IS 6408 (Part 2) : 1992

(Reaffirmed 1996)

भारतीय मानक

भवन निर्माण उद्योग में मॉड्यूली समन्वय हेतु सिफारिशें : छूटें

भाग 2 सिद्धांत और अनुप्रयोग

(पहला पुनरीक्षण)

Indian Standard

RECOMMENDATIONS FOR MODULAR CO-ORDINATION IN BUILDING INDUSTRY : TOLERANCES

PART 2 PRINCIPLES AND APPLICATIONS

(First Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Planning, Byelaws and Dimensional Co-ordination Sectional Committee had been approved by the Civil Engineering Division Council.

One of the aims of modular co-ordination is to provide compatibility and inter-changeability of components. In earlier days a practical system of tolerances was derived as clearance fit, prescribing minus tolerances on each component without any allowance to the space in which it is to be placed. In the past, the building industry never faced the problem of tolerances, except in the field of mechanical and structural engineering. It is a common practice, to instal readymade doors/windowsets while brickwork is in progress. Any inaccuracies in size, shape or position of doors/windowsets is adjusted by the brickwork and inaccuracies in the brick itself adjusted in mortar joints. The extensive use of prefabricated elements and components in building construction have provoked the concept of tolerance in recent years. The concept of tolerance is indeed a tool to be used for dimensional control of the component which can fit without any problem for size, squareness, bow, plumbness, position and appearance.

The value of tolerances is subject to fabrication and assembly of materials, design of moulds and manufacturing process. Moreover it can be employed to delimit the dimensional variations for factory produced or site-cast, precast and precast prestressed concrete products. This can be used by designers, architects, engineers, general contractors, manufacturers, erectors, quality control agencies and related or interfacing trades.

This standard is intended to be a working reference for the dimensional control of prefabricated components and precast concrete products.

This standard was originally published as IS 6408 : 1971 'Recommendations for modular co-ordination application of tolerance in building industry'. In the usage of this standard, a need was felt to cover the terminology in a comprehensive manner in addition to effecting the other technical changes deemed necessary on the basis of the experience gained over the years. As a result, the standard has been published in the following two parts:

Part 1 Glossary of terms, and

Part 2 Principles and applications.

This part has been made comprehensive by incorporating the advancement made in the field of joint design systems and process of manufacture for precast concrete products and other allied components employed in building construction. Further, general concept concerning tolerances for building and building components and illustrative examples supported by figures have been included. The derivation of manufacture sizes for modular space, calculation of joint clearance, distribution of tolerances, specification of tolerances and indication of tolerances on drawings have also been elaborated to make this standard comprehensive.

In the preparation of this standard considerable assistance has been rendered by the National Buildings Organization, New Delhi.

In the preparation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. This has been met by deriving assistance from the following documents:

a) Industrialized building and modular design. Henrik Nissen Cement and Concrete Association, London 1972.

b) The principles of modular co-ordination in building (*revised*). CIB W24. The International Modular Group 1982.

c) Modular co-ordination of low cost housing. United Nations Publications 1970.

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Indian Standard

RECOMMENDATIONS FOR MODULAR CO-ORDINATION IN BUILDING INDUSTRY : TOLERANCES

PART 2 PRINCIPLES AND APPLICATIONS

(First Revision)

1 SCOPE

1.1 This standard (Part 2) covers the basic principles to be adopted for the inaccuracies which occur in setting out of the building on the sites, erecting or manufacturing of building components.

1.2 This deals with theory and application of dimensional deviations which shall be limited by these tolerances in construction industry.

1.3 Tolerances are intended to be applied whether or not a system of dimensional co-ordination is used in design process.

2 REFERENCES

The following Indian standards are necessary adjuncts to this standard:

IS No.	*Title*
1077 : 1986	Specification for common burnt clay building bricks (*fourth revision*)
4993 : 1983	Glossary of terms relating to modular co-ordination (*second revision*)
6408 (Part 1) : 1991	Recommendations for modular co-ordination in building industry : Tolerances, Part 1 Glossary of terms

3 AIMS

3.1 Every process of construction entails some degree of inaccuracy due to dimensional variation material and methods employed for production. These will become apparent only when components will not fit into their allocated modular spaces or when spaces between two components become so large or small that components fail to meet joint requirements. It becomes necessary to assess the likely variation that may occur in joint clearances in order to select suitable joint techniques or building components so designed to accommodate the extremes of variations (*see* Fig. 1). Such a process helps to derive the work size of building components.

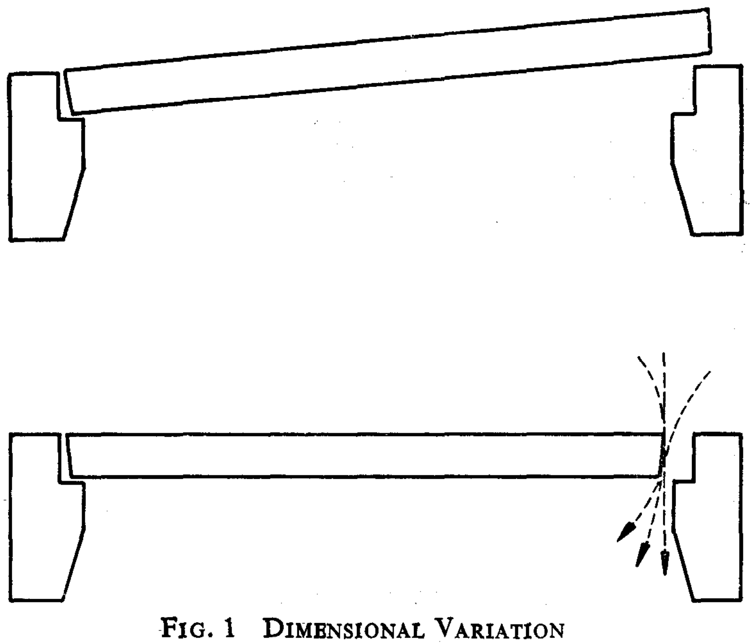


FIG. 1 DIMENSIONAL VARIATION

3.2 The pre-requisite to achieve aim of precast, prestressed or prefabricated building components that are connected on site without shaping, can only be achieved if components are produced with a suitable degree of accuracy.

3.3 The components must fit into their modular zones without an accumulation of error while installing them in position (*see* Fig. 2).

3.4 With the use of the fabricated building components which are neither intended to nor capable of being shaped on site, it is necessary to obtain certain degree of accuracy in both manufacturing and placing/assembly.

3.5 While preparing dimensional specification and quality requirements of fabricated building components the controlling dimensions, basic dimensions and tolerances shall be specified by the supplier to encourage the use of their products in the construction industry.

4 FIELD OF APPLICATION

4.1 Derivation of Dimensions for Modular Component

In component building design the application of the special reference system and the selection of preferred sizes for component and space dimensions is only the first step towards ensuring that components as supplied can be assembled with ease of fit.

4.2 The reference system enables designers to relate the position and size of components by means of modular planes. Such co-ordinating planes form the boundaries of modular component spaces and include allowances for inaccuracy and the size clearances.

4.3 In modular design practice, therefore, these spaces shall be defined by co-ordinating dimensions which are modular.

4.4 It is important to stress the essential theoretical nature of such dimensions in the context of building component manufacture.

4.5 The modular co-ordination shall provide co-ordinating length, width and thickness of components. By this, it means it shall provide flexible dimensional compatibility between the position of different material sub-systems comprising the components and positioning and dimensions of these functional sub-systems.

4.6 The modular sizes shall provide the basis only for determining the manufacturing sizes of components as explained in Fig. 3.

4.7 Deduction from the modular sizes shall require to be made to accommodate any allowance for joint and for the dimensional deviations that occur in production and erection.

4.8 The System of Tolerances to Modular Components

4.8.1 In this system the space between modular planes or gridlines is a whole multiple of the basic module. This is also the modular size of the component, which is used for architectural design in general arrangement of plans, elevations and sections. For detailed drawings of joints and for specifying the size to be manufactured, it is necessary to consider the aspects given in **4.8.1.1** and **4.8.1.2**.

4.8.1.1 First the width of the joint between components shall be deducted (2g) and next an allowance for inaccuracy in erection (position tolerance). These two together comprise the minimum deduction from the modular size to give the maximum size for the component. Then an allowance is made for inaccuracy in manufacture (the manufacturing tolerance) and the minimum size for the manufacture component is reached. Care shall be taken that the tolerances are not so coarse that the maximum deduction create too large a space for available techniques in jointing.

4.8.1.2 This being a proven system for derivation of work size to a modular component, further guidance shall be required on tolerance values to be prescribed for gap, position and production.

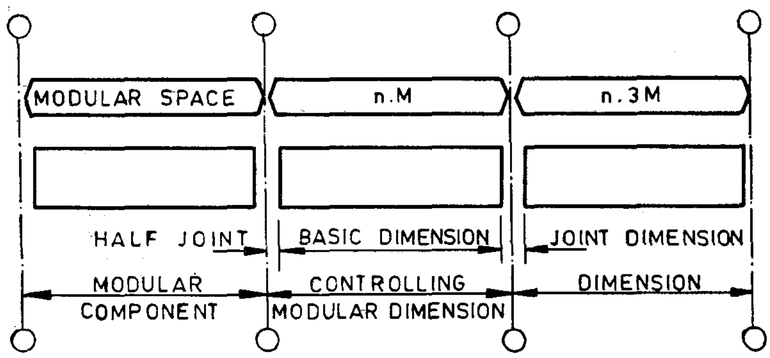


FIG. 2 MODULAR COMPONENTS

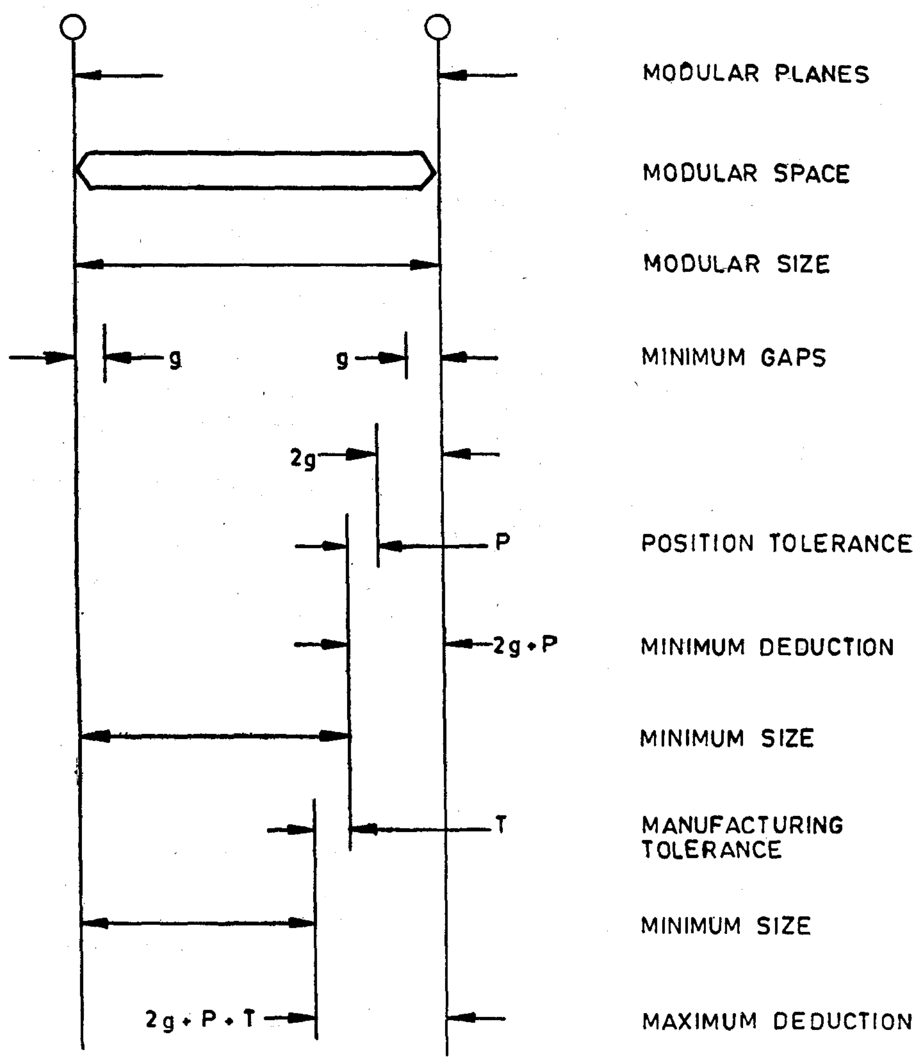


FIG. 3 SYSTEM OF TOLERANCES FOR MODULAR COMPONENTS

4.9 Reliable information on the quantification of building tolerances is hard to find. As some indication of the order of magnitude is to be taken into consideration, values for various tolerance classes are given in Annex A, which are based on the experiences gained in the field by undertaking study and analysis of actual measurements.

5 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 6408 (Part 1) : 1990 and IS 4993 : 1983 shall apply.

6 GENERAL CONCEPT

6.1 The concept of tolerances applicable to building and building components is relatively new and less known in our country. Therefore, it is proper to lay down uniform rules for application of tolerances so that manufacturers, designers and builders may improve the dimensional control in manufactured products at design, production and assembly stages.

6.2 Small variations in dimensions are unavoidable in construction industry which can be tolerated within certain limits, if the linkage is to be made as designed. The limits of the permissible deviations determine the tolerance, that is, permitted deviations for the building components and total building unit.

6.3 The manufacturing, setting-out and erection tolerances together shall comprise the construction tolerance. These shall be determined with respect to construction method adopted for satisfactory performance. Sometimes these are also recognized as product, erection and interfacing tolerances in industrialized building construction methods.

7 TYPE OF DIMENSIONAL DEVIATIONS

7.0 Dimensional deviations are of two types:

a) Induced deviations, and

b) Inherent deviations.

7.1 Induced deviations are divided in three groups: namely, (a) manufacturing deviations, (b) setting out deviations, and (c) location deviations.

7.1.1 Induced deviations shall arise as a result of manufacturing and building processes.

7.1.2 While selecting the size of components and their joints to suit a standard modular component, the inherent deviations are summed arithmetically and combined with the statistically summed induced deviations to provide a sensible indication of the total allowance for all relevant specified permitted deviations.

7.1.3 These geometrical deviations are caused by human error, inaccuracy of tools and limitations in precise measurements.

7.2 Inherent deviations falls in two groups: namely, (a) Irreversible, and (b) reversible.

7.2.1 These shall arise as a result of inherent property of materials used in manufacture of components and elements.

7.2.2 The irreversible deviations are caused by initial shrinkage, settlement and creep.

7.2.3 The reversible deviations are caused by the change in temperature or humidity or by deflection due to live/wind loading.

7.2.4 It shall be necessary, when dealing with tolerances, to specify reference conditions, such as, (a) choice of jointing technique and selection of work size for the components, (b) design of joint to ensure movement which may occur at a particular place, and (c) large size wall elements made of materials having low thermal expansion coefficients and low moisture movement exposed to weather.

7.3 The dimensional tolerance, orientation tolerance and shape tolerance together shall comprise the manufacturing tolerance.

7.4 The positional and orientation tolerances for arranging components together shall comprise the setting out tolerance.

7.5 The position and orientation tolerances for erection together shall comprise the erection tolerance.

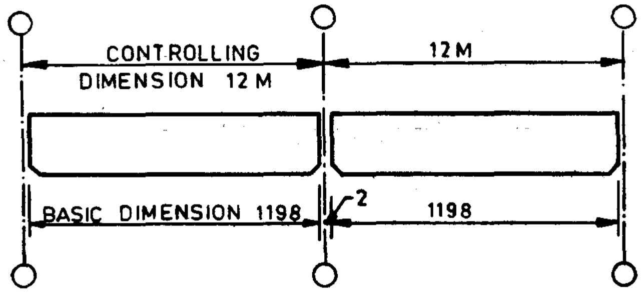
8 DEVIATIONS AND TOLERANCES

8.1 Deviations arise in all work processes, production and assembly. No dimensional specification can be fulfilled with 100 percent accuracy.

8.2 In order to ensure linkage and correct functioning, these deviations shall be limited. This shall be done by selecting limits for permissible deviations.

8.3 In construction industry the tolerances shall be specified with $\pm$ deviations from the specified dimension which shall be called basic dimension. The basic dimension shall be within the controlling dimensions (*see* Fig. 4).

8.4 The tolerance shall then be defined as the total difference between maximum and minimum permissible dimensions (*see* Fig. 5).



All dimensions in millimetres.

FIG. 4 CONTROLLING DIMENSION AND BASIC DIMENSION

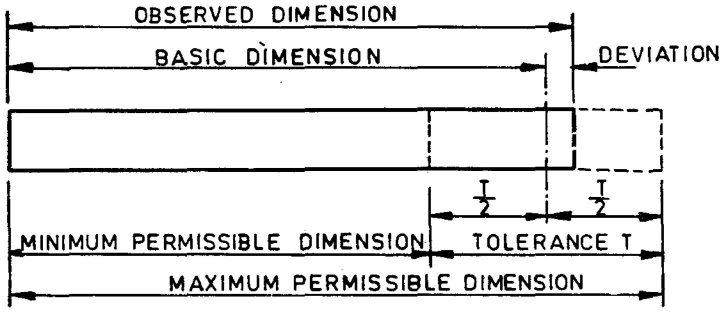


FIG. 5 OBSERVED DIMENSION AND DEVIATION

8.5 The tolerance specification shall denote the symmetrical tolerance system.

Example:

The length shall be specified by the basic dimensions 2990 mm. It shall be permissible for this length to vary between the limits:

2985 mm (minimum permissible dimensions), and

2995 mm (maximum permissible dimensions).

The tolerance shall be 2995 – 2985 = 10 mm. The basic dimensions with tolerances shall be expressed as 2990 ± 5 mm.

8.6 In other branches of industry following different methods of specifying tolerances are used on drawings:

2980^{+15}_{+05} 2985^{+10}_{+0} 2988^{+7}_{-3} 2995^{+0}_{-10} 3000^{-5}_{-15}

and these five dimensional specifications shall correspond to same dimensions and same limits for the deviations.

8.7 The length obtained by actual measurement of component shall be called as 'observed dimensions' and the difference between the length and the controlling dimension shall denote the 'deviation' (*see* Fig. 6). The deviation shall be reckoned with signs (±).

9.5 Measurement of the deviation '*a*' of an arbitrary point *P* is achieved in practice from a check plane (line) 3 at known distance '*b*' from the basic plane (or line) 2 (*see* Fig. 6).

9.6 Flatness Deviations

9.6.1 Flatness deviations shall be determined by the principles as shown in Fig. 7. Deviation is the distance from any point on the surface to a surface representing a median plane for all four corner points.

9.6.2 In practice the measurement shall be made from a plane exterior to the component and parallel to two main directions of the component.

9.6.3. Deviation shall be measured at various points over the entire surface area.

9.7 Skewness

9.7.1 Skewness is a special case of flatness deviation affecting a rectangular surface with well defined corners (*see* Fig. 8).

9.8 Angular Deviations

9.8.1 Correspondingly, angular deviations shall be expressed in three ways as deviation in length.

9.8.1.1 The difference between the observed angle and the basic angle is expressed by means of the length *l* and *d* as given below (*see* Fig. 9 and

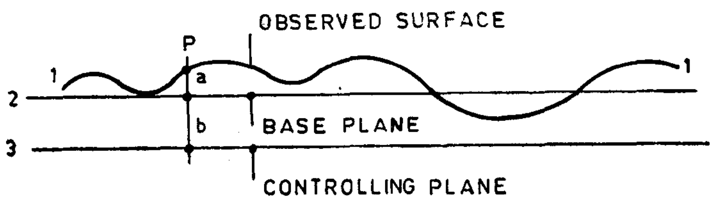


FIG. 6 DEVIATION FROM BASIC PLANE (expressed by '*a*')

9 BASIC SHAPE, OBSERVED SHAPE AND DEVIATION IN SHAPE

9.1 In practice, it is seldom possible to manage with one dimension tolerances. Limits have to be set for the deviation in shape occurring in all three dimensions of building components.

9.2 In case of one dimension tolerance, the prescribed shape shall denote the basic shape. The difference between the observed and the basic shape shall be called the 'deviation in shape'.

9.3 Deviation in length, angle, straightness or planeness shall be expressed by means of 'deviation in length'.

9.4 The deviations from a plane or a straightness at one of edges of a member shall be expressed by means of distance from points, lines or planes on an observed surface (or curve) 1, to the basic plane or a line 2 (*see* Fig. 6).

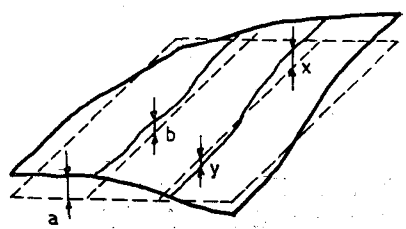


FIG. 7 FLATNESS DEVIATION

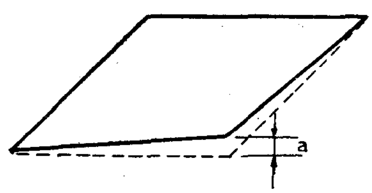


FIG. 8 SKEWNESS

Fig. 10):

a) Observed angle is more than basic angle ; l

b) Observed angle is less than basic angle $(l_2 - l_1)$

c) Observed diagonal is less than basic diagonal $(d_2 - d_1)$

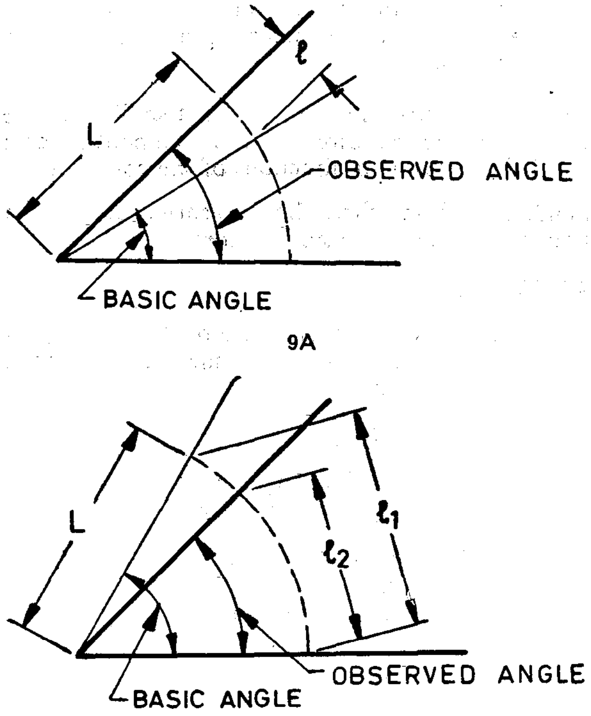


FIG. 9 DEVIATION IN ANGLE
[expressed by length l and $(l_2 - l_1)$]

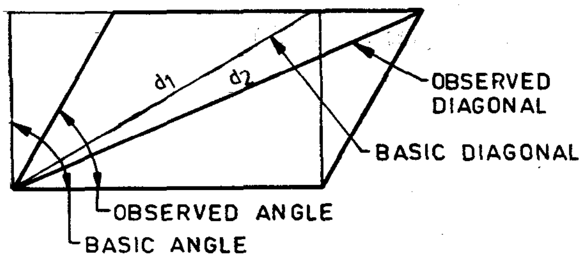


FIG. 10 DEVIATION IN SHAPE
[expressed by $(d_2 - d_1)$]

9.9 Setting Out Deviation

9.9.1 The setting out deviation shall be determined by the principle as shown in Fig. 11.

9.10 Erection Deviation

9.10.1 The erection deviation shall be determined by the principle as shown in Fig. 12.

10 BOX PRINCIPLE

10.1 Box is the imaginary and arbitrary shape which encloses three dimensional space between two forms of surface symmetrical to each other and are so placed that the distance of each one of them is one quarter of a tolerance away from the basic surface inside and outside directions.

10.2 Shape tolerances which are intended to limit the deviations in a component length, angle, straightness and planeness easily become confusing and difficult to apply in practices. The tolerances on the shape of a component are, therefore, collectively used in box principle.

10.3 Figure 13 shows an arbitrary basic shape lying between an inner and outer figure, the surfaces of which are located symmetrically about the surface of the basic figure. One surface shall be located $T/4$ inside the surface of the basic figure, and the other $T/4$ outside it.

10.4 This principle has limitation of adoption in both shape and size. It delimits the control of three length tolerances. However, it does not establish the inside control of figure.

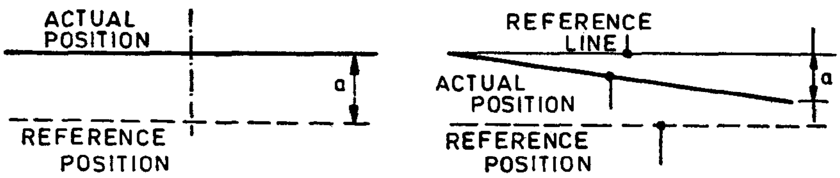
11 COMBINATION OF TOLERANCES

11.1 When a number of components are linked, their partial dimensions and joints shall often amount to series of dimensions having a total dimension. The tolerances on partial dimensions and total dimensions shall be interdependent.

11.2 Additive Principle

11.2.1 The most elementary way of establishing this relationship shall be by means of adding the values of partial tolerances. Thus, assuming the series of partial tolerances as $T_1, T_2, \ldots\ldots T_n$ the maximum deviation on total sum dimensions 'A_S' shall be calculated from the following equation:

$$A_S = \pm 1/2 \times [T_1 + T_2 + \ldots\ldots T_n]$$



11 A POSITIONAL   11 B ORIENTATION

FIG. 11 SETTING OUT DEVIATION FOR A LINE

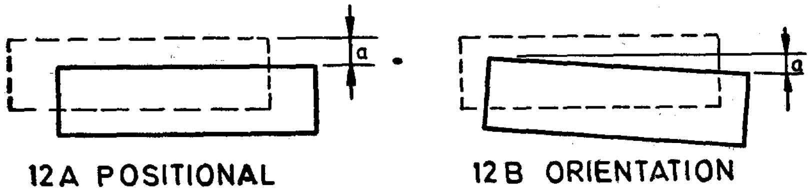


FIG. 12 ERECTION DEVIATIONS FOR A COMPONENT

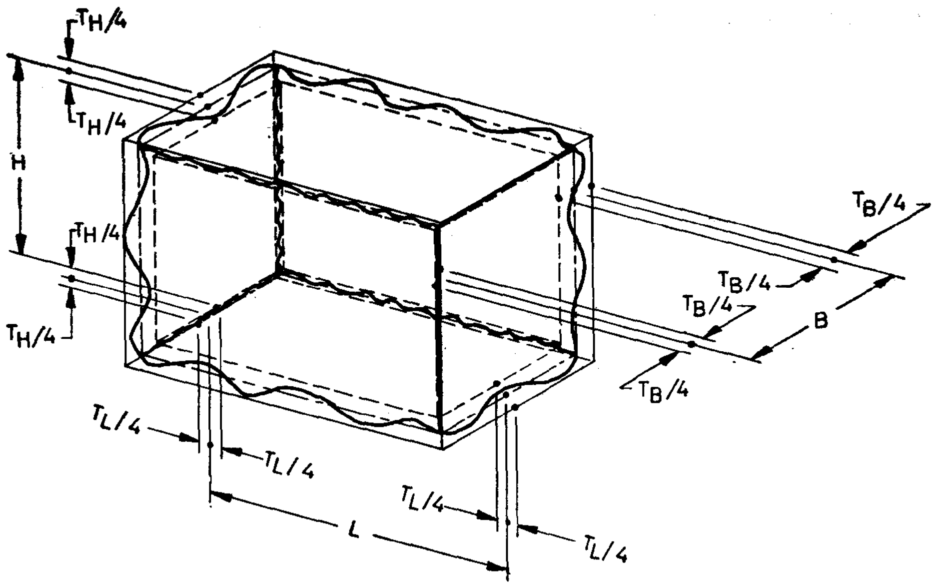


FIG. 13 BOX PRINCIPLE (DEVIATION OF FORM)

11.2.2 Assuming total tolerance T_S is equal to $2A_S$, it will always hold good. If it is required to select a part tolerance on the basis of a given sum (total) tolerance T_S, the sum may be worked out from the following relationship:

$$T_1 + T_2 + \dots\dots\dots T_n \geqslant T_S$$

11.2.3 This relationship between partial tolerances and total tolerances is called the additive principle. This principle is also known as arithmetical summation principle.

11.3 Summation of Tolerances

11.3.1 It is a theoretical presumption that each component shall be erected within its allocated modular space with high degree of workmanship in joints. But in practice, it is seldom achieved.

11.3.1.1 The inaccuracy which occurs in size, squareness, bow, plumbness and position of each component and minimum joint width, if summed arithmetically, shall result into large space for joints (*see* Fig. 14). For example, if minimum 5 mm is applied to five aspects of tolerances for two components shall result into (5×5) + 5 + (5×5) = 55 mm space for joint. This will be too large sum tolerance for a component.

12 CO-ORDINATE TOLERANCES

Application of the additive principle can lead to unrealistic values for small part tolerances or large sum tolerances. The principle can, therefore, be modified by introducing further tolerances which act differently on one and the same dimension, the so-called collaterally regulating tolerances or co-ordinate tolerances. These details are explained in **13** to **17**.

13 CHOICE OF TOLERANCE SIZE

13.1 The size of tolerance shall be chosen on the basis of the production method, jointing system, aesthetics and economy.

13.2 The relationship of four dimension, namely, (a) controlling dimension, (b) basic dimension, (c) joint dimension, and (d) tolerances shall depend on the connections between the components.

13.3 The tolerances on the basic dimensions of a component are absorbed and equalized in joints between additive elements. For example of tolerance equalization Fig. 15 may be referred to.

Referring to the sizes shown in the Fig. the distance between C and D lines:

With large component and small joint:

$$CD = \frac{F_{min}}{2} + \frac{l_{max}}{2} + \frac{T_m}{2}$$

With small component and large joint:

$$CD = \frac{F_{max}}{2} + \frac{l_{min}}{2} - \frac{T_m}{2}$$

From above two equations:

$$F_{max} - F_{min} = l_{max} - l_{min} + 2\,T_m$$

or,

$$T_f = T_1 + 2\,T_m$$

13.3.1 It can be seen that the given relationship between two dimensions shall result in uneven joints which perhaps may not absorb the tolerance on joint. It can also be seen that the positional tolerance tends towards zero value due to high value of tolerance on component. This shall call for high degree of site workmanship which may not be practical.

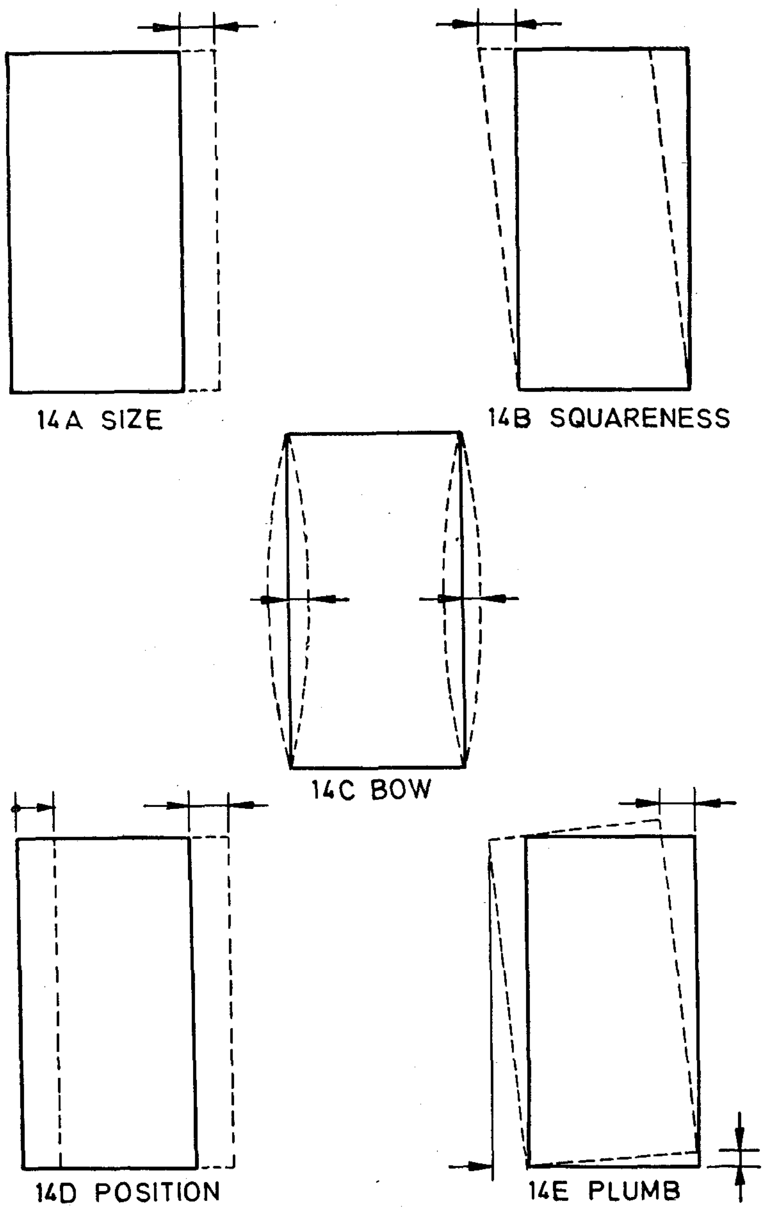
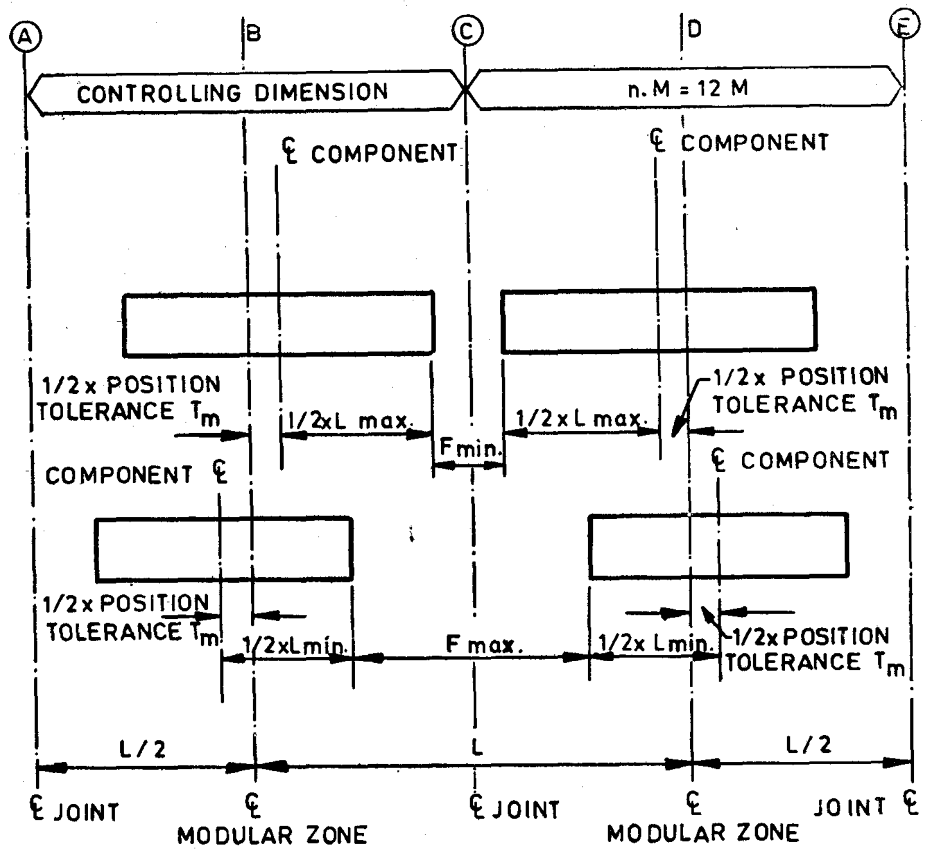


FIG. 14 ASPECTS OF TOLERANCE



L — Controlling dimension
l — Basic dimension component
F — Basic dimension joint

T_m — Position tolerance
T_l — Tolerance on component
T_f — Tolerance on joint

FIG. 15 RELATIONSHIP BETWEEN CONTROLLING DIMENSIONS, COMPONENTS DIMENSIONS, JOINT DIMENSIONS AND TOLERANCES

14 TOLERANCE OF FLOOR COMPONENTS

14.1 In linkage of the floor components the joint is assumed to be self-forming, which can be possible by grouting the joint from top without form work and without mortar running right through.

Example:

The floor components comply with their controlling dimension 1 200 mm.

This means the floor components shall not be wider than 1 200 mm.

The basic dimension for the width is expressed as 1 198 + 2 mm.

This limits the following dimensions for the component:

Minimum permissible dimension	1 196 mm
Maximum permissible dimension	1 200 mm
Basic dimension	1 198 mm
Tolerance	4 mm

15 TOLERANCE ON BRICK SIZE

15.1 Modular Size

15.1.1 As shown in Fig. 16 modular standard brickwork result in horizontal controlling dimensions that are divisible by 1 M (= 100 mm). In order that the controlling dimension may be observed during construction, bricks must be produced having suitable degree of accuracy.

15.1.2 The stretcher course with full bricks and corresponding vertical joint, the marginal dimension of work shall be determined as under:

The controlling dimension	=	200 mm
Maximum permissible joint	=	16 mm
Minimum permissible joint	=	8 mm

15.1.2.1 On the basis of above assumptions:

Upper marginal dimensions for the brick

= 200 − 8 = 192 mm

Lower marginal dimension for the brick

= 200 − 16 = 184 mm

The basic dimension of brick $\frac{(192 + 184)}{2}$

= 188 mm and

Tolerance = 192 − 184 = 8 mm or ± 4 mm.

15.1.2.2 In order to achieve controlling dimension of 200 mm, each brick must have limits for joint dimension with length of 188 ± 4 mm or ± 2·1 percent.

15.1.3 In case, 200 mm controlling dimension is to be observed with nominal dimension of brick 190 mm and tolerance of ± 6 mm (in accordance with IS 1077 : 1986) (*see* Note) it results in the marginal dimensions with variations ± 3·1 percent.

Maximum brick length = 190 + 6 = 196 mm

Minimum brick length = 190 − 6 = 184 mm.

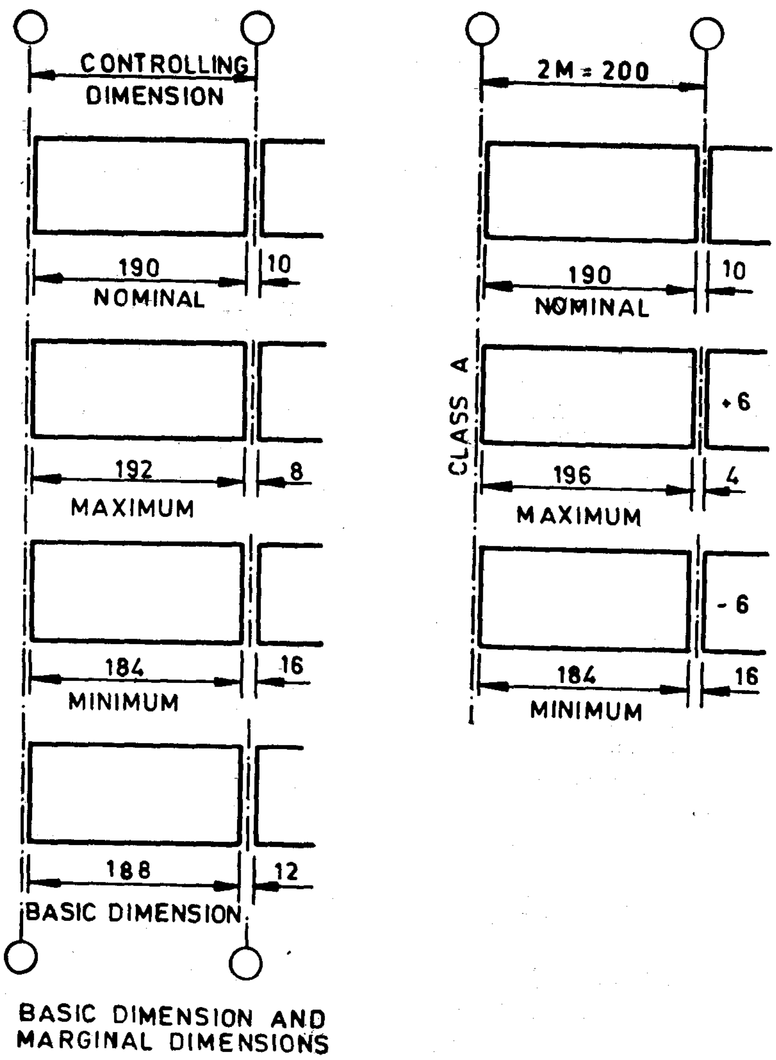
This corresponds to joint of 4 mm minimum and 16 mm maximum.

NOTE — As per IS 1077 : 1986, tolerance on 20 brick lengths is ± 80 mm which gives an 'average' tolerance of ± 4 mm per brick length and hence a '*max*' tolerance of ± 6 mm per brick can be permitted, provided that tolerance on any 20 bricks shall not exceed ± 80 mm.

15.1.3.1 It can be seen from above that joint dimensions calculated are unrealistic and very often too large for achieving controlling dimensions of 200 mm, even if it is calculated average of 20 bricks.

The deviations are equalized over larger length of brickwork, while adhering to the essential dimensions for openings for doors and windows, it shall not be attained. Therefore, tolerances stipulations should be based on statistical basis.

15.1.3.2 In order to achieve desired controlling dimensions, dimensions of each brick should have limits as specified in **15.1.2.1** and **15.2.2.1**.



All dimensions in millimetres.

FIG. 16 MODULAR BRICK TOLERANCES

15.2 Non-modular Conventional Size

15.2.1 As shown in Fig. 17, the non-modular conventional brickwork result in horizontal controlling dimensions that are divisible by 60 mm (¼ brick). In order that the controlling dimension may be observed during construction, bricks must be produced having a suitable degree of accuracy.

15.2.2 The stretcher course with full bricks and corresponding vertical joints, the marginal dimensions of brick shall be determined as under:

The controlling dimension = 240 mm

Maximum permissible joint = 16 mm

Minimum permissible joint = 8 mm

15.2.2.1 On the basis of above assumptions:

Upper marginal dimension for the brick
$= 240 - 8 = 232$ mm

Lower marginal dimension for the brick
$= 240 - 16 = 224$ mm

The basic dimension of brick

$$= \frac{232 + 224}{2} = 228 \text{ mm, and}$$

Tolerance $= 232 - 224 = 8$ mm or ± 4 mm.

15.2.2.2 In order to achieve controlling dimension of 240 mm, the each brick must have limits for joint dimension with length of 228 ± 4 mm or $\pm 1{\cdot}8$ percent.

15.2.3 In case, 240 mm controlling dimension is to be observed with nominal dimension of brick 230 mm and tolerance of ± 3 percent and ± 8 percent, for class A and class B types of bricks; it results in the marginal dimensions.

Class A

Maximum brick length $= 230 + 3\ \%$
$= 237$ mm

Minimum brick length $= 230 - 3\ \%$
$= 223$ mm

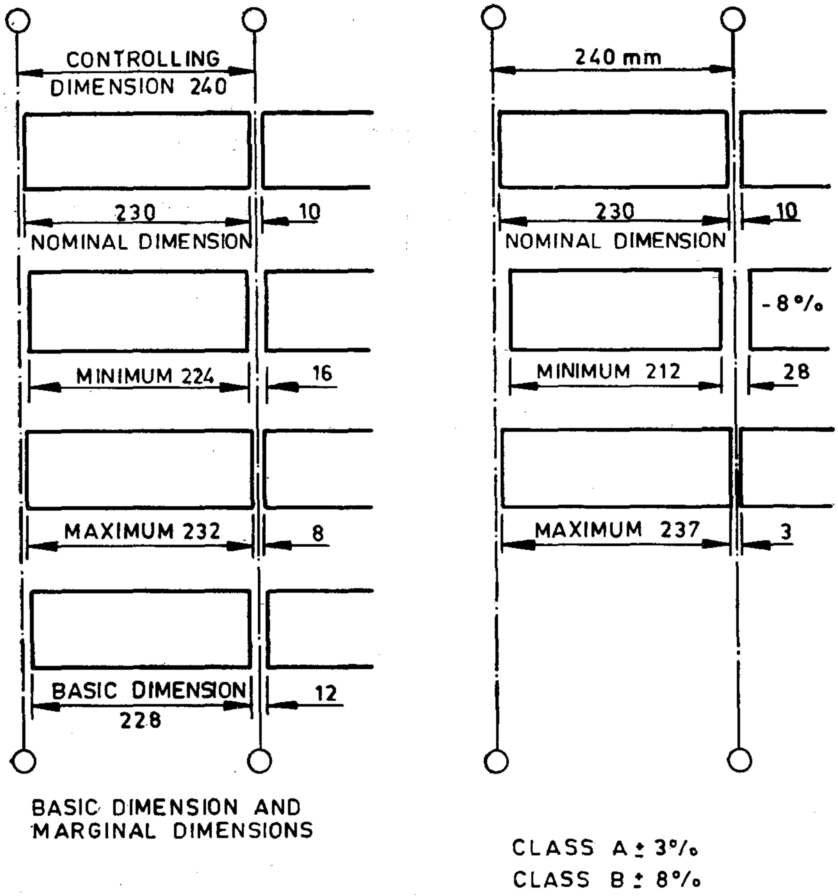
This corresponds to a joint of 3 mm minimum and 17 mm maximum.

Class B

Maximum brick length $= 230 + 8\ \%$
$= 248$ mm

Minimum brick length $= 230 - 8\ \%$
$= 212$ mm

This corresponds to a joint of 28 mm.



All dimensions in millimetres.

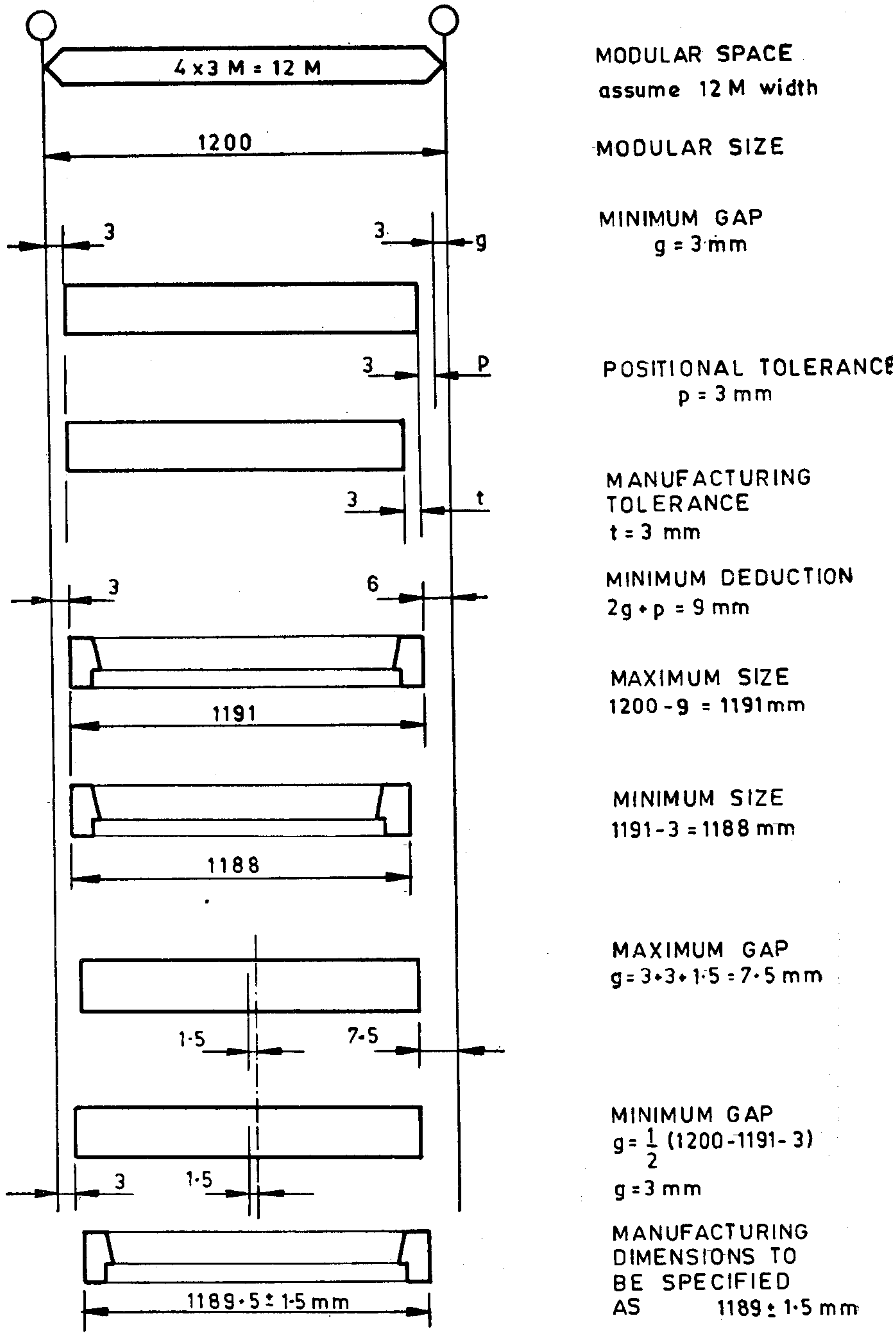
FIG. 17 STANDARD BRICK TOLERANCES

15.2.3.1 It can be seen from above that the joint dimensions calculated are unrealistic and large for strict adherence to the controlling dimensions of 240 mm. Therefore, tolerance specification shall have to be prepared on a statistical basis.

16 TOLERANCE ON COMPONENT, DOORSET/WINDOWSET WIDTH

16.1 Building designers are not usually accomplished to determine the tolerances for building components, but nevertheless, the procedure for calculation shall abreast them to deliberate with manufacturers who can render advise on manufacturing tolerances for a product-positional tolerances which are based on information gained from site assembly experiences.

16.2 The process of calculating maximum and minimum size acceptable on site for a modular component is illustrated in Fig. 18.



All dimensions in millimetres.

FIG. 18 DERIVATION OF MANUFACTURE SIZES

16.2.1 As a first step, select modular size of the component, and define the maximum gap, positional and manufacturing tolerances.

16.2.2 When the above have been settled, add up $g + p + g$ and deduct it from modular size, which is the maximum size.

16.2.3 Manufacturing tolerance deduced from maximum size shall be a minimum size.

16.2.4 Check the maximum gap $= g + p + t/2$ and also minimum gap $= 1/2$ (modular size — maximum — positional tolerance), or difference between maximum size and minimum size.

16.2.5 Lastly specify manfacturing dimension as $+ 1/2$ minimum gap after adding 1/2 minimum gap to minimum size.

17 MODIFICATION OF THE ADDITIVE PRINCIPLE BY ADJUSTMENT

17.1 When building elements are assembled by means of joints which may vary within definite limits, one may within these limits adjust the position of the element during assembly taking into consideration the actual measurement of the element. For a given joint tolerance, therefore, it is possible to set a large tolerance on the element than what is permitted by the additive principle. Such a modification implies, however, that it is not possible to combine all measurements which satisfy the indicated tolerance required.

17.2 Taking an example of a prefabricated or partially prefabricated building having precast concrete planks for floor component and the load bearing precast beam/joist (connection as shown in Fig. 19), the maximum permissible displacement of floor in relation to joint is ± 10 mm.

17.2.1 If site concrete joint width of 60 mm (*NZ* 60) minimum is required and floor component should have support of minimum 35 mm corresponding to the width of joist and maximum 75 mm from centre line, which are also on modular line.

17.2.2 The displacement between floor and joist/wall arises as a result of inaccuracies in:

a) thickness of joist/wall component
   $= T_1 =$ thickness

b) erection of floor component
   $= T_2 =$ placement

c) length of floor component
   $= T_3 =$ length

d) assembly of floor component
   $= T_4 =$ placement

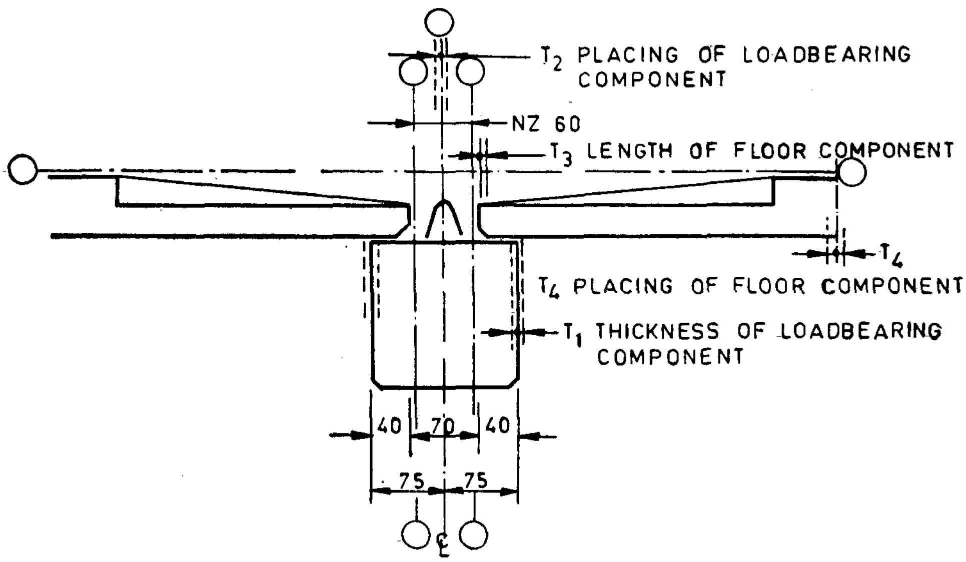
17.2.3 The tolerance are selected taking into consideration the normal practice followed in production and assembly. To determine T_4 (assuming $T_1 = 6$ mm, $T_2 = 10$ mm, and $T_3 = 10$ mm and taking the minimum displacement '*F*' from the location determined from the basic dimensions to minimum support), the calculation shall be as follows:

$$F = \frac{T_1}{4} + \frac{T_2}{2} + \frac{T_3}{4} + \frac{T_4}{2} = 10 \text{ mm}$$

that is, $$\frac{6}{4} + \frac{10}{2} + \frac{10}{4} + \frac{T_4}{2} = 10 \text{ mm}$$

therefore, $T_4 = 2$ mm

This is quite an unrealistic tolerance to be applied. In such cases adjustment may be done on site to obtain the required joint width.



All dimensions in millimetres.

FIG. 19 LOAD-BEARING FLOOR-BEAM/WALL CONNECTION IN PARTLY PRE-CAST JOISTS AND PRE-CAST RC PLANKS

18 APPLICATION OF CO-ORDINATE TOLERANCES

18.1 Co-ordinate tolerance are based on the assumption that erection on a number of parallel prefabricated wall components shall be adjusted on site. Thus T_5 is introduced with a value of 10 mm, for determining the displacement of the support (*see* Fig. 20). This shall be calculated as:

$$F = \frac{T_5}{4} + \frac{T_3}{4} + \frac{T_4}{2} = 10$$

that is $$2{\cdot}5 + 2{\cdot}5 + \frac{T_4}{2} = 10$$

therefore, $T_4 = 10$ mm

18.1.1 It can be noticed from above two principles that the effect T_1 and T_2 is replaced by the effect of T_5, which offers more realistic value for adoption in erection work.

19 THE SQUARE ROOT RULE

19.1 In practice, tolerance of the types T_1, T_2, T_3 and T_4 are also calculated with this principles:

$$F = \left\{ \left[\frac{T_1}{4}\right]^2 + \left[\frac{T_2}{2}\right]^2 + \left[\frac{T_3}{4}\right]^2 + \left[\frac{T_4}{2}\right]^2 \right\}^{1/2} = 10$$

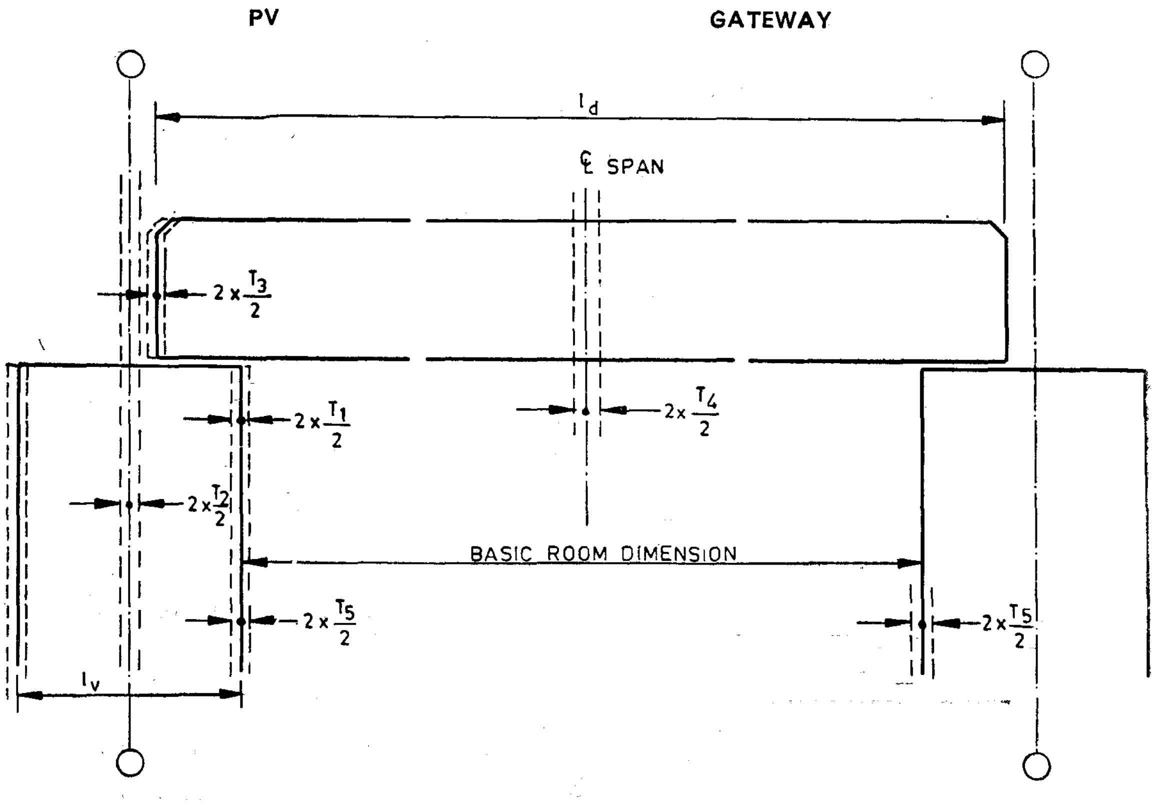
that is

$$\left\{ \left[\frac{6}{4}\right]^2 + \left[\frac{10}{2}\right]^2 + \left[\frac{10}{4}\right]^2 + \left[\frac{T_4}{2}\right]^2 \right\}^{1/2} = 10$$

that is

$$\left[\frac{36}{16} + \frac{100}{4} + \frac{100}{16} + \left[\frac{T_4}{4}\right]^2 \right]^{1/2} = 10$$

Therefore, $T_4 = 16{\cdot}3$ mm



TOLERANCES

T_1 = Thickness of wall component
T_2 = Placing of wall component
T_3 = Length of floor component
T_4 = Placing of floor component
T_5 = Room dimension
l_v = Dimension of wall component
l_d = Dimension of floor component

FIG. 20 CO-ORDINATE TOLERANCES

19.2 The calculation is based on following assumptions:

a) All the deviations in thickness, length and assembly have normal distribution,

b) There are no systematic errors,

c) It has some probability of error, and

d) All deviations shall be independent.

19.3 It is seldom possible to have fulfilment of above assumptions in practice. Thus, error on T_4 will be equal to T_1, T_2, and T_3.

20 CONTROL OF MEASUREMENT

20.1 In order to avoid ambiguity for control measurement, it shall be necessary to satisfy the tolerance measurement precisely.

20.2 It shall include the information on numbers of measurements, methods of production and manufacturer's constraints also.

21 SHRINKAGE AND CREEP

21.1 The dimensions in various building products are subjected to constant alteration due to change in temperature and moisture content, shrinkage and other deformation under conditions of use. This shall be clearly specified in order to avoid possible rejection.

21.2 The contributions from measuring instruments and methods adopted to determine the deviation shall remain negligible if authorised quality control department is involved for carrying out the tests on rendom samples.

22 APPROVAL

22.1 If the control measurements show deviations with numerical values which are less than or equal to half the tolerance, the dimension shall be adopted, otherwise it shall be rejected.

22.2 Agreement on production and supply shall contain clear understandings on consequences arising from possible rejection.

ANNEX A

(*Clause* 4.9)

SERIES OF EXAMPLES OF THE PRECISION CLASSES

Precision class PC 4 :
- Steel sections;
- Timber moulding and profiles of fine grained ashlar.

Precision class PC 5 :
- Steel windows, door, frames, trim; wood trim windows and door sections; components in fine grained ashlar; wall, ceiling, and floor surfaces.

Precision class PC 6 :
- Prepared and fitted components (such as framework, staircases, railings, floors, panels, cladding, gutters, rainpipes);
- Metal castings;
- Wood windows and doors;
- Built in furniture;
- Parquet flooring;
- Fine flooring, fine concrete components;
- Components of medium grained ashlar;
- Fine ceramics (e.g. paving tiles, ceramic tile claddings);
- Floor coverings;
- Installations (such as gas, water and heating pipes).

Precision class PC 7 :
- Forged and fabricated frames and railings;
- Wrought components (such as floors, wall coverings, steps);
- Planed boards, planks battens;
- Coarse flooring, Medium-grained concrete components;
- Ashlar facing;
- Plaster surfaces;
- Faces of joints.

Precision class PC 8 :
- Unwrought components, carpentary (such as framework joints, refters, unplanted boards, planks, battens);
- Components having finished surfces of state degree of accuracy (such as concrete facework components cast in metal forms);
- Surface of heavy concrete decks;

Facing brickwork, Fair-face walling, Clay block-work, masonry.

Precision class PC 9 : Components to be plastered or clad (such as components cast in wooden forms, heavy decks and stairs in the rough concrete);

Components to be plastered or clad (such as walls, piers, decks stairs);

Rough brickwork and blockwork.

Precision class PC 10 : Components not requiring great accuracy (such as foundations);

Walls, Room dimensions; Components not requiring great accuracy (such as foundations, retaining walls) unless an even coarser degree of accuracy is sufficient.

Table 1 Exact Values of Tolerance Grades

(*Clause* 4.9)

Tolerance grades for basic size ranges (millimetres)

Class	Up to 100	100 to 250	250 to 1 000	1 000 to 2 500	2 500 to 10 000	Over 10 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)
PC 1	0·25	0·4	0·6	0·8	1·0	1·2
PC 2	0·4	0·6	1·0	1·2	1·6	2·0
PC 3	0·6	1·0	1·6	2·0	2·5	3·2
PC 4	1·0	1·6	2·5	3·2	4·0	5·0
PC 5	1·6	2·3	4·0	5·0	6·0	8·0
PC 6	2·5	4	6	8	10	12
PC 7	4	6	10	12	16	28
PC 8	6	10	16	20	25	32
PC 9	10	16	25	32	40	50
PC 10	16	25	40	50	60	80

(Continued from second cover)

d) Dimensional co-ordination for building. DC12. HMSO Publication 1972.

e) PCI committee report on Tolerances for precast and prestressed concrete, PCI Journal, Vol 30, No. 1, Jan/Feb. 1985.

f) ISO 4464-1980 Tolerances in building — relationship between the different types of deviations and tolerances used for specification. International Organization for Standardization.

g) DS/R 1050-1982 Application of dimensional tolerances in building. Dansk Standardiseringsraad.

h) DIN 18201-1984 Tolerances in buildings: terminology, principles, application and testing. Deustsehes Institute for Normong.

j) DIN 18201-1958 Dimensional tolerances in buildings: terminology, fundamental tolerances, application and testing. Deustsehes Institute for Normong.

For the purpose of deciding whether a particular requirement of the standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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