Foam Concrete as A Green Building Material

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ABSTRACT

As known, concrete is one of the most popular construction materials used since hundred years ago. Because of its flexibility and its usage many structures around us build by concrete. A green building is an environmentally conscious building, designed, constructed and operated to minimise the total environmental impacts. Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. It is claimed that 5% of the world's carbon dioxide emission is attributed to cement industry, which is the vital constituent of concrete. Due to CO_2 there is significant contribution to the environmental pollution, there is a need for finding an optimal solution along with satisfying the civil construction needs. Foam concrete is a new innovative technology for sustainable building and civil construction which fulfills the criteria of being a Green Material. This paper concludes that Foam Concrete can be an effective sustainable material for construction and also focuses on the cost effectiveness in using Foam Concrete as a building material in replacement with Clay Brick or other bricks.

Keywords — Foam Concrete, Aluminium powder, Green Building Material, GBRS (Green Building Rating System).

1. INTRODUCTION

Foam concrete is a mixture of cement, fine sand, water and aluminium powder which is used as foaming agent, which once hardened results in a strong, lightweight concrete containing millions of evenly distributed, consistently sized air bubbles or cells. The density of Foam Concrete is determined by the amount of aluminium added to foam concrete & different mix proportion added to the basic cement and sand mixture. Foam concrete is both fire and water resistant. It possesses high sound and thermal insulation properties. Foam concrete is similar to conventional concrete as it uses the same ingredients the only difference is no coarse aggregate is used in foam concrete. However, foam concrete differs from conventional concrete in that the use of aggregates in the former is eliminated.

2. GREEN BUILDING RATING SYSTEM

A green building is an environmentally sustainable building, designed, constructed and operated to minimise the total environmental impacts. The US Green Building Council defines Green Building Design "To significantly reduce or eliminate the negative impact of buildings on the environment and on the building occupants." In other words, Green Building is defined as "The one which uses less water, optimizes energy, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building."

The Leadership in Energy and Environmental Design (LEED-INDIA) Green Building Rating System is a nationally and internationally accepted benchmark for the design, construction and operation of high performance green buildings. LEED is a credit-based system. 64 credit points are divided among the first 5 environmental impact areas excluding 5 additional points for the last category of Innovation and design process.[1]

LEED EVALUATION	CREDIT POINTS
Sustainable Sites	13

Water Efficiency	06
Energy and Atmosphere	17
Materials and Resources	13
Indoor Environmental Quality	15
Innovation and Design Process	05

Table-1: Lead Evaluation & Credit Points.

2.1. Foam Concrete Rating as per (GBRS)

a) **Water Efficient:** Water required for Foam concrete is less as compare to normal concrete.

b) **Energy and Atmosphere:** Foam concrete has various excellent insulating qualities resulting in energy efficiency, Thermal insulation, Sound insulation, Fire resistance is the energy saving in buildings of Foam Concrete.

c) **Materials and Resources:** In India, the total production of fly ash is more than 100 million tons, but our utilization of fly ash is only about 5% of the production. Also the disposal of fly ash has become a serious concern to the environmental protection. Use of fly ash in foam concrete satisfies the GBRS.

d) **Indoor Environmental Quality:** An additional quality contributing to the sustainability of a building product is its ability to reduce and absorb noise or to improve or maintain indoor air quality.

e) **Innovation and Design Process:** The introduction of innovative raw materials like surfactant sand usage of fly ash, in the production process of Foam Concrete fits it to the title of Green Concrete.

3. FOAM CONCRETE

Foam concrete is a mixture of cement, fine sand, water and foam which once hardened results in a strong, lightweight concrete containing millions of evenly distributed, consistently sized air bubbles or cells. Foam concrete is both fire and water resistant. In some cases sand is replaced with quarry dust. It possesses high sound and thermal insulation properties. Foam concrete is similar to conventional concrete as it uses the same ingredients. However, foam concrete differs from conventional concrete in that the use of aggregates in the former is eliminated. A foam agent is used to absorb humidity for as long as the product is exposed to the atmosphere, allowing the hydration process of the cement to progress in its ever-continuing strength development.

Foam concrete can be defined as a type of concrete which includes an expanding agent in it that increases the volume of the mixture while reducing the dead weight. It is lighter than the conventional concrete with a dry density of 300 kg/m^3 to 1840 kg/m^3.The main specialties of foam concrete are its low density and low thermal conductivity. 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 paper, aluminium powder has been used as an air entraining agent of concrete. The fine powder of Aluminium to the slurry reacts with the calcium hydroxide producing hydrogen gas. This hydrogen gas in the slurry mix gives the cellular structure and makes the concrete lighter than the conventional concrete that's why it is called as foam concrete or light weight concrete.

3.1. Aluminium Powder (Foaming Agent):

Aluminium is used as a foaming agent in Autoclave Aerated Concrete production worldwide and it is widely proven as the best solution for its purpose. When aluminium is added (usually at about 0.2% to 0.5% by dry weight of cement) to the mixing ingredients, it reacts with hydroxide of calcium or alkali which liberates hydrogen gas ($3H_2$) and forms bubbles. The speed at which the air bubbles form is critical to the success of the final aerated concrete product.

$$2Al + 3Ca(OH)_2 + 6H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O + 3H_2$$

Aluminium is available in various forms. For the AAC industry the most used forms are powder and paste. Either one of these has its specific advantages and disadvantages regarding the production of autoclaved aerated concrete.

Aluminium is used as a foaming agent to produce AAC. It can be concluded that aluminium powder is the best performing form of aluminium for AAC production when Product quality and production costs are the most important performance measures. However, the production of AAC requires aluminium powders that contain fractions finer than 100 or 50µm. Furthermore use of powder is more economical than paste since it gives less waste and brings more flexibility due to the fact that different powders can easily be used through one another.[17]

3.2. Physical and Chemical Properties of Aluminium:

Molecular Formula : Al

Form : Powder

Color : Silver

Melting point : 660oC (1220oF)

Boiling point : 2467oC (4473oF)

Density : 2.7g/ml at 25oC (77oF)

Ignition Temperature : 760oC (1400oF)

Auto Ignition Temperature: Catches fire spontaneously if exposed to air.

Oder : Odorless

3.3. Mix Proportion Adopted for Test

Following are the mix adopted using various percentages of cement, sand, quarry dust and fly ash as follows:

TRIAL MIX	CEMENTITIOUS MATERIAL [C + FA]	S + QD
M1	100% C	100% S
M2	100% C	50% S + 50% QD
M3	100% C	100% QD
M4	70%C + 30% FA	100% S
M5	70%C + 30% FA	50% S + 50% QD
M6	70%C + 30% FA	100% QD
M7	40%C + 60% FA	100% S
M8	40%C + 60% FA	50% S + 50% QD
M9	40%C + 60% FA	100% QD

C- Cement, FA – Fly ash, S – Sand, QD – Quarry Dust

Table-2: Trial Mix & Mix Proportion.

4. TEST ON HARDENED CONCRETE

4.1 Following were the compressive strength on cubes was measured at 7, 14 and 28 days of curing. Here total mixes are categorized in 3 categories as per the cement & fly ash percentage used in the mix.

A. For Trial Mix M1, M2 & M3 Compressive Strength where cement used is upto 100% with 1:1 proportion.

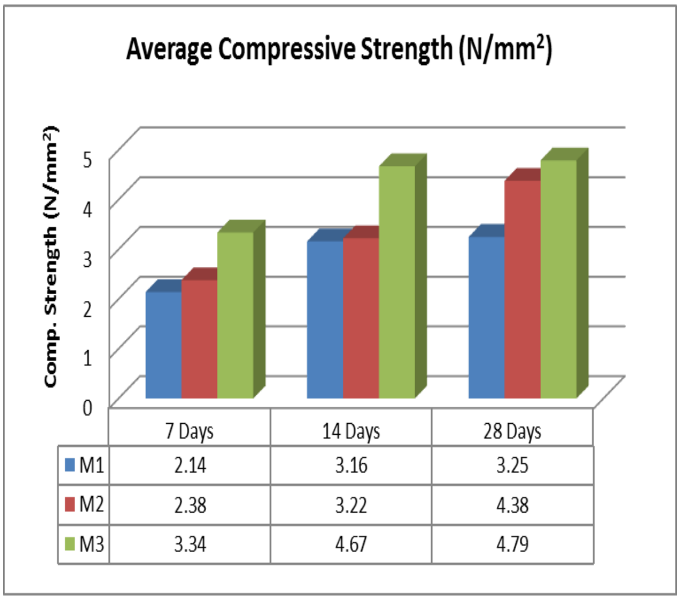

Fig-1: Avg Compressive Strength for Mix M1, M2, M3.

B. For Trial Mix M4, M5 & M6 Compressive Strength where cement used is upto 70% and Fly ash used upto 30 % with 1:1 proportion (Cementitious to other material).

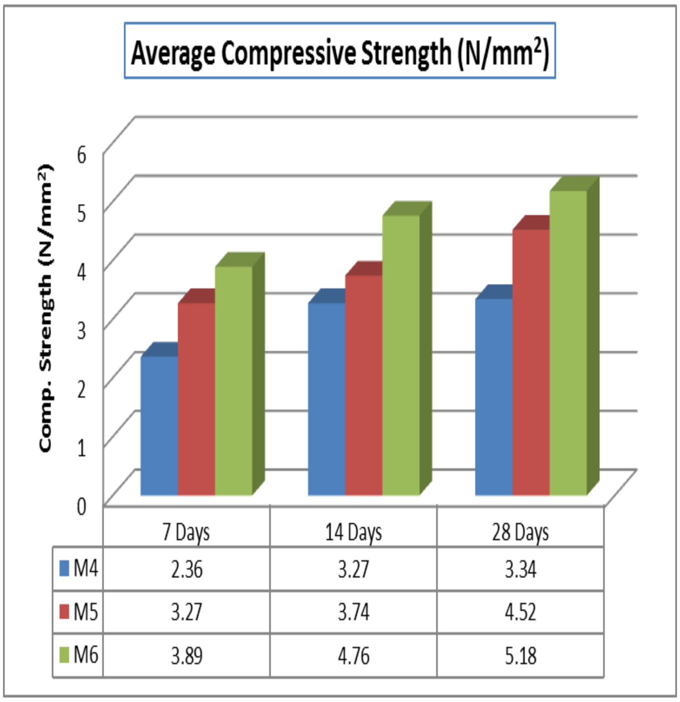

Fig-2: Avg Compressive Strength for Mix M4, M5, M6.

C. For Trial Mix M7, M8 & M9 Compressive Strength where cement used is upto 40% and Fly ash used upto 60 % with 1:1 proportion (Cementitious to other material).

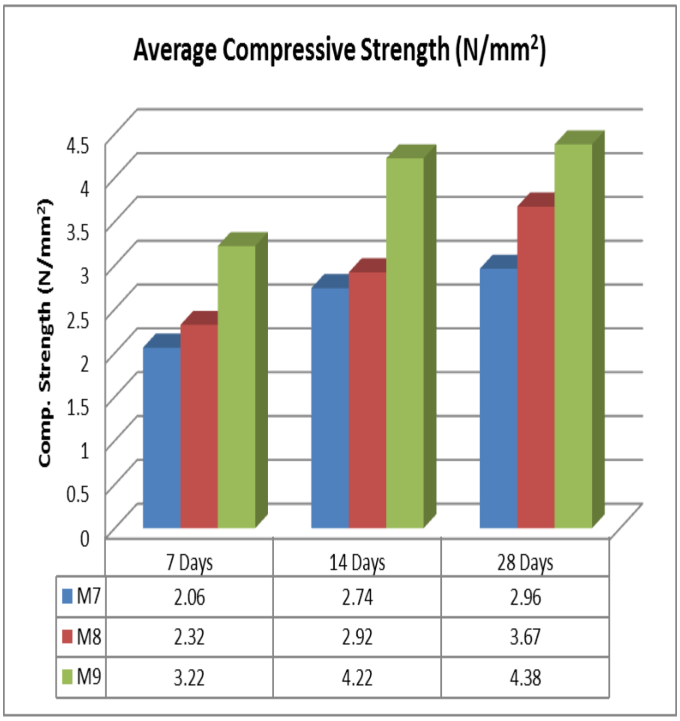

Fig-3: Avg Compressive Strength for Mix M7, M8, M9.

D. For Trial All Trial Mix M1, M2, M3, M4, M5, M6, M7, M8, M9.Comparitive result for Average Compressive Strength comparison for 7 days, 14 days & 28 days.

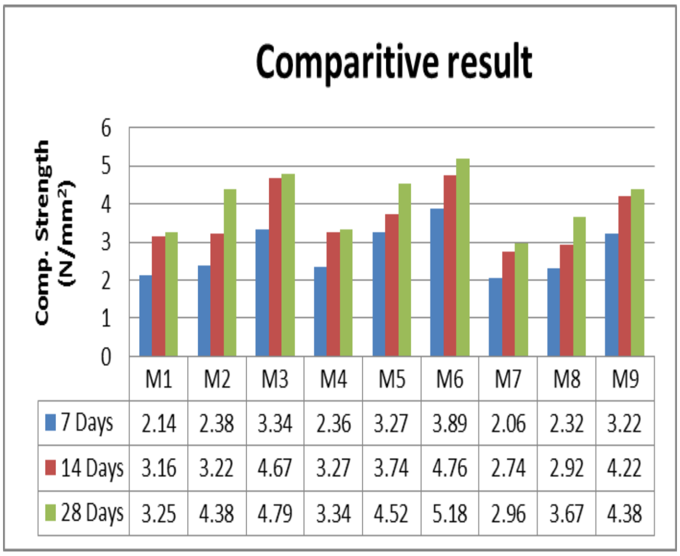

Fig-4: Comparative Compressive Strength Result

4.2 Following were the split tensile strength on cylinders were measured at 7, 14 and 28 days of curing. Here total mixes are categorized in 3 categories as per the cement & fly ash percentage used in the mix.

A. For Trial Mix M1, M2 & M3 Split Tensile Strength where cement used is upto 100% with 1:1 proportion.

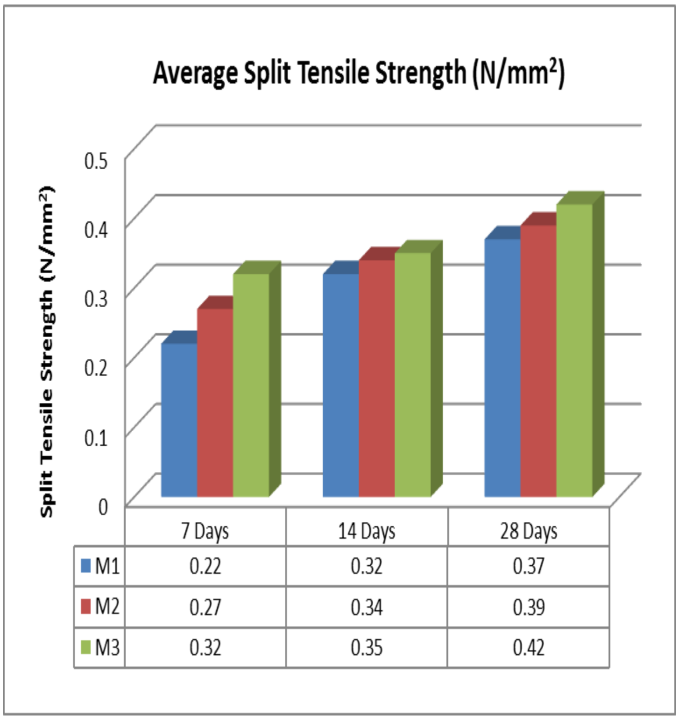

Fig-5: Avg Split Tensile Strength for Mix M1, M2, M3.

B. For Trial Mix M4, M5 & M6 Split Tensile Strength where cement used is upto 70% and Fly ash used upto 30 % with 1:1 proportion (Cementitious to other material).

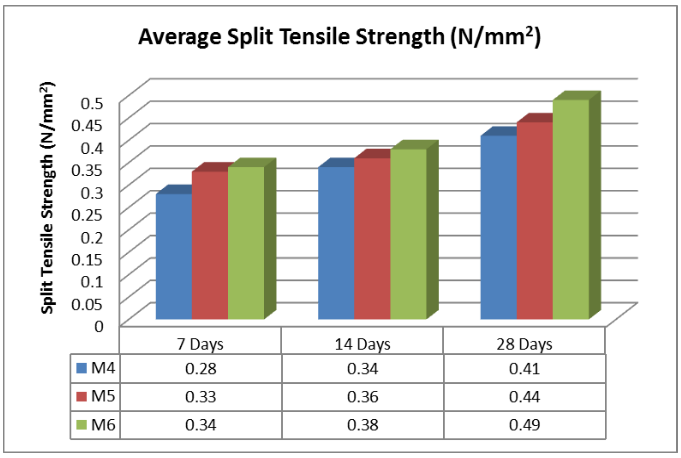

Fig-6: Avg Split Tensile Strength for Mix M4, M5, M6.

C. For Trial Mix M7, M8 & M9 Compressive Strength where cement used is upto 40% and Fly ash used upto 60 % with 1:1 proportion (Cementitious to other material).

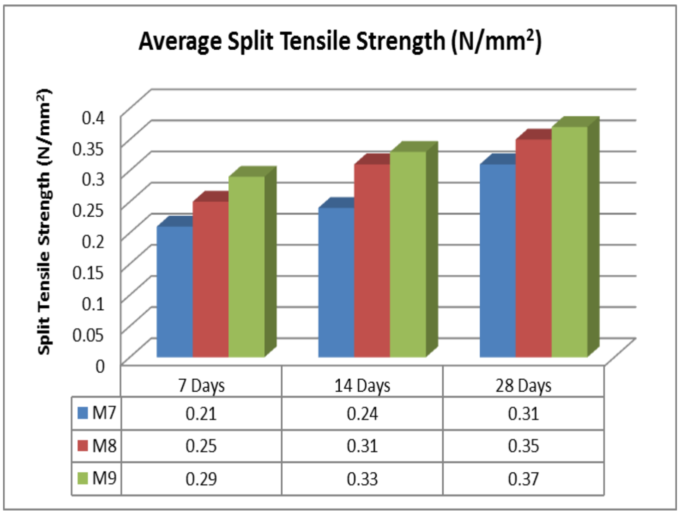

Fig-7: Avg Split Tensile Strength for Mix M7, M8, M9.

D. For Trial All Trial Mix M1, M2, M3, M4, M5, M6, M7, M8, M9.Comparitive result for Average Split Tensile Test comparison for 7 days, 14 days & 28 days.

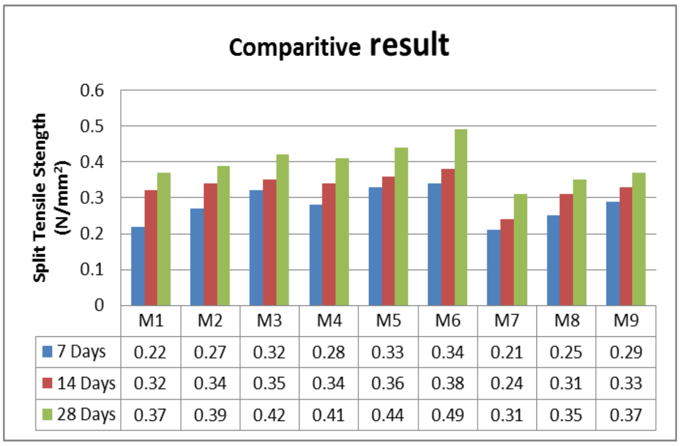

Fig-8: Comparative Split Tensile Strength Result

4.3.1 Density for all trial mix from M1 – M9 following results obtained is as follows.

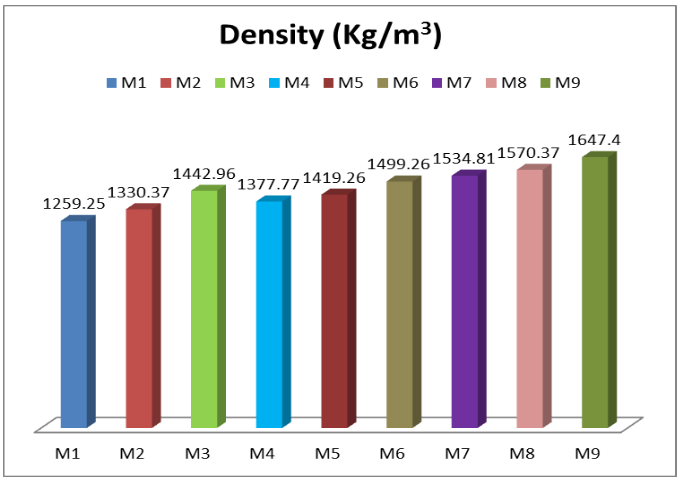

Fig-9: Density for All Trial Mixes

4.3.2 Water Absorption for all trial mix from M1 – M9 following results obtained is as follows.

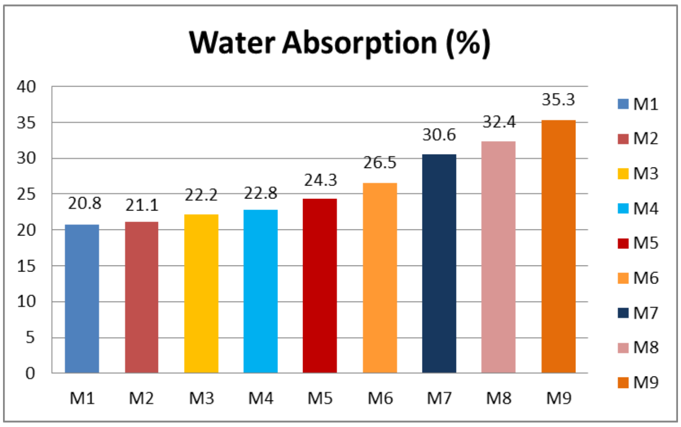

Fig-10: Water Absorption for All Trial Mixes

5. RESULT AND DISCUSSIONS

Based on the data obtained from experiment following conclusions can be drawn:

1) In first case M1, M2, M3 shows gradual increase in compressive strength, whereas M1 shows lowest & M3 shows highest compressive strength & Split Tensile test.
2) In second case M4, M5, M6 shows gradual increase in compressive strength, whereas M4 shows lowest & M6 shows highest compressive strength Split Tensile test.
3) In third case M7, M8, M9 does show the same pattern. But higher percentage of fly ash gives different result if we compare the combine results for 7days, 14 days, 28 days, when 60% fly ash is used in replacement of cement it gives lesser strength in both Compression test as well as in Split Tensile test.
4) When fly ash is used in different proportion it is observed that as percentage of fly ash is increase density is increased.
5) Fly ash proportion is directly related to density.
6) For better mix fluidity is required otherwise aluminium powder may not mix properly & observed values does not give appropriate results.

6. CONCLUSIONS

6.1 Diverse Range of Applications

The material in different density ranges is suitable for specific types of application in civil construction projects.

6.2 Higher Density Range

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

Illustration - "A" –Single storey Insitu house Constructed at Tndonesia

6.3 Assembly of Precast Walling Panels

Another system of applying this technology is initially pre-casting standardized - say 900/1000 mm wide 150/200 mm thick fiber reinforced or unreinforced storey high hollow core panels in density 1200/ 1400 kg/m^3, then assembling and grouting the same to form walls on readymade floor pads for the houses. The roofing generally is of sheeting. This system is popular in Malaysia and Taiwan.

Illustration - "B" – Reinforced CLC Load bearing walls used for 4-storey dwelling at South of Delhi – 1997.

An example of 156 EWS Group Housing units has been shown in Illustration "B". These units were constructed using this technology in twin blocks of four storey high apartments in DLF City, south of Delhi in 1997. The nominally reinforced Cellular Lightweight Concrete cross walls of the dwellings have a uniform thickness of 150mm throughout. The density of material reduces from 1600 kg/m^3 in ground floor walls to 1200 kg/m^3 in the top floor walls. The minor partition and cladding walls were masoned using site produced pre-cast CLC blocks of size 500x250x100mm in density 1000kg/m^3

6.4 Medium Density Range

CLC in dry density range of 800-1000 kg/m3 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.

6.5 Lower Density Range

The lower densities of 400 to 600 kg/m3 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 Thermo Cole, glass wool, wood wool etc. or age old practices of using mud-phaska or Lime terracing.

Illustration - "C" – Low Density CLC Blocks used in Institutional Project at Hyderabad

6.6 Relevance For Wider Application

a) Foam Concrete is a far more versatile material than bricks or dense concrete blocks for its application even as a cheaper substitute for dense concrete as reinforced structural elements and as a thermal insulting product.

b) It is not only that the production process of FC is totally free of any environmental pollution, but it offers additional possibility of further reduction in environmental pollution by enabling Fly Ash - an industrial waste - to be used as one of the main constituent materials.

c) Production process of FC is even simpler than producing ordinary dense concrete for 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.

d) FC 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, fireproof and durable as any other concrete. [18]

REFERENCES

[1] K. Krishna BhavaniSiram, K. Arjun Raj "Concrete + Green = Foam Concrete", International Journal of Civil Engineering & Technology (IJCIET), Volume 4, Issue 4, July – August 2013, pp. 179 - 184, ISSN Print:0976 – 6308, ISSN Online: 0976 – 6316.

[2] K. Krishna BhavaniSiram "Foam Concrete – The Present Generation's Building Solution", International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD), Volume 3, Issue 4, October 2013, pp. 59 - 62, ISSN:2249 – 6866.

[3] Ali J. Hamad "Materials, Production, Properties and Application of Aerated Lightweight Concrete", International Journal of Materials Science and Engineering Vol. 2, No. 2 December 2014.

[4] C. G. Puttappa, K. U. Muthu, H. S Raghavendra, M S R Institute Of Technology, Rudreshm, M/S Vijaya Metal Finishers Materials & Honey Hill Synergy System, A. Ibrahim, University Teknologi Mara, Selangor, Malaysia. "Mechanical Properties of Foamed Concrete" Pp. 491-500. International Conference on Construction & Building Technology – 2008.

[5] Dr. N. Arunachalam, V. Mahesh, P. Dileepkumar, and V. Sounder "Development Of Innovative Building Blocks (TNSCST- Sponsored Research Project)" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278 - 1684, p-ISSN: 2320 - 334X, PP 01-07.

[6] Prof. M.S Shetty text book on, "Concrete Technology-Theory and Practice".

[7] K.Krishna Bhavani Siram. "*Foam Concrete* –The Present Generation's Building Solution" International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) ISSN 2249-6866 Vol. 3, Issue 4, Oct 2013, 59-62

[8] Ali J. Hamad "Materials, Production, Properties And Application Of Aerated Lightweight Concrete: Review", International Journal of Materials Science and Engineering, Vol. 2, No. 2 December 2013.

[9] Jihad Hamad Mohammed, Ali Jihad Hamad, "A Classification Of Lightweight Concrete: Materials, Properties And Application Review", International Journal of Advanced Engineering Applications, Vol.7, Iss.1, pp.52-57 (2014).

[10] Nahro Radi Husein, V. C. Agarwal, Anupam Rawat. "An Experimental Study On Using Light Weight Web Sandwich Panel As A Floor And A Wall", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-7, December 2013.

[11] Vivek Sood, Ashok Kumar, "Effect Of Additives On The Development Of Non Autoclaved Cellular Light Weight Blocks", International Journal of IT, Engineering and Applied Sciences Research (IJIEASR) ISSN: 2319-4413, Volume 2, No. 5, May 2013.

[12] Keertana. B, Sini Sara Mani, M. Thenmozhi. "A Potential Partial Cement Replacement Material In Aerated Concrete" Keertana. B, Sini Sara Mani, M. Thenmozhi. International Journal of Engineering Science and Technology (IJEST) ISSN: 0975-5462, Vol. 3 No. 1 Jan 2011.

[13] Prakash T M, Naresh kumar B G, Karisiddappa, Raghunath S, "Properties of Aerated (Foamed) Concrete Blocks", International Journal of Scientific & Engineering Research Volume 4, Issue 1, January-2013, ISSN 2229-5518.

[14] Hemant K. Sarje, Amol S. Autade, "Consequences of Protein Based Foaming Agent on Lightweight Concrete", International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, Volume-3 Issue-5, November 2014.

[15] Dr. A. S. Kanagalakshmi, K. Sasikumar, E. Britto Pravin, "An Investigation On Foam Concrete With Quarry Dust Replacement For Filler In Mix Design", International Journal of Emerging Technology in

Computer Science & Electronics (IJETCSE), ISSN: 0976-1353 Volume 13 Issue 1 –MARCH 2015.

[16] G.Balamurugan, Dr.P.Perumal, “Use of Quarry Dust to Replace Sand in Concrete –An Experimental Study”, International Journal of Scientific and Research Publications, Volume 3, Issue 12, December 2013, ISSN 2250-3153.

[17] Daan R. van Boggelen, “Safe aluminium dosing in AAC plants”

[18] Atika D. Gohad, “ Experimental study of cellular lightweight concrete by using flyash”

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