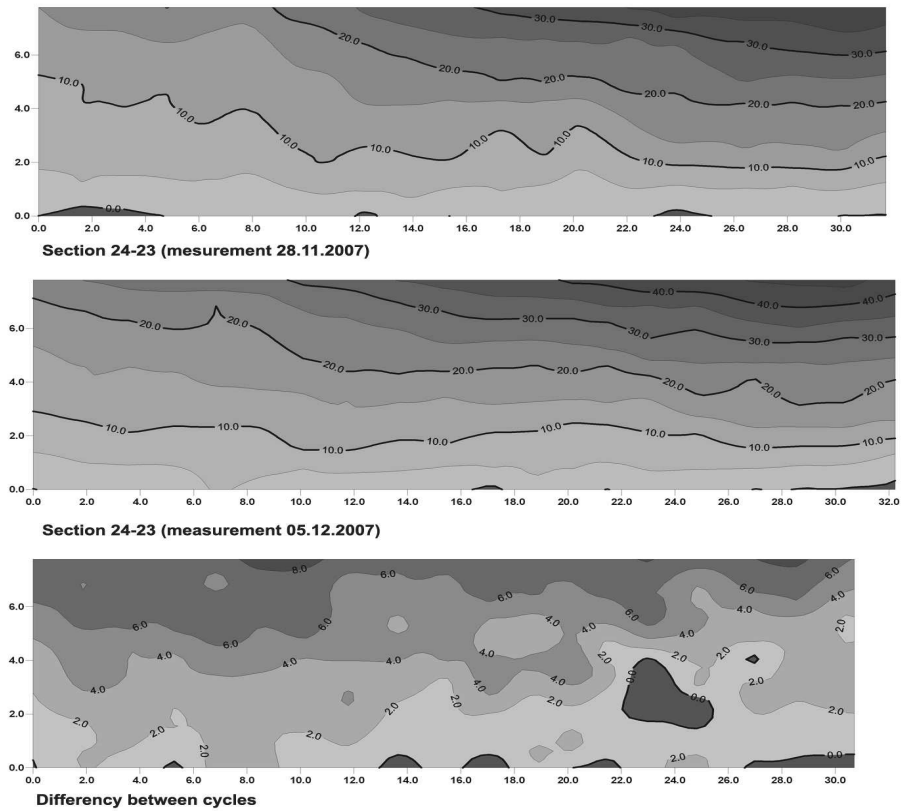

Fig. 2. Changes in the shape between two cycles of the inventory

The accuracy of shape determination depends directly on the accuracy of distance measurements. In the case of prism reflectors, the corrections are known and described in professional literature.
The problem arises when a tape is used as a reflector or reflectorless measurements are performed. In these cases we observe the degradation of measurements accuracy, which depends on both the eccentricity of the laser beam and inclination of a reflection surface.
Reflectorless measurements are burdened with systematic errors connected with measurement eccentricity and the shape of a measuring laser spot (see Fig. 3).

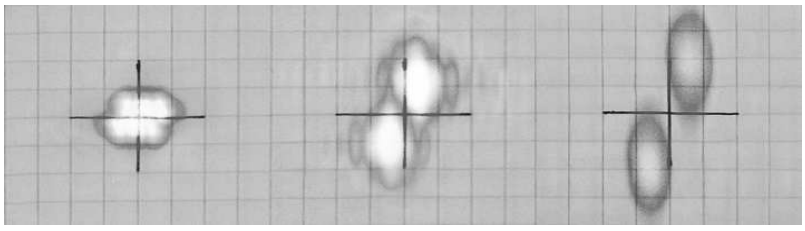

Fig. 3. The eccenter of a measuring beam for distances: 10, 30 and 50 m

The 3D shape of reflective surface has a considerable influence on the results of measured distances and impairs the coordinates of control points.
We are going to present the results of testing accuracy of shape inventory measurements using total Leica TCRP 1202, TCR 407 stations and the errors of a polar measuring method.

3. THE TEST OF INCLINATION INFLUENCE OF A REFLECTIVE TAPE AGAINST THE LASER BEAM OF A DISTANCE METER

The quality of measurements depends on the direction of a reflecting surface and the instrument aiming. The tests were carried out for the distances of 10, 30, 36 meters using both a tape reflector and no reflector. As a target we used a Leica Certificated Reflective Tape and a special adapter. The results of slope distance measurements are most important for the analysis of the position errors of control points. Because of the eccentricity of a measuring beam we have a difference between the measurements in two faces of the telescope (Fig. 5).

Fig. 4. The instrument TCRP 1202 and the rotating target

It is especially visible when a large inclination of the measuring surface occurs. In flatness or plumbing investigations, the results achieved in one face of a telescope are inaccurate. The error depends on a change in the distance and incidence angle.

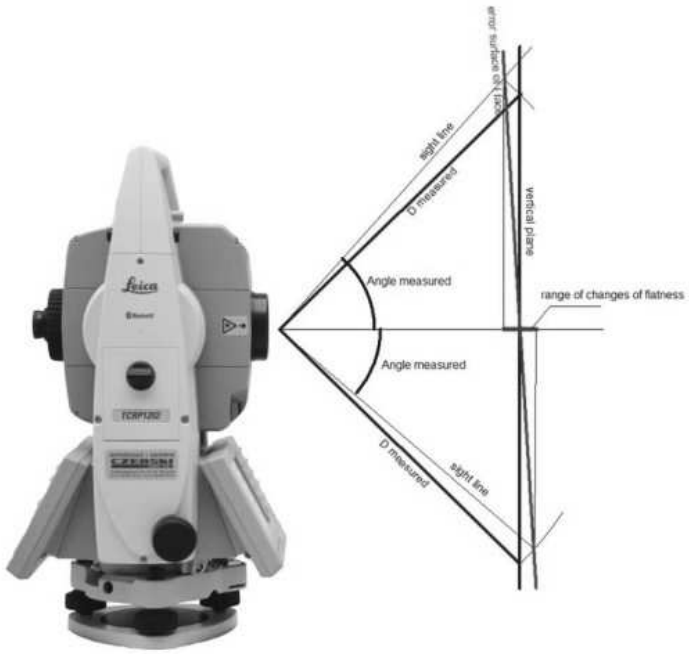

Fig. 5. Geometry of a measurement laser beam

4. THE TEST OF INCIDENCE ANGLE INFLUENCE ON A CHANGE IN THE MEASURED DISTANCE

Performed measurements show the dependency of measurement changes on the distance meter measurement mode and the type of a reflecting material. For the "reflective tape" we observe errors within the acceptance limit even for high inclination angles (40 degrees). It applies for both horizontal and vertical planes (see Fig. 6).

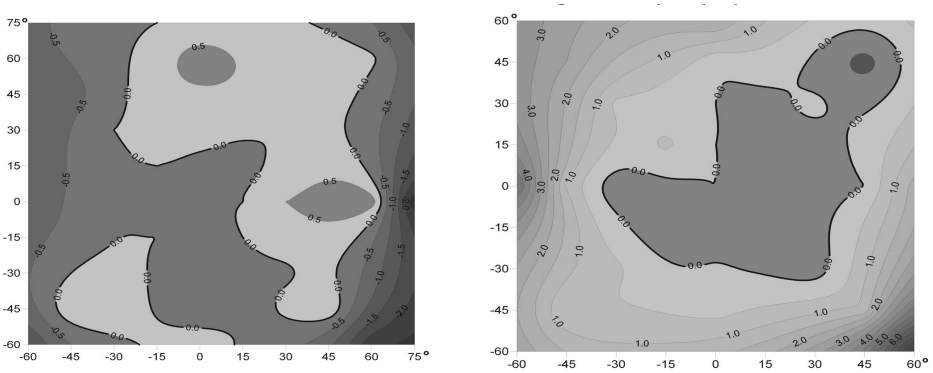

Fig. 6. Distance changes for a reflective tape for 10 and 30 m

The reflectorless mode is encumbered with a high error that increases with distance (see Fig. 6 and 7). These significant errors are correlated with the eccentricity of the beam and deform the shape of an object (see Fig. 1). We could observe a higher discrepancy of measurements on a vertical plane than on a horizontal one. This is due to the construction of the measurement track of a distance meter (see Fig. 5).
In inventory measurements the error can be as high as 10 mm between different cycles. It can be caused by changes in the telescope or station position (see Fig. 7).

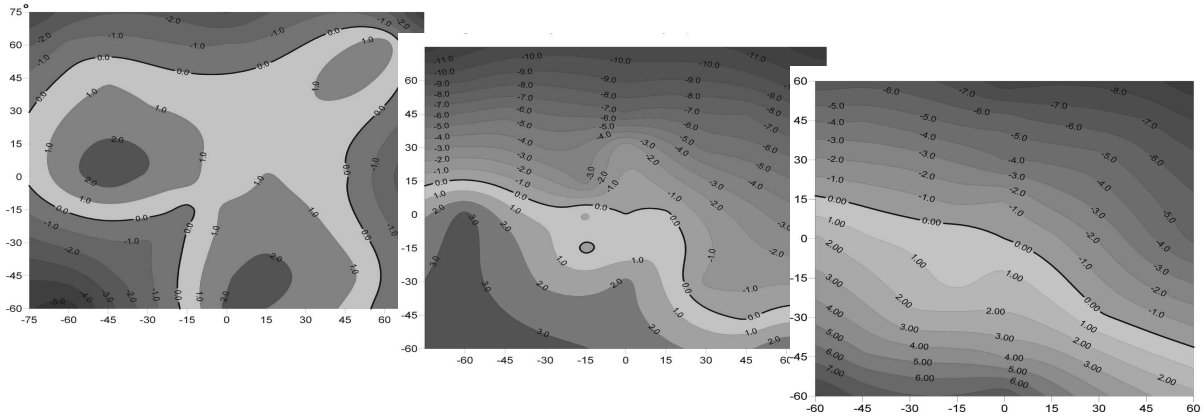

Fig. 7. Distances changes using reflectorless mode for the distances: 10, 30 and 36 m

The errors of distance measurements against the incidence angle are put together in the table below. These data show that the standard deviation of measurements is similar for all angles and within the limits given by the producer. For the Hz angle the distance error is below 1mm, for the incidence angle - up to 45 degrees. A much higher error is for the V angle.

RL for distance 30 m

Changes od distance and its standard deviations									
Hz angle (degree)	60	45	30	15	0	15	30	45	60
DELTA (mm)	5,1	0,9	-0,3	-0,1	0	-0,2	-0,1	0	1,7
Standard deviation (mm)	0,20	0,15	0,10	0,64	0,12	0,07	0,10	0,25	0,18

V angle (degree)	60	45	30	15	0	15	30	45	60
DELTA (mm)	-9,1	-6,9	-1,2	-0,6	0	0,4	2,2	-	-
Standard deviation (mm)	0,15	0,10	0,09	0,14	0,05	0,08	0,09	-	-

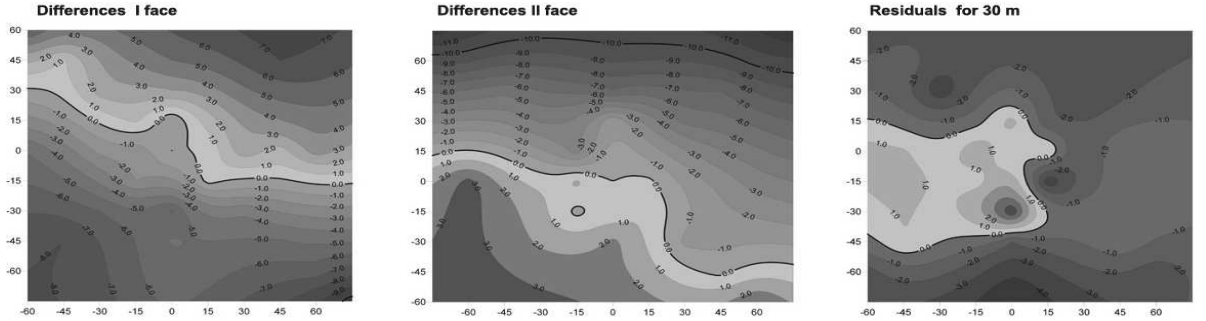

Fig. 7. Errors of shape determination for 30 meters, for one and two faces of a tacheometer telescope

The test was repeated for the TCR 407 instrument. We obtained a similar dependence between a geometry laser-target and distance changes for a TCRP.

5. CONCLUDING REMARKS

- **Infrared measurements using a "reflective tape" are much more accurate than those of reflectorless mode;**
- **The measurement error for a significant inclination of the reflecting surface depends on distance. The error can be as high as 10 mm with a standard deviation of 0.6 mm for optimal conditions;**
- **Inventory measurements can be greatly improved by performing measurements in 2 positions of the telescope. However, the targeting point must be marked on the object;**
- **In displacement monitoring, in order to satisfy high measuring accuracy it is important to preserve a similar geometrical setup during all cycles of measurements;**
- **The accuracy of measurements with a "reflective tape" is reduced if the inclination of a measuring surface is more than 30 degrees. The reflectorless measurement error is much higher and the V angle has a higher influence on the error than the Hz angle.**

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