

# Relevance of Fly ash based Cellular Lightweight Concrete for Greener Buildings & Environment

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## 1.0. INTRODUCTION

All the developing countries have some typically common characteristics: -

- (a) Most of these have huge population, which keeps on growing at a high pace.
- (b) These are primarily agricultural economies and are somehow managing to feed their millions by virtue of hard labour of their farming sector and improved seeds and farming techniques developed by their agricultural institutions.
- (c) The other basic need of shelter for all is far from satisfied and tremendous effort is being put-in to meet this challenge.
- (d) The infrastructure is poor and needs improvement. The authorities are treating this as a priority sector and doing their best to improve means of transportation, communication network, Power availability etc.
- (e) Bulk of the power in most of these countries is being made available from thermal power stations based on locally available medium/low grade coal. Fly Ash is a by-product of these power plants, being the residue discharged after burning of pulverized coal during power generation process. Disposal of this waste material is proving to be a big problem at these thermal plants, where huge stocks are getting piled up endangering the environment in the surrounding area.

## 2.0. CURRENT ART OF CONSTRUCTION

2.1. The low-rise walk-up housing is primarily being constructed using burnt clay bricks as the primary walling material. The high-rise make use of skeletal framework of steel or reinforced concrete. The filler walls for dwellings are commonly in brick masonry, while the institutional buildings mostly use glass for cladding and some kinds of thermally/sound insulated plastic/gypsum/block-board panels for internal partitions.

2.2. Considering the facts that: -

- (i) Production of clay bricks leads to wastage of precious agricultural topsoil, which is badly needed to feed the growing millions, so its use should be discouraged.
- (ii) Baking of bricks needs energy, which also in short supply, so needs to be avoided.
- (iii) Brick kilns also emit smoke during baking process, which pollute environment and should be curbed.

2.3. It has been very common practice to use of a layer of mud as a thermal insulating membrane on roofs of houses. The superior class dwellings and institutional buildings increasingly rely on synthetic products like Styropore, Glass/rock wool, polystyrene etc. to achieve thermal and sound efficacy.

Such use of mud, which apart from being relatively heavy and not very efficient thermally, is desired to be avoided, to spare land for agricultural use exclusively. The synthetic insulation materials, though very efficient for insulation, are not environment friendly, for these emit toxic fumes under fire, which if inhaled could be fatal.

2.4. Steel used for structural framework or in the form of reinforcing steel in reinforced concrete members as also cement used in concrete, mortars or reinforced elements, are both costly primary raw materials for construction. Attempt should be made to economise on their use to save costs and energy expended in their manufacture.

### **3.0. SCOUTING FOR ALTERNATIVES**

In mid-nineties while the author was involved with development of major real estate projects around New Delhi, he was keen to look for an appropriate alternative for burnt clay bricks for masonry work. Use of Dense Concrete blocks, Aerated Autoclaved Concrete blocks and Sand Lime bricks was considered, but not found acceptable. However, we came across another simple technology to produce Cellular Lightweight Concrete (CLC) under ambient conditions in wide range of densities from  $400\text{kg/m}^3$  to  $1,800\text{ kg/m}^3$ . This material, like concrete, can either be poured in-situ or converted into pre-cast elements like blocks or reinforced structural components.

The technology, originating from Germany has the primary constituents of: Cement, Sand, Water and Preformed Stable Foam. This version was being exploited in over 50 countries of the World. More than 1,00,000 dwelling units and other structures had already been constructed with this technology in diverse climatic conditions

It is a type of concrete, where the coarse aggregate is substituted with pre-formed stable foam. The same infrastructure, plant and equipment, as available at ordinary construction sites, supplemented with a small Foam Generator, is suitable for producing CLC. The wet mix slurry is either poured or pumped into assembled moulds of blocks or formwork of reinforced structural elements or poured onto flat roofs for thermal insulation or for filling of voids. The foam imparts free flowing characteristics to this slurry due to ball bearing effect of foam bubbles, enabling it to easily flow into all corners. It levels and compacts in the moulds/forms by itself, without requiring any kind of external vibration or compaction.

This CLC was considered to be a worthwhile alternative to be pursued and as result of some investigative efforts, we could incorporate Fly Ash as a new additional constituent in its production. Fly ash can comprises more than 25% content (*ranging between 26% to 33%*) of the solid material constituents of CLC mixes for different density outputs. We, thereby not only found a productive use of a waste industrial product, but incorporation of Fly Ash also saves over 35% in cement content, otherwise needed for the corresponding Cement + Sand only mixes, thereby also leading to substantial reduction in the cost of production.

This fly ash based version of CLC was then used primarily as a substitute for brick masonry in group housing projects of over 4.0 m sft. during 1995 –1998, where some of the blocks rise up-to 27-floors above ground level.

### **4.0. VERSATILE APPLICATIONS OF CLC**

This CLC in different density ranges is suitable for specific types of application in civil construction projects.

#### **4.1. Higher Density Range**

The density range from  $1,200\text{ kg/m}^3$  (*Having 28-day cube crushing strength of  $65\text{ kg/cm}^2$* ) to  $1800\text{ kg/m}^3$  (*Crushing strength  $250\text{ kg/cm}^2$* ) is reckoned as structural grade material. It is utilized for the construction load carrying structural elements like walls, suspended flooring/ roofing slabs, pre-cast blocks or of any other types of Reinforced Pre-cast elements like cladding units etc.

#### 4.1.1. **Poured In-situ Structural Application**

The structural grade of material can be poured into storey high assembly of forms for reinforced load-bearing walls of walk-up apartments upto 5-floors above ground. An example of such an application for a group of 156 units in 2-blocks of four storey high dwellings is shown in “Illustration – A”. The 150 mm thick load bearing walls were cast in density of 1,600 kg/m<sup>3</sup>, while the density was progressively reduced to 1,200 kg/m<sup>3</sup> for the upper two floors.



Reinforced CLC Load-bearing walls used for these 4-storey dwellings south of Delhi – 1997

#### 4.1.2. **Use of CLC Block Masonry for Load-bearing Walls**

This is another option of using CLC blocks of this density range for load-bearing walls for walk-up apartments up-to 15m high constructions. Illustration “B” shows a project where CLC blocks of density 1,400 kg/cum have been used for two storey high Housing colony project in eastern India.



CLC block masonry density 1,400 kg/cum used for Colony near Calcutta

#### 4.2. Medium Density Range

CLC in dry density range of 800-1000 kg/m<sup>3</sup> is utilized for making pre-cast blocks for non-load-bearing walling masonry for internal and/or external walls in framed structures. The size of blocks for the party/external walls may be 500x250x200 mm and the internal partition blocks may be 500x250x100 mm nominal size, although any desired size as per requirements may be produced.

Substitution of brick walls with such CLC masonry, cuts down dead weight of walls by over 50%, thereby resulting in substantial saving in the design of structural elements and foundations. These savings become more pronounced with rising height of dwelling blocks and when earthquake forces are the governing design criteria. Illustration – “C” shows use of such blocks in group housing towers rising up-to 27- floors above ground, in large-scale constructions south of Delhi.

Moreover replacement of 230mm/115mm brickwork with 200mm/ 100 mm block-work improved carpet/plinth area efficiency by nearly 7%. Working with these large sized lighter blocks is much faster, substantially saving on mortar consumption for masonry and plastering. These blocks can also be cut and nailed like wood. Chase cutting for service lines is fast and easy. They also make it feasible to do dry fixing of door/window frames, thereby saving substantially on input of skilled labour and time spent in fixing and grouting holdfasts.



CLC blocks of density 1000 kg/cum used in such towers south of New Delhi

The use of CLC block work instead of brickwork in these buildings not only saved wastage of agricultural land for brick making, saving on energy expended in baking & transporting bricks, enabled use of industrial waste material like fly ash, but also resulted in 10% to 15% saving in the cost of structures.

#### 4.3. Lower Density Range

The lower densities of 400 to 600 kg/m<sup>3</sup> are ideal for thermal insulation applications. CLC's fire proof-ness, termite-resistance, very low water absorption make it a far superior alternative to the commonly used synthetic products like styropore, glasswool, woodwool etc. or age old practices of using mud-phaska or Lime terracing.

The synthetic insulation materials, though lighter in weight and somewhat thermally superior, are far more expensive and lose their efficacy with slight ingress of moisture. These materials are also not environment friendly. Mud-phaska & Lime terracing are nearly four times heavier than CLC and around nine (9) fold thermally less effective than CLC. Moreover cellular lightweight concrete once placed would bond very well with concrete roof slab and last for the life of the structure. Moreover being a mineral product, it is totally environment friendly and durable. The mud-phaska and lime terracing treatments need repair/ replacement every few years. One of the institutional projects in New Delhi, using such thermal insulation is shown in Illustration –“D”.

This range is also used in laying sound insulating layer over structural slabs of intermediate floors in high-class hotels and institution buildings to prevent transmission of noise between lower and upper floors. It can also be used as a filling in depressions in bathrooms or other floors due to up-stand beams etc. as shown in Illustration”E”.



Illustration – “D”  
Roof Insulation being laid in New Delhi

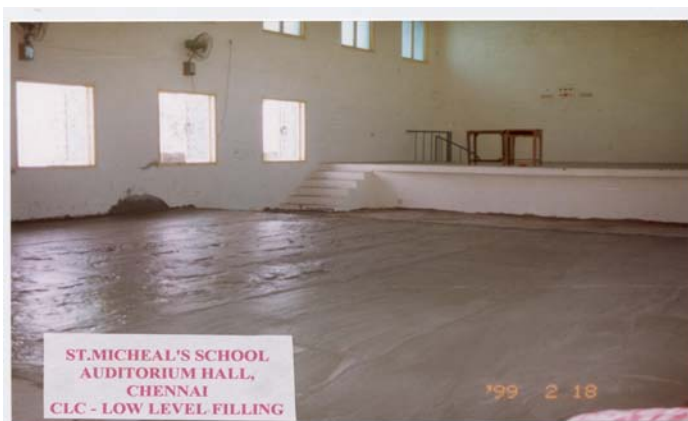


Illustration “E”  
Floor filling in School Auditorium, Chennai

## 5.0. CONCLUDING REMARKS

This Alternative material: -

- saves on wastage of top agricultural soil otherwise wasted in clay brick production.
- It also needs no energy in its manufacture, for it is produced under ambient conditions, unlike Autoclaved version and is moist cured like concrete.
- Being lighter in weight it saves on energy and cost in transportation and handling at site.
- Curtailing dead weight of walls by over 50% in comparison to brick masonry, it enables substantial savings in consumption of primary materials like steel and cement needed for structural framework and foundations., thereby also economising on cost of construction.
- It is also much easier to work with this material, for these can be sawn, chased or nailed like timber. Such blocks substitute nearly 15 standard bricks and being lighter enable faster pace of work and save on labour and masonry material.
- It is not only that the production process of CLC is totally free of any environmental pollution, but it affords the possibility of making the environment greener by enabling Fly Ash – an industrial waste - to be used as one of the main constituent materials.
- The capital investment in production of CLC is far far less (*in fact less than 0.1%*) than the investment needed for producing Aerated Autoclaved Concrete. Only one low investment Foam Generator needs to be added to a normal Concrete making establishment.
- CLC also has lower water absorption than clay bricks and far lower than Aerated Autoclaved version of lightweight concrete.
- Moreover, being the typical concrete, it keeps gaining strength with time, so long as some moisture is available in the surroundings. It is therefore as weatherproof, termite resistant and durable as any other concrete.
- Production process of CLC is even simpler than producing ordinary dense concrete and it also saves on labour and energy needed for vibration and compaction of dense concrete. Dense concrete elements could have honeycombs or voids on surface, but such internal/ surface blemishes are ruled out in CLC units

In view of the above, the material is finding increasing acceptance by various builders in India. Even the national institutions in India like BMTPC, HUDCO, NTPC, Fly Ash Mission are promoting this material as one of the desirable alternative for construction projects.