Mechanical, Durability and Electrical Performance of GGBS-Based Geopolymer Concrete Incorporating Post Metal Recovery E Waste Residue

Naveen Konda[1] Prashanth Hugar[2]

[1]M. Tech Student, Department of Civil Engineering, J B Institute of Engineering and Technology (JBIET), Bhaskar nagar, Moinabad, Hyderabad, Telangana 500075

[2]Assistant Professor, Department of Civil Engineering, J B Institute of Engineering and Technology (JBIET), Bhaskar nagar, Moinabad, Hyderabad, Telangana 500075

Abstract Exploration for complete OPC free concrefte is as yet advancing and there is a requirement for creating elective restricting specialists which are earth cordial. One such option is distinguished to be geopolymer which regularly comprises of GGBS debris, sodium silicate, and sodium or potassium hydroxide (NaOH or KOH). Since, many coal based force plants in India have been resigning because of pushed towards cleaner vitality creation and this may prompt shortage of GGBS debris in future. The creation of Ordinary Portland cement and the use of typical waterway sand are expanded because of the interest of concrete in development Industries. The outflow of CO2 increments during the creation of cement and simultaneously the accessibility of waterway sand is likewise getting costlier and shortage because of unlawful digging of stream sand. The primary intension of this exploration paper is to center the eco neighborly elective material for the cement and waterway sand.

Thus the target of this examination is to consolidate other Pozzolanic materials in geopolymer concrete. In accordance with target two Pozzolanic materials granulated impact heater slag (GGBS) in geopolymer concrete and the level of E Waste Residue. Concrete blend structure of M25 and M30 were done dependent on Indian standard code (IS 10262) and altered rules. Concrete 3D squares and barrel shaped examples were tried for advancing the compressive strength and split rigidity by fluctuating the rates of GGBS,RHA and M-sand in concrete

The percentage replacement of GGBS in Geopolymer concrete by using E Waste residue at the percentages of 0% E Waste Residue, 2.5% E Waste Residue, 5% E Waste Residue, 7.5% E Waste Residue and 10% E Waste Residue. The various tests like compressive, tensile, flexural, Durability and electrical resistance tests are performed on geopolymer concrete by varying percentages of E waste residue.

KEY WORDS: Geopolymer, GGBS, E Waste, Compressive strength, Split tensile strength, Flexural strength, Durability.

1. INTRODUCTION

Cement is a widely used construction material due to its strength, durability and ease of mixing and placing. China, India and United States are the top 3 cement- producing countries. China has produced 2350 million metric tonnes of cement in 2015 followed by India at 270 million metric tonnes. (www.statista.com). Global demand for cement is in the uptrend and expected to rise by 4.5% in the next five years. 5190 million metric tonnes of cement is projected as the global demand in 2019 (www. world cement.com).

Cement is manufactured from limestone and clay mixture heated by an electrical furnace or coal fired furnace. In addition, production of cement emits Carbon dioxide, one of the major green-house gases that cause Global Warming. It is estimated that 1 tonne of cement during production releases approximately, 1 tonne of (CO_2 into the atmosphere Davidovits, 1996). 6 % of the total CO_2 emission is from the cement industry (www.epa.gov). Mankind is facing the wrath of nature, as huge inexplicable natural calamities, it is imperative to keep our environment unpolluted. As manufacture of cement consumes natural resources, energy and leaves a carbon footprint on the environment, (Scrivener, 2007) it is necessary to find an alternative to cement.

Ground Granulated Blast Furnace Slag (GGBS) in Concrete

Ground Granulated Blast Furnace Slag (GGBS), also known as GGBFS, is a finely ground by-product obtained during the manufacture of iron in a blast furnace. When molten iron slag is rapidly quenched with water, it forms a glassy, granular material that is subsequently dried and ground into a fine powder known as GGBS. Due to its high content of calcium, silica, and alumina, GGBS exhibits latent hydraulic and pozzolanic properties, making it an excellent supplementary cementitious material (SCM) for concrete. It is widely used as a partial replacement for Ordinary Portland Cement (OPC) to improve the mechanical properties, durability, and sustainability of concrete. The incorporation of GGBS in concrete significantly enhances its performance by refining the pore structure and producing additional calcium silicate hydrate (C-S-H) gel through secondary hydration reactions. This results in higher long-term compressive strength, reduced permeability, and improved resistance to chloride penetration, sulfate attack, alkali–silica reaction, and chemical corrosion. GGBS also lowers the heat of hydration, making it particularly suitable for mass concrete structures such as dams, foundations, bridges, and retaining walls, where thermal cracking must be minimized. In addition, concrete containing GGBS exhibits better workability, improved surface finish, and increased resistance to fire and aggressive environmental conditions.

Objectives of the study

Our aim is to have an alternative binder instead of Cement in Concrete. The reason is during the production of cement, higher amounts of Carbon dioxide is released into atmosphere and causes global warming. In this respect Geopolymer concrete is produced by replacing cement with Geopolymer binder which consists of GGBS and alkaline liquid sand also fine aggregate is replaced with quarry dust because it is most economical than fine aggregate.

1. To study the workability properties of GGBS based geopolymer
2. To study the strength characteristics of GGBS based geopolymer concrete using E Waste residue.
3. The study the durability of concrete by using various percentages of E Waste residue.

II LITERATURE REVIEW

Romain Rodrigues (2020), this study provides an up-to-date review on corrosion mechanisms and recent advances in electrical methods for corrosion monitoring. When assessing corrosion mechanism, the inherent heterogeneity of RC structures and the significant effect of environmental factors remain major issues in data interpretations. The steel surface condition and local in homogeneities at the steel–concrete interface appear to have an important effect on corrosion initiation. The use of electrical resistivity tomography allows to consider appropriately the inherent heterogeneity of concrete and provides more insights on transport phenomena (e.g. water and salts ingress) in the material. Nevertheless, during the corrosion propagation stage, the polarization resistance remains the most important parameter to be determined as it provides quantitative information of the corrosion rate. If conventional three-electrode configuration methods can supply an accurate determination in the case of uniform corrosion, they often fail in the case of macro cell corrosion in field experiments. A four-electrode configuration without any connection to the rebar can rather be used for the non-destructive testing and evaluation of corrosion.

Javier Sanchez et.al (2016), aims primarily to develop a modified version of the four-point method to measure resistivity in reinforced concrete structures with thinly covered rebar. Concrete quality can be tested on site by coring or non-destructive testing. This paper describes a method based on the four-point or Wenner procedure for measuring electrical resistivity, deployed on a bridge over the River Danube between Vidin, Bulgaria and Calafat, Romania. Due to the high reinforcement density in bridge members, a model had to be developed to measure resistivity in the concrete cover and the instruments conventionally used had to be modified. Concrete durability can be determined based on electrical resistivity, a parameter readily and nondestructively measured on site. A modified version of the four-point or Wenner method was developed and applied to a bridge spanning the River Danube. The new procedure introduced a 'rebar factor', fb, to measure resistivity in reinforced concrete structures with thin concrete covers. The model findings showed that this factor is not dependent upon resistivity.

Ali Akbar Ramezanianpour et.al (2010), Investigate the possibility of replacing the Rapid Chloride Penetration Test and water penetration test by the simple non-destructive surface resistivity test. The present study is an exploratory research concerned with the relationship of these methods. Based on the correlation of concrete resistivity with water penetration and Rapid Chloride Penetration Test (RCPT) results, two new models for relating these parameters are presented. Based on the correlation of concrete resistivity with water penetration and Rapid Chloride Penetration Test (RCPT) data, a relationship that can be used to estimate permeability of concrete from the measured resistivity values was discovered. Results show that although in concretes with similar cementations materials different relationships can be found, but generally because of different mechanisms of compressive strength and electrical resistivity, there is no appropriate relationship between them. Consequently, it is not recommended to use electrical resistivity as an indicator for evaluation of compressive strength.

III MATERIALS AND MIX PROPORTIONING

Coarse aggregates

Locally accessible pulverized rock stone total of 10mm size was utilized ascoarse total. The coarse total going through 10mm and holding 4.75mm was utilized for exploratory work (Djwantoro Hardjito, 2008). The properties of coarse totals were resolved as per IS: 2386-1963.

Fine aggregates

The locally accessible stream sand, going through 4.75 mm was utilized in this test work. The properties of fine totals were resolved according to May be: 2386-1963.

GGBS

Granulated Blast Furnace Slag is acquired by quickly chilling (extinguishing) the liquid fiery remains from the heater with the assistance of water. Amid this procedure, the slag gets divided and changed into formless granules (glass), meeting the prerequisite of IS 12089:1987 (fabricating detail for granulated slag utilized in Portland Slag Cement). The granulated slag is ground to wanted fineness for creating GGBS (Rashida A Jhumarwala, 2013).

GGBS

Alkaline solution

A mix of sodium silicate arrangement and sodium hydroxide arrangement was utilized as soluble arrangement.

Sodium hydroxide

The most well-known soluble activator utilized in geopolymerisation is a combinationof sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate(Na_2SiO_3) or potassium silicate (K_2SiO_3). The sort and convergence of salt arrangement influence the disintegration of Pozzolanic material (Usha T G, 2015). It is a white strong and exceptionally causticmetallic base and soluble base salt which is accessible in pellets, drops, granules, and as prepared solutions at various diverse fixations. Sodium hydroxide frames an approximately half (by weight) soaked arrangement with water.

Preparation of NaOH solution

Silicate

Sodium silicate is the basic name for mixes with the equation $Na_2(SiO_2)$ Concrete treated with a sodium silicate arrangement serves to significantlyreduce porosity in most stone work items, for example, concrete. A synthetic response occurswith the overabundance $Ca(OH)_2$ (portlandite) exhibit in the solid that for all time ties the silicates with the surface, making them undeniably strong and water repellent (Sashidhar C, 2015).

E Waste Residue

Electronic waste (E-waste) residue refers to the remaining materials obtained after the collection, dismantling, recycling, or processing of discarded electrical and electronic equipment (EEE). With the rapid advancement of technology, increasing consumer demand, and shorter product life cycles, the generation of E-waste has become one of the fastest-growing waste streams worldwide. E-waste includes obsolete or discarded electronic devices such as computers, mobile phones, televisions, printers, circuit boards, batteries, cables, and household appliances. During recycling and recovery processes, valuable metals such as copper, aluminum, gold, silver, and palladium are extracted, while the remaining non-recoverable materials, known as E-waste residue, consist of plastics, glass, ceramics, rubber, fiberglass, printed circuit board fragments, and trace quantities of heavy metals. Improper disposal of these residues can lead to significant environmental pollution through the release of hazardous substances, including lead, cadmium, mercury, chromium, and brominated flame retardants, which contaminate soil, water, and air.

E Waste samples

ADMIXTURE

To secure usefulness of clean Geopolymer Concrete, Sulphonated napthalene polymer based absolutely great plasticizer Conplast SP430 in the state of a dark colored fluid immediately dispersible in water,

MIX DESIGN

For M25 Grade Concrete-1:0.78:2.5

For M30 Grade Concrete-1:0.77:2.4

IV EXPERIMENTAL INVESTIGATION

Mix Ratios used for the study

In this current research the M30 grade was considered with below specified mix ratios

M0 – 0% E Waste residue

M1 – 2.5% E Waste residue

M2 – 5% E Waste residue

M3 – 5.5% E Waste residue

M4 – 10% E Waste residue

Manufacture of Fresh Concrete and Casting

Geopolymer cement can be produced by embracing the traditional systems utilized in the make of Portland bond concrete. In the research facility, the fly fiery remains and the totals were first combined for 3 minutes. The totals were set up in immersed surface dry condition (Sabina Kramar, 2015).

Mixing of Geopolymer concrete

Curing of Geopolymer concrete

Surrounding restoring of low calcium fly fiery debris based geopolymer concrete is for the most part prescribed. Surrounding relieving generously helps the substance response that happens in the geopolymer glue. Both restoring time and relieving temperature impact the compressive quality of geopolymer concrete. The restoring time differed from 12 to 24 hours (Daniel L.Y. Kong, 2010).

Curing of Test Specimens

In the wake of throwing, geopolymer solid examples were relieved quickly. Two composes ofcuring were utilized in this examination, i.e. Broiler restoring and Ambient relieving. For Oven relieving, thetest examples were restored in the broiler and for encompassing restoring, they were kept underambient conditions for relieving at room temperature. The examples were broiler relieved at 60°C and 100°C for 24 hours in the stove. After the relieving time frame, the test specimenswere left in the molds for no less than six hours so as to stay away from an extraordinary change in the ecological conditions.

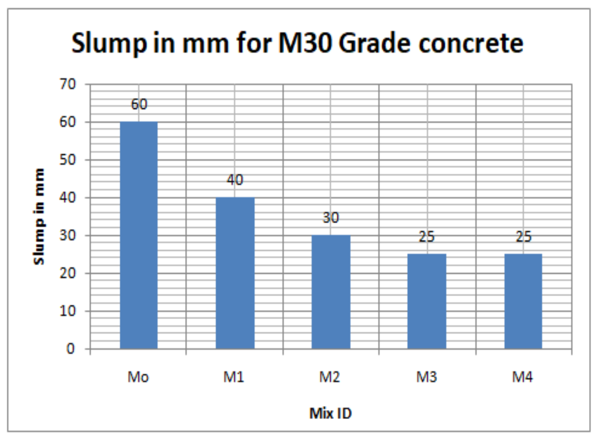
Tests to be conducted on concrete

Fresh concrete tests
Slump cone test
Compaction factor test
Hardened concrete tests
Compressive strength
Split tensile strength
Flexural strength
Durability
Electric conductivity test

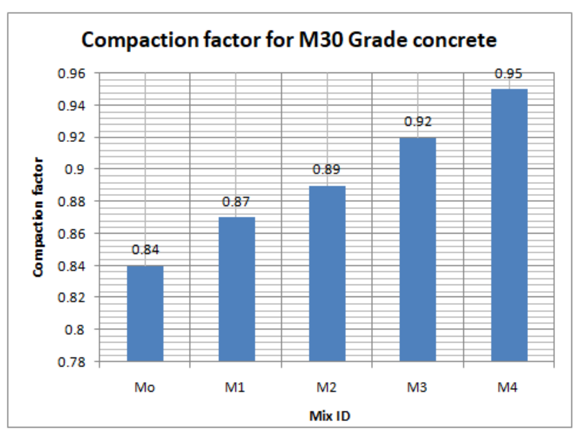
V RESULTS AND ANALYSIS

Workability of concrete

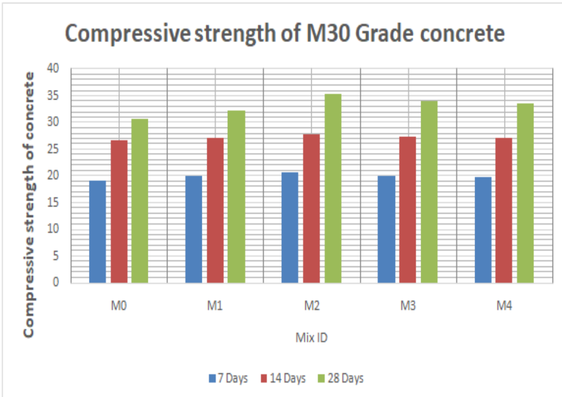
Slump cone test



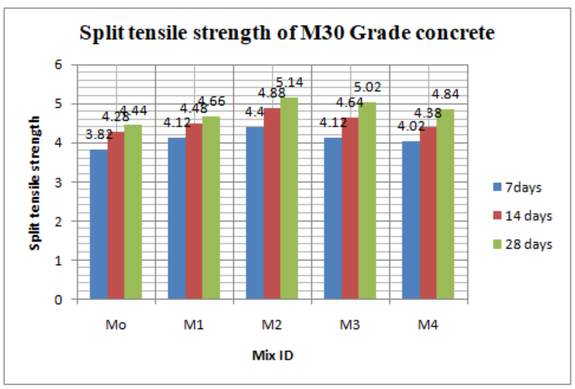
Compaction factor test



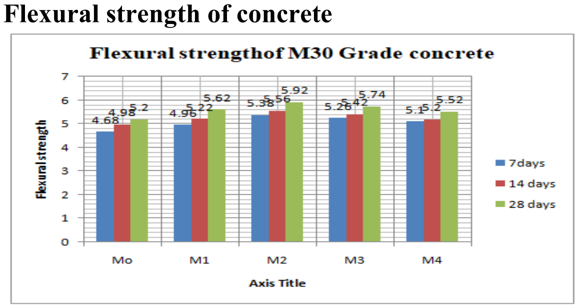
Compressive strength of concrete



Split tensile strength of concrete

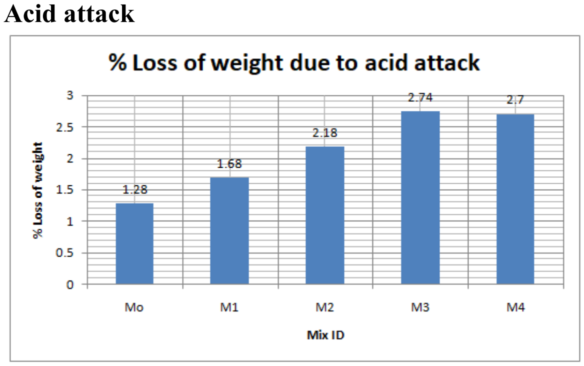


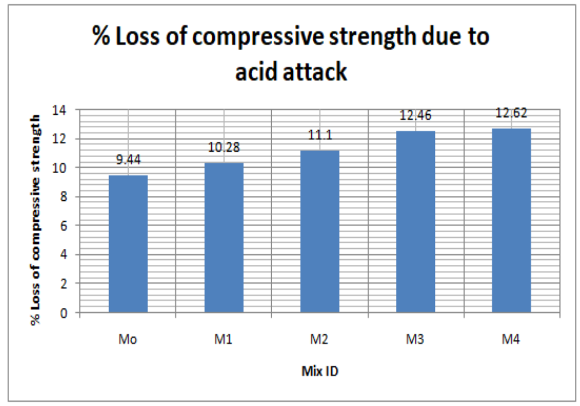
Flexural strength of concrete



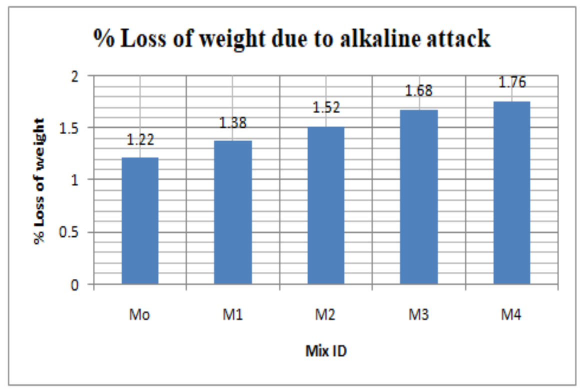
Durability of concrete

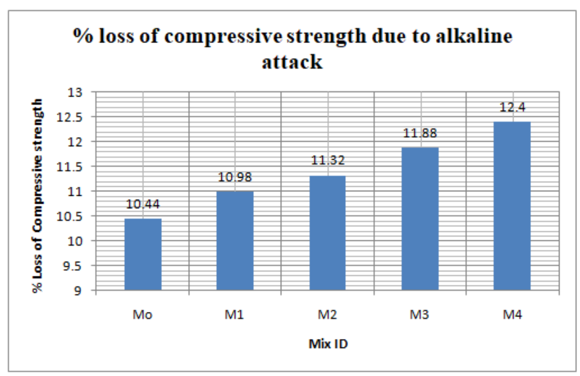
Acid attack



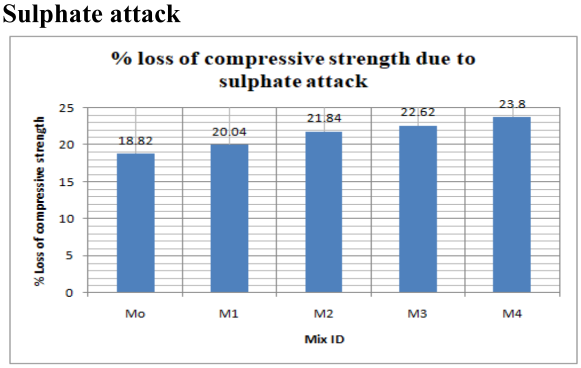


Alkaline attack

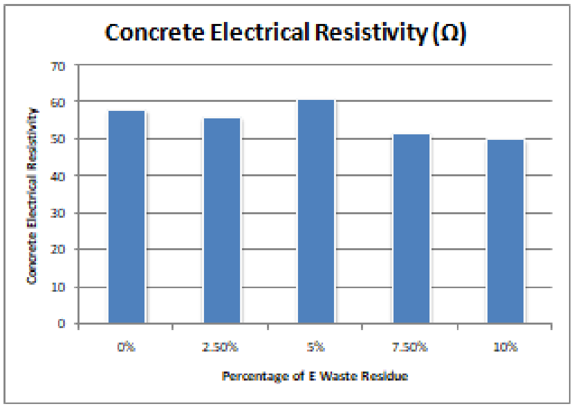




Sulphate attack



Electric conductivity test



V CONCLUSIONS

From the above experimental study the following conclusions were made

1. Geopolymer concrete tend to show no significant physical change in its properties at normal operating room temperature which is observed in case of normal variety. The complete setting of Geopolymer concrete specimens will take upto 72 hours without any reminisces on the surface on which it is hardened.
2. The value of slump decreases from 60mm to 25mm with increase in the percentage of E Waste residue from 2.5% to 10%.
3. The value of compaction factor increases from 0.84 to 0.95 for M30 Grade concrete with increase in the percentage of E Waste residue from 2.5% to 10%.
4. The optimal value (maximum value) of compressive strength was observed at 5% E waste residue for 7days, 14 days and 28 days.
5. The optimal value (maximum value) of Split tensile strength was observed at 5% E waste residue for 7 days ,14 days,28days curing for M30 grade of concrete
6. The optimal value (maximum value) of Flexural strength was observed at 5% E waste residue for 7 days ,14 days,28days curing for M30 grade of concrete
7. The durability of concrete due to acid attack, alkalinine attack, sulphate attack increases with increase in the percentage of 5% E waste residue in M30 grade of concrete
8. The GGBS can be used to produce geo polymeric binder phase which can bind the aggregate systems consisting of fine and coarse aggregate to form geo polymer concrete. Therefore these concrete can be considered as eco-friendly material Compressive, flexural and split tensile strengths are increases with the Higher the ratio of sodium silicate -to-sodium hydroxide ratio by mass.
9. Higher concentration (in terms of molar) of sodium hydroxide solution resultsin higher compressive strength of GGBS based geopolymer concrete Higher the ratio of sodium silicate-to-sodium hydroxide ratio by mass, higheris the compressive strength of fly ash-based geopolymer concrete
10. The value of electrical resistivity decreases with increase in the percentage of E waste residue in M30 grade concrete.

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