A STUDY ON CONSTRUCTION OF PREFABRICATED BUILDING COMPONENTS USING FLY ASH

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Abstract : Now a days there is great boom in infrastructural development in the form of fast track construction. As an effective strategy for improving the productivity of the construction industry, prefabricated construction has attracted concerns worldwide. In today's world, where speed and convenience play a big part in influencing the use of any product, the age of prefabricated housing products seems to have finally arrived. The usefulness of these products help significantly in speeding up construction by offering ready-to-install building elements such as blocks, joist beams, roof blocks and panels is being widely recognized in the industry. Pre-fabricated components are becoming immensely popular due to the several attractive advantages that they offer, such as off-site fabrication, which allows reduction in construction time and this function helps greatly in managing the schedule of the construction project. Due to their low density, the pre- fabricated components impose a relatively lighter load on the structure and superior quality can also be achieved as these components are manufactured under a strictly controlled environment. In recent times few innovations in the field of materials are expected to make these products even more popular, user friendly and eco-friendly. The present paper discusses on the manufacturing of prefabricated building components using fly ash, and explains regarding fabrication, centering, placing, applications and the advantages over the monolithic construction.

Keywords - Prefabrication, Material, Construction industry, Fly ash.

I. INTRODUCTION

1.1 Prefabrication:

"Prefabrication" is the manufacture of an entire building or components cast in a factory or on site before being placed in position, assembling the structural units so that they can be easily and rapidly erected. Prefabricated buildings are pre-cut, pre-drilled, and pre-engineered before the actual building is constructed. Prefabricated Structures (PFS) are useful for sites, which are not suitable for normal construction methods such as hilly regions, and also when normal construction materials are not easily available. Structures which are used repeatedly and can be standardized such as mass housing, storage sheds, godowns, shelters, bus stands, security cabins, site offices, foot over bridges, road bridges, concrete building blocks etc., are prefabricated structures. This paper discussing about the mix proportions of the materials to manufacture the prefab components and the construction procedure for an ordinary single story residential building.

1.2 Criteria for selection of prefab in India:

In India, the technology adopted for housing components should be of the order that, the production and erection technology be adjusted to suit the level of skills and handling Facilities available under metropolitan, urban and rural conditions. In other words, the structural systems and components selected should ensure minimum material Utilization with maximum structural advantage. However, the component and systems so designed are to be manufactured and erected by manual means in villages, semi mechanical techniques in towns and more or less fully mechanical operations in the metropolitan cities. In urban areas, the concentration of construction activity does not justify prefabrication.

A wide variety of roofing methods to suit these requirements have been developed and used on mass scale in many housing projects such as funicular shell, cored slabs, RCC channel units, precast cellular units, precast RC planks and joists, prefab brick panels and joists, RCC joists and hollow concreteblocks.

1.3 Material used for Prefabrication:

Prefabricated components can be manufactured using many materials, depends up on the type of structure. Generally materials used are Wood, Steel, concrete, plastic and composite materials .If the structure is wooden house then prefabricated woodenpanels, columns, posts are used. If the structure is prefabricated steel truss bridge then steel members like angles, I, L-sections and rives, bolts are used. If the structure is houses in developed countries then the prefabricated plastic internal partition walls, doors, panels and toilets are used. The man made rock concrete is also widely used for the manufacturing of the prefabricated

members. Instead of using complete cement concrete we are replacing the some quantity of cement with an industrial waste product like fly ash. Because of adding the fly ash we can get many benefits for the environment as well as prefabricated structure.

1.4 Fly Ash:

Fly Ash is a by-product of a thermal power station, after combustion of coal and production of power. Fly Ash is generated from coal fired generation units. Coal has a dominating role for the power generation in India. Presently there are 70 coal based thermal power plants operating in India. Most of the thermal power plants in India use inferior quality coal, having low calorific value which after combustion, leaves behinds a larger per cent of ash. As the power required in industrial and agricultural sectors increase, production of ash increases. Fly ash contains many toxic elements. Abundant quantities of fly ash are being produced by thermal power plants situated all over the world. At present 100 MT of coal ash is produced annually in India.

Fly ash is a complex material and its characterization is quite difficult. It is observed that the overall chemical composition varies from particle to particle and from one sample another. Even initial pulverization of the coal and efficiency of firing have significant influence on the grading of the fly ash produced. It appears that difference in particle size distribution; morphology and surface characteristics of fly ash would influence water demand and reactivity. The principal constituents of fly ash are silica (SiO_2), Alumina (Al_2O_3), Iron oxide (Fe_2O_3), Calcium oxide (CaO), small amounts of magnesium, sulphur, and unburned carbon. Let us know the properties of the Fly Ash.

1.4.1 Physical Properties:

Fly ash particles are typically spherical ranging in diameter from 1 to 150 microns. The type of dust collection equipment used largely determines the range of particle size in any given fly ash. The fly ash from boilers where mechanical collectors are used is coarser than fly ash from electrostatic precipitators. Fly ash consists of the large part of solid or hollow spherical particles of siliceous and aluminous gas with small proportions of thin walled, multifaceted poly- hedrousiron content and are irregularly shaped, relatively porous carbon or carbon coated particles. The fineness of fly ash in many a case is to the same extent as that of Portland cement. The color varies from light to dark grey depending upon its carbon contents. The quality of fly ash varies from source to source and is seldom uniform even for the same source because of the important factors like the nature and size of coal, the type of combustion equipment, control of combustion process, mode of fly ash collection etc. the product from a modern power plant when working on base-load is normally quite consistent.

Table-1: PHYSICAL PROPERTIES OF FLYASH

S.NO.	Property	IS 3812 Requirement	
		Grade I	Grade II
1.	Fineness (Blaine Cm^2/gm)	3200	2500
2.	Lime Reactivity N/mm2	4.0 min	3.0 max
3.	Drying Shrinkage %	0.15 max	0.1 max
4.	Auto Clave Expansion %	0.8 max	0.8 Max

1.4.2 Chemical Properties:

In Indian fly ashes, contents of SiO2, Al_2O_3 are relatively higher than Fe_2O_3, SO3. The crystalline phases were identified as mullite, magnetite, hematite and quartz. The chemical composition of fly ash and its particle size differ widely for different power plants. This is due to different types of coal used, their various treatment and different types adopted for combustion. Generally, fly ash is differentiated on the basis of degree of fineness and their carbon contents.

Table-2: CHEMICAL COMPOSITION OF INDIAN FLY ASH

S.NO.	DESCRIPTION OF PROPERTY	AVERAGE RANGE OF VALUES(%)
1.	SiO_2	44-58
2.	Al_2O_3	21-27
3.	Fe_2O_3	4-18

4.	CaO	3-6
5.	MgO	1-25
6.	SO_3	0.3-1.7

1.4.3 Advantages and applications of Fly ash:

Fly Ash is having so many advantages due to their unique properties like,

- Strength is more and reduces the permeability.
- Corrosive resistances, specific gravity, lime reactivity.
- It is cheaply available and fulfils all the requirements.
- Fly Ash can be used for land fillings, soil stabilization.
- Can be used as a partial replacement of cement, as fine aggregate and as coarse aggregates.
- Improves the 20% to 40% of production in agriculture.
- In the manufacturing of Special concretes.
- Finally in the manufacturing of prefabricated components like bricks, blocks, inter locking members, flooring,walltile

2. LITERATURE REVIEW

Prefabricated concrete construction is a key stimulant to industrialization and economical growth in developing countries, prefabrication is preferred on the building components are made off-site in a factory. Off site fabrication provides an effective constructional technique in terms of quality, time, cost, management, function and safety.

The advantages of prefabricated building components are:
1. Shorter construction time - less than half of conventional cast in-situ construction
2. Independent of adverse weather conditions during construction
3. Continuing erection in Winter time until -20 °C
4. Quality surveillance system
5. Factory made products
6. Opportunities for good architecture
7. Healthy buildings

Comparing benefits of prefabrication elements and on-site building process:

Factor	Prefabrication	On-site
Quality	In a climate-controlled environment using efficient equipment operated by well-trained people	Uncertain weather can result in less-than expected construction
Speed	Speedy process (up to 70% less)	Time consuming. The process can be delayed by weather or scheduling conflicts.
Cost	Greater control over manufacturing results dramatically reduces the chance of cost overruns	Uncontrollable variables such as weather and scheduling can increase the construction cost
Site space	Panels arrive on a flatbed trailer and are installed with sufficient listing plants.	Bigger space is needed. In addition costly scaffolding is often necessary for installation.
Site refuse	Less waste is generated at the site.	A significant amount of waste produced and removed from the site, which often adds to cost.

3. PREFABRICATED COMPONENTS USED IN CONSTRUCTION:

In a building the foundation, walls, doors and windows, floor and roof are the most important components. These components can be analyzed individually based on the needs. This will improve the speed of construction and reduce the construction cost.

3.1 Foundations:

Various type of foundations normally adopted are Open foundations, Rib foundations, Columns and footings and RCC raft foundation. Conventional methods using in-situ techniques are found to be economical and more practical for low cost housing of

slums, which generally consists of low rise structures. In seismic regions, special attention is required to make the foundations continuous using horizontal reinforcement. Prefabrication is not recommended for foundations in normal situations.

3.2 Walls:

In the construction of walls, rammed earth, normal bricks, soil cement blocks, hollow clay blocks, dense concrete blocks, small, medium and room size panels etc of different sizes are used. However, bricks continue to be the backbone of the building industry. In actual construction, the number of the bricks or blocks that are broken into different sizes to fit into position at site is very large. As a result of this, there is wastage of material and the quality of construction also suffers. Increasing the size of wall blocks will prove economical due to greater speed and less mortar consumption, which can be achieved by producing low-density bigger size wall blocks and advantages of industrial wastes like blast furnace slag and fly ash, can be made. Several prefabrication techniques have been developed and executed for walls but these medium and large panel techniques have not proved economical for low-rise buildings as compared to traditional brickwork.

3.3 Floor and Roof:

Structural floors/roofs account for substantial cost of a building in normal situation. Therefore, any savings achieved in floor/ roofs considerably reduce the cost of buildings. Traditional cast-in-situ concrete roof involve the use of temporary shuttering, which adds to the cost of construction and time.Use of standardized and optimized roofing components where shuttering is avoided prove to be economical, fast and better in quality. Some of the prefabricated roofing/flooring components found suitable in many low-cost housing projects are Precast RC planks, precast hollow concrete panels, Precast RB panels; Precast RB curved panels, precast concrete panels, and Precast RC channel units.

3.4 Thin Precast RCC Lintel:

Normally lintels are designed on the assumption that the load from a triangular portion of the masonry above, acts on the lintel. Bending moment will be WL/8 where W is the load on the lintel and L is the span assumed for the design purpose. By this method, a thickness of 15 cm is required. Thin precast RCC lintels are designed taking into account the composite action of the lintel with the brickwork. The thickness of the lintel is kept equal to the thickness of brick itself having a bearing of 230 mm on either supports. Use of precast lintels speeds up the construction of walls besides eliminating shuttering and centering. Adoption of thin lintels results in up to 50% saving in materials and overall cost of lintels.

3.5 Doors and Windows:

Innumerable types and sizes of doors and windows used in single and similar buildings. This involves the use of additional skilled labor on site and off site and also wastage of expensive materials like timber, glass etc. Economy can be achieved by:

(i) Standardizing and optimizing dimensions;
(ii) Evolving restricted number of doors and window sizes; and Use of precast door and window frames

4. MANUFACTURING PROCEDURE OF THE COMPONENTS:

Generally for the manufacturing of the components these proportions are used,

GYPSUM	**2%**
LIME	**8%**
FLY ASH	**73%**
BOTTOM ASH / POND ASH	**Remaining**

4.1 MIXING PROCESS:

The above materials are mixed in a grinding /mixer as per proportions and some water (2-3%of total wt) for at least 6 minutes and then the mixer is pumped in to the "Hydraulic brick manufacture unit" and then solid bricks can be manufacture. In small- scale plants by using "Manual Leg-line hydraulic machine" is used. But the solid bricks manufactured using Mechanical unit will give smooth finish and more productivity. Then hollow bricks, column blocks and beam blocks are manufactured using moulds (the moulds are made with cast iron) are filled with the fly ash mixer which is prepared previously and hollow bricks are prepared. The roof blocks and joist beams are prepared by skilled labour because these are used for the roof covering.

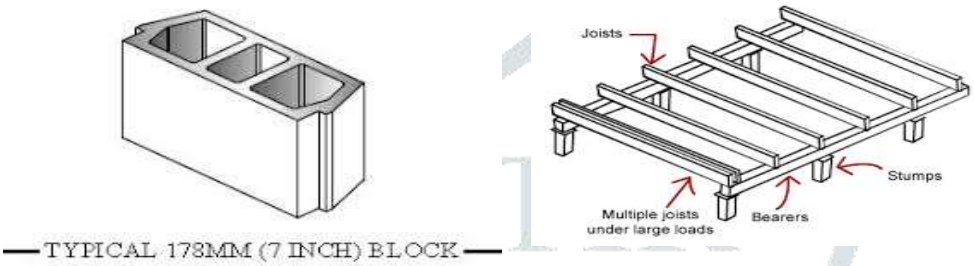
4.2 ROOF BLOCK:

Roof blocks are the roof coving blocks, which are placed over the joist beams. These are prepared based upon the dimensions of the rooms and the load coming over the roof. Based up on loads the thickness is fixed. The shape of the roof blocks is shown in figure. It consists of central holes, which acts as a ventilator for the room.

4.3 JOIST BEAM:

Joist beam is the prefab component, which is used as a support for the roof blocks. These joist beams length and width are decided based on the clear span of the rooms. These joist beams can be laid up to span of 15meters without any supports/ scaffoldings. First these are placed over compound walls then with a spacing of the width of the roof blocks another joist beam is placed in b/w these beams roof blocks are placed one beside the another as shown then the entire roof is completed

These figures show the roof blocks and joist beams



5. ADVANTAGES OF PRECAST/PREFABRICATED CONSTRUCTION:

- ✓ In prefabricated construction as the components is readymade, self- supporting, shuttering and scaffolding is eliminated with a saving in shuttering cost.
- ✓ In traditional construction, the repetitive use of shuttering is limited, as it gets damaged due to frequent cutting, nailing etc. On the other hand, the mould for the precast components can be used for large number of repetitions thereby reducing, the cost of the mould per unit.
- ✓ In prefabricated housing system, there is saving of time as the elements can be casted before hand during the course of foundations being laid and even after laying slab, the finishes and services can be done below the slab immediately. While in the conventional in-situ RCC slabs, due to props and shuttering, the work cannot be done, till they are removed. Saving of time means saving of money.
- ✓ In prefabricated construction, there is better quality control, shape and size of precast elements. Therefore, in structural design, full advantage of properties of cement and steel can be exploited. There is disciplined use of scarce materials like cement, steel and timber.
- ✓ In precast construction, the construction is not affected due to weather, rain, wind etc.
- ✓ We can save Labour cost of mixing, placing of concrete.
- ✓ As the components are light weight they can be transport easily and place and construct ever is needed especially during natural calamities like floods, earth quakes, major accidents are takes place.
- ✓ Because of easy of placing, these are mainly used for construction of temporary bridges during wars.
- ✓ We can construct structures which are located in congested places like where the lack of place for storage of materials and machinery.

6. WHY SHOULD WE PREFER PREFABRICATION?

In India, adoption of prefabrication building techniques has many merits, like availability of materials, labour, and technical skills. Advantages of prefabrication are multiple as the components are readymade and self-supporting, shuttering and scaffolding is eliminated, with a saving in shuttering cost. In traditional construction, the repetitive use of shuttering is limited, as it gets damaged due to frequent cutting, nailing, etc. On the other hand, the mould for the precast components can be used for a large number of repetitions, thereby reducing the cost of the mould per unit. In the prefabricated housing system, there is saving of time, as the elements can be cast beforehand during the course of the foundation being laid. Even after laying slab, the finishes and services can be done below the slab immediately. In the conventional in- situ RCC slabs, due to props and shuttering, the work cannot be done till these are removed. Saving of time means saving of money. In prefabricated construction, there is better quality control, shape and size of precast elements. Therefore, in structural design, full advantage of the properties of cement and steel can be taken. There is disciplined use of expensive materials like cement, steel and timber.

7. CONSTRUCTION PROCEDURE USING PRE FAB COMPONETS:

- For case study we consider, single storied residential building consists of 4- rooms constructed with prefab components and compared with monolithic construction. *Steps for construction using* prefabricated components:
- The *foundation* is constructed as usual monolithic construction procedure; here also we can use fly ash blocks for supporting walls.
- For construction of *columns* a specially made *column blocks* are available which is having central gaps, which are useful for placing of the reinforcement.
- All the load bearing and internal *walls* are constructed with *solid fly ash bricks* and hollow bricks.
- The corners joints can be constructed using *inter locking wall bricks*.
- After completion of the room height *beam blocks* are laid over the walls, which are acted as a beams for the building.
- Roof is constructed as explained in roof blocks and joist beams.
- After placing all the roof blocks and joist beams, a 6mm wire mesh is laid over the entire roof then lean mix of cement mortar is laid over it and the total thickness of the roof should be restricted to 4 inches only.
- Being long spans of joist beams are available we can lay the roof for all the rooms at a time so that economically we can save the manpower.
- After hardening of 3 days curing is to be done for two days. Then the finishing of walls and floors are to be done. Since the bricks used are fly ash, the plastering cement can be minimized.

Then the construction is compared with monolithic construction,

- So by using prefab comp., we can save the materials up to40%.
- Come for cost of construction is about 25-30% we can save.
- We can get more strength with less weight.
- We can control the temperature variations.
- We can save 15% of labour cost.

8. LIMITATIONS OF PREFABRICATIONS:

As the coin has both faces prefabricated construction is having some drawbacks, As the precast elements have to behave monolithic on erections, extra reinforcement may be necessary in some cases.

- As the precast elements have to behave monolithic on erections, extra reinforcement may be necessary in some cases.
- Extra reinforcement is required to take care of handling and erection stresses.
- Temporary props may be required in some cases, before the in-situ concrete joints achieve strength
- The cracks may develop at the joints between the precast and in-situ concrete due to shrinkage and temperature stresses. To overcome them, extra steel is required across the joint.
- As there are chances of leakage/seepage through the joints between the precast components, extra care is required to make them leak proof.
- The greater cost of transporting precasting units as compared with transporting materials.

9. CONCLUSIONS:

Mass housing targets can be achieved by replacing the conventional methods of planning and executing building operation based on special and individual needs and accepting common denominator based on surveys, population needs and rational use of materials and resources. No single approach and solution is available which can satisfy the community at large. However, what is ideal and desirable is to have a system, which can provide choice for people and also appropriate techniques to meet the situation. The essence lies in the system approach in building methodology and not necessarily particular construction type or design. Adoption of any alternative technology on large scale needs a guaranteed market to function and this cannot be established unless the product is effective and economical. Partial prefabrication is an approach towards the above operation under controlled conditions.

The methodology for low cost housing has to be of intermediate type less sophisticated involving less capital investment. The Govt. of India has to popularize these components and the implement them at least for low cost Govt. houses. People should be more aware about these products and save the environment by using the thermal waste in a better manner.

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