Foam Transparent Concrete

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***Abstract*—**At present scenario construction field all around the world is facing a serious problem with price hike of raw materials. So they are very much concern to reduce the consumption of readily available raw materials. It is also important for engineers to develop ecofriendly material, as environment is getting affected day by day by the increasing construction activities It is much of importance for developing a new kind of building material, which can integrate green energy saving with self-sensing properties of functional material such that the excellent properties of light guiding and light weight, a smart transparent light weight concrete is researched by arranging the glass crystals & resin-hardener into the concrete. A research has been undertaken to study the effects, on the workability, compressive strength with light transparency of foamed concrete by replacing fine aggregate with glass crystals at every 25% interval (i.e. 0%, 25%, 50%, 75%,100%) to the volume of concrete. This paper reports some recent findings on the densities, workability, shrinkage and compressive strength development of foamed concrete.

Keywords: Foam, Glass crystal , Transparent, Concrete, Resin, Hardener.

I. INTRODUCTION

Concrete has been used since Roman times for the development of infrastructure and housing, but its basic components have remained the same. Three ingredients make up the dry mix: coarse aggregate, consisting of larger pieces of material like stones or gravel; fine aggregate, made up of smaller particles such as sand; and cement, a very fine powder material that binds the mix together when water is added.

Just a few decades ago concrete was often misunderstood, disliked and captured by its image fixed due to the rapid urbanization of the 1960s. But since that time, concrete has made considerable progress, not only in technical terms, but also in aesthetic terms.

It is no longer the heavy, cold and grey material of the past; it has become beautiful and lively. By research and innovation, newly developed concrete has been created which is more resistant, lighter, white or colored, etc. Concrete has learned to adapt to almost all new challenges that appeared.

Concrete is known as a common material which is widely used in the construction industry, from basic work to multi-storey building and mega structure. Concrete is a material where mixture by cement, water, and aggregate (fine and coarse) which must be workable, resistance to freezing, chemicals resistance, low permeability, wear resistance, and economy (Metha&Monteiro, 2006).

FOAM CONCRETE:-

Lightweight concrete also know as foamed concrete which is lightweightmaterial formed by entrapping or generating small bubbles of air into Portland cement mix by mechanical or chemical means. Lightweight foamed concrete with density from 400 kg/rn3 to 1600 kg/m3 can be produced strength up to 12 MPa. Characteristics of lightweight foamed concrete is depends on the mix design there are however a number of general properties which are constant across a range of mix designs are high strength to weight ratio, low coefficient of permeability, low water absorption, good freeze/thaw resistance, high modulus of elasticity, low shrinkage, thermal insulating properties, and fire resistance. Light weight concrete - or foamed concrete - is a versatile material which consists primarily of a cement based mortar mixed with at least 20% of volume air. It possesses high flow ability, low self-weight, minimal consumption of aggregate, controlled low strength and excellent thermal insulation properties. It can have a range of dry densities, typically from 400 kg/m3 to 1600 kg/m3 and a range of compressive strengths, 1 MPa to 15 MPa .

TRANSPERENT CONCRETE:-

In 2001, the concept of transparent concrete was first put forward by Hungarian architect AronLosonzi at the

Technical University of Budapest, and the first transparent concrete block was successfully produced by mixing large amount of glass fiber into concrete in 2003, named as LiTraCon. The transparent concrete mainly focuses on transparency and its objective of application pertains to green technology and artistic finish. It is the "combination of optical fibers and fine concrete". At present, green structures focus greatly on saving energy with indoor thermal systems. Therefore it is imperative to develop a new functional material to satisfy the structure in terms of safety monitoring (such as damage detection, fire warning), environmental protection and energy saving and artistic modeling. Due to globalization and construction of high-rise building, the space between buildings is reduced; this causes to increasing the use of non- renewable energy sources, so therefore there is a need of smart construction technique like green building and indoor thermal system. Translucent concrete (Transparent concrete) is new technique different from normal concrete. Translucent concrete allow more light and less weight compared to normal concrete. The use of sunlight source of light instead of using electrical energy is main purpose of translucent concrete, so as to reduce the load on non- renewable sources and result it into the energy saving. Optical fibers is a sensing or transmission element, so decrease the use of artificial light, the normal concrete is replaced by translucent concrete, which has natural lighting and art design.

II. AIM AND OBJECTIVES

At present scenario construction field all around the world is facing a serious problem with price hike of raw materials. It is also important for engineers to develop ecofriendly material, as environment is getting affected day by day by the increasing construction activities It is much of importance for developing a new kind of building material, which can integrate green energy saving with self-sensing properties of functional material such that the excellent properties of light guiding and light weight, a smart transparent light weight concrete is researched by arranging the glass crystals & resin-hardener into the concrete.

The way to control the density of lightweight foamed concrete become difficult. By using different quantities of foaming agent will affect the strength and quality of foam concrete.

III. DESCRIPTION OF MATERIAL

- **Cement**

We are using 53 grade OPC. Confirming IS 269:2015. ordinary Portland cement is usually used as the main binder for foamed concrete. Portland cement is a hydraulic cement that when mixed in the proper proportions with water, will harden under water (as well as in air). The basic ingredient for Portland cement consists of:

i). Lime-rich materials, such as limestone, seashells, marl, and chalk that Provided the calcareous components;

ii). Clay, shale, fly ash, or sand to provide the silica and alumina;

iii). Iron ore, iron containing shale, mill scale or similar material to provide the Iron or ferriferous component.

sr.no.	PROPERTIES	RESULTS
1	finess of cement (sq.m/kg)	not less than 225m2/kg
2	soundness	
	a) lechatelier expansion (mm)	Not more than 10mm
	b) auto clave expansion expansion (%)	not more than 0.08%
3	setting time (in minute)	
	a)intial setting	Not less than 30 minutes
	b) final setting time	not greater than 600 minutes
4	specific gravity	3.15

Physical Properties of Cement

- **Water**

Water is one of the important materials for the foamed concrete. The criterion of portability of water is not absolute. Water with Ph. 6 to 8 which not tested saline or brackish is suitable for use. Natural water that is slightly acidic is harmless, but water containing humic or other organic acids may adversely affect the hardening of concrete. The present of algae in the mixing water will result in air entrainment with consequent loss of strength. Hardness of water does not affect the efficiency of air-entraining admixtures. The use of the sea water as mixing water must be considered. Sea water has, typically, a total salinity of about 3.5 per cent. It can cause the long term-strength of the concrete become low. Sea water also contain a lot of chlorides it can cause corrosion for the reinforcement concrete. So the mixing water shall be clear and apparently clean

- **Fine aggregates**

Fly Sand is naturally occurring granular material composed of finely divided rocks and mineral particle. We are using river sand. Confirming IS 383:1979

Generally the fine aggregate shall consist of natural sand, manufactured sand or combination of them. the fine aggregate for concrete that subjected wetting, extended exposure to humid atmosphere, or contact with moist ground shall not contain any material that deleteriously

reactive in cement to cause excessive expansion of mortar concrete.

For sand Such &Seifert (1999) recommend that only fine sands suitable for concrete (to BS 882:1992) or mortar (to BS 1200: 1976) having particle sizes up to about 4 mm and with an even distribution of sizes should be used for foamed concrete. This is mainly because coarser aggregate might settle in a lightweight mix and lead to collapse of the foam during mixing. For practical reasons, most sands can only be used to produce foamed concrete having a dry density in excess of about 1200 kg/m 3.

However, fly ash can be used as a partial or total replacement for sand to produce foam concrete with a dry density below about 1400 kg/m. There are two general classes of fly ash can be defined, low calcium fly ash (FL) and high calcium fly ash (FH). FL is produced by burning anthracite or bituminous coal. FL is categorized as a normal pozzolan, a material consisting of silicate glass modified with aluminium and iron. The CaO content is less than 10%. While FH is produced by burning lignite or sub-bituminous coal, it can be categorized as cementations material when CaO is greater than 20% or as cementations and pozzolanic material when CaO varies between 10% to 20%. Therefore, fly ash is one of the major industrial by-products and utilization of it has great significance on economy and environment.

sr.no.	PROPERTIES	RESULTS
1	Particle Shape, Size	round, 4.75mm down
2	Finesss Modulus	3.17
3	Silt Content	1.67%
4	Specific Gravity	2.6
5	Bulking of sand	4.16%
6	Bulk Density	1793 kg /m3
7	Surface Moisture	Nil

Physical Properties of Fine Aggregate (sand)

- **Foam**

incorpo Form release guard: Gubbi Enterprises.

Foaming agents is also defined as air entraining agent. Air entraining agents are organic materials. When foaming agents added into the mix water it will produce discrete bubbles cavities which become rated in the cement paste. The properties of foamed concrete are critically dependent upon the quality of the foam. There are two types of foaming agent:

i). Synthetic-suitable for densities of 1000 kg/m3 and above.

ii). Protein-suitable for densities from 400 kg/m3 to 1600 kg/m3.

Foams from protein-based have a weight of around 80 g/ litter. Protein-based foaming agents come from animal proteins out of horn, blood, bones of cows, pigs and other remainders of animal carcasses. This leads not only to occasional variations in quality, due to the differing raw materials used in different batches, but also to a very intense stench of such foaming agents. Synthetic foams have a density of about 40 g/litter. Synthetic foaming agents are purely chemical products. They are very stable at concrete densities above 1000 kg/m3 and give good strength. Their shelf life is about 1 year under sealed conditions. Synthetic foam has finer bubble sizes compared to protein but they generally give lower strength foamed concrete especially at densities below 1,000 kg/m3(Brady & Jones, 2001).

- **Waste Glass Crystals**

Glass is a uniform amorphous solid material, usually produced when the viscous molten material cols very rapidly to below its glass transition temperature, without sufficient time for a regular crystal lattice to form. The most familiar form of glass is the silica-based material used for windows, containers and decorative objects. Crystals size less than 4.75mm**.**

IV. LITERATURE REVIEW

RESEARCH REVIEW:-

The effect and properties of fresh concrete, Air content, Unit weight, Shrinkage, Hardened Properties like compressive and Tensile Strength Properties, Toughness and Impact Resistance, Freezing and Thawing Resistance of the concrete by the addition of flyash has been studied by many researchers.

FOAM CONCRETE:-

B. Karthikeyan, etal (2015):- They focus on the properties of lightweight foam concrete with addition of various binders /fillers such as Fly ash, Micro silica, Sio2 powder, clay and Rice husk ash. The results are discussed elaborately with respect to compressive strength, split tensile strength, and water absorption.(Mechanical Properties of foam concrete/ International Journal of Earth Science & Engineering. ISSN0974-5904)

SerkanSubasi (2009) investigated the effect of using fly ash in high

strength light weight aggregate concrete produced with expanded clay aggregate on physical and mechanical properties of the concrete. The cement content with 450 Kg/m3 among concrete mixtures produced high strength value and the mechanical properties could be enhanced by using 10% fly ash.

A saving in cement content and cost could be achieved. An experimental study was carried out by **NusretBozkurt et al (2010)** to investigate the influence of addition of pozzolanic materials and curing regions on the mechanical properties and the capillary water absorption (Sorptivity) characteristics of light weight concrete. The results showed a good correlation between the strength development of concrete and itssorptivity. As the compressive and tensile strength increased due to the hydration, the sorptivity coefficients decreased significantly.

Josef HadiPramana et al (2010)have reported that light weight concrete can be utilized as a normal concrete replacement structure shield. Aerated concrete and light weight aggregate concrete can be used as energy absorbent. Good energy absorption is due to the homogenized microstructure of aerated concrete component and air void entrapment in cement depending upon the materials used light weight aggregate concrete improves its strength to prevent local damage caused by ballistic loading. Lower modulus of elasticity and higher tensile strain capacity provides better iMPact resistance to light weight concrete than normal weight concrete.

Abdullahi et al (2009) have employed a statistical technique for modelling of light weight concrete mixtures using palm oil clinker obtained from by-product of palm oil milling as aggregate. Mix design was conducted using absolute volume method. They carried out an experimental workinvolving 20 trial mixes at different factor and level combination. Statistical modelling was done at 95% confidence interval. The test results shows that a polynomial model is adequate to predict the slump, air-dry density and compressive strength of palm oil clinker concrete. The terms considered in the models were significant with Ø-Values less than 0.5. The analysis of variance shows that the developed models adequately fit the experimental data with aØ-Value for the regression line less than 0.5 these statistics assures reasonable response prediction statistical approach is a useful tool for modelling of light weight concrete mixture.

A study was made by **RamazanDemirboga et al (2003)** on the effects of expanded perlite aggregate, silica fume and fly ash on the thermal conductivity of light weight concrete .The silica fume and fly ash were added as replacement for cement by decreasing the cement weights in different ratios by weight. They observed the decrease in thermal conductivity with the increase of silica fume and fly ash as replacement of cement.

HjhKamsiahMohd.Ismail et al (1999) have studied the behavior of light weight concrete and performance of aerated light weight concrete such as Compressive strength tests, water absorption and density and coMParisons made with other types of light weight concrete.

CelikOzyildirim (2009) has studied the durability of structural light weight concrete which includes the physical and chemical aspects of durability, the effect of cracking and resistance of light weight aggregates to freezing and thawing.

EmreSancak et al (2008) have investigated structural light weight concrete produced by Pumice and concrete with normal light weight aggregate. Compressive strength and weight loss of the concrete were determined after being exposed to high temperatures. They replaced the Portland cement by silica fume in different ratio and added super plasticizer. They observed the rate of deterioration was higher in normal weight concrete when coMPared to light weight concrete.

Chen et al (1999) have reported that concrete is considered to be a

composite material consisting of mortar and coarse aggregate and its strength depends on the mortar strength and coarse aggregate strength. During the strength development stage of light weight aggregate concrete, a critical condition under which the type of stress distribution changes occurs as the values of the modulus of elasticity of the light weight aggregate and mortarbecome the same. The concrete strength corresponding to this instant is named “Dividing Strength”. The concept of a dividing strength can be utilized to optimize a mix design for light weight aggregate concrete.

Daniel Rypl et al (2008) have dealt with the modelling of the concrete microstructure for the assessment of the percolation threshold of interfacial transition zone. They utilized hard core soft shell model, each aggregate particle described in terms of the spherical harmonic expansion surrounded by a shell of constant thickness representing the interfacial transition zone.

Spinnery(1993) studied on Non-shrinking foam concrete replacing cement with an equal amount of cementitious fines which can be fly ash, slag cement etc.

Kamaya et al (1996) pointed out that it is preferable to usenon-organic materials, which have specific surface area higher than 7500 cm^2/g as supplementary material, for the production of high strength foam concrete.

Kearsley&visagie(1999) reported that using unclassified flay ash of which around 40% of the particles have diameters exceeding 45 micro meter & the 56 days compressive strength of foam concrete with wet density of 1500 kg/m^3 could achieve around 45 MPa.

TRANSPARENT CONCRETE:-

PatilGaurao S., PatilSwapnil V.(2015)properties of light guiding andelasto-optic effect of optical fiber, a novel smart transparent concrete is researched by arranging the optical fibers into the concrete.(Light transmitting concrete –a new Innovation/ International Journal of Engineering Research & General Science. Volume 3 Issue 2, part 2. ISSN 2091-2730)

Akshay B Kamdi(2013) has studied the manufacturing, uses, and future scope of transparent concrete.(Transparent concrete as a green material for building / International Journal of Structural & Civil Engineering Research Volume 2, No.3 ISSN 2319-6009)

Dinesh W Gawatre, Suraj D Giri, Bhagavat B Bande studied that the smart translucent concrete can be regarded as a green energy saving construction material.(Transparent concrete as an ecofriendly material for building/International Journal of Engineering Science Invention Volume 5, Issue 3 ISSN 2319-6726)

Bhavin K Kashiyani, VarshaRaina, Jayesh Kumar Pitroda, Dr. Bhavnaben K Shah(2013) Integrated the merits of concrete & optical fibers for developing transparent concrete by arranging a high numerical aperture plastic optical fibers or big diameter glass optical fibers into concrete.(A study on transparent concrete: A Novel Architectural Material to explore construction sector International Journal of Engineering & Innovative Technology(IJEIT) Volume 2, Issue 8 ISSN 2277-3754)

Soumyajit Paul, AvikDutta(2013) has studied the Translucent characteristics(Translucent concrete/International Journal of scientific & Research Publication Volume 3, Issue 10 ISSN 2250-3153)

V. CASTING OF SPECIMEN

All the specimens were cast having mix proportions as given in Tables. For these mix proportions, required quantities of materials were weighed. The mixing procedure adopted as follows:

a. To make cement slurry or sand cement slurry that is appropriate for the mix design.

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b. The foam is made separately from the slurry. Once the foam has been made it is blended in to the slurry to make foamed concrete.

c. We have taken the Resin and Hardener in the proportion of 98%: 2%. The resin and hardener was mix using special mixing equipment.

All the moulds were properly oiled before casting the specimens. The casting immediately followed mixing, after carrying out the tests for fresh properties. The top surface of the specimens was scraped to remove excess material and achieve smooth finish. The specimens were removed from moulds after 24 hours and cured in water till testing or as per requirement of the test.

VI. TEST

- **Workability test**

Workability is defined as the easiness with which a concrete can be transported, placed and consolidated without excessive bleeding or segregation.
Factors affecting concrete workability:

a) Water-Cement ratio
b) Amount and type of Aggregate
c) Amount and type of Cement
d) Weather conditions
e) Temperature
f) Wind Chemical Admixtures
g) Sand to Aggregate ratio

- **Compressive strength test**

This test is performed to determine compressive strength of concrete. The compressive strength is most important characteristic of concrete. The compressive strength increases if the cement content is increased. Compressive strength is influenced by several factors such as:

a) W/C ratio
b) Type of cement and its quality
c) Type and structure of aggregate
d) Degree of compaction
e) Efficiency of crushing
f) Time required for hardening

Total 30 concrete cubes of 150 x 150 x 150 mm size are prepared for each mix.

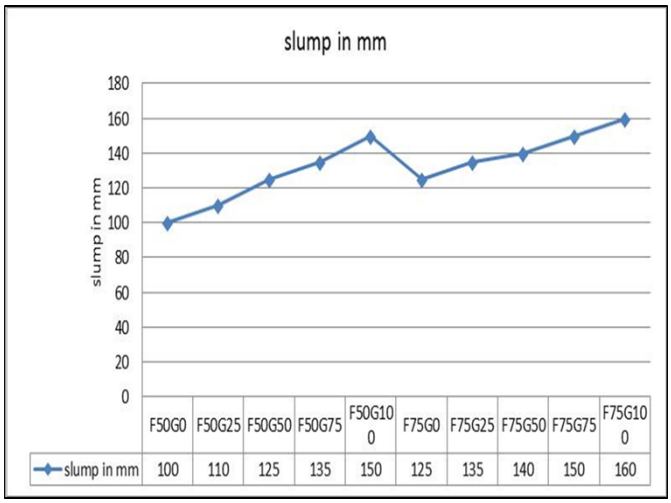
- **Flexural strength test**

Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little depends on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However tensile stresses likely to developed in concrete due to shrinkages, rusting of steel reinforcement, temperature gradients and many reasons.

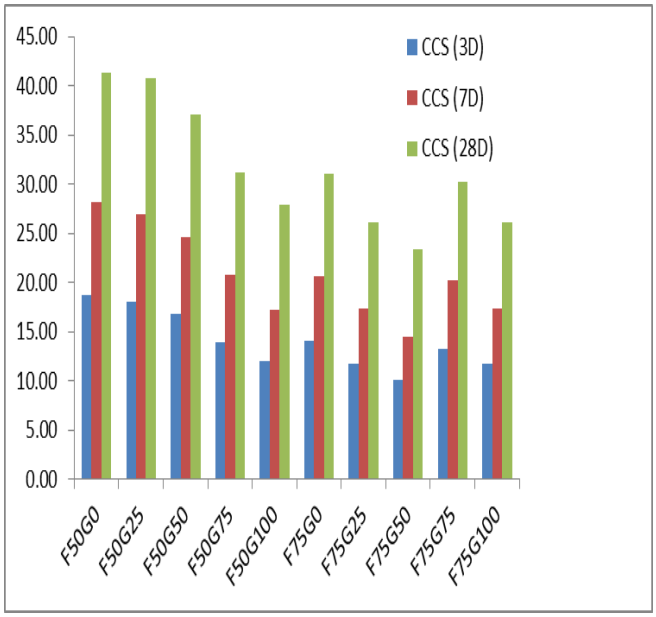
The knowledge of tensile strength of the concrete is of importance. The standard size of the specimens are 15cm x 15cmx 70cm.
Total 3 beams were casted of size 150 x 150 x 700mm and tested for 28 days strength.

VII.RESULT ANALYSIS & DISCUSSION

- SLUMP CONE TEST

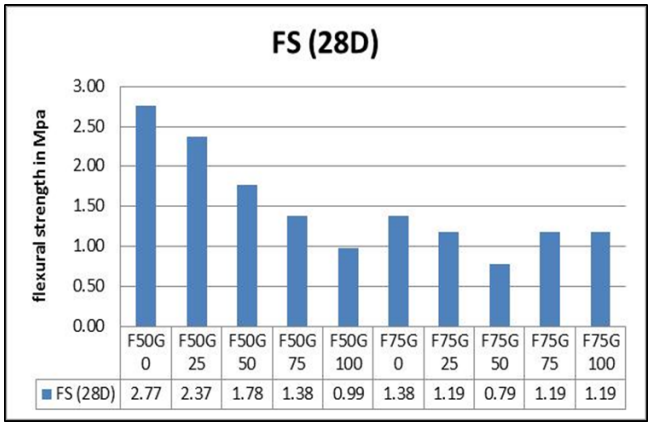


- COMPRESSIVE STRENGTH OF 3D,7D & 28D

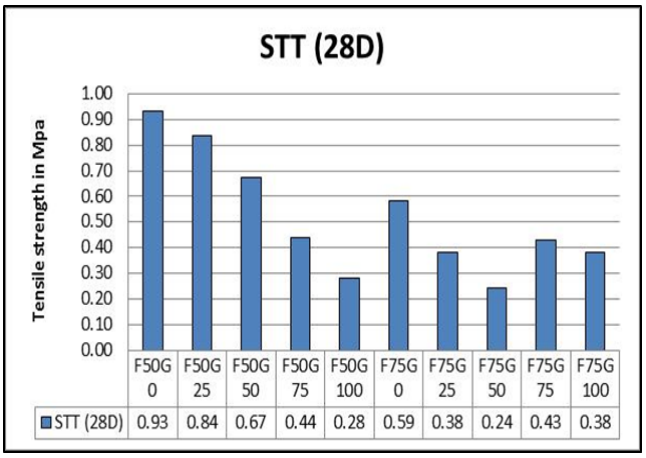


Type of concrete	Avg. 3 days (N/mm^2)	Avg. 7 days (N/mm^2)	Avg. 28 days (N/mm^2)
F50G0	18.71	28.13	41.38
F50G25	18.00	26.99	40.83
F50G50	16.80	24.65	37.07
F50G75	13.99	20.76	31.26
F50G100	12.01	17.24	27.87
F75G0	14.07	20.65	31.04
F75G25	11.72	17.38	26.19
F75G50	10.07	14.46	23.36
F75G75	13.27	20.21	30.24
F75G100	11.72	17.38	26.19

- **FLEXURAL STRENGTH**



- **SPLIT TENSILE STRENGTH**



VIII. CONCLUSIONS & RECOMENDATIONS

To test the suitability of Glass crystals as a replacement to fine aggregate partially, it was used in incremental levels of 25 % from 0 % to 100 % for 50% and 75% of foam. Different tests like workability, compressive strength, flexural strength, tensile strength and water absorption were conducted on specimen of cubes, beams cylinders according to relevant IS recommendations.

The following conclusions can be drawn from the experimental investigations conducted on the behaviour of concretes with glass crystals as a replacement for fine aggregate and also the use of resin and hardener for transparency.

1. Workability increases with the increase in the percentage of finely ground waste glass crystals.
2. Variation in compressive strength, flexural strength and tensile strength is observed in the presence of finely ground waste glass crystals.
3. It is also observed that the use of resin and hardener instead of optical fibres can also transmit the light effectively.
4. The reuse of very finely ground waste glass in concrete has economical and technical advantages.

If the glass could be ground to very fine size, it could satisfy the active pozzolanic behavior. Glass waste is recognized to be increasing year by year in large volume from shops, construction areas and factories.

5. Thus uses of waste glass in construction sector is also advantageous as the construction cost gets lowered.

References

[1] Indu Siva Ranjani, K. Ramamurthy, "Relative Assessment of Density and Stability of Foam Produced with Four Synthetic Surfactants", *Materials and Structures*, Vol.43, 1317- 1325, 2010.

[2] Fahrizal Zulkarnain, Mahyuddin Ramli, "Performance And Characteristic Foamed Concrete Mix Design With Silica Fume For Housing Development", *International Journal of Academic Research*, Vol.3, No.2 March 2011.

[3] E.K. Kunhanadan Nambiar, K. Ramamurthy, "Sorption Characteristics of Foam Concrete", Cement and Concrete Research, Vol. 37, 1341- 1347, 2007.

[4] Pan Zhihua, Fujiwara Hiromi, Wee Tionghuan, "Preparation of High Performance Foamed Concrete from Cement, Sand and Mineral Admixtures", *Materials and Structures*, 2010.

[5] Nagesh. Mustapure and H. Eramma **"**Experimental investigation on cellular lightweight concrete blocks for varying grades of density", *International Journal of Advanced Technology in Engineering and Science*, Volume No.02, Issue No. 08, August 2014.

[6] E.P. Kearsley, P.J. Wainwright, "Ash Content for Optimum Strength of Foamed Concrete", *Cement and Concrete Research*, Vol.32, 241-246, 2002.

[7] K. Ramamurthy, E.K. Kunhanandan Nambiar, G. Indu Siva Ranjani, "A Classification of Studies on Properties of Foam Concrete", *Cement & Concrete Composite*, 31 388-396 2009.

[8] N. Narayanan, K. Ramamurthy, "Microstructural Investigations on Aerated Concretes", *Materials Cement and Concrete Research*, 30, 457 - 464, 2000.

[9] E.K. Kunhanadan Nambiar, K. Ramamurthy, "Models for Strength Prediction of Foam Concrete", *Materials and Structures*, Vol.41, 247- 254, 2008.

[10] R. C. Valore , Digital Image Cellular concretes – Part I. Composition and methods of preparation , J Am Concr Inst, 1954;25 (9):773 -95 .

[11] J.M. Chi, R. Huang, C.C. Yang, and J.J. Chang "Effect of Aggregate Properties on the Strength and Stiffness of Lightweight Concrete", Journal of Cement & Concrete Composites, 25. 197-205, 2003.

[12] D.D.L. Chung. Cement reinforced with short carbon fibers: a multifunctional material. Composites: Part B.31:511-526, 2000

[13] F. Ansari. Practical Implementation of Optical Fiber Sensors in Civil Structural Health Monitoring. Journal of Intelligent Material Systems and Structures, 18(8):879-889, 2007.

[14] H.Li, H.G. Xiao, J.P. Ou. Microstructure of cement mortar with nano-particles. Composites Part B Engineering, 35:185-189, 2004.

[15] Jianping He, Zhi Zhou, JinpingOu, Minghua Huang, "Study on Smart Transparent Concrete Product and Its Performances", Dalian, China, 2011.

[16] Kalymnios, D. Plastic Optical Fibers (POF) in sensing – current status and prospects. 17th International Conference on Optical Fiber Sensors SPIE, 5855, 2005.

[17] K.S.C. Kuang, M. Maalej, S.T. Quek. Hybrid optical fiber sensor system based on fiber Bragg gratings and plastic optical fibers for health monitoring of engineering structures. Proc. of SPIE, 6174(61742P) : 1-12, 2006.

[18] Scherafe, T. "fabric Structure outpace applications: Recent structural development expand the range of fabric options", Building design and construction, pp.128-138,1988

[19] Victoria Bailey, "Translucent Concrete", MEEN 3344-001

[20] Z. Zhou, J.P. Ou, and B. Wang. Smart FRP-OFGB Bars and Their Application in Reinforced Concrete Beams. Proceedings of the First International Conference on Structural Health Monitoring and Intelligent Structure, Japan: 861~866, 2003.

[21] seminarprojects.com/s/transparent-concrete-ppt

[22] byen.wikipedia.org/wiki/LiTraCon

[23] en.wikipedia.org/wiki/Optical_fiber

[24]en.wikipedia.org/wiki/Translucent_concrete

[25www.archicentral.com/litracon-transparent-concrete-4379/

[26]www.engineer.tamuk.edu/.../Translucent%20Concrete_Victoria_Baile

[27] www.foundationsakc.org/potential

[28] www.impactlightinginc.com

[29] www.litracon.hu/