INTERNATIONAL STANDARD

ISO 4463-1

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Measurement methods for building — Setting-out and measurement —

Part 1:
Planning and organization, measuring procedures, acceptance criteria

Méthodes de mesurage pour la construction — Piquetage et mesurage —
Partie 1: Planification et organisation, procédures de mesurage et critères d'acceptation

Reference number
ISO 4463-1 : 1989 (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 approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 4463-1 was prepared by Technical Committee ISO/TC 59, *Building construction*.

This first edition of ISO 4463-1 cancels and replaces ISO 4463 : 1979, of which it constitutes a technical revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Contents

Measurement methods for building — Setting-out and measurement —

Part 1: Planning and organization, measuring procedures, acceptance criteria

0 Introduction

This part of ISO 4463 forms one of a series concerning the accuracy of measurement methods on building sites.

Part 2 will deal with measuring stations and targets and part 3 will deal with setting-out drawings.

1 Scope

This part of ISO 4463 deals with the progressive stages of setting-out work in building construction, i.e. acquisition of information, establishing the primary system, setting-out the secondary system, vertical transfer of points in the secondary system to other levels, and setting-out the position points and the establishment and transfer of levels (bench marks).

In addition it gives values of permitted deviations and guidance on independent check measurements (quality control) using instruments and methods currently in common use at each stage of the setting-out process.

2 Field of application

This part of ISO 4463 applies to common types of building construction. Special operations such as setting-out of precision machinery or the legal location of the building, as specified for example in planning laws or local regulations, are not covered by this part of ISO 4463 since all recommendations are subject to statutory legislation in a particular country.

3 References

ISO 1803-1, *Building construction — Tolerances — Vocabulary — Part 1: General terms.*

ISO 1803-2, *Building construction — Tolerances — Vocabulary — Part 2: Derived terms.*

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

ISO 7976-1, *Tolerances for building — Guidelines indicating methods of measurement of buildings and building products — Part 1: Instruments and accuracy.*

ISO 7976-2, *Tolerances for building — Guidelines indicating methods of measurement of buildings and building products — Part 2: Position of measuring points.*

ISO 8322 (all parts), *Building construction — Measuring instruments — Procedures for determining accuracy-in-use.* [1)]

4 Definitions

For the purposes of this part of ISO 4463, the definitions of ISO 1803 and ISO 7078, together with the following, apply.

4.1 site surveyor: Person entrusted with the carrying-out of one or more of the different measuring operations in the building process.

As practice can differ from country to country, the term site surveyor is intended to refer to a competent operator in this field irrespective of his formal qualifications.

4.2 compliance measurement: Measurement carried out to verify compliance with the specified permitted deviation of a completed stage of the construction process (for example, building components, setting-out and constructed work).

4.3 check measurement: Independent informal measurement to check the correctness and accuracy of a previous measurement.

4.4 secondary line: Any line used for the purpose of setting-out the proposed building and for checking and compliance of the building or building parts.

4.5 acceptance criteria: Conditions to be fulfilled prior to acceptance of a completed task or process.

1) To be published.

Section one: General introduction

5 General introduction

5.1 The process of setting-out on any building site may be described as the determination and establishment of a well-defined system of lines, distances and planes to provide a suitable network for the determination of the accurate position and level of buildings and building elements.

This International Standard is concerned with the complete range of setting-out on building sites and thus adopts a three-stage order of reference systems which are commonly required for large and complex building projects.

As shown in figure 1, the order of establishment and connection of reference systems is as follows:

a) Primary system, which is connected to the official control system[1] and normally covers the whole site and to which subsequent measurements on that site are related (see clause 14);

b) Secondary system, which serves as the main reference system or grid for the erection of a particular building or group of buildings and associated works (see clause 15);

c) Position points, which mark the location of individual elements, for instance columns and walls (see clause 16).

5.2 The choice of the number and type of reference systems required for a particular building project will be dependent on the size, complexity, and configuration of the site, the shape, size and position of each building, the amount of space available, the proposed methods of construction and the erection sequence. In practice, therefore, the previously established reference system from which the secondary setting-out system can be established may be either

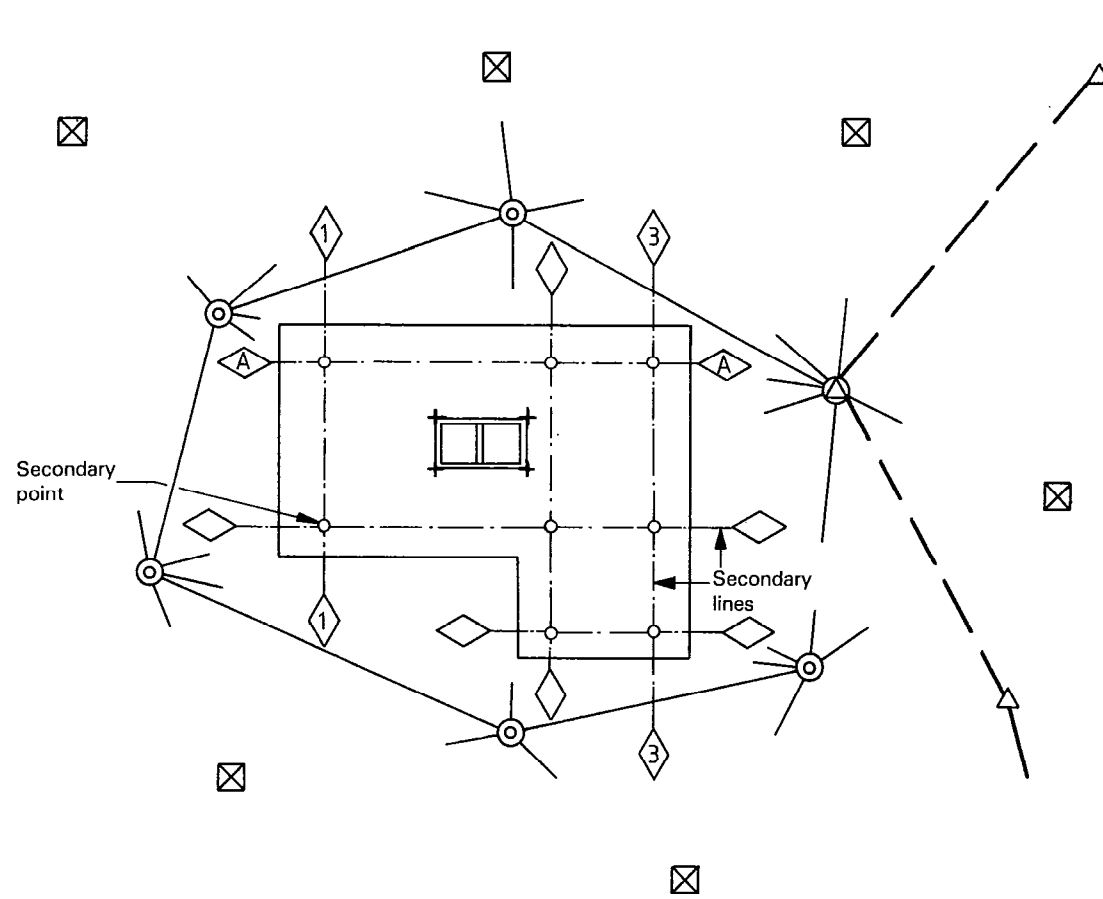
— an existing co-ordinate system which covers the particular site, that is an official control system; or

— a network of measuring points specially established for the building project, that is a primary system; or

— corner points or other important points relating to a particular building established for example by the local authority (see figure 7); or

— in the case of an extension of a building or infilling between existing buildings, reference lines established by extending one or more secondary lines, for example lines parallel to the column centre-lines.

1) An official control system can be the national, municipal or other agreed higher order coordinate system.



Key

Points in the official control system

Stage 1 Points in primary system, marked at ground level

Stage 1 Point in primary system, marked with elevated aiming target

Stage 2 Point and line of secondary system

Stage 3 Position point

NOTE — Some of the primary, secondary and position points are shown. Primary points are marked and measured in. Secondary and position points are set out and marked.

Figure 1 — Example of the three stages of setting-out as adopted in this International Standard

Section two: Planning and organization of setting-out

6 Acquisition of information

Detailed information is required on the size and shape of the site, planning regulations, existing services, adjacent structures above and below ground, and the existing survey network.

Some of this information is often available from the statutory authorities (local authority). A site survey to confirm and update the above information should be carried out. Such information will enable the designer to relate the position of the proposed building and ancillary work to the survey system around the site and also facilitate the contractor's reconnaissance for the setting-out work.

7 Planning the setting-out

7.1 Reconnaissance

A reconnaissance of the site and planning of the setting-out are essential. Based on the site survey drawing relating the building and ancillary work, a suitable reference system should be selected and established.

The system selected will depend on

— the shape and size of the site and the position of any existing buildings or obstructions;

— the position of the proposed building and ancillary work;

— the sequence of excavation and construction.

The chosen reference system should be such that redundant observations are possible and that the measuring points can be referred to during construction.

The positions of the main ground stations should be chosen and protected such that they are at minimum risk to damage or movement and unobstructed lines of sight can be maintained.

Elevated permanent targets on existing buildings could serve this purpose but may be more difficult to use than protected stations on the ground.

Primary and secondary benchmarks should be positioned such that change points are kept to a minimum and sight lengths do not exceed 40 m.

The type of instruments and the method of setting-out should be selected to meet the specified accuracy. This may require calculations. A flow diagram similar to that in ISO 8322 should be used as an aid for such an exercise as well as for the practical accuracy test.

7.2 Grids

Prior to and during the building process, use can be made of the following grids:

— location grids;

— site grids;

— structural grids/system.

7.2.1 Location grids

Location grids (see figure 2) are mostly used for large sites or schemes. Their main function is to assist planning authorities and designers in plotting the location of boundaries, buildings, roads, underground utilities or other features. On plans or drawings, a location grid may be presented either by continuous lines or by the points of intersection of these lines (grid intersections).

7.2.2 Site grids

Site grids (see figure 3) can be considered as the transfer of the location grid from the plan or drawing to the site by setting-out. This can be the grid in its whole or a part of it, with the same spacing or a closer one.

In those cases where the internal accuracy of a previously established site grid falls outside the acceptance criteria for primary or secondary systems (see clauses 14 and 15), further setting-out may be done by using one grid intersection as a reference point and one grid line through it, as a reference direction. Such a procedure is only then allowed if no other acceptance criteria towards other grid intersections are specified or shown to be necessary for the setting-out. Otherwise the site grid — or the particular part of it — has to be resurveyed.

7.2.3 Structural grids (building grids) and secondary grids or systems

Structural grids (see figure 3) are used by designers to define the position of structural elements — usually their centre-lines.

A setting-out grid (see figure 3) is one which will generally be parallel to the structural grid; it is used for the setting-out of position points and for compliance measurements, as the erected elements progressively obscure the structural grid. Such a grid can also be projected up and along the building as the construction proceeds.

Setting-out related to specially laid out grids follows the same procedure as described in this International Standard.

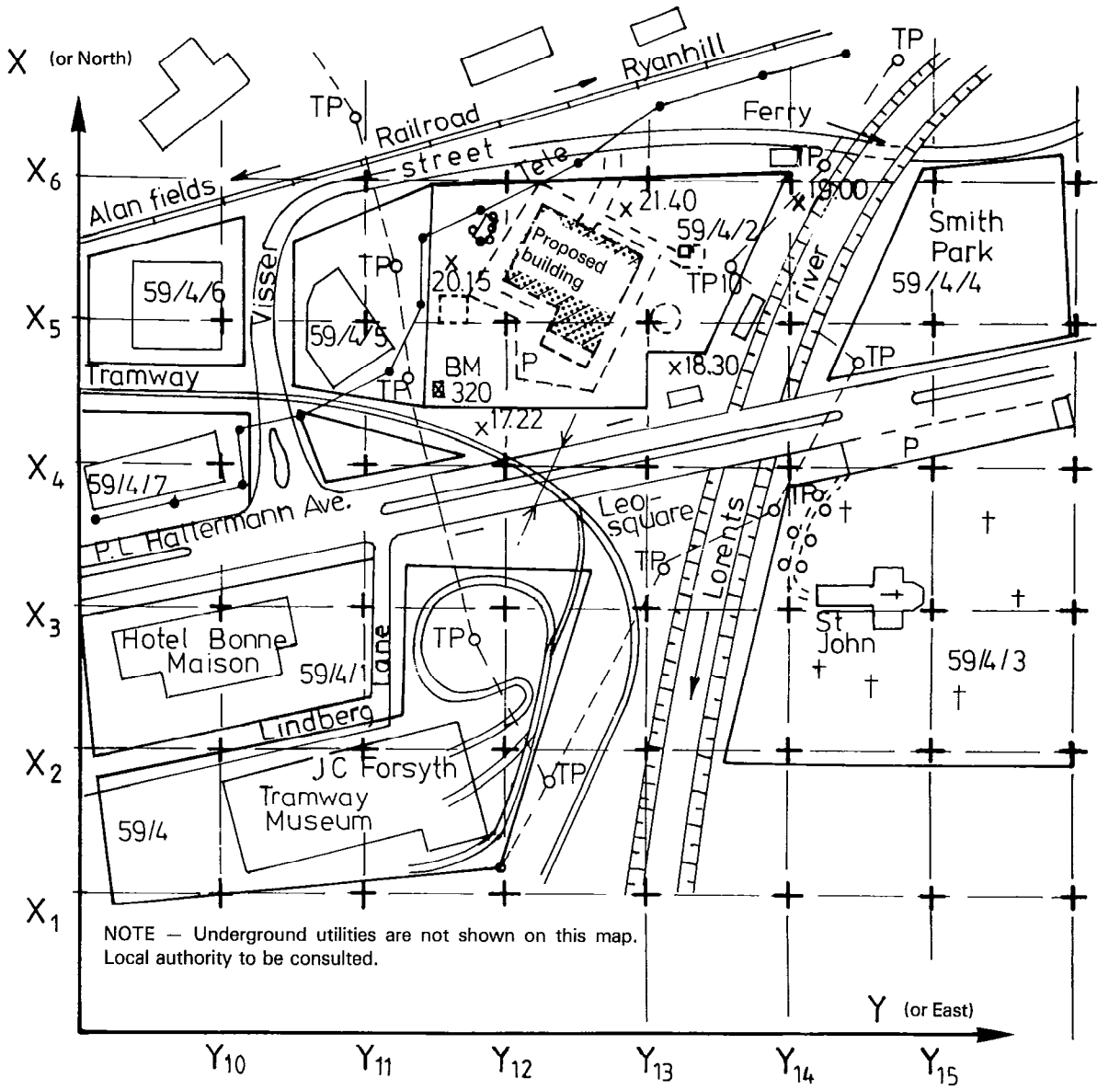


Figure 2 — Example of location grid

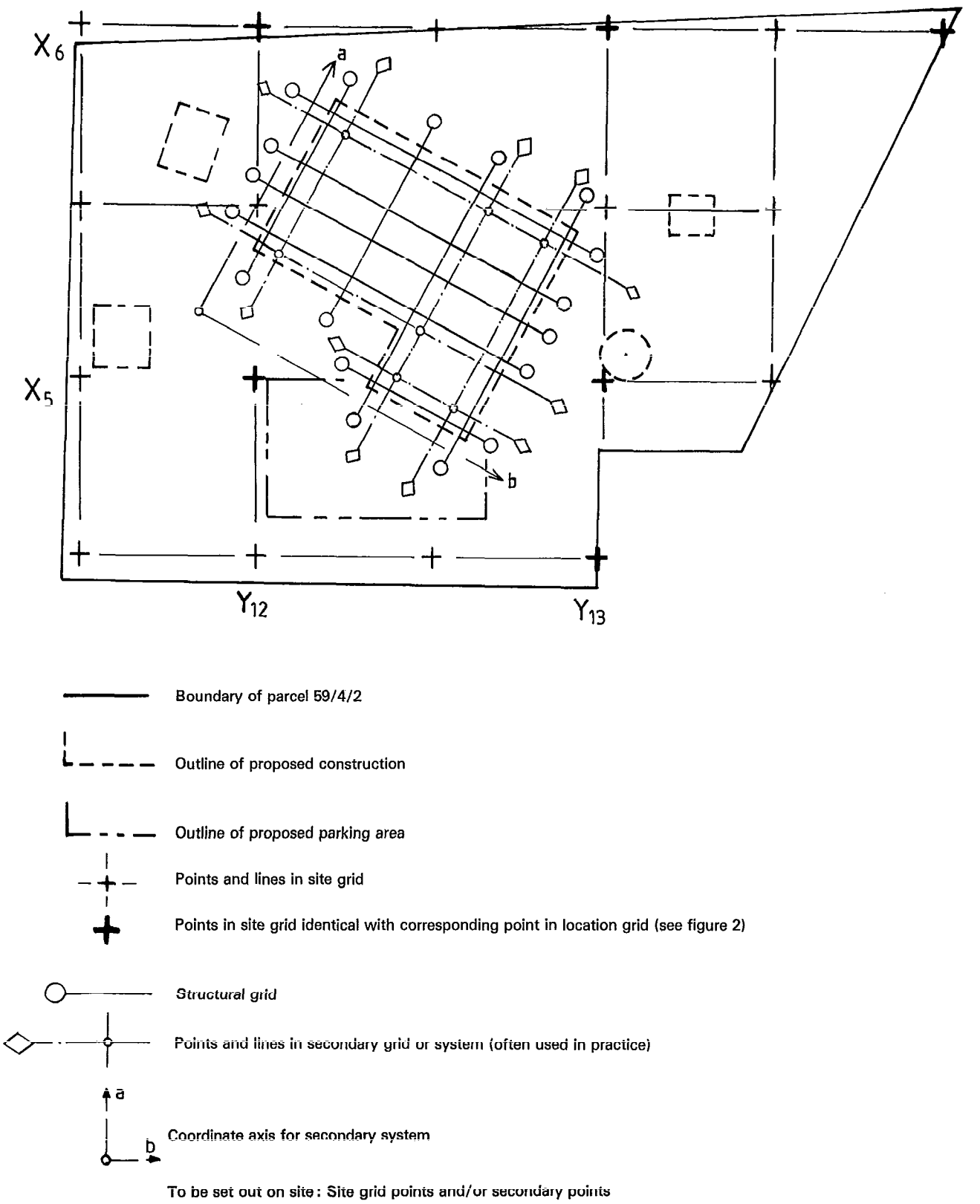


Figure 3 — Relationship between the different grids used during the building process

8 Setting-out drawings

The designer should prepare setting-out drawings showing the location of the buildings and ancillary work, coordinates of setting-out points and lines of sight. These drawings should be maintained on site and be available to the site staff.

Setting-out drawings will be dealt with in ISO 4463-3.

9 Functional responsibilities

The parties who will be responsible for each stage of the setting-out work and for verifying compliance should be clearly stated in the documentation or statutory regulations before construction starts.

The parties can be the local authority, a consulting firm, the client, the contractor or an acceptable combination of these.

Regulations, situations and practices such as defining areas of tasks and responsibilities can vary from country to country and from site to site.

In some countries regulations specify the duties and responsibilities of the statutory authority concerning, for example, the use of the official coordinate system, the measuring of primary systems or the right to carry out check measurements on the site. Other countries allow the carrying out of official tasks by authorized private organizations. Another alternative is that the main contractor will be held responsible for the setting-out done by subcontractors.

The contract documents should also state the name of the party responsible for the maintenance of measuring points during the construction period or parts of it.

Additionally, as a precaution, it is recommended that anyone commissioning works involving setting-out should check this work upon completion according to the rules in this International Standard, before starting any further setting-out or construction work.

A general example of how a work/inspection schedule might be prepared is given in the annex.

10 Qualifications

It is recommended that those entrusted with each stage of the setting-out should be competent in the relevant survey techniques. The establishment of the primary and secondary systems may require particular knowledge of adjustment procedures and their analyses.

Unless specified elsewhere it is recommended that agreements are made on the professional and practical qualifications required for the carrying out of the different stages of the setting-out.

11 Survey and site documentation

The documentation to be maintained on site shall be prepared so that any measurement concerning the setting-out can be reconstructed. Copies of setting-out drawings, field books or computer print-outs should be retained on site. Records of all important data should be kept in a secure place.

The documentation shall contain, in addition to measuring values, date, time, place, observer's name, equipment used, instrument checks carried out, measuring points used and atmospheric conditions.

12 Calculation

All calculations should be such that there are inbuilt checks; calculations of particular importance should be rechecked, if possible with a different procedure. Computer calculation programs should be checked before use by test data.

Before starting any setting-out the information on the setting-out drawings, or other relevant drawings, should be checked for agreement of intermediate and overall dimensions and for the position of boundaries and of existing features on or adjacent to the site.

Section three: Setting-out and measuring procedures — Accuracy specifications

13 Introduction

This section gives a general description of setting-out and measuring procedures which can be applied, including the choice of instruments. Acceptance criteria for these procedures are also recommended.

13.1 General

A copy of the setting-out information and the setting-out drawing, based on the site survey, should be available on the site.

13.2 Instruments

In the following clauses it is assumed that the instruments and their ancillary equipment are in a good state of permanent adjustment and are checked at regular intervals. (In ISO 7976-1, information is given on sources of errors and precautions to be taken.) Investigations about achievable measuring accuracies should be carried out according to ISO 8322.

13.3 Methods

Setting-out should contain a number of redundant observations so that gross errors can be detected and rectified. Where possible, measurements should start and close at measuring points of known position.

13.4 Points

Measuring points should be sharply defined and clearly marked since rough marks lead to errors. The points should be established in such a way that any displacement in their position is prevented as far as possible. Secondary and position points should be checked directly after setting-out.

The identity of the point should be shown alongside the mark. Targets indicating the position of a measuring point should be illuminated when used in poor lighting conditions.

The position of each measuring point should be referenced to at least three other points or local features.

Frequent checking will enable any disturbance to be recognized and corrected.

Profile boards (see figure 5) should be situated outside the confines of proposed excavations and roadworks so as not to suffer damage or movement.

13.5 Acceptance criteria

Acceptance criteria specified below are in terms of internal rather than absolute accuracies. Internal accuracies are more critical to the building process than the absolute accuracy of points in a higher order coordinate system.

The acceptance criteria in this International Standard are given as permitted deviations for distances, angles and levels.

These acceptance criteria are valid for compliance measurements but may also be used for check measurements.

This part of ISO 4463 does not deal with acceptance criteria in terms of standard deviations or mean square errors.

The use of standard deviations or mean square errors should be restricted to those parts of site measurements which relate to higher order surveys on the site. However, the relationship between permitted deviations (PD) and relative mean square errors (S), that is the internal accuracy between points, is

$$PD = 2{,}5 \times S$$

14 Primary system

14.1 Introduction

This clause specifies the procedure for setting out and compliance measurement of primary points, and the acceptance criteria with regard to their internal position.

Primary systems are usually required on, for example,

- large sites;
- long buildings;
- complicated constructions;
- sites with limited access.

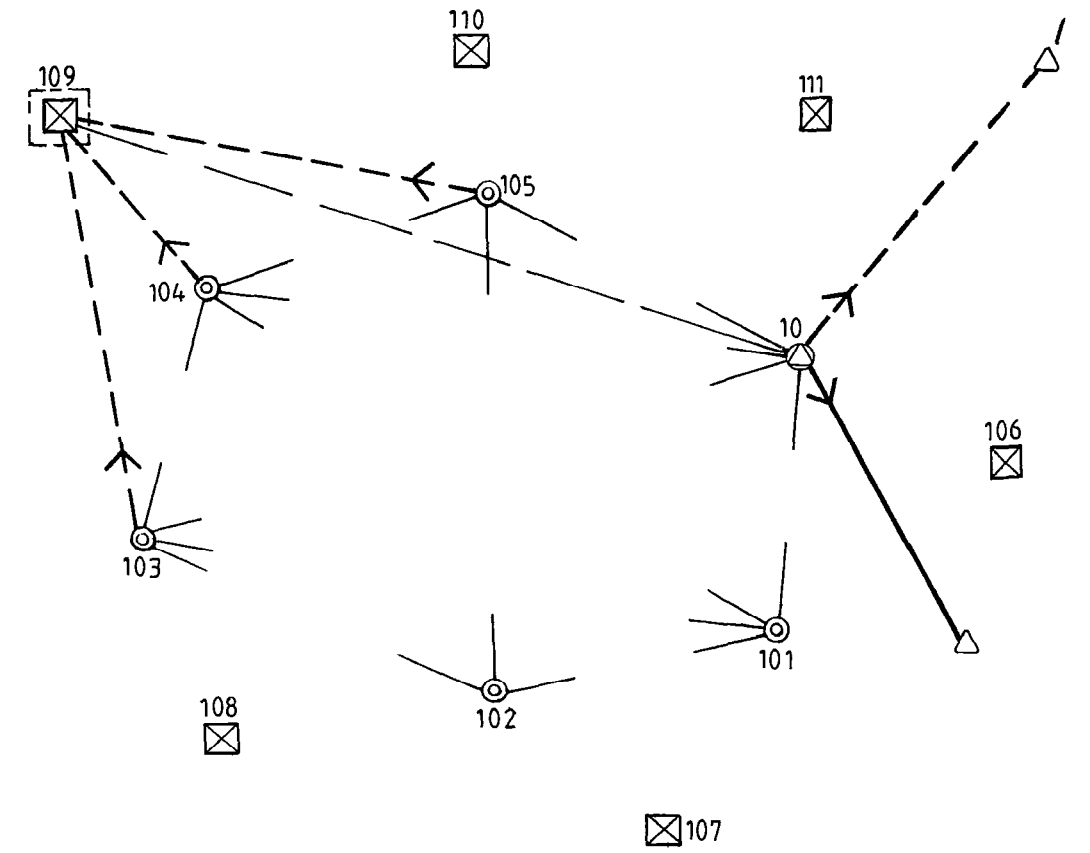
14.2 Reconnaissance

Where the primary system is a network of points it should be measured, calculated and adjusted in its entirety; wherever possible the primary system should form a closed configuration.

Supplementary primary points may later be added, determined by redundant resection, intersection, polar or any similar method. All these points constitute the primary system of the building site (see figure 4). As the accuracy of the primary points is likely to be influenced by inaccuracies in the official system, the connecting of the primary system to the official system by more than one official point and one direction from it is not generally recommended.

Inaccuracies in the official system can occur due to settlement or vandalism after the original survey or because points have been part of measuring series with different grades of accuracy.

Information regarding suitable connecting points in an official coordinate system should be obtained from the appropriate authority.



Points in the official control system (national or municipal) or other agreed system

Connecting point

Connecting direction

Redundant measurement for checking connecting direction

Point in the primary system marked at ground level, with distance and/or direction measurements towards other primary points

Elevated target point in the primary system, for example on a building

Points of the primary system, to be measured and adjusted in its entirety

Supplementary elevated primary point which has been measured-in after the initial measurement and adjustment of the primary system

Primary point at ground level with direction measurement towards supplementary primary point

NOTE — From and towards each point at least one redundant measurement (distance or direction) should be taken. It is preferable to measure all distances, but at least two distances at different locations shall be measured (for example 10-103 and 102-105).

Figure 4 — Example of the general principle of a primary system, with some elevated points shown

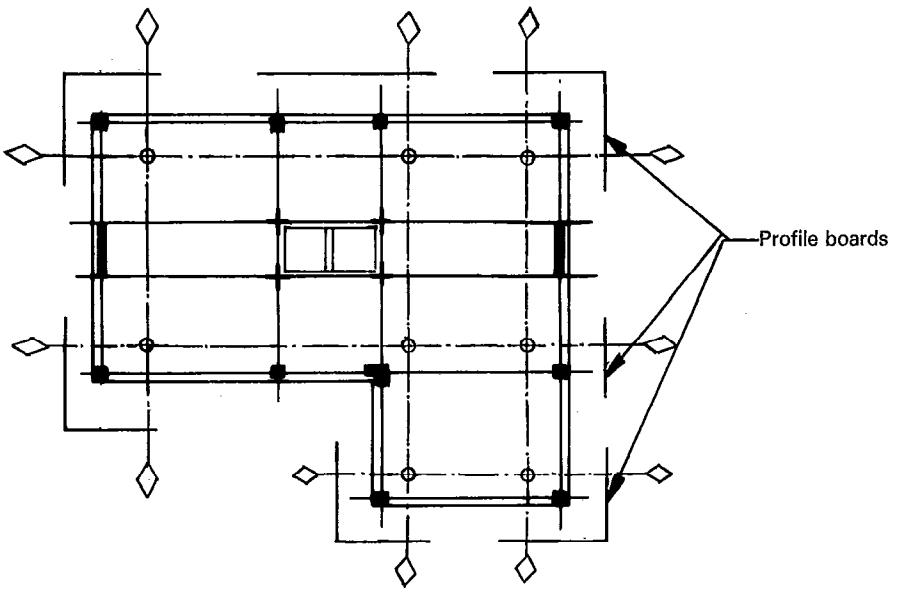


Figure 5 — Example of how profile boards might be placed outside a proposed building

14.3 Marking

Primary points should be established in good time before determining their position to allow for settlement. Whenever possible, primary points should be placed outside the actual working zone on the site.

Where possible a sufficient number of elevated primary points around the site should be established in order to avoid obstructed back sights during the construction (see also 13.4).

14.4 Measuring-in of the primary system

Where the primary system forms a network it has to be observed by measuring sufficient distances and angles to have a redundant number of observations and then be adjusted by the method of least squares. In this way all aspects of quality control are fulfilled.

14.4.1 Distance measurement

There are two alternatives:

a) Using an EDM

Distances to be measured by EDM between primary points should normally be greater than 30 m and measured from each end. The systematic errors of the instrument should be taken into consideration. The instrument should be checked regularly according to ISO 8322-8 or ISO 8322-9 (see also 13.2).

b) Using a steel tape

All distances should be measured at least twice. The values measured should be corrected for temperature, sag, slope and tension. A tension device shall be used with the tape.

Distances to be measured should not be greater than twice the length of the measuring tape to be used. The characteristics of the tape, for example concerning graduation accuracy and reference temperature, need to be known. If possible, measuring tapes conforming to the OIML recommendations or national standards shall be used (see also 13.2).

14.4.2 Angular measurement

Angles should be measured with a theodolite reading directly to 1 mgon (10") or better. The measurements should be made in at least two sets. Each set is formed by two observations, one on each face of the instrument. When targets are not fixed as permanent marks they should be mounted on tripods and constrained centring should be applied. Targets shall be well defined (see also 13.2).

14.5 Acceptance criteria for the position of primary points

The primary system should be subjected to two stages of acceptance, namely:

— Stage one, comparing the measured distances and angles with those derived from the adjusted coordinates; and/or

— Stage two, comparing distances and angles derived from given coordinates with those determined by compliance measurement. This can for example be the case on sites where only a coordinate register is available.

14.5.1 Stage one

The relationship between the measured distances and angles and those derived from the adjusted coordinates is examined. The differences shall not exceed the following permitted deviations:

For distances: $\pm 0{,}75\sqrt{L}$
with a minimum of 4 mm

For angles:

in degrees: $\pm \frac{0,045}{\sqrt{L}} \left(\text{or} \pm \frac{2' 42''}{\sqrt{L}} \right)$

in gon: $\pm \frac{0,05}{\sqrt{L}}$

or as offset: $\pm 0,75\sqrt{L}$ mm

where L is the distance in metres between the primary points concerned; in the case of angles, the shorter of the two distances defining the angle.

14.5.2 Stage two

The relationship between distances and angles derived from given coordinates and subsequently measured distances and angles is examined. The differences shall not exceed the following permitted deviations:

For distances: $\pm 1,5\sqrt{L}$
with a minimum of 8 mm

For angles:

in degrees: $\pm \frac{0,09}{\sqrt{L}} \left(\text{or} \pm \frac{5' 24''}{\sqrt{L}} \right)$

in gon: $\pm \frac{0,1}{\sqrt{L}}$

or as offset: $\pm 1,5\sqrt{L}$ mm

where L is the distance in metres between the primary points concerned; in the case of angles, the shorter of the two distances defining the angle.

For compliance measurements of the primary points, 14.4 applies but a different operator with different equipment of the same accuracy class should be used.

In the case of supplementary primary points which according to 14.2 have been determined by redundant observations (for example point 109 in figure 4), two or more pairs of coordinates will be obtained. Then the mean value of the coordinates should be chosen, provided that the maximum differences between the coordinates fulfil the above recommended criteria.

14.6 Consequences of non-compliance

Before rejecting the primary net, the integrity of all points should be checked. All suspect items (distances and angles) should be re-measured. If compliance has still not been achieved, refer back to the surveyor who carried out the primary scheme.

15 Secondary system

15.1 Introduction

This clause specifies the procedure for setting out and compliance measurement of secondary points, and the acceptance criteria with regard to the internal position of points in the secondary system and between primary points (according to clause 14) and secondary points (see also clause 5).

In this case the coordinates of the primary system are accepted as true and their inaccuracies need not be taken into consideration.

15.2 Application

Secondary points are used for setting-out position points indicating the details of one or more buildings.

The setting-out of secondary points is done by using either

— the primary system as shown in figure 6; or

— previously set-out secondary points (as shown in figure 7).

Previously set-out secondary points should be checked, according to clause 15, prior to any further setting-out.

All the secondary points taken together form the secondary system of the site. Lines through secondary points are called secondary lines.

15.3 Marking

See 13.4 and figure 5.

15.4 Setting-out of secondary points

The setting-out of secondary points should be carried out with redundant measurements and in such a way as to allow for cross-checking.

15.4.1 Distance measurement

There are two alternatives:

a) Using an EDM

Distances to be measured by EDM between primary points and secondary points and between secondary points should normally be greater than 30 m and preferably be measured from each end. However, where it can be demonstrated that a particular instrument has a high accuracy at shorter distances, lengths less than 30 m are acceptable. The systematic errors of the instrument should be taken into consideration. The instrument should be checked regularly according to ISO 8322-8 or ISO 8322-9 (see also 13.2).

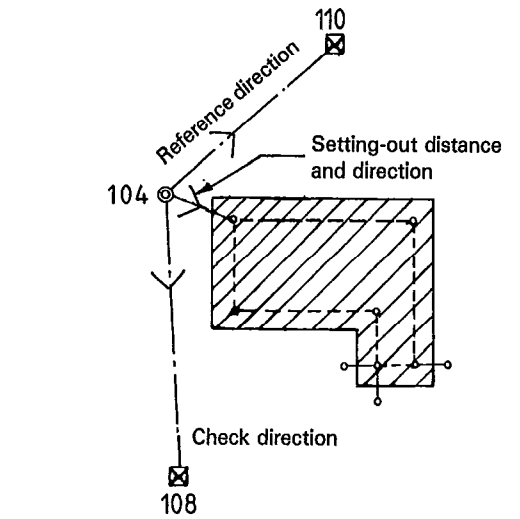
b) Using a tape

All distances should be measured at least twice, preferably in opposite directions. The values measured should be corrected for temperature, sag, slope and tension. A tension device shall be used with the tape.

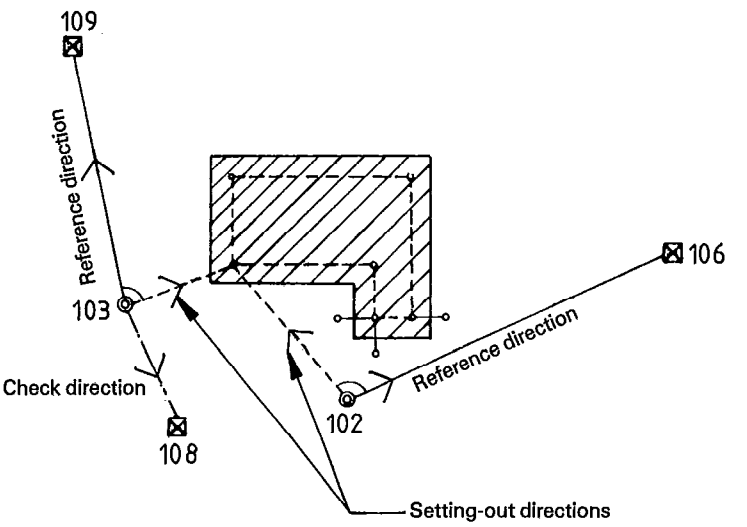
Distances to be measured should not be greater than twice the length of the measuring tape to be used. The characteristics of the tape, for example concerning graduation accuracy and reference temperature, need to be known. If possible, measuring tapes conforming to OIML recommendations or national standards should be used (see also 13.2).

15.4.2 Angular measurement

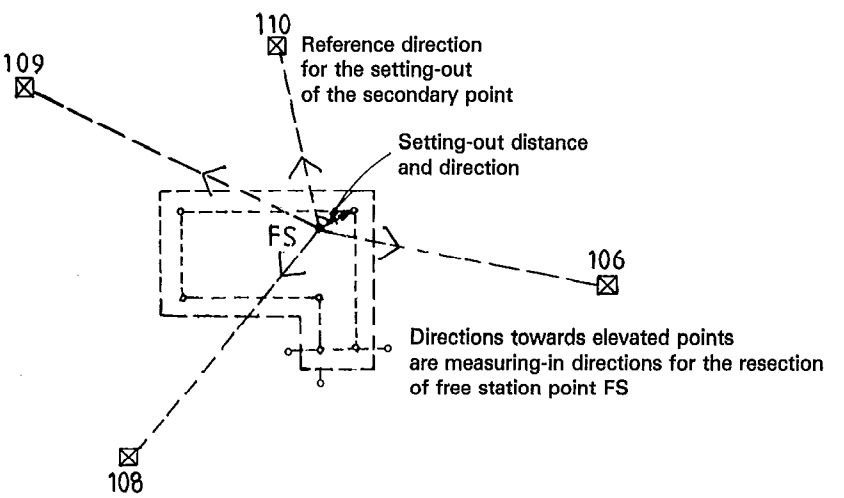
Angles should be measured and set-out with a theodolite reading directly to 10 mgon (1') or better. The measurements shall be made in at least one set. A set is formed by two observations, one on each face of the instrument.



a) **Polar method**



b) **Intersection method**



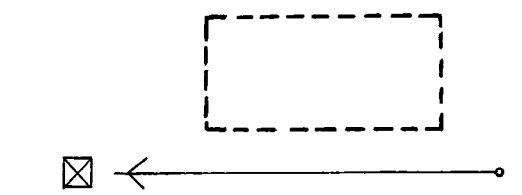
c) **Free station method**

⊠ Elevated target point in primary system

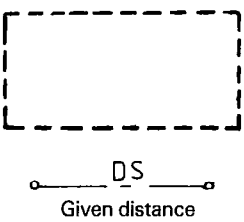
—o— Secondary point

NOTE — The elevated targets facilitate use of the method throughout the whole construction period. See also figure 4.

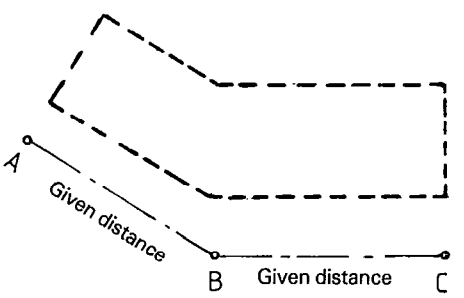
Figure 6 — Some examples of the setting-out of secondary points within the building using the primary system



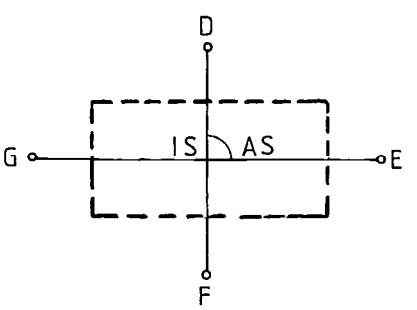
Given	Check
One reference point, one reference direction	Not possible



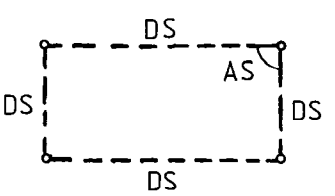
Given	Check
Two reference points	Given distance DS



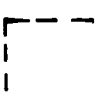
Given	Check
Three reference points	Distances AB and BC, and angle ABC



Given	Check
Four reference points	Determine point of intersection IS, angle AS and, where relevant, distances D-E-F-G-D



Given	Check
Four reference points, for example on the outlines of the proposed building	Distances (DS) and angles (AS) and diagonals



Outline of proposed building

Figure 7 — Previously set-out secondary points should be checked according to 15.5 prior to further setting-out

15.5 Acceptance criteria for the position of secondary points

Secondary points should be subjected to two stages of acceptance, namely:

— stage one, in relation to key primary points; and

— stage two, in relation to other secondary points controlling the same building or the same section of the building.

15.5.1 Stage one

15.5.1.1 Distances

The difference between a given or calculated distance and a compliance distance shall not exceed the following permitted deviations:

Distances up to 7 m: ± 4 mm

Distances greater than 7 m: $\pm 1{,}5\sqrt{L}$ mm

where L is the distance in metres.

15.5.1.2 Angles

The difference between a given or calculated angle and a compliance angle shall not exceed the following permitted deviations:

in degrees: $\pm \frac{0{,}09}{\sqrt{L}} \left(\text{or} \pm \frac{5' 24''}{\sqrt{L}} \right)$

in gon: $\pm \frac{0{,}1}{\sqrt{L}}$

or as offset: $\pm 1{,}5\sqrt{L}$ mm

where L is the length in metres of the shorter side of the angle.

15.5.2 Stage two

Distances and angles shall both be as for stage one.

For compliance measurements of the secondary points or lines 15.4 applies, but a different operator with different equipment of the same accuracy class should be used.

15.6 Consequences of non-compliance

Before rejecting the secondary net, the integrity of all points should be checked. All suspect items (distances and angles) should be remeasured. If there is still non-compliance, the site surveyor who carried out the secondary scheme should be consulted.

16 Position points

16.1 Introduction

This clause specifies the procedure for setting out and compliance measurement of position points, and the acceptance criteria with regard to the internal position of position points and between secondary points and position points.

In this case the coordinates of the primary and secondary systems (see clause 5) are accepted as true and their inaccuracies need not be taken into consideration.

16.2 Application

Position points give the location of the details of the building. Position points can be set out either from the secondary system or directly from the primary system.

If the position points are set out directly from the primary system, some secondary points should be established for future setting-out or compliance measurements inside the building. This is advisable since erection of building elements is likely to obscure the lines of sight to the primary system.

16.3 Marking

The most suitable way (where, when and how) of marking the position points or lines should be agreed between those involved in their use (see figure 8). The setting-out of position points or lines should contain a sufficient number of observations to allow cross-checking and they should be marked so that their positions in relation to other setting-out points or lines can be checked (see also 13.4).

16.4 Setting-out of position points

The setting-out of position points should be carried out in such a way as to allow for cross-checking. The acceptance criteria for the setting-out of position points depend on the type of work, of which some examples are given in table 1. Setting-out for values of $K_1 = 5$ or less should be carried out according to this clause.

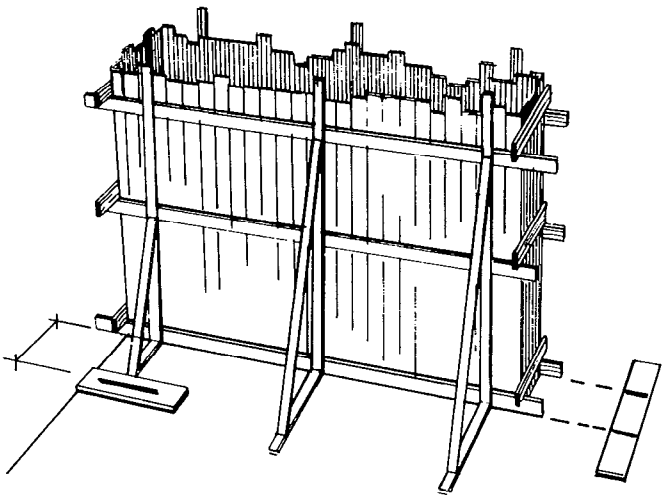
Setting-out of ancillary construction, for example external works, roads and drainage, is also possible, although part of the position point setting-out may be established using any of the previously located reference systems.

16.4.1 Distance measurement

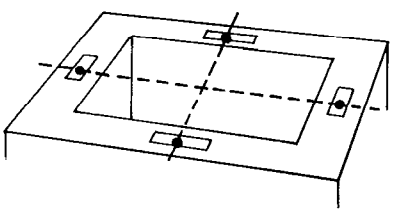
There are two alternatives:

a) Using an EDM

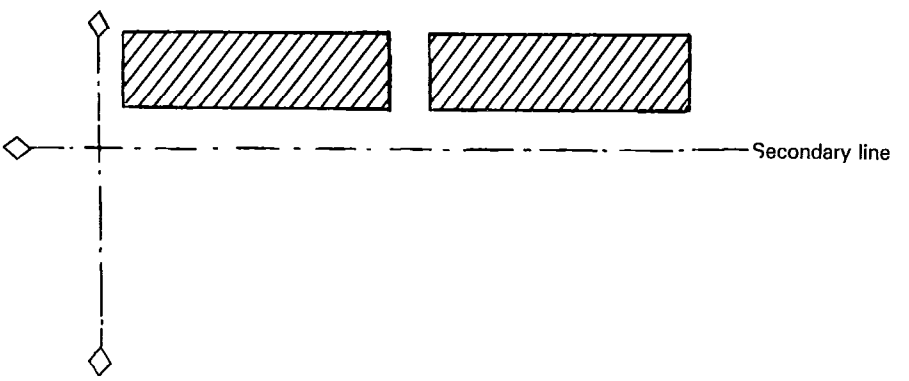
When measuring with an EDM instrument at least two pointings should be made and the distances should normally be greater than 30 m. However, where it can be demonstrated that a particular instrument has a high accuracy at shorter distances, lengths less than 30 m are acceptable. The systematic errors of the instrument should be taken into consideration. The instrument should be checked regularly according to ISO 8322-8 or ISO 8322-9 (see also 13.2).



a) Marks for shuttering



b) Marking centre-lines on pockets for columns



c) Marks for components

NOTE — The most suitable way of marking position points or lines should be agreed between those involved in their use.

Figure 8 — General examples of marking position points or lines

b) Using a tape

All distances should be measured at least twice, preferably in opposite directions. The characteristics of the tape, for example concerning graduation accuracy and reference temperature, should be known. If possible, measuring tapes conforming to OIML recommendations or national standards should be used (see also 13.2).

When measuring distances greater than 10 m, corrections should be applied; see 15.4.1.

However, where relevant, correction for slope should be applied also on distances less than 10 m. Distances to be measured should not be greater than twice the length of the measuring tape to be used and preferably not greater than 20 m.

16.4.2 Angles

Angles should be measured and set out with a theodolite reading to 10 mgon (1') or better.

16.5 Acceptance criteria for the position of position points

Position points should be subjected to two stages of acceptance, namely:

— stage one, in relation to a secondary point (or where relevant primary point); and

— stage two, in relation to other position points in the same section of the building.

16.5.1 Stage one

The difference between a calculated distance or a distance specified on the drawing and a compliance distance shall not exceed the following permitted deviations:

Distances up to 4 m: $\pm 2K_1$ mm

Distances greater than 4 m: $\pm K_1\sqrt{L}$ mm

where

L is the distance, in metres;

K_1 is a constant according to table 1.

16.5.2 Stage two

The difference between a distance specified on the drawing and a compliance distance should not exceed the permitted deviations for stage one.

Table 1

Example of application on site	K_1
Earthwork without any particular accuracy requirements, for example excavations, slopes	10
Earth work subject to normal accuracy requirements, for example road works, pipe trenches	5
In situ cast concrete structures, precast concrete structures, steel structures	1,5

For compliance measurements of the position points or lines 16.4 applies, but a different operator with different equipment of the same accuracy class should be used.

Where a particular design requirement demands tighter accuracy than stated above, the element, space or location should be identified, indicating the accuracy required, in the specifications.

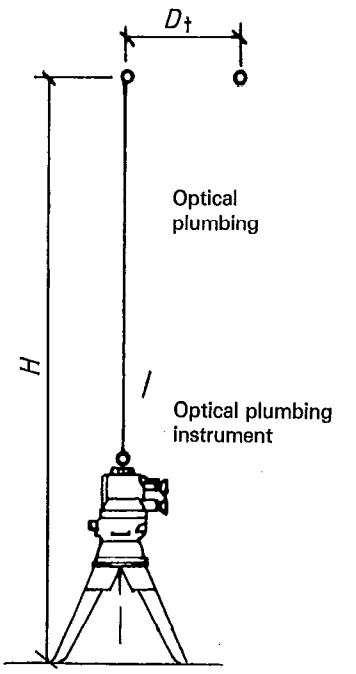
16.6 Consequences of non-compliance

Before rejecting the position points or lines, the integrity of all points should be checked. All suspect items (distances and angles) should be remeasured. If there is still non-compliance, the site surveyor who carried out the detail scheme should be consulted.

17 Vertical transfer of points (plumbing)

17.1 Introduction

This clause specifies the procedure for the vertical transfer of secondary points, and the acceptance criteria with regard to the position of secondary points transferred to other levels.

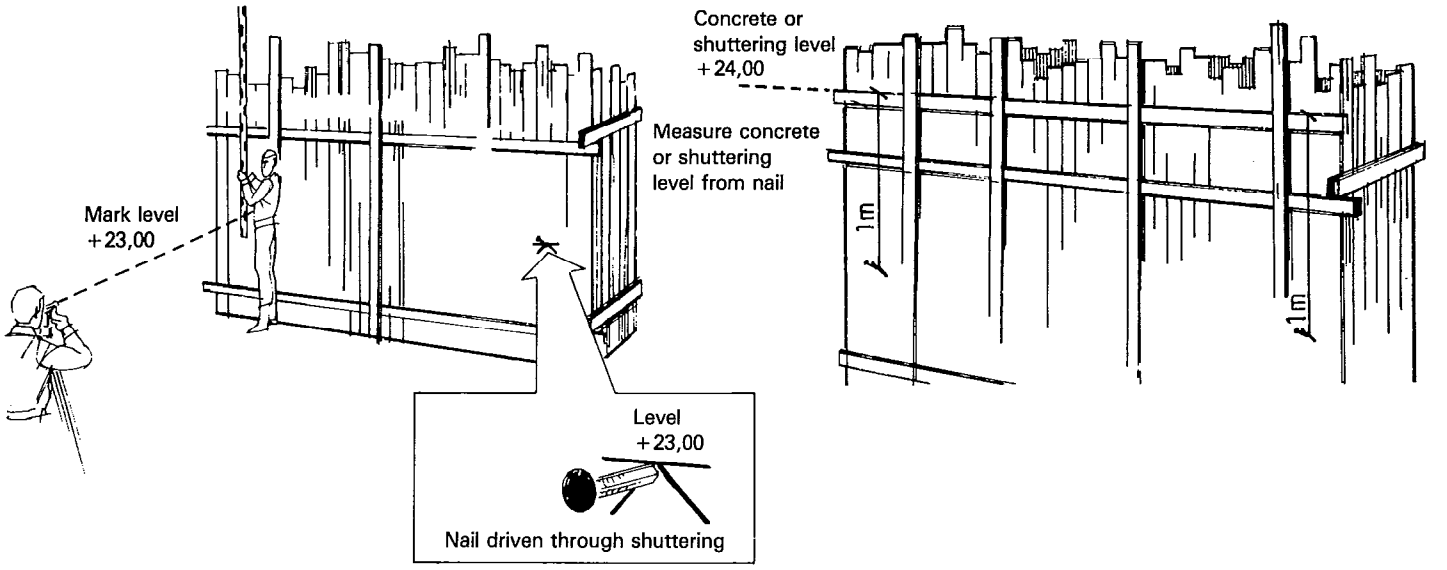


NOTE — Position deviation D_t is the distance between the vertically transferred point (plumbing) and its compliance point. H is the height of transfer (plumbing height).

Figure 9 — Verticality deviation

17.2 Reconnaissance

It is necessary to ensure that the required transfer process can be carried out. Where the transfer process is to be carried out from outside the building, sufficient space and clear lines of sight should be available. Where the transfer process is to be carried out within the building, provision for unobstructed plumbing holes should be made.



NOTE — The most suitable way of marking levels of position points or lines should be agreed on between those involved in their use.

Figure 10 — Examples of marking levels on shuttering

In determining levels with a measuring tape, the characteristics concerning graduation accuracy and reference temperature shall be known. If possible, measuring tapes conforming to OIML or national standards should be used. The values measured shall be corrected for temperature and tension. A tension device should be used with the tape (see figure 11).

Levelling up and down stairs is not generally recommended since it may cause gross errors.

Levelling for primary and secondary benchmarks should always start and close at different benchmarks.

As settlements can be expected during construction secondary benchmarks within each structure should be established to serve as a reference for that particular structure.

18.5 Acceptance criteria for the levels of benchmarks and position points

The difference between a given or calculated level and a compliance level should not exceed the permitted deviations given in table 2.

For compliance measurements of benchmarks and position points 18.4 applies, but a different operator with different equipment of the same accuracy class should be used.

Where a particular design requirement demands tighter accuracy than stated above, the element, space or location should be identified, indicating the accuracy required, in the specifications.

Table 2

Measurement	Permitted deviation mm
between an official bench mark and a primary benchmark	± 5
between any two primary benchmarks	± 5
between a primary and a secondary benchmark	± 5
between two adjacent secondary benchmarks —	
for differences in level up to 4 m	± 3
for differences in level larger than 4 m, where H is the vertical distance in metres	$\pm 1{,}5\sqrt{H}$
between a secondary benchmark and a level of a position point the level of which has been set out from that secondary benchmark, where K_2 is a constant according to table 3	$\pm K_2$
between two position points the level of which has been set out from the same secondary benchmark, where K_2 is a constant according to table 3	$\pm K_2$

Table 3

Example of application on site	K_2
Earthwork without any particular accuracy requirements, for example excavations and slopes	30
Earthwork subject to normal accuracy requirements, for example road works, pipe trenches	10
In situ cast concrete structures, precast concrete structures, steel structures	3

17.3 Measuring methods

The transfer of points is done either

— directly with an optical plumbing instrument or a theodolite pointing in the vertical direction, or using the vertical plane described when the telescope of the theodolite is rotated around the trunnion axis; or

— indirectly with the aid of intersection, method of free station points or similar method. Such methods usually require that points are determined in coordinate form.

17.4 Marking

See 13.4.

17.5 Plumbing

Plumbing shall be carried out either with an optical plumbing instrument or a theodolite and, if possible, from the same initial secondary point, for example the one on the ground floor.

Using previously transferred points as a reference should whenever possible be avoided.

When plumbing with a theodolite which is set up away from the point to be transferred, it is necessary to take observations on both faces of the instrument and to use the mean result.

When an optical plumbing instrument or a theodolite with the telescope pointing vertically is used, at least four observations shall be made at 100 gon (90°) to each other on the horizontal circle.

The practical working range of the optical plumbing instrument or theodolite used should allow for millimetre readings.

In the case of indirect transfer theodolites, readings to 10 mgon (1') or better should be used (see also 15.4.2 and 16.4.2).

17.6 Acceptance criteria for the position of transferred points

The permitted deviation of a transferred point is:

for heights up to 4 m: $D_t = \pm 3$ mm

for heights greater than 4 m: $D_t = \pm 1{,}5\sqrt{H}$ mm

where H is the vertical distance in metres between the initial main point and the transferred point.

When more than one point has been transferred, the relationship between the transferred points should comply with the acceptance criteria for position of secondary points (see 15.5).

For compliance measurements of transferred points, 17.5 applies, but a different operator with different equipment of the same accuracy class should be used.

17.7 Consequences of non-compliance

Before rejecting the transferred points, the integrity of all points should be checked. All suspect items should be remeasured. If there is still non-compliance, the site surveyor who carried out the transfer of the points should be consulted.

18 Levelling

18.1 Introduction

This clause specifies the procedure and the acceptance criteria with regard to the relationship of the levels of benchmarks and position (datum) points.

18.2 Reconnaissance

On a building site several types of benchmarks are used:

— Official master benchmarks, of which the level has been established by an official survey: these may be used as primary benchmarks provided their relative accuracy fulfils the requirements specified in 18.5.

— Primary benchmarks of which the levels are obtained from the national, municipal or other agreed levelling system and which may be adjusted locally are reference levels for secondary benchmarks.

— Secondary benchmarks are used for the setting-out of levels of position points unless these levels are set out directly from a primary benchmark.

Information regarding suitable official benchmarks for use as the reference level in the setting-out system should be obtained from the appropriate authority.

Primary benchmarks should be levelled with instruments fitted with a parallel plate micrometer and invar staves should be used. Distances between instrument and staff should normally be at least 25 m but not exceed 40 m.

There should be sufficient benchmarks so that distances between benchmarks and position (datum) points to be served from a particular benchmark shall not exceed 80 m.

18.3 Marking

The most suitable way (where, when and how) of marking benchmarks and position (datum) points or lines should be agreed between those involved in their use (see figure 10). The levelling of these points (datums) or lines should contain a sufficient number of observations to allow cross-checking and they should be marked so that their levels in relation to other bench marks or position (datum) points can be checked (see also 13.4).

18.4 Levelling

The levelling instrument used and the method applied shall be of such accuracy that the acceptance criteria specified in 18.5 can be fulfilled. Unless information about this is available, accuracy tests should be carried out according to the procedures recommended in ISO 8322-3.

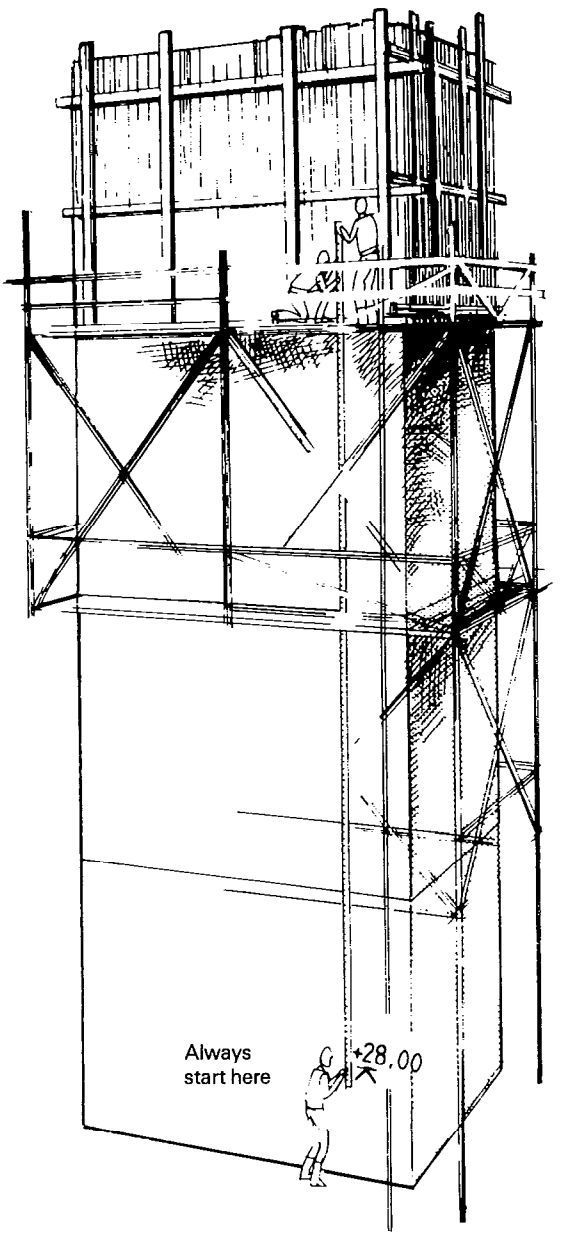


Figure 11 — Use of a tension device when transferring levels with the aid of a tape

18.6 Consequences of non-compliance

Before rejecting the levels of benchmarks and position points, the integrity of all points should be checked. All suspect items should be remeasured. If there is still non-compliance, the site surveyor who carried out the levelling should be consulted.

Bibliography

Measuring practice on the building site, CIB Report No. 69. Published as document M83 : 16, National Swedish Institute for Building Research.

Material measures of lengths for general use, OIML (International Organization of Legal Metrology), Recommendation 35, 1984.

Annex

Example of a working/inspection schedule of setting-out showing tasks and responsibilities

(This annex does not form part of the Standard.)

Measuring activity	Carried out by (= C) or Responsible for (= R)	Compliance carried out by	Time of check	In case of rejection
Primary net, stage 1	Specialist survey organization (C + R) measuring calculation adjustment	Same specialist survey organization and client stage 1 (according to 14.5.1)	Directly after adjustment	Resurvey of the net or a part of it
Primary net, stage 2	Specialist survey organization (C + R)	Contractor stage 2 (according to 14.5.2)	Before any further setting-out	Resurvey of the net or a part of it (for calculation check)
Secondary net	Consulting firm (C + R) setting-out	Contractor (according to 15.5)	Before the setting-out of position-points	New setting-out
Position points	Subcontractor (C) Contractor (R)	Contractor (according to 16.5)	Before form-work or erection	New setting-out

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