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Bangladesh J. Sci. Ind. Res. **53(3)**, 225-232, 2018

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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Light weight concrete from rice husk ash and glass powder

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Received: 06 November 2017
Revised: 06 December 2017
Accepted: 06 December 2017

DOI: http://dx.doi.org/10.3329/bjsir.v53i3.38270

Abstract

Light weight concrete (LWC) found very similar properties and constructability with respect to normal concrete (NC). LWC was prepared using red clay (RC), sodium lauryl sulphate (SLS) and borax with the addition of waste materials like rice husk ash (RHA) and glass powder (GP) in aggregate composition. The compressive strength of NC and LWC found almost similar for seven, fourteen and twenty eight days with the inclusion of RHA and GP as the partial replacement of light weight aggregate in composition. Apparent porosity (AP) of LWC found slightly higher than the NC but the bulk density (BD) is about 13% lower than the NC. SLS (10% of water solution) was used as foaming agent. Borax (10% of water solution) might effect on hydration rate and temperature. The partial incorporation of GP and RHA in LWC lessen the thermal conductivity as compared to NC.

Keywords: Light weight concrete; Normal concrete; Rice husk ash; Glass powder; SLS; Borax; Compressive strength; Dead load

Introduction

Lightweight concrete can be prepared either by injecting air in its composition or it can be achieved by considering the sizes of the aggregate or even replacing them by a hollow, cellular or porous aggregate.Particularly, lightweight concrete can be categorized into three groups such as no-fines concrete, lightweight aggregate concrete and aerated/foamed concrete.Normal and waste materials (glass powder, rice husk ash) are used to make these specially designed concretes. Lightweight concrete is a type of expanding agent containing concrete with low density and low thermal conductivity. Its advantages are the reduction of dead load, lower handling cost and ultimately faster building rates in construction. These lightweight aggregates will range from the extremely light materials used for insulative and non-structural concrete all the way to expanded clays and shale used for structural concrete. Since the lightness of these aggregates derives from the air trapped in each individual particle, the more air that is trapped per particle unit, the lighter is the weight and the better the insulation but, conversely, the lower the strength. The accompanying concrete shows the relative weights and differing applications of the various lightweight aggregates now in use. Light weight aggregate was prepared using rice husk ash (RHA), glass powder (GP), red clay (RC) instead of normal aggregate. Sodium lauryl sulphate (SLS) in water generates foam that could make the concrete lighter. Different compositions of concrete materials were used. SLS and borax with RHA, GP, RC were used to compare with the light weight aggregate and aggregate of normal concrete composition. High performance concrete (HPC) was fabricated using special materials like Rice Husk Ash (Islam *et al.,* 2012). RHA consists of non-crystalline silicon dioxide with high surface area and high pozzolanic (siliceous and aluminous) activity. Better compressive strength was observed for partial replacement of cement with 5 to 10% rice husk ash and 1% alum and nitrate that is comparable to Ordinary Portland Cement (OPC). It was used to improve the properties of normal concrete to HPC.

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Enormous potentiality for industrial application of RHA especially, as a super reactive pozzolanic activity in cement and concrete production was observed.

The glass that has been used in our investigations–contains approximately14% of Na_2O and K_2O. In the glass structure the ions of these metals have considerably less binding energy as compared to covalent bond of Si-O in the structural fragment of $Si\text{-}O\text{-}Na^+$ or $Si\text{-}O\text{-}K^+$. In water solution Na^+ and K^+ ions are easily diffused from glass to the solution and form sodium and potassium hydroxides in the solution, correspondingly. They are displaced by H^+ ions from water and thus hydrate the surfaces of glass grains. Separate glass powder in water under normal conditions has alkalinity in the range from 0.15 (colorless glass) to 0.55 (green glass) ml of 0.1N HCl. Thus, the total alkalinity has to increase, however alkalinity of cement mixture with glass additives is 35-40 % less. In our view, it is connected with high content of SiO_2 in the glass (near 70 %), which results in the formation of calcium hydro silicate (CSH)(Chidiac and Federico, 2007), as shown in chemical reaction:

$$2(3CaO.SiO_2) + 6H_2O = 3\,CaO.2SiO_2.3H_2O + 3Ca\,(OH)_2$$

(Tricalcium Silicate) (Calcium Silicate Hydrate, CSH) (Calcium Hydroxide)

$$3Ca\,(OH)_2 + SiO_2 + (n\text{-}1)\,H_2O = CaO.SiO_2.nH_2O$$

(Calcium hydroxide) (Glass) (Calcium Silicate Hydrate)

In presence of water, the RHA actively reacts with Ca $(OH)_2$ liberated during cement hydration (pozzolanic reaction) and produces additional calcium silicate hydrate (CSH) (Sata *et al*, 2007 and Yu *et al*, 1999). The development of more C-S-H gel in concrete with RHA may progress the concrete properties due to the reaction among RHA and calcium hydroxide in hydrating cement.

Pozzolanic reaction: $Ca\,(OH)_2 + RHA\,(SiO_2) + H_2O \rightarrow CSH$

The pozzolanic reaction product fills the pores existing in between cement grains and results in dense calcium silicate hydrate.

Ramli and Dawood, (2010) reported the enhancement of the compressive and flexural strength for the incorporation of palm fiberin the light weight crushed brick concrete and these mechanical strength was highest for the insertion about 0.8% of volume fraction of palm fiber. Titarmare *et al.,* (2012) studied on the mixed concrete by partial replacement of cement, with the pozzolanic material like fly ash, fixed water cement ratio 0.39 and 1.2% superplasticizer and reported better strength, workability, durability and economical than conventional concrete. Ikponmwosa *et al.,* (2014) investigated on the flexural performance of foamed aerated concrete beams with bamboo splint as tensile reinforcement and reported that specimens with compression reinforcement in the compression zone displayed a better flexural performance than specimens without compression reinforcement in the compression zone. Alam *et al.,* (2013) evaluated the performance of Styrofoam in concrete as lightweight aggregate by focusing on its ability to reduce dead load without significant reduction in compressive strength. Ewadh and Basri (2012) studied to determine maximum usage of polystyrene bead from solid waste as aggregate replacement material in concrete and observed increased work ability of the concrete mixtures with the increasing of polystyrene.

Burning of the Rice husk under controlled temperature below 873K can produce ash with silica mainly in amorphous form (Chandrasekhar *et al.*, 2003). RHA has been used in lime-pozzolanic mixes and could be a suitable partly replacement for Portland cement (Sata *et al.*, 2007). Rao *et al.,* (2013) studied on the steel fiber reinforced concrete and reported the increase of compressive strength with the fiber content. The optimum value of fiber content was 1.5%.

Purushothaman and Mani, (2014) studied about recycled aggregate obtained from crushed concrete rubble can be reused in building industry. The laboratory investigation on various physical properties of concrete shows encouraging result to use 100% recycled aggregate concrete with quarry dust compared to 100% natural aggregate concrete.

Many researchers have investigated the fabrication of light weight concrete, but there is still a growing demand to find higher compressive strength and lighter concrete than the conventional one. There is no well explained experimental result with high compressive strength and light weight concrete using RHA, waste GP in composition as the replacement of normal aggregates with the inclusion of SLS and borax in concrete. Borax of 10% wt./vol. of water solution was used in the present experiment. Yang and Qian (2010) reported that borax could adjust pH value of the mixing solution. It effects on hydration rate and temperature. Borax content reduces the setting time. Sodium lauryl sulphate10% wt./vol. of water solution was used as foaming agent. Therefore, inclusion of rice husk ash, glass powder, borax solution and sodium lauryl sulphate solution in concrete composition could be an interesting approach.

Materials and methods

Chemical analysis of OPC, RHA, RC and GP

Different types of materials such as silica, lime, alumina and ferric oxide, magnesia with small amount of the oxides of alkali metals were observed. Loss on ignition, total silica, sesquioxides (Fe_2O_3+Al_2O_3), lime (CaO), magnesia, ferric oxide (RIC method), sodium oxide and potassium oxide were obtained by laboratory analysis and are illustrated in Table I. Analysis was done by fusing with sodium carbonate (ASTM, 1995).

Table I. Chemical analysis of OPC and RHA, RC and GP

Name of component	LOI %	IR %	CaO %	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	MgO %	SO_3 %	Na_2O %	K_2O %
OPC	0.61	0.43	65.08	20.09	3.14	6.86	1.75	1.97	0.24	0.15
RHA	3.68	---	1.61	88.35	0.34	0.45	0.31	---	1.45	1.53
RC	0.71	---	1.99	66.01	21.69	10.01	0.66	---	0.31	0.14
GP	2.01	---	19.03	62.98	6.25	4.31	0.20	---	3.53	2.14

LOI: Loss on ignition, IR: Insoluble residue

Specific surface area determination by Blain air permeability

Surface area for different materials was measure by Blain Air Permeability method (Paykov *et al.*, 2013) and the specific surface values (S) in m^2/kg are plotted in Table II.

Setting time

The setting time of cement was determined by mixing 100 mL of water with 400g of cement, the resulting paste would lose its plasticity and form into a hard rock. One or two hours after the mixing of cement and water, the paste would lose its fluidity and gain stiffness. Setting could be divided into two stages which is the initial set and the final set. The initial setting time is not less than 45 minutes after water is poured into the mix and the final setting time occurs not more than 10 hours (ASTM, 1995). During the final setting time, hydration process still occurs inside the core of the concrete. To ensure that the cement is constantly hydrated, curing should be done.

Particle size distribution (OPC, RHA, sand, coarse, GP)

Particle size distribution of materials (OPC, RHA, sand, coarse, GP) for light weight concrete is very important. Compressive strength can vary for materials of different size and composition such as generally big coarse is suitable for LWC. For determining the particle size (OPC, RHA, sand, GP), different kinds of mesh (20, 30, 50, 100, 140, 170, 200, 325 μm mesh) were used. For coarse particle size, 4.75, 8, 25 mm (diameter) sieves were used.

Preparation of LWCs composition

The ratio of cement (OPC): sand: coarse was 1:2:3 for the composition of LWC. RHA, RC, GP were mixed with water to prepare light weight aggregate.At first control composition was made with OPC, sand, coarse and normal water. Manual mixing process was done in this experiment. Whenever finished the mixing then the mixing materials were put into a

Table II. Surface area and Specific gravity of OPC, RHA, RC and GP

Name	Surface area (m^2/kg)	Specific gravity
OPC	359.323	4.26
RHA	378.481	2.13
RC	385.032	2.63
GP	401.325	2.75

mold (3") and started tempering. After that vibrations were done for the uniform composition by a vibrator. Finally, blocks were taken into the desiccators after initial setting for one night.

Curing

Proper curing of concrete is one of the most important requirements for optimum performance in any environment or application. Poor curing practices adversely affect the desirable properties of light weight concrete, just as they do any concrete. The surface zone will be seriously weakened by increased permeability due to poor curing. The importance of adequate curing is very evident in its effect on the permeability of the skin (surface) of the concrete. Therefore, after the mixing of LWC composition, the cubes were taken from desiccators for 7, 14 and 28 days curing.

Determination of compressive strength

After the curing period, blocks were taken into hydraulic press for the determination of compressive strength. For the determination of compressive strength, the blocks are placed into the hydraulic press and apply pressure. The compressive strength of the blocks is determined in psi unit.

Table III. Particle size distribution of OPC, RHA, GP and sand

Seive Number (Identity)	Seive Opening in (mm)	OPC (g)	RHA (g)	Sand (g)	GP (g)
20	0.841	0	0	0	0
30	0.60	0	0	0	0
50	0.297	0	1 (0.94%)	69.95 (47.35%)	0
100	0.149	0	6 (5.67%)	65.10 (44.07%)	0
140	0.105	0.65 (0.62%)	7.02 (6.63%)	7.97 (5.39%)	71.01 (67.01%)
170	0.088	2.50 (2.41%)	9.12 (8.62%)	3.01 (2.03%)	15.85 (14.95%)
200	0.074	1.85 (1.78%)	8.23 (7.78%)	0.69 (0.47%)	16.25 (15.33%)
325	0.045	13.75 (13.22%)	50.12 (47.37%)	0.99 (0.67%)	2.01 (1.90%)
-325 (Finer than 325)	-0.044 (smaller than 0.044)	82.96 (79.77%)	24.31 (22.98%)	0	0.84 (0.79%)

Determination of bulk density (BD) and apparent porosity (AP)

Bulk density (BD) and apparent porosity (AP) were measured by the previously published procedure(USDA, 2013). For the determination of bulk density and apparent porosity, at first small pieces of blocks (used in the compressive strength) were taken and dried them at 110 °C in oven. Dried, soaked and suspended weights were taken for small pieces of block and finally calculate the bulk density (BD) and apparent porosity (AP).

Results and discussion

Particle size, fineness

OPC, RHA, Sand and GP coarse were taken for measurement of particle size distribution and found different particle size of OPC, RHA, sand and GP coarse which are shown in Table III. Most of the cement particles are smaller in size (mesh). Experimental data shows that approximately 79.77% of the cement particles are smaller than 0.044 mm. The particle size distribution is also related to the fineness of cement. The greater the amount of smaller cement particles, the higher is the cement fineness. Smaller particle sizes increase the rate of cement hydration, and thus accelerate the strength development in concrete. About 23 % of the RHA particles are smaller than 0.044mm and 47 % are smaller than 0.074mm. The lower particle size of RHA contributes to reduce the bleeding in concrete. A lower particle size increases the density of the paste, and thus lessens the bleeding in concrete by obstructing the movement of rising water. Around 67 % of the GP particles are smaller than 0.149mm and 15 % are smaller than 0.088mm. The lower particle size of GP also improves the particle packing in binder paste.

Setting time

The initial and final setting times of control (OPC) were 58 min and 106min, respectively. The initial and final setting time was increased for the both composition of OPC, RHA and GP due to additional pozzolanic materials.

Water to cement ratio

Light weight concrete shall have a water-cementations material with water to cement ratio is less than or equal to 0.45 (Islam *et al.,* 2012). Water to cement ratio is directly related to the mechanical and physical properties and the durability. The lower water-cement ratio ensures the higher concrete strength and durability. Light weight concrete with high water to cement ratio would have insufficient hydration products to block the capillary pores and is therefore porous and permeable. In our experiment, the water to cement was greater than 0.45.

Weight of LWC and normal concrete (NC)

Weight was measured using normal aggregate concrete and light weight aggregate (RHA, RC and GP) concrete for 7, 14 and 28 days. Light weight concrete was 13% lighter than the normal concrete shown in Fig. 1.

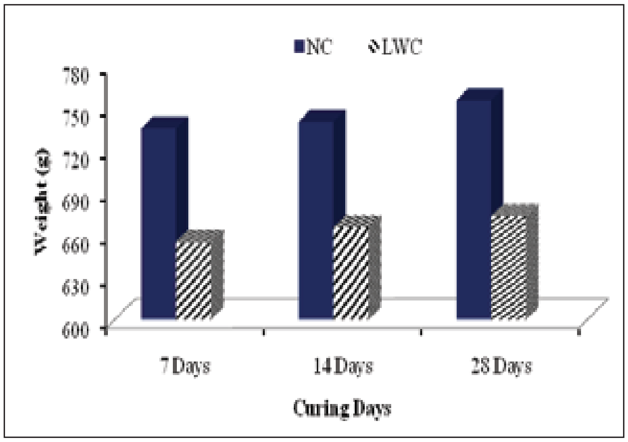

Fig. 1. Weight of normal concrete (NC) and light weight concrete (LWC) for 7, 14 and 28 days

Water absorption (WA) and density

Water absorption and density of normal aggregate concrete and light weight aggregate (RHA, RC and GP) concrete were measured and represented in Fig. 2. Water absorption of both types of aggregates were found almost similar but the density of light weight concrete found about 13% lower than the normal concrete.

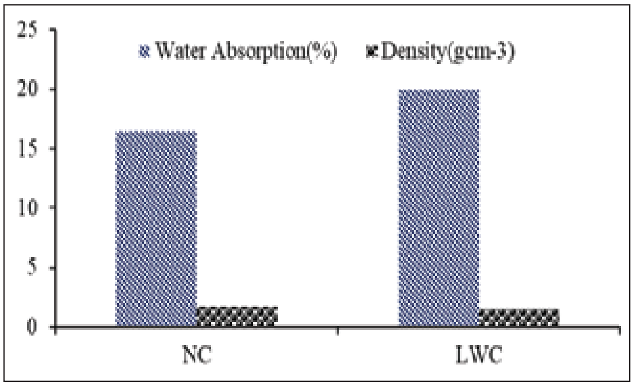

Fig. 2. Water absorption and density of normal concrete (NC) and light weight concrete (LWC)

Compressive strength (CS) with different curing time

The compressive strength of normal concrete (NC) and light weight concrete (LWC) were measured after 7, 14 and 28 days. The observed data are plotted in Fig. 3.

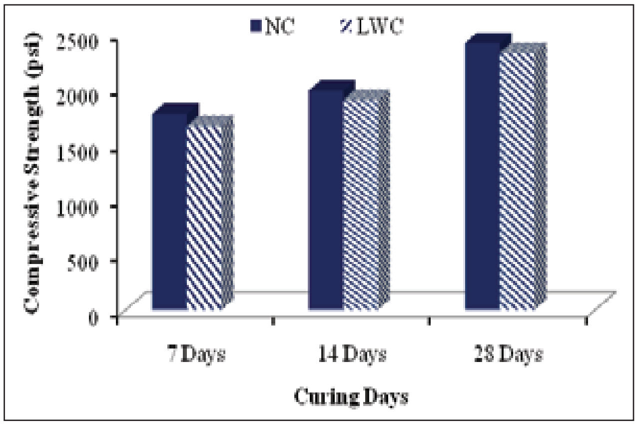

Fig. 3. Compressive strength of normal concrete (NC) and light weight concrete (LWC) for 7, 14 and 28 days

After 7 days curing, LWC possess averagely 6% less compressive strength than NC and this difference decreases to 3% after 14 and 28 days. Therefore, it can be said that GP and RHA component in LWC may lessen the weight of concrete retaining the similar pozzolanic activity as in NC. Consequently, the compressive strength of NC and LWC were almost comparable.

Comparisons of BD, AP with CS of NC & WC

The variation of BD and AP with CS of normal concrete (NC) and light weight concrete (LWC) were studied after 7, 14 and 28 days. The observations are graphically expressed in the Fig. 4. The compressive strength of normal concrete and light weight concrete found almost similar for 7, 14 and 28 days. Apparent porosity (AP) of light weight concrete found slightly higher than the normal concrete but the bulk density (BD) of light weight concrete is about 17% lower than the normal concrete for 7, 14 and 28 days, respectively.

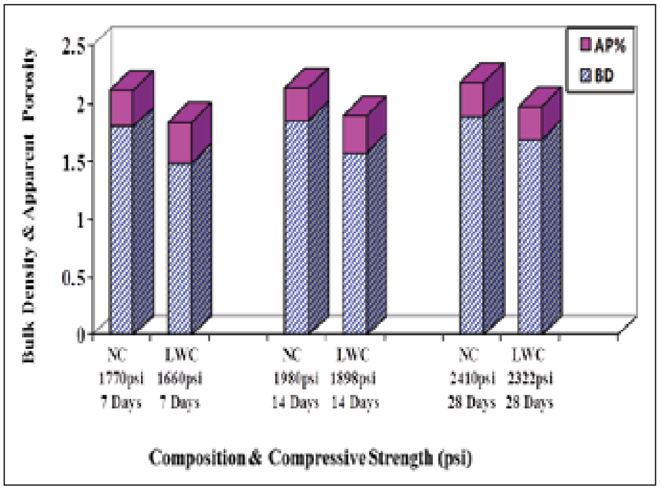

Fig. 4. Variation of bulk density, apparent porosity with compressive strength of normal concrete (NC) and light weight concrete (LWC) after 7, 14 and 28 days

Thermal conductivity

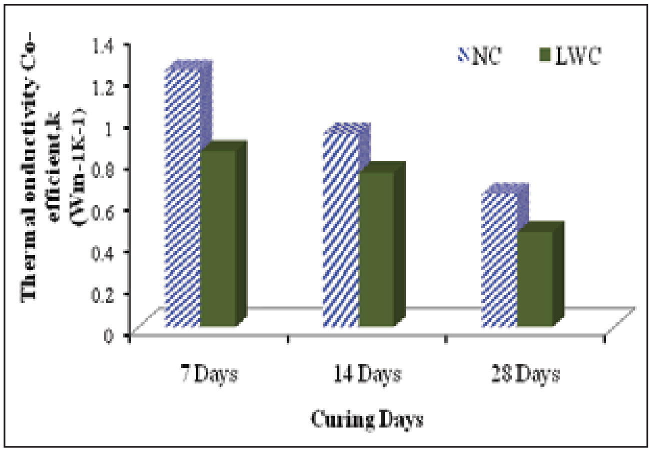

Fig. 5. Thermal conductivity co-efficient of normal concrete (NC) and light weight concrete (LWC) for 7, 14 and 28 days

Thermal conductivity is regarded as the most important characteristic of a thermal insulator, since it affects directly the resistance to transmission of heat that a material offers. The lower the thermal conductivity value, the lower will be the overall heats transfer. Thermal conductivity co-efficient of normal concrete and light weight concrete for 7, 14 and 28 days is shown in Fig. 5. Comparing the result of thermal conductivity of normal concrete and light weight concrete after seven, fourteen and twenty-eight days it is found that the thermal conductivity of light weight concrete is around 20% lower than the normal concrete. This may be due the lower value of the thermal conductivity of the selected materials because all of them are non-metals with high insulating value. Thus, GP and RHA used in this research for the production of LWC might act as alkaline activator that strengthen the concrete with condensed structure and give heat resistivity (Tchakouté *et al.*, 2016)

Conclusion

The engagement of rice husk ash (RHA) and waste glass powder (GP) as light weight aggregate composition in concrete has gained considerable importance because of the requirements of environmental safety and more durable construction in the future. Present study demonstrates that RHA is an effective pozzolan which can contribute to develop the properties of light weight concrete. In this research, the similar compressive strength comes out from the composition of 40% red clay, 40% rice husk ash with 20% glass powder in lightweight aggregate composition compared to normal aggregate. Additionally, the present composition decreases the density and weight. Sodium lauryl sulphate was used as foaming agent. Incorporation of RHA as a partial replacement of red clay might be sufficient to control deleterious expansion due to alkali-silica reaction in concrete. It could be concluded that the use of glass powder shows similar compressive strength but significantly reduce the dead load, density and negligibly increase the porosity for7, 14 and 28 days. This research also states the better heat insulating properties of light weight concrete using RHA and GP compared to the normal concrete. Finally, the partial replacement of red clay (RC) by rice husk ash, glass powder with sodium lauryl sulphate (SLS) and borax showed the considerable development in the properties of concrete which leads to a durable and extra safety in the context of earthquake. More investigation is required with different composition of RHA and GP. Further experiments will help to know the mechanism of SLS and borax in LWC composition.

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