BRITISH STANDARD

BS 7334-3:
1990
ISO 8322-3:
1989

Incorporating Amendment No. 1

Measuring instruments for building construction —

Part 3: Methods for determining accuracy in use: Optical levelling instruments

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Policy Committee (BDB/-) to Technical Committee BDB/4, upon which the following bodies were represented:

Association of County Councils
British Standards Society
Building Employers' Confederation
Chartered Institution of Building Services Engineers
Concrete Society
Department of Education and Science
Department of the Environment (Building Research Establishment)
Department of the Environment (Property Services Agency)
Incorporated Association of Architects and Surveyors
Institute of Building Control
Institute of Clerks of Works of Great Britain Inc.
Institution of Civil Engineers
Institution of Structural Engineers
Institution of Water and Environmental Management
Royal Institute of British Architects
Royal Institution of Chartered Surveyors

The following body was also represented in the drafting of the standard, through subcommittees and panels:

Chartered Institute of Building

This British Standard, having been prepared under the direction of the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 30 September 1990

The following BSI references relate to the work on this standard:
Committee reference BDB/4
Draft for comment 87/10028 DC

ISBN 0 580 18697 0

Amendments issued since publication

Amd. No.	Date	Comments
9319	November 1996	Indicated by a sideline in the margin

Contents

National foreword

This Part of BS 7334 has been prepared under the direction of the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Policy Committee. It is identical with ISO 8322-3:1989 *"Building construction — Measuring instruments — Procedures for determining accuracy in use — Part 3: Optical levelling instruments"* published by the International Organization for Standardization (ISO); and gives the testing procedures to be adopted for optical levelling instruments.

The series of Parts comprising BS 7334 will assist in ascertaining whether particular measuring equipment is appropriate to intended measuring tasks; they are also intended for assessing the accuracy in use of measuring instruments in general use on construction sites.

— *Part 1:1990 Theory;*

— *Part 2:1990 Measuring tapes;*

— *Part 3:1990 Optical levelling instruments;*

— *Part 4:1992 Theodolites;*

— *Part 5:1992 Optical plumbing instruments;*

— *Part 6:1992 Laser instruments;*

— *Part 7:1992 Instruments when used for setting out;*

— *Part 8:1992 Electronic distance-measuring instruments up to 150 m.*

The Parts are referred to in BS 5606:1990 *"Guide to accuracy in building"*.

Cross-references

International standard	Corresponding British Standard
	BS ISO 3534 *Statistics, vocabulary and symbols*
ISO 3534-1:1993	BS ISO 3534-1:1993 *Probability and general statistical terms* (Identical)
ISO 3534-3:1985	BS ISO 3534-3:1985 *Glossary of terms relating to the design of experiments* (Identical) BS 5964 *Building setting out and measurement*
ISO 4463-1:1989	Part 1:1990 *Methods of measuring, planning and organization and acceptance criteria* (Identical)
ISO 4463-2:1995	Part 2:1996 *Measuring stations and targets* (Identical)
ISO 4463-3:1995	Part 3:1996 *Check-lists for the procurement of surveys and measurement services* (Identical)
ISO 7078:1985	BS 6953:1988 *Glossary of terms for procedures for setting out, measurement and surveying in building construction (including guidance notes)* (Identical)

The Technical Committee has reviewed the provisions of ISO 7077, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 10, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

blank

0 Introduction

This International Standard consists of a series of parts specifying test procedures to be adopted when determining and assessing the accuracy in use of measuring instruments in building construction. The first part gives the theory; subsequent parts give the procedures for determining the accuracy in use of measuring instruments for measurements. The complete series will consist of the following parts:

— *Part 1: Theory;*

— *Part 2: Measuring tapes;*

— *Part 3: Optical levelling instruments;*

— *Part 4: Theodolites;*

— *Part 5: Optical plumbing instruments;*

— *Part 6: Laser instruments;*

— *Part 7: Instruments when used for setting out;*

— *Part 8: Electronic distance-measuring instruments.*

Other International Standards for testing measuring instruments for land surveying purposes, and for measuring procedures in ordnance survey, are in preparation.

1 Scope

This part of ISO 8322 specifies test procedures to be adopted when determining and assessing the accuracy in use of optical levelling instruments for measurement purposes.

2 Field of application

The procedures given in this part of ISO 8322 apply when these optical levelling instruments are used in building construction for surveying, check and compliance measurements, and also when obtaining accuracy data.

3 References

ISO 3534, *Statistics — Vocabulary and symbols.*

ISO 4463-1, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization measuring procedures, acceptance criteria.*

ISO 7077, *Measuring methods for building — General principles and procedures for the verification of dimensional compliance.*

ISO 7078, *Building construction — Procedures for setting out measurement and surveying — Vocabulary and guidance notes.*

ISO 8322-1, *Building construction — Measuring instruments — Procedures for determining accuracy in use — Part 1: Theory.*

4 General

4.1 Before commencing surveying, check and compliance measurements, when obtaining accuracy data or setting out, it is important that the operator investigates that the accuracy in use of the measuring equipment is appropriate to the intended measuring task. This International Standard recommends that the operator carries out test measurements under field conditions to establish the accuracy achieved when he uses a particular measuring instrument and its ancillary equipment.

To ensure that the assessment takes account of various environmental influences, two series of measurements need to be carried out under different conditions. The particular conditions to be taken into account may vary depending on where the tasks are to be undertaken. These conditions will include variations in air temperature, wind speed, cloud cover and visibility. Note should also be made of the actual weather conditions at the time of measurement and the type of surface over which the measurements are made. The sets of conditions chosen for the tests should match those expected when the intended measuring task is actually carried out. See ISO 7077 and ISO 7078.

The procedures are designed so that the systematic errors are largely eliminated and assume that the particular instruments are in known and acceptable states of user adjustment according to methods detailed in the manufacturer's handbooks.

Accuracy in use procedures require tests to be made with the same instrumentation and the same observer, within a short interval of time. These are "repeatability conditions" as defined in ISO 3534.

The accuracy in use is expressed in terms of the standard deviation.

4.2 Figure 1 indicates schematically the decisions to be made when establishing that the accuracy associated with a given surveying method and particular measuring equipment is appropriate to the intended measuring task. In particular, the decisions apply when adopted by a particular operator under a range of environmental conditions which are likely to occur when the task is actually carried out. Where the contract documentation specifies the required tolerance for the intended measuring task, it is recommended that this tolerance, which is normally given in terms of the permitted deviation $\pm P$ ($P = 2{,}5\ \sigma$) of the measuring task, is compared with the accuracy in use data obtained either from previous accuracy in use tests or from general data A which indicate the expected accuracy in use of given measuring equipment. On those occasions that the previously obtained data indicates that the accuracy in use associated with the given measuring equipment exceeds the specified permitted deviation of the measuring task, consideration should be given to either selecting a different method and/or a more precise instrument, or discussing with the designer the need for such a small permitted deviation. See ISO 4463-1.

Before obtaining an overall estimate of the accuracy in use, it is recommended that each standard deviation for a given series of measurements undertaken under particular environmental conditions is compared, as indicated in Figure 1, with the specified permitted deviation. Where the comparison shows that the specified permitted deviation has not been achieved for one series of measurements, an additional series of measurements should be carried out under as near as possible similar environmental conditions to those which applied in that original series of measurements.

5 Procedures for optical levelling instruments

5.1 General

The normal practice is for measuring accuracy to be referred to 1 km of double levelling. However, the operating distance in building construction will not normally exceed 40 m. Therefore this part of ISO 8322 recommends that the accuracy in use is presented in terms of a standard deviation for a distance of 1 km (method 1) or for a distance of 40 m (method 2). Each presentation should be in terms of double levelling. The operator shall choose the method most relevant to this requirement.

The following test procedures should be adopted for determining the accuracy in use by a particular survey team with a particular instrument and its ancillary equipment.

5.2 Method 1

5.2.1 ***Observation procedure*** (see Table 1)

5.2.1.1 Establish two levelling points approximately 250 m apart. The points shall be reliably defined for the duration of the test measurements.

5.2.1.2 Each of the two series of measurements on separate days shall consist of five double levellings: the forward and reverse levelling are considered to be measurements independent of each other. When establishing the accuracy in use for very accurate levels (sometimes incorrectly called "precision levels": see ISO 7078 regarding the difference between "accuracy" and "precision"), sighting distance should be approximately 20 m; otherwise the sighting distance should be about 40 m. All measurements should be taken to the nearest millimetre or to the nearest 0,1 mm when using a level fitted with a parallel plate micrometer.

5.2.1.3 The ancillary equipment used and the environmental conditions shall be similar to those expected in the intended actual measurement.

5.2.1.4 Record the environmental conditions. Changes of environmental conditions during the construction period may render the test result inapplicable. In such a case the test should be repeated under the new conditions.

Assumptions: ± P is the permitted deviation of the measuring task

A is the accuracy in use, generally expressed as deviation ± A; (both ± P and ± A are considered to include the dimensional variability associated with ± 2,5 times the standard deviation ÷)

s are the deviations obtained in the field tests

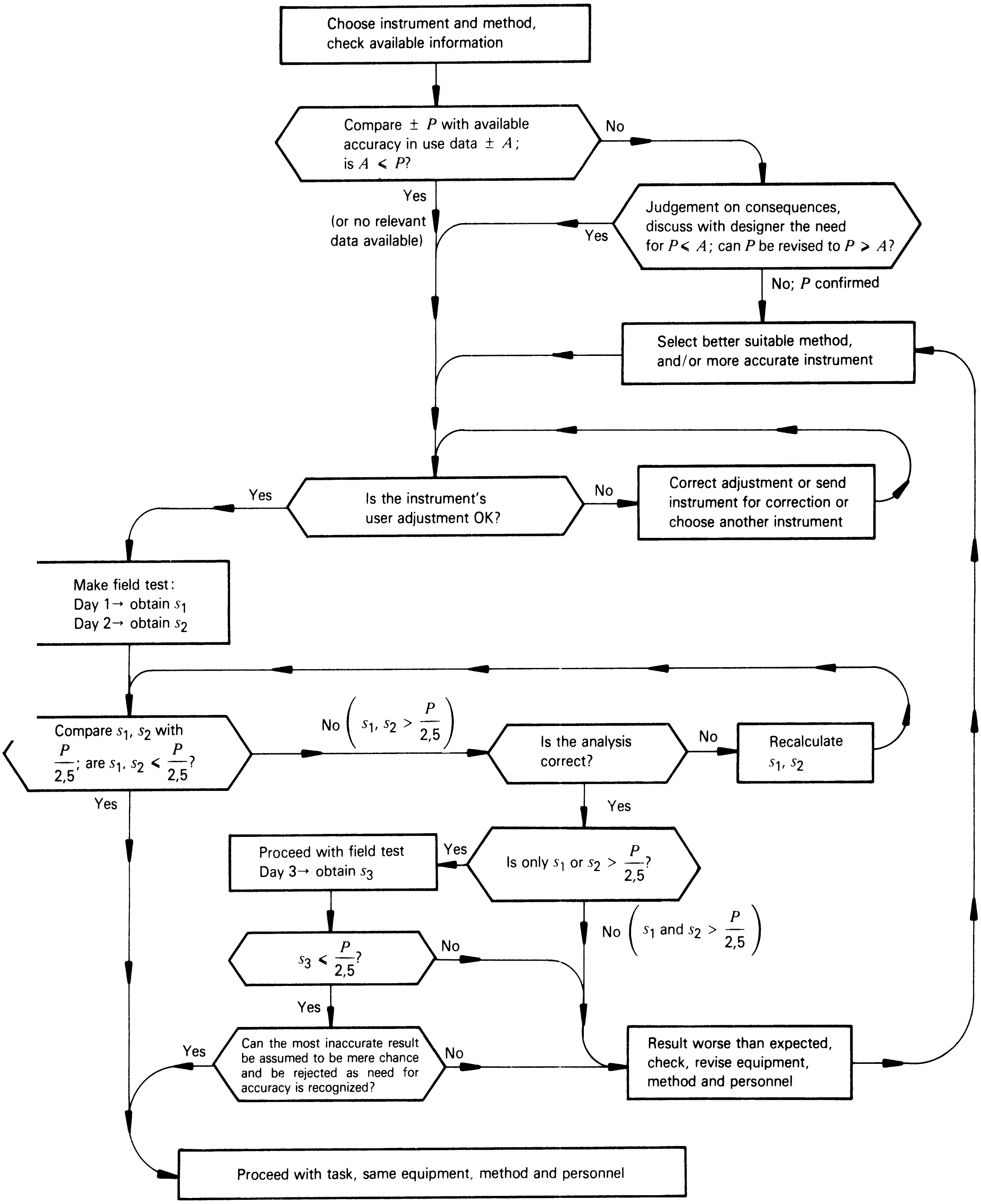

Figure 1 — Flow diagram for accuracy in use tests

5.2.2 ***Calculation procedure*** *(see Table 1)*

A complete example of the analysis is given in Table 1 (columns 3, 4 and 5) for an engineer's level and it is recommended that this form of presentation be generally adopted. All calculations are in terms of the value of the differences of level between the two stabilized level points.

5.2.2.1 Calculate the arithmetic mean $\bar{x}$ (column 3).

For example: 318,5

5.2.2.2 Calculate the deviations v of each value from arithmetic mean (column 4).

For example: level 2 reverse: – 1,5 mm

To minimize the effect of rounding errors, the calculation of each deviation v should be carried out to the nearest 0,1 mm if the values are in millimetres and to the nearest 0,01 mm if the values are in 0,1 mm.

As an arithmetic check the sum of the ten deviations should be zero.

5.2.2.3 Calculate the squares v^2 of all values in column 4 and the sum of the squares.

For example: level 2 reverse: 2,25 mm^2
the sum of the squares: 94,50 mm^2

5.2.2.4 Calculate the standard deviation s_1 of a difference in level for a line of 250 m length on the first day as the square root of the sum of squares divided by 9 (= number of redundant observations).

For example: $s_1 = \sqrt{\frac{94,50}{9}} = \sqrt{10,5} = 3,2 \text{ mm}$

5.2.2.5 Calculate the standard deviation $s_{1(\text{km})}$ of a difference in level for a line of 1 km as the standard deviation of the line of 250 m length multiplied by the square root of 4.

For example: $s_{1(\text{km})} = 3,2\sqrt{4} = 6,4 \text{ mm}$

5.2.2.6 Calculate the standard deviation of a difference in double levelling for a line of 1 km as the standard deviation of a 1 km levelling line divided by the square root of 2.

For example: $s_{1(\text{km double level})} = \frac{6,4}{\sqrt{2}} = 4,5 \text{ mm}$

5.2.2.7 Repeat procedures **5.2.1.2** to **5.2.2.6** on a second day to obtain s_2.

5.2.2.8 The overall standard deviation to be expected of any 1 km double levelling is

$$s_{(\text{km double level})} = \sqrt{\frac{s^2_{1(\text{km d. l.})} + s^2_{2(\text{km d.l.})}}{2}}$$

For example $s_{(\text{km double level})} = 6 \text{ mm}$

Table 1a) — Field observations and calculations: example

Date: ....

Location: ....

Observer: ....

Instrument: Engineer's level

Conditions: Warm, sunny, light wind

Series: I

Measurement	Difference in level mm	Mean mm	v mm	v^2 mm^2
1	2	3	4	5
1 Forward Reverse	320 315		+ 1,5 – 3,5	2,25 12,25
2 Forward Reverse	324 317		+ 5,5 – 1,5	30,25 2,25
3 Forward Reverse	319 319		+ 0,5 + 0,5	0,25 0,25
4 Forward Reverse	314 316		– 4,5 – 2,5	20,25 6,25
5 Forward Reverse	323 318		+ 4,5 – 0,5	20,25 0,25
		318,5	$\Sigma v = 0,0$	$\Sigma v^2 = 94,50$

$$s_1 = \sqrt{\frac{94,50}{9}} = 3,2 \text{ mm}$$

$$s_{1(\text{km})} = 2,0 \times 3,2 = 6,4 \text{ mm}$$

$$s_{1(\text{km double level})} = \frac{6,4}{\sqrt{2}} = 4,5 \text{ mm}$$

$$s_{2(\text{km double level})} = 7,8 \text{ mm}$$

$$s = \sqrt{\frac{4,5^2 + 7,8^2}{2}} = 6,4 \text{ mm}$$

$$s = 6 \text{ mm}$$

Table 1b) — Field observations and calculations: data sheet

Date: ....

Location: ....

Observer: ....

Instrument: ....

Conditions: ....

Series: ....

Measurement	Difference in level mm	Mean mm	v mm	v^2 mm^2
1	2	3	4	5
1 Forward Reverse				
2 Forward Reverse				
3 Forward Reverse				
4 Forward Reverse				
5 Forward Reverse				
			$\Sigma v =$	$\Sigma v^2 =$

$$s_1 = \sqrt{\frac{\quad}{9}} = \quad \text{mm}$$

$$s_{1(\text{km})} = \quad \times \quad = \quad \text{mm}$$

$$s_{1(\text{km double level})} = \frac{\quad}{\sqrt{2}} = \quad \text{mm}$$

$$s_{2(\text{km double level})} = \quad \text{mm}$$

$$s = \sqrt{\frac{\quad + \quad}{2}} = \quad \text{mm}$$

$$s = \quad \text{mm}$$

5.3 Method 2

5.3.1 *Observation procedure* (see Table 2)

If the required levelling task only involves distances up to 40 m or the transferring of a level to a different floor, for example a flight of steps, the following procedure shall be taken.

5.3.1.1 Establish at least four levelling points [Figure 2 a)]. The distances between the points and the distances between the levelling instrument and the points (sight-distances) shall be approximately the same as those expected on a particular construction site. In general, they are not equal. Five of the possible differences in height (level) are to be measured, for example at first the difference between B and C and so on. Other configurations of five differences in height are acceptable [for example Figure 2 b)]. The points shall be in stable locations for the duration of the test measurements. In the case of a rombus-shaped or triangle-shaped test field [Figure 2 a)], the resulting loop conditions will not be considered.

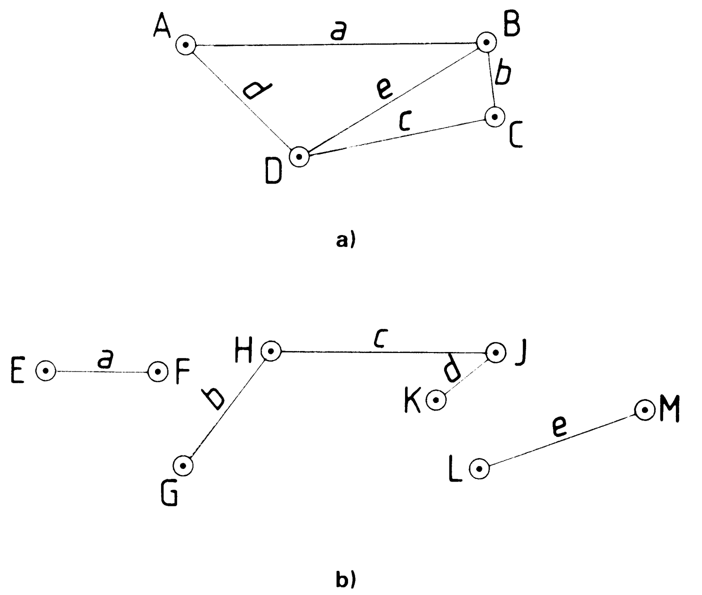

Figure 2 — Selection of levelling points

5.3.1.2 Each of the two series of measurements on separate days shall consist of five double measurements of the differences in height (level). This has to be organized in such a way that after the first determination of the difference in height, the level has to be disturbed and reset. All measurements should be taken to the nearest millimetre.

5.3.1.3 The ancillary equipment used and the environmental conditions shall be similar to those expected in the intended actual measurement.

5.3.1.4 Record the environmental conditions. Changes of environmental conditions during the construction period may render the test result inapplicable. In such a case the test should be repeated under the new conditions.

5.3.2 ***Calculation procedure*** *(see Table 2)*

A complete example of the analysis is given in Table 2, columns 8, 11, 12, 13, for an engineer's level using the measurements given in columns 6, 7, 9, 10, and it is recommended that this form of presentation be generally adopted.

5.3.2.1 Calculate the differences between reading reverse and reading forward (column 6 minus column 7 and column 9 minus column 10).

For example: Measurement 2: – 2 080 and + 2 077

5.3.2.2 Calculate the absolute difference d between column 8 and column 11.

For example: Measurement 2: $d = 3$

5.3.2.3 Calculate the square of d and the sum of the squares.

For example: Measurement 2: $d^2 = 9$
Sum of squares: 143

5.3.2.4 Calculate the standard deviation of a once-measured difference in height as the square root of the sum of the squares divided by 10 (number of measurements multiplied by 2).

For example: $s_1 = \sqrt{\frac{143}{10}} = \sqrt{14{,}3} = 3{,}8$ mm

5.3.2.5 Calculate the standard deviation of a double-levelled difference in height on the first day as the standard deviation of a once-measured difference in height divided by $\sqrt{2}$.

For example $s_{1\ \text{double}} = \frac{3{,}8}{\sqrt{2}} = 2{,}7$ mm

5.3.2.6 Repeat procedures **5.3.1.2** to **5.3.2.5** on a second day to obtain $s_{2\ \text{double}}$.

5.3.2.7 The overall standard deviation of a double-levelled difference in height is

$$s_{\text{double}} = \sqrt{\frac{s_{1\text{double}}^2 + s_{2\text{double}}^2}{2}}$$

For example: $s_{\text{double}} = 3$ mm

Table 2a) — Field observations and calculations: example

Date: ....

Location: ....

Observer: ....

Instrument: Engineer's level

Conditions: Cloudy, warm, no wind

No.	Point i	Point j	Distance from instrument to		Reading reverse	Reading forward	Reverse-forward	Reading reverse	Reading forward	Reverse-forward	Absolute difference	d^2
			Point i	Point j	Point i	Point j		Point j	Point i		$\left\| \|\text{Col. 8}\| - \|\text{Col. 11}\| \right\|$ d	
			m	m	mm	mm	mm	mm	mm	mm	mm	mm^2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	A	B	4	10	1 437	781	+ 656	823	1 482	– 659	3	9
2	B	C	15	15	1 841	3 921	– 2 080	3 942	1 865	+ 2 077	3	9
3	D	B	4	25	251	2 410	– 2 159	2 392	236	+ 2 156	3	9
4	D	E	20	10	671	1 349	– 678	1 503	821	+ 682	4	16
5	E	A	30	6	2 003	2 410	– 407	2 392	1 995	+ 397	10	100

$\Sigma d^2 = 143$

$$s_1 = \sqrt{\frac{143}{10}} = \sqrt{14{,}3} = 3{,}8 \text{ mm}$$

$$s_{1\ \text{double}} = \frac{3{,}8}{\sqrt{2}} = 2{,}7 \text{ mm}$$

$$s_{2\ \text{double}} = 4{,}0 \text{ mm}$$

$$s_{\text{double}} = \sqrt{\frac{2{,}7^2 + 4{,}0^2}{2}} = 3{,}4 \text{ mm}$$

$$s_{\text{double}} = 3 \text{ mm}$$

Table 2b) — Field observations and calculations: data sheet

Date: ....

Location: ....

Observer: ....

Instrument: ....

Conditions: ....

No.	Point i	Point j	Distance from instrument to Point i	Distance from instrument to Point j	Reading reverse Point i	Reading forward Point j	Reverse-forward	Reading reverse Point j	Reading forward Point i	Reverse-forward	Absolute difference $\lvert \lvert \text{Col. 8} \rvert - \lvert \text{Col. 11} \rvert \rvert$ d	d^2
			m	m	mm	mm	mm	mm	mm	mm	mm	mm^2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	A	B										
2	B	C										
3	D	B										
4	D	E										
5	E	A										

$\Sigma d^2 =$

$s_1 = \sqrt{\frac{\quad}{10}} = \sqrt{\quad} =$ mm

$s_{1\ \text{double}} = \frac{\quad}{\sqrt{2}} =$ mm

$s_{2\ \text{double}} =$ 4,1 mm

$s_{\text{double}} = \sqrt{\frac{\quad + \quad}{2}} = \sqrt{\frac{\quad}{2}} = \sqrt{\quad} =$ mm

Publications referred to

See national foreword.

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL