# Techno-economic feasibility study for the manufacture of lime-flyash cellular concrete blocks

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**A techno-economic feasibility study was conducted for the manufacture of lime-flyash cellular concrete blocks in the Delhi region with a view to utilizing the locally available flyash from the thermal power stations. The paper outlines the manufacturing process and technical details. A layout of the plant is proposed. It is concluded that such blocks, an alternative to the traditional burnt clay bricks, can be used in building construction.**

1 Gypsum storage
2 Belt conveyor for gypsum
3 Rotary table feeder
4 Conical ball mill for grinding of gypsum
5 Screw conveyor for gypsum
6 Bucket elevator
7 Storage silo for gypsum powder
8 Limestone storage
9 Lime kiln
10 Jaw crusher
11 Belt conveyor
12 Rotary table feeder
13 Conical ball mill for grinding of lime
14 Screw conveyor
15 Bucket elevator
16 Storage silo for lime powder
17 Hopper for dumping of flyash
18 Storage silo for flyash
19 Silo for flyash
20 Silo for gypsum powder
21 Silo for lime
22 Automatic weighing arrangement
23 Centrifugal pump for water
24 Storage silo for aluminium powder
25 Mixer
26 Trolley for carrying slurry
27 Mould filled with cellular concrete mix
28 Longitudinal cutting machine
29 Transverse cutting machine
30 Moulded component after cutting
31 Autoclave
32 Autoclaved component
33 Storage for product component

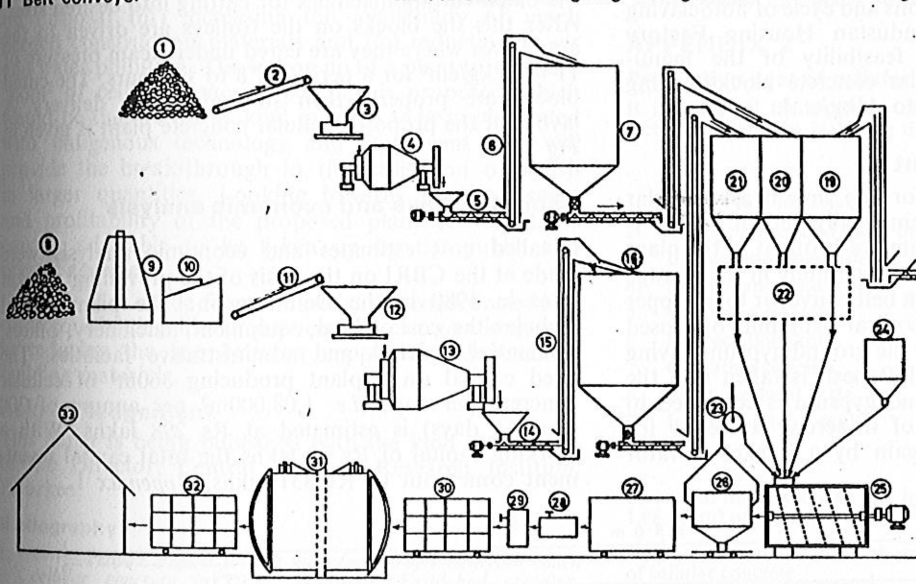

Fig 1 Process flow chart

The unfulfilled demand for houses and the shortage of conventional building materials like bricks and cement have necessitated the development of new building materials based on new technologies and using industrial wastes as raw materials. The production of cellular concrete using lime and flyash is a step in this direction. It is a lightweight building material produced by autoclaving a set mix of a fine siliceous material, such as flyash and a binder in the form of lime. Lightness is achieved by incorporating a large proportion of closed microscopic pores in the slurry with the help of air entraining or foaming agents.

The numerous advantages of cellular concrete over bricks, are in terms of its strength to weight ratio, low thermal conductivity, sound insulation, stability to variations in temperature and humidity, nailability and resistance to fire. Its low density permits larger building units which is a unique advantage in prefabrication. Appreciable savings are effected in foundation loads in multistoreyed constructions. This concrete has found general application in the form of masonry blocks in most of the European countries and its use is now being advocated in the developing countries including India.

The present production of flyash in India is about 8.5 million tonnes per annum. It is a pozzolanic material which reacts with lime in the presence of moisture forming cementitious compounds. Laboratory investigations were carried out at the Central Building Research Institute, Roorkee by Chopra, Taneja and Tehri to produce cellular concrete using lime, flyash and gypsum

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as raw materials and a small amount of aluminium powder as gassing agent[1]. Factors affecting the properties of cellular concrete; *viz*, nature and fineness of flyash, quality of lime, quality of aluminium powder, mixing technique and cycle of autoclaving were studied in order to work out the technology for producing cellular concrete of density 700kg/m³.

## Manufacturing process

The production of cellular concrete involves the admixing of high calcium quicklime and gypsum to a slurry of flyash. A small amount of aluminium powder is then added to the slurry for its aeration. Hydrogen gas is released from the interaction of aluminium with calcium hydroxide

$$2Al + 3Ca(OH)_2 = 3CaO + Al_2O_3 + 3H_2$$

The liberation of hydrogen aerates the slurry which is then poured into the moulds where it rises in much the same manner as bread. Setting takes place in 4 to 5 hours. Thereafter the material is demoulded and cut into blocks of desired sizes. The blocks are subsequently autoclaved at a steam pressure of 11 to 12kg/cm². They are then allowed to cool and stacked for use.

Studies carried out at the Central Building Research Institute helped in designing the mix proportions mixing schedule, temperature conditions and cycle of autoclaving Full scale trials at the Hindustan Housing Factory demonstrated the technical feasibility of the manufacture of flyash based cellular concrete blocks having compressive strengths of 40 to 44kg/cm².

## Plant operation and layout

The process flow diagram for the lime-flyash cellular concrete plant has been schematically shown in *Fig* 1. The limestone, coal and gypsum are brought to the plant site in trucks and are stockpiled separately in the storage section. The gypsum is fed by a belt conveyor to a hopper charging into an airswept conical ball mill of closed circuit type for grinding while the ground gypsum having fineness 90 percent through 170-mesh is taken into the product collection. The ground gypsum is conveyed to the storage silo by means of a screw conveyor for horizontal movement and again by a bucket elevator for vertical movement.

The loading of mixed feed of limestone and coal into the kiln is effected by a skip hoist. The quicklime obtained from the kiln is crushed by a jaw crusher to below 12.5-mm size. It is conveyed by belt conveyor to the charging hopper fitted to an airswept closed circuit conical ball mill. The ground material having fineness of 90 percent through 170-mesh goes to the product collector for subsequent transportation to the storage silo.

Flyash received from the trucks is directly unloaded into a hopper installed at the ground level having a capacity of one truck load. From this hopper the flyash is conveyed to the storage silo by means of a screw conveyor and bucket elevator. The ground gypsum, lime and flyash are conveyed to their respective storage silos.

From here appropriately proportioned and weighed amounts of ground lime, gypsum and flyash are discharged into a mixer with the requisite addition of water at the same time. Aluminium powder is subsequently added to the slurry inside the mixer. The slurry is poured into the moulds kept on trolleys. The trolleys are then manually moved to a setting chamber where the moulds are removed by an overhead travelling crane and allowed to set. The blocks are then carried on to the block cutting machines for cutting into desired sizes. After this the blocks on the trolleys are driven to the autoclaves where they are cured under steam pressure of 11 to 12kg/cm² for a period of 8 to 10 hours. The cured blocks are properly then stocked before delivery. A layout of the proposed cellular concrete plant is given in *Fig* 2.

## Capital outlays and economic analysis

Detailed cost estimates and economic analysis were made at the CBRI on the basis of the prevailing market rates in 1980 in the Delhi region. The plant capital includes the cost of land, equipment, machinery, offices, residential quarters and administrative facilities. The fixed capital on a plant producing 360m³ of cellular concrete per day; (*i.e.* 1,08,000m³ per annum of 300 working days) is estimated at Rs 298 lakhs. With a working capital of Rs 33 lakhs the total capital investment comes out to Rs 331 lakhs, *Appendix* 1.

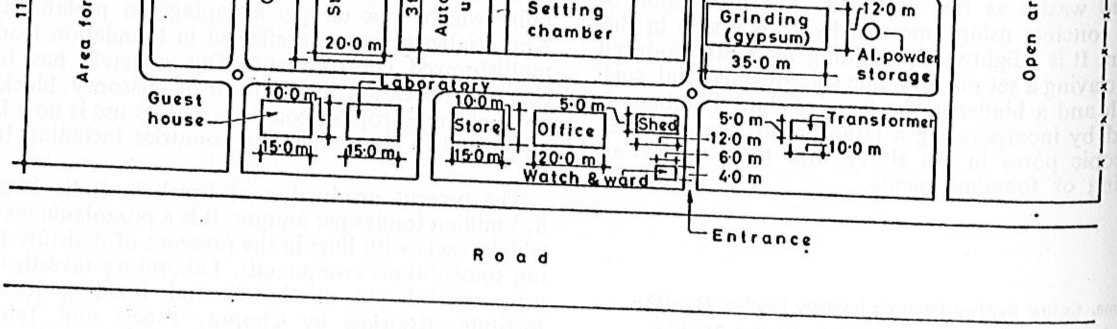


Fig 2 Plant layout

The total cost of production for the plant producing lime-flyash cellular concrete operating in three shifts per day has been estimated to be Rs 221.40/m³, *Appendix* 2. The proposed selling price with 20 percent gross return on investment works out to be Rs 282.70/m³ leading to an annual profit of Rs 66.20 lakhs before taxes, *Appendix* 3. The economic estimates outlined herein are of generalised nature with a view to studying the economic feasibility of this process. The actual returns on investment could be worked out for various sponsors from a knowledge of the specific sites, exact nature and source of the financing body and locally available materials.

Cost of production of cellular concrete produced from lime and flyash is much lower than that of aerated concrete produced from portland cement and ground sand because of lower costs of the raw materials.

As a walling material alternative to the traditional burnt clay bricks its use in single storey construction is not economical. However, becuase of lightweight it is advantageous to use it in multistoreyed construction as it reduces the dead load on the foundation and it provides better thermal comforts on account of its low thermal conductivity as compared to bricks.

## Concluding remarks

The utilization of flyash has four advantages: (*i*) conversion of waste into wealth, (*ii*) saving in expenditure on disposal (*iii*) increasing the availability of much needed construction materials and (*iv*) reduction in air and water pollution. The setting up of a plant to produce 360m³ of cellular concrete per day is proposed which would be the first of its kind in India to be implemented with indigenous technology and equipment and will provide the break-through in the utilisation of flyash in larger quantities. Looking towards the investment and profitability of the proposed plant it would be equally advisable to be taken up by the public and private agencies.

Blocks thus made from industrial siliceous wastes and calcareous binders like lime or cement can go a long way to reducing the gap between supply and demand of building materials.

## Acknowledgement

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## APPENDIX 1

### Capital outlays

*Fixed capital Investment*

| | |
|---|---|
| A. Capital on land and buildings— | *Rs*, lakhs |
| Requirement of land, 35000m² at Rs 50/m² | 17.50 |
| Factory and office building | 36.00 |
| Site development | 3.50 |
| Staff housing | 30.56 |
| Medical unit | 3.00 |
| Furniture | 1.00 |
| say, Rs | 91.00 lakhs |

| | |
|---|---|
| B. Capital costs on plant, equipment and machinery— | |
| Equipment cost including laboratory and workshop machinery | 142.00 |
| Erection cost of plant at 15 percent of equipment cost | 21.30 |
| Electric installation at 10 percent of equipment cost above | 14.20 |
| Water services | 1.00 |
| Design, engineering and controls at 10 percent of equipment cost | 14.20 |
| Contingencies at 10 percent of equipment cost | 14.20 |
| say, Rs | 207.00 lakhs |
| C. Fixed capital Investment (A+B) = | Rs 298.00 lakhs |

*Working capital*

The criterion recommended for estimation of the working capital amounts to about 10 percent of the total investment.

Total capital investment = fixed capital + working capital

or, TCI $= FC + WC$

$= FC + 0.10\ TCI$

or, TCI $= \frac{FC}{0.90}$

So TCI $= \frac{298}{0.9} =$ Rs 331 lakhs.

WC $= 33.1$ lakhs

Thus working capital required = Rs 33 lakhs

Total capital investment = Rs 331 lakhs.

## APPENDIX 2

### Production cost of cellular concrete

It includes all the expenses directly connected with the manufacturing operation including the transportation costs

| | | *Rs*, lakhs |
|---|---|---|
| 1. | Cost of raw materials | 99.844 |
| 2. | Electric power and other utilities | 19.930 |
| 3. | Labour and supervision | 15.282 |
| 4. | Maintenance and repairs | 12.185 |
| 5. | Taxes and insurance | 5.960 |
| 6. | Depreciation costs | 16.05 |
| 7. | Operating supplies | 1.825 |
| 8. | Plant overhead costs | 3.488 |
| 9. | Interest on total capital | 57.600 |
| | | Rs 232.144 lakhs |

| | |
|---|---|
| So annual manufacturing cost for 1,08,000m³ of product | Rs 232.144 lakhs |
| Ex-plant manufacturing cost per m³ of cellular concrete | Rs 214.95 lakhs |
| General expenses per m³ of concrete on administration distribution and sales at 3 percent | Rs 6.54 lakhs |
| The total production cost per m³ of cellular concrete | Rs 221.40 lakhs |

## APPENDIX 3

### Profitability analysis

(*i*) Fixation of selling price — basis at 20 percent gross return on investment

Percent return on investment (ROI) $= \frac{\text{annual return (AR)} \times 100}{\text{total capital investment (TCI)}}$

or AR $= \frac{TCI \times ROI}{100}$

$= \frac{331 \times 20}{100}$

= Rs 66.20 lakhs

| | | |
|---|---|---|
| Annual return (AR) | = | Gross annual income (GAI) — Annual Cost of Production (ACP) |
| 66.20 | = | GAI — ACP |
| GAI | = | 66.20+239.112 lakhs |
| | = | Rs 305.312 lakhs |
| Thus selling price per m³ of concrete | = | Rs. 282.70 |
| Gross annual sales | = | Rs 305.312 lakhs |

| | | |
|---|---|---|
| Annual production cost | = | Rs 239.112 lakhs |
| Annual return (gross) | = | Rs 66.20 lakhs |
| Corporate taxes at 55 percent | = | Rs 36.41 lakhs |
| Annual profit (net) | = | Rs 29.79 lakhs |
| Net return on investment | = | $\frac{29.79\times100}{331}$ |
| | = | 9 percent. |