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APPLICATION OF MODULAR CO-ORDINATION IN LOWER-COST HOUSING

by

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SYNOPSIS

There is a world shortage of houses and the Governments are doing their best to produce maximum number of housing units with limited financial resources. To eliminate waste of materials and labour, Modular co-ordination is used in the design of new houses. All building components are placed at the respective positions without undergoing any changes at the site. The thickness of the smallest wall is chosen as the basic module M and is taken as 4 ins. (10 cm.), and all measurements are multiples of this basic module. Chosen components of different sizes could be arranged to have a flexibility of 1M.

The sizes of wall blocks are multiples of M, these sizes being reduced by 3/8 in. to allow for joints. Suitable sizes for horizontal and vertical courses are discussed. The dimensions of doors, windows and lintels to co-ordinate with these courses are considered. Based on experiments elsewhere, ceiling heights are recommended. Standardising of one dimension for all rooms and arrangement of slab components for flexibility of 1M above a critical number are considered.

The Author discusses the advantage in having Modular dimensions for slab, beams, clear span between beams, columns, floor to floor and floor to ceiling.

INTRODUCTION

In the past houses have been constructed by using building components whose sizes vary extensively. For example, bricks, hollow tile blocks, concrete blocks, etc. of different sizes have been used in the construction of walls. The size of door frames and window frames vary from place to place. This resulted in cutting of wall blocks to fit in position at the site. As a result irregular and bad joints have been formed. Roof sheeting and ceiling have been cut at site. There have been cuts in almost every building material used in house building. A wastage of material and labour results in higher cost per unit area of floor space.

There is a world shortage of houses and particularly in developing countries. With the annual increase of population the position is made worse. Various countries have been trying their best to solve the housing problems on a national basis. However, the financial resources in most of the countries is limited and every effort is being made to lower the cost of new houses without in any way curtailing the necessary amenities demanded by the modern society. During the last decade, under the sponsorship of United Nations building Section (1, 2) modular co-ordination has been increasingly used in certain countries in the design of lower-cost houses and flats. The object is to eliminate wastes, cuts of material and fittings and save loss of time. In this sytem all the building components are placed at the respective positions without undergoing any changes at the site. By this process, the cost of material and labour is cut down, and with the saving thus achieved, additional units of dwellings could be provided.

PRINCIPLE OF MODULAR CO-ORDINATION

A small unit of size is chosen as the basic module M and all components and measurements in the house are related to this. This basic module must be small enough to relate all components and measurements to this unit and should be multiples of this basic module. In general, all measurements are nM, where n is a whole number. Sub-modules or portions of basic modules are discouraged in measurements. Thus modular co-ordination is a process of addition and not subtraction. However, sometimes it may be necessary to use 0.5M and 0.25M and this may be allowed if 2n and 4n components are used respectively to cover a particular length or portion of length thus getting multiples of basic module. The basic module M is too small for component sizes. Therefore, to simplify the method of construction, a few numbers of selected component sizes are chosen and these are multiples of M.

The variation of sizes should be cut down to the minimum and it is desirable to work with 2 or 3 different sizes of components of the same kind, while at the same time giving the desired flexibility.

All modular dimensions of the components (viz. walls, slabs, etc.) should be cut down by the joint thickness. Thus the component length plus the joint would give a modular dimension. In this method no cutting is done at site, and every component occupies a predetermined position as decided by architects and engineers.

It should be notes that, in order to satisfy the functional values of a house and also to economise, certain areas could not be of modular size. For example, the height between a sloping roof and the top of a wall would vary and would not be of modular size. In such a case a neutral zone which is not a multiple of the basic module is introduced to tie up modulated components.

BASIC MODULE

There will be no objection to a country choosing the unit of its own basic module. However it has been internationally accepted that 4 ins. (10 cm.) is a suitable unit for a basic module and all measurements for the various building components and dimensions of space should be multiples of this basic module. At present, most of the countries are changing to Metric system and 10 cm. is a suitable unit to be used as a basic module.

DIMENSIONS IN PLAN AND ELEVATION

All internal dimensions of rooms between surfaces of plastered walls should be simple multiples of the basic module M. This principle should apply to measurements in plan and elevation for bedrooms, living rooms, bathrooms, kitchen, corridors, etc and thickness of walls. There would be no difficulty in planning all cupboards so that all external dimensions are modulated.

WALLS

At present, clay bricks, hollow tile blocks and concrete blocks of different sizes are used. The horizontal lengths of blocks is 2M and 3M. 2M is too small except for bricks and the labour cost goes up. The Author recommends the use of blocks of length 3M and 4M, and by a combination of these blocks any dimension could be accommodated, and a flexibility of 1M for all measurements above 6M could be achieved. Section 9 gives a method for obtaining the critical value 6M. In the case of vertical courses 1M, 2M, and 3M have been used at present. The Author recommends standardising the heights (vertical courses) to 2M. This has several advantages when doors, windows, ceiling heights are co-ordinated with wall heights. Obviously there are definite advantages in keeping the total wall height to multiples of 2M. In special circumstances 1M height blocks may be used to tie up with the wall heights if the wall height is not a multiple of 2M. The thickness of the wall blocks should be either 1M or 2M. In some countries 1.5M thickness blocks are used. These should normally be discouraged. If necessity demands the use of such blocks these should be confined only in external walls where these could be placed in such a manner not to interfere with the modular co-ordination of the various components in the building. All the above recommended dimensions of blocks should be reduced by 3/8 in. to cover joints and plastering.

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DOORS AND WINDOWS

The modular group (3, 4) has recommended that the external width and the height of door frames should be 8M and 21M respectively. To accommodate this, horizontal courses of 2M and vertical courses of 3M are to be used. In Section 5 it has been pointed out by the Author that the adoption of 2M for vertical courses has advantages, and in keeping with this, the Author recommends a height of 20M for the door. The width of the door frame could either be 8M or 9M depending on whether the door is internal or external. Both these widths could be well accommodated by the combined use of 3M and 4M long blocks.

To co-ordinate with the door height, the window height could be either 12M or 20M. For the former the sill height is 8M. The width of window frames could either be 8M or 9M.

LINTELS

In the case of small windows 1M lintel is used at present, and in the case of wide windows 2M and 3M deep lintels are used. The Author recommends that in all windows it is desirable to standardise the lintel size to 2M height to co-ordinate with vertical courses of 2M, and the concrete mix could be adjusted accordingly.

HEIGHT OF CEILING

There is controversy as to what the ceiling height should be. The ceiling height varies from 21M (7 ft.) to 36M (12 ft.). In tropical countries like India, Ceylon, Malaysia, etc. there are buildings with ceiling heights even up to 48M (16 ft.). The building codes varied from country to country. In a Canadian report Stein and Brass (5) have indicated that ceiling heights of 22M would be sufficient. In Israel, research had been done to assess the degree of comfort depending on the ceiling heights and it has been found that the reduction of ceiling height to 22M does not materially affect the human comfort, but 25M and 26M are recommended. In India (6) the Building Research Institute at Roorkee had taken temperature measurements on different experimental houses with ceiling heights varying from 8 ft. to 12 ft. When the height was increased from 24M to 27M the temperature in the room increased by 3° - 4° F. Further increase of height has not materially changed the temperature. Based on this, 27M is recommended in India for houses with ceiling fans, while lower values are allowed when ceiling fans are not used. It should be noted that, when ceiling heights are reduced, window openings should be increased by as much as 20% to improve the ventilation. In many countries window openings cost more than the cost of wall blocks to fill this space. It should be recognised that in temperate countries there would be economy in heating of houses if the ceiling height is decreased to keep the air volume low.

Having considered the views expressed in reports from various countries, the Author feels that the optimum ceiling height for tropical countries should be different from the optimum ceiling height in temperate countries. In tropical countries the Author recommends a ceiling height of 26M - 27M where ceiling fans are in use; when ceiling fans are not used the height may be cut down to 24M. In temperate countries this height should be 23M - 24M.

ROOF COMPONENTS

The dimension of the roof components, sheets or slabs, should be multiples of the basic module. As there are joints, the distance between centre line of joints should be modulated. It will be economical to restrict the breadth of these components to one or two different sizes, or at most to three sizes.

A study of the various plan measurements used in houses would indicate that most of the measurements except for corridors and bathrooms fall within the range 24M and 60M. The various dimensions suitable for rooms in a house are discussed in detail in a United Nations report (5) of 1970 and recommended dimensions are given therein, having taken into account furniture arrangement, etc. Very often one measurement in bedrooms, sitting room, kitchen and corridor, bathroom and corridor would be in the range 33M, 36M, 39M, 32M. If load bearing walls are used it will be possible for the planner to have one of these measurements (33M, 36M, 39M, 42M) common in every part of the house. This means that the span could be made constant thereby standardising the structural unit used for the roof.

The breadth of these units will depend on the type of crane available at the site. In developing countries where labour is cheap, breadth of these units could be restricted to a breadth of 3M to 6M. In developed countries and in other countries where crane facilities are easily available larger breadths of the order of 12M could be used. It is recommended that the breadths of component sizes should be chosen in such a way that a flexibility of 1M is obtained to accommodate all measurements. For example, if two unequal sizes of breadth pM and qM are chosen it is possible to find out the critical number above which the flexibility of 1M could be obtained. The critical number is obtained from the formula:

$$\text{Critical number} = (p-1)\,(q-1)$$

If sizes are 3M and 5M, the critical number = (3-1) (5-1) = 8. This means that if breadths of 3M and 5M are combined a flexibility of 1M would be obtained for all measurements above 8M. Similarly when 5M and 7M components are combined the critical number =

$$(5-1)\,(7-1) = 24$$

If three <u>consecutive</u> sizes (p, p+ 1, p+ 2) are used the critical numbers are:

(a) $\text{Critical number} = \frac{p(p-1)}{2}$ if p is odd

(b) $\text{Critical number} = \frac{p^2}{2}$ if p is even.

Thus for 3, 4, 5 $\text{Critical number} = \frac{3(3-1)}{2} = 3$

for 6, 7, 8 $\text{Critical number} = \frac{6^2}{2} = 18$

MULTISTOREYED FLATS AND FLOOR ARRANGEMENT

There is debate at international level as to whether floor to floor or floor to ceiling should be modulated. There are great advantages in having both these heights modulated. In a load bearing wall construction the reinforcement in the slab would be adjusted so that the thickness of the slab could be either 1M or 2M depending on the span.

In slab and beam construction, as the spans and the reinforcement used in the structural members are well within the control of a designer, it would be possible to adjust the clear distance between beams, thickness of slab, breadth and depth of beams to multiples of basic modules. This leads to simplification of shuttering and repeating units as many times as possible. Figure 1 gives convenient sizes for slabs and beams in such a construction. This arrangement makes it easy to build the wall to the soffit of slab, soffit of beams and also to ceiling level. Also the drainage pipes could automatically be made modular.

The Author strongly feels that the sizes of columns could be well within the modular dimensions. In a column the amount of reinforcement used could vary from 0.8% to 8%. Therefore, by adjusting the percentage of steel the cross-sectional size of the column could be easily made modular. Figure 2 gives the possible shapes and size for columns in multistoreyed flats.

EXPERIMENTAL MODULAR HOUSE IN TRINIDAD

Figure 3 gives an experimental modular house with a plinth area of 600 ft^2 (proposed for families of low income group) which was designed by Mr. Alvarro Ortega (United Nations) and the Author (7) and constructed for the National Housing Authority in Trinidad. The house is built of concrete foundation, concrete slab floors, precast concrete wall blocks, aluminium roofs, timber wall plates and beams. Doors, frames and cupboards are prefabricated in timber. Electricity, sanitary facilities, wash basins, kitchen sinks, drainage and water supply mains are also provided. The design of this house is simplified by the use of modular coordination. All the dimensions are multiples of the basic module

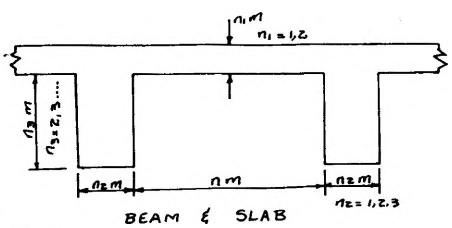

Fig. 1.

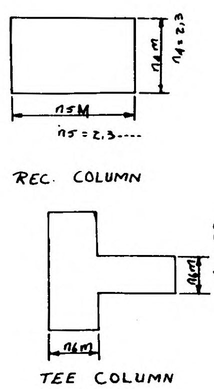

Fig. 2.

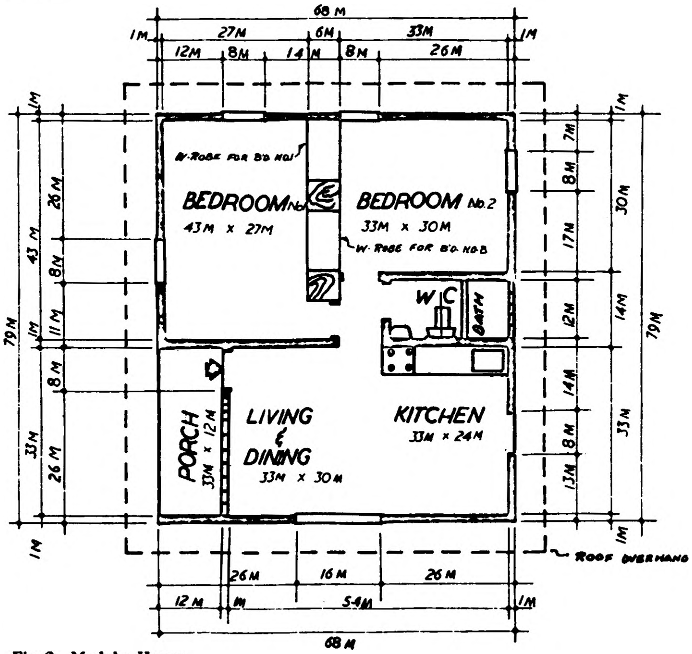

Fig. 3. Modular House

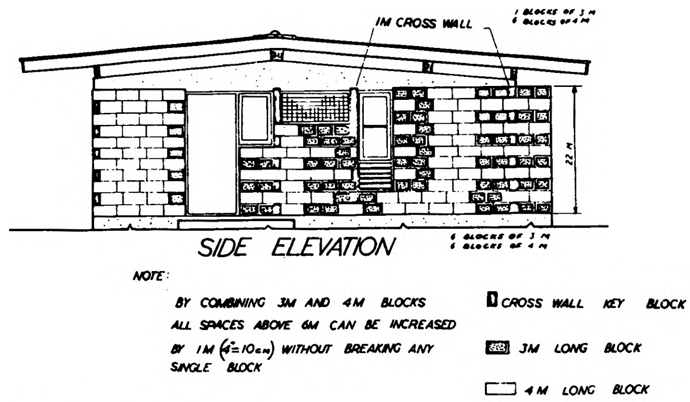

Fig. 4. Side Elevation

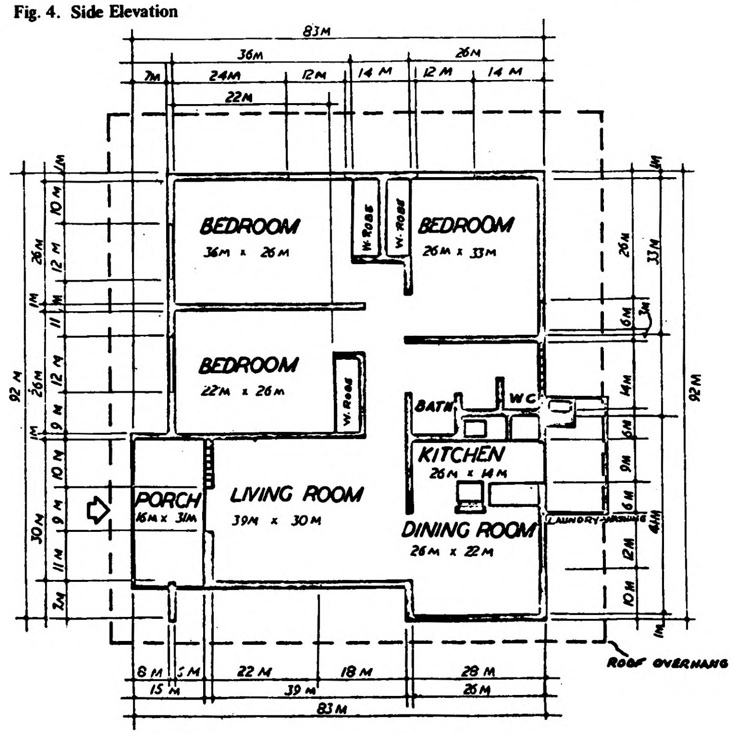

Fig. 5. Modular House

(4 in.). The room is inclined in one direction and specially rolled aluminium sheet span over 12 ft. The arrangement of the various elements have been made easy and the details are laid out within a rectangular shell so that the wall and the roof areas could be minimised.

MODULAR HOUSES UNDER I.D.B. PROGRAMME

The proposed two bedroomed and three bedroomed houses (2,000) to be built in the suburban areas for middle class families under the International Development Bank Programme, have been modified by Mr. Alvarro Ortega and the Author (7) to cut down the costs. These are given in Figures 4 and 5, and Figure 4 clearly demonstrates how 3M and 4M blocks are arranged.

Factory produced wall blocks, finished on one side, was used. Thus, the outer face of the external walls do not require any plastering. Only colour washing is given. Two coats of lime cement wash is found to be a sufficient alternative to the use of distemper or oil emulsion.

CONCLUSION

From the studies made by the Author it should be concluded that there are several advantages in having all dimensions in a house as multiples of the basic module. Wall blocks with horizontal lengths of 3M and 4M and vertical height of 2M fit in better with other components in the house. The ceiling heights in tropical and temperate countries should be 26M - 27M and 23M - 24M respectively. Having modular dimension to slabs, beams and columns simplifies the arrangement and tie well with all structural elements.

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