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The Use of Light Weight Aggregates for Precast Concrete Structural Members

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Abstract

Agriculture industry is the one of the main industry in India due to favorable climatic conditions for the plantation. In agriculture industry one of the main craop is palm oil fruits. These fruits are using for the oil extraction; the oil is known as palm oil. In this palm oil industry the waste is outer part (shell) of the palm oil fruit. That shell is being used as a light weight aggregate in concrete production. In this present work is main focusing on precast concrete, in this precast the aggregates are more weight compare to the all other ingredients. So, in this work mainly focusing on light weight aggregates. In this light weight aggregates are considered as POS (palm oil shell) and PA (pumice aggregates). The PA and POS are light in weight and also physical and chemical properties are approximately equal to the normal aggregates. This paper reviews the use of such light weight aggregate concrete in reinforced concrete structural members , which were carried out by researchers in past. It is hoped that the knowledge attained from the paper will provide design engineers and researchers with better idea and proper application of design criteria for structural members using such light weight aggregates.

Keywords: palm oil shell, pumice aggregates, precast concrete, light weight aggregates and reinforced concrete, light weight aggregate concrete.

INTRODUCTION

Up to now, studies on lightweight concrete with lightweight aggregate (LWA) have been scarce. However, considerable research work has been carried out on normal weight concrete (NWC) and artificial lightweight aggregate concrete (ALWAC). Knowledge in the difference between LWAC and NWC is helpful for the study of high-strength lightweight aggregate concrete. The classifications, definitions and limitations of lightweight aggregate concrete, the difference between LWAC and NWC is presented and studies on properties of palm oil shell and pumice aggregates; palm oil shell and pumice aggregate concretes are discussed.

Historical Background of Lightweight Aggregate Concrete

The use of lightweight aggregate concrete (LWAC) can be traced to as early as 3000 BC, when the famous towns of Mohenjo-Daro and Harappa were built during the Indus Valley civilization. In Europe, earlier use of LWAC occurred about two thousand years ago when the Romans built the Pantheon, the aqueducts, and the Collosseum in Rome.

Earlier lightweight aggregate (LWA) were of natural origin, mostly volcanic (pumice, scoria, tuff, etc.). These have been used both as fine and coarse aggregate. They function as active pozzolanic material when used as fine aggregate. They interact with calcium hydroxide generated from the binder during hydration and produce calcium silicate hydrate which strengthens the structure and modifies the pore structure, enhancing the durability properties. Pumice mine has been used first by Greek and later by Romans long before Cristianism.

It has been used in wall construction, water channels and many other monumental structures in Roma. In U.S.A pumice mine has been used since 1851 in construction. Additionally, pumice has been used from 1908 to 1918 in aqueduct construction in Los Angeles. It has been started to be used as lightweight insulating building material since 1935 in U.S.A and after that showed steady increase in this sector. In U.S.A despite early usage of pumice in the domestic construction industry, has fallen behind compared to the other countries. Before Wold War-2 Germany has been possessed a strong trade in lightweight building materials unit in the world.

The Greeks and the Romans used pumice in building construction. Some of these magnificent ancient structures still exist, like St. Sofia Cathedral or Hagia Sofia, in Istanbul, Turkey, built by two engineers, Isidore of Milctus and Anthemius of Tralles, commissioned by the Emperor Justinian in the 4th century A.D., the Roman temple, Pantheon which was erected in the years A.D. 118 to 128; the prestigious adueduct, Pont du Gard, built A.D. 70 and 82. In addition to building construction, the Romans used natural lightweight aggregates and hollow vases for their “Opus Caementitium” in order to reduce the weight. This was also used in the construction of the Pyramids during the Mayan period in Mexico.

The first building frame of reinforced LWAC in Great Britain was a three story Office block at Bent ford, near London, built in 1958. Since then, many structures have been built of precast, in-situ prestressed or reinforced lightweight aggregate concrete.

Other early application is the ship built with the LWAC at the end of World War 1, 1917. One of the famous ships was named as Selma. After so many years of service in harsh climate, it is still in satisfactory condition. This impels of the durability of the Lightweight Aggregate Concrete. In addition to the materials, the technique adopted by the ship builders to construct the ship is equally important. It was so well constructed that some of the factors have become specifications for ship making.

Pumice is still used today as an aggregate for making masonry unit and lightweight structural concrete in certain countries such as Turkey, Germany, Italy, Iceland and Japan. In some places, like Malaysia, palm oil shells are used for making lightweight aggregate concrete.

LIGHTWEIGHT AGGREGATE

Introduction, Definitions and limitations

The aggregates used in structural lightweight concrete may be a combination of fractions of both lightweight coarse and fine materials and lightweight coarse material with an appropriate, natural fine aggregate.

Any aggregate with a particle density of less than 2000 kg/m^3 or a dry loose bulk density of less than 1200 kg/m^3 is defined as lightweight. However, this necessary dual qualification in definition highlights a practical difference from most other aggregates used in structural concrete where particle densities greater than 2000 kg/m^3 are used. In the case of an appropriate lightweight aggregate the encapsulated pores within the structure of the particle have to be combined with both the interstitial voids and the surface vesicles. Nevertheless, these features in combination should not increase the density of the compacted concrete either by significant water absorption or cement paste pervasion into the body of the aggregate particle when the aggregate is mixed into concrete.

Types of Lightweight Aggregate

Lightweight aggregate can be divided in two categories:

- Those occurring naturally and are ready to use only with mechanical treatment, i.e., crushing and sieving. Important examples for this type of aggregate are volcanic aggregates, or pumice and scoria aggregates.
- Artificial lightweight aggregates such as Foamed Slag, expanded clay, Sintered PFA, Blast furnace slag, expanded slate, expanded shale, etc. According to Clarke J.L.

Types of Lightweight Concrete

Lightweight concrete can be made by injecting air into the composition of concrete. It will make the concrete containing with air bubble which can reduce the weight and the density of concrete. The other way to produce this concrete is replacing the aggregate by hollow, cellular and porous aggregate (Newman, et al.2003). Particularly, lightweight concrete can be categorized into three types:

- No-fines concrete
- Aerated or foamed concrete
- Lightweight aggregate concrete

No-fines concrete

No fines-concrete means that the concrete is only contain with cement and rough aggregates which can provide voids in the concrete. It is commonly used for construct outside bearing wall, non-bearing wall and plaster wall for structure and slab. The advantages of using this concrete are low density, less cost because of small amount of cement required, low thermal transfer, no segregations and capillary rises, good energy of sound absorb because of the voids (Neville, 1981).

Aerated or foamed concrete

Aerated or foamed concrete is made by mixing sand, cement, water and small amount of aerated agent. This agent provides air bubbles in concrete which make the concrete as a lightweight concrete. These air bubbles are created to reduce the density of the concrete and to provide good thermo-acoustic insulation. However, aerated concrete exhibits low compressive strength and high rate of water absorption (Arreshvhina, 2002). When the mixing process, the concrete will be expanded like cakes because of the agent. Unused of the coarse aggregate make it lighter than normal concrete. The density of aerated concrete is about 1900 kg/m3 compared to normal concrete which have density 2400 kg/m^3 (Chandra and Berntsson,2002).

Lightweight aggregate concrete

Lightweight aggregate concrete (LWAC) is one of the lightweight concrete which widely used in building constructions today. According to Chandra and Berntsson (2002), the applications of LWAC can be traced to as early as 3000 BC. It happens when the famous town of Harappa and Mohenjo-Daro were built during the Indus Valley Civilization. In Europe, the application of LWAC was existed in 2000 years ago when Romans built Pantheon, the aqueducts, and the Collosseum in Rome. It is interesting that pumice sill be used today as an aggregate for some country like Germany, Italy, Iceland and Japan. In Malaysia, palm oil shells are used as light aggregate for making LWAC. In Great Britain, there have the first building frame of reinforce LWAC. It built in 1958 with a three-story office block at Bent ford, near London.

Lightweight aggregate can be classified into two categories; natural aggregates and artificially manufactured aggregates. Natural lightweight aggregates are normally obtained from the volcanic rocks such as pumice with density ranges from 500 kg/m3 to 900 kg/m^3 (Short and Kinniburgh, 1978). The rocks formed when the volcanic lava is suddenly cooled. The common artificially lightweight aggregates used are expended clay, expended shale, foamed slag, blast furnace slag, pulverized fuel ash and polystyrene. The bulk dry density of these aggregates range from 425 kg/m^3 to 900 kg/m^3 (Short and Kinniburgh, 1978).

Difference between Lightweight Aggregate Concrete and Normal Weight Concrete

Differences between LWAC and NWC concern the mixing stage, hardening stage, ductility, failure modes et al. In the mixing stage, the porous, water-absorbing lightweight aggregates can affect the workability of the concrete (Neville et al., 1987) as well as the effective water/binder ratio. In the hardening stage, the relatively low specific heat and high insulating capacity of LWAC will cause a higher hydration temperature. The water initially present in the porous aggregate particles may affect the moisture state in the hardening system to a large extent. Volume changes take place with the changes in the state of water in the pore system in the early stage of hardening. In the hardened concrete, the differences between LWAC and NWC are mainly due to differences in the strength and elastic modulus of the aggregate, and particularly to differences of the matrix-aggregate interfacial zone. These differences determine the degree of heterogeneity of concrete. The properties of the interfacial zone are determined by the surface characteristics of the aggregate, as well as the pore structure and the initial water content of the aggregates (Isserman and Bentur, 1996). Depending on the pore structure of the aggregates, some reaction products e.g. calcium hydroxide, will even penetrate into the pores of the aggregates. This is more likely in aggregates with higher absorption and bigger pores (Isserman and Bentur, 1996).

The strength of many lightweight aggregates (LWA) is about the same as the strength of the hardened paste. The matrix-aggregate interfacial zone is of a higher quality than in the case of NWC. The bleeding effect on aggregate surfaces is also reduced due to the reduced response of the LWA to vibration energy during compaction of the concrete. It means that in many LWAC, the interfacial zone is not the weakest link. With comparable modulus of elasticity for the LWA and the mortar, the stress will be more evenly distributed in LWAC than in NWC. Often, the LWA has even lower modulus of elasticity than the mortar phase, causing the mortar to attract more stress. The resulting local transverse tensile stress will act in the mortar, and not in the interface zone. As a matter of fact, in this case, the interface zone will partly be confined by transverse compressive stress (FIP, 1983). The strength and fracture toughness of LWA are substantially lower than those of normal weight aggregate (NWA) of natural origin, and possibly even the mortar phase. The crack initiation of LWAC takes place at a rather high stress level due to the elastic compatibility of the phases. The strength of LWA can be the strength limit of LWAC (Bremner and Holm, 1986; Chi and Huang, 2003).

Production of Lightweight Aggregates

Lightweight aggregate can be occurred naturally or produced by thermal treatment. For the aggregate occurred naturally, the aggregate is ready to be use only after the mechanical treatment which include crushing and sieving. Some industrial by-products, waste materials, naturally occurring materials, etc., thermal treatments are applied in order to make them as aggregate.

The properties of lightweight aggregate concrete depend on the properties of the aggregate used, which in turn depend on the type of the material and the producing process to produce these aggregates. In lightweight aggregate concrete, there is a vast variation in the density of the aggregate, thus, there will be a vast variation in the strength of the lightweight aggregate concrete.

Palm Oil Shells

Palm oil shells are one of the naturally occurring raw materials and obtained as a by-product when palm oil is extracted from the palm nuts. The palm oil tree, which the palm oil shell is extracted from, is a type of wet tropical tree, which found mostly around the equatorial zone. Palm oil shells are agriculture wastes which are renewable and occurring abundance in some countries, and begin interested in alternative to the traditional building materials particularly for low cost construction.

The agricultural waste as aggregates can be used as an alternative to conventional construction material in producing the lightweight aggregate concrete. These agricultural wastes are produced in a large quantity from the palm oil mills and can be used as aggregates in producing lightweight concrete. These agricultural wastes also can be used in production of cementitious materials, its fibers can be used in particle boards or sheets and its shell can be used as aggregates.

The material properties and structural performance of lightweight concrete made from palm oil shell are found to be similar with the lightweight concrete made from common aggregates such as clinker, foamed slag, and expanded clay. The palm oil shells are hard and crushed as a result of the process of extracting the oil. Sieving is needed in order to remove the fine particles. After sieving, the shells are air-dried before used in concrete mixing.

Pumice Aggregate

In many countries, although there is extensive usage area to use pumice in concrete industry in the world. In the world, the main usage areas of lightweight pumice concrete are:

- One story residential building
- Boundary wall where noise pollution is higher especially in airports
- Concert, theatre, disco, cinema hall

The main reasons to use lightweight pumice concrete are as follows:

Unit volume weight is usually 1/2 – 2/3 of normal weight concrete (reduction in dead load).Reduction in dead load causes gives serious advantages to the buildings, these are:

- Dispose in range of 13% - 17% in reinforcing steel
- Decrease in size of structural element sections such as beams, columns
- Dispose around 30 % in workmanship

Pumice aggregates combined with Portland cement and water produces a lightweight thermal and sound insulating, fire-resistant lightweight concrete for roof decks, lightweight floor fills, insulating structural floor decks, curtain wall system, either prefabricated or in situ, pumice aggregate masonry blocks and a variety of other permanent insulating applications. Moreover, the thermal conductivity of normal concrete is around 2 W/mK. This shows that lightweight pumice aggregate possesses higher thermal insulation capacity compared with normal weight concrete. It is clear that lightweight pumice concrete provides 4 to 6 times higher thermal insulation performance compared with normal concrete.

Increasing utilisation of lightweight materials in civil engineering structure applications is making pumice stone a very popular raw material as a lightweight rock. Due to having a good ability for making the different products based on its physical, chemical and mechanical properties, the pumice aggregate finds a large using area in civil industry as a construction material. In order to design an initial stage of a building project, the construction material properties should be well evaluated. Therefore, the need arises to analyse the materials to be used in construction experimentally in detail. This form the backbone of any material analysis models in engineering applications. Lightweight concrete is used in civil engineering field, as filler or for the manufacture of heat and sound insulation elements such as panels, masonries, partitions as well as load bearing structural elements.

It is a common use to apply lightweight concrete (LWC) for both structural and non-structural applications. As a structural material, it should have specific characteristics to meet the strength and performance requirements for the application. Thus, naturally, before recommending any material for a specific application (whether structural or non-structural) there is a need to study the mechanical characteristics to establish its suitability.

The Palm oil

Elaeis guineensis Jacq. Which is generally known as oil palm is an important species in the genus Elaeis which belongs to the Palmae family. The palm oil is an erect monoecious plant that produces both separate female and male inflorescences. This palm trees are cross-pollinated and the weevil act as the pollinating agent. The harvesting can be started after 24 to 30 months of planting and each palm can produce in the range of eight to fifth-teen fresh fruit bunches per year. Each fresh fruit bunches can contain about 1000 to 1300 fruitlet. Figure 1 shows the fresh fruit bunches of oil palm. Each fruitlet consists of a fibrous mesocarp layer and the endocarp which is the shell that contain the kernel.

Figure 1 Fresh fruit bunches

The common cultivars are the Dura, Tenera and Pisifera which are classified by the thickness of the endocarp or shell and the mesocarp content. Dura palms have an endocarp thickness of 2 8mm and a medium mesocarp content which consist the 35%-55% of fruit weight. The tenera race has an endocarp thickness of 0.5-3mm thick and high mesocarp content of 60%-95%. The pisifera palms do not have endocarp and have about 95% of mesocarp. Figure 2 shows the cross section of the palm oil fruit. Figure 3 shows the type of the palm oil fruits.

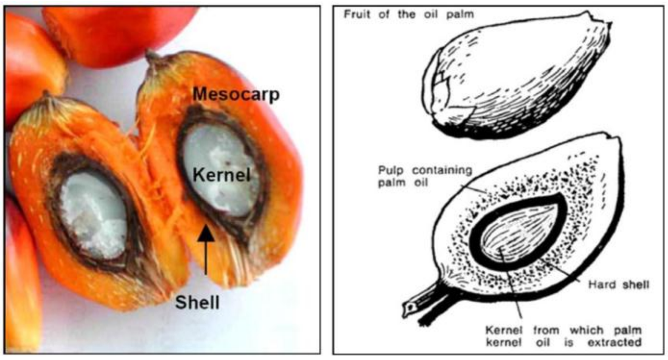

Figure 2. Cross-section of palm oil fruit

The palm oil produces two types of oils. The fibrous mesocarp produces the palm oil whereas the palm kernel produces the lauric oil. In the conventional milling process, the fresh fruit bunches are sterilized, then the fruitless are stripped off, then digested and pressed to extract the crude palm oil. The nuts separated from the fiber in the press cake and cracked to obtain the palm kernels. The palm kernel then crushed in another plant to obtain the crude palm kernel oil and a by-product, palm kernel cake which is used as animal feed. Palm oil has a balanced ratio of saturated and unsaturated fatty acids whereas the palm kernel oil has saturated fatty acids almost the same with the composition of coconut oil.

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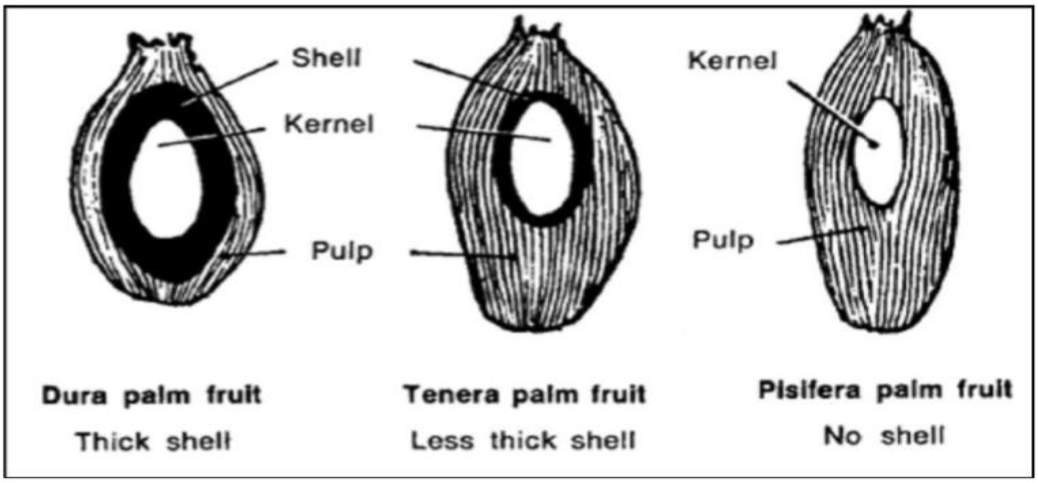

Figure 3 Types of palm oil fruit

The Pumice

Pumice is a volcanic origin natural material. As technical terminology pumice stone is known as a natural lightweight aggregate.

According to TS 3234 pumice defined as:

- Volcanic origin natural lightweight aggregate
- Contains up to 80% air voids
- Voids disconnected with each other
- Sponge looking
- Silicate essential - Unit weight usually less than 1gr/cm^3 - Specific gravity generally
- more than 2.1gr/cm^3
- Glassy texture
- Contains no crystal water

Pumice is formed by the release of gases during the solidification of lava. The cellular structure of pumice is created by the formation of bubbles or air voids when gases contained in the molten lava flowing from volcanoes become trapped on cooling. The cells are elongated and parallel to one another and are sometimes interconnected. Due to formation process pumice stones contains up to 80% air voids. Pumice possesses very high porosity and it is also named as volcanic rock glass.

Pumice contains up to 75 percent silicon dioxide (SiO_2) in chemical composition. As general the chemical composition of pumice as follows:

- 45% - 75% SiO_2
- 13% - 21% Al_2O_3
- 1% - 7% Fe_2O_3
- 1% - 11% CaO
- 7% - 9% Na_2O- K_2O volcanic rock glass.

SiO_2 composition in the rock causes to gain abrasiveness property. As for composition of Al_2O_3 causes to gain fire and heat resistance property of the rock. Consequently, pumice aggregate is a volcanic origin industrial raw material that used since long time before in many different international industrial sectors.

As it is well known, pumice is used as a raw material in many industrial sectors. Construction sector is the main sector in terms of usage of pumice as a raw material in the world. The main usage area of pumice is:

- Construction Sector
- Textile Sector
- Agricultural Sector
- Chemical Sector
- Other Industrial and Technological Areas

There is extensive usage area to use pumice in construction sector depending on characteristic properties of pumice. The reasons to be preferred of pumice to use as a raw material in construction sector are as follows:

- Low unit volume weight
- High thermal and sound insulation
- High resistance to fire
- High resistance to freeze-thaw effects
- High resistance to climatic effect
- Perfect acoustic property

Properties of Palm Oil Shells (POS)

Palm oil shells is a type of agricultural solid wastes and as being an organic material, it can be biodegradable and decay over a long period of time if the environment is full with moisture and sufficient air are present. Presently, the uses of palm oil shell are limited to the fuel for burning and as finishes in mud houses. The shells can provide several advantages if it was found to be structurally adequate. Such advantages include the low density of the shells which can reduce the self-weight of the material, good thermal insulation and good sound absorption.

Palm oil shells are dark grey to black in colour. The shell has two faces that are outer face and inner face. The outer face is from which the fibers and palm oil has been extracted, and this face can be smooth or rough depend on the extraction process. The inner faces are from which the kernel is extracted, and this face is relatively smooth.

The shells also have irregular shapes such as angular or polygonal, depending on the extraction process. Besides, the thickness of the shells is variable and can range from 0.15 to bout 3mm, depend on the species and the time of year. Sometimes, the oil coating can present on the surface of fresh palm oil shells, therefore, pre-treatment to remove this oil coating are necessary. The pre-treatment can be done via various ways, including natural weathering, boiling in water, and washing with detergent.

The shell has higher water absorption with a capacity of 23.3%. This high-water absorption may due to the high porosity in the shell. This shows that the shell need more water compared to the conventional aggregate to attain the same consistency. Since the shell has higher water absorption, the shells need to be pre-soaked in potable water for 24 hour to achieve saturated surface dry (SSD) condition before mixing. This is to prevent the absorption from occurring during the mixing.

The aggregate impact value (AIV) and the aggregate abrasion value of POS aggregates are having more lower value compared to the conventional crushed stone aggregate, which indicate that the POS aggregate have good absorbance to shock. The abrasion value of the shell determine from the Los Angeles abrasion test was 4.80%. This value was lower than the 24.0% obtained for the granite which is normal weight aggregate. The abrasion value of aggregate shows the wear resistance of aggregate. The lower value shows that the aggregate has higher wear resistance, hence, it shows that the POS aggregate have good resistance to wear compared to conventional aggregate. This property of the shell has been exploited by forefathers as floor finishes in mud house. Evidence shows that the floor is still existence to date, despite the structure has severely deteriorated for many years. Most of the house are not inhabited and not maintained, but the floor is still relatively in good condition.

The specific gravity of the shell was found to be 1.17. The specific gravity is depending on the specific gravity of the minerals of which the aggregate is composed and the voids. The shell has a bulk unit weight of 500-600 kg/m^3, thus, this place the POS within the range of the bulk density of lightweight aggregate. The bulk density of the lightweight aggregate can vary from 300 to 1100 kg/m^3. Hence, the palm oil shell can be classified as lightweight aggregate.

Properties of Lightweight Aggregate Concrete

The various types of lightweight aggregate available allow the density of concrete to range from a little over 300 up to 1850 kg/m^3, with a corresponding compressive strength ranging of 0.3 and 40 MPa and sometimes even higher. Compressive strengths up to 60 MPa can be obtained with very high cement content (560 kg/m^3).

The suitability of a lightweight concrete is governed by the desired properties: density, cost, strength, and thermal conductivity. The low thermal conductivity of lightweight aggregate concrete is clearly advantageous for applications requiring very good insulation, but the same property causes a higher temperature rise under mass-curing conditions, which is relevant to the possibility of early-age thermal cracking.

Other properties which have to be considered are workability, absorption, drying shrinkage, and moisture movement. For equal workability (easy of compaction), lightweight aggregate concrete registers a lower slump and a lower compacting factor than normal weight concrete because the work done by gravity is smaller in the case of the lighter material. A consequential danger is that, if a higher workability is used, there is a greater tendency to segregation.

The porous nature of lightweight aggregates means that they have high and rapid water absorption. Thus, if the aggregate is dry at the time of mixing, it will rapidly absorb water and the workability will quickly decrease.

Lightweight aggregate mixes tend to be harsh, but harshness can be reduced by air entrainment: water requirement is reduced and so is the tendency to bleeding and segregation. The usual total air contents by volume are: 4 to 8 per cent for 20 mm maximum size of aggregate, and 5 to 9 per cent for 10 mm maximum size of aggregate. Air contents in excess of these values lower the compressive strength by about 1 MPa for each additional percentage point of air.

The use of lightweight fines, as well as of lightweight coarse aggregate, aggregates the problem of low workability. It may, therefore, be preferable to use normal weight fines with ightweight coarse aggregate. Such concrete is referred to as semi lightweight (or sand lightweight) concrete, and of course, its density and thermal conductivity is higher than when all-lightweight aggregate is used. Typically, for the same workability, semi-lightweight concrete will require 12 to 14 per cent less mixing water than lightweight aggregate concrete. The modulus of elasticity of semi lightweight concrete is higher and its shrinkage is lower than when all-lightweight aggregate is used.

Some other properties of lightweight aggregate concretes as compared with normal weight concrete may be of interest:

- For the same strength, the modulus of elasticity is lower by 25 to 50 per cent; hence, deflections are greater.
- Resistance to freezing and thawing is greater because of the greater porosity of the lightweight aggregate, provided the aggregate is not saturated before mixing.
- Fire resistance is greater because lightweight aggregate have a lesser tendency to spall; the concrete also suffers a lower loss of strength with a rise in temperature.
- Lightweight concrete is easier to cut or to have fitments attached.
- For the same compressive strength, the shear strength is lower by 15 to 25 per cent and the bond strength is lower by 20 to 50 per cent.
- The tensile strain capacity is about 50 per cent greater than in normal weight concrete. Hence, the

ability to withstand restraint to movement, e.g. due to internal temperature gradients, is greater for lightweight concrete.

- For the same strength, creep of lightweight aggregate concrete is about the same as that of normal weight concrete.
- Thermal insulation value of lightweight concrete is about three to six times that of bricks and about ten times that of concrete. A 200-mm thick wall of aerated concrete of density 800 kg/m^3 has the same degree of insulation as a 400-mm thick brick wall of density 1600kg/m^3.
- Sound insulation value of lightweight concrete is higher compared with dense concrete.
- Lightweight products can be easily sawn, cut, drilled or nailed. This makes construction easier. Local repairs to the structure can also be attended to as and when require without affecting the rest of the structure.
- Due to lightweight, their use results in lesser consumption of steel. Composite floor construction using precast unreinforced lightweight concrete blocks and reinforced concrete grid beams (ribs) results in appreciable saving in the consumption of cement and steel, and thereby reduces the cost of construction of floors and roofs considerably. A saving of as much as 15 to 20 per cent in the cost of construction of floors and roofs may be achieved by using this type of construction compared to conventional construction.
- A better-quality control is exercised in the construction of structure with light-weight concrete products owing to use of factory made units.

Application Area of Lightweight Aggregate Concrete

Lightweight aggregate concrete (LWAC) has been used since the ancient periods. Apart from building construction, lightweight aggregate concrete has also been used in ship building, and for thermal insulation. Lightweight aggregates are used in horticulture. The low density of lightweight aggregate concrete made with pumice aggregates and palm oil shell results in a reduction in the weight of the structures and the foundations, and in considerable savings in thermal insulation. Lightweight concrete has been widely used in buildings as masonry blocks, wall panels, roof decks and precast concrete units. Reduction in weight by the use of lightweight aggregate concrete is preferred, especially for structures built in seismic zones. Lightweight concrete manufactured either from natural or from artificial aggregate, which is classified into three categories according to its strength and density. The first category is termed low strength, corresponding to low density and is mostly used for insulation purposes. The second category is moderate strength and is used for filling and block concrete. The third category is structural lightweight concrete and is used for reinforced concrete. As states, earlier one of the most important applications of lightweight aggregate concrete (LWAC) is its utilization as wall block units. The use of LWAC has been increasing and has better properties in terms of density and thermal insulation compared with traditional construction materials.

The thermal resistance of LWAC is up to six times that of normal weight concrete. In some designs, when the LWAC is used for exterior wall construction in place of the normal weight aggregate concrete, a substantial reduction in heating cost results. Normally for a 200- mm thick wall, the savings in heating cost in Fredericton, New Brunswick, Canada, over a period of two years, will cover the cost of the lightweight concrete masonry. Also, for a 100- mm brick wall with 25 mm cavity and 200 mm concrete masonry unit, the annual return on the original investment using domestic fuel oil in heating is 32 percent when a normal weight masonry unit is replaced with a lightweight one.

Use of LWAC instead of normal weight concrete (NWC), for example, as a floor salbe in a multi-story building, depends on the relative costs and the potential savings hat can occur by the use of a lighter material. LWAC is about 28 percent lighter than normal concrete and, in a design where the dead load is equal to the live load, a saving of 14 percent in energy intensive steel reinforcement can result. Equal or greater savings are achieved in columns and footings. For long-span bridges, the live load are a minor part of the total load and a reduction in density is translated into reductions is not only mass, but also in section zone. The lower mass and density are extremely important in seismic areas where a reduction in the initial effects of the dead load may mean the difference between section survival and section failure.

Previous Studies on Palm Oil Shells and Pumice Aggregate Concrete

A brief review on LWAC materials related to the present strength properties from the available studies are presented below:

Study-1

As per Bryan, Dennis S.P (1989) Natural lightweight aggregates (NLWA) may be defined as inherently low density and natural mineral materials. In construction trade, the main control is on weight reduction because it equates to cost savings. NLWA products are used because of its lower density which contain lightweight Portland cement concrete and lightweight concrete masonry units. In addition to this based on location also some of the natural lightweight aggregates are taking part with normal weight constructions aggregates for uses like road base and common backfill material.

Study-2

Mannan and Ganapathy led a test on the mix design of the LWC with POS aggregates. They determined that the procedures for mix design of POS concrete differ broadly from those of the normal concrete, with crushed stone aggregates. It was also disclosed that the mix design depends on the properties of the aggregates.

Study-3

Owens, P.L (1993) had declared that since from long period the lightweight concrete was used for structural purposes. According to his study, the LWAC is a material with low bulk density and often made with sphere-shaped aggregates. The density of structural LWAC is ranges from 1400 kg/m^3 to 2000 kg/m^3 compared with that of NWAC about 2400 kg/m^3.

Study-4

Hossain (2004) studied the porous nature of the POS aggregate, low bulk density and high water absorption. The low bulk density is advantageous, as the resulting hardened concrete was found to be lighter compared to the conventional granite concrete. This reduces the overall dead load on the structure, which comes with a significant amount of savings on the total construction cost. In addition, the lightweight nature of the resulting concrete plays a crucial role in countries where the occurrence of an earthquake is inevitable, as the catastrophic inertia forces that influence the structures can also be ultimately reduced, as these forces are proportional to the weight of the structure. In general, most lightweight aggregates have higher water absorption values compared to that of the conventional aggregate. Although, POS has a high-water absorption value, even higher water absorption values were recorded for pumice aggregates, which have a value of about 37%.

CONCLUSION:

The concrete with crushed palm oil shell and pumice (LWA) as CA will have lesser compressive and flexural strength of LWA associated with the NWC. The concrete beam with LWA as aggregates almost shows similar flexural behaviour as the NWC beam. But, the load carrying capacity was lesser related with the NWC beam. Additionally, widespread cracks were created for the LWA (i.e., POS & Pumice) concrete beams related to the NWC beam. The cracks provide adequate cautions for the beam beforehand when failure happened.

Pumice as coarse aggregates can be used to reduce the member self-weight, which can reduce the cost for bigger dimension for beam and column required, the quantity of the reinforcement bar required and the bearing capacity of the foundations. Besides, it can save the gravel aggregates usage and hence decrease the depletion rate of the gravel aggregates.

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