THE INTERNATIONAL MODULAR GROUP

THE PRINCIPLES OF MODULAR CO-ORDINATION IN BUILDING

CIB W24 * CIB REPORT NO. 68 * 1984

Preface

In 1967/68 the International Modular Group (IMG) presented "Condensed Principles of Modular Co-ordination". "Condensed Principles", so called, informed the development of international standard ISO 2848, Modular Co-ordination, Principles and Rules.

The 12th Plenary Session of CIB W24/IMG (Dublin, 1978) decided that it would be desirable to provide a new document which would reflect developments since the publication of the "Condensed Principles". Much experience has been gained through application in practice of the contents of "Condensed Principles" and subsequent ISO standards and national standards. It is important now to provide a new document which will reflect the impact of practice on principle and act as a guide for further development of modular co-ordination in building both nationally and internationally.

Mr. W McEvatt, An Foras Forbartha, Dublin, Ireland, agreed to act as Rapporteur for the task formulated by the 12th Plenary Session.

(For complete text of task see inside back cover)

Subsequently a series of working sessions was arranged: in Paris, October 1979; in Rotterdam, February 1980; and in London, April 1980. Drafts for the new document were reviewed and discussed at these working sessions. Further comments on the drafts were obtained by correspondence and at meetings organized by, for example, the United Nations, CIB and ISO, where members of CIB W24/IMG had the opportunity also of informal meetings. A complete draft document was circulated to all the members of CIB W24/IMG (65 members in 28 countries), and was subsequently reviewed at the 13th Plenary Session of CIB 24/IMG, in Paris, October 1980 (24 members representing 11 countries were present). Comments received were once more considered and circulated to all members of CIB W24/IMG, and a final draft was approved at the 14th Plenary Session held in Zürich, October 1981.

The present document has been amended in accord with the views expressed at that meeting and can be considered as representing a general consensus of CIB W24/IMG members' views on the question of principles.

Many matters remain to be resolved, much work has yet to be done within CIB W24/IMG. In follow-up documents the methodologies developed to facilitate practical application of these principles will be explored.

As the preparation of the present document has only been possible with the full co-operation of the members of CIB W24/IMG so also further necessary work will only be brought to fulfilment by the continued active involvement of the membership.

K Blach
Co-ordinator CIB W24
President, International
Modular Group 1973–81

W McEvatt
Co-ordinator CIB W24
President, International
Modular Group

ISBN 87-563-0543-5

CONSEIL INTERNATIONAL DU BÂTIMENT
POUR LA RECHERCE, l'ÉTUDE ET LA
DOCUMENTATION (CIB)

INTERNATIONAL COUNCIL FOR
BUILDING RESEARCH, STUDIES AND
DOCUMENTATION (CIB)

AN FORAS FORBARTHA
The National Institute for Physical Planning and
Construction Research, Ireland

DANISH BUILDING RESEARCH INSTITUTE 1984

THE
PRINCIPLES OF MODULAR CO-ORDINATION IN BUILDING

Contents

Contact adresses:

An Foras Forbartha
St. Martin's House
Waterloo Road
Dublin 4/Ireland

Danish Building Research Institute
Postboks 119
DK-2970 Hørsholm/Denmark

The Principles of
MODULAR CO-ORDINATION IN BUILDING
Revised by CIB W24 The International Modular Group
(1983)

1.0 Objective and Benefits

1.1 Principal Objective

To provide a practical and coherent method for the co-ordination of the position and dimensions of elements, components and spaces in building design.

1.2 Means of Achievement

- By the application of the internationally agreed *100 mm module* to the sizing of building components, installations and service systems and to the design of buildings.
- By the development of an agreed *terminology* which will be sufficient to ensure that the range of concepts which comprise the principles of modular co-ordination, can be fully described, communicated and applied.
- By stating a set of *interrelated concepts,* which comprise the general principles of modular co-ordination, and which can be applied comprehensively or partially, depending upon the particular circumstances.
- By developing an agreed *set of conventions* which makes possible the practical application of the relevant concepts in design, manufacture and construction.

1.3 Benefits

The application of modular co-ordination can yield a range of practical benefits, among which the following are af major significance:

1) Reducing waste by eliminating cutting to fit on site, as far as practicable.
2) Improving productivity through:
   - increasing use of standard modular components
   - reducing the number of dimensionally imcompatible components
   - providing for ease of fit and assembly
3) Effecting economy in distribution of components.
4) Improving communication and efficiency by providing a common dimensional "language".
5) Providing the potential of interchangeability which allows a creative response to client and user requirements and reduction of maintenance costs.
6) Contributing to design freedom in the use of standardized components.
7) Providing a context for the systematic consideration of joint design enabling the range of size of components to be predicted and thus make it possible to obtain improved performance.
8) Achieving improved quality of construction by the combination of industrial production of components, application of a design discipline and improved communication.

The list does not imply a hierarchy of benefits and indeed, the significance of any particular benefit or group of benefits will vary depending upon whether they are viewed from the standpoint of the designer, manufacturer, builder or user. Other factors which can affect the achievement of benefits in application include the nature and size of projects.

2.0 Field of Application

Modular co-ordination may be applied to the design, manufacture and assembly of buildings, their components and installations, and it affects the twin factors of position and dimension. For each participant in the building team, it can allow a relative independence in decision making within the common dimensional language.
Therefore, wherever it is necessary to position and size components and to ensure their fit with a minimum of on-site modification and materials wastage, modular co-ordination will be found to be essential.
Modular co-ordination may be applied to a wide range of building technologies, ranging from component building through partial prefabrication to rationalized traditional building methods. Additionally, components which are co-ordinated on a modular basis may be used in renovation programmes.

3.0 Terminology

In order to ensure that the concepts of modular co-ordination find clear and unambiguous expression in practice, the following glossaries of terms have been agreed within the International Organization for Standardization (ISO):
ISO 1791 - 1973 - Modular Co-ordination, Vocabulary, with two further publications of the International Organization for Standardization: ISO 1803 - 1973, Tolerances for Building, Vocabulary, and ISO 2444 - 1974, Joints in Building, Vocabulary.
However, a basic terminology for modular co-ordination has been accepted by CIB W24/IMG as providing the necessary and sufficient set of terms to cover the field of modular co-ordination only, excluding those terms relative to tolerances and joints and other related subjects.

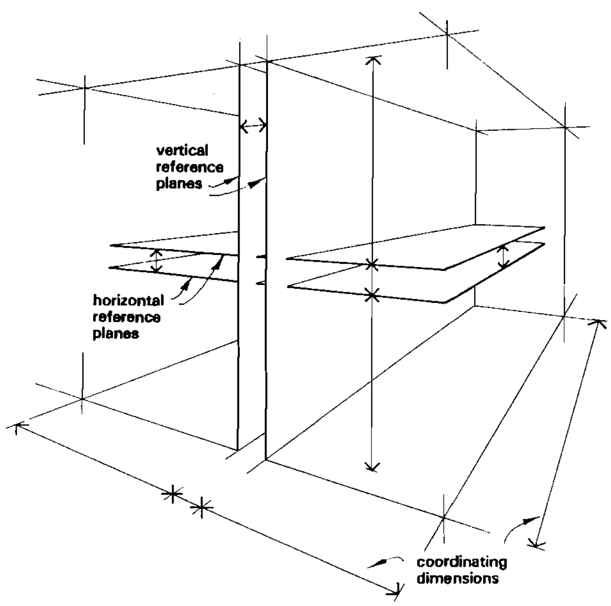


Figure 1. Dimensional co-ordination – the spatial reference system.

1) Size	Magnitude of a dimension in terms of a defined unit.
2) Module	Standard unit of *size* used to co-ordinate the dimensions of buildings and components.
3) Basic Module	*Module* of 100 mm.
4) Modular (Co-ordinating) Size	*Size* which is a multiple of the *basic module.*
5) Multi-module	*Module* that is a selected multiple of the *basic module.*
6) Infra-modular Size	*Size* smaller than the *basic module.*
7) Component	Building product formed as a distinct unit having specified *sizes* in three dimensions.
8) Modular Component	*Component* that has *modular co-ordinating sizes.*
9) Reference System	System of points, lines and planes to which the *sizes* and positions of a component, an assembly, or an element may be related.
10) Modular Reference System	Rectangular co-ordinate *reference system* in which the distance between consecutive planes is the *basic module* or a *multi-module.* This *multi-module* may differ for each of the three dimensions of the space grid.
11) Modular Co-ordination	Method of sizing the dimensions of a building and of positioning and sizing *components* on the basis of a *modular reference system.*

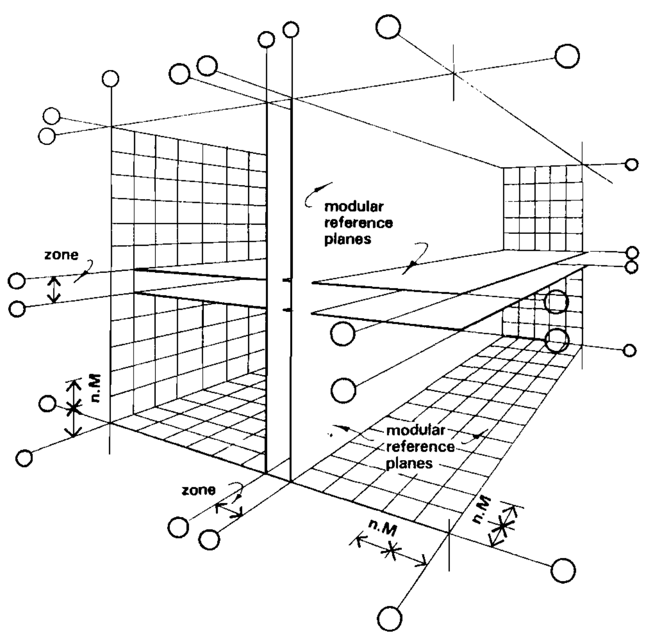


Figure 2. Modular co-ordination – the modular reference system.

4.0 Rationalization of the Building Process - General Concepts

Modular co-ordination may be more readily understood as one of a range of general concepts which relate to the rationalization of the building process. The following list outlines such a range:

4.1 Dimensional Co-ordination

A convention for the co-ordination of the dimensions of building components and the buildings incorporating them, for their design, manufacture and assembly (figure 1).

4.2 The Spatial Reference System

A three-dimensional system of points, lines and planes to which the position and size of a component, assembly or element may be related.

4.3 The Basic Module

The fundamental module used in modular co-ordination, the size of which is selected for general application to buildings and components.

4.4 Modular Co-ordination
Dimensional co-ordination employing the basic module or some whole multiple thereof.

4.5 The Modular Reference System
A three dimensional system of points, lines and planes in which the dimensional increment is the basic module or some whole multiple thereof (figure 2).

4.6 Building Fit and Tolerance
The dimensional relationship between a component and the space intended to accommodate it with due regard to the practical limits within which the size and position of each should lie.

4.7 Standardization
A co-operative undertaking, the aim of which is to achieve agreements on any particular aspect of building work; where appropriate the application of the notion of different levels of standards moving progressively from the most general, i.e. agreed principles, to the more specific, i.e. component standards.

4.8 The Performance Concept
The performance concept proposes the definition, in quantitative terms where feasible, of the behaviour related to use of buildings, parts of buildings or spaces, including consideration of dimensions, geometry and tolerances.

5.0 The Concept of Modular Co-ordination

5.1 Basic Module
The basic module is the fundamental unit of size in modular co-ordination. The value of the basic module is 100 mm and it may be represented by the letter M. The basic module is considered to be large enough to effect some variety reduction in ranges of component sizes and small enough to provide a flexible unit of measure for the purposes of design. The basic module is the smallest module to be used for design in a three-dimensional modular reference system.

5.2 Multi-modules
A multi-module is a module the size of which is a selected whole simple multiple of the basic module. Multi-modules are generally chosen for particular application, e.g.
- Determining spans and room sizes
- Determining storey and room heights
- Determining sizes for components and spaces

5.3 Sub-multiples of the Basic Module
Certain sub-multiples of the basic module which are whole simple fractions may be used where there is a clear need for an increment smaller than 1M (100 mm). This may arise when determining the sizes of modular components which require increments smaller than 1M (100 m) to fulfil specific performance needs. Within the CIB W24/IMG and a working group of Technical Committee 59 of ISO the concept of "inter-modular Sizes" has been put forward.
An "inter-modular size" is defined as a non-modular size which arises from the combination of a modular size and a supplementary size. It is suggested that such supplementary sizes be based upon sub-multiples of the basic module.
This implies that practical design decisions can be facilitated by standardizing such supplementary sizes and ensuring in practice that, within a modular reference system, these sizes are selected so as to form 1M increments when used in combination.
The concept provides a rationale for sensibly dealing with adaptation spaces, so called, i.e. where non-modular floor and wall constructions are located within modular zones and also resolving the question whether to locate the storey height reference plane at finished floor level or at the structural slab level.

5.4 The Modular Reference System
In modular co-ordination by the term modular reference system is meant the three-dimensional system of orthogonal space co-ordinates within which the positions and sizes of components, elements and installations can be related by reference to points, lines or planes. Within this reference system dimensional increments are in terms of the basic module (100 mm) or some multiple thereof.
Buildings comprise elements of construction which are either loadbearing or non-loadbearing and which include an external envelope and horizontal and vertical elements which sub-divide the enclosed space.
The modular reference system enables designers to relate sensibly these main elements of construction and the intervening space.
Certain essential reference planes can be identified which locate the main vertical and horizontal elements of construction, e.g. floor, walls and columns. These planes delimit the modular height, length and width dimensions of built spaces whether the spaces are, for example, activity spaces or zones to be occupied by the building fabric (figure 3).
A zone in this context is a modular or non-modular space between reference planes which is provided for a component or group of components which do not necessarily fill the space, or which may be left empty (figures 4a and 4b).
At the design stage of projects the modular reference system may be represented on drawings by means of two-dimensional modular grids which are applied in plan and section.
The dimensional increments of such grids are, as already stated, the basic module or some multiple thereof.

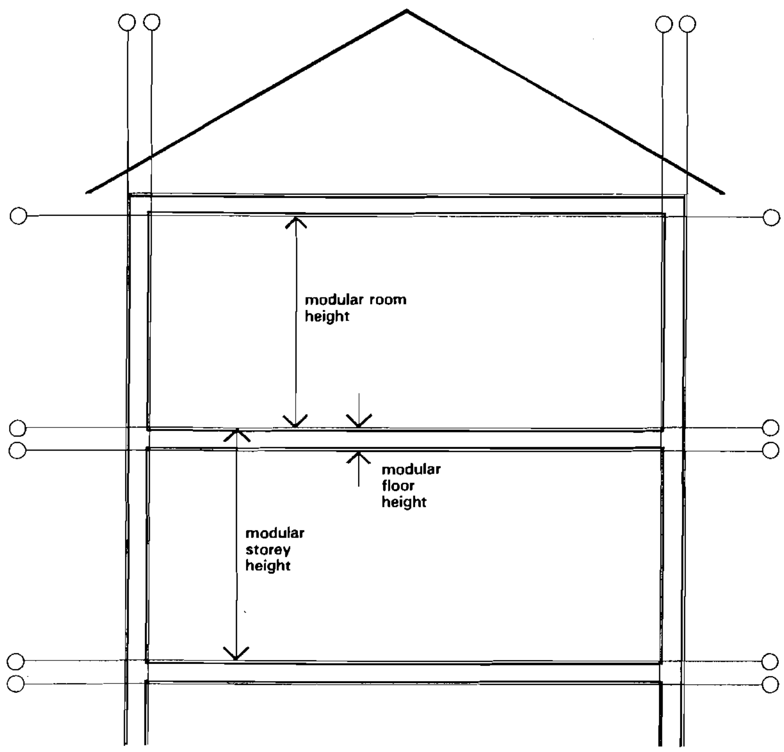


Figure 3. Locating the main elements by means of a modular reference system.

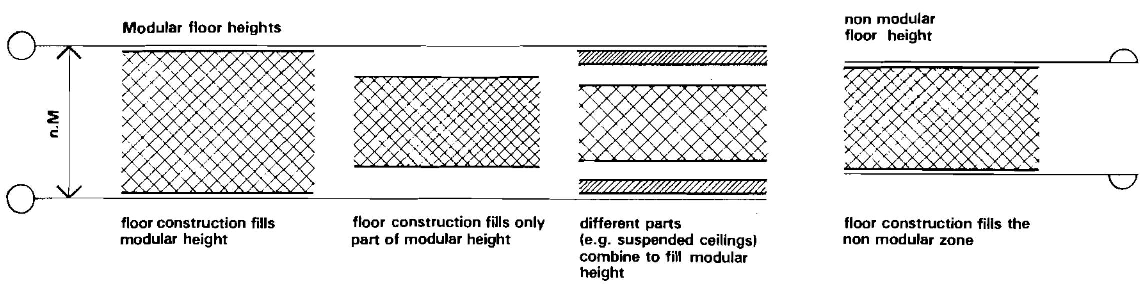


Figure 4a. Floor zone - vertical section.

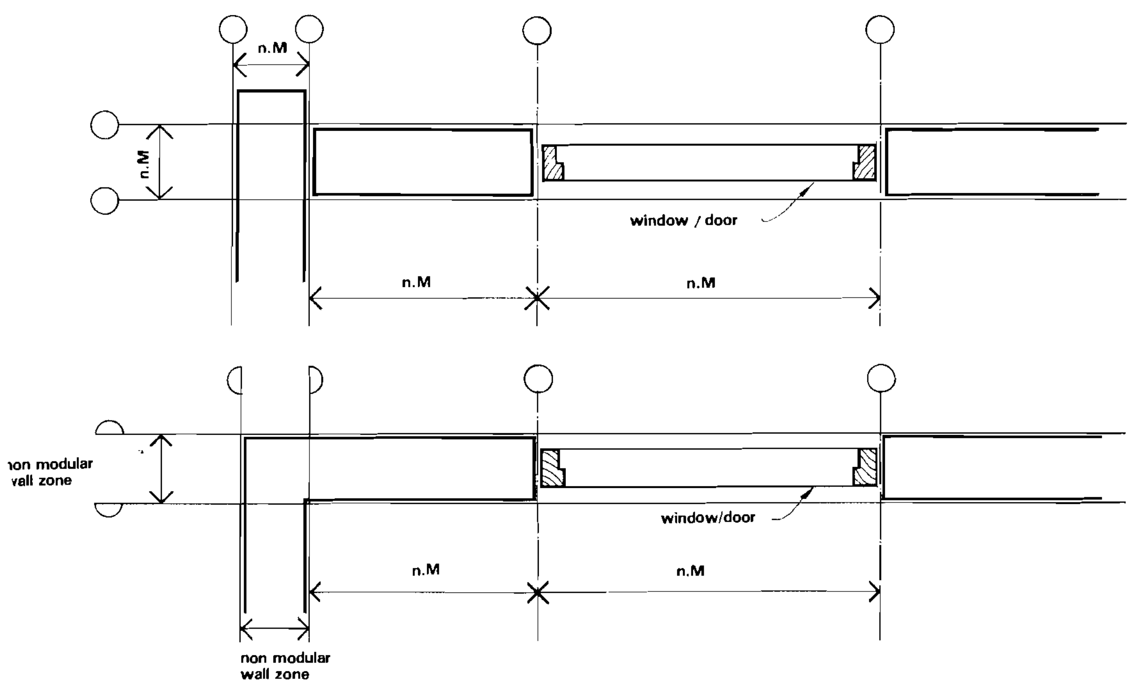


Figure 4b. Wall zone - horizontal section.

The increment may differ for each of the two-dimensions of the grid. In practice grids may be used as a comprehensive planning tool, but equally, planning may proceed on the basis of selecting a few essential reference planes. Where for economic or other reasons it is necessary to accommodate non-modular components within a modular space, additional grid lines may be used if considered necessary to represent the co-ordinated reference planes of such components and facilitate their effective co-ordination within the modular reference system (figures 5a and 5b). This assists the determination of the position and size of adaptation spaces or make-up pieces where these are required.

In the application of modular co-ordination, as in any system of dimensional co-ordination, the assembly sequence for component systems and installations is a crucial factor in the achievement of efficient construction. It may, therefore, be helpful to distinguish between sequential systems in a design by means of a distinguishing mark or graphic convention.

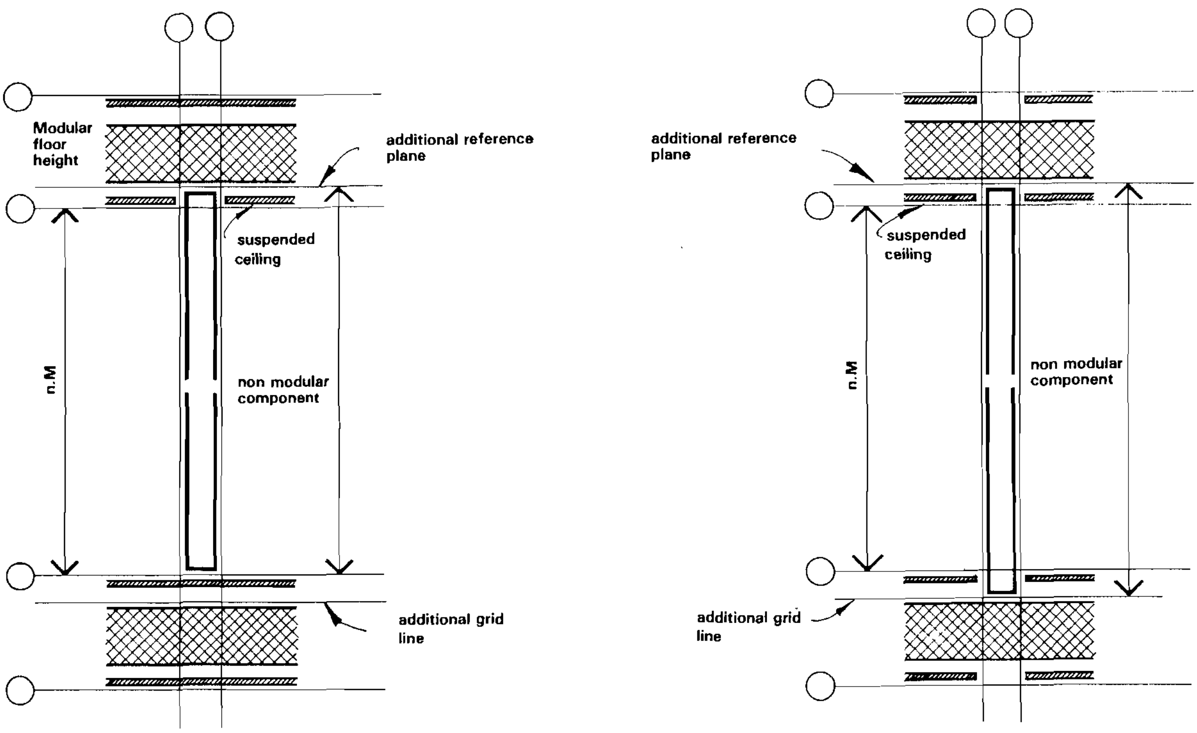


Figure 5a. Use of additional grid lines – modular floor height.

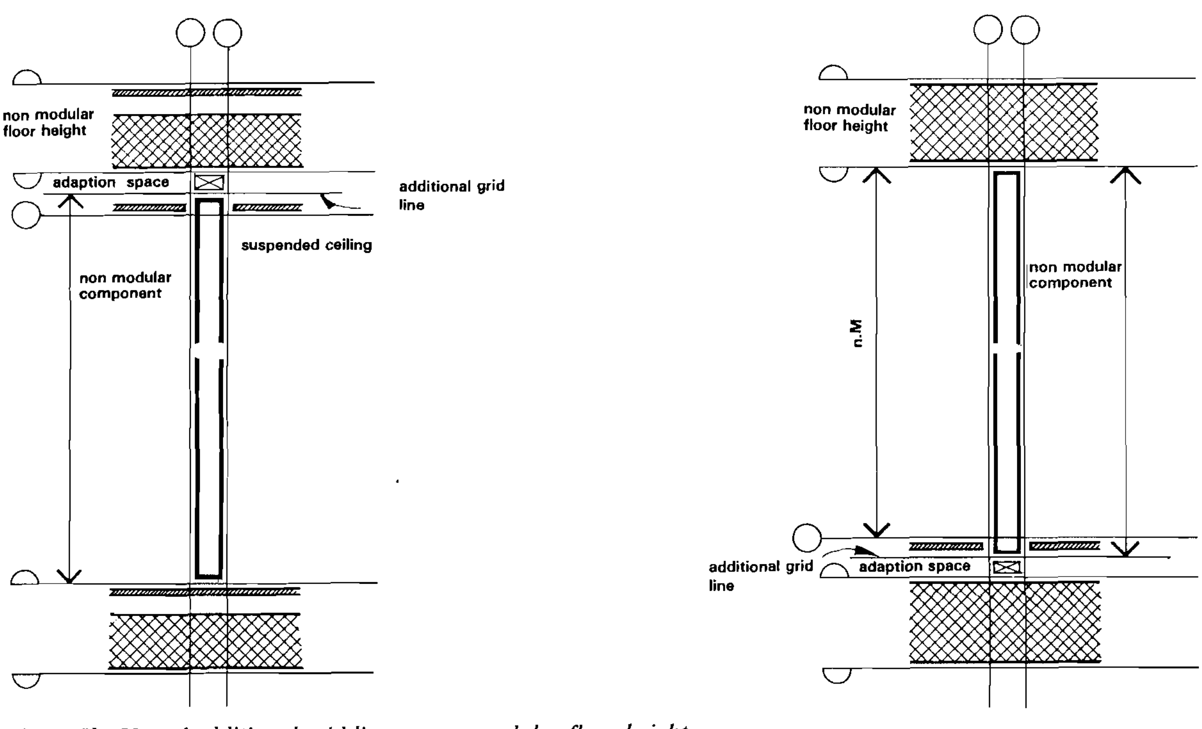


Figure 5b. Use of additional grid lines – non modular floor height.

In the text and diagrams which follow, under the headings of horizontal and vertical co-ordination, the application of modular grids is explained and illustrated by means of examples which reflect broadly accepted current practice.

5.4.1 Horizontal Co-ordination

Traditionally, modular theory has distinguished between boundary (or face) planning and axial (or centre line) planning. In practice, however, such a clear-cut distinction may not exist.

The modular grid constitutes the fundamental planning reference. Boundary planning is the first preference for positioning components and elements of construction in relation to such grids (figure 6). Boundary planning determines both the position and size of components and elements of construction. Centre line (or axial) planning normally only determines the position of certain components, e.g. columns, cross walls (figure 7). Boundary planning may be combined with axial planning, e.g. for positioning structural elements (figure 8).

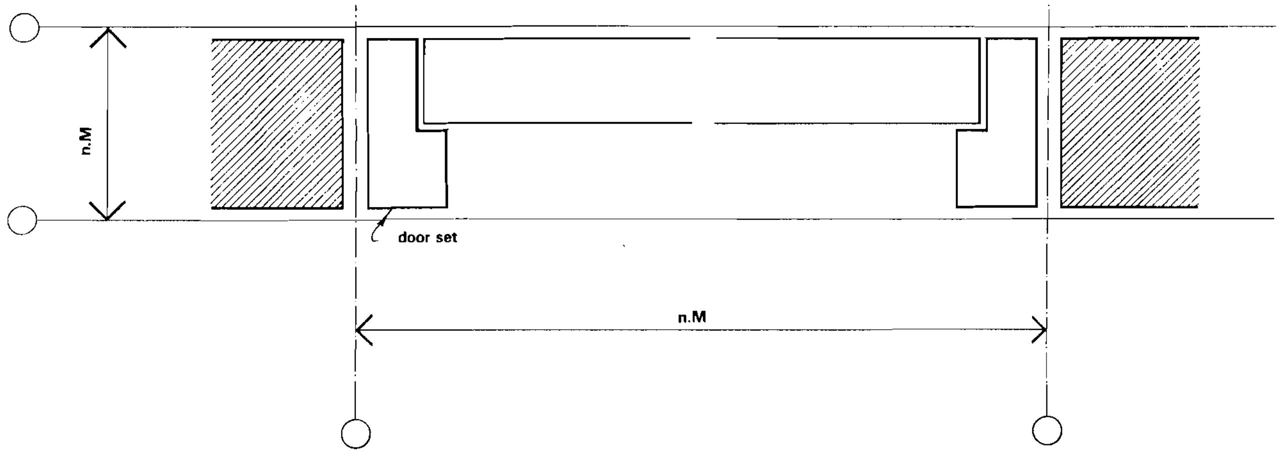


Figure 6. Modular co-ordination - component location.

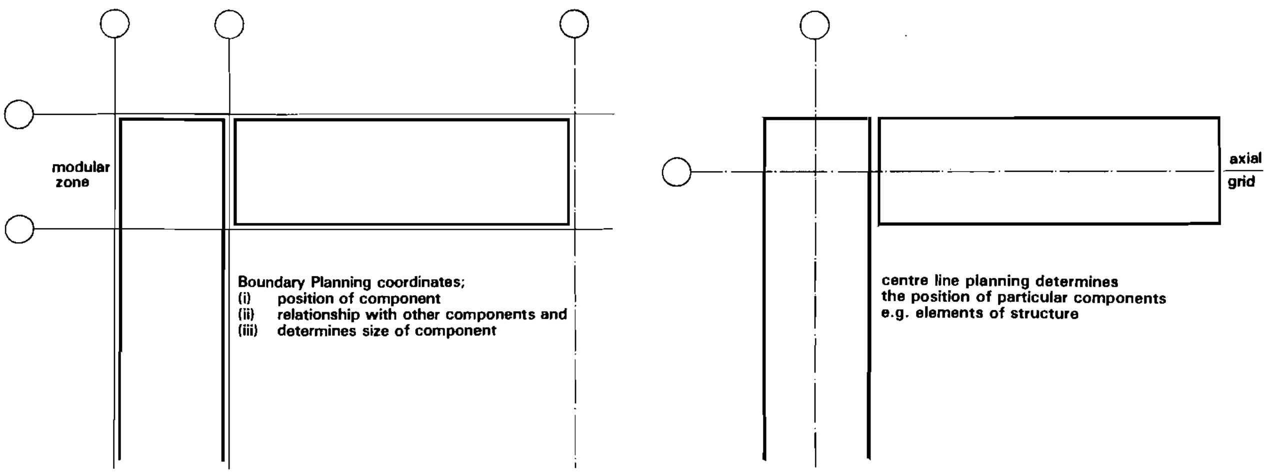


Figure 7. Modular co-ordination - Boundary Planning. *Centre Line Planning.*

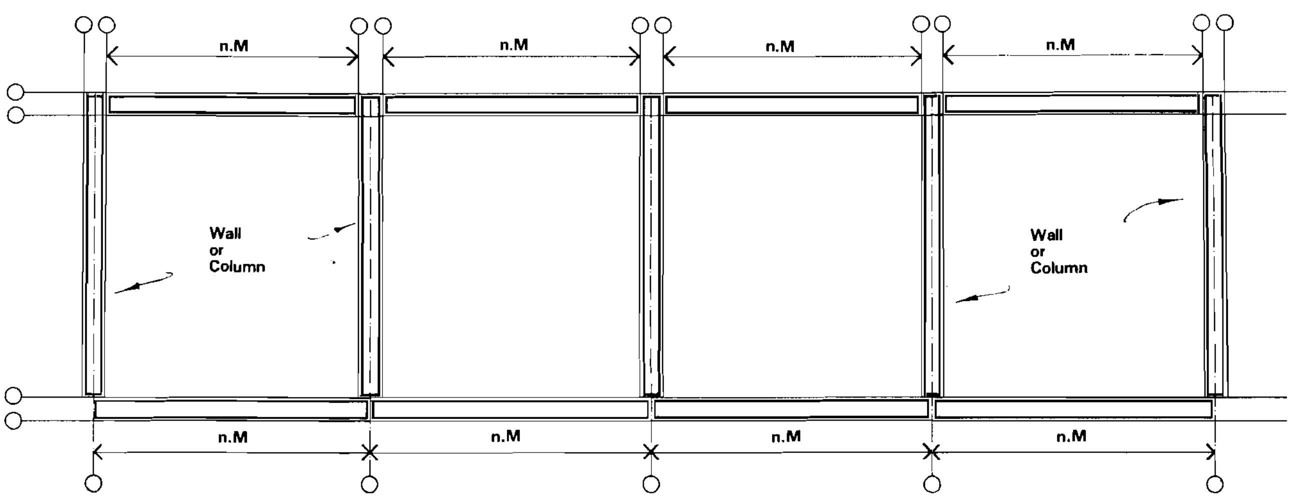


Figure 8. Centre line and boundary planning.

5.4.2 Basic Modular Grid

The fundamental modular grid is that in which the intervals between consecutive parallel lines is equal to the basic module. This is the smallest planning grid used in modular co-ordination and is used as the basis for developing other grids (figure 9a). The basic modular grid is normally shown only on large-scale drawings to clarify the interrelationships between components.

5.4.3 Multi-modular Grid

In addition to the basic modular grid, multi-modular grids, in which the interval between consecutive lines is a multi-module, may be used (figure 9b). This multi-module may differ for each of the two directions of the grid (figure 9c). Multi-modular planning grids are based upon selected multiples of the basic module adopted for specific applications. Such grids are used to determine the layout of building complexes, buildings and/or the position of main structural features, and to ensure consistent co-ordination of components in relation to the user/activity space they enclose. These grids, most frequently used in the early design stages, are normally used on small-scale general location drawings.

Modular grids should preferably be continuous, i.e. extend without interruption over the whole of a building plan or complex. Interrupted grids, i.e. grids of regular modular or multi-modular intervals which are interrupted at coherent intervals by bands of different modular dimension or in certain cases non-modular dimension are, however, commonly encountered in practice. The occurrence of movement joints can also create an interruption of the modular planning grids. Modular grids may be superimposed, one upon another at various stages of the planning process, and in certain circumstances may be displaced in relation one to another (figure 9d).

5.4.4 Tartan Grid

The term tartan grid is used to describe an interrupted modular planning grid in which the intervals or bands of interruption are regularly spaced in both directions, and are of different modular order to the general modular planning grid (figure 9e).

5.4.5 Vertical Co-ordination

In the vertical section the modular floor plane is the reference plane from which modular dimensions are taken (figure 10a).

The modular floor plane is defined in general as: A horizontal modular plane continuous over the whole of each storey of a building and coinciding with the upper surface of the floor covering, the upper surface of the rough floor, or the upper surface of the structural floor (figure 10b). Additional grid lines may assist the co-ordination of a floor construction with partitions or external walling by facilitating the positioning and sizing of adaptation pieces where these are necessary (figure 10c).

Normally only the main modular reference planes delimiting the zones containing external envelope and the internal elements of construction which subdivide the building, horizontally and vertically, are identified on drawings of vertical sections, e.g. Modular Storey Height; Modular Room Height; and Modular Floor Height.

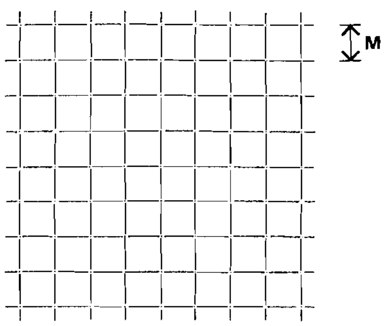


Figure 9a.

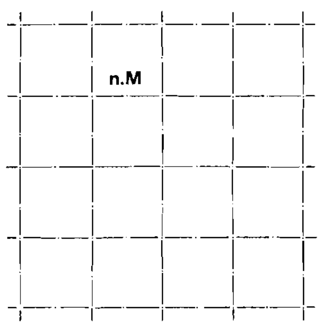


Figure 9b.

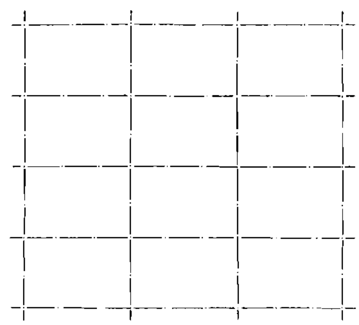


Figure 9c.

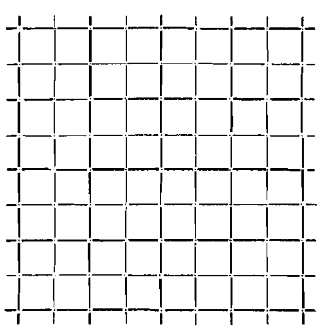


Figure 9d.

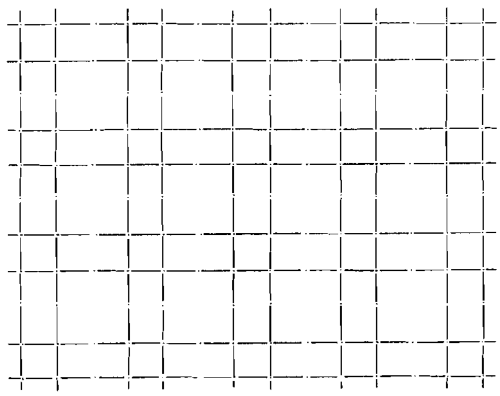


Figure 9e.

Figures 9a–9e. Grids.

Additionally, the modular heights of doorsets, window heads and window sills, are important.
Grid lines representing the modular reference planes define the co-ordinating spaces of components and elements, and such spaces are deemed to include allowances for deviations and joint clearances.
Since the modular grid is essentially a design tool, it need not necessarily appear on the drawings which are part of the production information.
However, where grids as such are dispensed with it will be important to select certain modular reference planes as the basis for dimensioning drawings of a project and positioning components on site. In such cases care should be taken to ensure that the builder's setting out system is effectively related to the reference planes chosen.
In addition, care should be exercised in marking dimensions on drawings to clearly distinguish between modular dimensions and basic sizes (work sizes) expressed in millimetres or metres.

5.5 Preferred Sizes

A preferred size is a modular or multi-modular size which is selected in advance of others.
The selection should be made for specific purposes.
Preferred multi-modular sizes are primarily intended for sizing components, assemblies and spaces.
If the advantage of variety reduction is to accrue in ranges of components as a result of modular co-ordination, then a careful consideration of the numerical basis upon which series of preferred sizes are founded becomes necessary.
Traditionally, designers have tended to use simple whole number ratios, e.g. halving, doubling, tripling, to express relationships in sets of dimensions. It is also true that irrational ratios, e.g. $1{:}\sqrt{2}$, $1{:}\sqrt{3}$ have been chosen on occasion.
Modular co-ordination provides a sound basis for an ordered selection of dimensions and accommodates a proportional flexibility that satisfies the needs of architectural aesthetics.
Much consideration has been given to the nature of preferred systems of modular dimensions and some general characteristics have been defined such as:

1) All dimensions should be whole multiples of M (100 mm).
2) All dimensions in the system should be divisible by the greatest posssible number of smaller dimensions.
3) All dimensions should be obtained by multiplication or addition of the smaller dimensions, and
4) The smaller dimensions should be more densely distributed than the larger.

A large number of systems have been proposed as the basis for selecting preferred sizes among which can be listed (figure 11):

(I) The EPA system (1956)
(II) The COMECON system (1960)
(III) The Japanese system (1966), and
(IV) The Draft Proposal of ISO (1977)

All the systems share the same objective of providing a flexible method for the choice of preferred multi-modular dimensions in line with the characteristics which mark conventional dimensional practice in building and to which reference has been made earlier. Normally, the preference is for smaller dimensional increments in the vertical plane than is the case in the horizontal.
It is possible, by a careful selection of a set of modular component sizes, to use them in combination to fill spaces of almost any modular dimension. The degree of flexibility which results in a particular case depends upon the particular modular sizes selected and the number of sizes used.
Where sizes in a set of modular components share a common factor, e.g. 3M and 6M, then only the spaces which are a multiple of that common factor (3M) can be filled, i.e. 9M, 12M, 18M.
Where the component sizes do not share a common factor, they can be combined beyond a certain point to fill all multiples of 1M. The point in question is referred to as the critical number. Thus, if components 3M and 4M long are selected, they can be combined to fill all spaces that are multiples of 1M from 6M upwards.
The following formulae may be used to dertermine the critical number (CN) for (a) pairs of component sizes and (b) triplets of components with sizes which are consecutive multiples of M.

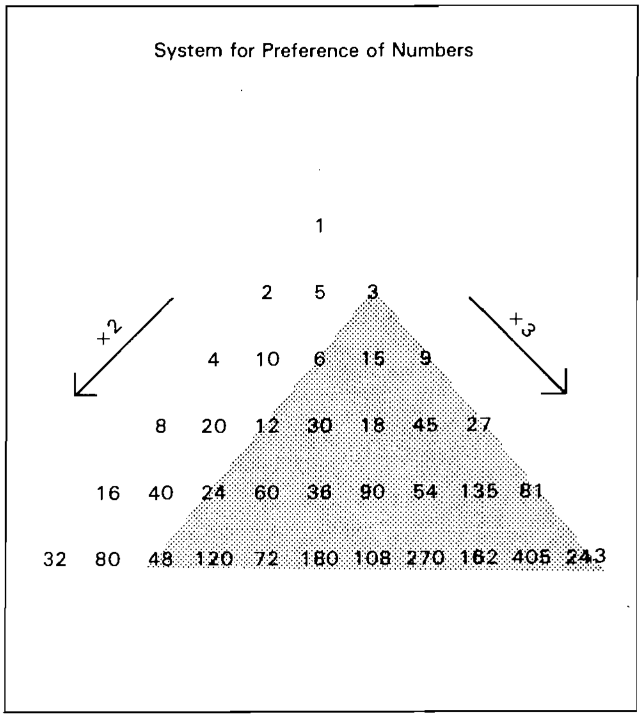
(a) $CN = (a-1)\,(b-1)$
(b) $CN = a^2/2$
where a is the smallest size and is an even number, and
$CN = a(a-1)/2$
where a is the smallest size and is an odd number.

The numerical basis for the selection of preferred sizes or the mathematical techniques for combining component sizes should be seen as a tool subordinate to the functional requirements.
The use of surveys of dimensional usage and of existing component sizes can provide a rational basis for the identification of preferred modular increments which may be related to particular element groups.

6.0 Sizing Modular Components and Joints

6.1 Co-ordinating Size

In component building design the application of the spatial 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.
The reference system enables designers to relate the position and size of components by means of reference planes. Such co-ordinating planes form the boundaries of component spaces which include allowances for inaccuracy and joint clearances.
It is important to stress the essential theoretic nature of

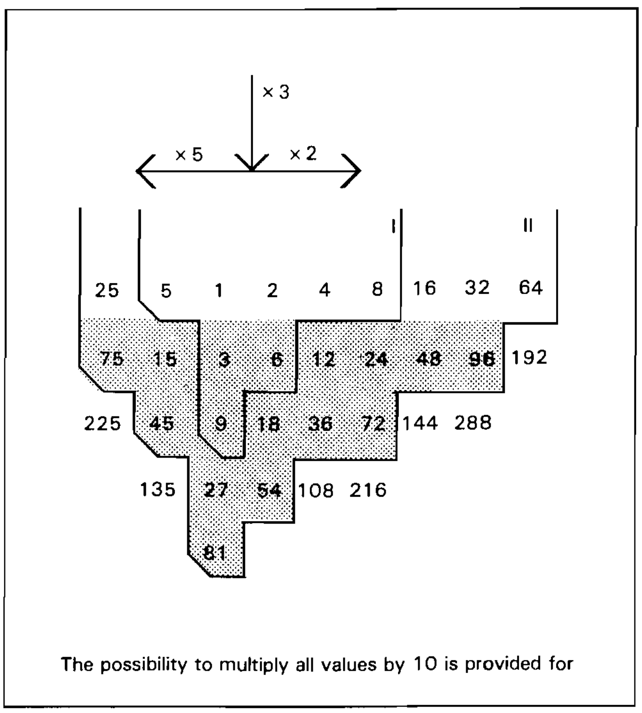


(i) EPA System (1956)

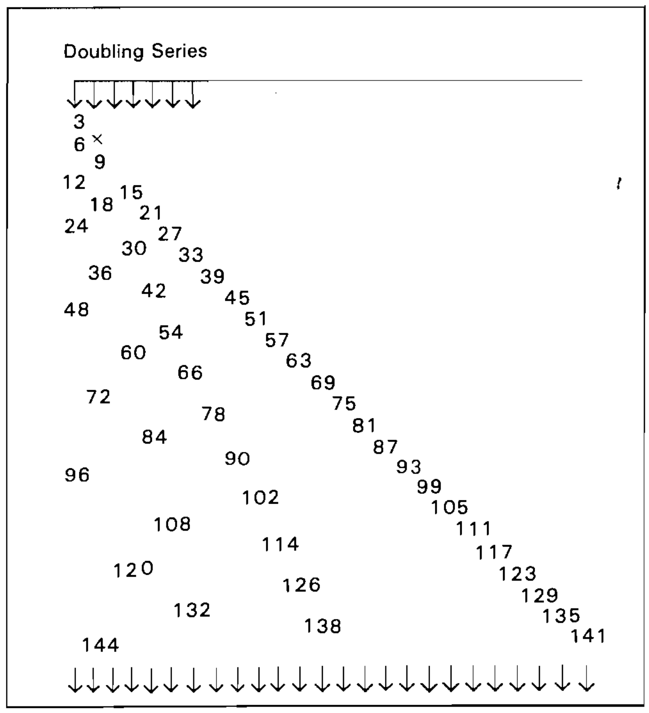
Sizes for Horizontal Dimensions

multiple of multimodules	within the range of up to
3M	36M/72M
6M	72M
12M	72M
15M	120M
30M	180M/240M
60M	

(ii) Comecon System (1960)



(iii) Japanese System (1966)



(iv) draft proposal ISO (1977)

Figure 11. Examples of preferred number systems.

such dimensions in the context of building component manufacture.

As well as providing for the co-ordination of length, width and thickness dimensions of components, dimensional co-ordination provides the means for the co-ordination of the internal dimensions of components. By this is meant the facility to ensure dimensional compatibility between the position of different materials' sub-systems comprising a component and the positioning and dimensioning of any functional sub-systems, e.g. for the integration of services systems.

6.2 Modular Size

All that follows on sizing components and joints is true for any application of dimensional co-ordination in component building design. Much of contemporary building practice involves a high degree of such dimensional co-ordination.

In modular design practice, however, the co-ordinating spaces will, by definition, be determined by co-ordinating dimensions which are modular. As in the case of all co-ordinating dimensions, modular co-ordinating dimensions include allowances for tolerances and joint clearances.

In providing the common dimensional language modular co-ordination becomes the medium through which those benefits affecting the design, manufacture and construction processes can accrue.

6.3 Deductions from Modular Size

Modular sizes provide the basis for determining the manufacturing sizes of components.

Deductions from the modular sizes have to be made to accommodate an allowance for joints and for the dimensional deviations that occur in production and erection (figure 12).

The crucial question that arises for designers and for manufacturers relates to the order of magnitude of these deductions.

This will be determined in particular cases by the nature of the construction process, the performance characteristics of the components being joined, the requirements of joint design, and finally, the specified limits of permitted deviation relating to manufacture, erection and setting out.

All these matters are relevant to determining the size of a component, i.e. the size by reference to which the permitted limits of size are expressed by permitted deviations. Evaluation of component size, therefore, is inseparable from the problems of joints and the problems of dimensional deviation in building and manufacture.

6.4 Joint Standardization

The concept of joint may be defined as follows: A detail in a construction formed by the adjacent parts of two or more building products, e.g. the putting together of components, with or without the use of a jointing product.

Although there are, as yet, no ready-made standard solutions to the problems of joints, there exists a body of information which facilitates the systematic appraisal of joint design in a coherent manner, and avoidance of the proliferation of unconnected ad hoc proposals for standardization.

This, however, is not to say that all characteristics of joints are equally suited, or indeed necessary, for standardization. Early notions of a universal interchangeability of components as commonly interpreted has not proved practicable. Some more limited interchangeability is feasible within certain element groups, but depends upon a degree of joint standardization.

6.5 Terminology for Joints

The terminology for joints, agreed within the International Organization for Standardization is set out in:

ISO 2444 - Joints in Building - Vocabulary

Design principles are set out in:

ISO 2445 - Joints in Building; Fundamental Principles for Design, and

ISO 3447 - Joints in Building; General Checklist of Joint Functions.

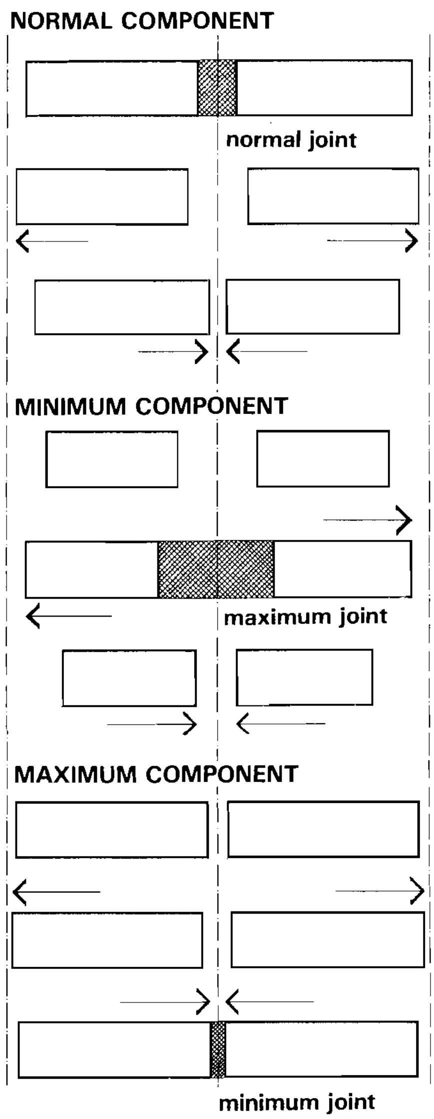


Figure 12. Deriving joint size.

6.6 Joint Characteristics

CIB Report No. 36, Geometry of Joints (2nd revised edition), produced by CIB W24/IMG, provides an essential state of the art review of jointing and elaborates on many crucial aspects of the interdependence of joint size and component size.

Certain intrinsic characteristics of joints affect their performance. Among these are (figure 13):

(a) the gap
(b) the profiles of the components joined, and
(c) the jointing product

The geometry of a component should be such - despite inaccuracies in manufacture and assembly and movement in use - that within the resulting range of joint dimension, the jointing method will function satisfactorily.

Of assistance also in relation to component sizing and joint design is the development of a convention which assists the identification of key junctions in particular building designs.

Such a convention has obvious value in the development of building systems and sub-systems, in identifying generic groups of joints and extending the range of applicability of particular components.

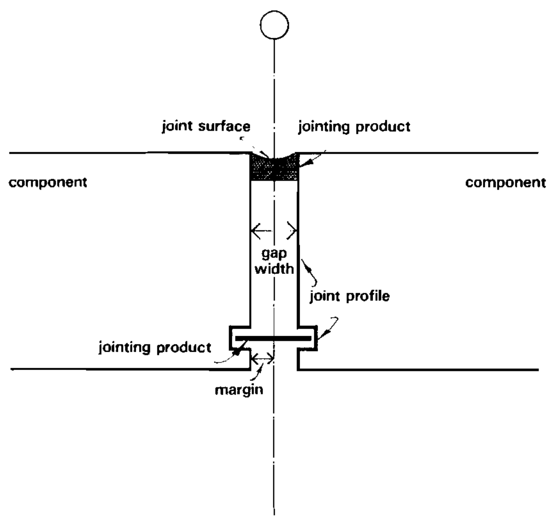


Figure 13. Joint terminology.

6.7 Joint Location

Modular co-ordination provides within its reference systems an effective means for identifying the position of component joints. The performance of a building element depends upon the performance of its components and their joints taken together. The performance of joints is related to their position in a building. Joints between adjacent building components are described in relation to their relevant modular reference plane.

The facility to identify joint and component position is valuable in appraising the performance of design details, particularly at node points, i.e. at the intersections of horizontal and vertical elements of construction. In addition to general functional requirements the possibility and effect of component substitution throughout a design can be speedily examined.

6.8 Assembly Conditions

Components or elements may have to extend beyond the reference plane bounding their modular space, or fall short of one or other such reference plane in order to meet a specific performance need.

Such modifications of the component size create boundary conditions which may be catered for by increasing or reducing the component size by an increment or decrement which can be modular or sub-modular (figure 14).

Interchangeability of components is best served where the components are of modular size only. Use of submodular increments to satisfy boundary conditions can limit the applicability of a particular component.

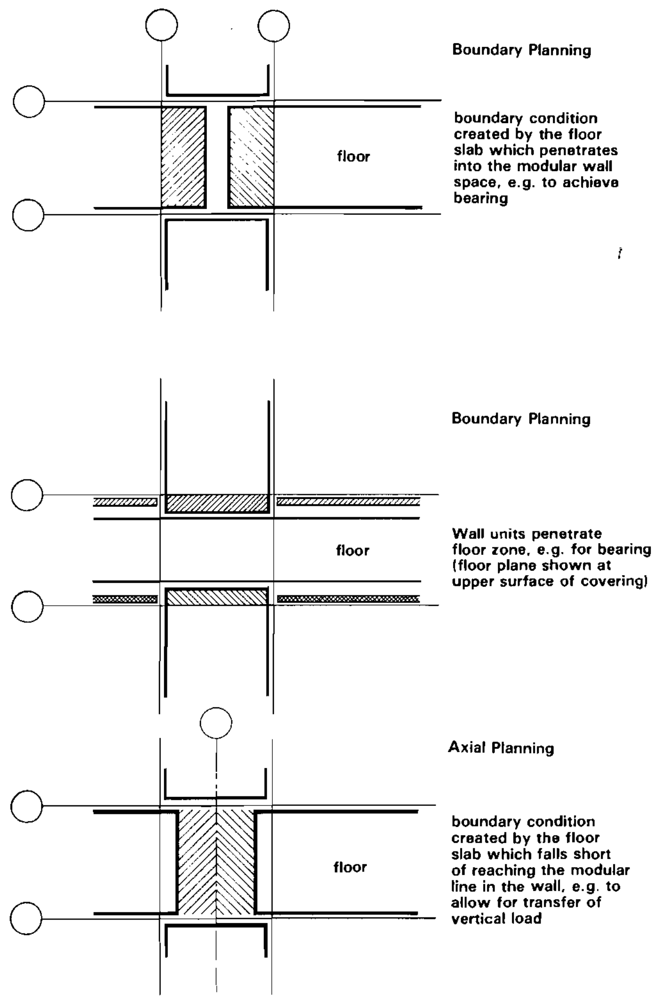


Figure 14. Assembly conditions.

7.0 Building Fit and Tolerance

7.1 Building Fit

The following sections are relevant in the context of dimensional co-ordination generally, and are, similarly, of primary importance in the implementation of modular co-ordination.

Modular dimensions provide a convenient means of describing components in catalogues and for allocating spaces for them on design drawings. Additionally, they provide, as earlier stated, the basis for determining the manufacturing dimensions of components.

Deductions which must be made from the modular dimensions include an allowance for the joints and for aspects of inaccuracy likely to occur in production and erection together with allowances for those inherent characteristics of components which may result in a change in dimension or shape.

The resolution of the interaction between the dimensional demands of effective joint function and the constraints of inaccuracy, so as to achieve joints in accord with satisfactory performance, is what is to be understood by the term Building Fit.

In traditional building practice the builder read the construction drawings and made allowances for fitting and jointing materials between adjacent components as seemed reasonable in the light of his knowledge and experience.

There was no formal specification of permissible deviation, and cutting and shaping to achieve fit was accepted as normal. The capacity to cater for inaccuracy was implicit in the traditional craft process.

Contemporary construction techniques and the increasing use of factory produced, pre-finished components, has necessitated the development of a systematic approach to the problems of inaccuracy. That which was implicit in the traditional craft process must be made explicit in the contemporary industrialized process.

7.2 Inaccuracy

Inaccuracy resulting from a wide variety of dimensional deviation has been observed to conform, in a significant number of cases, to what is known as a Normal or Gaussian distribution curve (figure 15).

This makes available a mathematical tool which can be used to predict the likely occurrence of any level of deviation.

Such a probabilistic approach to the consideration of dimensional deviation has now generally superseded the deterministic approach which assumed the simultaneous occurrence of all specified permitted deviations and often summed these arithmetically.

7.3 Tolerances

The term Tolerance has been subject to a variety of definitions and interpretations. In the present context Tolerance is taken to describe the sum, irrespective of sign, of the agreed limits of permitted deviation for a particular aspect of dimensional deviation.

Dimensional deviations are of two basic kinds - induced deviations and inherent deviations.

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

Inherent deviations are those which result from the response of materials, components and elements, to changes in their environment (loading, temperature, etc.). Such deviations may be reversible or irreversible, and since certain base line conditions, e.g. age, temperature and humidity, will have been assumed when sizes were fixed, these deviations can in general be estimated with an acceptable degree of accuracy.

A coherent system of tolerance, applicable to building components and spaces, is an integral part of the theory of modular co-ordination, as limits to dimensional deviation must be agreed to provide an effective key which links theory and practice.

7.4 Terminology for Tolerances

The terminology pertaining to the area of tolerances is available in the following:

- CIB Report No. 28 - A checklist for tolerances.
- CIB Report No. 67 - Dimensional tolerances, guidelines.
- ISO 1803:1973 - Tolerances for Building - Vocabulary.
- ISO 4463:1979 - Measurement Methods for Building - Setting Out and Measurement - Permissible Measuring Deviations.
- ISO 3443/1:1979 - Tolerances for Building - Part 1: Basic Principles for Evaluation and Specification.
- ISO 3443/2:1979 - Tolerances for Building - Part 2: Statistical Basis for Predicting Fit Between Components having a Normal Distribution of Sizes.

7.5 Joint Clearance and Dimensional Deviation

The basis for dimensional co-ordination and hence modular co-ordination, is the idea of the controlled interconnection of components which are holding station in their reference spaces.

It is frequently in the joints, therefore, between components in an assembly and between an assembly and other

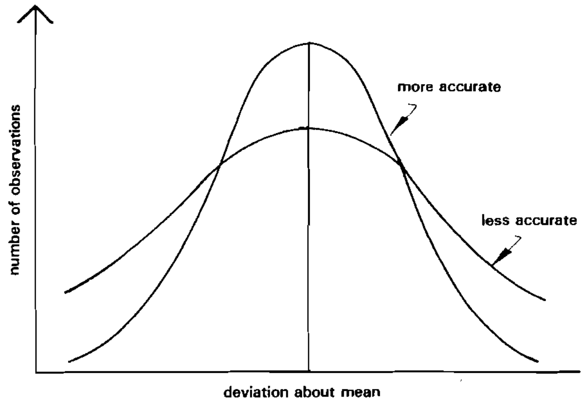


Figure 15. Gaussian distribution curve.

elements of construction that the problems of inaccuracy must be resolved.

Each joint will generally have a minimum clearance or width and a maximum clearance or width (figure 16). This range of joint clearance makes available a space within which, by sensible specification of limits of permitted deviation, a joint may be designed, which will achieve effective performance, within the capacity of the jointing product where relevant, and cater for all aspects of dimensional deviation.

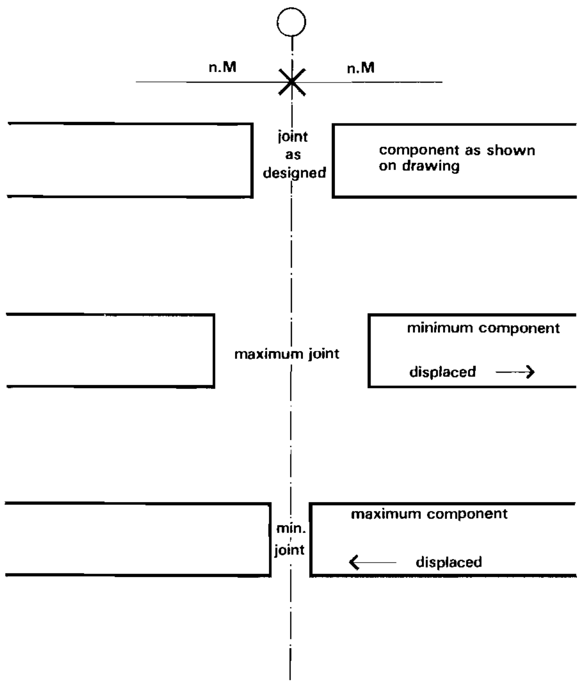


Figure 16. Joint clearance.

7.6 Interaction of Position and Size

It is evident that a range of detailed design decisions has to be made in designing for component building which was not usual in more traditional building processes.

A design may call for a careful positioning of each component within its allocated space or for the positioning of an assembly of components between two significant reference planes. Careful specification of permitted deviations and effective control during erection will enable positioning of the component or components to be achieved within the design conditions.

Where small additive components, such as bricks or blocks, are being used, the assembly of brickwork or blockwork is frequently seen as the "unit" for co-ordination and not the individual brick or block. This acknowledges the capacity of the jointing system to absorb a degree of variation and also the characteristic of cutting units associated with the craft technique.

7.7 Dimensional Variables

In sizing a component and its joints, or in sizing a joint to suit a standard modular component, these variables, which are subject to probability considerations and which must be considered are:

- setting out deviations
- manufacturing deviations
- location deviations

Levels of permitted deviations ascribed to each of these variables may be summed statistically. There is, in addition, a range of parameters which is not subject to probability considerations, and which must be taken into account also:

- modular dimensions
- adaptation spaces
- minimum and maximum joint
- inherent deviations
- geometry of joint profile

7.8 Calculating Deductions

Because there is certainty regarding the occurrence of inherent deviations they 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.

A combination of this total allowance for permitted deviation and an appropriate joint size will normally provide the amount of the total deduction required to be made from the modular size or co-ordinating dimension in order to determine the manufacturing sizes.

7.9 Control of Deviation

Careful consideration of the matters relevant to dimensional specification is vital at an early design stage, but ultimately any dimensional specification will only prove as good as the control system devised to effect its achievement.

The needs of component building and modular co-ordination do not necessarily call for a higher level of accuracy. Special consideration of economic factors is necessary in the cases where a higher degree of accuracy is demanded than that traditionally acceptable in the particular circumstances.

8.0 Draughting Conventions

A modular plane may be represented by a continuous straight line with a circle at the extremity (1).

A modular plane may be distinguished from other co-ordinating planes, e.g. those indicating the finished floor levels or the axial position of the supporting structure, by placing a number or letter within the circle (2) and (3).

A modular plane which indicates the axial position of a component may be represented by a chain dotted line (4).

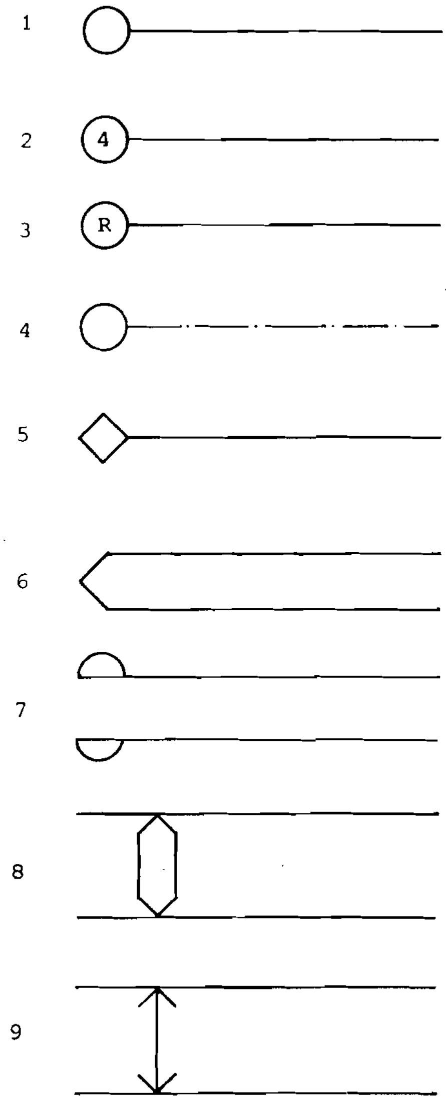
When a modular plane is used as a basis for setting out components it may be represented by a square set diagonally at the extremity of the line (5).

A zone used to accommodate a building element or for use as an activity space may be represented by joining the relevant co-ordinating planes by two oblique strokes at 45° (6).

A non-modular zone may be represented by two straight lines terminating in semi circles (7).

The dimension of a modular space may be represented by a pair of parallel lines closed at each end by oblique strokes at 45° (8).

The modular dimension of a building component may be represented by a straight line with an open arrowhead at each end (9).



In representing a modular reference plane on drawings a chain dot or broken line may be preferred for reasons of clarity. This will normally occur in the case of text books and trade publications.

References

Condensed Principles of Modular Co-ordination. The International Modular Group. 1967/68.

Some Notcs on a Convention for Fixings for Catologue Building. CIB W24/IMG. Document 5-78, 1979.

Some Notes on Geometry of Joints for Catalogue Building. CIB W24/IMG. CIB Report No. 36, second revised edition, 1980.

A Systematic Survey of Key Junctions.
CIB W24/IMG. Report, 1983.

International and National Standards on Dimensional Co-ordination, Modular Co-ordination, Tolerances and Joints in Building. Hans J. Milton; U.S. Department of Commerce/National Bureau of Standards; 1980.

"Task for Rapporteur

The Rapporteur is asked to review and propose additions and changes in the content of the 'Condensed Principles' in order to emphasise the relevance of Modular Co-ordination and its practical application in contemporary building construction throughout the world. In particular, he is asked to include simple statements reflecting recent development in modular co-ordination in international standards in joints, fixings and tolerances, in order to promote the possibility of using components and sub-systems bought from stock, without regard to source, for use in all kinds of construction. The rapporteur must bear in mind the recent worldwide changes in philosophies and interchangeability, in the conservation of resources, and in the consideration of users' requirements."

THE

PRINCIPLES OF MODULAR CO-ORDINATION IN BUILDING