HIGH-PRECISION OPTICAL INSTRUMENT FOR MEASUREMENT OF SHORT DISTANCES

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Abstract

There are several methods for measuring short (2 m — 20 m) distances, but to guarantee the value of the standard error about 0.1 — 0.15 mm is not easy. The author presents in this paper a high-precision optical instrument developed and constructed by the Department of Surveying, Institute of Geodesy, Surveying and Photogrammetry, Technical University, Budapest.

The measurement with this instrument is similar to geodetic levelling, but we measure horizontal distances. The distance to be measured is divided into parts each nearly 3 m in length and their connection is provided by a technique similar to geodetic levelling.

In the course of engineer surveyings, it is often necessary to measure short distances at a high accuracy. Recently developed distance meters enable measurement of distances with a standard error of 0.1 mm, but the use of these instruments is limited by the fact that they cannot measure short distances at a high accuracy. So there is a need for methods or instruments capable of measuring short distances with the accuracy of modern distance meters.

Invar tapes, wires and subtense bars are used for measuring the length of the sides of micronetworks, for deformation monitoring and base line measurement. The most accurate is the invar wire method, but the manufacturing of the special invar wire makes this method very expensive. It is also disadvantageous that a number of wires with different lengths have to be made and standardized. For special invar wire measurement methods, the Distinvar and the Distometer instruments were developed.

One can make a distance measurement with the same accuracy as with the invar wires with the instrument developed and constructed by the Department of Surveying, Institute of Geodesy, Surveying and Photogrammetry, Technical University, Budapest. The principle of this method is the same as that of geodetic levelling, but horizontal distances are measured.

The main idea lies in the combination of two parallel sided attachment glass-blocks with an optical micrometer belonging to it. These optical micrometers enable highly accurate readings to be taken. These parts of the instrument were combined with a Zeiss-type optical plummet. The instrument is shown in Figure 1.

The two MOM K 321 type optical micrometers were put together in such a way that the deviations of the light will be perpendicular to each other.

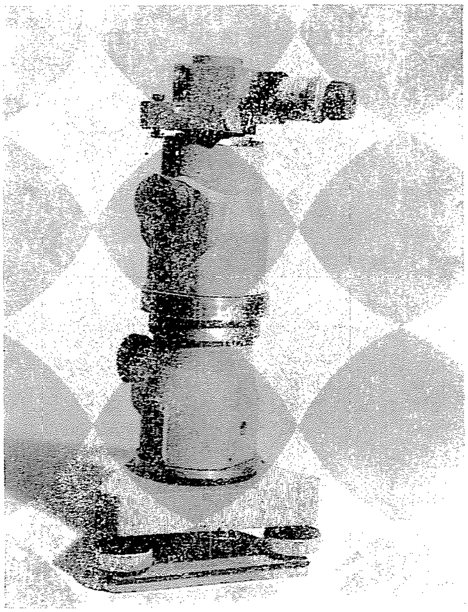

Fig. 1

In this way the line of collimation can be shifted max. 5 mm by two perpendicular deviations.

The two optical micrometers are set before the objective of the plummet. If light hits the first parallel plate at 90°, there will be no deviation, if it hits the parallel plate at an angle ε, the shift will be

$$\tilde{d} \approx d \cdot \mathrm{tg}\,\alpha \frac{n-1}{n}$$

where d is the thickness of the parallel plate,

n is the index of refraction (Figure 2.).

The magnitude of the shift can be read on the micrometer scale. For constructing a micrometer, formula (1) is accurate enough. The grades on the

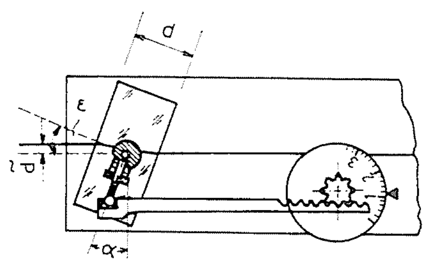

Fig. 2

scale are marked so that the middle reading belongs to the position in which there is no deviation of the light.

The micrometer is divided into 50 parts, accordingly one spacing is equal to 0.1 mm. By estimating the reading, an accuracy of 0.01 mm can be reached. The optical axis of the Zeiss plummet and the two blocks is common. This instrument can be set into a Zeiss forced centering device. (Figure 3)

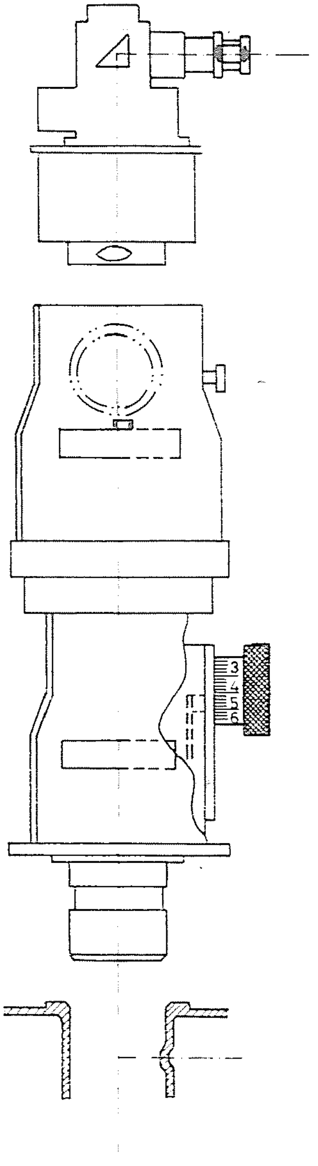

Fig. 3

Complementary equipment

A 3 m long invar levelling rod is used for distance measurement. One graduation line on the rod — in accordance with the graduated micrometer — is equal to 0.5 cm.

During measurement, only one of the two rows of graduation lines on the rod has to be used.

The coefficient of thermal expansion of the invar tape for 1 m is about 1 μm/°C, the error of graduation is smaller than 0.01 mm/m, so the calibration of these rods can be done once every six months, or before using, or after any strong physical force was applied to it. The rod has to be propped up at the 150 and 450 grade. For supporting the rod, there is a support system which

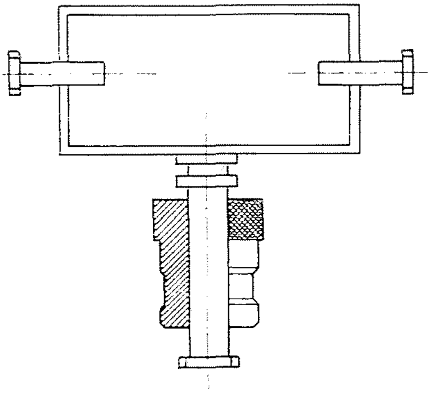

Fig. 4

can be fit into a Zeiss lower part. (Figure 4) The support system ensures that the rod can be lifted 10 cm, and in this way the rod can be levelled. For this purpose there is spirit level.

Measuring with the instrument

At one end of the distance, the instrument has to be set up, by levelling the vertical axis. At the other end, a theodolite has to be set up above the survey mark. The instrument has to be rotated until one of the optical axes of the parallel plates looks in the direction of the distance; the axis of the other parallel plate is now perpendicular to the direction of the distance. The rotation is done as follows: with the theodolite, the initial point has to be targeted, and the instrument has to be rotated until the target on the instrument falls in the vertical wire of the theodolite. On the micrometer scale the grades grow in opposite direction as the measurement procedure. In this way there are no decadic readings.

With the set up instrument the survey mark at the beginning has to be read off on the micrometer in four positions, each perpendicular to the other. Every reading has to be done twice. The mean value of the eight readings — which will not contain due to the parallel and perpendicular errors the axis of the parallel plate — will be the first "fore sight" reading. After the reading at the initial mark, the rod has to be put above the mark (as shown in Figure 5),

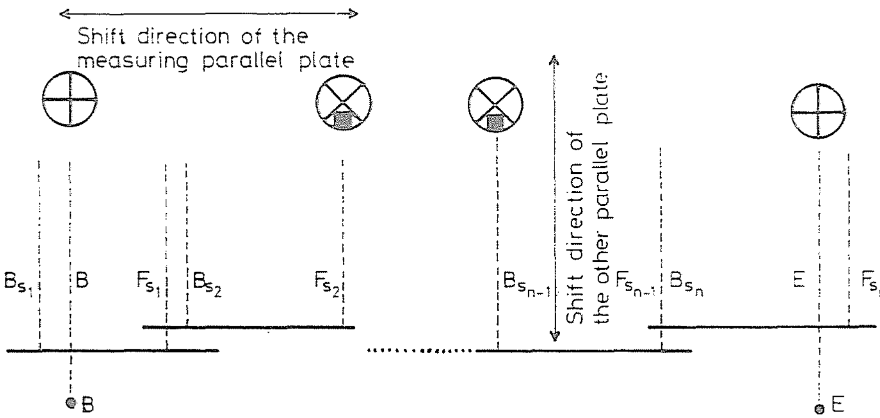

Fig. 5

it is to be aligned and levelled. One of the grades is setting in coincidence and a reading has to be made on the micrometer scale. The micrometer scale reading is the mean value of the eight readings in four positions, each perpendicular to another.

The readings are done with only one of the micrometer scales belonging to one of the parallel plates, the role of the other parallel plate is only to set the centre of the cross hairs on the target or the grade. (Upper part of Figure 5). The verification of rotation at the optical plummet can be done with the index at 45° and 90°, and this helps accurate setting.

After taking the reading at the beginning of the rod (the "back sight"), the instrument is set at the end of the rod, and a reading is taken. The next step is to set the rod in a new position, and after levelling and alignement the initial and final readings (back and fore sights) are done. This procedure is done until the end of the distance is reached, and the instrument is put in the place of the theodolite. Here, first a reading is made on the rod, and micrometer scale (last "fore sight"), then the rod is taken away and after targeting the end point, readings are taken on the micrometer scale (last "back sight"). The process can be seen in Figure 5.

Table I

Point	Fore sight reading					Back sight reading				
			$F_{s\,I}$		$F_{s\,III}$			$B_{s\,I}$		$B_{s\,III}$
			$F_{s\,II}$		$F_{s\,IV}$			$B_{s\,II}$		$B_{s\,IV}$
			$F_{s\,I}+F_{s\,II}$		$F_{s\,III}+F_{s\,IV}$			$B_{s\,I}+B_{s\,II}$		$B_{s\,III}+B_{s\,IV}$
			$(F_{s\,I}+F_{s\,II})/2$		$(F_{s\,III}+F_{s\,IV})/2$			$(B_{s\,I}+B_{s\,II})/2$		$(B_{s\,III}+B_{s\,IV})/2$
		t°C		F_s					B_s	
		476	480	500	500		646	648	576	573
		484		500			650		570	
		648	649	640	635		560	570	636	633
41	000	650		630		018	580		630	
			1129		1135			1218		1206
			564		568			609		603
				566					606	
		278	279	340	340		858	854	770	774
		280		340			850		778	
		320	323	280	280		800	798	870	871
1tp	572	326		280		009	706		872	
			602		620			1652		1645
			301		310			826		822
				306					824	
		1000	1000	930	925		660	653	600	605
		1000		920			646		610	
		970	965	1040	1039		598	599	670	667
2tp	600	960		1038		013	600		664	
			1965		1964			1252		1272
			982		982			626		636
				982					631	
		378	374	420	416		682	686	740	735
		370		412			690		730	
		410	415	366	363		740	748	670	680
3tp	593	420		360		020	756		690	
			789		779			1434		1415
			394		390			717		708
				392					712	
		378	372	362	369		580	578	638	632
		366		376			576		626	
		338	334	340	336		600	606	558	554
33	601	330		332		000	612		550	
			706		705			1184		1186
			353		352			592		593
				352					592	

2368598
63365
2305233 : 2 = 11.52616

The distance can be calculated by the formula:

$$2t = \sum_{j=1}^{n} F_{sj} + B - \left(\sum_{j=1}^{n} Bs_j + E \right) \tag{2}$$

where

- B initial reading (survey mark),
- E final reading (survey mark),
- Fs_j the "fore sight" readings,
- Bs_j the "back sight" readings.

The booking is shown in Table I. From formula (2) it follows that if the reading at the beginning is written into the fore sight column and the reading at the end is written into the back sight column, then the double of the distance ($2t$) will be the difference between the sum of the fore sight readings and the back sight readings.

The time to complete this process depends on the observer's practice and, of course, the distance itself. To measure a distance of 15 m takes about 1.5—2 hours.

The accuracy of the measurements done until now is $\pm 0.05-0.15$ mm, depending on the distance and number of repeated measurements.

The advantage of this distance measuring instrument is that the prescribed accuracy can be maintained even in the engineer surveying praxis, where the survey marks are not very precise. At the initial and end points the micrometer readings can be repeated, and because of this, the different survey marks have only a minimal effect on the accuracy of the measurement.

References

1. ASHKENAZI, V.—DODSON, A. H.—CRANE, S. A.—LIDBURY, J.: Setting out and Deformation Measurements for a Nuclear Accelerator. III. International Symposium on deformation measurements by geodetic methods. Budapest, 1982.
2. DEDE, K.: Absteckungsmikronetze der Reaktorgebäude von Kernkraftwerken. Vermessungstechnik *12*/1988.
3. DEUMLICH, F.- Instrumentenkunde der Vermessungstechnik. VEB Verlag für Bauwesen, Berlin, 1972.
4. EGGER, K.: Neue Instrumente und deren Anwendung bei der geodätischen Deformationmessung an Staumauern. VII. Internationaler Kurs für Ingenieurmessungen hoher Präzision Darmstadt, Band II. 1976.
5. FIALOVSZKY, L.: Geodetic instruments. Műszaki Könyvkiadó, Budapest, 1979. (Hungarian language)
6. LÁSZLÓ, S.: Precise measurements with Zeiss BRT-006 distance-meter. Geod. és Kart. 1979/1.
7. MAHRZAHN, K.: Untersuchungen an Invarband-Nivellierlatten. DGK. Reihe C. 1957.
8. SCHLEMMER, H.: Laser-Interferenzkomparator zur Prüfung von Präzisionsnivellierlatten. DGK. Reihe C. 1975.
9. WERNER, H.: Die internationale Entwicklung der Meßtechnik im Maschinen- und Anlagenbau im kurzen Überblick. Vermessungstechnik 4/1987.

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