International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Strength Characteristics of Concrete Using Eco-Friendly Materials

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Abstract: ***Utilization of industrial waste products in concrete is gaining importance all around the world. Replacement with supplementary materials will address two problems by reduce Greenhouse gases and cost effective rice husk is the outermost layer of paddy it contains 86.94% of SiO_2 and Hypo sludge is such an industrial waste produced in plenty by paper mills. Therefore, In this paper, the effect of rice husk ash and Hypo sludge on properties of Ordinary Portland Cement (OPC) Concrete of M25 grade are investigated with silica fume as powder along with cement. The test was carried out to evaluate the mechanical properties like compressive strength of 7 and 28 days.***

Keywords: Rice Husk Ash; Silica Fume; Hypo Sludge; Slump Test; Compressive Test.

1. Introduction

Natural resources are not unlimited therefore, they must be optimally consumed. The manufacturing of Ordinary Portland cement (OPC) which is the main ingredient of concrete but it releases a large amount of greenhouse gases specially CO_2. On the other side dumping of wastes produced from industries causes a major problem to environmental issues. This shall help not only to control degradation of environment but also the conserve them for the use of future generation. This can be achieved by the process of recycling and, making use of industrial wastes, disposal of which otherwise is a serious problem.

Rice Hush Ash (RHA) a local additive which has been investigated to be super pozzolanic in a good proportion to reduce the high cost of structural concrete. Rice Husk Ash (RHA) is obtained from an agricultural waste product. This material is actually a super pozzolan, since it is rich in Silica and has about 80% to 90% Silica content. A "pozzolan" is therefore defined as "a siliceous or siliceous and aluminum material, which itself possess little cementing property, but will in a finely divided form and in the presence of moisture chemically react with calcium hydroxide at certain temperatures to form compounds possessing cementite's properties. A good way of utilizing this material is to use it for making "high performance concrete" which means high workability and very high early strengths, or consider high workability and long term durability of the concrete.

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. Silica fume has been recognized as a pozzolanic admixture that is effective in greatly enhancing mechanical properties. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO_2).The addition of silica fume to concrete improves the latter's durability by reducing permeability and refining pore structure, leading to a reduction in the diffusion of harmful ions and the calcium hydroxide content, resulting in greater resistance to sulfate attack.

Over 300 million tons of waste produced per annum in India in the form of chemical and agricultural waste. Paper making industries generally produces a large amount of solid waste. This paper mill sludge consumes a large percentage of local landfill space for each and every year.

Benefits of Hypo Sludge

- Hypo sludge improves the properties of fresh and hardens concrete.
- Hypo sludge reduces degradation and bleeding.
- Hypo sludge improves the durability of concrete.
- Environmental friendly.
- Light weight compare to conventional concrete.
- Hypo sludge is the cheaper substitute to OPC.
- Hypo sludge improves the setting of concrete due to presence of silica and magnesium.
- Use of hypo sludge in construction of rigid pavement.

Limitations of Hypo Sludge

- Availability
- Handling problem

Chemical reactions involved in partially replaced in concrete

1. Primary Hydration

$$\text{Cement} + \text{Water} \longrightarrow \text{C-S-H (gel)} + Ca(OH)_2$$

2. Secondary Hydration

Here rice husk ash, silica fume and hypo sludge acts as a pozzolana

$$Ca(OH)_2 + \text{Pozzolana} \longrightarrow \text{C-S-H (gel)}$$

Increase in amount of C-S-h gel increase the compressive strength but only up to a certain extent.

2. Literature Review

R.Srinivasan, K.Sathiya & M. Palanisamy reported on "Experimental investigations in developing low cost concrete from paper industry waste". Over 300 million tons of industrial wastes are being produced per annum by chemical and agricultural process in India. These materials pose

problems of disposal and health hazards. The wastes like phosphor gypsum and red mud contain obnoxious impurities which adversely affect the strength and other properties of building materials based on them.

A Balwaik & SP Raut reported on "Utilization of waste paper pulp by partial replacement of cement in concrete". The use of paper-mill pulp in concrete formulations was investigated as an alternative to landfill disposal. The cement has been replaced by waste paper sludge accordingly in the range of 5% to 20% by weight for M-20 and M-30 mix. By using adequate amount of the waste paper pulp and water, concrete mixtures were produced and compared in terms of slump and strength with the conventional concrete.

S Selvarani reported on "Structural performance of concrete by partial replacement of concrete with hypo sludge". It is concluded that the waste material from paper industry can be used as a replacement for cement. It is found that 20% replacement of cement by industrial waste give maximum result in strength and quality aspects than the conventional concrete. The results are proved that the replacement of 20% of cement by the paper waste induced compressive strength and split tensile strength is higher. Thus the environmental effects from the industrial waste can be significantly reduced and also the cost of cement can be reduced a lot by the replacement of this waste material for hypo sludge.

Kartini & Mahmud reported on the "Improvement on Mechanical Properties of Rice Husk Ash Concrete with Super plasticizer". Without super plasticizer RHA concrete attained lower compressive strength than that of the control due to the higher amount of water for similar workability. RHA concrete improves the durability of concrete. It is concluded from the paper that by adding super plasticizer to the RHA mixes, higher replacement levels are possible. Concrete containing up to 30%RHA can attain strength of 30 N/mm2 at 28 days.

Maurice & Godwin reported on "Investigated the effects of partially replacing OPC with RHA". It is concluded that Adding RHA to concrete resulted in increased water demand, increase in workability and enhanced strength compared to the control sample. This results show that an addition of RHA from 5-10% will increase the strength.

H. Katkhuda, B. Hanayneh & N. Shatarat reported on "The effects of silica fume on compressive strengths on high strength lightweight concrete". They carried out by replacing cement with different percentages of silica fume at different constant water-binder ratio keeping other mix design variables constant. The silica fume was replaced by 0%, and 8% for a water-binder ratios ranging from 0.26 to 0.42. For all mixes, compressive strength was determined at 7& 28 days. The results showed that the compressive strengths increased with silica fume incorporation but the optimum replacement percentage is not constant because it depends on the water cementitious material (w/c) ratio of the mix. Based on the results, a relationship between compressive strengths of silica fume concrete was developed using statistical methods.

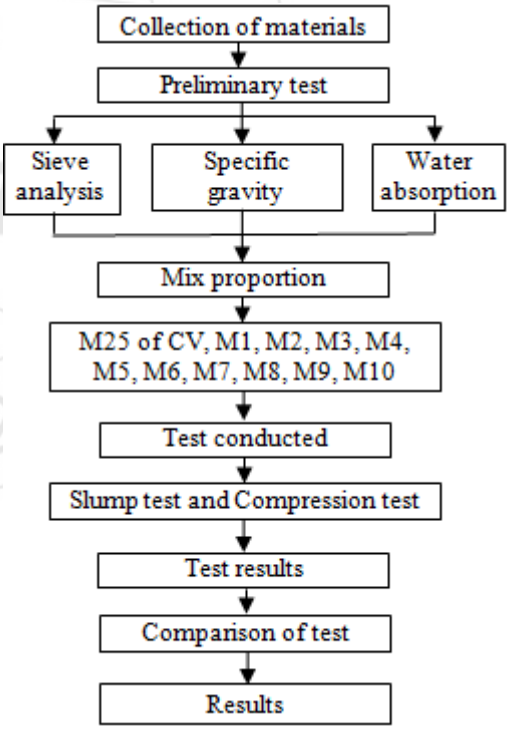
3. Significance of the work

The cost cement is more expensive and is not eco-friendly. One ton of cement producing one ton of Greenhouse gases. Replacement with supplementary materials will address two problems by reducing Greenhouse gases and cost effective. By recycling the waste materials with cement we can decrease optimum amount of waste. In some cases the concrete will allows water from one surface to another. The waste materials produced by industry like hypo sludge, rice husk ash, fly ash, silica fume, etc., can be replaced with cement with suitable proportions. Hypo sludge is easily adopted in field. It minimizes the maximum degradation in environmental due to cement and safeguard the ozone layer from Greenhouse gases. Rice husk ash is a material which can improves compressive strength, flexural strength and split tensile strength of concrete. Rice hush ash makes a role to increased resistance to chemical attack. For every construction projects workability plays an important role for that particular problem silica fume will increases the workability.

4. Materials and Methods

4.1 Methodology

The methodology of the work is given in flow



4.2 Materials

1) ***Cement:*** Ordinary Portland cement of 53 grades, with Specific gravity 3.15.
2) ***Fine Aggregate:*** Locally available natural river sand confirming to grading zone-II (IS 388-1970) with specific gravity 2.65 was used as fine Aggregate.
3) ***Coarse Aggregate:*** Crushed granite confirming to IS: 383-1970, consisting of 20 mm maximum size of

aggregates and with specific gravity 2.67, was obtained from the local quarry.

Table 1: Physical properties of aggregates

Physical properties	*Fine aggregate*	*Coarse aggregate*
Specific gravity	2.6	2.55
Fineness modules	2.9	-
Water absorption (%)	1.8	0.50
Maximum size (mm)	4.75	20
Bulk density (kg/m^3)	1520	1575
Sand equivalent (%)	83	-

iv) *Rice Husk Ash:* Rice Husk was burnt for approximately 48hrs in an open air and uncontrolled burning process. The temperature was in the range of 400-600 C. The ash collected was sieved through BS standard sieve size 75µm and its color was grey. Batching was done by volume at replacement percentages of 5 & 10%.

Table 2: Chemical properties of Rice husk ash

Ingredients	*% in Rice husk ash*
SiO_2	89.94
Al_2O_3	0.2
Fe_2O_3	0.1
CaO	2
MgO	0.4
Igneous	2.4

v) Hypo Sludge: Hypo sludge is also known as paper industry waste. It is the by-product of the paper waste. This hypo sludge contains low calcium and minimum amount of silica. Hypo sludge behaves like cement because of silica and magnesium properties. Hypo sludge may be used as part replacement of cement. It is usually used in proportion of percent of cement content of the mix.

Table 3: Chemical properties of Hypo sludge

Ingredients	*% in Hypo sludge*
Moister	56.80
CaO	46.20
MgO	3.3
SiO_2	9.00
R_2O_3	3.6
Igneous	27

vi) *Silica Fume:* Silica fume particles are extremely small; with more than 95% of the particles being less than 1 µm. particle size is extremely important for both the physical and chemical properties of silica fume of concrete.

Table 4: Chemical properties of Silica fume

Ingredients	*% in Rice husk ash*
SiO_2	92.08
Al_2O_3	1.16
Fe_2O_3	1.24
CaO	1.07
MgO	0.84
SO_3	1.27
Igneous (K_2O, Na_2O)	1.80

5. Mix Design of M-25 Concrete

Design Stipulations:
Characteristic Compressive Strength required at the end of 28 days: 25
N/mm2 Maximum size of Aggregate: 20mm
Type of Exposure: Severe
Degree of quality Control: Good

Test Data for Materials:
Specific Gravity of Cement: 3.15
Specific Gravity of Coarse Aggregate: 2.70
Specific Gravity of Fine Aggregate: 2.65
Specific Gravity of RHA: 2.280
Specific Gravity of Silica Fume: 2.20
Specific Gravity of Hypo Sludge: 2.82

Target Mean Strength of Concrete:
For a tolerance factor of 1.65, the obtained target means strength for the given grade of concrete
= 25 + 4 x1.65 = 31.6 N/mm2**.**

Selection Cement Ratio:
The free water cement ratio for the obtained target mean strength is 0.42. This is equal to the value prescribed for moderate condition in IS 456-2000.

Table 5: Mix proportion

	Water	*Cement*	Fine	*Coarse*
By weight (kg)	0.5	1.31	2.4	3.91
By volume	0.38	1	1.83	2.98

Table 6: Percentage replacement materials

Sl.no	*Typo of mix*	*Silica fume (%)*	*RHA (%)*	*Hypo sludge*	*Cement (%)*
1.	CV	-	-	-	100
2.	M1	5	-	-	95
3.	M2	5	5	-	90
4.	M3	5	5	5	85
5.	M4	5	5	10	80
6.	M5	5	10	5	80
7.	M6	5	5	15	75
8.	M7	5	10	10	75
9.	M8	5	5	20	70
10.	M9	5	10	15	70
11.	M10	5	10	20	65

6. Results and Discussion

6.1 Test on Fresh Concrete

The concrete slump test will measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete. Therefore, the easy with which concrete flows.

Table 6: Workability of concrete

Sl.No	*Type of mix*	*Slump (mm)*
1.	CV	133
2.	M1	128
3.	M2	125
4.	M3	110
5.	M4	115
6.	M5	113
7.	M6	110
8.	M7	102
9.	M8	95
10.	M9	105
11.	M10	90

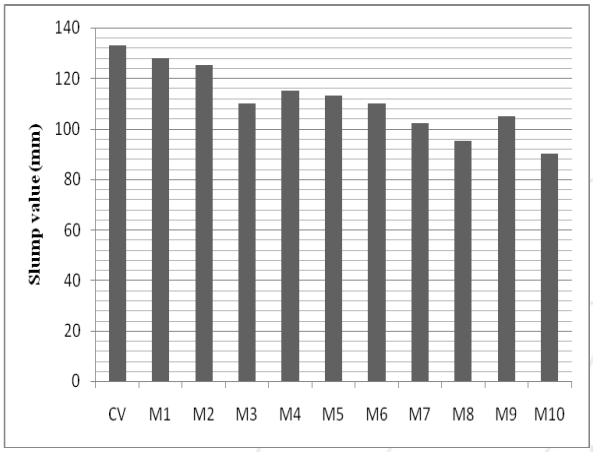


Figure 1: Slump test (mm) of replacement percentage of concrete

6.2 Casting of samples

Cubic specimens of concrete with size 150 x 150 x 150 mm were cast for determination of all measurements. Eleven mixes were prepared using different percentages of 0%, 5%, 10%, 15%, 20%, 25%, 30% and 35%. The concrete was mixed, placed and compacted in three layers. The samples were demoulded after 24 hours and kept in a curing tank for 7 and 28 days as required.

6.3 Compressive Strength

As we know that concrete is a compressive (brittle) material. The strength of the concrete increase with the age. At the age of 1, 3, 7, 14, 21 and 28 days the percentage of compressive strength is 16%, 40%, 65%, 90%, 95% and 99% respectively.

Table 7: Compressive strength of concrete

Sl.No	*Typo of Mix*	*Compressive strength (Mpa)*	
		7 Days	*28 Days*
1	CV	19.3	32.5
2	M1	21.2	34.7
3	M2	21.1	35.2
4	M3	20.8	34.4
5	M4	19.6	33.8
6	M5	20.3	34.7
7	M6	18.8	31.7
8	M7	19.6	33.8
9	M8	17.5	28.4
10	M9	19.2	32.1
11	M10	16.9	28.2

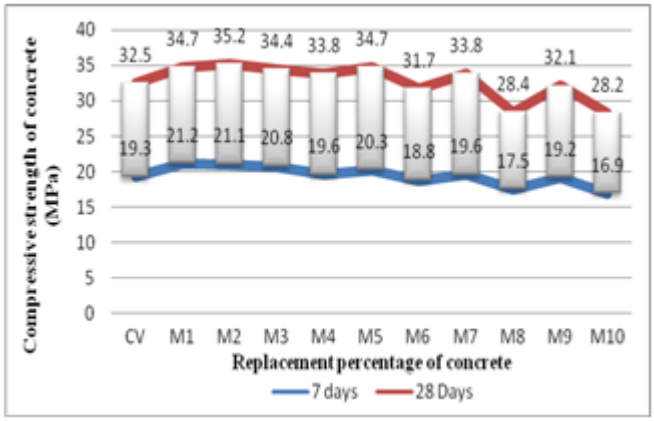


Figure 2: Compressive strength of concrete of 7 and 28 days

7. Conclusion

With the experimental studies conducted on the following conclusions can be drawn:

- Cement replacement in M7 and M9 i.e., 25% (5% Silica Fume, 10% RHA, 10% Hypo Sludge) and 30% (5% Silica Fume, 10% RHA, 15% Hypo Sludge) compressive strengths increased, for M25 grade.
- Beyond 35% there is a decrease in compressive strength for 28 days curing have period. There is a decrease in any way as the replacement level increases, and hence water Consumption will be more for higher replacements.
- Use of silica fume gives significant result on properties of concrete as compared to normal concrete.
- Slump value is depended on amount of hypo sludge.

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