Ferrocast Structural Elements For Mass Housing For Low Income Group In India

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ABSTRACT

The present work aims at providing structural design and methods of manufacturing of structural components designed using light weight ferrocast cement. The Ferrocast technology uses reinforced cement mortar to cast structural components of low cost housing scheme. The method of manufacturing these structural components is suggested. This method of manufacturing when employed for mass manufacturing of components, will control cost of housing at minimum level. The method of construction suggested promotes fast construction, making it advantageous, economical in many situations. The technology proposed for low cost housing using ferrocast cement uses light weight elements, low technology manufacturing and quick responses to constructional need, hence this proposes a solution that is unmatched with normal reinforced concrete construction. This poses a very good alternative for construction industry to face ever increasing demand of low cost, mass housing in India.

KEY WORDS:

Ferrocement, precast structural component, mould, mass manufacturing.

CHALLENGES IN LOW COST HOUSING

Presently new and innovative development program is being vigorously followed by Indian government. Large allocation of funds is made by Governments and Charitable corporate sector. The thrust area being in Sanitation and rural housing. Rural India lacks basic Sanitation facility like toilets. This leads to unhealthy conditions leading to permanent prevalence of communicable diseases like cholera, typhoid etc. This results in high early deaths in young children. The estimated number of household toilet units required for the entire country would be 7 million. An ambitious program is launched to install these numbers of toilets in next ten years. The requirement of housing for the country is seven million units of approximately 250Square foot each, to be completed in next ten years. It is sighted that there should be no difficulty related to ability to construct these units irrespective of geographic spread, temperature conditions, and difficulty in proper access to site and constructional equipment and manpower at its location.

The main problem in India is manufacturing and installing /executing units in such large numbers and its logistics. The facilities are to be constructed all over India, primarily in rural areas. There can be villages located very far from the nearest main road, or in remote jungles to areas in Himalayan region. The cost cannot change much even under changing conditions. There is of course no compromise on the quality, strength and ability to withstand the high Seismic and wind loadings.
Another difficulty faced by contractors in such remote locations is the availability of trained labour. **All these problems can only be solved by constructing the houses with factory made precast elements**. The other requirement for the individual elements is the dead weight. Village roads cannot support heavy trucks. The handling of building parts has to be done manually during removal from the trucks at site and then during erection. This puts a restriction of 125kg (275 lb) for any one part, as the crane access is restricted at site.

MATERIALS AND METHODS: USE OF FERROCAST ELEMENTS

In order to get over these difficulties, design of elements was done in Ferrocement. To be able to use the structural strength of Ferrocement in tension and compression all elements were cast with 30 MPa strength mortar mix. Hand plastering was not used in this construction. ACI committee 549 [1, 2] in its state of Art report in 97 does not give any value for the tensile stresses generated in the section in Bending. Values that can be obtained in tests have been given by Dr. Antone Namman in his book " Ferrocement & Laminated Cementitious Composites ", [4] which are 25 to 35 Mpa. In order to get the stress values, in Tension, slab and beam elements were tested. Ferrocast jacketing rings were tested with 30 MPa inner concrete cores to get tensile capacity of section in hoop tension [5]. All experiments indicated an ultimate value of strength of Ferrocement 23 to 25 MPa for tension in Bending and in hoop. These values were used with a factor of safety of 2 for the design purpose. The design was done on working load as that ensured complete elastic behavior as indicated in experiments.

To confirm the behavior of sections in actual structure, an experiment was carried out by constructing a room of 3.6m x 4m area with 3m height (Figure1).The members were designed as reinforced Ferrocement sections. The simply supported sections carried its own dead load along with members supported on it. After placing steel to ensure continuity for slabs and beams, topping concrete was placed. The structure was designed to support the live loads. The experiment proved the ease of construction and the behavior of the sections as per design assumptions (Figure 2).
One more part of the building is, ` the walling`. Thin section walls were designed with stiffeners to be the external and internal walling. The panels were of about 1m width where handling will be totally manual. Panels of about 1.5m width were used where small cranes could access the site. Where the building construction was to be in zone of extreme temperature, the space formed by stiffeners was filled with foam concrete to give heat insulation.

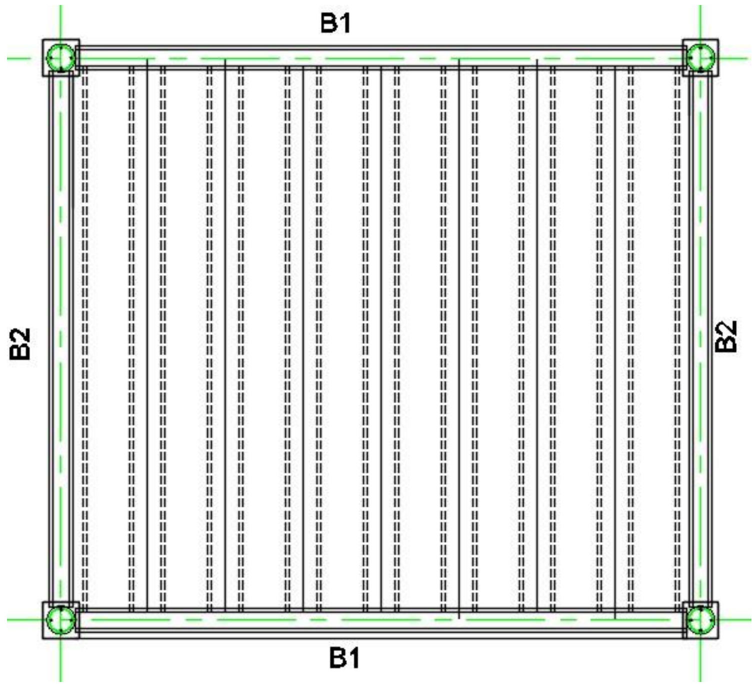

Figure 1. Plan of room constructed using Ferrocement members

Figure 2. Erection of Ferrocement member

MANUFACTURING

Looking to the various problems associated with this housing program, it was necessary to keep the method of manufacturing very simple. It was also necessary to be easily replicable without complex machinery. The level of sophistication had to be such that anyone with basic civil engineering knowledge and experience in precasting like spun pipe manufacturing could enter into this work. The success of this large manufacturing activity depended on large number of units participating in this effort. Following points were incorporated in the manufacturing process.

MOULD DESIGN AND HANDLING.

As weight of each item is critical for ease of handling, the mould design also follows the same principle. All panels are cast horizontally on the bed. The member thickness, for wall or stiffener does not exceed 30mm. This also follows the requirement of the section to be designed as a Ferrocement element. Thus the mould plates are of 3 to 4mm thickness and very light and can be handled manually. Care is taken to impart sufficient rigidity to avoid twisting of the mould plate during use. The minimum number of usage of each mould is taken as 400 for its impact on the cost of casting. Careful handling of mould is therefore necessary. Less repetition of use of mould will impact the cost structure of units which are very cost sensitive.
A good casting is a result of careful placing of mortar mix in the mould and its proper compaction. As the wall and slab mould are cast horizontally, the depth of casting is small. This ensures easy placement and its ingress into all the parts of the mould. The casting has large open surface and it is advantageous to use surface vibrator to get proper consolidation. The surface also gets a plane and smooth surface with application of surface vibration. The beams are cast upside down with bottom flange at top. The two side webs of the channel section could have a depth of up to 450/500 mm. To ensure that it was filled properly, self-compacting mortar of 30Mpa strength was used. The results were excellent. (Figure 3). As the span for slabs does not exceed 4m, the stem of the Double Tee Slab is not more than 100mm. Hence casting of this magnitude of depth does not require self-compacting mortar mix. As all casting is done in horizontal position, a large platform needs to be built on which moulds are placed. The casting is done from a centralized mixing unit and transported to the mould by hand carts. For ease of handling the cast member, "A" frames with a lifting capacity, of **one Tonne** is used. The frame span is same as the platform and has wheels. It can either move on rails or rubber tyre pushed by workers.
The choice is normally made in India on the basis of available power at casting yard and also the cost of labor which varies from INR. 250/day (approximately $4/day) to INR.500/day ($8/day).The location determines the availability of power 24/7 and the cost of the labor. The normal manufacturing quantum expected per day would be about 8 to 10 toilet units and/or 2 to 3 housing units. The casting yards are designed with above stated estimated quantity of production per day. Large capital outlay is avoided as this manufacturing would last from 5 to 10 years only at that location. Thereafter the manufacturing will have to shift to other products.

Figure 3. Ferrocast Beam

SETTING UP CASTING YARD.

The location and logistics of setting and operating a casting yard is different from that in Developed country. Situation in India may be similar to that in Africa or in Latin American States. The main constraint is lack of proper roads and non-availability of electric power supply even during working hours. These shortcomings in operating the plant have to be factored in planning. The emphasis is placed on simple equipment, more manual labor and mostly diesel engine operated equipment like mixers, generator sets for welding and cutting machinery. The logistics of transport of cast parts to location of assembly, is a sever restraint for erection in remote villages in Himalayan region. This will highlight the difficulties encountered during execution of the objective.

MANUAL ERECTION:

With difficulty in taking castings to the location by normal trucks, they have to be delivered by light vehicles. The same is the case of taking erection crane to site. It is therefore necessary to complete the erection with manual labor. The ultimate user of the toilet in the villages is encouraged to do it with a supervisor sent with the material. This sensitizes the end user about the ownership and its continuous upkeep.

PLANS FOR DIFFERENT REQUIREMENTS.

With the construction method explained above, structures needed for mass construction were designed for specific requirements. They were essentially for construction of toilets for different user conditions. The housing units of 1, 2 or 3 rooms were designed. The roofing is either of Galvanized Iron Sheets or concrete slab, depending on the cost restraints.

a) One Room Unit

These are provided for construction workers which are given individual room with a common toilet block having facility for bath. The units are made of wall panels joined together by bolting. It is necessary to dismantle the facility and shift to another work site after completion of work on that site. The wall design and its connection facilitate any number of units in rows. The front wall has one panel with window and another with a door (Figure 4).

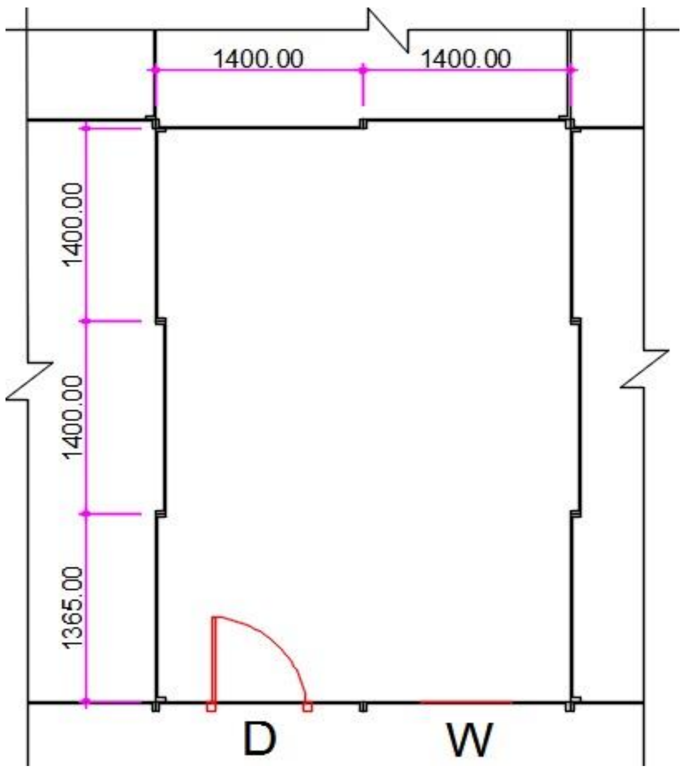

Figure 4. Plan of One room unit

b) Two Room Unit.

The plan shown in (Figure 5) has been proposed by the Central Government for the housing proposed for the poor in rural areas. These are generally in a cluster. It is easier and cheaper to give other services like water supply, drainage and sewage treatment and electric power supply to a group of houses than spread out individual units. The total number of units needed is 10millon to be completed in 10 years. Requirement of more units being in the Northern and Eastern States in India. Two types of roof coverings are offered; with concrete sloping slab or G.I. Sheets on purlins.Precast trusses with channel section used as members are proposed. The cost works out to half that of structural steel. The unit can be constructed in less than 3 weeks and occupied.

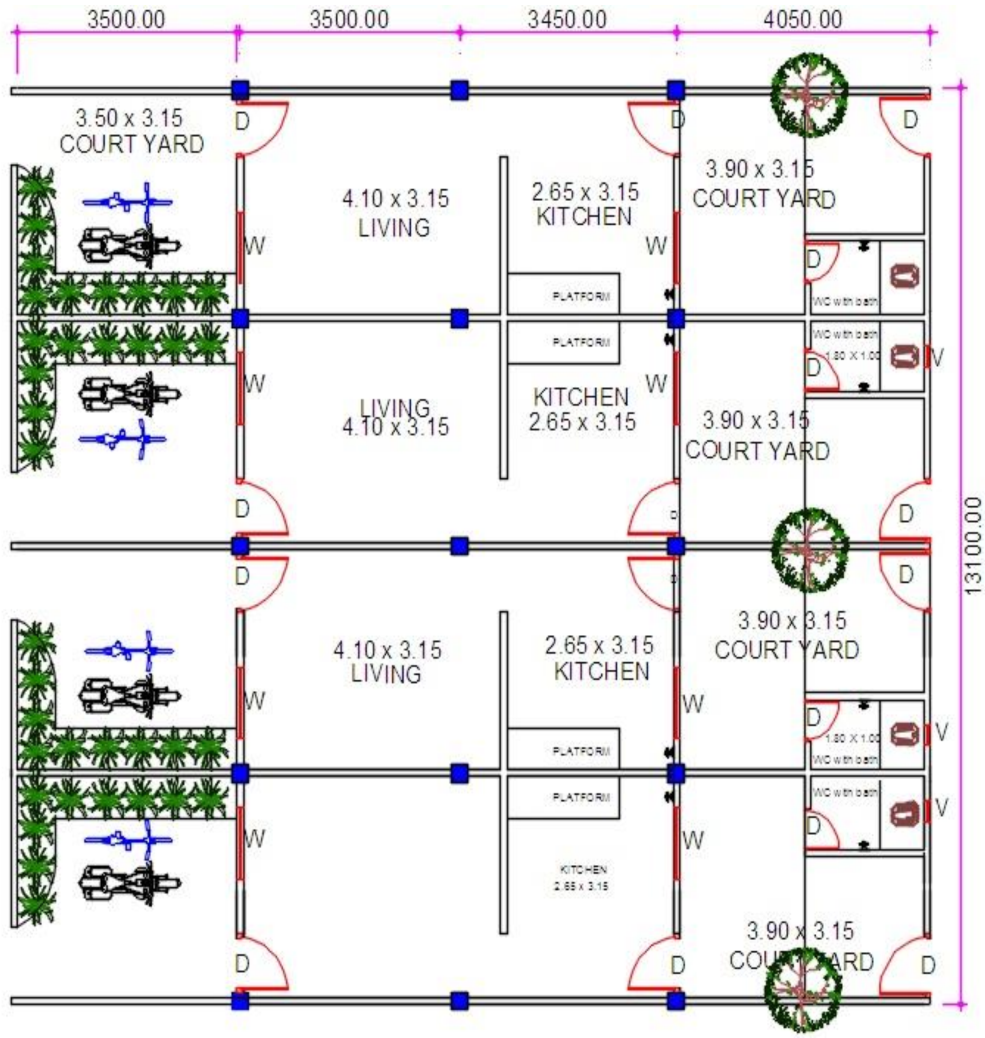

Figure 5. Plan of Two room unit

c) Three room unit.

This is essentially for disaster mitigation where people have lost their permanent houses in Earthquakes, floods, Tsunami, like natural disaster. The unit can be extended one first floor by adding a staircase. The toilet block can be detached or attached. This has its structural frame designed for appropriate seismic and/or wind forces. The construction time would be 3 weeks. Multiple units at one location will give huge time advantage in completion time(Figure 6)

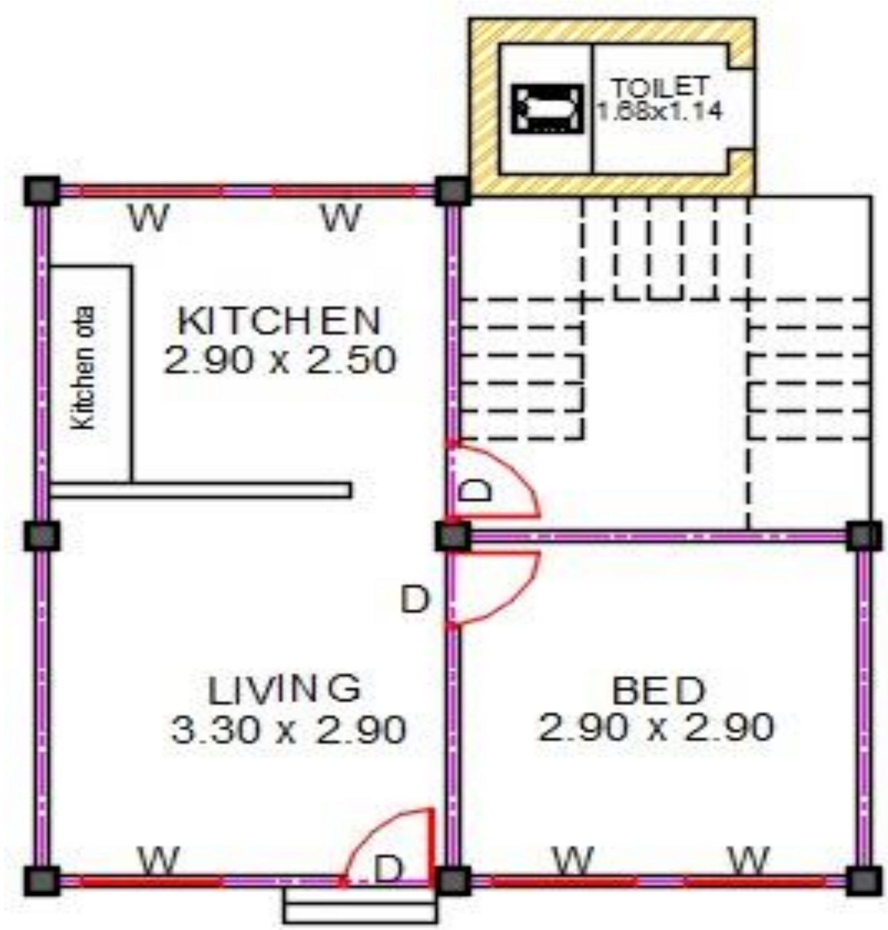

Figure 6. Plan of Three room unit

d) Single and Multiple Toilet Units.

The number of toilet units needed in 10 years is a staggering figure of 100 Million. It is impossible to construct such numbers in that time. As these units are all over the geographical spread, the manufacturing yards will have to be spread all over. Economic distance for transportation is about 75 mile radius from casting yard as the unit cost of one precasting panel set is very price sensitive. The unit cost of one installed toilet without septic tank is Rs. 12000/- ($200) and with septic tank is Rs. 20000/- ($ 335).
The multiple unit is for village schools which generally have 100/120 students. The wall panels are so designed that they are common for single and multiple units. The roof can be G.I. Sheets or concrete slabs which are also ferrocast as standard Double Tee Units. Plans of each type and picture of completed unit is shown in (Figure 7, 8, 9, 10)

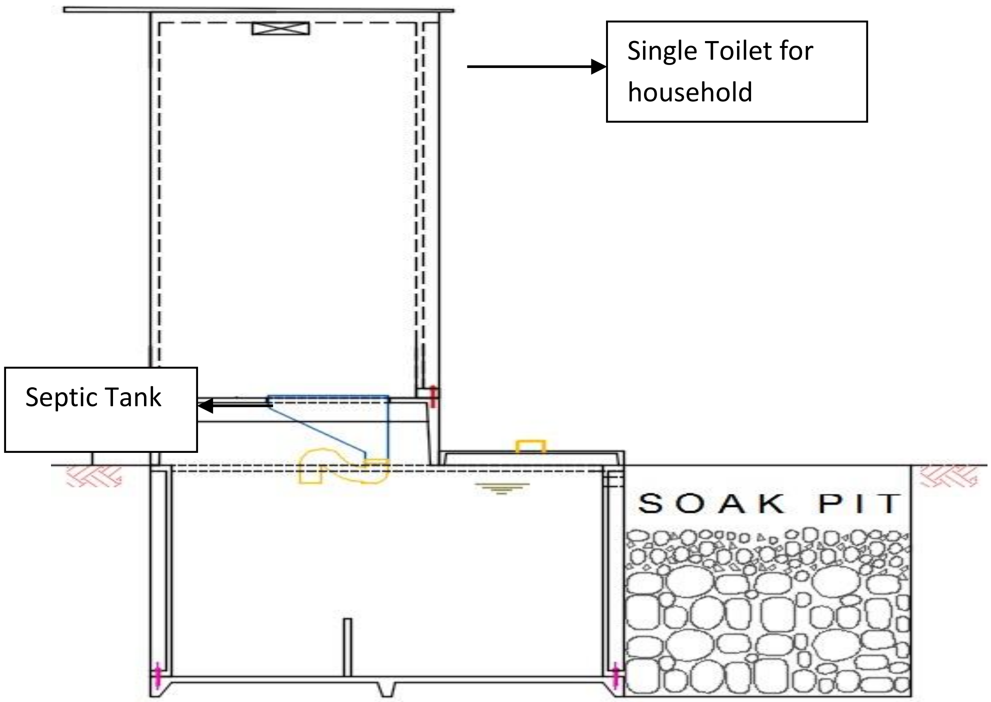

Figure 7. Section of Single toilet unit

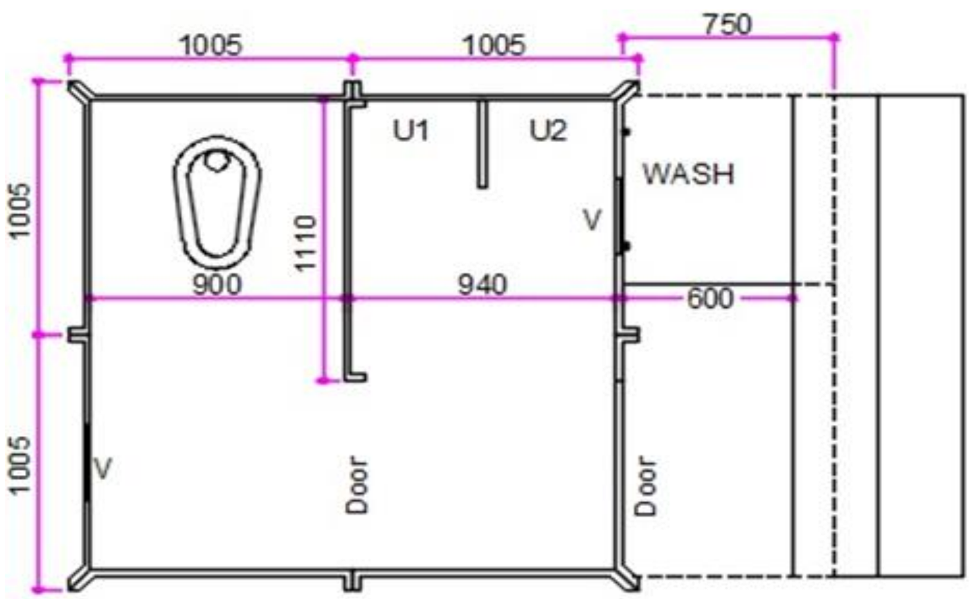

Figure 8. Plan of Double toilet unit

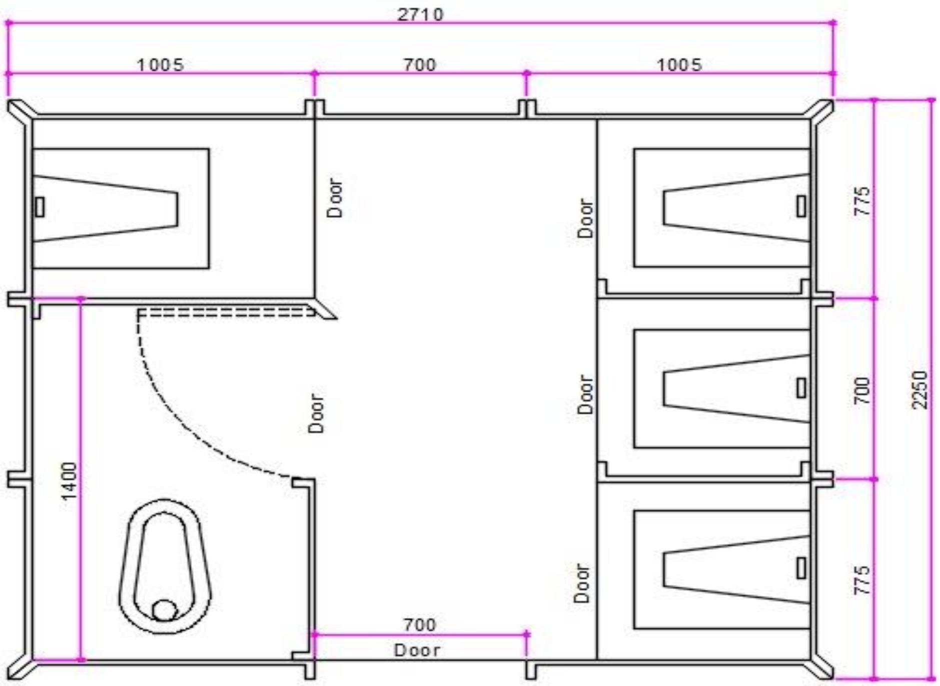

Figure 9. Plan of Multiple toilet unit

a)Toilet installed in farm

b)Toilet installed in slum

Figure 10. Completed toilet unit

SPECIAL CONSTRUCTIONAL ADVANTAGES

When basic amenities like toilets and cheap houses are to be provided in semi developed or undeveloped countries, the major difficulty is in approach roads. The sites are not easily accessible due to which construction materials, labour and equipment cannot reach the location. The quantum of work at each location could also be such that heavy expenditure cannot be made which will impact the price of individual unit. This problem is faced at many locations in India which leads to non-execution of such construction. Ferrocast elements solve most of the problems at such sites. Some such locations encountered in India are enumerated.

a) Remote Villages
b) Tribal area in Hilly terrain
c) Himalayan Region
d) Quick response to natural calamities like
   i) Earth Quake ii) Floods
   iii) Cyclone iv) Tsunami

CONCLUSION

This method of construction should be viewed through its various advantages. It is not only useful for low cost mass housing construction; it could be advantageously used in many situations. The Light weight components of ferrocast material are structural components with same structural behavior as RCC structural components with advantage of light weight and ease of erecting members on site.Much simpler technology is required for manufacturing of these structural components using ferrocast material. Due to ease of construction, this technology supports quick responses to constructional need.The quality of construction, finish and structural stability are unmatched with normal reinforced concrete construction. This technology saves construction time so Indian construction professionals are thinking seriously about this alternative available to conventional RCC construction. This may have revolutionary effect on Indian construction scenario.

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