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STRUCTURAL SYSTEM FOR LOW RISE HOUSING IN SEISMIC AREAS.

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ABSTRACT

Various structural systems using the material like brick, stone reinforced cement concdrete, steel and timber are prevailing in the seismic regions of the country. The performance of these system during past earthquake has been found to be very unsatisfactory. The reasons being its heavy mass and rigid construction which attract more seismic forces during an Earthquake. It has been observed that during construciton no strengthening measures are adopted from seismic point of view in these type of systems specially masonry construction suffers enormous damages.

The structural system discussed in this paper permit the use of these materials in a rational manner, so as to get the maximum advantage of each material when used in a appropriate position depending upon its structural performance in the system. Further advantage of such system are durability, greater flexibility and use of self help labour concept. Use of the ductile material like reinforced concrete to a bare minimum has been made in the main component resisting the lateral forces alongwith a versetile material like ferrocement. This system permits use of other locally available materials like adobe, bamboo, reeds, stones and slates etc. The main advantage being its light weight and ductile in nature which is ideal from seismic point of view.

KEY WORDS

Ferro-unit, Skin unit, Partial prefabrication, Adobe, structural properties, cladding.

INTRODUCTION

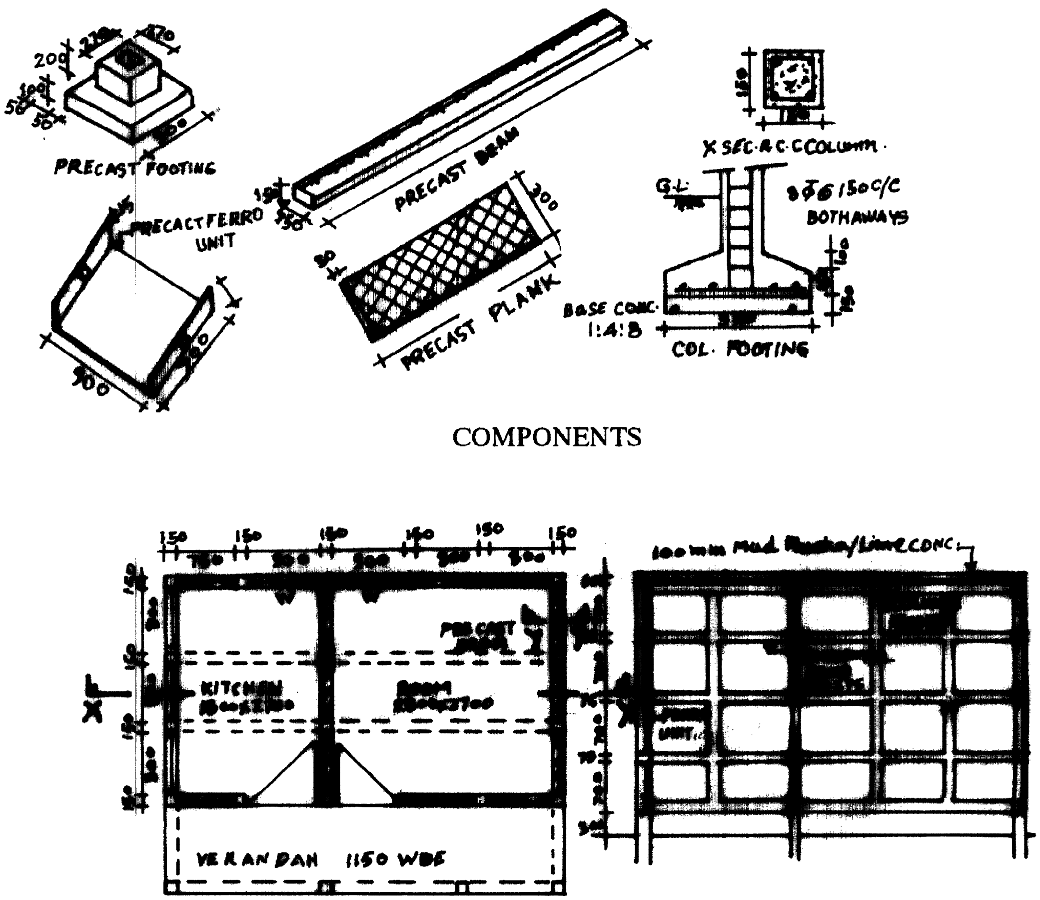
There are three main components of the structure of dwellings foundations, walls and roof. The roof structure is practically independent, the type of foundation is closely related with wall types. Commonly used structural system (Arya et al, 1984, Singh et. al, 1981) for housing in most of the developing cuntries like India are based on stone mud, adobe, burnt clay brick unreinforced or reinforced concrete, steel and timber. The most common practice for low rise houses is to use load bearing masonry either of adobe, burnt clay brick, solid/hollow concrete blocks for walls. The low strength masonry strcuture houses built with such system needs special consideration from seismic point of view. It has been observed that such houses have suffered maximum damages during past earthquake. Such masonry structures are hetrogeneous and brittle in nature. These have much less resistance to bending and shearing stresses developed during an earthquake and having low values of design seismic coefficients gives little guidance about their safety in real earthquakes.

Reinforced cement concrete framed houses have proved to be dependable solution in regions of high seismic activity as observed from past experiences. Such construction systems consumes more materials like brick and reinforced cement concsrete etc. and makes the structures massive and inturn expensive. With these aims and economic consideration a structural system named as composite system has been develped and discussed in this paper.

In this composite structural system use of reinforced cement concrete alongwith a versatile technology of ferrocement is recommended. The insitu small section reinforced concrete columns alongwith the ferro-unit resist the vertical and lateral loads developed during an earthquake. The precast ferro-unit serve as a permanent form work and infill panel between columns. These act as a shear wall or diagonal strut in resisting the lateral forces. The roof/floor elements like partially precast beam and plate serves as a rigid diaphram. In this system the advantage of inherent physical and structural properites of different materials have been made depending upon physical and structural requirement of the element. Like use of adobe or ike material is made for internal cladding to have thermal comfort in tropical climate. In addition to reduction mass just fifty percent in comparison to masonry construction, the further advantages of such system are industrialised production, better quality control, use of self help labour concept which ideally suits to economically weaker people.

COMPOSITE SYSTEM

The structural system named as composite system is shown in Fig.1. It is based on utilisation of optimum structural and other engineering properties of different prevailing materials and resources to suit the intermmediate level of technology of partial prefabrication. Basically the system is a framed structure made composite with



COMPONENTS

PLAN

SEC. ELEVATION

FIG- 1. TYPICAL PLAN & COMPONENTS

Ferrocement and reinforced concrete and comprises of following elements :

1. Foundation footing (Precast/Insitu)
2. Ferro-Unit
3. RCC Column
4. Flooring/roofing elements
5. Cladding

FOUNDATION FOOTING :

Fig. 1 shows a precast pocket footing having a pocket 170mm x 170mm x 200mm in size for sitting the insitu column. There may be an option to site engineer to adopt a precast section or insitu foundation footing. Depending upon the site conditions, bearing capacity of soil and load being transferred by column the size can be designed accrodingly as standard code of practices. The section shown in Fig.2 is suitable for a normal soil bearing capacity of 10 tonne/square metre and column is loaded on both side having a room of 3.5 m width and single storeyed construction.

FERRO UNIT

It is a precast ferrocement skin unit (Fig.1). Its total weight is 35 kg. only. It is a matrix of single layer chicken wire mesh with nominal skeletol steel and cement mortar. It is in the form of a channel. The web length is 900 mm and flanges are 150 mm wide, wall thickness is 15mm only with a total height of 700 mm. Mortar mix use in matrix is 1:3 (cement:sand). These units are cast at a central place. After casting and comnplete curing and drying these are used for construction of system.

These are designed like infill panels for resisting lateral loads in highly seismic regions. In general these serve as a skin units and given protection to poor cladding material like mud brick/block.

RCC COLUMN

Fig.1 shows the reinforced cement concrete (grade M 15) column. The size of the column is 150 x 150 mm square Depending upon the requirement the size of column can also vary. It is observed that for normal residential houses 150x150mm column is adequate. This size is in relation to width of flange of the Ferro Unit. This size also accommodate the skin thickness of ferro unit and the cladding thickness of 100 to 120 mm equivalent to half brick thickness.

Its design is based on standard code of practices (BIS, 1975, 1984, 1993) for reinforced cement concrete structure. Depending upon the requirements it can be designed for a particular seismic zone or an earthquake by seismic coefficient, response speetra or even by dynamic analysis. The ferro unit between the columns acts as filler panel. As given in Fig.1 the columns are interconnected at plinth, sill, lintel and roof level by the RCC bands. For casting of these columns form work only on two sides is required, as the form work for other two sides along the length of wall is provided by the ferro - units. Connecting bands helps in reduction of slenderness ratio of the columns.

FLOORING/ROOFING ELEMENT :

Flooring/roofing elements as shown in Fig.1 comprises of precast reinforced cement concrete(grade M-15) plates and partially precast beam. The plates are supported over partially precast beam which in turn are supported over insitu RCC columns.

The maximum span recommended for beam is 4000mm. The maximum recommended length of plate is 950mm and 900x30mm in cross section depending upon structural requirement. The structural design is carried out in accordance with codal provisions. Plate is designed as simply supported on two edges for self load including the weight of insitu concrete on top, and as a continuous slab for live load and dead loads of floor finish or water proofing treatment.

Partially Pre-cast beams are designed as simply supported T-beam with flange thickness equal to the thickness of the plate and insitu concrete. Casting of plate and the joist is done in normal way with suitable moulds. After the elements are ready for use the erection and assembly of floor/roof is completed which acts as a monolithic mass.

CLADDING

Fig.1 it is the non-structural component and can be left to individual. It is used only in inner part of the ferro units as shown in Fig.2. It may be of any locally available material like mud brick, burnt brick, slate or stone. With the use of cladding a better thermal comfort can be achieved. It has been observed that a 100mm thick mud wall gives better thermal comfort than that of 230mm thick burnt brick wall. In hot/cold climate, it is desirable to use mud bricks in such a configuration. These bricks get an coverage and appearance of cement finish due to ferro unit on outer face. The thickness of cladding is 100 to 120 mm. This thickness can be easily adopted by using half brick thick masonry.

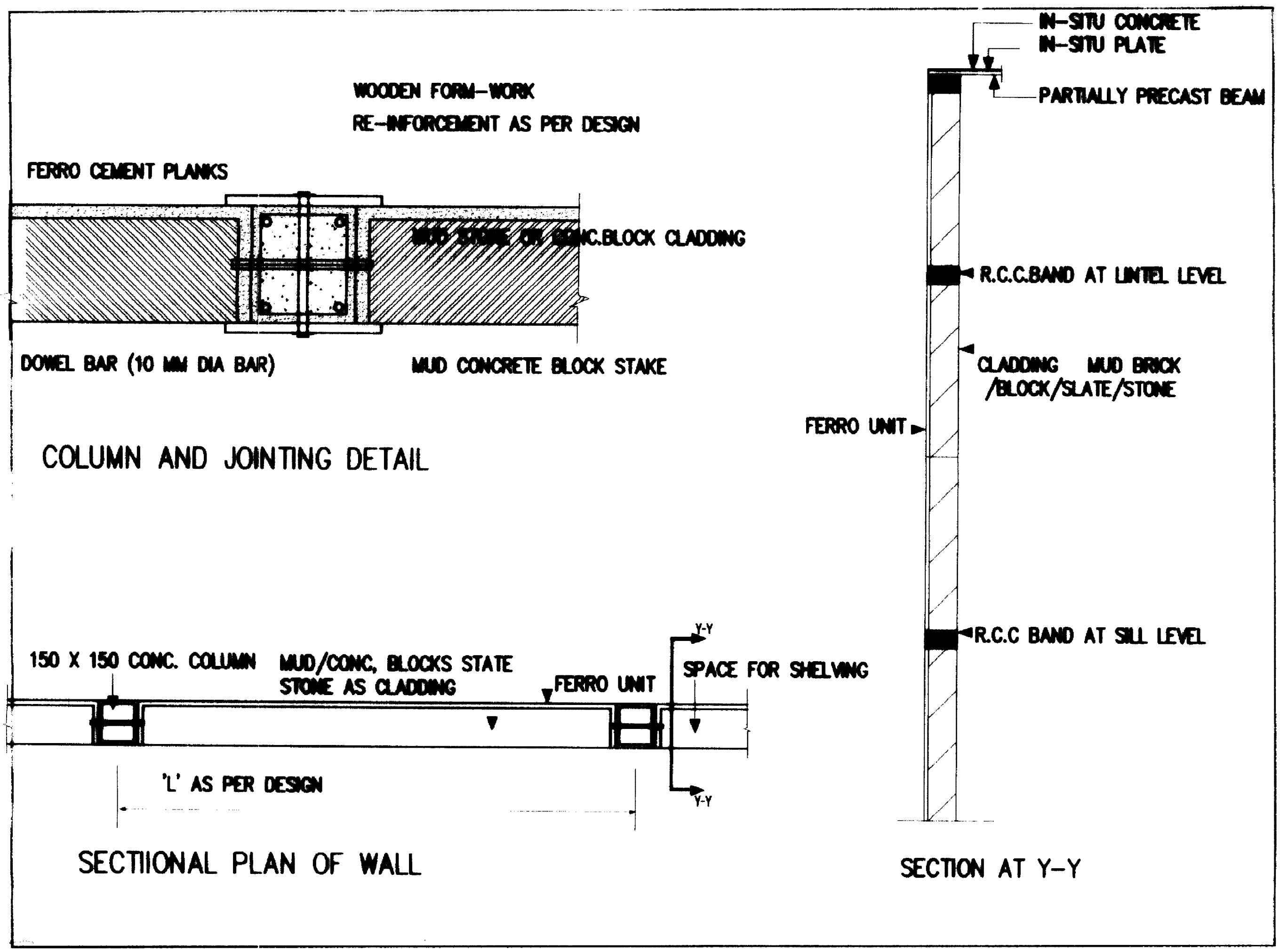


FIG-2. ASSEMBLY DETAILS

CONSTRUCTION AND ASEMBLY OF SYSTEM :

After layout and laying of base concrete at appropriate positions, the following operations are followed :

1. The precast pocket footing is placed in the exact position, with a layer of 1:6 cement mortar bedding at the bottom.
2. The reinforcement cage of the column is then placed in the pocket in a vertical and correct position and filled with concrete of grade M 15.

3. The pit for the footing is then back filled with earth upto top level of the footing and well compacted.
4. The ferro units are then placed along the length of walls and leaving adequate gap to column reinforcement in between as shown in Fig.2.
5. Dowel bars are then palced passing through column reinforcement and two adjecent webs of the ferro-unit as shown in Fig.2.
6. After putting required form work on two sides as shown in Fig.2 the required concrete grade M15 is poured to the one height of ferro units i.e. 700mm.
7. After concreting in column upto a height equal to one Ferro Unit the next height of ferro units are errrected and the dowel base are inserted.
8. The form work on the two facaes is done, and the gap between two ferro units is filled with concrete grade M15
9. At the appropriate height window and door frames are also fixed by embedding the hold fasts in the concrete of columns.
10. The process of erection of ferro units and concreting in columns is completed to the required height.
11. Horizontal band/beams are also laid at plinth sill, lintel and roof level all along the periphery of columns and ferro units.
12. After reaching roof level percast beams are placed and are propped at every middle third.
13. Over the joists the precast plates are supported.
14. After laying all plates and the required reinforcement the insitu deck concrete of grade M15 is laid over the plates. Props are removed after the deck concrete attains its strength.
15. Thus the complete structure is assembed.
16. Other items like cladding between columns and ferro units is done either with burnt or mud bricks or with locally available material like thatch, reeds or bamboomat, slate or stone etc. depending upon the availability.
17. Flooring, door and window shutters electrification, water supply and sanitary fittings installation is done in a conventional way depeding upon the individual requirement and financial condition.

PRECAUTIONS DURING CONSTRUCTION

1. All column footings and ferro unis shall be placed in their exact position.
2. All concrete/reinforced concrete work insitu or precast shall be in accordance wih Indian Standard Code of Practice.
3. For casting of ferro unit cement sand mortar leaner than 1:3 should not be used.
4. The beam should be propped up just after placing them in position at every 1-meter spacing until insitu concrete on top attain sufficient strength. It would normally take about two weeks.
5. The minimum bearing of precast plate on beam should be 25mm.
6. If the soil conditions are extremely poor or soil is expansive the foundation system would need to be checked.
7. Internal cladding should be self supporting. It is preferable to use cladding of light weight material.

ECONOMY

With the advantages like speed in constrution and saving in formwork there is a considerable saving in materials and labour too. The system works out to be 15 percent economical if compared with to load bearing masonry construction and 25 percent economical than framed construction.

CONCLUSION

The system is strongly recommended for construction of small and low rise houses in seismic areas. Its light weight and use of better quality material to a bare minimum save scarece material like cement and steel. With implementation of partial prefabrication technology it is ideally suitable for mass construction.

ACKNOWLEDGEMENT

The work described in the paper is a concept of construction based on a detailed review of the different level of construction technologies, knowledge available on the subject and research experience in this field.

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