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Designing, Developing and Testing of Cellular Lightweight Concrete Brick (CLC) Wall built in Rat-Trap bond

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Abstract - Although building techniques and materials have evolved over thousands of years, construction is still a long, complex, and expensive process. Construction industry boom can be seen in almost all the developing countries. With the increase in material costs in the construction industry, there is a need to find more cost saving alternatives so as to maintain the cost of constructing houses at prices affordable to people. There is need to develop an alternative system of building component which would impart more benefits and are multifunctional with optimum use of labour and material. Cellular light weight brick wall in Rat-trap bond is an innovative technique for building masonry unit which reduces the construction cost, time and labor considerably. This may not solve all construction problems but they do resolve many issues associated with traditional materials.

Keywords - Rat-Tarp Bond, Cellular lightweight concrete, alternative building material, Cost Effective.

1. INTRODUCTION

The construction method of using conventional bricks has been revolutionized by the development and usage of lightweight concrete blocks. The tedious and time-consuming traditional brick-laying tasks are greatly simplified by the usage of these effective alternative solutions. The focus is now more on seeking environmental solutions for greener environment. The usage of Cellular Light-weight Concrete (CLC) blocks in Rat-Trap bond would gives a prospective solution to building construction industry along with environmental preseration.

Despite all initiatives to introduce alternative walling materials like cellular light weight concrete, sand lime bricks, compressed earth blocks, concrete / stonecrete blocks, and fly ash bricks, it is envisaged that sand lime bricks and cellular light weight concrete bricks would still occupy the dominant position in the foreseeable decade. The excellent mechanical properties and durability of CLC and fly ash brick enlarges its scope for application in building construction and development of infrastructure, construction of pavements, dams, tanks, under water works, canal lining and irrigation work etc. Enormous quantities of CLC and fly ash are available in and around thermal power stations in all the states. The demand of bricks could be met by establishing small units near thermal power stations and to meet the local demand with less transportation costs.

1.1 Cellular Lightweight concrete Bricks:

Foam concrete is cellular material made with a mixture of cement, Fly ash, and sand (optional), stable Foam and special additives (if required) which will help to form unique cellular structure material. The hardened material consists of small enclosed air bubbles thereby resulting in a lightweight stable cellular material with densities ranging from 400kg/m3 to 1800kg/m3 according to various compositions. Foam concrete manufacturing consumes higher amounts of fly ash (which is waste material from thermal power stations) hence it is considered as green building material. The Basic foam concrete is made from mixing aquas which is produced from foam generator into slurry of cement, fly ash, sand (optional) water and other additives in a precisely specially designed mixer for accurately mixing without disturbing its original chemical and physical properties.

The final mixture results in many small cells uniformly distributed throughout the concrete which will create cellular structural material from densities ranging from 400kg/m3 to 1800kg/m3. The precise control of volume of air cell in foam will result controlled densities and strengths of foam concrete.

The use of Cellular Lightweight Concrete masonry will result in cheaper and faster construction compared with framed building construction for low-rise buildings. Cellular lightweight concrete block system is promoted as a new building technique that may result in even greater economy. The use of Cellular lightweight concrete blocks in building construction speeds up the construction process as a result of the reduction of mortar layers due to less number of joints. Further, due to the less number of joints of the blocks, the walls can be assembled at much faster speed compared to mortared masonry construction. The low cost housing sector is still underdeveloped as compared to conventional building in both public and private sectors and is far from meeting the demand of low cost housing sector. The proposed system using Cellular lightweight concrete blocks may provide the solution to overcome this shortage as these blocks can be used in the construction of both non-load bearing and load bearing walls.

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1.2 Rat-Tarp bond:

The rat-trap bond technology has been developed by Architect Laurie Baker in India and is a result of its experimentations in cost-effective housing technologies conducted over 40 years. This technology has been used in India for over 20 years. Rat-Trap bond is innovative type of technique which is strength compatible with standard 9" brick wall, but consumes 20% less material. The rat-trap brick can be constructed in 8" or 9" thicknesses. The air medium that is created by the bond helps maintaining a good thermal comfort inside the building. As the construction is appealing to the eye both internally & externally, plastering is not necessary. The overall cost saving on this wall compared to the conventional 9" wall is about 26%.

In Rat-Trap bond the bricks were laid in alternate Shiner and rowlock pattern but the dimensions of the brick are so kept that even though the bricks are laid in header and stretcher pattern the cavity in the Rat-trap bond is kept intact. In brick the brick is narrowed on the stretcher side i.e. horizontally and its height is increases on shiner side i.e. vertically.

This gives the wall with an internal cavity bridged by the rowlock. This is the major reason where virgin materials like brick clay and cement can be considerably saved. This adds this technology to the list of Green building technologies and sustainability for an appropriate option as against conventional solid brick wall masonry.

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Rat trap bond wall is a cavity wall construction with added advantage of thermal comfort. The interiors remain cooler in summer and warmer in winters. It is a step towards green building innovative.

The Rat trap bond construction is a modular type of masonry construction. Due care must be taken while designing the wall lengths and heights for a structure. The openings and the wall dimensions are to be in multiples of the module. Also the course below sill and lintel are to be a solid course by placing bricks on edge. The masonry on the sides of the openings also to be solid as will help in fixing of the opening frame.

Fig.1 Typical picture of Rat-Trap bond

The focus is now more on seeking environmental solutions for greener environment. The usage of Cellular Light-weight Concrete (CLC) blocks in Rat-Trap bond would give a prospective solution to building construction industry along with environmental preservation.

1.3 Housing Problem:

Non-affordability of housing by economically weaker sections of society and low income families in urban areas is directly linked with the magnitude of urban poverty. Housing is one of the basic requirements for survival of human beings. Ownership of house provides significant economic security and social status in a society. The total housing shortage in the country at the end of 10th five year plan was estimated to be 24.71 million dwelling units for 67.40 million households where 98% of shortage was in the low income and economically weaker sections. The situation even at the end of 11th five year plan, the total housing requirement will be 26.53 million dwelling units for 75.01 million households.

2. Advantages of Using Rat Trap Bond Technology

1. By adopting this method of masonry, one can save approx. 20-35% less bricks and 30-50% less mortar; also this reduces the cost of a 250 mm wall by 20-30 % and productivity of work enhances.
2. For 1 m^3 of Rat trap bond, 470 bricks are required compared to conventional brick wall where a total of 550 bricks are required.
3. Rat trap bond wall is a cavity wall construction with added advantage of thermal comfort. The interiors remain cooler in summer and warmer in winters.
4. Rat-trap bond when kept exposed, create aesthetically pleasing wall surface and cost of plastering and painting also may be avoided.
5. Rat trap bond can be used for load bearing as well as thick partition walls.
6. All works such as pillars, sill bands, window and tie beams can be concealed.
7. The walls have approx. 20% less dead weight and hence the foundations and other supporting structural members can suitably be designed, this gives an added advantage of cost saving for foundation.
8. Service's installations should be planned during the masonry construction if not exposed.
9. Virgin materials such as bricks, cement and steel can be considerably saved by adopting this technology. It will also help reduce the Embodied Energy of virgin materials and reduces the production of Green House Gases into the atmosphere.
10. In case for more structural safety, reinforcement bars can be inserted through the cavity till the foundation.

2.1 Advantages of Using CLC Bricks:

1. CLC is a light weight brick where water absorption is less compare to red and fly-ash brick
2. High thermal insulation
3. High sound Insulation
4. Compressive strength is more than other bricks
5. Environmental friendly
6. Quantity of cement is less when making a wall why because accurate edges and even surface
7. CLC bricks life span is more than other bricks

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8. CLC block size can be made of any size according to our requirements

2.2 Comparison between Burnt clay brick, Fly ash brick an CLC brick:

Table 1 Comparison between burnt clay brick, Fly ash brick and CLC brick

S. No	Parameters	Burnt Clay Bricks	Fly Ash Bricks	CLC Bricks
1	Basic Raw Material	Agricultural/Red soil and wood, coal or Bagasse for firing	Cement, Fly ash, sand, aggregate	Cement, Fly ash, Foaming agent.
2	Production process	Process in brick kiln	Plant /project site	Plant/project site
3	Dry Density	1800-2000	900-2100	400-1800
4	Application	Load bearing and non load bearing	Load bearing and non load bearing	Thermal insulation, partition wall, non load bearing external wall
5	Compressive strength kg/cm^2	20-80	30-150	25-40
6	Block size LxBxH mm	190x90x90, 230 x 110 x 76 and 230 x 150 x 76	190x90x90, 230 x 110 x 76 and 230 x 150 x 76	Int brick 230x76x95 And 300x150x150 or 600x300x100/ 150/200
7	Efflorescence	Slight – Moderate	Nil	Nil
8	Warpage	<2.5 to 3.0 mm	< 1.0 to 2.0 mm	< 1.0 to 2.0 mm
9	Aging	No	Yes	Gains strength with age
10	Thermal Insulation	Better	Normal	Very good
11	Sound insulation	Normal	Better	Very good
12	Ease in working	Normal	Normal	Very easy
13	Labour requirement	100%	100%	50% of normal brick work
14	Eco Friendliness	-Process creates smoke, - Uses high energy for firing, - Agricultural soil is wasted	- no smoke - low energy only for hydraulic press and mixing of ingredients	- Pollution free - Least energy requirement - consumes fly ash which is a waste from thermal power plant - Green building product - Uses no Agricultural soil and natural sand

3. Design and Casting Process of CLC Brick

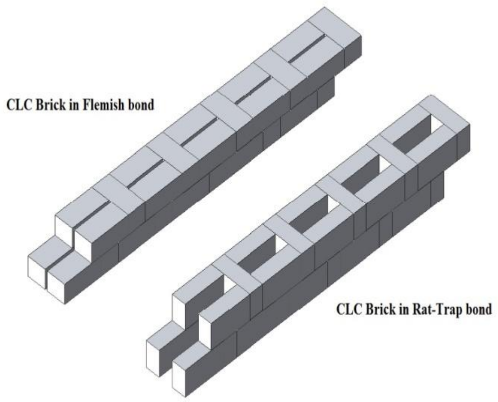

Fig. 1 Rat-Trap and Flemish bond in CLC brick

Dimensions of brick:

Length : 230 mm
Width : 100 mm
Height : 76 mm

Material used for producing 1m^3 CLC

Cement – 250 kg
Fly ash – 950 – 1000 kg
Chemical (foaming agent) – 1.2liters
Once diluted in 40 parts of potable water.
Water – 250 – 300 liters

3.1 Production Procedure of CLC brick:

The production of CLC brick requires much precision than the burnt clay brick. The casting brick in clay soil was not easy. Also making brick in cement concrete was not feasible as the brick would be heavy in weight and cost more.

The best option for producing brick was to use the material which is easy to cast, with precision and should be cost effective. The material which fulfills these requirements is Cellular light weight concrete brick. CLC brick is easy to produce, precise in dimensions due to use of moulds and light in weight.

Following are the steps of casting brick in Cellular light weight concrete:

3.1.1 Preparation of moulds:

For smooth surfaces clean the moulds completely of remaining concrete, the steel/ wood surface must be oiled. Mostly vegetable oil is preferred. Trials with different materials will have to show best results. The oil is applied thoroughly to the corners of the mould so that the brick can be easily dismantled from mould without breaking its edges. Oil will not destroy the mix, once the foam has been mixed in the mortar.

3.1.2 Preparation and mixing of foam:

The foam is a vital part of cellular lightweight concrete so it is also called as foam concrete. The foam is produced by using a protein based liquid compound. This compound is diluted in water at 30 ml/liters. This foam is put into specially designed machine for producing foam. The machine comprises of two units viz. pump for suction of diluted compound and air compressor for mixing air and producing foam.

There is a unit which mixes the compressed air with diluted compound at given pressure resulting in foam. The foam is dense and containing small uniform shape bubbles. The bubbles in the foam do not disperse like soap bubbles but when mixed with the cement fly ash mixture it forms a homogenous mixture. The bubble in the foam gets trapped in the cement fly ash mixture making the brick light weight.

3.1.3 Charging and Mixing:

Before charging the mixer with material, it must be rinsed, in particular if the concrete produced before, used any additive, which might have adverse reaction on the foam. Where possible, start the mixer before charging it with material. The material viz. cement and fly is placed in the mixing drum in 1:5 proportion and mixed by adding water, if the mixture is dry mixed the fly ash will disperse away as it is very fine. The mixture is of different type than normal concrete mixture. It has stationary outer drum unlike the moving drum of concrete mixture, and inner helix which is revolving at 250-300 RPM. The helical operation is used instead of revolving entire drum so that the bubbles in the foam do not get dispersed. If the drum is used for mixing instead of helix the bubbles would get dispersed due to descending of material on each other.

Fig. Mixing of CLC with foam

3.1.4 Placing/Pouring of CLC in the mould:

The oiled mould is placed on clean surface preferably in shade avoiding direct sunlight. The prepared foam is then poured slowly in the mould and at the same time the mould is shaken so that the material reaches in every corner of the mould. The mould is filled completely and the extra material top surface is striped out and made plain. The mould is then kept for 24 hours for setting of material.

In between pours, the mixer should be kept in motion until it is completely discharged. CLC always should be poured in the shortest possible time. Use aluminum or other straight and sharp-edged screed slats immediately after pouring the CLC.

3.1.5 Curing &Transport:

The brick should be positioned upwards on the curing yard, resting on a soft underground - best on a rake or wooden beams. All possible efforts should be taken, in particular in dry and hot climate or more even when windy, to keep the brick damp for at least three, better for more days. It should be preferably kept in shade and in damp condition as the dry condition would absorb the moisture from the brick reducing its strength. A sprinkler will be helpful or gunny bag that is kept wet. Curing compound would be the costly alternative. Standards call for a 24 day curing period for cement-based bricks. Due to reduced weight, more volume of CLC more bricks can be transported at the same (increased pay-load) then of CC. Brick should be kept upright during transport and also on a soft/wooden underground. Unload properly.

3.1.6 Assembly:

Assembly of brick in CLC happens usually the same way as with normal bricks. Special care has to be taken not to apply any mechanical force to avoid damage. If necessary, CLC bricks may be sawn (no gravel), definitely nailed (without the use of dowels as in AAC), drilled or profiled. In densities of 1200 kg/m³ and higher, where reinforcement is used, CLC requires no special coating/plaster on the outside. Water-repellent paint (dispersion paint) will be suitable.

4. Results and Discussion

4.1 Test on CLC brick:

Test on brick was carried out in accordance with reference to IS codes on Burnt clay brick (IS 2691:1988 & IS 1077:1992) and IS code on Pulverized fuel ash lime brick (IS 12894:2002). The test results of CLC brick are compared with Pulverized fuel ash lime brick as both have common raw material i.e. Fly ash and sand. Even though CLC brick is light in weight due to use of foam it should not compromise with the required strength.

Table no.2 Test Results compared with Standard values confirming IS Code

Particulars	Unit	Value CLC Brick	Standard values Confirming of (Red brick Is 2691 – 1988 IS 1077 – 1992 & pulverized Fuel Ash Lime brick IS 12894:2002)
Size (LxBxH)	mm	230x76x95 mm	190x90x90 mm
Avg Compressive strength (9 Brick samples) Is 3495 part 1 1992	N/mm^2	2.9 – 3.7 N/mm2	3.5 N/mm2
Avg Water absorption (9 Brick samples) Is 3495 part 2 1992	%	18-20%	<20 %
Determination of efflorescence (9 Brick samples) Is 3495 part 3 1992	%	Nil	<12.5 %
Determination of warpage (9 Brick samples) Is 3495 part 4 1992	mm	< 2mm	<2.5mm for height <3.0mm for length and width
Crushing strength of Wall (1m x 1m) tested	N/mm^2	0.87 N/mm^2	Greater than 0.35 N/mm^2 According to IS 1905-1987 (pg 16 table No. 8)

Following tests were conducted on Brick:

- Compressive strength
  Is 3495 part 1 1992
- Water absorption
  Is 3495 part 2 1992
- Determination of efflorescence
  Is 3495 part 3 1992
- Determination of warpage
  Is 3495 part 4 1992
- Crushing strength of Wall
  (1m x 1m) tested

4.2 Cost Analysis of CLC brick:

Brick of dry density 1400 kg/m^3 was selected. To produce 1 m^3 CLC the brick of dry density 1400 kg/m^3 raw material is used in following quantity:
Cement - 250 kg & Fly ash – 1000 kg:
Making proportion of 1:5

Table no.3 Cost Analysis

Item	Qty.	Rate	Amount (Rs.)
Cement	250 kg	6 /kg	1500
Fly ash	1000 kg	1.5/kg	1500
Foaming agent	1.2 liter	200 /liter	240
Labour (semi-skill)	2	200 /day	400
Operating cost & over head charges	-	-	250
	Total		3890
	Profit (Add 5% in total)		**4100**

Therefore cost for producing 1m^3 CLC material is = Rs. 4100/-

4.3 Cost of CLC brick of size 9” x 4” x 3”:

Brick size – 9” x 4” x 3” - 0.23 x 0.10 x 0.075 m = 0.001725 m^3

Bricks casted in 1 m^3 CLC material = $\frac{1}{0.001725}$ = 579.71 ≈ **575 Nos.**

In Rat-Trap bond for every 9 brick 2 brick are saved due to cavity.

Therefore total saving in 1 m^3 = $\frac{575}{9} \times 7$ = 447.22 ≈ **445 nos.**

Therefore cost of brick = $\frac{4100}{575}$ = 7.013 ≈ **Rs. 7.00 /-**

5. Conclusion

CLC brick in Rat-Trap bond is an innovative technique for efficient brick work system with many advantages over the conventional brick work system. It reduces the use of material (natural river sand and red soil) and uses the waste material (fly-ash), hence it is green construction material. CLC brick is designed specially to build wall in Rat-Trap bond as efforts have not yet been made to design CLC brick in Rat-Trap bond. The test results on CLC brick are quite satisfactory and it can be used for non load bearing exterior and interior wall. Also the light weight of CLC brick in Rat-trap reduces the dead load on the structure and provides good thermal insulation. Thus this CLC brick in Rat-trap bond has a very good future scope for its development as a commercial product.

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