Green Concrete Evolution: A Study on Industrial and Agri By-Product Incorporation

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Abstract
Green concrete is nothing but concrete made with eco friendly wastes. In concrete industries green concrete is a revolutionary topic. Green Concrete is an environmental friendly material. Normal concrete is responsible for release of carbon dioxide to some extent. To reduce such emissions, various types of concrete were developed by various researchers by using some waste products from industries and agriculture. It depicts the convenience of the usage of various by products such as dust, marble, fly ash, plastic waste, marble granules, silica fumes, blast furnace, slag, etc. which requires less amount of energy and it is also less harmful to environment. Green Concrete is capable for sustainable development by the application of industrial waste to reduce the consumption of natural resources and energy etc. Use of such materials saves approximately 20% of cements. Thus, green concrete is an excellent substitute of cement as it is cheaper, due to which it is made up of waste products, saving energy. Green Concrete has greater strength & durability compared to normal concrete. The performance of concrete containing brick dust was compared to the control samples developed for this investigation. In all concrete samples, the water-cement ratio was standardized at 0.65.To fulfill the study's goal, brick dust was crushed and added to the concrete mixture to substitute cement in varying proportions of 0%, 5%, 10%, and 15%. Workability and compressive strength testing were carried out in the laboratory for 7, 14, and 28 days. The results show that a 10% replacement proportion of brick dust in concrete over 28 days of curing enhanced the compressive strength of the concrete when compared to control specimens and laboratory testing. The results of the testing of the material, compressive strengths, Durability Properties, Structural Behavior of the of Rice husk Ash concrete, Fly Ash concrete, Brick Dust concrete and variations in the respective weights of the cubes with the changing proportions. This paper analyzes the durability properties of green concrete with industrial wastes and agri wastes.

Keywords: Green Concrete, aggregates, sustainability, durability, fly ash, Rice husk ash, brick dust, supplementary cementious materials, industrial wastes, agricultural waste, construction industries, carbon dioxide emissions

1. Introduction

Concrete which is made from concrete wastes that are eco-friendly are called as “Green concrete”. Green concrete is the production of concrete using as many as recycled materials as possible and leaving the smallest carbon footprint as possible. The other name for green concrete is resource saving structures with reduced environmental impact for e.g. Energy saving, co2 emissions, waste water. “Green concrete” is a revolutionary topic in the history of concrete industry. This was first invented in

Denmark in the year 1998 by Dr. WG.Concrete wastes like slag, power plant wastes, recycled concrete, mining and quarrying wastes, waste glass, incinerator residue, red mud, burnt clay, sawdust, combustor ash and foundry sand. Green Concrete is a term given to a concrete that has had extra steps taken in the mix design and placement to insure a sustainable structure and a long-life cycle with a low maintenance surface e.g. Energy saving, CO2 emissions, waste water. The goal of the Centre for Green Concrete is to reduce the environmental impact of concrete. To enable this, new technology is developed.

Fly Ash(FA),Rice Husk Ash(RHA) and Brick Dust(BD) materials used concrete is discussed in this paper.The objective of this paper is to the scope for the use of Brick Dust and Rice Husk Ash in to reduce the amount of cement in concrete for the construction work. This is done via material testing of concretes with various percentage of replacement of cement by Fly Ash from Reliance power plant and Rice Husk Ash and Brick Dust. the results of the testing of the material, compressive strengths, Durability Properties, Structural Behavior of the of Rice husk Ash concrete, Fly Ash concrete, Brick Dust concrete and variations in the respective weights of the cubes with the changing proportions. the scope of use of Rice Husk Ash and Brick Dust as a replacement of a percentage of cement in concrete instead of Fly Ash which summarize the whole experiment, results and finding of this study as well as possibilities for future work.

2. Literature Review

Studies with Green Concrete

In 2016, Praveer Singh, et al after studying about silica fume he concluded that increased usage and demand of cement at present times, cement has become a vulnerable resource all over the world. silica fume as a pozzolana material is rapidly used. Silica fume improves both the fresh and hard properties of concrete when mixed in suitable and proper proportions. Adding of silica fume in proper proportion improves durability attack by acidic waters.

In 2018, Dr. Pulkit Gupta , Ankit Laddha - Green Concrete is that type of concrete that is used to create the construction materials having a lesser effect on the environment. This version of concrete is made up from the mix of the industrial waste and inorganic polymer. The most commonly way to produce green concrete is by using the industrial waste products such as fly ash, blast furnace slag, and cement mixture. This means concrete that uses less energy in its production & produces less carbon dioxide than normal concrete is green concrete

In 2021, Abathar Al-Hamrani,Murat Kucukvar,Wael Alnahhal, Elsadig Mahdi and Nuri C. Onat, A primary concern of conventional Portland cement concrete (PCC) is associated with the massive amount of global cement and natural coarse aggregates (NCA) consumption, which causes depletion of natural resources on the one hand and ecological problems on the other. As a result, the concept of green concrete (GC), by replacing cement with supplementary cementitious materials (SCMs) such as ground granulated blast furnace slag (GGBFS), fly ash (FA), silica fume (SF), and metakaolin (MK), or replacing NCA with recycled coarse aggregates, can play an essential role in addressing the environmental threat of PCC.

In 2021, Nachiket1 Dr. J N Vyas, To compare conventional concrete and green concrete in terms of its workability and strength. The use of various materials like fly ash, GGBS, quarry dust, broken bricks etc in concrete helps in minimizing the resources consumption used to develop the conventional concrete and provide benefits like improved strength and workability of concrete with useful disposal of by-products. This type of concrete will also used to control the energy consumption and will able to minimize the hazards caused to the environment.

Studies with Fly Ash

(Alvin Harison, 2014) Investigated out to study the utilization of non-conventional building material (fly ash) for development of new materials and technologies. It is aimed at materials which can fulfil the expectations of the construction industry in different areas. In this study, cement has been replaced by fly ash accordingly in the range of 0% (without fly ash), 10%, 20%, 30%, 40%, 50% and 60% by weight of cement for M-25 mix with 0.46 water cement ratio. Concrete mixtures were produced, tested and compared in terms of compressive strength. It was observed that 20% replacement Portland Pozzolana Cement (PPC) by fly ash strength increased marginally (1.9% to 3.2%) at 28 and 56 d respectively. It was also observed that up to 30% replacement of PPC by fly ash strength is almost equal to referral concrete after 56 d. PPC gained strength after the 56 d curing because of slow hydration process.

(Suhendro Trinugroho, Ammar Abyan Alkatiry, 2023) A review of existing research on Nano Fly Ash (NFA) aims to show that using Nano Fly Ash (NFA) on High Volume Fly Ash Concrete is possible. The application can have an impact on durability improving concrete strength. The higher the compressive strength of the concrete, the more Nano Fly Ash (NFA) is utilized as a partial replacement for cement. The goal of this literature review is to determine how the addition of nano fly ash to high volume fly ash can be accelerated during the manufacturing process.

Studies with Rice Husk Ash

Ramakrishnan S, Velrajkumar G, Ranjith S R.S. Publication (January 2014),This paper explain the behavior of concrete for pavement replacing different percentages of ashes hush up by weight of cement for concrete quality control mixture M40. To study the effect of the rice husk ash (RHA) on the performance of various concrete parameters to produce an economic concrete for rigid pavements. An attempt was made to use the bending strength of concrete reaches in the design of the rigid floor which is greater than the resistance to bending about the necessary IRC: 58-2002

Studies with Brick Dust

Aggregate Prithvi Pati et. Al (2022) - In order to better understand the background and relevant research in the field of employing waste materials in the production of concrete, the study "Utilisation of Waste Bricks as Substituent of Fine Aggregate" conducted a literature review. The study focuses on replacing some of the fine aggregate in concrete with crushed brick detritus. It draws attention to the expanding concern regarding environmental sustainability in the construction industry as a result of the depletion of natural resources and the rising amount of waste produced by construction and demolition operations.

Tugci Busra et. al (2023)- The study of expansive soil using brick dust as a stabiliser led to a notable decrease in the soil's behaviour related to swelling and shrinking. The soil's plastic limit and shrinkage limit increased when marble dust was added as a stabilising agent, but its liquid limit, plasticity index, and shrinkage index fell. The engineering characteristics and behaviour of the expansive soil were enhanced by the addition of brick dust at a rate of 50% of the soil's dry weight. The soil's swelling and shrinking decreased when compared between 100% black cotton soil and a mixture of 50% black cotton soil and 50% brick dust.

3. Materials

Concrete Making Materials

There are many types of concrete available, created by varying the proportions of the main ingredients below. By varying the proportions of materials, or by substitution for the cement and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties. The mix design depends on the type of structure being built, how the concrete will be mixed and delivered, and how it will be placed to form this structure.

Cement

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 43 grade (Jaypee OPC) conforming to IS:8112-1989 is used. Many tests were conducted on cement; some of them are specific gravity, consistency tests, setting time tests, compressive strengths, etc. (IS8112, 2013)

Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.46 for M20, 0.42 for M25, 0.38 for M30 concretes. Combining water with a cementitious material forms a cement paste by the process of hydration.

Reaction: Cement chemist notation: $C_3S + H \rightarrow C\text{-}S\text{-}H + CH$

Standard notation: $Ca_3SiO_5 + H_2O \rightarrow (CaO).(SiO_2).(H_2O)(gel) + Ca(OH)_2$

Balanced: $2Ca_3SiO_5 + 7H_2O \rightarrow 3(CaO).2(SiO_2).4(H_2O)(gel) + 3Ca(OH)_2$

Aggregates

Fine and coarse aggregate make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are mainly used for this purpose. Recycled aggregates (from construction, demolition and excavation waste) are increasingly used as partial replacements of natural aggregate, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.

Chemical Admixtures

Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement, and are added to the concrete at the time of batching/mixing.

Fly Ash

Fly Ash used was taken from L&T plant which is bought and brought from Reliance power plant in Rosa, Uttar Pradesh with a density of 746kg/m3

Brick Dust

Brick Dust was collected from the fields of Brick Kilns. The brick waste collected was then ball grinded. After grinding Brick Dust was sieved from 300µ sieve and the portion which passed from the sieve was used in the experiment. Density measured were 1542kg/m3.

Rice Husk Ash

Rice Husk taken was burnt in the gasifier plant in G.S.K. Bharat pvt limited under a controlled burning of 600-800 degree celcius and then the residue ash was ball grinded to a fine powder. After grinding Rice Husk Ash was sieved from 300µ sieve and the portion which passed from the sieve was used in the experiment. Density measured was 167kg/m3.

4. Methodology

Mix Proportion Designation

The common method expressing the proportion of ingredients of a concrete in the terms of parts of ratios of cement, fine and coarse aggregates. For e.g. a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4. The proportions are either by volume or by mass.

Factors to Be Considered For Mix Design

The design of concrete mix will be based on the following factors:

Table 1: Grades of Concrete ((IS456, 2000) clause 6.1)

Grade Designation	Specified Characteristic Compressive Grade Designation Strength In N/Mm2 At 28 Days Curing
M10	10
M15	15
M20	20
M25	25
M30	30
M35	35
M40	40
M45	45
M50	50
M55	55
M60	60

In the designation of a concrete mix M refers to the mix design and the number to the specified characteristic compressive strength of 15 cm3 cube at 28 days curing expressed in N/mm2. M 15 and less grades of concrete may be used for lean concrete bases and simple foundation for masonry walls. Grades of concrete lower than M 20 shall not be used in reinforced concrete structure as per 456-2000. Grades of concrete lower than M 30 shall not be used in pre stressed concrete structure. (IS456, 2000).

i. Maximum nominal size of aggregate: It is found that larger the size of aggregate, smaller is the cement requirement for particular water cement ratio. Aggregates having a maximum nominal size of 20mm or smaller are generally considered satisfactory.

ii. Minimum water-cement ratio: The minimum w/c ratio for specified strength depends on the type of cement.

iii. Workability: The workability of concrete for satisfactory placing and compaction is related to the size and shape of the section to be concreted.

Target Mean Strength

Considering the inherent variability of concrete strength during production it is necessary to design the mix to have a target mean strength which is greater than characteristic strength by a suitable margin.

$ft = fck + 1.65 \times S$

where,ft = Target mean strength fck = Characteristic strength S = Standard deviation of the particular mix which is available in IS 456-2000. The value of k is equal to 1.65 as per IS 456-2000 where not more than 5% of the test results are expected to fall below the characteristics strength.

Table: 2 Assumed Standard Deviation (S) (IS10262, Concrete mix proportioning, 2009) clauses 3.2.1.2, A-3 and B-3)

Grade of Concrete	M10	M15	M20	M25	M30	M35	M40	M50
Standard Deviation (N/mm^2)	3.5	3.5	4.0	4.0	5.0	5.0	5.0	5.0

Procedure

i. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day fck and the level of quality control.

ft = fck + 1.65 S

Where S is the standard deviation obtained from the table of approximate content given after the design mix.

ii. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water-cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in Table and adopt the lower of the two values.

iii. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

iv. Select the water cement, for the required workability and the maximum size of aggregates (for aggregates in saturated surface dry condition) from table.

v. Determine the percentage of fine aggregates in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

vi. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate, the values are given in table.

vii. Calculate the cement content from the water cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

viii. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps F and G above, calculate the content of coarse and fine aggregate per unit volume of concrete from the following relations:-

V=[W+C/SC+1/P fa/Sfa]X 1/1000

V=[W+C/SC+1/(1-P) Ca/Cca]X 1/1000

Where V = Absolute volume of concrete

= Gross volume (1 m3) minus the volume of entrapped air

Sc = Specific gravity of cement

W = Mass of water per metre cube of concrete, in kg

C = Mass of cement per metre cube of concrete, in kg

p = Ratio of fine aggregate to total aggregate by absolute volume

fa, Ca = Total masses of coarse and fine aggregates, per cubic metre of concrete respectively, in kg

Sfa, Sca = Specific gravities of saturated surface dry fine and coarse aggregates respectively.

ix. Determine the concrete mix proportions for the first trial mix.

x. Prepare the concrete using the calculated proportions and cast three cubes of 150mm size and test them wet after 28-days moist curing and check for the strength.

Various tests carried out for mix design like Determination of Fineness of Cement ,Determination of Normal Consistency for Cement, Determination of Setting Time of Cement, Determination of Compressive Strength of Cement, Determination of Silt Content in Fine Aggregates, Determination of Bulking of Sand, Determination of Particle Size Distribution of Fine Aggregates By Sieve Analysis, Determination of Specific Gravity Index of Aggregates, Determination of Water Absorption of Aggregates are tested and compared to standards.

Design Mix for M25 Grade Concrete

A mix M25 grade was designed as per (IS10262, Concrete Mix Design, 2009) and the same was used to prepare the test samples.

A. Data for mix proportion:

The following data are required for mix proportion of a particular grade of concrete:

i. Grade designation. ii. Type of cement. iii. Maximum nominal size of aggregate.

iv. Minimum cement content. v. Maximum water cement ratio. vi. Workability.

vii. Exposure condition as per table 4 and 5 of IS 456. viii. Max temperature of concrete at the time of placing. ix. Method of transporting and placing. x. Early age strength requirements, if required.

xi. Type of aggregate. xii. Max cement content.

B. Target strength of mix proportioning:

Target mean compressive strength f'_{ck} is given by:

$f'_{ck} = f_{ck}+1.65s$ (IS10262, Concrete Mix Design, 2009),3.2

where

f'_{ck} = Target mean compressive strength at 28 days in N/mm^2

f_{ck} = Characteristic compressive strength at 28 days strength in N/mm^2

S = Standard deviation N/mm^2

C. Concrete mix proportion:

$f'_{ck} = f_{ck}+1.65s = 25+1.65*4$

(IS10262, Concrete Mix Design, 2009) clauses 3.2.1.2, A-3 and B-3)= 31.60N/mm^2

D. Calculation of water content:

W/C= 0.42

Water content for 25-50 mm slump = 186 liters (IS10262, Concrete Mix Design, 2009)clause 4.2, A-5 and B-5)

Water content for 120 mm slump = 186+6/120*186

= 195 liters

E. Calculation of cement content:

W/C = 0.42 Cement content = 195/0.42 = 465 kg.465>300 (ok) (IS456, 2000)

F. Proportioning of coarse and fine aggregate:

From table 3 of ((IS10262, Concrete Mix Design, 2009) table-5) volume of coarse aggregate for 0.5 W/C = 0.62 Present W/C = 0.42 Therefore volume of coarse aggregate need to increase to decrease fine aggregate by 0.08 The coarse aggregate increase by the formula: +- 0.01 for every +- 0.05 change of W/C ratio Coarse aggregate for 0.42 W/C ratio = 0.016+0.62 = 0.636 For pump able reduce by 10% Volume of coarse aggregate = 0.636*0.9 = 0.57 Volume of fine aggregate = 1-0.57 = 0.43

G. Mix calculation:

a) Volume of concrete = 1 m^3 b) Volume of cement = Mass/sp.gravity*1/1000 = 465/3.15*1/1000 = 0.14 m^3 c) Volume of water = Mass/ sp. gravity* 1/1000 = 195/1000 = 0.195 m^3 d) Volume of all aggregate = 1- (0.14+0.195) e = 0.665 m^3 e) Mass of coarse aggregate = e*volume of coarse*sp.gravity*1000 = 0.665*0.57*2.88*1000 = 1092 kg f) Mass of fine aggregate = e*volume of fine*sp.gravity*1000 = 0.665*0.43*2.65*1000 = 758 kg

H. Mix proportion:

Cement = 465 kg Water = 195 liters Fine aggregate = 758 kg Coarse aggregate = 1092 kg W/C ratio = 0.42 **Ratio = 1:1.63:2.35**

Table: 3 design mix proportion for M25 Grade Concrete replacing Fly Ash

Grade	W/C	% Replaced	Cement (kg)	Fly Ash(FA) (kg)	FA (kg)	CA (Kg)		Water (Kg)	Slump (mm)	No.of Cubes
						20mm	12.5mm			
M25	0.42	0%	24.742	0	40.82	16.33	38.102	10.39	120	12
		5%	23.505	1.237	40.82	16.33	38.102	10.39	120	12
		10%	22.268	2.474	40.82	16.33	38.102	10.39	120	12
		15%	21.03	3.711	40.82	16.33	38.102	10.39	110	12
		20%	19.794	4.948	40.82	16.33	38.102	10.39	105	12
		25%	18.556	6.186	40.82	16.33	38.102	10.39	100	12
		30%	17.319	7.423	40.82	16.33	38.102	10.39	100	12
		35%	16.082	8.660	40.82	16.33	38.102	10.39	95	12
		40%	14.845	9.897	40.82	16.33	38.102	10.39	90	12

Table: 4 design mix proportion for M25 Grade Concrete replacing Brick Dust

Grade	W/C	% Replaced	Cement (kg)	Brick Dust (BD) (kg)	FA (kg)	CA (Kg)		Water (Kg)	Slump (mm)	No.of Cubes
						20mm	12.5mm			
M25	0.42	0%	24.742	0	40.82	16.33	38.102	10.39	120	12
		5%	23.505	1.237	40.82	16.33	38.102	10.39	120	12
		10%	22.268	2.474	40.82	16.33	38.102	10.39	120	12
		15%	21.03	3.711	40.82	16.33	38.102	10.39	110	12
		20%	19.794	4.948	40.82	16.33	38.102	10.39	105	12
		25%	18.556	6.186	40.82	16.33	38.102	10.39	100	12
		30%	17.319	7.423	40.82	16.33	38.102	10.39	95	12
		35%	16.082	8.660	40.82	16.33	38.102	10.39	90	12
		40%	14.845	9.897	40.82	16.33	38.102	10.39	80(0.6)	12

(0.6) Refers that to maintain the slump of 80-120, 0.6% Superplastisizer was used

Table: 5 design mix proportion for M25 Grade Concrete replacing Rice Husk Ash

Grade	W/C	% Replaced	Cement (kg)	Rice Husk Ash (RHA) (kg)	FA (kg)	CA (Kg) 20mm	CA (Kg) 12.5mm	Water (Kg)	Slump (mm)	No.of Cubes
M25	0.42	0%	24.742	0	40.82	16.33	38.102	10.39	120	12
		5%	23.505	1.237	40.82	16.33	38.102	10.39	120	12
		10%	22.268	2.474	40.82	16.33	38.102	10.39	120	12
		15%	21.03	3.711	40.82	16.33	38.102	10.39	110	12
		20%	19.794	4.948	40.82	16.33	38.102	10.39	100	12
		25%	18.556	6.186	40.82	16.33	38.102	10.39	90	12
		30%	17.319	7.423	40.82	16.33	38.102	10.39	80(0.5)	12
		35%	16.082	8.660	40.82	16.33	38.102	10.39	80(0.7)	12
		40%	14.845	9.897	40.82	16.33	38.102	10.39	80(1)	12

(0.5), (0.7), (1) Refers that to maintain the slump of 80-120, 0.5% , 0.7% and 1% Superplastisizer was used

Cube Moulds: (As per IS: 516 – 1959)

The mould shall be of metal, preferably steel or cast iron, and stout enough to prevent distortion. It shall be constructed in such a manner as to facilitate the removal of the moulded specimen without damage, and shall be so machined that, when it is assembled ready for use, the dimensions and internal faces shall be accurate within the following limits: The height of the mould and the distance between opposite faces shall be the specified size + 0.2mm. The angle between adjacent internal faces and between internal faces and top and bottom planes of the mould shall be 900+ 0.50. The interior faces of the mould shall be plane surfaces with a permissible variation of 0.03 mm. Each mould shall be provided with a metal base plate having a plane surface. The base plate shall be such dimensions as to support the mould during the filling without leakage and it shall be preferably attached to the mould by spring or screws. The parts of the mould when assembled shall be positively and rigidly held together, and suitable methods of ensuring this, both during the filling and on subsequent handling of the filled mould shall be provide. The interior surfaces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the concrete.

Figure 1:Concrete Casted in Moulds

Durability Properties

The factors which influence the deterioration of concrete are saturated water absorption, sorptivity, corrosion, acid attack and chloride ion penetration. The important factor governing concrete durability is saturated water absorption and gas and ion penetration which depend on the microstructure, porosity and the permeability of the cement paste. Corrosion of reinforcement in concrete is the most common cause of deterioration in aggressive environment.

Rice husk is an agricultural residue which accounts for 20% of the 649.7 million tons of rice produced annually worldwide1. The produced partially burnt husk from the milling plants when used as a fuel also contributes to pollution and efforts are being made to overcome this environmental issue by utilizing this material as a supplementary cementing material. The chemical composition of rice husk is found to vary from one sample to another due to the differences in the type of paddy, crop year, climate and geographical conditions.Sulphate Attack, Chloride Ion Penetration, and Freezing and Thawing Sulphate Content Test, Chloride Ion Penetration,Chloride Test and Freeze-thaw test are carried out.

Molding Specimens

All concretes were molded and compacted on a vibration table in the following forms: Cubes with sides of 100 mm and cubes with sides of 150 mm. After 24 h, all specimens were demolded and then stored in a climatic chamber (RH = 100%, T = 20 _C) for 27 days, according to EN 12390-2 . Then,the specimens were prepared for the following tests: Oven-dried density; density under saturated conditions; water absorption; compressive strength under oven-dried and saturated conditions; the depth of water penetration under pressure; and freeze-thaw resistance. The tests conducted, the types of concrete specimens and their number, the concrete age for the tests, and the standard test procedures are listed in below Table. Additionally, for comparison reasons, for some tests, reference specimens of plain mortars of w/c = 0.55 (matrix 1) and 0.37 (matrix 2), which were used as cement matrixes for both concrete series 1 and 2, were employed.

Table 6: Test type, time,specimen type and number of tests.

Test	Specimens	Specimens Qty	Concrete Age
Density	Cube 150 mm	3	28 days
Compressive Strength	Cube 150 mm	6	28 days
Water Permeability	Cube 150 mm	6	28 + 7 days
Water Absorption	Cube 150 mm	3	28 days
Freeze-Thaw Resistance	Cube 150 mm	10	28 + 7 days

Rice Husk Ash Concrete

For Rice Husk Ash concrete durability properties was tested by Saturated Water Absorption and Porosity, Rapid Chloride Permeability Test, Acid Attack Test, Alkaline Attack Test and Sulfate Attack Test .

Brick Dust Concrete

For Brick Dust concrete durability properties was tested by Rapid Chloride Penetration Test (RCPT), Water Permeability of Concrete (WP),Initial Surface Absorption Test (ISAT) and Water Absorption (WA).

Structural Properties

The Structural properties of concrete include compressive strength, tensile strength, flexural strength, elasticity, permeability and hardness.

The following tests were carried out in accordance with relevant BS Standards.

1. The aggregates were tested for physical properties such as: specific gravity, Particle distribution test and bulk density.

2. The fresh concrete was subjected to the following tests.
(i) Slump Test
While the following properties were tested in the hardened state of the concrete.
(i) Density test
(iii) Compressive strength test.
(iv) Flexural strength test
(v) Split tensile test.

5. Results and Discussion

Durability Properties

Rice Husk Ash

Saturated Water Absorption

Saturated Water Absorption (SWA) is a measure of the pore volume or porosity in hardened concrete, which is occupied by water in saturated condition. The test results of saturated water absorption of concrete with and without superplasticizers for various percentages of rice husk ash are shown in **Tables 7 and 8**. SWA values for 0, 5, 10, 15 and 20% of rice husk ash as CRM are 1.62, 1.68, 1.74, 1.88 and 2.15% for M30 grade concrete mixtures without superplasticizer. But the addition of superplasticizer showed lesser SWA values up to 10% rice husk ash content.

Table 7 Saturated Water Absorption of M30 Grade Concrete Mixtures with and without RHA and SP

Sl.No	Mixing ID	RHA Content %	SP content by Weight of Binder (%)	Saturated Water Absorption @ 60 Days (%)	
				without SP	with SP
1	MR1	5	0.40	1.68	1.34
2	MR1	10	0.80	1.74	1.20
3	MR3	15	1.40	1.88	1.56
4	MR4	20	2.80	2.15	1.98

Porosity

The porosity test values of control concrete and different percentage of rice husk ash as CRM in concrete after 60 days are shown in Tables 8 and 9. From the results it is observed that the porosity value decreases as the percentage of replacement increases. The porosity values at 0, 5, 10, 15 and 20% rice husk ash contents 3.45, 3.90, 4.20, 4.50 and 4.70% respectively, for M30 concrete mixtures without superplasticizers. But the addition of superplasticizers showed the porosity values vary from 3.80 to 5.20% and 2.95 to 4.20% for M30 grade concrete mixtures, respectively, with SP.

Table 8 Porosity of M30 Grade Concrete Mixtures with and without RHA and SP

Sl.No	Mixing ID	RHA Content %	SP content by Weight of Binder (%)	Porosity@ 60 Days (%)	
				without SP	with SP
1	MR1	5	0.40	3.90	3.90
2	MR1	10	0.80	4.20	3.80

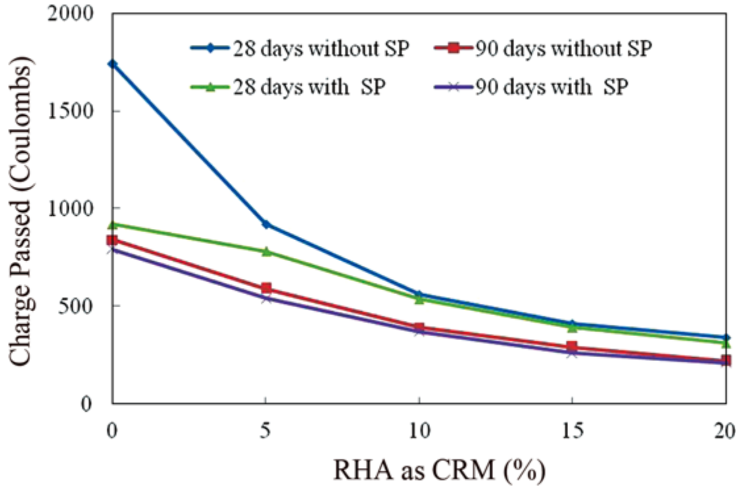
3	MR3	15	1.40	4.50	4.40
4	MR4	20	2.80	4.70	5.20

Rapid Chloride Permeability Test

RCPT is based on the principle that negatively charged chloride ions are attracted to a positive electrode and consists of measuring the total charge passed through a sample over the six hours test duration when a direct current potential difference of 60V is applied across the end of the samples. The quality of material is quantitatively assessed based on the total charge passed during the test, which is considered to be the measure of the chloride permeability of concrete. Test results for the resistance to penetration of chloride ions into concrete of 28 and 90 days after casting, measured in terms of the electric charges passed through the specimens in Coulombs for M30 grade concrete mixtures with and without SP are given in **Fig. 11** and **Fig. 12**. From the figures it is observed that most of the chloride ion permeability values fall in the range of very low (100-1000 Coulombs) category.

The charge passed through the M30 grade concrete mixtures without SP are 2420, 910, 675, 570 and 420 Coulombs at the age of 28 days and 1340, 720, 428, 380 and 290 coulombs, at the age of 90 days, respectively for the cement replacement levels of 0, 5, 10, 15 and 20%. But with the addition of SP, the values are 980, 740, 590, 470 and 380 Coulombs at the age of 28 days and 945, 640, 370, 290, 210 Coulombs at the age of 90 days respectively.

Fig. 2 Rapid Chloride Ion Permeability in M30 Grade Concrete with and without RHA and SP



Effect of Rice Husk Ash and Superplasticizers on Acid Resistance

The action of acids on hardened concrete is the conversion of calcium compounds into the calcium salts of the attacking acid. Hydrochloric Acid (HCl) with concrete produces calcium chloride. As a result of these reactions, the structure of concrete gets destroyed. For this test nine cubes were cast for each mix. All the cubes were cured normally for 28 days. Out of these 3 cubes were taken out and tested for their strength. Remaining six cubes were immersed in HCl solution for 60 and 90 days. At the end of 60 days the 3 cubes were taken out and tested for their strength. Similarly remaining cubes were tested at 90 days. The loss in compressive strength was worked out for each specimen. The loss of strength of concrete under HCl curing after 60 and 90 days as found to be 12.45, 8.75, 7.10, 6.80 and 5% after the immersion period of 60 days and 20.50, 17.40, 15.60, 13.00 and 10.00% at 90 days, respectively, for

M30 grade concrete with replacement level of 0, 5, 10, 15, and 20%. The addition of SP in M30 grade concrete mixtures show the loss of compressive strength of 10.50, 6.50, 5.80, 4.30 and 3.90% after the immersion period of 60 days and 18.00, 13.70, 11.50, 8.50 and 6.80 at 90 days, respectively, for the cement replacement levels of 0, 5, 10, 15, and 20%.

It has been found for M30 grade concrete, that there is a continuous increase in resistance up to 20% replacement of cement by RHA. The above behaviour found to be true with and without addition of SP and immersion period of 60 and 90 days.

Fig. 3 Loss in Weight for Acid Attack on M30 Grade Concrete with and without RHA and SP

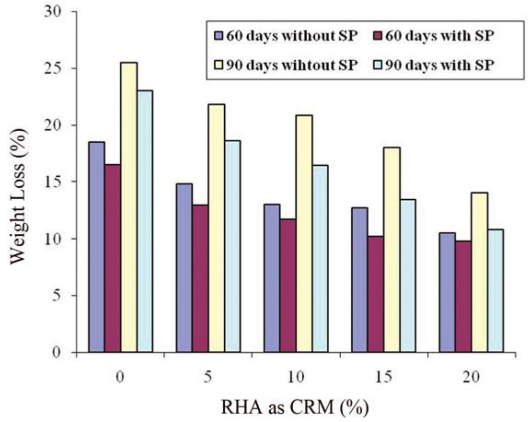


Table 9 Effect of Rice Husk Ash on Resistance against Acid Attack of M30 Grade Concrete Compared to Control Concrete

Sl.No	Mixing ID	RHA Content %	Dosage of SP (%)	Percentage of Resistance against Acid Attack			
				Concrete without SP		Concrete with SP	
				60 days	90 days	60 days	90 days
1	MR1	5	0.40	29.88	15.35	38.60	23.85
2	MR1	10	0.80	43.65	24.00	45.20	37.20
3	MR3	15	1.40	45.00	37.20	60.15	53.00
4	MR4	20	2.80	59.00	50.95	62.90	64.00

Effect of Rice Husk Ash and Superplasticizers on Alkaline Resistance

The results of alkaline resistance of concrete in terms of loss in compressive strength of M30 grade with and without SP and RHA are presented in **Tables 9 and 10**. In M30 grade concrete the loss of compressive strength for replacement of cement by rice husk ash content of 0, 5, 10, 15, and 20% are 12.00, 9.00, 7.90, 6.20 and 4.60% after the immersion period of 60 days and 17.00, 12.00, 9.00, 6.80 and 5.00% at 90 days, respectively, for the mixture without superplasticizers. The addition of superplasticizer shows the loss of compressive strength for replacement of cement by rice husk ash content of 0, 5, 10, 15, and 20% are 10.00, 8.70, 7.20, 5.30 and 3.20% after the immersion period of 60 days and 15.80, 10.00, 7.50, 5.90 and 4.10% at 90 days, respectively. The addition of superplasticizers shows much resistance against the alkaline attack. The weight loss and compressive strength loss due to alkaline attack of M30

Fig. 4 Loss in Weight for Alkaline Attack on M30 Grade Concrete with and without RHA and SP

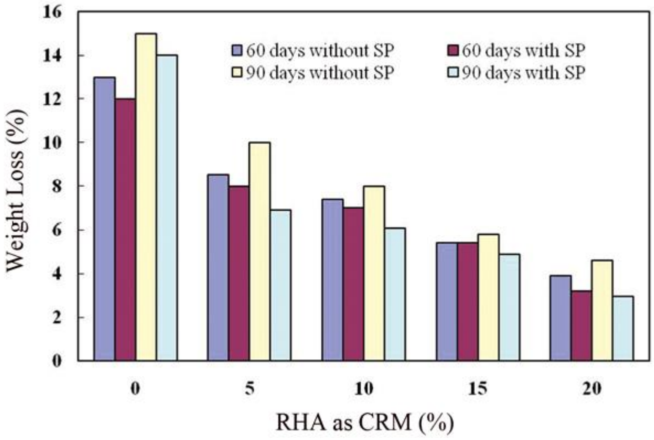


Table 10 Effect of Rice Husk Ash on Resistance against Alkaline Attack of M30 Grade of Concrete Compared to Control Concrete

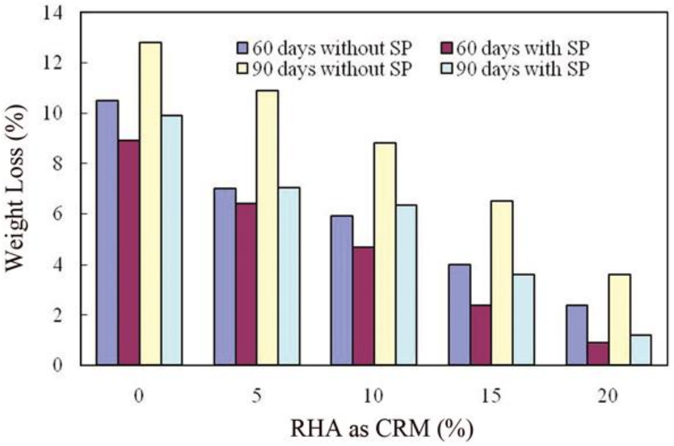
Sl.No	Mixing ID	RHA Content %	Dosage of SP (%)	Percentage of Resistance against Alkaline Attack			
				Concrete without SP		Concrete with SP	
				60 days	90 days	60 days	90 days
1	MR1	5	0.40	26.10	30.05	13.50	37.15
2	MR1	10	0.80	34.50	47.00	28.00	52.50
3	MR3	15	1.40	49.05	61.05	48.00	62.70
4	MR4	20	2.80	67.05	71.50	67.00	75.05

Effect of Rice Husk Ash and Superplasticizers on Sulphate Resistance

Sulphate attack is caused by the chemical reaction between sulphate and calcium hydroxide ($Ca(OH)_2$), forming gypsum. The gypsum may react with tricalcium aluminate (C_3A) in the concrete to form Ettringite and monosulphoaluminate. These reactions result in a substantial increase in volume with subsequent cracking and peeling. The sources of sulphate ion are seawater, sewage industrial waste, salts in ground water and delayed release of clinker. The reaction of rice husk ash with calcium hydroxide released during cemen thydration results in the formation of additional CSH and the accompanying reduction in permeability of the concrete. The effect of rice husk ash content on the sulphate resistance of concrete under continuous soaking condition was studied by replacement of rice husk ash from 0 to 20% in concrete mixtures.

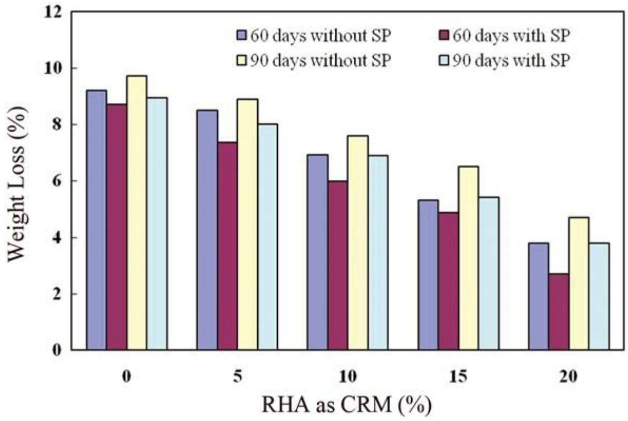
The loss in compressive strength decreases with increase of rice husk ash content. In M30 grade concrete the loss in compressive strength after the immersion period of 60 days and 90 days at sulphate solution are 9.50, 7.90, 6.00, 4.90 and 3% at 60 days and 11.20, 9.50, 7.50, 6.20 and 4.50% at 90 days without SP, respectively. But the addition of superplasticizer might improve the resistance against sulphate attack.

Fig. 5 Loss in Weight for Sulphate Attack under Continuous Soaking Condition on M30 Grade Concrete with and without RHA and SP



The loss in compressive strength in M30 grade concrete mixtures without SP are 9.20, 8.50, 6.90, 5.30 and 3.80% at 60 days and 9.70, 8.90, 7.60, 6.50 and 4.70% at 90 days, respectively, for 0, 5, 10, 15 and 20% of rice husk ash as a CRM in concrete mixes. The addition of SP improves the resistance due to sulphate attack. In M30grade concrete the loss in compressive strength of concrete with SP are 8.70, 7.30, 5.90, 4.80 and 2.70% at 60 days and 8.90, 8.00, 6.90, 5.40 and 3.80% at 90 days, respectively.

Fig. 6 Loss in Weight by Sulphate Attack under Cyclic Wet and Dry Condition on M30 Grade Concrete with and without RHA and SP



Conclusion

Being on organic and fibrous material rice husk ash .absorbs more water and hence necessity as addition of SP to improve the workability properties of RHA concrete. The increase in compressive strength for 5% and 10% of cement replacement by RHA are 4.10% and 5.00% at 28 days, respectively, for M30 grade concrete. The addition of superplasticizer shows a 9% higher compressive strength than the control concrete at the RHA content. The saturated water absorption was decreased when the mixture containing 10% RHA by 16.60% and 7.00% for M30 grade concrete, respectively, when compared to concrete.

Replacement of cement with Fly Ash, Brick Dust and Rice Husk Ash:

1. Fly Ash

The field test on fly ash showed that it is possible to use Fly Ash as a partial replacement upto 40% of cement to produce concrete that achieves desired strength for different grades of concrete(M20, M25, M30). Although compressive strength increased upto 5% replacement, then starts decreasing after replacing cement more than 5% as compared to conventional concrete.The following trends were identified by replacing cement by Fly Ash.

- **For M25** grade of concrete it was found that around 40-45% increase in strength from 7 days to 28 days, 5-6% increase in strength from 28 days to 90 days and around 7-8% increase in strength from 90days to 180 days.
- **For M30** grade of concrete it was found that around 35-40% increase in strength from 7 days to 28 days, 5-6% increase in strength from 28 days to 90 days and around 7-8% increase in strength from 90days to 180 days.

2. Brick Dust

The field test on Brick Dust showed that it is possible to use Brick Dust as a partial replacement upto 40% of cement to produce concrete that achieves desired strength for different grades of concrete(M20, M25, M30). Although compressive strength increased upto 10% replacement, then starts decreasing gradually after replacing cement more than 10% as compared to conventional concrete. The following trends were identified by replacing cement by Brick Dust.

- For M25 grade of concrete it was found that around 35-40% increase in strength from 7 days to 28 days, 4-5% increase in strength from 28 days to 90 days and around 4-5% increase in strength from 90days to 180 days
- For M30 grade of concrete it was found that around 35-40% increase in strength from 7 days to 28 days, 6-8% increase in strength from 28 days to 90 days and around 3-5% increase in strength from 90days to 180 days.

3. Rice Husk Ash

The field test on Rice Husk Ash showed that it is possible to use Rice Husk Ash as a partial replacement upto 40% of cement to produce concrete that achieves desired strength for different grades of concrete(M20, M25, M30). Although compressive strength increased upto 5% replacement, then starts decreasing gradually after replacing cement more than 10% as compared to conventional concrete. The following trends were identified by replacing cement by Rice Husk Ash.

- For M25 grade of concrete it was found that around 40-45% increase in strength from 7 days to 28 days, 6-7% increase in strength from 28 days to 90 days and around 6-7% increase in strength from 90days to 180 days.
- For M30 grade of concrete it was found that around 40-45% increase in strength from 7 days to 28 days, 4-6% increase in strength from 28 days to 90 days and around 3-4% increase in strength from 90days to 180 days.

Effect of Industrial Wastes on the Weight of Concrete

- Fly Ash: In Fly Ash concrete there was increase in the weight of the concrete upto 15% replacement of cement with Fly Ash, then there was a gradual reduction in the mass of the Fly Ash concrete after 15% replacement of cement. At 40% replacement of cement with Fly Ash mass reduced upto 4%.
- Brick Dust: In Brick Dust concrete there was increase in the weight of the concrete continuously and at 40 % replacement of cement with Brick Dust mass increased upto 4.6%.

- Rice Husk Ash: In Rice Husk Ash concrete there was decrease in the weight of the concrete continuously and at 40 % replacement of cement with Rice Husk Ash mass decreased upto 7%.

Economic Analysis

- The cost of Ordinary Portland Cement is about Rs.435/- for 50kg bag. The cost of cement per meter cube is around Rs 3900/- for M20 grade, Rs 5500/- for M25 grade and Rs.6500/- for M30 grade of concrete.
- The cost of Fly Ash is Rs 1/ kg, Rice Husk Ash and Brick Dust will be around 30paisa/ kg as Rice Husk Ash and Brick Dust is locally available material the transportation cost will reduce.
- Based on the result of the present study a 40% replacement of Fly Ash, Rice Husk Ash and Brick Dust is possible in concrete to achieve desired strength.With this level of substitution the price of Fly Ash concrete will reduce upto 33% and upto 40% in case of Brick Dust concrete and Rice Husk concrete.
- The durability and Structural properties of these concrete are so good.

6. Conclusion

The results show that it is possible to achieve desired strength in concrete by replacing cement up to 40% by Fly Ash, Brick Dust and Rice Husk Ash. The conclusion is as follows:

- Fly Ash and Brick Dust concrete shows more strength as compare to Rice Husk Ash concrete.
- Rice Husk Ash makes concrete light in weight as compared to Fly Ash and Brick Dust concrete. So it will be helpful in reducing dead load of the construction.
- Brick Dust makes concrete heavier so it will be helpful in using it in foundation work and making earthen dams etc where heavy weight is essential for the structure.
- There is 33-40% reduction in cost of concrete by using these industrial wastes (FA, RHA and BD).
- There is 7% reduction in the cost of concrete when using Rice Husk Ash and Brick Dust as compared to Fly Ash concrete.

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