An Experimental study on Self curing concrete by partial replacement of cement with flyash and ricehusk ash and sand with copper slag

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Abstract—**As important as water for life, the same way concrete for engineering structures. The ingredients of concrete are binding material (Cement), aggregates (Sand & HBG metal) and water. Present era; the cement and sand are now became a non-renewable materials because of lack of limestone deposits and sand in rivers or streams. Even though, while the production of cement (OPC) a lot of CO_2 emission causes to global warming and air pollution. Although, the necessity of concrete increasing year by year. In-spite of alarming water scarcity, concrete production needs considerable amount of water, since water is needed for 28 days curing of concrete members. Reduction in water content (like arid areas, negligence in watering, presence of salts, etc.) leads to loss in strength and deterioration of concrete structures. The main scope of this project is to reduce the cement and sand content replacing with fly ash(FA) and Rice husk ash (RHA) to cement, and Copper slag (CS) to sand for M25 grade of cement concrete and instead of traditional curing method, a new method of curing is adopted i.e. Self-Curing by using Polyethylene glycol 400 (PEG-400). The adopted methodology is the cement is replaced by FA & RHA in equal proportion i.e. 5, 7.5, 10, 12.5 & 15% by weight of cement and sand is replaced by CS as 20, 40, 60, 80 & 100%. The PEG-400 is added to the concrete by 1.0% by weight of binding material. The casted cubes, cylinders and beams are tested for Compressive strength, Split tensile strength and Flexural strength respectively. From the laboratory results, the Trial-4 (20% binding material & 60% FA) showed the optimum values for the above mentioned tests.**

Index Terms—**Self-curing concrete, Fly ash, Ricehusk ash, Copper slag and PEG-400**

I. INTRODUCTION

Today concrete is most widely used as construction material. Concrete is the best material of choice where the strength, durability, fire resistance and absorption resistance are required.

Curing plays an important role in strength development and durability of concrete. Curing takes place immediately after concrete placing and finishing, and involves maintenance of desired moisture and temperature conditions, both at depth and near the surface, for extended periods of time. Properly cured concrete has an adequate amount of moisture for continued hydration and development of strength, volume stability, resistance to freezing and thawing, abrasion and scaling resistance.

The curing is adopted by applying water to the concrete surface for a desired period (generally 28 days). This process is termed as External Curing Method. As per the ACI-308 code- "Internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water".

Internal curing is often also referred as Self–curing. Self-Curing Concrete can be achieved by adding self-curing agents. The concept of self-curing agents is to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete. It was found that water soluble polymers can be used as self-curing agents in concrete. The different types of curing agents are comprising with Poly Vinyl Alcohol (PVA), Poly Ethylene Glycol (PEG) and Super Absorbent Polymer (SAP).

The present competitive world encouraging towards rapid development, results in large construction activities cause to heavy amount of concrete consumption. The raw materials of concrete are purely related to natural resources which are non-renewable. And during the manufacturing or processing, it also leads to environmental instability. So to minimize the use of natural resources and to control the stability of environment, the alternative materials are introduced to the concrete, and this type of replacement experiments on concrete are enormously conducted by different research scholars all over the world.

Among the different research replacements, one of the replacement in self curing concrete is nothing but introducing replacing materials to the traditional ingredients of concrete. The binding material generally used is Ordinary Portland Cement can be replaced by a material having hydraulic or pozzolanic activity or both like Lime stone, Fly ash, Ground Granulated Blast Furnace Slag (GGBS), Silicon fume, Metakaolin, Rice husk ash, etc. The fine aggregate (usually Sand preferred) is basically chemically inert materials used for particles smaller than 4.75mm, contains particles in the size range 75µm to 4.75mm, are partially or fully can be replaced by Crushed sand (Manufacture sand), Crusher dust (Quarry dust), Washed bottom ash, Granulated blast furnace slag, Copper slag, etc.

Rice husk is an agricultural residue from the milling process. It has been found beneficial to burn this rice husk in kilns to make various things. The rice husk ash is then used as a substitute or admixture in cement. Fly ash is a light, fine, powdery substance and handling is similar to cement powder. Copper slag, which is produced during pyro metallurgical production of copper from copper ores, contains materials like iron, alumina, calcium oxide, silica etc.

II. Materials

For this experimental project, the used materials are 53 grade OPC, Fine aggregate (Sand), Coarse aggregate (20mm and 10mm HBG metal), Rice husk ash(RHA), Fly ash, Copper slag, Water and Self curing agent- PEG 400.

The ordinary Portland cement (OPC) 53 grade of Ultratech company is used in the series of cement operations. Fine aggregate(Sand) is taken from the river Godavari. A crushed coarse aggregate of 20mm and 10mm produced from the RMC plant near KIMS medical college, Amalapuram was used. The collecting rice husks have a very low nutrition value and as they take very long to decompose are not appropriate for composting or manure. Burning process is adopted at Hotel of Palivela Viilage, Kothapeta mandal of East Godavari district under control temperature below 800degree centigrade produces ash with silica mainly in amorphous form.

Fig. 1. Rice husk ash

Table 1. Chemical properties of binding materials (as per references)

Chemical elements	% in OPC	% in RHA	% in Flyash
SiO_2	19.71	78.21	40
Al_2O_3	5.2	15.24	25
Fe_2O_3	3.73		6
CaO	62.91	0.99	20
MgO	2.54	4.89	3.71

In this project the used fly ash is collected from a Supplier in Vizag who supplies all types of industrial waste components to the researchers. The supplied Fly ash is class "F" type. The copper slag is also collected from the same supplier. The used curing agent is Poly Ethylene Glycol - 400 purely a polymer based chemical which is collected from Scientific Engineers Chemical Laboratory, Kakinada.

Table 2. Physical & Chemical properties of PEG-400

Appearances	Clear liquid of white solid
Odour	Mild odour
Solubility	Soluble in water
Density range	1.1 to 1.2 (increases as molecular weight increases)

Fig. 2. Fly ash

Fig.3 Copper Slag

Fig. 4 PEG-400

III. Properties of Tested Materials

The collected materials were tested for the engineering properties to check for the suitability of concrete mix design. And also for the Concrete mix design as per IS:10262-2009. The following table represents the properties of materials.

Table 3. Physical properties of materials

S.No.	Name of the material	Name of the property	Value of the property	S.No.	Name of the material	Name of the property	Value of the property
1	Cement	Specific gravity	3.15	4	Copper slag	Specific gravity	3.67
		Consistency	33%			Sieve analysis	FM-4.98

		Fineness	93%	5	Fly ash	Specific gravity	2.95
2	Sand	Specific gravity	2.66			Fineness	96%
		% of bulking	36%	6	Ricehusk ash	Specific gravity	2.78
		Sieve analysis	Z-II, FM-4.53			Fineness	92%
3	HBG metal	Specific gravity	2.87(20mm), 2.91(10mm)				
		Water absorption	0.574%(20mm), 0.576%(10mm)				
		Sieve analysis	FM-2.368				

IV. Mix Design

As per IS:10262-2009 code of Mix design, the following proportions are made for M25 grade of concrete.

Table 4. Mix proportion of M25 grade of concrete

Water	Cement	Fine aggregate	Coarse Aggregate
193 lit.	386 kg/m^3	804 kg/m^3	1104 kg/m^3
0.5 (W/C)	1	2.08	2.86

V. Methodology

The adopted methodology was to compare the results between conventional M25 grade Self curing concrete and the replacements of Self curing concrete by trials. The entire execution of concrete was divided as the following trials.

- Trial 0- Conventional Concrete with out Self curing
- Trial 1- Conventional Concrete with Self curing
- Trial 2- Replacement of binding material 10% and fine aggregate 20%
- Trial 3- Replacement of binding material 15% and fine aggregate 40%
- Trial 4- Replacement of binding material 20% and fine aggregate 60%
- Trial 5- Replacement of binding material 25% and fine aggregate 80%
- Trial 6- Replacement of binding material 30% and fine aggregate 100%

In trial 0, as per mix design proportions M25 grade concrete Cubes, Cylinders and Beams are casted. For trail 1, the same process is adopted as trial 0 but additionally added 1% of PEG-400 by weight of binding material. In trial 2, the same process is adopted as in trial 1 but replacements made in the binding material and fine aggregate as the 10% is replaced by RHA(5%) and FA(5%) to the Cement and 20% is replaced by CS to the Sand. In trial 3, the same process is adopted as in trial 1 but replacements made in the binding material and fine aggregate as the 15% is replaced by RHA(7.5%) and FA(7.5%) to the Cement and 40% is replaced by CS to the Sand. In trial 4, the same process is adopted as in trial 1 but replacements made in the binding material and fine aggregate as the 20% is replaced by RHA(10%) and FA(10%) to the Cement and 60% is replaced by CS to the Sand. In trial 5, the same process is adopted as in trial 1 but replacements made in the binding material and fine aggregate as the 25% is replaced by RHA(12.5%) and FA(12.5%) to the Cement and 80% is replaced by CS to the Sand. In trial 6, the same process is adopted as in trial 1 but replacements made in the binding material and fine aggregate as the 30% is replaced by RHA(15%) and FA(15%) to the Cement and 100% is replaced by CS to the Sand. Table 5 and 6, indicates the quantities of ingredients for 9 specimens of cubes, 9 specimens of cylinders and 9 specimens of beams.

Table 5. Quantities for Conventional and Self-curing concrete

for Conventional			for Self-curing		
S.no	Constituents	Quantity	S.no	Constituents	Quantity
1	Cement	52.11 kg	1	Cement	52.11kg
2	FA	108.54 kg	2	FA	108.54kg
3	CA 20mm 10mm	 89.43 kg 59.61 kg	3	CA 20mm 10mm	 89.43kg 59.61kg
4	Water	193 kg	4	Water	193 kg
5	W/C	0.5	5	W/C ratio	0.5
			6	PEG-400	521 ml

Table 6. Quantities for Self curing concrete

S.no	Constituents	Trail-2	Trail-3	Trail-4	Trail-5	Trail-6
1	Cement (kg)	46.9	44.3	41.7	39.1	36.5
2	Rice husk ash (kg)	2.6	3.9	5.2	6.5	7.8
3	Fly ash (kg)	2.6	3.9	5.2	6.5	7.8
4	Fine aggregate (kg)	86.8	65.1	43.4	21.7	-
5	Copper slag (kg)	30.4	60.8	91.2	121.5	151.9
6	Coarse aggregate (kg) 20mm 10mm	 89.4 59.6	 89.4 59.6	 89.4 59.6	 89.4 59.6	 89.4 59.6
7	Water(kg)	193	193	193	193	193
8	W/C ratio	0.5	0.5	0.5	0.5	0.5
9	PEG-400 (ml)	521	521	521	521	521

VI. Tests & Results

Slump cone is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.

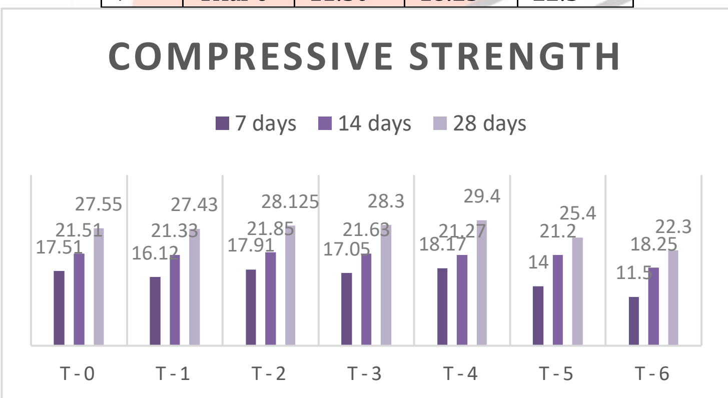
Table 7. Slump cone results

S.no	Mix Trials	Slump values(mm)	S.no	Mix Trials	Slump values(mm)
1	Trial 0	72	5	Trial 4	83
2	Trial 1	85	6	Trial 5	83
3	Trial 2	86	7	Trial 6	82
4	Trial 3	84			

Fig 5. Compressive strength test apparatus

Table 8. Compressive strength test results of Trials

S.no	Mix Trials	7 days N/mm²	14 days N/mm²	28 days N/mm²
1	Trial 0	17.51	21.51	27.55
2	Trial 1	16.12	21.33	27.43
3	Trial 2	17.91	21.85	28.12
4	Trial 3	17.05	21.63	28.3
5	Trial 4	18.17	21.27	29.4
6	Trial 5	14.00	21.20	25.4
7	Trial 6	11.50	18.25	22.3

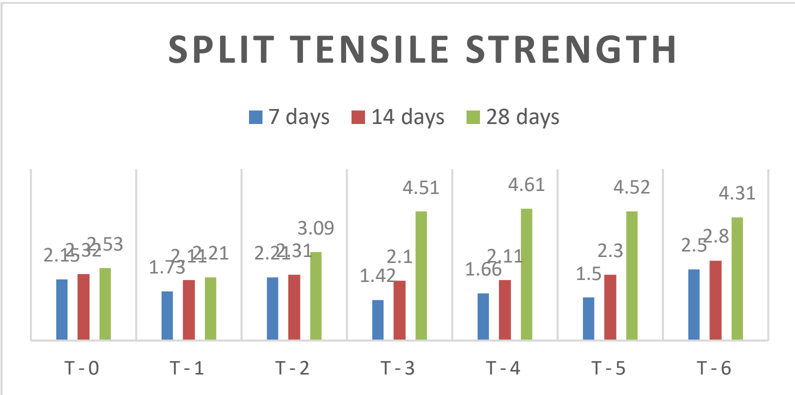


Graph1. Comparison of Compressive strength of Trials

Fig 6. Split tensile test

Table 9. Split tensile strength test results of Trials

S.no	Mix Trials	7 days N/mm²	14 days N/mm²	28 days N/mm²
1	Trial 0	2.15	2.32	2.53
2	Trial 1	1.73	2.11	2.21
3	Trial 2	2.21	2.31	3.09
4	Trial 3	1.42	2.10	4.51
5	Trial 4	1.66	2.11	4.61
6	Trial 5	1.50	2.30	4.52
7	Trial 6	2.5	2.8	4.31

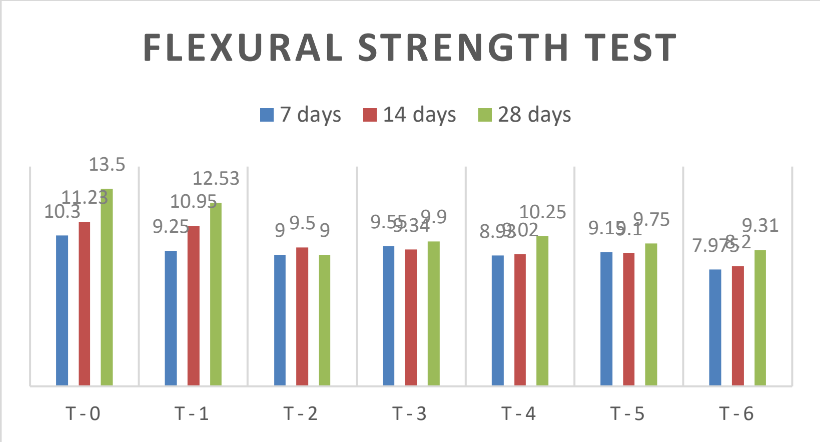


Graph2. Comparison of Split tensile strength of Trials

Fig 7. Flexural strength test

Table 10. Flexural strength test results of Trials

S.no	Mix Trials	7 days N/mm²	14 days N/mm²	28 days N/mm²
1	Trial 0	10.3	11.23	13.5
2	Trial 1	9.25	10.95	12.53
3	Trial 2	9.00	9.50	9.0
4	Trial 3	9.55	9.34	9.9
5	Trial 4	8.93	9.02	10.25
6	Trial 5	9.15	9.10	9.75
7	Trial 6	7.975	8.2	9.31



Graph3. Comparison of Flexural strength of Trials

VII. Conclusion & Future scope

After 28 days of curing period, all specimens of Trials are tested and the following points are concluded.

- The required Compressive strength of M25 grade of concrete is observed in **Trail-4(29.4MPa)** which is 6.71% higher than Trial-0(27.55MPa) and 7.18% higher than Trial-1(27.43MPa) after 28 days of curing.
- The Split tensile strength is also maximum in concrete of Trial-4(4.61MPa).
- But the Flexural strength in Trial-4(10.25MPa) was reduced by 24.07% of Trial-0(13.5MPa) and 18.2% of Trial-1(12.53Mpa).
- Beyond Trial-4, the Compressive, Tensile and Flexural strength values of Trial-5 and Trail-6 are decreased due to increase in quantities of Rice Husk Ash, Fly Ash and Copper Slag.
- The unit weight of the copper slag is almost double the unit weight of the sand, hence the unit weight of the concrete is increased Trial by Trial.
- With the help of curing agent PEG-400, the workability of concrete is maintained maximum when compared with Conventional concrete(Trial-0).
- The compressive strength between Conventional concrete(Trial-0) and Selfcuring concrete(Trial-1) is of negligible difference.
- The tensile strength of Trial-3, 4, 5 and 6 represented approximately same the value, with this reference the tensile strength is improved/stationed by increasing the Rice Husk Ash, Fly Ash and Copper Slag.
- M25 grade of concrete from Trial-1 (Selfcuring Concrete) can be effectively used instead of Conventional M25 grade of concrete (Trial-0) where availability of water is scarce, (or) contamination with salts (or) highly levied cost on curing by manual watering.
- Trial-4 of M25 grade of concrete can be used instead of Trial-1 of M25 grade of concrete which reduce the cost of the project by 20% of Gross value.

The Self curing Concrete of M25 grade with partial replacement of cement by Rice husk ash & Fly ash, and the Sand by Copper slag has the following points of future scope.

- Primarily it can be state that this concrete is economical concrete or green concrete by introducing industrial wastages such as Fly ash, Rice husk ash and copper slag up to an average percentage of 50% (actually 20% binding material and 60% fine aggregate replacement).
- By maintaining constant 60% of copper slag and the strength values can be improve by increasing Fly ash and Rice husk ash quantities.
- The primary Infrastructure can be executed at desert places or arid areas where the scarcity of water is main obstacle for execution of structures.
- Due to higher unit weight of this concrete over conventional concrete, it is suitable for heavy weight concrete structures which are capable of resisting horizontal forces.
- 28 days of curing is completely done by it self, so we can avoid the manual operation for curing.
- By using copper slag as fine aggregate, due to its high density, the concrete can be used for war sheds, nuclear complex, chimneys, furnaces, etc., where the heavy heat and impact to be resisted.

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