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Evaluation and Analysis of Lightweight Concrete (LWC) Manufacturing and Applications

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Abstract: This study presents the evaluation and analysis of LWC manufacturing and applications. Clear comparisons of different LWC types according to the physical specifications and properties lead to accurate selection of concrete type depending on the conditions surrounding the buildings projects. The widely used of LWC in all over the world is approaching researchers to seriously consider finding new techniques to produce more resistant varieties nearby conditions of construction projects. The LWC types are more sustainable than burnt brick due to its providing high densities and better insulation. This study has been carried out the deep discussion and comparison between the properties of fly ash, AAC and CLC concrete types. The advantage of aerated lightweight concrete compared with traditional concrete is present in advance strength to weight ration, less thermal expansion coefficient and high insulation of sound. The classified of aerated lightweight concrete into foamed and autoclaved concrete has attention in the suggested mixture. By maintain the density as constant parameter, their load carrying capacity in compression, water absorption and thermal insulation are to be tabulated and concluded by their performance.

Key words: LWC, foamed concrete, AAC, CLC, fly ash, aerated concrete

INTRODUCTION

Now a days, the most important factors in construction projects is represented by Lightweight Concrete (LWC) due to many facilities achieved in this type of materials (Berge, 2009). Current researches presented high concrete performance to be close with user demand according to material properties and applications (Pelisser *et al*., 2012). In addition, the cost effective factors with no quality scarify is another vital role in building structure with dead load reducing as in multi storage buildings and structure elements (Akcaozoglu and Atis, 2011). In natural sand and lightweight studies, the commercial fine aggregate has been investigated in place of natural sand manufacturing (Kockal and Ozturan, 2011). The environments and economic benefits of light weight concrete could be achieved in case of waste materials are used instead of fine light weight aggregate (Ducman and Mirtic, 2009). To provide light weight concrete, the natural aggregate will reduce the non renewable consumptions in modern buildings (Xu *et al*., 2012). Due to light weight concrete properties, one could not made heavy load bearing of infrastructures because of low bearing capacity (Trtik *et al*., 2011; Madandoust *et al*., 2011). To act link wall and supporting the structure building, the light weight should be used (Madandoust *et al*., 2011). The main types of LWC could be summarized by Shannag (2011) as follow:

Autoclaved aerated which is made up of cement, gypsum, water and sand with a bite amount of powder. In same it's called as aircrete due to entrain the air into the components with 50% air void. Additionally, this type of LWC is a porous material which consisting uniform air to make it lighter. The raw material is mixed with water as required density and expansion agent such as powder adding to the mixture which will increase the volume by 5 times the original quantity to react with calcium hydroxide and produce of water cement reactions. The powder and calcium hydroxide reactions produce uniform micro air bubbles resulting in higher volume of concrete.

The foam concrete mixed with sand, water, fly ash and cement is called cellular light weight concrete. After the foam agent was dilute with air and water, the mixture is then mixed with cement slurry to maintain the shape around the foam bubbles of about 30% entrain of air by volume to produce low density foam concrete. Then, one could categorize this type of LWC as cellular material due to its consisting of a high quantity of pores. Additional amount of foam concrete is depending on the quality and type of foams. Because this mixture is not contain coarse aggregate, the correct terms could be named mortar which have density varies from 400-600 kg/m^3. The two types of foam agent is used as construction material, 1 is called protein based foaming agents which is come from animal protein and the other is called synthetic foaming agents.

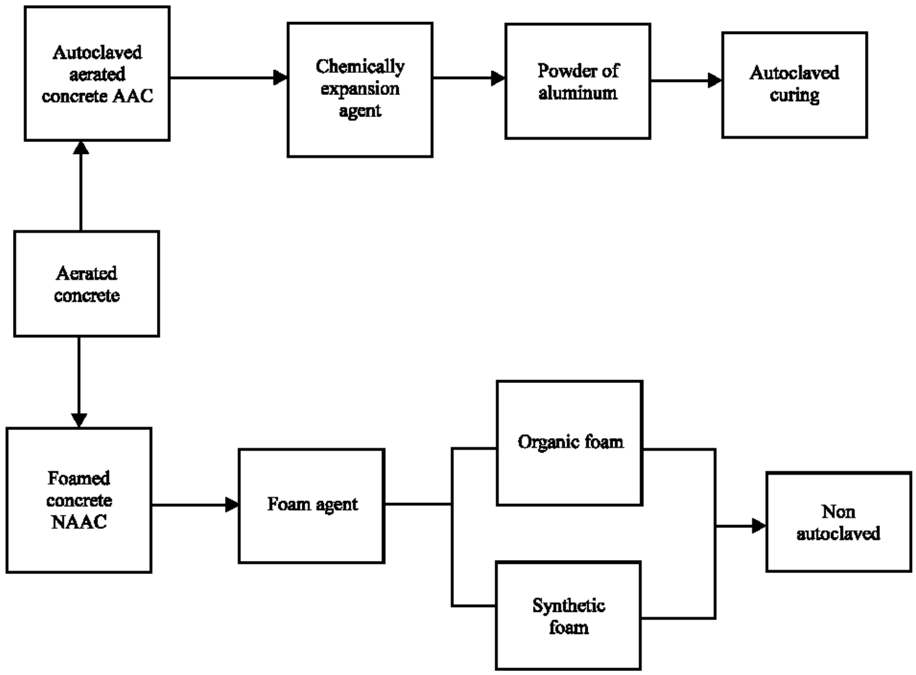

Fig.1: Aerated lightweight concrete class

The first type is suitable to produce concrete foam with high density and strength. The second type is used to reduce the surface tension of liquid.

The fly ash concrete have high economic and environmental advantage as coal combustion product which is divide the residue left into boiler, blast furnace. This type contain 20% of cementations material with three flash ash types such as class C and F of high lime, intermediate lime and low lime. These types are lighter in weight due to partial substitution of fine aggregate and coarse aggregate. A greater density and cost effective is the main properties of these types to compression the ratio of strength. The raw components of fly ash concrete are fly ash, water and sand which is mixed in good way according to the required task.

The most popular type of LWC is the aerated concrete which also knows as cellular concrete (Zhang, 2011). The two type of aerated concrete according to production technique, the first concrete type called Non Autoclaved Arated Concrete (NAAC) and the second type is called Autoclaved Aerated Concrete (AAC) (El-Gamal *et al*., 2012). Figure 1 illustrates the classification of aerated lightweight concrete.

By injection the performed stable foam or adding the special air entraining into mix of cement or mortar, the foamed concrete type NAAC is produced (Demirboga and Kan, 2012). By adding a portion of aluminum powder with sand, lime, slurry of ground, cement and water, the ACC foamed concrete is produced (Koksal *et al*., 2012). The foam concrete setting looks much better than lightweight aggregate (Hossain *et al*., 2011; Castro *et al*., 2011). Early 1920s, the foamed concrete is firstly, recorded by using date back for construction works was recognize at mid of 1970s (Sengul *et al*., 2011). The first time discovered the mixture of cement, sand, water and lime by Swedes in 1914 and expand by add aluminum powder to produce hydrogen gas in cement slurry (Ismail *et al*., 2013). Over 60 years ago, the Europe was reported that the foamed concrete is developed by invent minds had tried beaten egg white, yeast and other unusual technique of adding air to the concrete (Kim *et al*., 2012). The foam concrete provides minimum consumption of aggregate, high flow ability and minimum self weight (Kismi *et al*., 2012). In addition, these concrete types could support thermal insulation property, controlled low strength with high range of density up to 1600 kg/m^3 which could provide filling grades and partition (Shafigh *et al*., 2012). The foamed concrete is very stable density which provide more than 1000 kg/m^3 with good strength and shelf life of about 1 year under sealed conditions (Sariisik and Sariisik, 2012). The synthetic foam gives lower strength foamed concrete and has finer bubble size (ACI Committee 213, 2014; Bogas and Gomes, 2015). The aluminum powder is typically used to produce autoclaved aerated concrete with chemical response and generate gas in fresh mortar

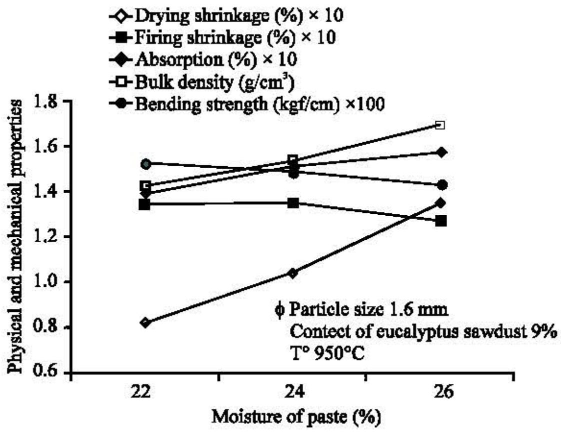

Fig. 2: Physical-mechanical properties proposed by Bachir Chemani and Halima Chemani

with large number of gas bubbler (Schackow *et al*., 2014). A worldwide using of foam agent is in ACC manufacturing with widely preventing the best solution (Kurweti *et al*., 2017). The adding of aluminum by 0.5% dry weight of cement to the ingredients mixing is classified intoatomizes flake and granules types (Chung *et al*., 2017). The weight, thickness and length of particle atomized are approximately same order when the width and length of flack particle may be many hundred times the thickness (Yoon *et al*., 2015). In ACC industry, the aluminum powder is made by foil scrap and exists of microscopic flack shape. Grain size of 100 μm with aluminum and fractions <50 μm could be form high flammable aero suspensions during pouring (Kim *et al*., 2016). The ACC type production required aluminum powder that consist fraction finer than 100 or 50 μm in order to produce requirements of mechanical properties of the aerated concrete (Ouellet *et al*., 2016). Many researchers were proposed new approach to generate LWC with better properties. The optimum quantity of waste of 9 wt.% sawdust is proposed by Chemani and Chemani (2012). These proportions generate bricks mechanical possessions which are suitable to use as minor raw material in ceramic element. In 2012, the relation of damp, physical and mechanical depend on particle size is presented by Chemani and Chemani (2012) as illustrated in Fig. 2.

The mixture of experimental ideas, technical means, hydration, hardening, raw materials and other possessions of the thermal insulation mortar block have been considered lengthily and methodically by Haibo (2017), Hwidi *et al*. (2018) and Hafid and Ridha (2016).

Table 1: Physical possessions of cement

Properties/standards	Details (IS-269.1989 and 383.1970)
Color	White
Gravity	3.15
Surface area	2250 (cm²/kg)
Compressive strength	53 (MPa)

Table 2: Fly ash propertie

Properties/standards	Details (IS-3812.1.2003)
Gravity	2.5
Fly ash	Class C
Surface area	4000 (cm²/g)
Color	White

MATERIALS AND METHODS

Experiment setup: In the proposed experiment, the subsequent material percentage is used to produce the foam concrete. First of all, the cement is a compulsory material used in building project that sets and hard-bitten to other materials when respond with the water. When cement is used with just fine aggregate, then the mortal is produces while when cement is mixed with fine aggregate and coarse aggregate, the result is known as concrete. Table 1 show physical properties of normal Portland cement type grade 53.

The fly ash is weakly rating element and sphericla shape with range from 0.5-300 μm which is consist of 25% cement to provide workability and reliability to concrete and less heat of hydration in this case. Fly ash could be used to increase the setting of concrete and providing high strength in the next stages. Table 2 illustrates the physical possessions used in the proposed experiment.

The sand used in this experiment is natural occurrence grainy material which is collected of finely divided rock and sandstone elements. The sand is defined by its size being better than gravel and coarser than the silt and the quantity of this sand is used to ensure less amount of cement and lesser water to increase the strength and durability but its produce less shrinkage to the concrete. Due to size range of sand used in this experiment is between (0.06-2mm) the gravity of sand used is 2.5 with fineness modulus is 2.6 and the coda standards is IS.383.1970.

The gypsum used in the proposed mixture is a type of mineral and hydrated calcium sulfate in the form of chemical material. The gypsum is a very important material in the recompense the rate of solidifies of cement which is used to control the setting time. Table 3 shows the gypsum physical properties.

Table 3: Gypsum properties

Properties/Standards	Details (IS-3812.1.2003)
Gravity	2.3
Chemical formula	$Ca(OH)_2.2H_2O$
Surface area	Up to (3800 cm^2/g)
Color	White gray
Size	<1mm

Table 4: Hydrated lime specifications

Properties/Standards	Details (IS-3115. 1992)
Gravity	2.81
Type	Hydrate lime
Surface area	4300 (cm^2/g)
Color	White
Chemical format	CaO

Table 5: Aluminum powder specifications

Properties/Standards	Details(IS.3115.1992)
Gravity	0.22
Melting point	-660°C
Surface area	7000 (cm^2/g)
Color	Gray
Particle size	45 (μm)

Table 6: Foaming agent physical specifications

Properties/Standard	Details (IS.3115.1992)
Gravity	1.15
State	Liquid
Color	Brown
Temperature	at 20°C

To make ACC type, the lime is used in order to reduce the water amount in concrete block as well as prevents ACC type from drying out too quickly and dry shrinkage. The main type of lime is represent by hydrated lime, fat lime and quick lime in which hydrated lime are widely used to produce the constructions. Table 4 shows the hydrated lime physical specifications.

The aluminum powder is finely grinded powder used in this experiment which reacts with calcium hydroxide of cement water reaction. After reaction between aluminum powder and calcium hydroxide, this mixture produce uniform micro bubbles which resultant in concrete volume rising creation it very light weight concrete. In Table 5 the physical specifications of aluminum powder could be summarized.

The foaming agent is a material used to facilitate the formation of foam like a surfactants property. After the foaming agent has added into the water with 1.30-1.40%, the foam will generate with low weight and brown-white color in this case. The foam concrete type CLC is produce after mixing slurry with foam. In Table 6 the physical specifications of foaming agent which is used to generate CLC concrete is summarized.

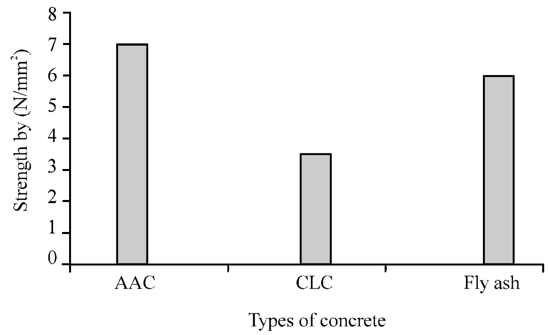

Fig. 3: Strength results of different concrete types (density 1000 kg/m^3)

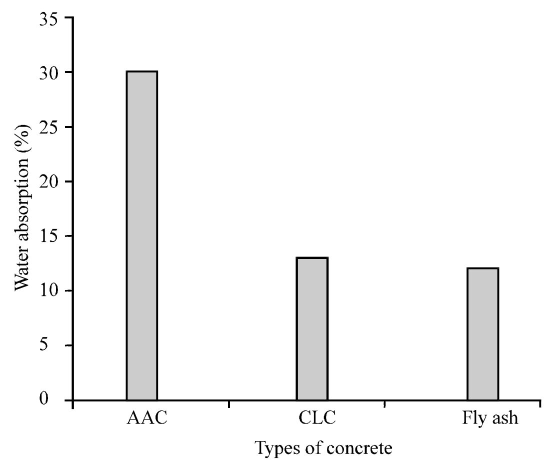

Fig. 4: Water absorption results of different types of concrete (density 1000 kg/m^3)

RESULTS AND DISCUSSION

The AAC type of concrete is durable and workable specifications of this block with the 15 cm^3 size. In case of fire resistance and sound insulation test, the thickness of AAC block is consider to be 100 mm. Table 7 illustrated the AAC properties in the proposed work and the strength results of different concrete types is shown in Fig. 3. The CLC concrete type durable and workable specifications block with 15 cm^3 size case. In case of fire resistance and sound insulation test, the thickness block of 100 mm have been considered. Table 8 illustrated the CLC properties in the proposed work. The water absorption results, thermal conductivity and sound insulation of concrete are illustrated in Fig. 4-6, respectively.

The fly ash concrete type durable and workable specifications block with 15 cm^3 size case. In case of fire resistance and sound insulation test, the thickness block of 100 mm have been considered. Table 9 illustrated the AAC properties in the proposed work.

Table 7: AAC specifications

Density (kg/m^3)	Strength (N/mm^2)	Water absorbtion (%)	Thermal conductivity (W/mk)	Resistance (h)	Sound insulation
1000	7	30	0.40	5	45
1100	8	25	0.49	5	46
1200	10	20	0.54	5.5	48
1300	11	15	0.62	6	50
1400	12	10	0.70	6	55

Table 8: CLC specifications

Density (kg/m^3)	Strength (N/mm^2)	Water absorbtion (%)	Thermal conductivity (W/mk)	Resistance (h)	Sound insulation (dB)
1000	7	30	0.40	5	45
1100	8	25	0.49	5	46
1200	10	20	0.54	5.5	48
1300	11	15	0.62	6	50
1400	12	10	0.70	6	55

Table 9: Fly ash specifications

Density (kg/m^3)	Strength (N/mm^2)	Water absorbtion (%)	Thermal conductivity (W/mk)	Resistance (h)	Sound insulation (dB)
1000	7	30	0.40	5	45
1100	8	25	0.49	5	46
1200	10	20	0.54	5.5	48
1300	11	15	0.62	6	50
1400	12	10	0.70	6	55

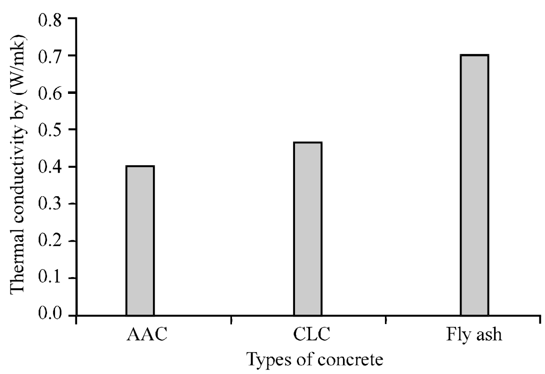

Fig. 5: Thermal conductivity results of different types of concrete (density 1000 kg/m^3)

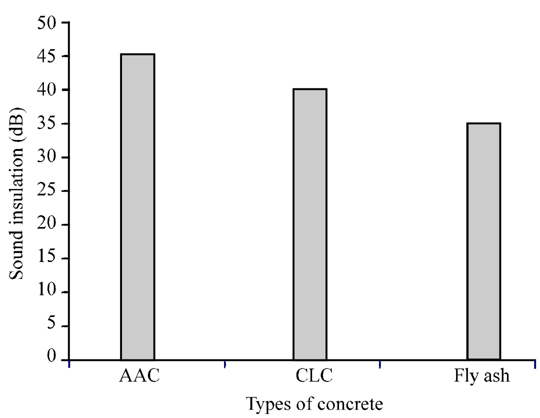

Fig. 6: Sound insulation results of different types of concrete (density 1000 kg/m^3)

CONCLUSION

This study present the evaluation and review of Lightweight Concrete (LWC) manufacturing and applications. Different type of LWC is investigated and explained as well such as AAC, CLC and fly ash concrete. The durable and bearable specifications and properties of these concrete types is illustrated with their own reassure field. The strength of compressive, the absorption of water, sound insulation and conductivity of thermal were compared by means of corresponding density. From compressive strength of AAC block looks better than CLC and fly ash base concrete while water absorption of fly ash based concrete is quit better with respect to other types of LWC. The thermal conductivity of AAC and CLC are providing same performance with better conductivity than fly ash. In the sound resistance side, the AAC provide better performance than CLC and fly ash. The test tables and analysis show that the AAC type of concrete are most preferable compared with other concrete types due to the strength of compressive as well as less dead load of AAC types. These results indicate that the AAC type of concrete looks more promising in current and future building projects. More investigation and tuning test could propose to produce better concrete mixture with high resistance and less weight.

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