Effect Of Recycled Coarse Aggregate On Geopolymer Concrete

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ABSTRACT *- India is one of the develop countries that need to face environmental pollution. Have many ways to reduce environmental pollution that causes by production of Portland cement and cause by the increasing of waste material. Worldwide consumption of concrete amounts to more than 1000 Kgs/person. Geopolymer concrete incorporating with recycle concrete aggregate (RCA) is one of the method. Alkaline liquid as a binder are being used to replace the Portland cement to produce geopolymer concrete.*

The alkaline liquid that been used in geopolymerisation is the combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).Geopolymer is an inorganic alumino-silicate polymer synthesized from predominantly silicon (Si) and aluminium (Al) materials of geological origin or by-product materials such as fly ash.

A modified concrete is prepared by replacing coarse aggregates in concrete with recycled aggregates by variations for partially replaced 5%, 10%, 15% and 20%. Cubes and cylinder for each percentage of replacement are casted and tested after 7 days, and 28th days of curing.

Keywords— Rubberized material, Compressive test, Split tenson test, Green comcrete.

I. INTRODUCTION

Concrete is one of the widely used manmade construction materials and its consumption is second only to water. Portland cement is the primary cementitious ingredient in concrete. Production of cement is not only energy intensive, but also responsible for emission of carbon dioxide (CO_2) in large quantity. It is estimated that, approximately 94.76x106 Joules of energy is required for the production of each ton of cement. Further, the production of one ton of cement releases approximately an equal quantity of CO_2 to the atmosphere. Cement production has increased over the years in developing countries. Statistics shows that with nearly 381 million tons of cement production capacity, India was the second largest cement producer in the world in the year 2013.

The world Earth Summits held in 1992 and 1997 expressed its concern about the unchecked and increased emission of green house gases to the atmosphere. The quantity of CO_2 produced due to cement manufacturing contributes to about 5% of the total release of CO_2 to the atmosphere. If an alternate material other than OPC is used in concrete, the corresponding CO_2 release to the atmosphere can be reduced. In India, one of the major sources of material for power generation is coal and it's by product- fly ash- is an environmental threat to the public, if not disposed of properly. Statistics shows that, during the year 2012 -2013, production of fly ash in India was 163.56 Million tons. Only about 38 % of fly ash generated in India is utilized for construction purposes and the remaining quantity is disposed in ash ponds or lagoons. Deposition of the fly ash in storage places can have a negative influence on water and soil because of its granulometric and mineral composition as well as morphology and filtration properties. Therefore the safe disposal of fly ash is still a major concern.

There are various methods to reduce the consumption of cement in concrete, like the partial replacement of cement with cementitious materials. However, partial replacement of cement with supplementary materials in concrete reduces the release of CO_2 gas only to a limited extent, and a complete replacement is always preferable. Geopolymer concrete is one such material, wherein, a building material (geopolymer) is formed by the process of alkali activation of alumino-silicate materials. The most commonly available alumino-silicate material is fly ash. So, the use of geopolymer concrete with fly ash as alumino-silicate material not only helps to reduce the release of CO_2 emission (by eliminating the production of cement), but also effectively disposes off fly ash, an industrial waste produced in large quantities.

The research in the area of geopolymer concrete has been gaining momentum since 1990. The study focuses on the influence of various ingredients, like alumino silicate materials, alkalis etc. on the physical and chemical behaviour of geopolymer concrete. Even though many research reports are available about the behaviour of OPC concrete at ambient temperatures, only limited information available is about the behaviour of geopolymer concrete.

II. OBJECTIVES

The primary objectives of this study are to:

- Examine the effects of increasing the coarse aggregate replacement percentage with recycled aggregate on geopolymer concrete.

- Provide recommendations for the use of recycled aggregate as a coarse aggregate replacement in a geopolymer concrete mixture designed for field implementation.

III. SCOPE

- The waste materials from industries can be effectively used in the replacement of coarse aggregate.
- Use of geopolymer reduces the demand of Portland cement which is responsible for high carbon dioxide emission .
- It reduces the percentage use of conventional aggregates in concrete.
- It can increase the various strength parameters of concrete.

IV. MATERIALS AND METHODS

A. Cement

Cement is one of the major ingredients in concrete. It is a binder material, which is capable of bonding material fragments in to solid mass. Ordinary Portland cement of 43 grade was used for this experimental work.

B. Recycled aggregates

The recycled aggregate for the locally available materials, construction concrete waste, materials and previous year project concrete. The part of the particular size 20mm sieve retained aggregate for the used in the project. Hammer, sieve materials used for recycled aggregate. Roller machine are the used for the shape size. Lateral cleaning on the aggregate water through 1 day dry for the normal sunlight.

C. Aggregate

Aggregates are the primary constituents of concrete. In early times aggregates were considered to be an inert material but recent researches proved that they are reactive to some extent.

Well graded coarse aggregate of size 20mm were used in this study. Fine aggregates are obtained from local resources confirming to zone II of IS: 383 – 1970. The sand was sieved through 4.75mm sieve to remove any particle greater than 4.75mm.

D. Water

Another important ingredient of concrete is water. Water initiates the hydration reaction of cement in concrete which provides the binding capacity for cement.

In this study fresh portable water is used for mixing and curing conforming to IS 456 – 2000.

E. Chemical Admixtures

A combination of silicate and hydroxide solution of sodium and potassium based elements were chosen as the activator liquids. Sodium and sodium hydroxide pellets and the silicate solution for both these materials are purchased from a local supplier.

V. MIX PROPORTION DESIGNATIONS

Mix Design can be defined as the process of selecting ingredients of concrete and determine their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

VI. METHODOLOGY

- Materials properties
- Mix design
- Casting of conventional concrete
- Rubber replacement sample
- Test for compressive strength
- Test for split tensile strength
- Comparison of results

VII. MATERIALS AND METHODS

Cement

Cement is one of the major ingredient in concrete. It is a binder material, which is capable of bonding material fragments in to solid mass. The Ordinary Portland cement was classified into three grades namely 33 grade, 43 grade and 53 grade. Ordinary Portland cement of 43 grade was used for this experimental work. The properties of cement listed in Table 4.1 was adopted from IS 4031.

Properties of cement

Sl.No	Components	Weight
1	Lime (CaO)	63%
2	Silica (SiO2)	21.9%
3	Alumina (Al2O3)	6.9%
4	Iron oxide (Fe2O3)	3%
5	Magnesium oxide (MgO)	2.5%
6	Sulphur trioxide & loss of ignition (SO3)	1.7%

Recycled aggregates

The recycled aggregate for the locally available materials, construction concrete waste, materials and previous year project concrete. The part of the particular size 20mm sieve retained aggregate for the used in the project. Hammer, sieve materials used for recycled aggregate. Roller machine are the used for the shape size. Lateral cleaning on the aggregate water through 1 day dry for the normal sunlight.

Recycled aggregates

- Smaller pieces of aggregates are used as gravel for new construction projects. Sub base gravels laid down as the lowest layer in a road. Recycled concrete can also be used as the dry aggregate for brand new concrete. Larger pieces can be used for erosion control.

Coarse aggregate

Aggregates are the primary constituents of concrete. In early times aggregates were considered to be an inert material but recent researches proved that they are reactive to some extent. As aggregates occupies major volume of concrete, changes in their property impose a major influence in the entire property of concrete. Good gradation of aggregates are necessary for producing workable concrete.

Fine aggregate

Well graded coarse aggregate of size 20mm were used in this study. Fine aggregates are obtained from local resources confirming to zone II of IS: 383 – 1970. The sand was sieved through 4.75mm sieve to remove any particle greater than 4.75mm.

Properties of coarse aggregate

Sl. No	Test	Obtained Values	Limited Values	As per Codes	Remarks
1	Specific gravity	2.7	2.5-3	IS 2386-1963 (Part 3)	Satisfied
2	Fineness modulus	6.80	6.5-8	IS 383-1970	Satisfied
3	Aggregate impact value	25%	45% (Not exceeds)	IS 2386-1963 (Part 4)	Satisfied
4	Aggregate crushing value	24%	45% (Not exceeds)	IS 2386 -1963 (Part 4)	Satisfied
5	Aggregate abrasion value	24%	30% (Not exceeds)	IS 2386 -1963 (Part 4)	Satisfied

Properties of fine aggregate

Sl. No	Test	Obtained Values	Limited Values	As per Codes	Remarks
1	Specific gravity	2.6	2.6-2.9	IS 383-1970	Satisfied
2	Fineness modulus	2.47	2.2-3.3	IS 383-1970	Satisfied
3	Bulk density	1638 kg/m3	1520-1680	IS 383-1970	Satisfied

Water

Another important ingredient of concrete is water. Water initiates the hydration reaction of cement in concrete which provides the binding capacity for cement. Thus proper precautions must be taken regarding the quantity of water used. Water also provides workability in concrete. Quality of water should be maintained to attain desired strength.

In this study fresh portable water is used for mixing and curing conforming to IS 456 – 2000.

MIX PROPORTION DESIGNATIONS

Mix Design can be defined as the process of selecting ingredients of concrete and determine their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass. Depending upon the level of quality control available at the site, the concrete mix has to be designed for the target mean strength, which is higher than the characteristic strength. The Mix proportion used for the study was M30 (1:2.0:2.80:0.50) grade concrete

Mix proportion for M20 grade concrete

Cement Kg/m3	Fine Aggregate Kg/m3	Coarse Aggregate Kg/m3	Water Kg/m3	Recycled Aggregate Kg/ m3
478.95	531.675	1167.40	186	233.48
1	1.11	2.44	0.4	20%

PREPARATION OF SPECIMENS

Batching of Concrete

Batching of concrete is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Here, in this project weigh-batching system was adopted. Percentage of accuracy, flexibility and simplicity in usage is more in weigh batching system when compared to volume batching system.

Preparation of moulds

Before mixing of concrete the moulds in which the specimen are to be casted was prepared. The sides of the moulds are properly clamped with nuts and bolts so that the inner faces make 90º with each other as well as with the base plate and to avoid leakage of water from the freshly mixed concrete.

Mould

VIII. Sizes of moulds

Specimen	Size Of Mould Adopted
Cube	150 mm x 150mm x 150mm
Cylinder	150mm x 300mm

Mixing of concrete

The mixing should ensure that the mass become homogeneous, uniform in colour and consistency. Here, in this project Hand mixing was adopted.

Mixing of concrete

IX. CASTING AND COMPACTING OF CONCRETE

The operation of casting and compacting of concrete are interdependent and are carried out simultaneously. They are most important for the purpose of ensuring the requirements of strength, impermeability and durability of hardened concrete in the actual structure. As for as placing is concerned, the main objective is to deposit the concrete as close as possible to its final position so that segregation is avoided and the concrete can be fully compacted.

IX. DEMOULDING OF SPECIMENS

Once the concrete specimen has been casted it is allowed to dry for 24 hours so that, the concrete specimen attains required strength such that it can be demoulded from the mould without causing damage to the sides of the specimen. Care should be taken to ensure the proper removal of mould as any damage can cause decrease in strength of specimen.

Demoulded sample

X. CURING

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This process results in concrete with increased strength and decreased permeability. Curing is also a key player in mitigating cracks, which can severely affect durability.

Concrete that has been specified, batched, mixed, placed and finished can still be a failure if improperly or inadequately cured. Here in this project once the concrete specimen has demoulded it was kept in ordinary curing tank and cured for 7 and 28 days.

EXPERIMENTAL PROGRAM

Test on fresh concrete

Slump test: Slump test is used to determine the workability or to measure the consistency of fresh concrete.

The internal surface of the mould is thoroughly cleaned and applied with a light coat of oil. The mould is placed on a smooth, horizontal, rigid and nonabsorbent surface.

XI. TESTS ON HARDENED CONCRETE

Compressive strength tests

A compression test determines behavior of materials under crushing loads. Once the curing period of particular specimen was gets over they were taken out and allowed to dry for sometimes. Then the cube of size 150mmx150mmx150mm was subjected to test as per IS: 516-1959. A standard compressive testing machine of 1000kN capacity was used in this project. The specimen was placed between the steel plates of compression testing machine.

The compressive strength of the cube specimen was calculated using the following formula:

Compressive Strength, fc = P/A N/mm^2.

Where, P = Load at failure in N

A = Area subjected to compression in mm^2.

Compression test

Split tensile test

A direct measurement of ensuring tensile strength of concrete is difficult. One of the indirect tension methods is split tension test. The split tensile was carried out on cylinder of 150 mm diameter and 300mm height using universal testing machine. The cylinder which was cured for required days was placed between steel plates longitudinally. Once the specimen was properly placed between the plunger the load was applied gradually as per IS 5816-1999 till it reaches the load in which it fails. The split tensile strength of the cylinder was calculated using the following formula:

XII. Split Tensile Strength = $\frac{2P}{\pi LD}$

XIII. Where, P = Compressive Load in N

XIV. L = Length in mm

XV. D = Diameter in mm

Split tensile test

Mix design for M30 Concrete

Design stipulation:

Characteristic compressive strength = 30 MPa
Maximum size of coarse aggregate = 20 mm
Specific gravity of coarse aggregate = 2.7
Specific gravity of fine aggregate = 2.65
Water absorption of coarse aggregate = 3%
Standard deviation = 4
Dry rodded bulk density of fine aggregate = 1726 Kg/m3
Dry rodded bulk density of coarse aggregate = 1638 Kg/m3
Workability = 0.90 (compacting factor)

Result:

Cement	=	478.95 kg/cu.m.
Water	=	186 litres
Fine Aggregate	=	531.675kg/cu.m.
Coarse Aggregate	=	1167.40kg/m^3
W/C	=	0.4
Recycled aggragates	=	203Kg/cu.m.
Mix ratio	=	1:1.11:2.44

Specimen Preparations:
Sample Pictures,

1. Moulded Sample:

2. Demoulded Sample:

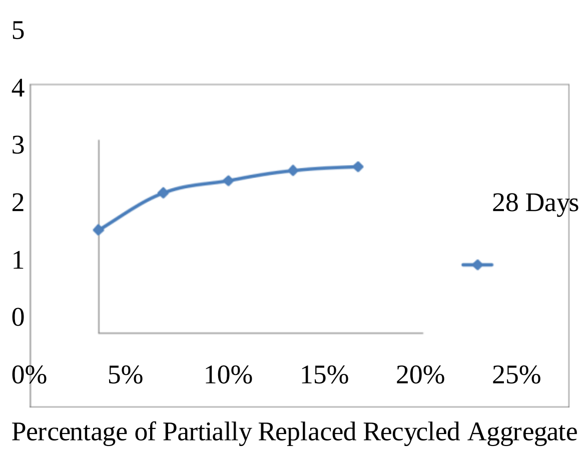
3. Curing Process

Testing Specimen:
After curing specimen ready to test
.

Test Reports:
For Cube,

Comparison result for cubes

Sl. No.	Percentage of recycled aggregate	Curing days	Compressive strength (N/mm^2)
1	10%	7 Days	20
2	15%		22
3	20%		23
4	10%	28 Days	32
5	15%		30
6	20%		39



CONCLUSION

- A convenient mix of M30 is adorable for both conventional and geopolymer concrete.
- There was a significant increase in compressive strength, split tensile strength, flexural strength with the increase in percentage of RCA from 0% to 20% in all curing periods. The optimum percentage of RCA obtained is 20% of its volume of coarse aggregate and also, the optimum percentage of RCA obtained is 10% of its coarse aggregate.
- In geopolymer concrete replacement of 10% recycled aggregates gives optimum increase in its mechanical properties.
- In large scale production of geopolymer concrete results 10% – 20% cheaper than conventional concrete.
- Geopolymer concrete gives more strength with minimum of 10% over than conventional concrete.
- Recycled aggregates can improve the strength of concrete without any additives.
- Results from the trial and error process the molarity of NaOH used in geopolymer concrete was fixed as 14. If the molarity gets increase that increase the density of gel.
- Percentage of mechanical strength in geopolymer concrete over than conventional concrete may be increase in HPC of fly ash based geopolymer concrete.
- The maximum compressive strength of conventional concrete for 3 days, 7days, 14 days and 28 days curing period is 12.50 MPa, 22.33 MPa, 26.75 MPa and 34.25 MPa respectively by partial replacement of coarse aggregate by 20% replacement of RCA and geopolymer concrete for 3 days, 7days, 14 days and 28 days curing period is 44.50 MPa, 46.00 MPa, 47.00MPa and 49.00 MPa respectively by partial replacement of coarse aggregate by 10% replacement of RCA.
- The maximum Split Tensile Strength of conventional concrete and geopolymer concrete for 28days curing period is 4.15 MPa and 6.36 MPa respectively by partial replacement of coarse aggregate by 20% and 10 % replacement of RCA.
- The maximum Flexural Tensile Strength of conventional concrete and geopolymer concrete for 28days curing period is 4.41 MPa and 6.43 MPa respectively by partial replacement of coarse aggregate by 20% and 10 % replacement of RCA.
- Maximum split tensile strength of cylinder was found to be 2.45 N/mm2 at 20% replacement of rubber tyre was added by the weight of concrete and it is similar to that of conventional concrete.

REFERENCE

1. Akash Rao, Kumar N. Jha b, SudhirMisra (2006) , Use of aggregates from recycled construction and demolition waste in concrete, Department of CE, IIT Kanpur, Kanpur 208016, India.

2. Bakharev, T. (2005b), “Durability of geopolymer materials in sodium and magnesium sulphate solutions.” Journal of Cement and Concrete, Research,35,1233-1232.

3. Chang, E. H. , Sarker, P, Lloyd, N and Rangan, B.V. (2007), "Shear behavior of reinforced fly ash-based geopolymer concrete beams", Proceedings of the 23rd Biennial Conference of the Concrete Institute of Australia, Adelaide, Australia, pp 679 - 688.

4. Committee BD-002 Standards Australia (2005), Concrete Structures: Draft Australian Standard AS3600-200x, Standards Australia.

5. Davidovits J., (1991), ―Geopolymers: inorganic polymeric new materials‖, Journal of Thermal Analysis, 37, PP., 1633–1656.

6. Harjito D., Rangan B.V., (2005), ―Development and properties of low calcium fly- ash based geopolymer concrete‖, Research report GC1, Curtin University of Technology, Perth, Australia.