

Partial Replacement of Fine Aggregate with Crushed Clay Brick in Cellular Concrete

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ABSTRACT: Light weight concrete has tremendous advantages such as lower density and thermal insulation property and also strong enough to be used for structural purposes. Cellular concrete comes under the classification of this light weight concrete. Most important property of cellular concrete is low thermal conductivity. This property can be improved by decreasing the density. It will significantly reduce the dead load of structural elements. In this present experimental investigation the cellular property is achieved by addition of aluminium metal powder in varied percentages such as 0.5, 1, 1.5, 2, 2.5, and 3%. Crushed clay brick is used as replacement of conventional fine aggregate with varied percentages such as 10, 20,23,25,27 and 30% in each percentage of cellular concrete. The cellular property is improved by increased addition of aluminium metal powder. The compressive strength will increase up to 25% replacement of crushed clay brick in cellular concrete. It is concluded that addition of 1% of aluminium metal powder along with varied crushed clay brick percentages, satisfy the light weight property and compressive strength. From these experimental results we can say that, this concrete belongs to structural light weight concrete.

KEYWORDS: Cellular concrete, Aluminium metal powder, Crushed clay brick powder, Structural light weight concrete.

I.INTRODUCTION

Lightweight concrete composite were used successfully for many years for structural members and elements in buildings and bridges. Lightweight concrete can be defined as a type of concrete which contains an expanding agent in that it increases the volume of the mixture while giving additional qualities and reduce the dead weight. The production of stable foam concrete mix depends on many factors such as selection of foaming agent, method of foam preparation and addition for uniform air voids distribution, materials section and mixture design strategies, production of foam concrete and performance with respect to fresh and hardened state are of greater significance. In addition to its lighter weight, which permits saving in dead load and so reduces the cost of both super structure and foundations, this concrete is more resistant to fire and provides better heat and sound insulation than concrete of normal density.

1.1 Cellular Concrete

cellular concrete is a mixture of cement, fine aggregate, water and foaming agents, which produces a strong, lightweight concrete containing millions of evenly distributed, consistently sized air bubbles or cells. The density of cellular concrete is determined by the amount of foaming agents added to the mixture. It possesses high flowability, low self weight, controlled low strength, excellent thermal insulation properties and fire resistance. Cellular concrete is similar to conventional concrete as it uses the same ingredients, but in foam concrete the use of aggregates is eliminated. Presence of lightweight aggregates and cenospheres materials convert a normal concrete to cellular concrete. Cellular concrete made either by forming method or Autoclaved aerated concrete-(consists of lime and expansion agent) method. Forming of concrete can be done by two ways one method is preformed foam and other is mix foaming agents. A foam

International Journal of Innovative Research in Science, Engineering and Technology

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aeration agent is used to absorb humidity as long as the concrete is exposed to the atmosphere, allowing the hydration process of the cement to progress in its ever-continuing strength development.

1.2 Crushed Clay Brick

River sand are depleting day by day and we have to go for other alternatives. Crushed clay bricks are easily available, and can be used as fine aggregate, which is shown in the figure 1. Nowadays cellular (aerated/formed) concrete is widely used because of its unique characteristics. Lot of researches have been reported to evaluate the potential of using crushed clay bricks as an alternative aggregate. Most current researches use crushed clay brick as a coarse and/or fine aggregate in conventional concrete. Few researches reported that crushed brick powder could be used as partial replacement of fine aggregate in concrete. Recycling crushed clay brick wastes needs more researches to make the use of these wastes. Producing aerated concrete with crushed clay brick as an alternative to fine aggregate will present solution for these recyclable wastes.



Fig.1. Crushed clay brick

1.3. Aluminium Metal Powder

Cellular concrete can be produced by cement and lime as calcareous materials and by quartz sand as the siliceous materials with traces of aluminium powder as a pore forming agent. Figure 2 shows the aluminium metal powder. After mixing these components with water, aluminium powder reacts with calcium hydroxide which liberates hydrogen gas and forms bubbles that lead to a porous structure concrete. The use of the correct amount of air entraining agent is very important. Air entraining agents produce countless tiny air bubbles that reduce the density of the concrete and contribute to the insulation values. These bubbles also help to prevent cracking and damage from freeze/thaw cycles. They do this by absorbing the effects of the concrete expanding and contracting. When adding air entraining agents, generally the intent is to create approximately 8-15% air in the final mix. Fine, uniform, smooth metallic powder free from aggregates available from market is used in this research and it has an atomic weight of 26.98.



Fig.2 Aluminium metal powder.

II. RELATED WORKS

Md. Abul Bashar Emon et.al(2016)[1], The study was based on Improving performance of light weight concrete with brick chips using, brick chips are considered as light weight aggregate (LWA) because of their light weight and porous structure. A comprehensive investigation has been made in this study on the improvement of strength and ductility of concrete having brick chips as coarse aggregate using locally produced low cost lightly galvanized mild steel wire fiber

International Journal of Innovative Research in Science, Engineering and Technology

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(commonly known as GI wire fiber in this region) as an alternative to conventional steel fibers. Marked improvement has been noticed for compressive and tensile strength of concrete through GI wire fibers addition. Ultimate strength and toughness showed maximum increment up to thirty percent for a certain range of fiber content. Moreover, fiber inclusion has enhanced resistance against crack formation and propagation which is evident from crack width, crack spacing with respect to loads applied and crack patterns. Results of the experiments and cost comparison reveal that GI fiber can be adopted as a viable low cost alternative to steel fibers for performance enhancement of brick chips concrete.

Mr. Ashish S. Moon et.al, (2015) [2], Study is conducted in Foam Concrete Can Be used for Sustainable Construction as a Building Material Foam concrete is a type of aerated lightweight concrete. Foam concrete does not contain any coarse aggregate. It requires no compaction, but it will flow readily from an outlet to fill restricted and irregular cavities. Foamed concrete is simple to produce but, at present, there is a need to provide close control during its production and on-site supervision during its placement and curing. Lightweight foamed concrete is use in low strength capacity for building and civil construction purposes as a result of its peculiar features such as low thermal conductivity, low self-weight and self-compacting features hence its high workability. This paper is attention to classified of aerated lightweight concrete into foamed concrete and non-autoclaved concrete.

Ahsan Habib et.al, (2015) [3], the main objective of this paper is the presentation of the potentiality and formation techniques of aerated concrete. In this experiment, generation method of hydrogen gas was used for the aeration process. In this gasification method, a finely powdered aluminium powder was added to the slurry of Ordinary Portland cement with different percentages such as 0.05%, 0.1%, 0.15%, 0.2%, and 0.25%. To determine the effect of aluminium powder on the final product properties, some test has been conducted such as density, water absorption and compressive strength test. However, it was observed that the concrete having 0.15% aluminium powder contributes in the strength gaining process of aerated concrete.

Mukesh D. Ghadge et.al (2015) [4], This Project deals with the development of Floating type of concrete by using lightweight aggregate (Pumice stone) and Aluminium powder as an air entraining agent. There are many types of lightweight concrete which can be produced either by using lightweight aggregate or by using an air entraining agent. In this study we have worked on combination of above mentioned types. This concrete is a non-structural concrete. In this study, comparison has be made between plain cement concrete and lightweight concrete having different proportion of Aggregate size and fix quantity of Aluminum content (i.e. 2%) by the weight of cement has been taken into account. It helps to increase volume of concrete and hence reduce the weight.

Trivedi Manoj S et.al, (2015) [5], This is an experimental work on cellular light-weight concrete cellular light weight concrete (CLC) block can be used as an alternative to conventional bricks, to reduce environmental pollution and global warming. The energy consumed in the production of CLC blocks is only a fraction compared to the production of conventional bricks and emits no pollution. Present study work is carry out the work on properties of fly-ash and foaming agent, experimental work (casting cubes) on cellular lightweight concrete and comparison of strength between CLC blocks and conventional brick. This work, shows the comparison of CLC blocks with conventional clay bricks. So for this type of comparison we have to prepare a mould as same size of the conventional brick. The standard size of conventional brick is 19cm x 9cm x 9cm. So we have casted same size of CLC blocks and check its compressive strength after 7th day, 14th day, and 21th day of curing in lab.

Indu Susan Raj et.al, (2014) [6], in this study based on the Properties of Air-Entrained Concrete for Masonry Blocks is to produce a light weight concrete for developing masonry block. Six dosages of aluminium powder (0.1, 0.2, 0.5, 1, 2 and 5%) by weight of cement are used to produce aerated (gas) concrete. Based on earlier investigations, cement to fine aggregate ratio of 1:1 have been adopted and water cement ratio is fixed as 0.5 by trial and error method. The wet and dry densities were observed. Addition of more than 5% aluminium powder reduces compressive strength and densities drastically. From this research, cement blocks were produced and compared with commercially available concrete blocks for its densities and compressive strength and found that the blocks made with aerated concrete is as good as or better than the conventional solid blocks.

Ali A. Aliabdo et.al, (2014) [7], The main objective of this research program is to study the effect of using crushed clay brick as an alternative aggregate in aerated concrete. Two series of mixtures were designed to investigate the physico-mechanical properties and micro-structural analysis of autoclave aerated concrete and foamed concrete,

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respectively. In each series, natural sand was replaced with crushed clay brick aggregate. In both series results showed a significant reduction in unit weight, thermal conductivity and sound attenuation coefficient while porosity has increased. Improvement on compressive strength of autoclave aerated concrete was observed at a percentage of 25% and 50% replacement, while in foamed concrete compressive strength gradually decreased by increasing crushed clay brick aggregate content. A comparatively uniform distribution of pore in case of foamed concrete with natural sand was observed by scanning electron microscope, while the pores were connected mostly and irregularly for mixes containing a percentage higher than 25% clay brick aggregate.

Norlia Mohamad Ibrahim et.al, (2013) [8], Performances of lightweight foamed concretes that are made from partial substitution of waste clay brick as coarse aggregate has been investigated in this study. The research aims were to identify the properties and characteristic of lightweight foamed concrete using waste clay brick as alternative materials to reduce the depletion of normal coarse aggregate from granite. Four different percentages of concrete mixtures using new coarse aggregate have been prepared that consist of 25%, 50%, 75%, and 100% waste clay brick. Foamed were injected into concrete mixture to produce lightweight concrete with appropriate proportions. The samples have undergone several testing including compression test, water absorption test, workability test and density test. From the results obtained, lightweight concrete that were produced with 25% substitution of waste clay brick showed the highest compressive strength of 25 MPa with density of 1647 kg/m³.

Ksenija Jankovic et.al.(2012)[9], The study is based on Concrete paving blocks and flags made with crushed brick as aggregate.. In this paper, the possibility of using crushed bricks in the Production of concrete elements for the pedestrian zone is shown. The application of recycled brick as aggregate, produces concrete of less density and strength, and of increased absorption. All of this also has an effect on the quality of concrete flags and paving blocks. Based on the results obtained by testing the resistance to frost of concrete it was assumed that it is possible to get the products comply with European Standards. The results show that replacing up to a 32.5% of natural aggregate with crushed brick Aggregate produces concrete blocks, and up to 65% of it produces concrete paving flags which meet the requirements of European standards.

F. Bektas et.al,(2009) [10], This paper reports an experimental study that aimed to investigate the effects of recycled clay brick, used as a part of fine aggregate, on mortar durability. The brick, in crushed form, was from a local brick manufacturer that salvages its off-standard products. It was used to replace 10% and 20% (by weight) of the river sand in mortar. Effects of the brick replacement on the mortar flow, compressive strength, shrinkage, freeze–thaw resistance, and alkali–silica reaction potential were investigated. The results showed that as the brick replacement level increased, the mortar flowability reduced. The 10% and 20% brick replacements had no negative effect on the mortar compressive strength and very limited effect on the mortar shrinkage. The freeze–thaw resistance of the mortar was improved by the brick replacement. However, the use of crushed brick as aggregate appeared not to reduce potential alkali–silica reaction. The microscopy study revealed the alkali–silica reaction product and associated cracking in the mortar. Additional study indicated that the brick aggregate used in the study had pessimum proportion, 30%, for the alkali–silica reaction expansion.

X.C. Qiao et.al, (2008) [11], This study is conducted on Production of lightweight concrete using incinerator bottom ash, The medium size fraction (14–40 mm) of aged incinerator bottom ash (IBA) obtained from a major UK energy from waste. Plant has been crushed to less than 5 mm (CIBA) and thermally treated at 600°C (TCIBA6), 700°C (TCIBA7), 800°C (TCIBA8) And 900°C (TCIBA9). Thermal treatment reduced the organic carbon content and increased the amount of wollastonite (casio₃), mayenite (Ca₁₂Al₁₄O₃₃) and gehlenite (Ca₂Al₂SiO₇). The crushed and thermally treated IBA has been mixed with Portland cement (PC) at Different water/solid (w/s) ratios and with different proportions of PC and Ca(OH)₂. The volume expansion during setting and bulk densities and compressive strengths were determined. Expansion occurred in all mixes contained IBA during curing. A lightweight material (density less than 1.8 g/cm³) with 28 day compressive strength of higher than 10 Mpa was prepared by mixing 20 wt% PC with 80 wt% TCIBA8 at w/s ratio of 0.20. The expansion and associated lightweight properties result from gas evolution during curing due to residual Metallic Al in the IBA. The main crystalline hydration products in 28 day cured samples were portlandite (Ca(OH)₂), calcite (caco₃) and calcium aluminate carbonate hydrates (Ca₄Al₂O₆(CO₃)_{0.5} Æ 12 H₂O and Ca₈Al₄O₁₄CO₂ Æ 24H₂O).

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Farid Debieb and Said Kenai, (2008)[12], This study was based on the use of coarse and fine crushed bricks as aggregate in concrete. This paper examines the possibility of using crushed brick as coarse and fine aggregate for a new concrete. Either natural Sand, coarse aggregates or both were partially replaced (25, 50,75 and 100%) with crushed brick aggregates. Compressive and flexural Strengths up to 90 days of age were compared with those of concrete made with natural aggregates. Porosity, water absorption, water Permeability and shrinkage were also measured. The test results indicate that it is possible to manufacture concrete containing crushed Bricks (coarse and fine) with characteristics similar to those of natural aggregates concrete provided that the percentage of recycled aggregates Is limited to 25% and 50% for the coarse and fine aggregates, respectively.

III.DESIGN MIX MATERIALS

Materials used for this thesis work are cement, fly ash, fine aggregate (both sand and crushed clay brick), potable water, aluminium metal powder as forming agent and also admixture (flowcon PC 55).

3.1. Cement

53 grade Ordinary Portland Cement was used in the study. The properties are shown in the table 1. Cement is the best binding material. Proper use of cement will provide adequate strength to the structure. Fresh cement should be used for work having uniform colour and free from lumps.

Table 1. Properties of cement.

Sl. No	PROPERTY	VALUE
1	Standard Consistency	29.8%
2	Initial Setting time	90 minutes
3	Final setting time	170 minutes
4	Fineness	4.75
5	Specific gravity	1
6	Compressive strength	60.1 N/mm ²

3.2. Fly ash

Properties of fly ash is shown in the table 2. Class F type fly ash is used in this study. F-type fly ash contain less lime content. Fly ash is generally used as cementitious material. This will reduce the cement content in the mix.

Table 2. Properties of fly ash.

Sl. No	PROPERTY	VALUE
1	Standard Consistency	31%
2	Initial Setting time	180 minutes
3	Final setting time	324 minutes
4	Specific gravity	2.89

3.3. Fine aggregate

Manufacturing sand (M-sand) is mainly used for concrete works. It is replaced by crushed clay brick passing though 4.75mm sieve in this study. Properties of both M-sand and crushed clay brick is given in the table 3. The absorption property of crushed brick is double as we compare with that of M-sand. The bulk density is more for M-sand.

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Table 3. Properties of fine aggregate.

Sl. No	PROPERTY	VALUE (M sand)	VALUE(BRICK POWDER)
1	Specific gravity	2.79	2.91
2	Water absorption	3.09 %	6.16%
3	Bulk density	1537.46 kg/m ³	1210kg/m ³
4	Moisture content	3.09 %	6.16%
5	Silt content	14 %	–

3.5. Admixture

FLOWCON PC-55, high water reducing and retarding hyper plasticizer is used in this research. It meets the requirement for plasticizer as per specification IS 9103-99. It improves the workability and strength gaining property. Other properties are shown in the table 4.

Table 4. Properties of admixture

Sl. No	PARAMETERS	RESULTS	SPECIFICATIONS(AS PER IS 9103-99)
1	Physical state	Amber colored liquid	-
2	Composition	Polycarboxylic ether based liquid.	Polycarboxylate polymers
3	Dry material content %	39.10	.95T ≤ DMC < 1.05T
4	Specific gravity	1.124	Within 0.02 of mfg. value
5	Chloride ion content (%)	Nil	Within 10%/within 0.2% whichever is greater of mfg. value.
6	p ^H	6.34	Min.6
7	Recommended dosage	0.2-0.9% bwoc	-

3.6. Experimental investigation

Mix design is fixed by trial and error method. The mix ratio of cementitious material : fine aggregate is 1:1.2. Water to cement ratio is 0.42. admixture used is 0.2% of total cementitious material. First mix fine aggregate for 2 minute in the mixer then add pre wetted crushed clay brick into the mixer then mix it for another 2 minutes. Then add cement to it and mix again for two minutes. Then water is added to the mix while mixing. Add admixture along with the addition of water. After that addition of aluminium metal powder to this mix. After the mixing with aluminium metal powder is done immediately pour it to mould because after 5minutes the mix will began to ferment. Mix it and pour it to ½ to ¾th of the 100mm x 100mm x100mm mould. After 5 minutes the mould will be filled due to hydrogen gas evolution in the mix. Cellular concrete have the property of self compaction, hence further compaction is not required. Figure 3.(a) and (b) shows the cubes during hydration and after setting respectively. We can see the raise of concrete from the mould after setting. Half filling of mould is good to avoiding loss of concrete. As the aeration increases more expansion of concrete occurs.

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Fig.3.(a) Concrete during hydrogen evolution process. (b) Concrete after setting.

Compressive strength

Compression testing machine have maximum capacity of 2000 kN and the rate of loading is 2.3 kN/second. The specimen is tested after 7 day and 28 day on compression testing machine, and the reading is noted. Diving the load by area gives the compressive strength or we can directly note the compressive strength. The figure below shows the compression testing and crack pattern. Figure 4.(a) shows the testing of specimen in compression testing machine and figure 4(b) shows the crack pattern of specimen.

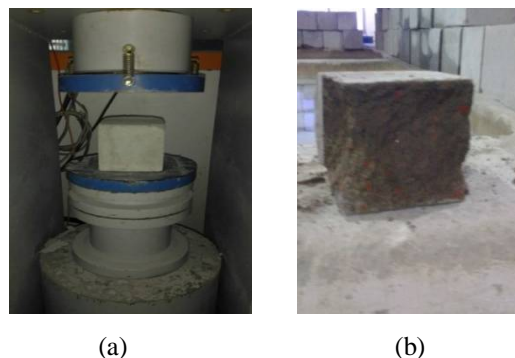


Fig 4: (a). Compression testing of specimen, (b). Crack pattern of specimen.

IV.RESULT AND DISCUSSION

4.1 Compressive Strength Results

Compressive strength results are shown in the table 5.The specimens are tested after 7 and 28 days of water curing, after wiping off the water from the surface of cubes, it is placed on the testing machine and centered the cube on the base plate. Then loading is applied at a rate of loading is 2.3 kN/sec. Compressive strength during ultimate loading is noted.

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Table 5. Compressive strength of cellular concrete.

Aluminium percentage	Compressive strength (N/mm ²)													
	7 th day							28 th day						
	Brick variation							Brick variation						
	0%	10%	20%	23%	25%	27%	30%	0%	10%	20%	23%	25%	27%	30%
0.5%	8.6	4	3.45	4.96	6.8	6.33	2.9	10.4	9.15	8.7	8.9	9.75	10.9	9.3
1%	3.2	3.6	2.8	3.12	5.2	4.2	2.2	6.5	7.35	7.6	6.55	7.975	7.31	7.8
1.5%	4.4	4.3	2.4	3.9	4.5	2.1	3.1	7.3	6.9	6.45	8.4	7.72	6.66	5.66
2%	3.4	2.2	1.8	2.75	2.83	1.85	1.62	6.3	6.8	4.6	9.1	6.2	6.2	5.2
2.5%	3.4	3.8	1.7	2.2	2.1	1.32	1.4	6.2	6.6	5.9	6.7	5.7	5.42	4.7
3%	1.2	1.7	1.0	1.6	1.3	1	1.02	5.6	4.9	4.2	4.9	4.25	5	3.6

4.2. Density results

The density of the specimen is calculated by taking the dry weight of specimen and then dividing the weight by area. Figure.5 shows the density of cellular concrete. Density decreases as the aeration property increases. Even though crushed clay brick is used density is decreasing depending on the aeration property. The range of density is between 1800-1400 kg/m³.

$$\text{Density} = \frac{\text{dry weight}}{\text{area of specimen}}$$

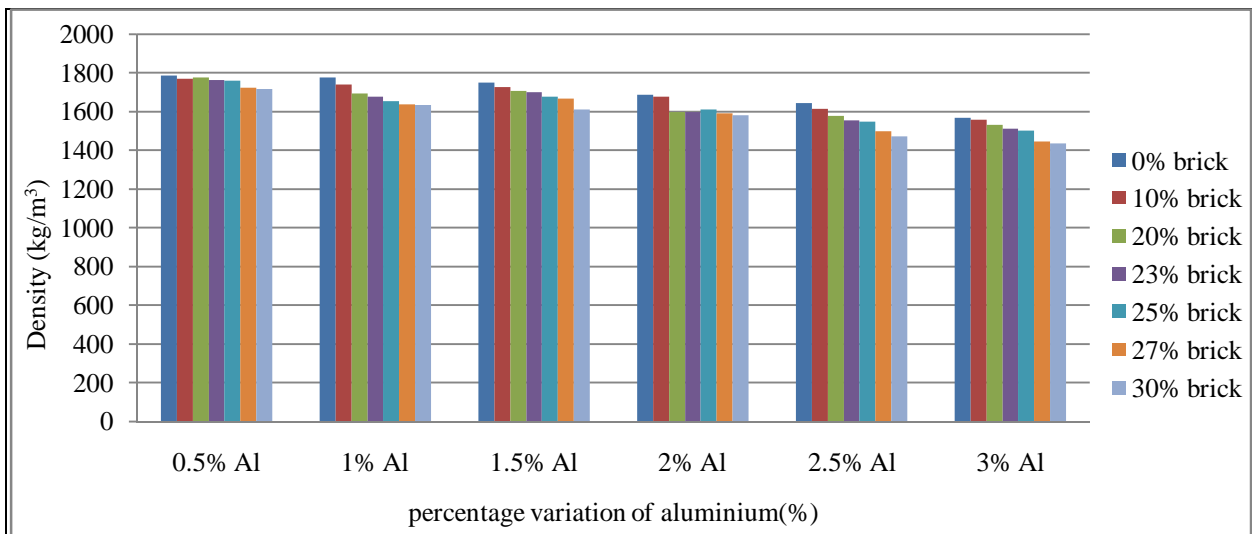


Fig.5 Density of cellular concrete in varied percentages of aluminium metal powder and crushed clay brick.

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V. CONCLUSION

1. Compressive strength reduces with increase in addition of aluminium metal powder.
2. When crushed clay brick powder is added the compressive strength reduces first and then increase at 25% of addition, after that the strength is reducing.
3. The cellular property is achieved
4. The density varies in the range 1800-1400 Kg/mm³, hence we can say that this cellular concrete belongs to structural light weight concrete.
5. Cellular concrete made with 1% Al metal powder and 25% crushed clay brick powder achieves adequate strength and posses light weight property.

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