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Economical Studies on Sustainable Concrete

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Abstract : *The increase in concrete consumption increases the utilization of large quantities of energy and decreases the natural resources available. Ordinary Portland Cement which is used in the production of concrete produces large amount of green house gases. Sustainable concrete is the only solution to make environmental friendly concrete. Sustainable concrete is manufactured by using industrial by-products like copper slag, fly ash, silica fume etc.In this study ceramic waste and silica fume are used as alternatives to cement. Copper slag is used as alternative to fine aggregate and Ferro chrome slag is used as an alternative to coarse aggregate. Various trail mixes are conducted by using mortar mixes with different percentages of ceramic waste, Silica fume and fly ash with varying percentages of alkaline solution to binder ratio. Of all the mixes ceramic waste (60%) and Silica fume (40%) with 0.6 alkaline solution to binder ratios is finalized. The ratio of NaOH to Na_2SiO_3 is taken as 2.5.The concentration of solution was fixed as 10M NaOH solution and 50% Na_2SiO_3 solution. 1% of SP 430 is used as a super plasticizer. Various tests conducted to determine the mechanical and durability properties of concrete.*

Keywords: *Alkaline solution, Materials, Mix proportions, Super plasticizer, Sustainable concrete.*

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I. Introduction

Ordinary Portland cement which is being traditionally been used as binder material in concrete is responsible for emission of huge amount of green house gases. The creation of non-decaying waste materials, combined with a growing consumer population has resulted in a waste disposal crisis. One solution to this crisis lies in recycling wastes into useful products for making the constructions economical and eco-friendly. If waste materials are used in concrete then it can be considered as Sustainable concrete. Sustainability means "meeting the needs of the present without compromising the ability of the future generations to meet their own needs". One of the biggest threats to the sustainability of the cement industry is the dwindling amount of limestone in some geographical regions. Sustainability requires those in the construction industry to consider the entire life cycle including construction, maintenance, demolition, and recycling of buildings. A sustainable concrete structure is one that is constructed so that the total societal impact during its entire life cycle is minimal. Designing with sustainability in mind includes accounting for the short-term and long-term consequences of the structure. To decrease the long-term impact of environment on structures, creation of durable structures is important. Cement plays a major role in production of concrete. A high amount of CO_2 is emitted during manufacture of Ordinary Portland Cement. Cement production contributes to 7% of global CO_2 emission. The key causes of high CO_2 emissions arising from Ordinary Portland Cement manufacture have been attributed to calcination of limestone and high energy consumption during manufacturing, including heating raw materials within a rotating kiln at temperatures greater than 1400°c.

II. Material Description

Ceramic Waste: Ceramic wastes can be separated in two categories in accordance with the source of raw materials. The first one are all fired wastes generated by the structural ceramic factories that use only red pastes to manufacture their products, such as brick, blocks and roof tiles. The second one is all fired waste produced in stoneware ceramic such as wall, floor tiles and sanitary ware. These producers use red and white pastes. The usage of white paste is more frequent and much higher in volume.

Silica Fume: Silica fume (also known as micro-silica) is a byproduct of silicon and Ferro-silicon alloy industries. It is very fine (<0.5μ) and hence can be effective as a pozzolanic admixture in cement. The following properties were studied to get the proper consistency of the mix

Copper Slag: Copper slag is a byproduct obtained during the smelting and refining of copper. Major constituents of a smelting charge are sulphides and oxides of iron and copper. Incorporation of copper slag as coarse aggregate increases the mechanical properties of high-strength concretes maybe due to the strength characteristics of copper slag and the stronger bonding between copper slag aggregate and the cement paste matrix and is used as 100% fine aggregate replacements. The particle size is in between 0.075mm to 4.75mm.

Ferro Chrome Slag: Ferro chrome slag is used as 100% coarse aggregate replacements. It is a byproduct, which is obtained as a slag during manufacturing of steel. The property of this Ferro chrome slag depends upon the temperature during which it is obtained. Ferro chrome slag in this study is from the nearby steel manufacturing plant. Aggregates of size greater than 4.75 are considered as coarse aggregate. In this study 10mm and 20 mm aggregates are tested and used.

Table.1.Physical properties of materials

S.No	properties	Ceramic waste	Silica fume	Copper slag	Ferro chrome slag
1.	Specific gravity	2.22	2.23	3.5	2.85
2.	Fineness	3.5%	2%	3.47%	5.36%

Alkaline Liquid: An alkaline liquid is used to react with silicon (Si) and aluminum (Al). The main constituents of alkaline liquid are sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na_2SiO_3) or potassium silicate (K_2SiO_3). Generally a combination of NaOH and Na_2SiO_3 are used as an alkaline liquid in the manufacture of GPC. This alkaline liquid when reacts with the source material of geological origin binders are produced. The chemical reaction that takes place in this process is caller polymerization. A solution of 10M sodium hydroxide and sodium silicate were used in this study.

Admixtures: Admixture increases workability, durability and modify the rate and decrease permeability of concrete. These materials include chemical admixture and mineral admixture.

Chemical Admixture: Chemical admixtures reduce the cost of construction, modify the properties of concrete and improve the quality of concrete during mixing, transportation, placing and curing. Super plasticizer - Conplast SP430 has been specially formulated to give high water reductions upto 25% without loss of workability or to produce high quality concrete of reduced permeability.

Mineral Admixture: Mineral admixtures generally include fly ash, silica fume, ground granulated blast furnace slag and metakaolin.

III. Methodology

Mix Design:

In this study, M20 grade of concrete mix was done as per IS: 10262-2009.Based on the design mix the concrete mix is prepared, slump cone test & compaction factor test was conducted on fresh concrete for knowing workability of concrete. Specimens of dimensions for cubes, cylinders and prisms were casted for knowing the compressive strength. All the specimens will be cured for 7, 14 and 28 days. All the cubes after completion of curing period will be test for its compression strength. To find the properties of all the ingredients of Geopolymer concrete such as ceramic waste, silica fume, copper slag and Ferro chrome slag. To find out the appropriate percentages of a combination of supplementary cementitious materials like GGBS, silica fume, fly ash. This process is carried out by using trail mortar mixes of ratios 1:3, 1:4 and 1:5. The cube used for this trail mortar mix is 70.6×70.6×70.6 mm. Compressive strength test of mortar mixes on compressive testing machine for 7, 14 and 28 days was done. Then the required specimens such as cubes (150×150×150 mm), cylinders (150×300 mm) an prisms (100×100×500 mm) are cast for evaluating all mechanical properties and rapid chloride permeability and temperature resistance tests are conducted for evaluating durability properties. All specimens are cured at ambient temperature.

Table.2.Design proportions after replacement

Water	Cement (ceramic waste(60%)+ silica fume(40%))		Fine aggregate (Copper slag)	Coarse aggregate (Ferro chrome slag)
186	272	182	680	1100
0.45	0.658	0.44	1.64	2.66

IV. Results And Discussion

The trail mixes are conducted for mortar mixes with various percentages of ceramic waste, Silica fume and fly ash. The ratio of binder to fine aggregate is taken as 1:4.The alkaline solutions to binder ratio is taken as 0.4.Consider the ratio of sodium silicate to sodium hydroxide as 2.5 and calculate their individual quantities from the quantity of alkaline solution. Based on the molarity of sodium hydroxide the amount of sodium hydroxide flakes in the solution changes. The quantity of binder is assumed as 1250gm and the percentage of slag is fixed to 60%.Trail mixes are carried out by varying the percentages of fly ash and silica fume from 0% to 40% for both of them. To achieve the desired setting qualities in the finished product, a quantity of finely ground gypsum (3% of binder) is added to the mixture. Various trail mixes are conducted by using different proportions and then the mix of good strength and workability is selected as the final mix.

4.1 Compressive Strength of cubes:

Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per IS 516:1959. The compressive strength is usually obtained experimentally by means of a compressive test.

Table.3. Compressive Strength of cubes

Age	7days	14days	28days
Compressive strength (MPa)	19.42	26.95	30.24

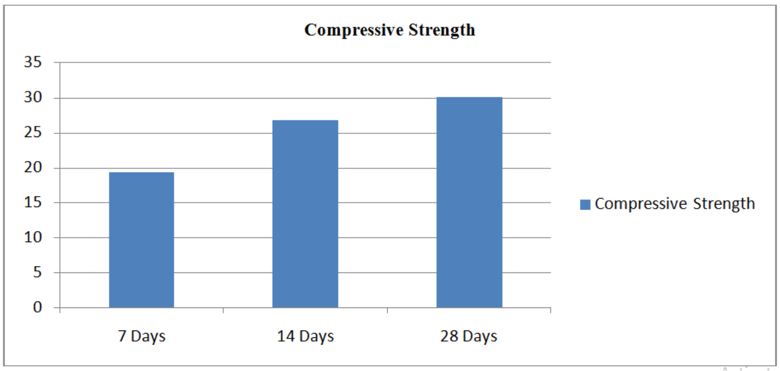

Fig.1. Variation of Compressive strength of cubes

4.2 Flexural Strength of Concrete:

The flexural strength (fb) is determined by conducting bending test on the prism as described as per IS: 456 2000.

Table.4. Flexural Strength of Prisms

Age	7days	14days	28days
Flexural strength (MPa)	2.48	3.11	3.31

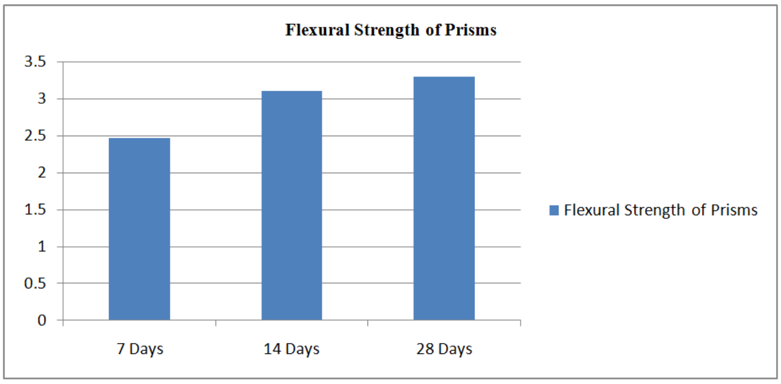

Fig.2. Variation of Flexure strength of prisms

4.3 Split Tensile Test:

The split tensile strength of concrete is tested by casting cylinder of size 150mm x 300mm and is continuously cured for 28 days testing. The values of split tensile strengths are shown in table

Table.5.split tensile test for cylinders

Age	7days	14days	28days
Split tensile strength(N/mm^2)	3.77	5.46	6.28

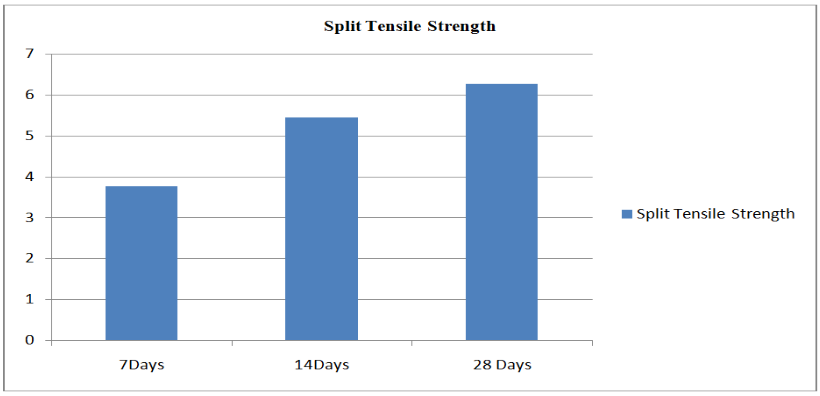

Fig.3. Variation of Splitting Tensile strength

4.4 Rapid Chloride Penetration Test:

It is the durability test used to assess the quality of material is 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 geopolymer concrete for 7 days after casting, measured in terms of the electric charges passed through the specimens .The test is carried for both the normal drying and oven during specimen's cylinders of size 50mm length and 50mm diameter.

Table.6.RCPT values

Age (days)	**Rcpt value (Columbs)**	
	Ambient curing	**Oven curing**
7	700	1650

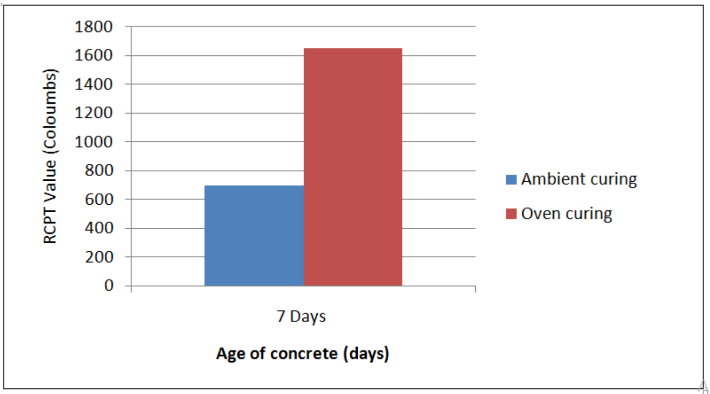

Fig.4.RCPT for sustainable concrete

4.5 Temperature resistance of specimen: The temperature resistance is tested for the cube specimens for 7, 14 and 28 days by placing the specimens in oven curing for 1, 2 and 3 hours.

Table.7. Compressive strength values after oven curing

Age(days)	**Time of oven curing(hours)**	**Peak stress (MPa)**
7	1	36.22
	2	32.91
	3	27.66
14	1	38.64
	2	34.21
	3	28.62
28	1	38.96
	2	32.64
	3	27.84

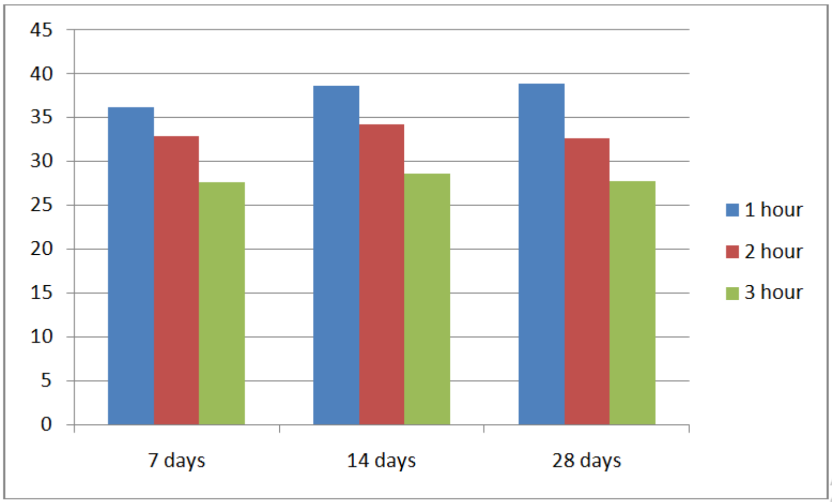

Fig.5. Compressive strength values after oven curing

V. Conclusion

1. The appropriate percentage of ceramic waste and silica fume are finalized as 60% and 40% by conducting various trail mortar mixes using ceramic waste, Silica fume and fly ash.
2. As the workability and setting time of geopolymer concrete are less, 0.6 alkaline liquid to binder ratio is finalized with respect to strength and workability.
3. Compressive strength of GPC decreases with increase or decrease in silica fume beyond 40%.
4. After studying 14 types of mortar trail mixes it is concluded that combination of ceramic waste (60%) and silica fume (40%) gives the maximum compressive strength and good workability with alkaline binder ratio 0.6.
5. Compressive strength of geopolymer concrete is comparatively higher than ordinary concrete for the same grade of concrete. It is also observed that the 7days compressive strength is almost equal to two third of 28 days strength which supports the application of this concrete as an alternative to normal concrete.
6. The rapid chloride penetration test, chloride ion permeability values fall below 1000 for ambient curing specimens and in the range of 1000 to 2000 for the oven curing specimens. The low chloride ion permeability indicates that concrete reduces the steel corrosion and hence can be recommended for RCC.
7. When compared to cement, fine aggregate and coarse aggregate the cost is much economical by using ceramic waste, silica fume, copper slag and ferrochrome slag.
8. By using these sustainable materials the strength and durability increases when compared to conventional concrete.

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