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Guide to

Accuracy in building

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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 (Property Services Agency)
- Department of the Environment (Building Research Establishment)
- 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 bodies were also represented in the drafting of the standard, through subcommittees and panels:

- British Constructional Steelwork Association Ltd.
- Chartered Institute of Building

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Foreword

This British Standard, having been prepared under the direction of the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Committee, is a revision of BS 5606:1978 which is withdrawn.

Difficulty has been experienced in the application of the original 1978 code, entitled “Code of practice for accuracy in building”. Accordingly this revision of BS 5606 has been retitled, rewritten and reorganized.

Users are advised that the contents of this standard are not intended to be invoked in the form: “All tolerances to conform to BS 5606”.

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 48, 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.

0 Introduction

0.1 General

In any building or manufacturing process some degree of dimensional variability is inevitable. Disregarding errors, it has been shown (see Appendix C) that dimensional variability occurs even when properly trained operatives using the correct tools, procedures and materials make a genuine attempt to achieve the specified size. This variability arises because of the physical limitations of the operative and inherent variability of the tools, measuring equipment and materials used. The magnitude of this variability varies from process to process and is characteristic of the process. This guide deals with this variability induced by the building process.

Most buildings include some factory made components. Indeed some buildings use virtually no traditional materials and skills at all, comprising as they do steel frames with proprietary roofs, cladding, internal partitions and sophisticated mechanical and electrical services. In these circumstances consideration has to be given as to how the factory made components, each with its characteristic variability, will fit together with those elements constructed on the site.

0.2 Historical aspects

Early in this century buildings were much simpler than they are today and were constructed by traditional methods, using relatively few and traditionally well understood materials, by operatives using well developed and established skills. In these circumstances the bricklayer could adjust the brickwork to the sizes required, the carpenter was able to make the traditional roof fit the brickwork, the joiner could make the windows fit the holes left by the bricklayer, and the plasterer could overcome any irregularities in walls and ceilings.

In the post war years widespread use of in situ reinforced concrete frames clad with precast concrete units or proprietary cladding systems gave rise to many acute problems of fit. These problems, which caused delays to contracts and increased costs, resulted in a request for BSI to prepare guidance on this subject. This resulted in the publication in 1969 of PD 6440 "Accuracy in building" (now withdrawn).

A weakness of PD 6440 was that it was based on estimated values of accuracy rather than actual measured data. To overcome this weakness a survey of the variability of building processes was carried out by The Building Research Establishment (BRE) which was the basis for BS 5606:1978 Code of practice for accuracy in building.

0.3 Buildings Research Establishment survey

Previous guidance by BSI on the subject of accuracy in building was hampered by the absence of data on the variability of the various building processes. To overcome this problem BSI and the Department of Environment commissioned a survey of dimensional variability on projects where tolerances had been specified. The results of the survey were analysed by the Building Research Establishment and are included in Table 4. Additional dimensional data for manufactured components have been obtained more recently and are included in Table 5. The original survey did not cover all building processes and data collection is continuing. The survey established the important concept of characteristic accuracy (see C.3) from which the values of deviation ranges (Table 1 and Table 2) are derived.

0.4 Objective of the guide

The objective of this guide is to provide advice on ways to avoid problems of inaccuracy or fit arising on site. The need for such advice on any particular project will vary, depending on the character of the project and the materials and methods of construction. This guide is designed to be relevant to all building types including the most sophisticated ones. Those concerned with an individual project will judge the extent to which each section of this guide is relevant to their particular needs.

This guide is particularly applicable wherever components, made off site, are to be assembled on site with site constructed work, or where statutory maximum or minimum sizes are required.

Section 1. General

1 Scope

This British Standard guide explains and gives examples of principles that relate to accuracy in building construction.

It is intended to be applied to building rather than civil engineering works and aims to assist in the following:

- a) avoiding or resolving problems of inaccuracy or fit by assessing the dimensional needs of a design regarding tolerances, and then designing and specifying appropriately;
- b) assessing the likely achievement of tolerances specified for a particular project, and giving guidance on their realization;
- c) monitoring and controlling work during construction to ensure that it complies with specified accuracy.

Appendices give information relating to site surveys, examples of the calculation of tolerances, characteristic accuracy values, and data from the BRE survey (see the introduction).

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this guide the definitions given in BS 6100-1.5.1 apply together with the following:

2.1

characteristic accuracy

accuracy, expressed in terms of systematic deviation or standard deviation or both, found by measurement of a representative sample and assumed to be characteristic of the whole¹⁾

NOTE See also Appendix C.

2.2

induced deviation

inevitable departure from target size due to the building process

2.3

inherent deviation

inevitable departure from target size due to the physical properties of building materials and soils (see 8.4)

2.4

reference size

size specified in the design to which deviations are related

2.5

target size

reference size from which deviations would ideally be zero

2.6

tolerance

permissible variation of the specified value of a quantity

¹⁾ Taken from BS 6100-1.5.1.

Section 2. Problems of inaccuracy or fit associated with elements and components of construction

3 General

If the variability of all construction operations, whether carried out on site or in the factory, is recognized at the design stage, problems of inaccuracy or fit can be minimized and delays and expensive remedial measures can be avoided.

The primary aim should be to remove as many constraints on fit as possible and provide for adjustability of fixing so that fine adjustment of position can be made on site.

An example of these principles can be seen in the development of kitchen furniture. Early furniture for fitted kitchens was made in the traditional way with the doors set into the carcass using traditional simple hinges. This approach gave rise to problems on site with fit and alignment of doors. To overcome these problems the constraints on fit of doors have been removed by mounting them on the face of the carcass and adjustability of position has been achieved by the development of special hinges.

The examples given in clauses 4 and 5 illustrate some of the more common of these problems.

4 Examples of typical problems

4.1 Concrete floors

In deriving the levels for a structural floor it should be remembered that the specified minimum thickness of in situ flooring will be applied over the highest point of the structural floor. See Figure 1.

As types of flooring of differing thicknesses may occur in adjacent areas of the same floor, the finished floor level is normally taken as the datum.

The thickness specified should allow for deviations from the designed structural level, for deflection and for the effect of dead load on camber as well as for conduits, ducts, cross-overs and junction boxes.

The flatness of integral surface finishes depends on the method of construction.

Recommended tolerances in the surface finish of in situ floorings are given in BS 8204-1 for surfaces to receive a covering, and in BS 8204-2 for concrete wearing surfaces.

4.2 Roof deckings

The design of a roof should allow not only for manufacturing deviations in the decking but also for deviations in the overall sizes and shape of the roof, in positions of supports and in the sizes and positions of roof lights, etc. The designed fall should be calculated to allow for deviations in the level of the supporting members and deflection of the deck.

4.3 Stairs

Where the thicknesses of the finish to a stair and adjoining floors will differ, allowance should be made in the structural design of floors and staircases.

Problems of fit may arise if consideration is not given to the tolerances in the storey height, in the dimensions of the stair flight and in the stair well to receive the stair flight (see BS 5395).

4.4 Lift wells

The specification of lift well sizes should receive special consideration so that accurate construction may be achieved: see BS 5655-5 and BS 5655-6 in addition to the tolerances given in Table 1. See also Figure 2 for guidance regarding the specification of target sizes for lift wells.

In forming the structural openings in concrete walls to lift wells, allowance for masking or packing should be provided to enable doors to be aligned vertically with each other in elevation, by increasing the width and height of the openings, and by reducing the size by means of packings after the doors have been located correctly.

Since door openings might not line up one above another in section through the shaft, adjustments should be allowed for in the width of linings to jambs to mask inaccuracies.

As the height of the lift well increases, the difficulty in getting door openings to line up one above the other increases also; therefore in lift wells higher than 60 m, the width of structural openings to receive lift doors should be increased by an appropriate amount (see Table 1).

It is important to facilitate the alignment of landing sills; one way of doing this is by providing, at each landing, an independent threshold, the position of which can be adjusted.

4.5 Cladding to external walls

Cladding which presents unbroken vertical planes needs special care. Supporting nibs, brackets, ties and fixings have to allow not only for expected deviations in floor edges and columns at one level alone, but also for expected deviations over the whole building face.

Deviations to be taken into account should include those in transferring reference marks up the building, in transferring reference marks horizontally at any level, in setting out the building face from the reference marks, and in the verticality, alignment and position on plan of floor edges or columns at any level; the total effect should be assessed statistically.

Fixings should be provided with a range of adjustability at least equal to the total range of expected deviation so assessed; consideration should be given to the strength and security of fixings when they are at the limit of their adjustability.

When cladding such as curtain walling forms a continuous plane it is recommended that, in addition to the adjustability described above, fixings should provide an additional "stand off" clearance to safeguard against intrusion of floor edges into the cladding zone between fixings. See CP 143, CP 297 and BS 8298 for further recommendations on cladding.

It is common practice in framed buildings for external walls to be built as brick panels supported on the floors. In some cases in this form of construction the elevation will show as a continuous brick face concealing the frame, and in such cases the walls should oversail the edges of the floors. The use of brick slips to be fixed to and to hide the edges of the floors is deprecated, as inaccuracies of line at the edges and of the position on plan, of successive floors relative to one another are such that consistent satisfactory bearing for the oversailing brickwork is unlikely to be achieved.

4.6 Windows, doors and panelling units

When windows, doorsets or panels are to be fixed into pre-formed openings it is essential that the sizes for openings and components should be determined by consideration of fit. Reference should be made for suitable procedures to Appendix B and to Parts 1, 2 and 3 of BS 6954. See also Figure 3.

Openings can be formed with greater precision by the use of temporary frames or jigs. However, the size of the temporary frame should take account of the dimensional variability of the component to be fitted into the opening and the thickness of the joint between the component and surrounding material.

When windows, doorsets or cladding units are to be built in as the work proceeds, and the positions of the openings are important, critical dimensions should be identified and the tolerances should be specified.

Composite windows spanning floor to ceiling have to be accommodated within only two joints, and deviations in parallelism and squareness of the opening are critical.

4.7 Prefabricated partitions

When partitions are to be fitted between previously constructed items, problems of fit can arise. It should be ensured that the particular system can accommodate any tolerance in the floor and ceiling level and is capable of maintaining the performance requirements specified for a particular project in the project documentation, for example for sound attenuation, thermal insulation and fire resistance.

Any trim should be large enough to accommodate the predicted total of deviations in the structure and adjacent components and in the partition.

Particular attention should be given to make-up pieces and the trim needed to mask the joints.

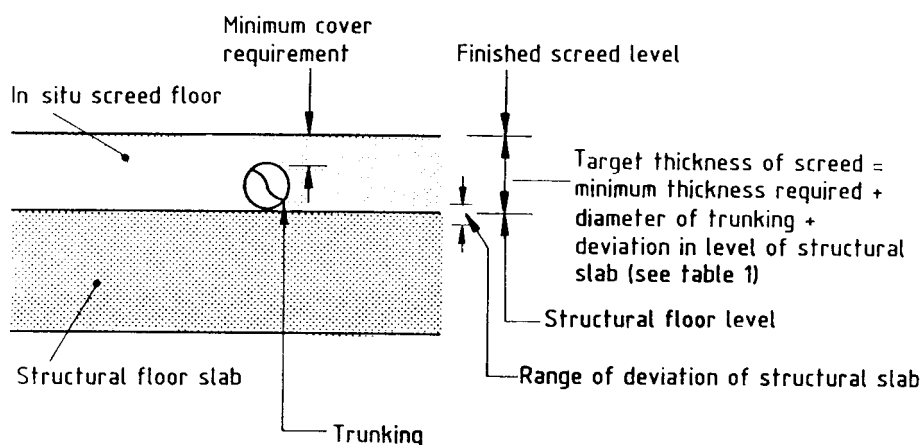


Figure 1 — Diagrammatic section showing screed accommodating trunking and range of deviations involved

Where partitions are to be fixed to pre-placed fixing blocks, allowance should be made for the size and position of the block so that the fixing device comes within the middle third of the block.

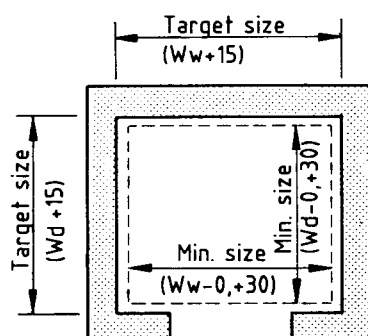
4.8 Pipework

It should be recognized that deviations will occur in the manufacture of pipework and conduit assemblies and in the location of inlets and outlets connected to the structure. The in situ connection should be designed to accommodate the predicted total of deviations from all sources.

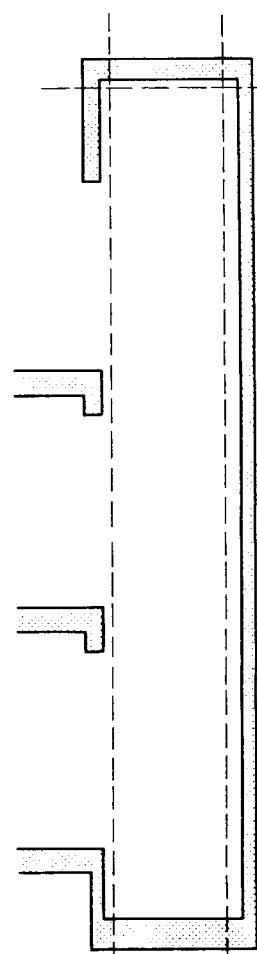
4.9 Ductwork

It is recommended that sizes of apertures for ducting, including allowance for insulation, joints, flanges, junctions, cross-overs, valves and fixing lugs, should be shown on the drawings.

Consideration should be given to the order of installation and the space needed for access to install, operate and maintain equipment. When insulation is to be applied to the duct after installation, sleeves should be inserted at the point where the ducting passes through the structure.



Plan of lift well



Section through lift well

Ww: Lift manufacturer's minimum lift well width
Wd: Lift manufacturer's minimum lift well depth

NOTE Lift manufacturers sometimes specify the sizes of the lift well with the tolerance expressed in the form $-0 + 30$. Since actual sizes are, for practical purposes, distributed equally about the target size (see Appendix C) it follows in this instance that the target size for the length and width of the lift well will be minimum size $+ 15$ with a tolerance of ± 15 .

Figure 2 — Target sizes of lift well

Tolerances specified for the sizes of the openings to be left should allow ventilating grilles or diffusers to be fitted and for flanges to mask the joints and/or packings.

4.10 Patterned finishes

If the finish consists of manufactured units, such as tiles which when applied form a pattern, consideration should be given to the manner in which the deviations in the structural frame and backing can be accommodated or masked.

Provision should be made in the layout of manufactured units, e.g. tiles, for deviation in manufacture and application; so that, for instance, whenever practicable joint lines coincide.

4.11 Furniture and fittings

When items are to be placed in position, or built in, account should be taken of the deviations in the dimensions of surfaces forming the recess or other position into which the items fit, and allowance should be made for manoeuvring the items into position.

4.12 Site information

In order that the location of each proposed building can be determined, accurate information should be provided regarding the location, dimensions and contours of the site, and regarding the position of any existing features and services that may affect or be affected by a new construction.

Recommendations concerning site surveys are given in Appendix A.

5 Designing out problems

Experience has shown that practical measures can be taken to avoid common problems. Examples of these measures are as follows.

- The visual effects of inaccuracies should be minimized, e.g. in a run of storey-height panels, each of which may vary in width within the stated tolerances, the position of each may be adjusted on site to achieve regular joint widths. Uneven joints will be far more noticeable than irregular panel sizes.
- The sizes of timber and structural steel sections are commonly described by nominal values that differ significantly from their work sizes. Design should be based on actual sizes.
- Fixings that have critical locations should have allowance made in the design and construction for dimensional adjustment.
- Fixings cast in situ or pockets for fixings, such as lift guides, should be avoided as far as possible by using fixings which do not require preformed holes.

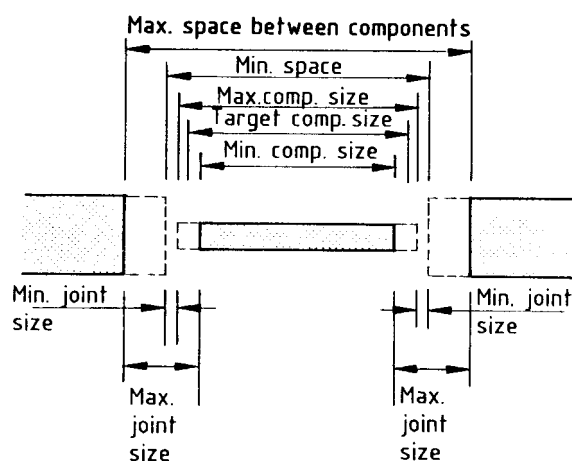


Figure 3 — Diagrammatic plan showing dimensional variabilities relating to component, prepared space and joint

Table 1 — Range of deviations normally achievable for construction (risk of non-compliance of approximately 1 in 22)
[see Appendix C)]

Item of construction		Location	Construction material					
			Brickwork	Blockwork	In situ concrete	Precast concrete	Steel	Timber
			mm	mm	mm	mm	mm	mm
T.1.1 space ^a between elements	Walls up to 7 m apart	At floor At soffit	± 15 ± 20	± 16 ± 21	± 24 ± 24	± 15 ± 18	NA NA	± 27 ± 32
	Columns up to 7 m apart	At floor At soffit	NA NA	NA NA	± 17 ± 18	± 13 ± 13	± 12 ± 10	± 12 ^b —
	Cased steel columns	At floor At soffit	NA NA	NA NA	NA NA	NA NA	± 16 ± 16	NA NA
	Beams and floor slabs	Floor to soffit height	NA	NA	± 23	± 19	—	—
T.1.2 openings	Window or door	Width up to 3 m (not jigged) Height up to 3 m (not jigged)	± 20 ± 20	— —	± 14 ± 20	± 11 ± 10	— —	— —

Table 1 — Range of deviations normally achievable for construction (risk of non-compliance of approximately 1 in 22)
[see Appendix C)]

Item of construction		Location	Construction material					
			Brickwork	Blockwork	In situ concrete	Precast concrete	Steel	Timber
			mm	mm	mm	mm	mm	mm
T.1.3 Size and shape of elements and components	Walls	Height up to 3 m	± 26	± 28	—	—	NA	—
		Thickness	± 20	± 19 ^b	± 8 ^b	—	NA	—
		Straightness in 5 m	± 5	± 6	± 9	± 6	NA	—
		Abrupt changes in a continuous surface	—	—	± 4 ^b	± 3 ^b	NA	NA
		Verticality up to 2 m	9	9	11	8	NA	14
		up to 3 m	10	10 ^b	17	11	NA	—
		up to 7 m	14 ^b	14	16 ^b	14 ^b	NA	NA
		Level of bed joints	± 11	± 13	NA	NA	NA	NA
	columns	Size on plan up to 1 m	—	—	± 8	—	—	—
		Verticality up to 3 m	NA	NA	12	10	6	10
		up to 7 m	NA	NA	16 ^b	14 ^b	8	—
		Cased steel verticality up to 3 m	NA	NA	NA	NA	10	NA
	Beams	Squareness	NA	NA	9	—	—	—
		Depth	NA	NA	± 13	—	—	—
		(Perimeter beams) up to 600 mm	NA	NA	± 20	—	—	—
		over 600 mm	NA	NA	± 12	—	—	—
		(Internal beams) up to 600 mm over 600 mm	NA	NA	± 16	—	—	—
		Level ^c	NA	NA	± 22	± 23	± 20	± 20 ^b
		Variation from target plane	NA	NA	10 ^b	8 ^b	8 ^b	10 ^b
		Straightness in 6 m	NA	NA	10 ^b	8 ^b	8 ^b	10 ^b

Table 1 — Range of deviations normally achievable for construction (risk of non-compliance of approximately 1 in 22)
[see Appendix C)]

Item of construction			Construction material					
			Brickwork	Blockwork	In situ concrete	Precast concrete	Steel	Timber
			mm	mm	mm	mm	mm	mm
T.1.3 Size and shape of elements and components (continued)	Suspended structural floor before laying of screed ^e	Level ^d						
		Variation from target plane in situ or precast slab	NA	NA	± 25	± 28	NA	—
		in situ topping on precast	NA	NA	NA	± 31	NA	NA
	Non suspended floor slabs before laying of screed ^f	Structural soffit	NA	NA	± 19	± 18	NA	—
		Thickness	NA	NA	± 10 ^b	—	NA	NA
		Level ^d						
		Variation from target plane	NA	NA	± 25 ^b	—	NA	NA
	In situ floorings	Surface regularity ^d						
		Direct finished base slabs, topping and screeds						
		Variation from target plane	NA	NA	± 15 ^b	—	NA	NA
		Flatness	NA	NA	± 5 ^b	—	—	—
		Abrupt change across joints	—	—	± 2 ^b	—	—	—

Table 1 — Range of deviations normally achievable for construction (risk of non-compliance of approximately 1 in 22)
[see Appendix C)]

Item of construction		Location	Construction material					
			Brickwork	Blockwork	In situ concrete	Precast concrete	Steel	Timber
			mm	mm	mm	mm	mm	mm
T.1.4 Overall size on plan	Building	Length or width up to 40 m	± 29	—	± 26	± 38	± 14	—
	Ground floor slab	Length or width	NA	NA	± 28	—	NA	NA
T.1.5 Position on plan in relation to the nearest reference line at the same level								
a) Foundations								
Mass concrete in excavated ground with minimum formwork Reinforced concrete including rafts, ground beams, column bases, pile caps and strip footings			NA	NA	± 50 ^b	NA	NA	—
			NA	NA	± 50 ^b	± 20 ^b	NA	—
b) Walls			± 10 ^b	± 10 ^b	± 16 ^b	± 14 ^b	± 10 ^b	± 14 ^b
c) Structural frame-columns			± 10 ^b	NA	± 12 ^b	± 10 ^b	± 10 ^b	± 10 ^b
d) Lift walls			± 10 ^b	± 10 ^b	± 12 ^b	± 10 ^b	NA	NA
e) Stair wells			± 10 ^b	± 10 ^b	± 12 ^b	± 10 ^b	NA	NA
f) Finished stairs (flight from landing to landing)			NA	NA	± 12 ^b	± 10 ^b	NA	NA
g) Door, window and other openings			± 10 ^b	± 10 ^b	± 12 ^b	± 10 ^b	NA	± 10 ^b
h) Formers for items to be cast or built in			± 6 ^b	± 6 ^b	± 6 ^b	± 6 ^b	NA	NA
i) All other elements above foundations			± 10 ^b	± 10 ^b	± 12 ^b	± 10 ^b	± 10 ^b	± 10 ^b

Table 1 — Range of deviations normally achievable for construction (risk of non-compliance of approximately 1 in 22)
[see Appendix C)]

Item of construction	Location	Construction material					
		Brickwork	Blockwork	In situ concrete	Precast concrete	Steel	Timber
		mm	mm	mm	mm	mm	mm
T.1.6 Dimensions on plan in relation to target sizes							
a) Foundations:							
Mass concrete [as T.1.5(a)]		NA	NA	± 50 ^b	NA	NA	NA
Reinforced concrete [as T.1.5(a)]		NA	NA	± 50 ^b	± 10 ^b	NA	NA
b) Structural frame length and width up to 8 m		± 12 ^b	± 12 ^b	± 16 ^b	± 12 ^b	± 12 ^b	± 12 ^b
Over 8 m and up to 15 m		± 16 ^b	± 16 ^b	± 18 ^b	± 16 ^b	± 16 ^b	± 16 ^b
Over 15 m and up to 25 m		± 18 ^b	± 18 ^b	± 20 ^b	± 18 ^b	± 18 ^b	± 18 ^b
c) Stairs (structural) ^g							
Length of clear span		NA	NA	± 14 ^b	± 12 ^b	± 12 ^b	± 12 ^b
Width of flight		NA	NA	± 8 ^b	± 6 ^b	± 6 ^b	± 8 ^b
Difference in width of tread or going of consecutive steps		NA	NA	± 10 ^b	± 8 ^b	± 8 ^b	± 10 ^b
Waist thickness measured square to slope of flight		NA	NA	± 8 ^b	± 6 ^b	± 6 ^b	± 8 ^b
Stairs (finished) ^g							
Length of clear span		NA	NA	± 12 ^b	± 10 ^b	± 10 ^b	± 12 ^b
Width of flight		NA	NA	± 10 ^b	± 10 ^b	± 10 ^b	± 10 ^b
T.1.7 Position in elevation in relation to the nearest reference line							
a) Door, window and other openings including lift landing doors		± 15 ^b	± 15 ^b	± 15 ^b	± 15 ^b	NA	—
b) Timber components		NA	NA	NA	NA	NA	± 10 ^b
c) Formers for items to be cast or built in		± 10 ^b	± 10 ^b	± 10 ^b	± 10 ^b	NA	NA