Rice husk ash based cementitious material for concrete canoe

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Abstract. This article study about the properties of light weight concrete canoe using Rice husk ash, micro-silica and microsphere. Rice husk ash, an industrial by-product from boilers for parboiling rice, has been exposed as admixture to replace part of cement in structural mortar. Micro silica addition improves mechanical and durability behaviour in mortars. A microsphere is a lightweight, inert, hollow sphere made largely of silica and alumina and filled with air or inert gas, typically produced as a by-product of coal combustion at thermal power plants. In addition, as the rice husk ash comes from agricultural waste resources their use as secondary raw material will contributes to circularity in the economy. Parametric design of the hull form and internal arrangement of single rower canoe is designed. The Hull Design and stability analysis is done using MAXSURF software. Heel angle was targeted to achieve 60 degree and it had achieved up to 89 percentage. Strength analysis is carried out for the designed hull and then analysed. After finalized the mix design and the hull design, the mould is prepared. Finally, the canoe is casted and tested for stability.

1. Introduction
Canoe was a slender open boat, tapering to a point at both ends, propelled by paddles or sometimes sails and traditionally formed of light framework such as fiberglass or timber. The canoe will be efficient in terms of cost, maintenance and repair if the traditional material was replaced with lightweight concrete. Due to its lightweight the construction technique and the production was very much easier when compared to conventional concrete. It not only reduces the weight it also acts as an insulating material and also have a good fire resisting capacity. It has been used in all type of constructions such as bridges, tall buildings, offshore constructions etc. The lightweight canoe will reduce the cost and maintenance when compared to conventional canoe [1-5]. The manufacturing of cement generally emits large amount of CO₂ gas into the atmosphere [6]. So, to reduce this kind of emission the cement content is reduced by producing lightweight concrete by a waste material called rice husk ash produced by controlled burning of the rice husk under the temperature of 500°C to 650°C [7]. India is one of the largest producers of paddy that is 20% of the worlds production, this rice husk
ash contains high carbon content whereas in uncontrolled burning of rice husk produces low carbon content ash [8]. The fly ash microsphere which is the by-product of thermal power plant which has smaller diameter and because of its lesser density it is used widely in light weight concrete. It is a very fine material so that it can fill up the voids inside the concrete. Silica fume which has a high pozzolanic activity it was widely used as a cement replacement in the high strength concrete as well as in light weight concrete and use of this kind of waste materials in the concrete reduces the cement production and also makes the materials available for the future generation [9].

2. Material Specification

2.1. Cementitious Material

2.1.1. Cement. Cement is finely ground powders that when mixed with water OPC 53 grade cement was required to a designed strength for 28 days of being a minimum of 53 Mpa or 530 kg/sq. cm to satisfy to BIS Specification IS:12269-1987. It has a specific gravity of 3.15. It provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure.

2.1.2. Rice Husk Ash (RHA). The rice husk ash was produced by burning the rice husk at the controlled temperature and under controlled incineration. The properties of a material are closely related to parental materials. It has a specific gravity of 2.27. The rice husk ash production can be done in two ways one was open burning and other was closed incineration burning. Generally open burning was not encouraged since, the RHA produced from open burning has high carbon content which adversely affect the structural properties of the concrete and results in highly crystalline form that was less reactive. By an open heaving at the temperature ranging from 350 to 450 degree Celsius the rice husk ash is produced. When this was converted into ash it contained large amount of unburnt carbon content. The ash produced by controlled burning of the rice husk between 500 to 750-degree Celsius temperatures.

2.1.3. Silica Fume. Silica fume was a byproduct from extraction of carbonaceous materials like coal, coke reduction of high purity quartz. It has a specific gravity of 2.63. It has an ultrafine powder collected as a by-product of silicon and ferro silicon alloy. The main production was pozzolanic activity in concrete due to presence of high silica content. Silica fume due to its fineness and high silica content it was a very effective pozzolanic material. These improves the mechanical properties resulting in the bonding between the silica fume and calcium hydroxide was good due to its fineness. The effect of setting time is different at different proportions. The requirement of water increases with increase in silica fume due to its high fineness.

2.2. Aggregate

2.2.1. Microsphere. Microsphere was the main component used in the thermal power production was the coal. After burning the coal, the by product was fly ash which contains largely of alumina and silica made up of hollow ceramic particles which was pozzolanic in nature. Microspheres are extracted by burning the coal in power plants. Fly ash was produced by burning the pulverized coal in thermal power plants and they are the lighter particles that are contained within the fly ash. The main reason for using microsphere in concrete was mainly due to its light weight from sand. Particles of microsphere are very minute due to which it behaves like a microscopic ball bearing in concrete mix. Due to this effect the workability increases.
2.3. Admixture

2.3.1. Polycarboxylic Ether. Superplasticizers are used to reduce the water content of the concrete for enhancing its properties. Polycarboxylic ether relatively has low dosage 0.15% - 0.3% by weight, they allow water reduction up to 40%. Naphthalene, Melamine, Polycarboxylic have comparable effect on relative slump value. However, PCE have highest compared to another w/b is 0.4. PCE because of presence of several lateral chains on PC molecules, it causes steric repulsion which improve plasticizing effect of PC. Compressive strength of N, M, PC are 12%, 5%, 7% respectively., directly related to stability behaviour of admixtures PC perform well at early age and strength loss is relatively minimal. PC in AAFA improves compressive strength before 7 days, adversely affects the strength in long term. PC shows good stability in Na2OnSiO2 solution compared to N and M, shows good plasticizing effect with minimal strength reduction.

2.3.2. Air Entraining Agent. Air entrainment was the intentional creation of tiny air bubbles in concrete. A concrete maker introduces the bubbles by adding to the mix an air entraining agent, a surfactant. The air bubbles are created during mixing of the plastic concrete, and most of them survive to be the hardened concrete. Conplast AEA was used and it increases the resistance of concrete by reducing problems of surface scaling and concrete failure.

2.3.3. Carbon Fibre Mesh. Carbon fibres are fibres which are composed mostly of carbon atoms with a diameter of 5-10 micrometres. Some of the advantages of carbon fibre are high stiffness, high tensile strength, high chemical resistance, low weight, high temperature tolerance and low thermal expansion. Carbon fibres are usually combined to form a composite. It is the light weight alternative for the heavy materials. Carbon fibres have high tensile strength, rigidity, stiffness, resistance to stretching, high temperature tolerance, high chemical resistance. When compared to the other alternatives, it has some advantages. It was more rigid compared to the glass fibre. It was 10 times stiffer than steel and aluminium. Carbon fibre has been manufactured as a solid piece of material whereas glass fibre is made of tiny glass particles, without hard covering it could easily come apart. The tensile strength of the carbon fibre is around 4.6 GPa, whereas the tensile strength of the glass fibre is 2.3 GPa. It was a non-corrosive and Lightweight and acceptable deformability. It has tailored design and Excellent Formability - Plastic deformation without getting damaged.

3. Hull Design

The Concrete Canoe’s shape follows the plans presented in fig. 1, fig.2, fig. 3 respectively. The Canoe has a dimension of 2 m long, 0.6 m width and 0.35 m depth. Its thickness was given as 0.025 m which consists of a layer of reinforcement present between the given thickness. The Hull design can be obtained by waterlines and sections and they denote the two set mutually perpendicular curves. Waterlines with horizontal plane and sections with vertical through hull, perpendicular to the bow-stern axis. The final design of hull was obtained by the trial and error method. The hull design shape depends on several parameters like length, breadth, depth and curves.

![Figure 1. Top View.](image1)
![Figure 2. Front View.](image2)
![Figure 3. Side View.](image3)
4. Stability Analysis
When a body is disturbed from its normal position, it will return to its original position and it is known as stability. A good maneuverability is produced by the symmetrical hull, when entering and exiting the canoe it has good initial stability. For accommodating solo canoeist Symmetric Canoes are great. An asymmetrical canoe loses initial stability, but it will improve secondary stability i.e. less chance of tipping on water. Canoe should have positive stability and negative stability which denotes that canoe was stable. The design has been made in MAXSURF Modeler and the design was further transferred in MAXSURF Stability to check the stability analysis. The design has made by Trial and Error method.

5. Mix Design
Mix design was one of the important phases of making a canoe. Mix design provides us the accurate information, how strong and dense the concrete will be. Concepts learned in concrete laboratory were implemented. Several trial mixes were made and one which gives good result are finalized for casting the canoe as shown in Table 1. First mix for conventional concrete was done and physical properties of cement, fine aggregate and coarse aggregate are studied. Specific gravity of cement, fine aggregate had been studied by using density bottle method and pycnometer method respectively. The trial mixes for light weight concrete was done with inclusion of admixtures and super plasticizer after studying the physical properties of the materials. The mix design has to be made with reference to the code books IS456 (2000) and IS10262 (2009). The light weight concrete was cast in size 70.6mm x 70.6mm x 70.6mm cubes and cured for 28 days.

| MATERIAL            | QUANTITY (Kg/m³) |
|---------------------|------------------|
| Water               | 200              |
| Cement              | 300              |
| Rice Husk Ash       | 72               |
| Silica Fume         | 83               |
| Superplasticizer    | 5                |
| Air Entraining Agent| 0.8              |
| Microsphere         | 438              |

6. Mould
Moulding was the process of manufacturing by shaping liquid material using rigid frame called mould. This have been made by the final model or object. Male mould was used for casting the canoe. Since, it will be easy for casting when compared to female mould. The design had been finalized and further it transferred to SOLIDWORKS and the sections are divided with the equal distance further it was transferred to AUTOCAD. The sections are taken prints and paste in a cardboard. The cardboard had been cut for the shapes and they are arranged accordingly. The sections are now placed in a 2.5 cm full length cardboard and the sections are locked with the help of L clamp with the cardboard as shown in Fig. 4. The clay has to be filled in the gaps of the section and make it smooth. Take clay according to the requirement for the mould. Clay was fully placed and the extra clay should be removed according to shape and the shape has to be fully pasted by the clay and finishing was done as shown in Fig. 5.
7. Casting and Curing

Once the mould was ready for casting the mica sheets are used to cover the mould because it avoids the mixing of clay and mortar. The mica sheets are cut into pieces and they are first pasted and the same process done for all the sections and they are finally joined by the use of packing tape. Shuttering oil has to be applied above the sheet to avoid joining or sticking as shown in Fig. 6. After completion of all work by applying shuttering oil, the batching to be done for each material. The materials are calculated for volume of 8 cubes of 15mm x 15mm x 15mm and are separated for mixing. Rice husk ash was sieved in a 300 microns sieve to be fine and they are used. Cement was also sieved in a 90 microns sieve to be fineness. The materials were weight batched and mixed in a mixer machine and were casted along the mould and after 24 hours curing process begins. Curing done for using Hessian cloth or Gunny Cloth. The bags used are thick so that it absorbs water and retains moisture for a long time as shown in Fig. 7. Concrete in this condition should be maintained for 24 hours and should not be allowed to dry fast in any situation. Curing was to be done in morning and evening a day so that the Hessian cloth will be enough wet and the same process is done for 28 days. The Hessian cloth was used for many times and hence it is very economical.

8. Demoulding and Finish

After 28 days of curing the canoe was demoulded by cutting the underneath layer of the mould for loosening the clay. The clay has been removed at the both the ends where there is maximum load and the canoe had removed from the mould and placed in water as shown in Fig. 8. After demoulding the canoe, the tapes are removed from the canoe and it has been weighed. The canoe has to be checked for the side surfaces because it causes damage for the peddler while rowing the canoe. The side surfaces are made smoother by using the sand paper as shown in Fig. 9.
9. Results and Discussion

9.1. Compression Test

As, the cube had casted with several mix and they were cured with water for 28 days. In which the compression test is done for 7th day, 14th day and 28th day. The strength was achieved by 60-70% in 7 days and finally, for 28 days the strength was achieved by 95-100% as shown in Table 2. The concrete achieved the density of 1050 Kg/m³ with a compression strength of 6.1 N/mm² after 28 days of curing. As, it was achieved with low density with good strength, this material was chosen for casting Concrete Canoe.

| Material | 7 days | 14 days | 28 days |
|----------|--------|---------|---------|
| Mix      | 4.4 N/mm² | 5.6 N/mm² | 6.1 N/mm² |

9.2. Stability Analysis

The simple load cases of single point loads at probable paddler position are given wherein an average of 100 kg human paddler is assumed and Upright Hydrostatics of the Canoe are analysed as shown in Table 3. The results are as under in which that the heel angle of 53.6 degree will be generated due to the occupancy of single paddler as shown in Fig. 10.

| Load case | Load Applied (Kg) |
|-----------|-------------------|
| Weight of Canoe | 60 |
| Peddler | 100 |
| Total | 160 |
9.3. Strength Analysis

Strength Analysis had done for the design using manual Calculation

Assumptions:

- Parabolic Beam
- Uniform Distribution of weight along entire canoe length
- Weight of Canoe, $W_c = 539.55$ N
- Weight of each paddler, $W_p = 980.66$ N
- Factor of Safety = 1.5

Known Values

- Length of canoe = 2m
- Width of canoe = 0.6m
- Depth of canoe = 0.35m
- Total Buoyancy Force = 0.312 kN

Moment Calculation

We know that,

$$\varepsilon \nu = 0$$

$$R_A + R_B + (0.234 \times 2) = (0.404 \times 2) + 1.47$$

$$R_A + R_B = 1.81\text{kN}$$

Using Double Integration Method,
\[ M_x = [R_B \cdot X] + (0.234 \cdot X/2) - [0.404 \cdot X/2] - [1.47(1-X)] \]

\[ = 1.725 \text{kNm} \]

**Centroid Calculation**

\[ A_b = \frac{2}{3} (\text{width} \cdot h) \cdot (\text{height} \cdot t_b) = \frac{2}{3} (600) (350) \]

\[ A_t = \frac{121600}{2} \text{mm}^2 \]

\[ y_b = (3/5) h_b = (3/5) (350) \]

\[ y_t = 210 \text{ mm} \]

\[ y = (A_b) (y_b) - (A_t) (y_t) / A_b - A_t \]

\[ y = 0.328 \text{ m} \]

*Approximate solution based on assumptions*

**Moment of Inertia Calculations**

\[ I_{xb} = \frac{4}{7} (\text{width} \cdot h/2) \cdot h \cdot b^3 = \frac{4}{7} (600) (350)^3 \]

\[ I_{xb} = 7350 \times 10^6 \text{ mm}^4 \]

\[ I_{xt} = 16/175 (\text{width} \cdot t/2) \cdot h \cdot c^3 + A_t \cdot y_t^2 = 16/175 (570/2) (320)^3 + (121600) (192)^2 \]

\[ I_{xt} = 5336.5 \times 10^6 \text{ mm}^4 \]

\[ I_x = I_{xb} - I_{xt} \]

\[ I_x = 2014 \times 10^6 \text{ mm}^4 \]

\[ I_{xc} = I_x - (A_b - A_t) (y^2) = 2014 \times 10^6 - (140000 - 121600) (0.328)^2 \]

\[ I_{xc} = 34.45 \times 10^6 \text{ mm}^4 \]

*Approximate solution based on assumptions*

**Stress Calculations**

\[ \sigma_t = \frac{M_{\text{max}} y_t}{I_{xc}} \]

\[ \sigma_t = -1.502 \text{ Mpa} \]

\[ \sigma_b = \frac{M_{\text{max}} y_b}{I_{xc}} \]

\[ \sigma_b = +16.02 \text{ Mpa} \]

*Approximate solution based on assumptions*
Moment, $M_x = 1.725 \text{ kNm}$

Centroid, $y = 0.328 \text{ m}$

Moment of Inertia, $I_{xc} = 34.45 \times 10^6 \text{ mm}^4$

Stress, $\sigma_t = -1.502 \text{ Mpa}$

$\sigma_b = +16.02 \text{ Mpa}$

10. Conclusion
By the use of lightweight concrete its physical and mechanical properties were studied and a one-man canoe was casted. The focus was centred towards innovation, reinvention and socially application. The idea of lightweight concrete canoe satisfies all these criteria. The mass of the canoe was found to be 55 kgs with concrete density of $1050 \text{ kg/m}^3$. Heel angle achieved was 53.6 degree. The lightweight concrete canoe can be used for any rescue operation in case of flood.

11. References
[1] Chandra S and Berntsson L 2002 Lightweight aggregate concrete *Elsevier*  
[2] Thomas M and Bremner T 2012 Performance of lightweight aggregate concrete containing slag after 25 years in a harsh marine environment *Cement and concrete research* 42 358-64  
[3] Bogas JA, Gomes A and Pereira MF.2012 Self-compacting lightweight concrete produced with expanded clay aggregate *Construction and Building Materials* 35 1013-22  
[4] Sales A, De Souza FR, Dos Santos WN, Zimer AM and Almeida FD 2010 Lightweight composite concrete produced with water treatment sludge and sawdust Thermal properties and potential application *Construction and building materials* 24 2446-53  
[5] Li Z 2011 Advanced concrete technology *John Wiley & Sons*  
[6] Kisku N, Joshi H, Ansari M, Panda SK, Nayak S and Dutta SC 2017 A critical review and assessment for usage of recycled aggregate as sustainable construction material *Construction and Building Materials* 131 721-40  
[7] Esfandiari J and Loghmani P 2019 Effect of perlite powder and silica fume on the compressive strength and microstructural characterization of self-compacting concrete with lime-cement binder Measurement 147 106846  
[8] Fapohunda C, Akinbile B and Shittu A 2017 Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement—A review *International Journal of Sustainable Built Environment* 6 675-92  
[9] Huang Z, Padmaja K, Li S and Liew JR 2018 Mechanical properties and microstructure of ultra-lightweight cement composites with fly ash cenospheres after exposure to high temperatures *Construction and building materials* 164 760-74