

## **LIGHTWEIGHT CONCRETE MATERIAL AND** **METHOD OF FABRICATING THE SAME**

This application is a divisional application of Singapore Patent Application No.  
5 2012062980 "STRUCTURAL LIGHTWEIGHT CONCRETE AND THE METHOD  
OF FABRICATION THEREOF" filed on 24.08.2012

### **Field of the Invention**

The present invention relates generally to concrete and more specifically to  
10 structural lightweight concrete material and a method for making a lightweight  
concrete for buildings.

### **Background of the Invention**

Concrete is versatile building material comprising cement, aggregate, and water  
15 and it is prepared in aqueous slurry and is then allowed to cure in a mold of  
desired shape and size. After hydration process, cement binds the aggregate in  
a hardened matrix having considerable compressive strength.

There are many building applications where relatively low density concrete or  
20 lightweight concrete is a suitable material. Lightweight concrete has the  
advantage and favourable thermal/acoustic insulation properties.

Generally there are two ways to achieve a low density concrete. The first way is  
to use a low density natural aggregate such as pumice or other lightweight rock.  
25 However, the use of lightweight aggregate material is not always feasible, since  
it is generally unavailable in many locations where lightweight concrete may be  
required. The second way of making low density concrete is to add foam to the  
concrete mix. The foam introduces small air bubbles into the slurry so that when  
the concrete cures, the air bubbles remain trapped therein, thus providing a so-  
30 called "cellular concrete" having a decreased overall density.

US Patent No. 4351670 discloses a method of making lightweight, substantially non-shrinking concrete comprising the steps of: (a) providing a body of cured cellular concrete material, said cellular concrete material being of a type whose curing is accompanied by substantial shrinkage; (b) breaking said body of cured  
5 cellular concrete material into fragments; (c) coating said fragments with a first cementitious material and allowing said cementitious material to cure; and (d) mixing said fragments, thus coated, with a second cementitious material for ultimate curing as a finished product, said second cementitious material being of a type whose curing is accompanied by minimal shrinkage. The lightweight,  
10 non-shrinking concrete material comprises: cementitious slurry of a type whose curing is accompanied by minimal shrinkage; and fabricated aggregate, each of the individual particles of which comprises a core of cured cellular concrete of a type whose curing is accompanied by substantial shrinkage and a coating of cured cement.

15 US Patent No. 4235640 discloses a method of treating scoria aggregate to reduce its absorption rate to make the scoria aggregate more suited as an aggregate for lightweight concrete, said method comprising: providing a slow or medium-setting asphalt emulsion; diluting the slow or medium-setting asphalt  
20 emulsion with water to provide a dilute asphalt emulsion; mixing aggregate consisting essentially of scoria aggregate with the dilute asphalt emulsion to impregnate the individual particles of the scoria aggregate with the dilute asphalt emulsion; and drying the scoria aggregate.

25 US Patent No. 4398958 discloses a method of making lightweight concrete comprising the steps of coating expanded polystyrene beads with an aqueous surfactant solution containing both a substantive cationic surfactant and a non-ionic surfactant, coating the wet beads with dry cement, and then mixing the cement-coated beads with a further supply of cement, water and sand or  
30 aggregate to complete the concrete mix.

US Patent No. 6488762 discloses a cellular concrete mixture comprising, by weight percent: (a) about 3% to 70% cement; (b) about 3% to 70% ground glass as a first cement substitute, wherein the ground glass is selected from the group consisting of mixed waste glass, flat glass, window glass, and mixtures thereof;  
5 (c) 0 to 60% of a second cement substitute; (d) a lime-containing material; (e) a gas-forming agent or foaming agent; and (f) at least 20% water.

US Patent No. 6616752 discloses a light weight aggregate for a casting compound that is bonded with a binder, comprising: a plurality of foam glass  
10 lumps of crushed foam glass, the foam glass lumps exhibiting a screen-analysis curve that is graded between 0 and a largest grain size with at least 3 fractions.

US Patent No. 6,676,862 discloses a method of forming a lightweight concrete building unit, comprising: providing a first mold having a plurality of side walls  
15 defining at least one mold cavity; forming a batch of cementitious slurry by mixing at least one dry cementitious ingredient, water and a temperature sensitive foaming agent for producing air cells in the cementitious slurry, wherein the foaming agent has a critical temperature at which the foaming agent destabilizes, wherein the cementitious slurry is formed at a temperature  
20 below the critical temperature; heating the sidewalls of the first mold to at least the critical temperature; dispensing said batch of cementitious slurry into said at least one mold cavity; and compressing said cementitious slurry from a first position to a substantially precise second position within said first mold, wherein the heat from the mold enables the slurry to form into a building unit and the  
25 heat causes air cells in the building unit to collapse to yield a closed cell surface and a dense outer layer around a less dense, lightweight inner core, wherein compressing said cementitious slurry assists in further collapsing air cells to increase the density of the outer layer.

30 The present invention relates to structural lightweight concrete being made by using expanded shale/clay coarse aggregate which is advantageous as compared to conventional type of material and method, the concrete thus

fabricated having substantially uniform dimensions and relatively consistent densities.

### **Summary of the Invention**

- 5 The present invention provides a method of making lightweight concrete comprising the steps of: (a) pre-wetting lightweight coarse aggregates by sprinkling water thereon; (b) charging coarse aggregates, sand and silica fume into a mixer; (c) adding Portland cement and water to the mixture obtained in step (b) above, and (d) mixing the above mixture for 40-50 seconds to obtain a  
10 homogeneous mixture.

A main object of the present invention is to provide a lightweight concrete material comprising: coarse aggregates having cellular segmented pore structure with solid volume ranging from 40-70%; cementitious material varying  
15 between 500-650 kg/m<sup>3</sup> and densified silica fume varying between 50 and 60 kg/m<sup>3</sup>; water and binder ratio being maintained around 0.30-0.40; and a SNF based superplasticizer being added in an amount of 1200-1400ml/100 kg cementitious material to achieve the desired consistency of the concrete.

- 20 Still a further object of the present invention is to provide a lightweight concrete and the method of fabrication thereof, wherein the average impact value of the coarse aggregates varies from 16-37%.

Yet a further object of the present invention is to provide a lightweight concrete  
25 and the method of fabrication thereof, wherein the amount of coarse aggregate in the mixture varies from 250 to 350 kg per cubic meter of concrete.

Yet a further object of the present invention is to provide a lightweight concrete and the method of fabrication thereof, wherein the natural sand varies between  
30 650-700 kg/m<sup>3</sup>.

Still another object of the present invention is to provide a lightweight concrete and the method of fabrication thereof, wherein the cementitious content has densified silica fume ranging between 50 and 60 kg/m<sup>3</sup>.

- 5 Yet another a further object of the present invention is to provide a lightweight concrete and the method of fabrication thereof, wherein the cementitious material is Portland cement varying above 500-650 kg/m<sup>3</sup>.

For a further understanding of the nature and advantages of the present invention, reference should be made to the remaining portions of the specification and drawing.

#### **Brief Description of the Drawings**

FIG. 1 is a block diagram showing the main operations involved in making structural lightweight concrete according to the present invention;

#### **Detailed Description of the Invention**

FIG. 1 is a block diagram showing the fabrication process to obtain lightweight concrete in accordance with the present invention. Block 200 shows the pre-wetting step of lightweight coarse aggregates, Sprinkling water is used and are brought to saturated surface dry condition (SSD) condition at the time of batching to obtain pre-wetted coarse aggregates,. Next, as shown in block 300, the coarse aggregates, sand and silica fume are first discharged into a mixer so as to obtain a homogeneous mixture. The mixed composition then is mixed with Portland cement and water, and the admixtures are added to the mix through the last portion of the mix water, as shown in block 400. The admixtures are then proceeded to mixing step for 40-60 second, shown in block 500. The product obtained in step shown in block 500 is proceeded to hydration.

In accordance with the preferred embodiment of the present invention, the structural lightweight concrete was fabricated by employing expanded shale/clay coarse aggregate. The characteristics of the coarse aggregate are of

5-15 mm size or 10-23 mm size, with 1.30 or 0.6 specific gravity. The average impact value, (AIV) of the coarse aggregate varies from 16-37%, depending on the physical condition of the aggregate (SSD/oven dry). The aggregates have cellular segmented pore structure with solid volume varying between 40 and 70%. In the lightweight concrete of the present invention, the amount of coarse aggregate varies from 250 to 350 kg per cubic meter of concrete with the balance consisting of natural sand, with the characteristics of 2.6 specific gravity, and 2.6-2.9 of finess modulus, and varies between 650 and 700 kg/m<sup>3</sup>. There were small quantity of washed copper slag was added as a replacement to sand to the mix, and the additional of the washed copper slag decreases the thermal conductivity but increases the unit weight/oven day density of the concrete. In the preferred embodiment of the present invention, the principal cementitious material is Portland cement (conforming to 52.5 N Grade) varying between 500 and 650 kg/m<sup>3</sup>. The cementitious content has densified Silica Fume varying between 50 and 60 kg/m<sup>3</sup>. The water to binder ratio was maintained around 0.30 to 0.40 to achieve an initial slump of 100 +/- 20 mm. A Sulphated Napthalene Formaldehyde, SNF based superplasticizer was added and the amount added was ranging from 1200- 1400 ml per 100 kg cementitious material in order to achieve the desired consistency of the lightweight concrete. In the present invention, an air entraining agent is also added in an amount of 300 ml per 100 kg cementitious materials to achieve an air content of 8-10%. The compressive strength of the lightweight concrete increases with decreases of air content in the composition.

### **Example 1**

In the present preferred embodiment, the lightweight coarse aggregates were pre-wetted before batching by sprinkling water and were brought to SSD condition at the time of batching. The coarse aggregates, sand and silica fumes were first discharged into the mixer and mixed followed by Portland cement, Silica Fume and water. The admixtures were added to the mix through the last portion of the mix water. The total mixing time varied between 40 to 60 seconds.

The lightweight concrete thus obtained has 28-day mean cube strengths between 38 and 53 MPa. The characteristic strengths with a margin of 8 MPa are 30 MPa to 45 MPa. The unit weight of the concrete is less than 2000 kg/m<sup>3</sup>. On drying the cube in the oven the density will drop by 4-8% from the wet density. The thermal conductivity (k) of the concrete is between 0.5 and 1.2 W/m deg K. The thermal conductivity increases with increasing evaporable water in the concrete. The coefficient of the thermal expansion (alpha) varies from 7-11 x 10<sup>-6</sup> mm/mm/deg C. The Static Modulus of Elasticity varies from 18 to 25 GPa depending on the 28-day mean cube strengths. The 28-day drying shrinkage is less than 400 microstrains.

The fabricated lightweight concrete in accordance with the present invention is advantageous over conventional concrete such as reduction in dead loads/foundation loads as it has smaller footings, fewer piles, smaller piles caps and less reinforcement steel. The concrete of the present invention has smaller support members such as decks, beams, girders, and reduce inertial seismic loads.

Other features of lightweight concrete thus fabricated include lower drying shrinkage, this is due to the reason that the concrete is of cellular pore structure, the water in the aggregate eases drying shrinkage of the concrete. In addition, as a result of good elastic compatibility between aggregate and the matrix there are less chances of micro cracking in the ITZ, leading to lower permeability and enhanced durability when the concrete is exposed to aggressive environment. In accordance with the present invention, the aggregate also makes the ITZ stronger due to Pozzolanic action provided by silica rich lightweight aggregates. The cellular pore structure also supports internal moist curing of the concrete.

The non-construction based application of the lightweight concrete includes application on marine vessels, as a top up layer on floors with minimum reduction in draft for free movement in shallow shipping channels. It can also be applied on floating docks/platform, for laying floor as the lightweight concrete,

which does not affect the reserve buoyancy of the floating structure. The concrete can also be used for casting floating concrete elements, which is used for urban greenery projects or the installation of solar panels on water bodies.

- 5 In summary it can be seen that the present invention provides an improved structural lightweight concrete product and method.

While the above provides a full and complete disclosure of the preferred embodiment of the invention, various modifications, alternate constructions, and  
10 equivalents may be employed without departing from the true spirit and scope of the invention. For example, the proportions of materials disclosed are representative, but particular applications may require departure therefrom. Moreover, while all the material at each stage of the process (except for by-product) is shown as being used in subsequent stages, it should be understood  
15 that various amounts of material of different sizes could be diverted for fill and other uses rather than as part of the low density concrete mix. Therefore, the above description and illustrations should not be construed as limiting the scope of the invention, which is defined by the appended claims.

## Claims

1. A method of making lightweight concrete comprising the steps of:
  - a. pre-wetting lightweight coarse aggregates by sprinkling water thereon;
  - 5        b. charging coarse aggregates, sand and silica fume into a mixer;
  - c. adding Portland cement and water to the mixture obtained in step (b) above;
  - d. mixing the above mixture for 40-50 seconds to obtain homogeneous mixture; and
  - 10       e. adding the concrete admixture in step (d) along with the last portion of water.
2. The method of making a lightweight concrete set forth in Claim 1, further comprising the step of :
  - 15        a. adding an air entraining agent in an amount of 300ml/100 kg cementitious materials to obtain an air content of 8-10%.
3. The method of claim 1, wherein the average impact value of the coarse aggregates varies from 16-37%.
- 20       4. The method of Claim 1, wherein the amount of coarse aggregate in the mixture varies from 250 to 350 kg per cubic meter of concrete.
5. The method of Claim 1, wherein the natural sand varies between 650-700 kg/m<sup>3</sup>.
- 25       6. The method of Claim 1, wherein the main cementitious material is Portland cement which from varies 500-650 kg/m<sup>3</sup>.
- 30       7. The method of Claim 1, wherein the cementitious content has densified silica fume ranging between 50 and 60 kg/m<sup>3</sup>.

8. A lightweight concrete material comprising:

- a. coarse aggregates having cellular segmented pore structure with solid volume ranging from 40-70%;
- b. Portland cement varying between 500-650 kg/m<sup>3</sup> and undensified silica fume varying between 50 and 60 kg/m<sup>3</sup>;
- c. water to binder ratio being maintained around 0.30-0.40; and a SNF based superplasticizer being added in an amount of 1200-1400ml/100 kg cementitious material to achieve the desired consistency of the concrete.

9. The lightweight concrete material of Claim 8, further comprising an air entraining agent in an amount of 300ml/100 kg cementitious materials to obtain an air content of 8-10%.

10. The lightweight concrete material of Claim 8, wherein the average impact value of the coarse aggregates varies from 16-37%.

11. The lightweight concrete material of Claim 8, wherein the amount of coarse aggregate in the mixture varies from 250 to 350 kg per cubic meter of concrete.

12. The lightweight concrete material of Claim 8, wherein the natural sand in the concrete varies between 650-700 kg/m<sup>3</sup>.

13. The lightweight concrete of Claim 8, wherein the main cementitious material being Portland cement varies above 500-650 kg/m<sup>3</sup>.

14. The lightweight concrete of Claim 8, wherein the cementitious content has densified silica fume ranging between 50 and 60 kg/m<sup>3</sup>.