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Prospective Use of Rice Husk Ash to Produce Concrete in India

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***Abstract*—**In this paper, the author studied the possibilities of using Rice Husk Ash (RHA) available in India; to produce concrete. Experiments conducted with RHA obtained from West Bengal, India; to replace cement partially to produce concrete of grade M10, M15, M20, M25 and M30. The concrete produced in the laboratory by replacing cement by 5%, 10%, 15%, 20%, 25% and 30% RHA. Compressive strength tests carried out to determine the strength of concrete. Cost analysis and comparison done to show the cost effectiveness of RHA Concrete. Traditional uses of Rice Husk in India pointed out and the advantages of using RHA in making concrete highlighted. Suggestion provided regarding prospective application of RHA concrete in India; which in turn will definitely reduce the cost of concrete and environmental friendly due to utilization of waste and replacement of Cement.

***Keywords*—**Cement replacement, Concrete, Environmental friendly, Rice Husk Ash.

I. Introduction

THE global market for cement and concrete is huge; it is the second biggest traded commodity in the world after water. Cement production now accounts for around 5% of the global CO_2 emission [6]. The production of one ton of cement results in the release of approximately one ton of CO_2 [7], [8]. One of the main key levers to reduce carbon emissions is replacing cement with cementitious material while producing concrete [8].

India is the world's second largest producer of rice after China [13]. The average yearly production of Rice in India is in the range of 100 million MT [13]. Rice milling generates a byproduct known as rice husk. Controlled incineration of rice husk between 500^0C and 800^0C produces non-crystalline amorphous RHA [1]. 1 MT of rice grain produces 200 KG of Rice Husk i.e., 20% by weight of rice grain. 1 MT of Rice Husk produces 200 KG of Rice Husk Ash i.e., 20% by weight of Rice Husk [1]. RHA is whitish or grey in colour. The particles of RHA occur in cellular structure with a very high surface fineness. They have 90% to 95% amorphous silica. Due to high silica content, RHA possess excellent pozzolanic property [2]-[5].

II. Processing and Production of RHA

A. Combustion

Rice husk has an energy value about half that of coal and is therefore an important potential energy source. Rice husk is still burnt as waste in rural areas of India. Rice husk is also used as energy source to boiler at rice mills. To produce the best pozzolanas, the burning of the husk must be carefully controlled to keep the temperature below 700^0C and to ensure that the creation of carbon is kept to a minimum by supplying an adequate quantity of air. At burning temperatures below 700^0C an ash rich in amorphous silica is formed which is highly reactive. Temperatures above 700^0C produce crystalline silica which is far less reactive [5], [8], [9].

The presence of large quantities of carbon in the ash will adversely affect the strength of any concrete or mortar produced using RHA cements. Where possible, the carbon content of the ash should be limited to a maximum of 10% [5].

B. Grinding

The second step in processing is grinding the RHA to a fine powder. Ball or hammer mills are usually used for this purpose. Crystalline ash is harder and will require more grinding in order to achieve the desired fineness [5].

III. Cement Hydration and Effect of RHA

Cement Hydration is the result of a chemical reaction that occurs between water and the chemical compounds present in Portland cement [3]. Portland Cement is predominantly composed of two calcium silicates which account for 70 percent to 80 percent of the cement. The two calcium silicates are dicalcium silicates (C_2S) and tricalcium silicate (C_3S). The reaction of dicalcium silicate and tricalcium silicate with water produces calcium silicate hydrate (C-Si-H) and calcium hydroxide $Ca(OH)_2$ as:

$$\text{Calcium Silicates + Water -> Ca-Si-H Gel} + Ca(OH)_2$$

Ca-Si-H Gel contributes to strength & long term durability & it accounts for more than half the volume of the hydrated cement paste. $Ca(OH)_2$ does not contribute to the strength & can potentially lead to reduced strength & lowered durability. It accounts for about 25% of the paste volume. RHA has high Silica content. The pozzolanic reaction of RHA converts the soluble $Ca(OH)_2$ to C-Si-H Gel, increasing the overall strength and durability of the concrete [3].

$$SiO_2 + Ca(OH)_2 \text{ -> Ca-Si-H Gel}$$

Additional Ca-Si-H Gel produced by RHA improves the properties of Portland cement concrete.

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IV. Cement Industry in India

The 'Liberalisation Policies' was implemented by the Government of India in 1991. The capacity and production of Cement increased due to effect of this implementation. The capacity of cement increased from a mere 64.55 million tonnes per annum in 1990-91 to over 350 million tonnes per annum in 2012-13 whereas the production of cement increased from a mere 48.90 million tonnes per annum in 1990-91 to over 251 million tonnes per annum in 2012-13. India produced about 7% of the world cement production, but had a per capita consumption of only 202 kg against a world average of 543 kg and China's 1518 kg, showing good prospects for the industry. The Indian cement industry consumed over 27% of the total fly ash and 100% slag generated in India [12].

The long journey of the Indian cement industry started one hundred years ago in 1914 in a small way. 1982 was a watershed year in the history of the Indian cement industry, when 'Partial Decontrol' of price was introduced, which culminated into full 'Decontrol' in 1989. The cement industry of India took 83 years to reach the first 100 million tonnes per annum capacity [12].

The cement industry brought the thermal energy consumption from 1300 to 1600 kcal/kg clinker in the 1950 to 1960 decade, down to 650 to 750 kcal/kg in the current decade and the power consumption from 115 to 130 kWh/t to a remarkable 70 to 90 kWh/t cement and the kiln capacity from 300 to 600 t/d to 4500 to 12000 t/d over the same period. Today, the industry has 93 large cement plants with ISO 14001:2004 EMS certification and 44 plants which have secured OHSAS 18001 Occupational Health and Safety Management System certification [12].

The CO_2 emission level reduced from 1.12 per tonne of cement produced in 1996 to 0.719 per tonne CO_2 emission in 2010. Similarly, particulate emission reduced from 400 mg/cum to 50 mg/cum over the last two decades. Furthermore, the Indian cement industry was the sixth largest revenue contributor to the national exchequer (0.6 billion USD to 0.64 billion USD per year), the second largest revenue contributor to railways – more than 1.37 billion USD in FY13. Production of one million tonne of cement in India creates employment for about 20,000 people downstream. The industry has also contributed immensely to the creation of greenbelts, water reservoirs in abandoned mines and other social causes having planted about 25 million trees in the last decade, besides several other similar activities [12].

V. Traditional Uses of Rice Husk in India

The average yearly production of Rice in India is in the range of 100 million MT [13]. As 1 MT of rice grain produces 200 KG of Rice Husk; so approx quantity of Rice Husk available is 20 million MT per year. The top ten rice producing states in India are West Bengal, Andhra Pradesh, Uttar Pradesh, Punjab, Orissa, Tamil Nadu, Chattisgarh, Bihar, Karnataka and Haryana. Rice Husk is the outermost layer of protection encasing a rice grain. It is yellowish in colour and has a convex shape. It is slightly larger than a grain of rice, thus length up to 7 mm are possible. Typical dimensions are 4 mm by 6 mm. It is light weight, having a ground bulk density of 340 kg / cum to 400 kg / cum. In India Rice Husk is generally used as given below:

i) Generally ground Rice Husk is used in small power plants based on feeding of Rice Husk.
ii) Rice Husk is used as biomass to fuel and co-fuel power plants.
iii) In horticulture Rice Husk is used for soil aeration.
iv) Rice Husk is a popular bedding material for animals in rural India. Compared to saw dust it is fire resistant, does not attract insects and it does not compress; meaning a softer bed for animals.
v) Nowadays some industries are manufacturing composites from Rice Husk for making furniture and wood plastic composite (WPC) decking.
vi) Rice Husk Ash is used as an insulator to line ladles in steel manufacturing.

VI. Advantages of Using RHA in Making Concrete

Recent researches on concrete using Rice Husk Ash reveal that RHA can be used to produce good quality concrete i.e. RHA is suitable to replace ordinary Portland cement [3], [5], [9]-[11]. Recent studies reveal the following advantages of using RHA in concrete:

i) Increased compressive & flexural strengths.
ii) Reduced permeability.
iii) Increased resistance to chemical attack.
iv) Increased durability.
v) Reduced effects of alkali-silica reactivity.
vi) Reduced shrinkage due to particle packing, making concrete denser.
vii) Enhanced workability of concrete.
viii) Reduced heat gain through the walls of buildings.
ix) Reduced amount of super plasticizer.
x) Reduced potential for efflorescence due to reduced calcium hydracids.

VII. Experiments with RHA Obtained from West Bengal, India

A. Material Used in Laboratory Experiments

- Ordinary Portland Cement: Ultratech brand Ordinary Portland Cement (OPC) 43 grade was used in the laboratory experiments. Typical properties and composition of this product are given in Table I.
- Rice Husk Ash: RHA was procured from "Manas Rice Husk Ash Research & Export India Pvt. Ltd., Bardhaman, West Bengal". Typical properties and composition of this product are given in Table II.
- Coarse Aggregate: Pakur variety 20 mm down was used as coarse aggregate in the laboratory experiments. Grading of this product is given in Table III. The bulk density obtained in the lab was 1440 kg / cum.

TABLE I
PROPERTIES AND COMPOSITION OF ORDINARY PORTLAND CEMENT

Type of cement	IS Code	Fineness m^2/kg (min.)	Setting Time in minutes		Soundness		Compressive Strength (MPa)		
			Initial (min.)	Final (max.)	Le Chatelier (mm)	Auto Clave (%)	3 days	7 days	28 days
OPC 43	8112 : 1989	225	30	600	10	0.8	23	33	43

Constituents	% Weight	Constituents	% Weight	Constituents	% Weight	Constituents	% Weight
SiO_2	17-25	Al_2O_3	4-8	Fe_2O_3	0.5-0.6	$Na_2O + K_2O$	0.4-1.3
CaO	61-63	MgO	0.1-4.0	SO_3	1.3-3.0	Cl	0.01-0.1
IR	0.6-1.75						

Ultratech brand OPC 43 grade was used in the laboratory experiments. Typical properties and composition of this product are obtained from their data sheet.

TABLE II
PROPERTIES AND COMPOSITION OF RICE HUSK ASH

Colour		Specific Gravity	
Light Grey		2.1	
Constituents	**% Weight**	**Constituents**	**% Weight**
SiO_2	90	Al_2O_3	0.39
CaO	0.46	MgO	0.88
Na_2O	0.07	P_2O_5	1.60
Fe_2O_3	0.37	K_2O	3.10
MnO	0.039	L.O.I (Loss of Ignition)	3.091

Rice Husk Ash was procured from “Manas Rice Husk Ash Research & Export India Pvt. Ltd., Bardhaman, West Bengal, India”. Typical properties and composition of this product are obtained from their data sheet.

TABLE III
GRADING OF COARSE AGGREGATE

I.S. Sieve (mm)	% Retained	Cum. % Retained	Cum. % Passing	Requirement of Cumulative % passing for 20 mm graded coarse aggregate as per I.S. 383
40	0	0	100	100
20	4	4	96	95-100
16	36	40	60	-
12.5	24	64	36	-
10	10	74	26	25-55
4.75	22	96	4	0-10

TABLE IV
GRADING OF FINE AGGREGATE

I.S. Sieve (mm)	% Retained	Cum. % Retained	Cum. % Passing	Requirement of Cumulative % passing for zone II sand as per I.S. 383
10	0	0	100	100
4.75	2	2	98	90-100
2.36	13	15	85	75-100
1.18	20	35	65	55-90
600 micron	20	55	45	35-59
300 micron	24	79	21	8-30
150 micron	18	97	3	0-10
Residual	3	100	0	

- Fine Aggregate: River sand from rivers at Bardhaman was used as fine aggregate in the laboratory experiments. Grading of this product is given in Table IV. The bulk density obtained in the lab was 1450 kg / cum. The fineness modulus obtained was 2.83.
- Water: The water that is supplied in the Civil Engineering Laboratory was used in the experiments. This water is potable and can be used for making concrete as per laboratory records.
- Plasticizer: Sika Plastiment BV/40 was used as plasticizer in the laboratory experiments. It complies with IS:9103-99, ASTM C 494 M-99a Type A. This plasticizer is of Modified Ligno Sulphonate type with dark brown colour. The specific gravity is around 1.16.
- Super Plasticizer: FOSROC Auramix 400 was used as super plasticizer in the laboratory experiments. It is High Range Water Reducer (HRWR) having polycarboxylic base and complies with IS:9103-99(2007), ASTM C 494 Type G. The specific gravity is around 1.09 and colour is light yellow.

B. Tests Conducted

Slump flow test: To determine the workability of concrete, slump flow test conducted with slump cone. The mould was filled in four layers, each roughly one quarter of the height of mould. Each layer tamped uniformly with twenty five strokes of the rounded end of the tamping rod with penetration slightly in to the underlying layer.

Compressive strength test: Cubes of 150x150x150 mm with OPC and OPC replaced by RHA at 0%, 5%, 10%, 15%, 20%, 25% and 30% replacement levels were cast. After 24 hours of casting, cubes were subjected to water curing for 7 to 28 days. The cubes were tested for compressive strength using compressive strength testing machine. The tests were carried out on triplicate specimens and the average compressive strength values were recorded.

C. Results and Discussion

The composition of concrete mixes along with results of slump flow tests and compressive strength tests are given in Tables V-X. Experiments with RHA obtained from West Bengal, India reveals the following observation:

i) IS 456:2000 (Indian Standard: Plain and Reinforced Concrete – Code of practice) marked M10, M15 and M20 grade of concrete as ‘Ordinary Concrete’. ‘Ordinary Concrete’ of Grade M10, M15 and M20 can be produced by replacing Ordinary Portland Cement with Rice Husk Ash upto 30%.
ii) Replacement of Ordinary Portland Cement upto 20% by RHA can be done to produce concrete of grade M20, M25 & M30.
iii) Slump flow test results show that the slump decreases with increase of replacement of cement with RHA. This is because adding RHA by weight results increase of the resulted concrete volume, as the density of RHA is

significantly lower than cement, i.e. 2.1 compared to 3.11 of cement.

iv) RHA replacement produced light concrete compared to 100% cement concrete.

D.Cost Analysis and Comparison

Cost analysis and comparison is done in Table XI between 'no replacement' and '20% replacement' for M10, M20 and M30 grade of concrete. It is observed that the cost of one cum concrete with '20% replacement' reduces by approximately 7%, 9% & 6% in comparison with 'no replacement' for M10, M20 and M30 grade of concrete respectively.

TABLE V
COMPOSITION OF CONCRETE MIXES AND TEST RESULTS FOR TARGET STRENGTH M10

Sample	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate (Kg/Cum)	Water / Binder Ratio	Slump (mm)	7 Days Weight (Kg/Cum)	7 Days Compressive Strength (MPa)	28 Days Weight (Kg/Cum)	28 Days Compressive Strength (MPa)
Cement 100% +RHA 0%	220 + 0 + 149.6 + 1340 + 770	0.68	60	2447	14.1	2459	17.8
Cement 95% +RHA 5%	209 + 11 + 149.6 + 1340 + 770	0.68	55	2441	13	2453	18.5
Cement 90% +RHA 10%	198 + 22 + 149.6 + 1340 + 770	0.68	45	2430	13	2447	18.5
Cement 85% +RHA 15%	187 + 33 + 149.6 + 1340 + 770	0.68	40	2430	11.9	2441	19.1
Cement 80% +RHA 20%	176 + 44 + 149.6 + 1340 + 770	0.68	37	2430	11.9	2441	19.3
Cement 75% +RHA 25%	165 + 55 + 149.6 + 1340 + 770	0.68	33	2424	10.4	2436	17.1
Cement 70% +RHA 30%	154 + 66 + 149.6 + 1340 + 770	0.68	30	2424	8.9	2436	16.3

TABLE VI
COMPOSITION OF CONCRETE MIXES AND TEST RESULTS FOR TARGET STRENGTH M15

Sample	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate (Kg/Cum)	Water / Binder Ratio	Slump (mm)	7 Days Weight (Kg/Cum)	7 Days Compressive Strength (MPa)	28 Days Weight (Kg/Cum)	28 Days Compressive Strength (MPa)
Cement 100% +RHA 0%	320 + 0 + 204.8 + 1333 + 711	0.64	80	2460	15.6	2477	20.7
Cement 95% +RHA 5%	304 + 16 + 204.8 + 1333 + 711	0.64	74	2454	15.6	2471	21.5
Cement 90% +RHA 10%	288 + 32 + 204.8 + 1333 + 711	0.64	68	2442	14.8	2465	20.7
Cement 85% +RHA 15%	272 + 48 + 204.8 + 1333 + 711	0.64	60	2442	14.8	2465	21.5
Cement 80% +RHA 20%	256 + 64 + 204.8 + 1333 + 711	0.64	52	2436	14.1	2454	22.3
Cement 75% +RHA 25%	240 + 80 + 204.8 + 1333 + 711	0.64	46	2430	11.9	2454	19.5
Cement 70% +RHA 30%	224 + 96 + 204.8 + 1333 + 711	0.64	40	2418	11.1	2436	18.5

TABLE VII
COMPOSITION OF CONCRETE MIXES AND TEST RESULTS FOR TARGET STRENGTH M20

Sample	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate (Kg/Cum)	Water / Binder Ratio	Slump (mm)	Plasticizer (Kg/Cum)	7 Days Weight (Kg/Cum)	7 Days Compressive Strength (MPa)	28 Days Weight (Kg/Cum)	28 Days Compressive Strength (MPa)
Cement 100% +RHA 0%	360 + 0 + 162 + 1333 + 652	0.45	88	2.88	2475	19.5	2489	26.0
Cement 95% +RHA 5%	342 + 18 + 162 + 1333 + 652	0.45	82	2.88	2470	18.7	2485	27.5
Cement 90% +RHA 10%	324 + 36 + 162 + 1333 + 652	0.45	76	2.88	2463	18.7	2480	28.3
Cement 85% +RHA 15%	306 + 54 + 162 + 1333 + 652	0.45	70	2.88	2460	17.9	2477	28.5
Cement 80% +RHA 20%	288 + 72 + 162 + 1333 + 652	0.45	55	2.88	2441	17.9	2460	29.3
Cement 75% +RHA 25%	270 + 90 + 162 + 1333 + 652	0.45	48	2.88	2430	16.0	2448	25.0
Cement 70% +RHA 30%	252 + 108 + 162 + 1333 + 652	0.45	40	2.88	2418	14.4	2441	22.0

TABLE VIII
COMPOSITION OF CONCRETE MIXES AND TEST RESULTS FOR TARGET STRENGTH M25

Sample	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate (Kg/Cum)	Water / Binder Ratio	Slump (mm)	Plasticizer (Kg/Cum)	7 Days Weight (Kg/Cum)	7 Days Compressive Strength (MPa)	28 Days Weight (Kg/Cum)	28 Days Compressive Strength (MPa)
Cement 100% +RHA 0%	380 + 0 + 171 + 1333 + 652	0.45	85	3.04	2493	23.5	2500	32.6
Cement 95% +RHA 5%	361 + 19 + 171 + 1333 + 652	0.45	78	3.04	2490	22.6	2500	32.8
Cement 90% +RHA 10%	342 + 38 + 171 + 1333 + 652	0.45	72	3.04	2488	22.7	2495	33.3
Cement 85% +RHA 15%	323 + 57 + 171 + 1333 + 652	0.45	68	3.04	2468	21.8	2485	33.5
Cement 80% +RHA 20%	304 + 76 + 171 + 1333 + 652	0.45	54	3.04	2450	21.4	2468	34.3
Cement 75% +RHA 25%	285 + 95 + 171 + 1333 + 652	0.45	46	3.04	2440	19.8	2455	28.0
Cement 70% +RHA 30%	266 + 114 + 171 + 1333 + 652	0.45	37	3.04	2426	18.4	2450	25.0

TABLE IX
COMPOSITION OF CONCRETE MIXES AND TEST RESULTS FOR TARGET STRENGTH M30

Sample	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate (Kg/Cum)	Water / Binder Ratio	Slump (mm)	Plasticizer (Kg/Cum)	7 Days Weight (Kg/Cum)	7 Days Compressive Strength (MPa)	28 Days Weight (Kg/Cum)	28 Days Compressive Strength (MPa)
Cement 100% +RHA 0%	400 + 0 + 180+ 1333 + 652	0.45	85	3.20	2515	25.5	2529	36.6
Cement 95% +RHA 5%	380 + 20 + 180+ 1333 + 652	0.45	80	3.20	2512	25.4	2527	36.8
Cement 90% +RHA 10%	360 + 40 + 180+ 1333 + 652	0.45	70	3.20	2505	24.9	2515	37.3
Cement 85% +RHA 15%	340 + 60 + 180+ 1333 + 652	0.45	68	3.20	2480	23.8	2495	38.5
Cement 80% +RHA 20%	320 + 80 + 180+ 1333 + 652	0.45	52	3.20	2478	23.4	2490	38.3
Cement 75% +RHA 25%	300 + 100 + 180+ 1333 + 652	0.45	48	3.20	2473	21.8	2488	30.9
Cement 70% +RHA 30%	280 + 120 + 180+ 1333 + 652	0.45	38	3.20	2462	19.6	2480	28.4

TABLE X
COMPOSITION OF CONCRETE MIXES AND TEST RESULTS FOR TARGET STRENGTH M30

Sample	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate (Kg/Cum)	Water / Binder Ratio	Slump (mm)	Super Plasticizer (Kg/Cum)	7 Days Weight (Kg/Cum)	7 Days Compressive Strength (MPa)	28 Days Weight (Kg/Cum)	28 Days Compressive Strength (MPa)
Cement 100% +RHA 0%	430 + 0 + 150.5+ 1270 + 690	0.35	95	3.44	2506	28.2	2520	41.8
Cement 95% +RHA 5%	408.5 + 21.5 + 150.5+ 1270 + 690	0.35	80	3.87	2500	30.4	2515	42.0
Cement 90% +RHA 10%	387 + 43 + 150.5+ 1270 + 690	0.35	75	4.30	2500	30.9	2512	42.3
Cement 85% +RHA 15%	365.5 + 64.5 + 150.5+ 1270 + 690	0.35	65	5.16	2484	30.8	2500	40.3
Cement 80% +RHA 20%	344 + 86 + 150.5+ 1270 + 690	0.35	54	6.02	2482	28.4	2500	39.3
Cement 75% +RHA 25%	322.5 + 107.5 + 150.5+ 1270 + 690	0.35	50	6.45	2469	25.8	2489	33.2
Cement 70% +RHA 30%	301 + 129 + 150.5+ 1270 + 690	0.35	45	6.88	2466	24.6	2487	30.4

TABLE XI
COST ANALYSIS AND COMPARISON

Grade of Concrete	Sample	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate+ Plasticizer + Super Plasticizer (Kg/Cum)	Cement + RHA + Water + Coarse Aggregate + Fine Aggregate + Plasticizer + Super Plasticizer (Price per Kg in Indian Rupees)	Mixing & placing cost per cum (Indian Rupees)	Total Cost per Cum of concrete (Indian Rupees)
M10	Cement 100% +RHA 0%	220 + 0 + 149.6 + 1340 + 770 + 0 + 0	8 + 1 + 0.5 + 1.20 + 0.35 + 75 + 90	700	4412.30
M10	Cement 80% +RHA 20%	176 + 44 + 149.6 + 1340 + 770 +0 +0	8 + 1 + 0.5 + 1.20 + 0.35 + 75 + 90	700	4104.30
M20	Cement 100% +RHA 0%	360 + 0 + 162 + 1333 + 652 + 2.88 + 0	8 + 1 + 0.5 + 1.20 + 0.35 + 75 + 90	700	5704.80
M20	Cement 80% +RHA 20%	288 + 72 + 162 + 1333 + 652 + 2.88 + 0	8 + 1 + 0.5 + 1.20 + 0.35 + 75 + 90	700	5200.80
M30	Cement 100% +RHA 0%	430 + 0 + 150.5+ 1270 + 690 + 0 + 3.44	8 + 1 + 0.5 + 1.20 + 0.35 + 75 + 90	700	6290.35
M30	Cement 80% +RHA 20%	344 + 86 + 150.5+ 1270 + 690 + 0 + 6.02	8 + 1 + 0.5 + 1.20 + 0.35 + 75 + 90	700	5920.55

Considering place of construction is within Bardhaman District area of West Bengal State in India and date of construction is Oct, 2014.
1 USD = 65 Indian Rupees

VIII. PROSPECTIVE APPLICATION OF RHA CONCRETE IN INDIA

In the following areas RHA concrete can be considered for application:

i) Plain cement concrete of grade M20 and below.
ii) Rigid pavements of rural roads.
iii) Reinforced Cement Concrete of grade upto M30.
iv) Buildings where upto M30 grade of concrete used.
v) Culverts, Boundary pillars etc. where upto M30 grade of concrete used.
vi) Paver Blocks, Concrete gratings, Concrete Kerb Stone etc.

IX. BUREAU OF INDIAN STANDARDS AND RHA CONCRETE

IS 456:2000 (Indian Standard: Plain and Reinforced Concrete – Code of practice) mentioned that "Rice Husk Ash giving required performance and uniformity characteristics may be used with the approval of deciding authority".

The application and process of RHA concrete has yet to be refined and tested in real-world conditions, so the idea is still mostly in its initial stages. However, when one considers that up and coming economic power India will be likely ramping up production of concrete for use in construction, the prospect of reducing carbon emissions and pollution through the use of risk husk ash in concrete becomes even more interesting.

X. CONCLUSION

Application of RHA concrete would be environmental friendly due to utilization of waste (RHA is basically a waste obtained from Rice Mill) and replacement of cement (Production of 1 MT cement emerges 1 MT Carbon-di-Oxide).

In a fast developing country like India; RHA based cement would definitely reduce the cost of concrete. It can be widely applied in semi-urban and rural areas. If the rice producing zones in India are earmarked and RHA is used to produce concrete in those areas then definitely it will enrich the economic condition of the poor and middle-class citizens.

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REFERENCES

[1] Rice Husk Ash market study – Bronzeoak Ltd., 2003.
[2] Pozzolanas: Rice Husk Ash (RHA) & Pulverised Fuel Ash (PFA) – Practical Action – The Schumacher Centre for Technology & Development, Bourton on Dunsmore, Warwickshire, UK, 2007.
[3] The possibility of adding the Rice Husk Ash to the concrete – Mauro M. Tashima, Carlos A.R. da Silva, Jorge L.Akasaki, Michele Beniti Barbosa – FEIS/UNESP, Brazil, 2007.
[4] Rice Husk Ash– Nick Zemke, Emmet Woods— California Polytechnic State University, 2009.
[5] Supplementary cementitious materials: Part I: Pozzolanic SCM—Adam. D. Neuwald—MC Magazine, Sept-Oct, 2004.
[6] A Sustainability Framework for Concrete Construction -- P Chana -- Proceedings of the International UKIERI Concrete Congress held at Indian Institute of Technology, New Delhi, India, 8th to 10th March, 2011.
[7] Green materials for sustainable housing development: Agro waste ashes as a cement replacement for concrete structures in hot arid climates. – Shahid Kabir, Universiti Sains, Malaysia. – The first built environmental development symposium: Sustainable real estate & housing development, 2007.
[8] Necessity and opportunity of sustainable concrete from Malaysia's waste materials – M. R. Karim, M. F. M. Zain, M. Jamil, F. C. Lai, M. N. Islam – Australian Journal of Basic and Applied Sciences, 5(5): 998-1006, 2011.
[9] Durability of conventional concretes containing black Rise Husk Ash – B. Chatveera, P. Lertwattanaruk – Journal of Environmental Management 92 (2011) 59-66.
[10] Kalyan Kumar Moulick - "Replacement of Ordinary Portland Cement by Rice Husk Ash to produce Concrete of Grade M20, M25 and M30" - 2013 Asian Conference on Civil, Material and Environmental Sciences (ACCMES'2013) – 15th to 17th March, 2013; Tokyo, Japan.
[11] Kalyan Kumar Moulick - "Replacement of Ordinary Portland Cement by Rice Husk Ash to produce Ordinary Concrete of Grade M10, M15 and M20" – International Journal of Emerging Technology and Advanced Engineering - Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 583-590 (An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459, available online at www.ijetae.com.)
[12] 52nd Annual Session of the Cement Manufacturers Association – New Delhi, India – 9th January, 2014.
[13] United States Department of Agriculture – Report 2013-14.