INTERNATIONAL STANDARD

ISO 8322-6

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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 6:
Laser instruments

Construction immobilière — Instruments de mesure — Procédures de détermination de l'exactitude d'utilisation —
Partie 6: Instruments à laser

Reference number
ISO 8322-6:1991(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8322-6 was prepared by Technical Committee ISO/TC 59, *Building construction*, Sub-Committee SC 4, *Limits and fits in building construction*.

ISO 8322 consists of the following parts, under the general title *Building construction — Measuring instruments — Procedures for determining accuracy in use*:

- *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 instrument s up to 150 m*
- *Part 9: Electronic distance-measuring instruments up to 500 m*
- *Part 10: Testing short-range reflectors*

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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.

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

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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 6:
Laser instruments

1 Scope

This part of ISO 8322 specifies test procedures to be adopted when determining and assessing the accuracy in use of laser instruments and ancillary equipment for measurements of distances from a plane, a line or a specific gradient defined by a laser beam. The plane or the line may be horizontal, vertical or sloping. The use of electronic distance-measuring instruments incorporating a laser beam is not covered by this part of ISO 8322.

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8322. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8322 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3534:1977, *Statistics — Vocabulary and symbols.*

ISO 4463-1:1989, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria.*

ISO 7077:1981, *Measuring methods for building — General principles and procedures for the verification of dimensional compliance.*

ISO 7078:1985, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes.*

3 General

3.1 Before commencing surveying, check and compliance measurements, when obtaining accuracy data or setting out, it is important that the operator investigate whether the accuracy in use of the measuring equipment is appropriate to the intended measuring task. This International Standard recommends that the operator carry 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.

Assumptions:

P is the permitted deviation of the measuring task

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

$\hat{s}$ are the root mean square errors obtained in field tests

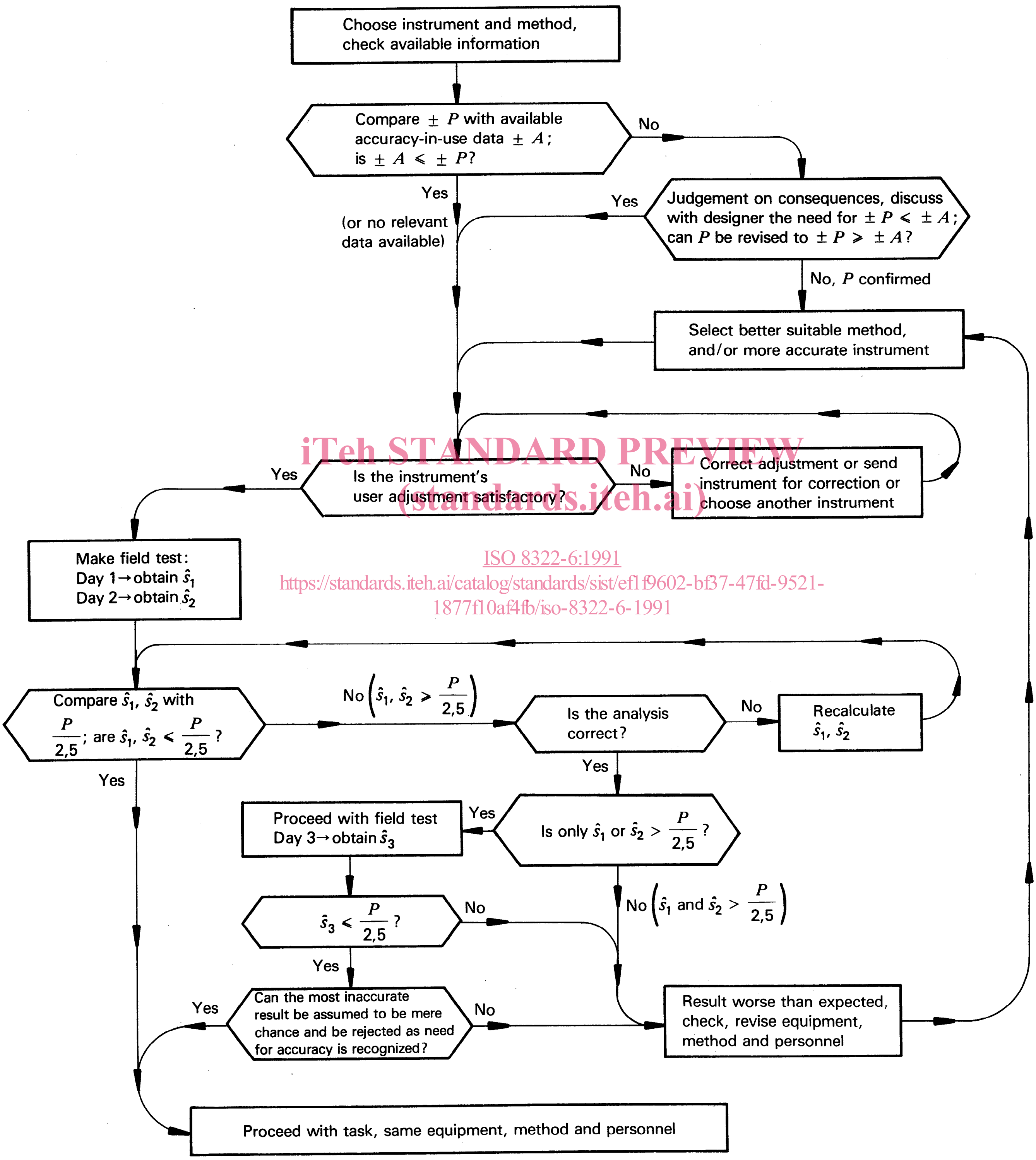

Figure 1 — Flow diagram for accuracy-in-use tests

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 manufacturers' handbooks.

Accuracy-in-use procedures require repeat 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.

3.2 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 P ($P = 2{,}5\ \sigma$) of the measuring task, be 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 indicate that the accuracy in use associated with the given measuring equipment does not meet 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 be compared, as indicated in figure 1, to 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 environmental conditions as near as possible similar to those which applied in that original series of measurements.

4 Procedures for laser instruments for determining a plane, a horizontal line or a specific gradient

4.1 Accuracy test procedure

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

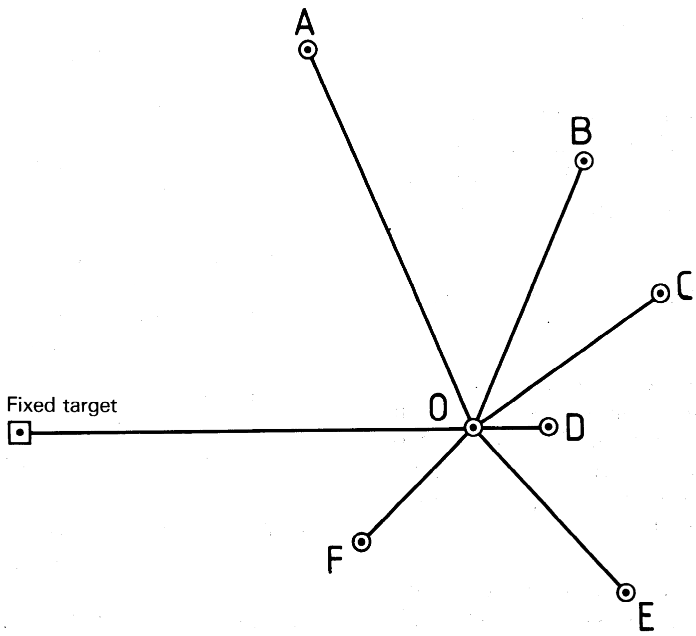

Figure 2 — Layout of target points

Three methods are given. The first is for determining a plane (method 1), the second one for determining a horizontal line (method 2), the third one for determining a specific gradient (method 3). To ensure that the accuracy is determined, and not merely the repeatability, the determination shall be carried out against true values.

4.1.1 Method 1: Determining a plane

The measurement results should be given in a table (see table 1-B). An example of a completed table is given in table 1-A.

4.1.1.1 Observations

a) Establish six points, e.g. A, B, C, D, E and F, at distances from a fixed instrument station O and of a form similar to that expected on a particular construction site. The points shall be spread over at least 100 gon or 90° in the plane under consideration (see figure 2). The points shall be in stable locations for the duration of the test measurements and at a distance not greater than 70 m.

   Measure the differences in level between the points A to F with an optical levelling instrument. If the determination for the laser instrument is in millimetres, the determination of the differences in level shall be 0,1 mm. In this case a precision levelling instrument shall be used.

   To be sure that the laser plane is stable during the whole measuring procedure, a fixed target shall be observed before and after each series of measurements.

b) Each of the two series of measurements on separate days shall consist of five separate sets of readings (see column 1 of table 1-B). A period of time of at least 10 min shall elapse between each separate set.

c) The beam shall be stable before the measurement starts.

d) Take the readings on the scale of the rod in the same manner as is to be used subsequently on site. This may be by visually reading the centre of the spot of the laser on the rod or by using an electronic device or other ancillary equipment for detecting the centre of the beam.

e) Record the environmental conditions and the time of commencement of measuring each set. Changes of environmental conditions during the construction period may render the test result inapplicable. In such a case repeat the test under the new conditions.

4.1.1.2 Calculation procedure

A complete example of the analysis is given in table 1-A using the measurements given in columns 3, 4, 6, 9, 10, 12, 15, 16 and 18 and it is recommended that this form of presentation be generally adopted.

In this procedure the root mean square error is calculated because true values are known from the levelling of the points.

a) Calculate the difference between the readings A and B (columns 3 and 4).

   EXAMPLE

   First set:
   1 256 − 1 392 = − 136 mm

b) Calculate the true difference ε (column 7) between the measured value (column 5) and the true value Δ level (column 6) derived from the levelling.

   EXAMPLE

   First set:
   − 136 − (− 133) = − 3 mm

c) Calculate the squares of all values from column 7 and the sum of the squares (column 8).

   EXAMPLE

   For the difference A − B:
   9 + 4 + 1 + 4 + 4 = 22 mm²

d) Calculate the overall sum of squares.

   EXAMPLE

   The sum of the first day is:
   22 + 52 + 37 = 111 mm²

e) Calculate the root mean square error, $\hat{s}_1$, of a single difference in level for the first day as the square root of the sum of squares divided by 15 (= number of individual differences).

   EXAMPLE

$$\hat{s}_1 = \sqrt{\frac{111}{15}} = \sqrt{7{,}4} = 2{,}7 \text{ mm}$$

f) Repeat the observation and calculation procedure on a second day to obtain $\hat{s}_2$.

g) The overall root mean square error, $\hat{s}_{diff}$, to be expected for any single difference in level is

$$\hat{s}_{diff} = \sqrt{\frac{\hat{s}_1^2 + \hat{s}_2^2}{2}}$$

EXAMPLE

If $\hat{s}_2 = 3{,}2$ mm, then $\hat{s}_{\text{diff}} = 3{,}0$ mm

h) The overall root mean square error to be expected for any single observation of a displacement is

$$\hat{s} = \frac{\hat{s}_{\text{diff}}}{\sqrt{2}}$$

EXAMPLE

$$\hat{s} = \frac{3{,}0}{\sqrt{2}} = 2 \text{ mm}$$

4.1.2 Method 2: Determining a horizontal line

The measurement results should be given in a table (see table 2-B). An example of a completed table is given in table 2-A.

4.1.2.1 Observations

a) Establish five points, e.g. A, B, C, D and E, at distances perpendicular from a fixed line and of a form similar to that expected on a particular construction site. The fixed line is defined by the station O and a target point P (see figure 3). The points shall be situated in the range from ± 50 mm to ± 300 mm perpendicular from the line to be checked (see figure 3). The points shall be in stable locations for the duration of the test measurements and at a distance not greater than 70 m. The true perpendicular distances are to be measured with a theodolite established over point O and with its line of sight directed to the target point P and a scale perpendicular to the line of sight.

To be sure that the laser line is stable during the whole measuring procedure, the fixed target P shall be observed before and after each series of measurements.

b) Each of the two series of measurements on separate days shall consist of five separate sets of readings (see column 1 of table 2-B). A period of time of at least 10 min shall elapse between each separate set.

c) The beam shall be stable before the measurement starts.

d) Take the readings on the scale of the rod in the same manner as is to be used subsequently on site. This may be by visually reading the centre of the spot of the laser on the rod or by using an electronic device or other ancillary equipment for detecting the centre of the beam.

e) Record the environmental conditions and the time of commencement of measuring each set. Changes of environmental conditions during the construction period may render the test result inapplicable. In such a case repeat the test under the new conditions.

4.1.2.2 Calculation procedure

A complete example of the analysis is given in table 2-A using the measurements given in columns 3, 4, 7, 8, 11, 12, 15, 16, 19 and 20. It is recommended that this form of presentation be generally adopted.

In this procedure the root mean square error is calculated because true values are known from the theodolite observations.

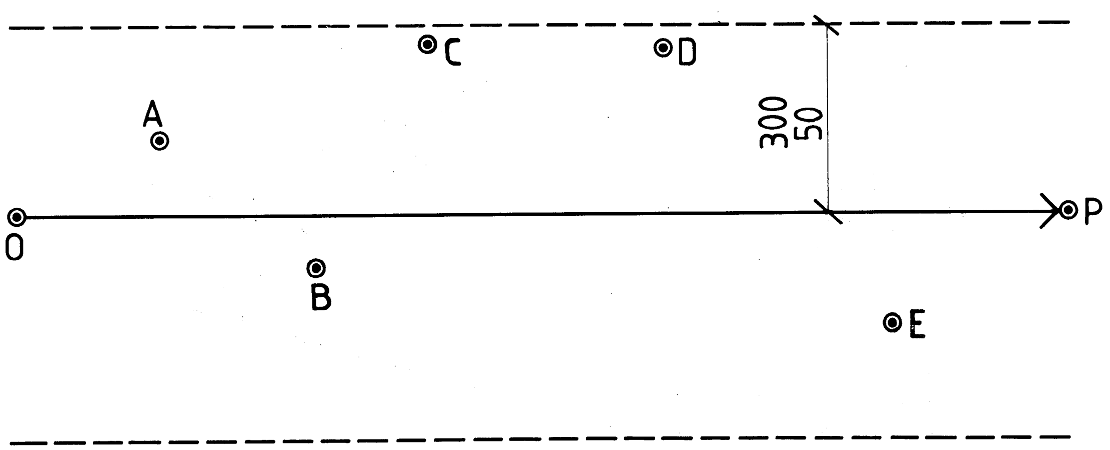

Figure 3 — Layout of measuring points

a) Calculate the true difference ε (column 5) between the reading (column 3) and the true value (column 4).

EXAMPLE

Second set point A:
$62 - 64 = -2$ mm

b) Calculate the squares of all values from column 5 and the sum of the squares (column 6).

EXAMPLE

For point A:
$\Sigma\varepsilon^2 = 14$ mm²

c) Calculate the overall sum of the squares.

EXAMPLE

The sum of the first day is:
$14 + 10 + 25 + 15 + 10 = 74$ mm²

d) Calculate the root mean square error, $\hat{s}_1$, of a displacement for the first day as the square root of the sum of squares divided by 25 (= number of observations).

EXAMPLE

$$\hat{s}_1 = \sqrt{\frac{74}{25}} = 1,7 \text{ mm}$$

e) Repeat the observation and calculation procedure on a second day to obtain $\hat{s}_2$.

f) The overall root mean square error, $\hat{s}$, to be expected for any single observation of a displacement is

$$\hat{s} = \sqrt{\frac{\hat{s}_1^2 + \hat{s}_2^2}{2}}$$

EXAMPLE

If $\hat{s}_2 = 2,3$ mm, then $\hat{s} = 2$ mm

4.1.3 Method 3: Determining a specific gradient

The measurement results should by given in a table (see table 3-B). An example of a completed table is given in table 3-A.

4.1.3.1 Observations

a) Establish two fixed points A and B at a distance apart of 70 m and on a slope similar to that expected on the site (see figure 4). The points shall be in stable locations for the duration of the test measurements. The true difference in level shall be determined by a levelling instrument.

b) Determine, by levelling, the difference in level, $\Delta H = H_A - H_B$, between points A and B (see figure 4).

Set the laser over A and measure the height of its axis, h, above the point.

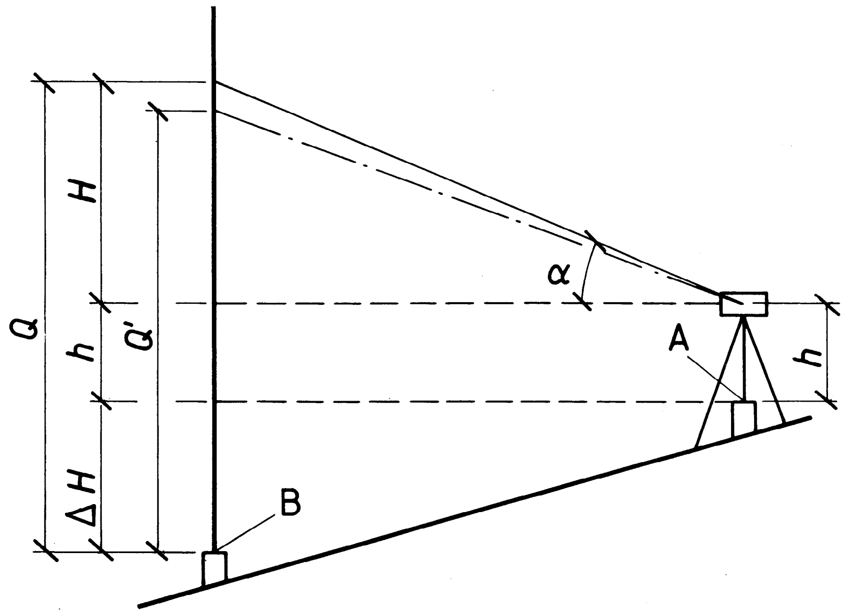

Figure 4 — Levelling

For a gradient of α ‰ at the horizontal distance for AB, calculate the vertical difference, H.

EXAMPLE

For a distance AB = 70 m and $\alpha = -15$ ‰ the vertical difference is $H = -1{,}050$ m.

The correct rod reading, Q, for that gradient is

$$Q = \Delta H + h + H$$

EXAMPLE

$\Delta H = 0{,}805\,5$ m

$h = 0{,}347\,5$ m

$H = -1{,}050$ m

$Q = 0{,}103$ m = 103 mm

Actual reading on the staff is Q'.

EXAMPLE

Measurement 1 with $\alpha = -15$ ‰,
$Q' = 101$ mm

Hence deviation is $\varepsilon = Q' - Q$.

EXAMPLE

Measurement 1 with $\alpha = -15$ ‰,
$\varepsilon = 101 - 103 = -2$ mm

Repeat the procedure for four other selected gradients and record results.

The whole procedure is to be repeated on a second day.

c) The beam shall be stable before the measurement starts.

d) Fix the laser instruments to the chosen values of inclination and read the laser beam on the scale of the rod consecutively. Each of the two series of measurements on separate days shall consist of five separate sets.

e) Take the reading on the scale of the rod in the same manner as is to be used subsequently on site. This may be by visually reading the centre of the spot of the laser on the rod or by using an electronic device or other ancillary equipment for detecting the centre of the beam.

f) Record the environmental conditions and the time of commencement of measuring each set. Changes of environmental conditions during the construction period may render the test result inapplicable. In such a case repeat the test under the new conditions.

4.1.3.2 Calculations

A complete example of the analysis is given in table 3-A using the measurements given in columns 2, 3, 6, 7, 10, 11, 14, 15, 18 and 19. It is recommended that this form of presentation be generally adopted.

In this procedure the root mean square error is calculated because the true values are known from the levelling procedure.

a) Calculate the true difference ε (column 4) between the reading in column 2 and the true value (column 3).

EXAMPLE

First measurement with $\alpha = -15$ ‰,
$\varepsilon = 101 - 103 = -2$ mm

b) Calculate the squares of all values in column 4 and the sums of the squares.

EXAMPLE

For $\alpha = -15$ ‰, $\Sigma\varepsilon^2 = 50$ mm²

c) Calculate the overall sum of the squares (column 5).

EXAMPLE

The sum of the first day is:
50 + 77 + 76 + 48 + 67 = 318 mm²

d) Calculate the root mean square error, $\hat{s}_1$, of a displacement for the first day as the square root of the sum of squares divided by 25 (= number of observations).

EXAMPLE

$$\hat{s}_1 = \sqrt{\frac{318}{25}} = 3{,}6 \text{ mm}$$

e) Repeat the observation and calculation procedure on a second day to obtain $\hat{s}_2$.

f) The overall mean square error, $\hat{s}$, to be expected for any single observation in the chosen range of inclination is

$$\hat{s} = \sqrt{\frac{\hat{s}_1^2 + \hat{s}_2^2}{2}}$$

EXAMPLE

If $\hat{s}_2 = 4{,}2$ mm, then $\hat{s} = 4$ mm