iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 Issue: VI Month of publication: June 2019

DOI: http://doi.org/10.22214/ijraset.2019.6435

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue VI, June 2019- Available at www.ijraset.com

Characteristic Study of Geopolymer Concrete by Replacing of Aggregate and Sand

Shilpa Singla[1], Dr. Rajesh Goel[2]
[1]*Ph.D Scholar, Civil Department, Desh Bhagat University –Mandi Gobindgarh, 147301, India*
[2]*Professor & Dean National Institute of Construction Management and Research, Bahadurgarh, India*

Abstract: India has done a major leap on developing the infrastructures such as express highways, power projects and industrial structures, dams, etc. to meet the requirements of globalization. For the construction of civil engineering works, concrete play main role and a large quantum of concrete is being utilized.

Both coarse aggregate and fine aggregate is a major constitute used for making conventional concrete, has become highly expensive and also scarce. In the backdrop, there is large demand for alternative materials from wastes. Every construction industry totally trust on cement, aggregates whether it is coarse or fine for the production of concrete.

In this research, we have replaced the cement with geopolymer cement and fresh coarse aggregate with recycled aggregate and sand with foundry sand. It was found from literature that foundry sand and recycled aggregate are used separately in different study but there is no use of these material in combination with geopolymer so this is good option to check the various properties of concrete by replacing foundry sand and recycled aggregate in various parentage.

Therefore, we have planned to prepare some number of cubes using geopolymer concrete at various proportions of recycled aggregate like 0%, 25%, 50% and 75 % by weight of coarse aggregate and foundry sand used in percentage like 0%, 2%, 4% and 6 %. The properties for fresh concrete are tested for compressive strength at the age of 7 and 28 days.

Keywords: Foundry Sand, Fresh Aggregate, Recycled Aggregate, Geopolymer Concrete, Coarse Aggregate

I. INTRODUCTION

Utilization of concrete as a major construction material is a worldwide phenomenon and the concrete industry is the largest user of natural resources in the world.

This use of concrete is driving the massive global production of cement, estimated at over 2.8 billion tonnes according to recent industry data.

After water concrete is the second largest material used all over the world. Associated with this is the inevitable carbon dioxide emissions estimated to be responsible for 5 to 7% of the total global production of carbon dioxide. Significant increases in cement production have been observed and were anticipated to increase due to the massive increase in infrastructure and various industries in India, China and South America.

II. MATERIAL USED IN STUDY

A. Geopolymer Concrete

Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, those results in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds.

Different ierature study reveals that water is released during the chemical reaction that occurs in the formation of geopolymers. This water, expelled from the geopolymer matrix during the curing and further drying periods, leaves behind discontinuous nano-pores in the matrix, which provide benefits to the performance of geopolymers.

B. Fly Ash

Fly ash is a waste by product from thermal power plants, which use coal as fuel. It is estimated that about 100 million tons of flyash is being produced from different thermal power plants in India consuming several thousand hectares of precious land for its disposal causing severe health and environmental hazards .

C. Coarse Aggregate
Coarse aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete.

D. Recycled Aggregate
Recycled aggregate is produced by crushing concrete, and sometimes asphalt, to reclaim the aggregate. Recycled aggregate can be used for many purposes. Recycling of concrete is a relatively simple process. It involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. Recycled aggregate is collect from Patiala (Punjab)

E. Foundry Sand
Foundry sand is a by product of various ferrous and nonferrous metal which are used in various types of casting industries. In present study foundry sand is collecting from Patiala city (Punjab). Foundries successfully recycle and reuse the sand many times. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as "used foundry sand".

F. Portland Cement
Portland cement is by far the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with Portland cement is by far the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with other materials (such as clay) to 1450 °C in a kiln, in a process known as calcinations, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix to form calcium silicates and other cementations compounds.

G. Water
The water employed in the mixtures was taken from the concrete laboratory which is tap water. This water was also used in the curing tanks.

III. LITERATURE REVIEW
Naidu [1] presented out a study on strength properties of geopolymer concrete with addition of GGBS. In this paper an attempt was made to study the strength properties of Geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. They obtained compressive strength of geopolymer concrete increases with increase in percentage of replacement of fly ash with GGBS was up to 28.57% of replacement of fly ash by GGBS, the setting was normal and fast setting was observed. Madheswaran et al. [2] conclude that compressive strength of the geopolymer concrete is increased with the increasing concentration of NaOH. The geopolymer concretes produced with different combination of FA and GGBS are able to produce structural concretes of high grades (much more than M40MPa) by self curing mechanisms only. Fiore et al. [3] studied the foundry sand reuse and recycling in concrete production and in his study he found that it is useful to reuse the foundry sand as a recycling material. Patel1 et al. [4] studied the application of used foundry sand as a replacement with cement is feasible for strength in interlocking paver blocks. Use of foundry sand in concrete can save the ferrous and non-ferrous metal industry's disposal, cost and produce a 'greener' concrete for construction. Sagoe et al. [5] stated that the difference between the characteristic of fresh recycled aggregate and natural aggregate is relatively narrower than reported for laboratory crush recycled aggregate mixes. Mirjana et al. [6] found that the workability of concrete with natural and recycled aggregate is almost the same if recycled aggregate is used. Also, if dried recycled aggregate is used and additional water quantity is added during mixing, the same workability can be achieved after a prescribed time. The modulus of elasticity of concrete also decreases with increasing recycled aggregate content as a consequence of lower modulus of elasticity of recycled aggregate compared to natural aggregate.

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IV. METHODOLOGY

This study was focused to determine whether recycled aggregate, foundry sand its subordinate can be used as fresh coarse aggregate for M40 grade of concrete in geopolymer concrete. Scope of this project is to check the characteristic strength of M40 grade of concrete for different proportion of each proportion of geopolymer concrete for M40 is suitable for footing, Residential and Highway application.

A. Mix Design

Concrete is a versatile building material and its mix design may be define as the art of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing of concrete of certain minimum strength and durability as economically as possible. It can be designed for strength ranging from M10 (10MPa) to M100 (100MPa) and workability ranging from 0 mm slump to 150mm slump. In all these cases the ingredients of concrete are same, but it is their relative proportioning that makes the difference.

Following tests are conducted to determine the workability, strength and durability indicators of the concrete. A complete list of the tests is given below

B. Aggregate Impact Value Test

Toughness is the property of a material to resist impact. Due to traffic loads, the road aggregate are subjected to the pounding action or impact and there is possibility of aggregate breaking into smaller pieces. The road aggregate should therefore be tough enough to resist fracture under impact. The aggregate impact test has been standardized by the British Standard Institution and the Indian Standard Institution. The aggregate impact value indicates a relative measure of the resistance of aggregate to a sudden shock or an impact, which in some aggregates differs from its resistance to a slow compressive load. The apparatus used for the test is shown in figure 1.

Figure 1 Aggregate Impact Test Machine

C. Water Absorption of Aggregate

Water absorption value used to calculate the change in weight of fine aggregate due to water absorbed in pore spaces. They are also used to calculate the amount of water that is absorbed by fine aggregate during Portland mix concrete preparation. The test is useful to determine the porosity of road aggregates and is an indirect measure of checking strength and quality of stones. The water absorption is expressed as the percent water absorbed by aggregate in terms of oven dried weight of the aggregate. This test helps to determine the water absorption of coarse aggregates as per IS: 2386 (Part III) – 1963.

Figure 2 Wire bucket for Specific gravity

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D. Compressive Strength Test

The test is conducted on cubes according to IS code 516-1959. Specimens are taken out from curing tank at the age of 7 and 28 days of moist curing and are then tested. Specimens are tested on 100 tones capacity of universal testing machine (UTM). The position of the cube while testing is at right angles to that of casting position. The load was applied gradually without any shock and increased at constant rate of 14 N/mm²/minute until failure of specimen takes place, thus the compressive strength of specimen was found out. Figure 3 shows the apparatus for compressive strength test.

Figure 3 Crushing strength test

E. Flexure Strength Test

The test is conducted on beams according to IS code 516-1959 .The Bearing surfaces of the supporting and loading rollers is wiped clean, and any looses material removed from the surfaces of the specimen where they were to make contact with the rollers. The specimen is then placed in the machine in such a manner that the load was applied to the uppermost surface as casting the mould, along two lines spaced 13.3cm apart. Figure 4 show the apparatus used to find the flexural strength test.

Figure 4 Flexural Strength Test Apparatus

V. RESULTS AND CONCLUSION

Results of mechanical properties of the concrete specimens, including compressive, the durability testing result (water absorption) are presented and discussed. Test results for various mixes are presented and discussed. C.A denotes coarse aggregate and R.S denote recycled aggregate.

A. Aggregate Impact Test

The aggregate used in building and roads should be tough enough to resist fracture under impact. A test designed to evaluate the toughness of aggregate i.e., the resistance of aggregate to fracture under repeated impacts may be called an impact test for the aggregate. The aggregate impact value test has been standardized by the British Standard Institution and the Indian Standard Institution. The aggregate impact value test is carried out for both fresh and recycled aggregate.

Table 5.1 Result of Aggregate Impact Value Test on Fresh Aggregate

Weight of collar	1259.5 kg
Weight of material	328 gm
Weight of material passing through the IS 2.36 mm sieve	48.60 gm
Impact value	14.81%

Table 5.2 Result of Aggregate Impact Value Test on Recycled Aggregate

Weight of collar	1259.5 kg
Weight of material	345 gm
Weight of material passing through the IS 2.36 mm sieve	42.30 gm
Impact value	12.26 %

B. Water Absorption Test

This test helps to determine the water absorption value of coarse aggregates as per IS: 2386 (Part III) – 1963. Take about 2kg of aggregate sample and place it in the wire basket and immersed in distilled water. The basket and aggregates removed from the water and weight after drying i.e. (Weight "A"). The aggregates should then be placed in an oven at a temperature of 100 to 110^{o}C for 24hrs. Oven dried aggregate is allowed to cool and weighed (Weight 'B').

Formula used is Water absorption = [(A - B)/B] x 100%.

Table 5.3 Result of Water Absorption test of Recycled Aggregate

weight of sample (before immersed in water)	2 kg
Weight of sample (after immersed in water)	1.203 kg
Weight of sample (after drying "A")	2.085 kg
Weight of sample (after oven "B")	1.988 kg
Water absorption amount	1 %

Table 5.4 Result of Water Absorption Test of Fresh Aggregate

weight of sample (before immersed in water)	2 kg
Weight of sample (after immersed in water)	0.710 kg
Weight of sample (after drying "A")	2.055 kg
Weight of sample (after oven "B")	1.996 kg
Water absorption amount	0.475

C. Workability Test

It can be seen that the incorporation of GPC, recycled aggregate and foundry sand resulted in maximum increase in slump value of concrete up. Hence, these results show that recycled aggregate and foundry sand possess good slump value so helps in improving the properties of the M40 concrete. Table 5.5 show the results of workability test for different percentage of recycled aggregate and foundry sand. Figure 5.1 to 5.3 shows the variation of workability at different percentage of recycled aggregate, geopolymer cement and foundry sand. As the percentage of recycled aggregate and foundry sand increases concrete become non workable or we can say workability of concrete become decreases. Due to the particle size of foundry sand and recycled aggregate there is large variation of water cement ratio in concrete as compared to normal concrete.

Table 5.5 Workability Test Result at Different % of Recycled Aggregate and Foundry Sand

S. No	% of Recycled Aggregate	% of Foundry sand	Slump value (mm)
1	25	2	55
2	25	4	54
3	25	6	52
4	50	2	50
5	50	4	50
6	50	6	47
7	75	2	44
8	75	4	44
9	75	6	42

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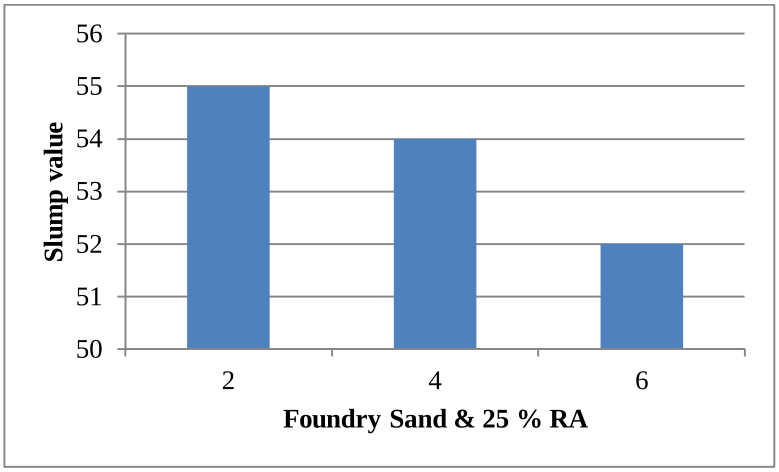

Figure 5.1 Slump Value at Varying % Found Sand and 25 % of Recycled Aggregate

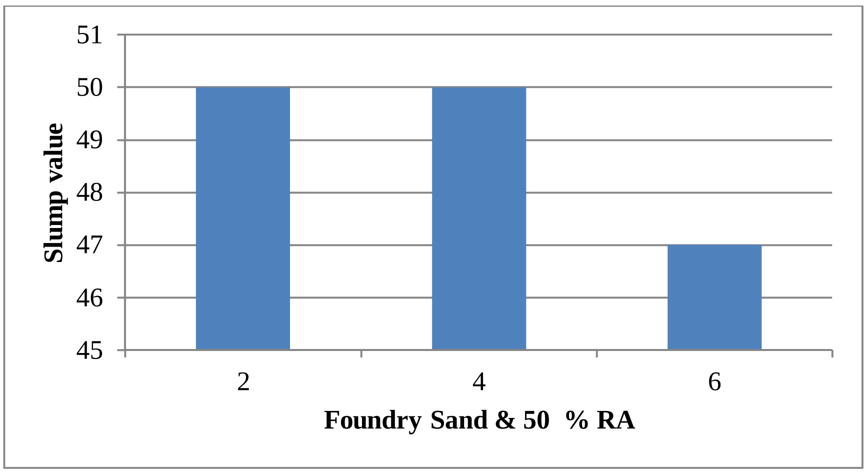

Figure 5.2 Slump Value at Varying % Found Sand and 50 % of Recycled Aggregate

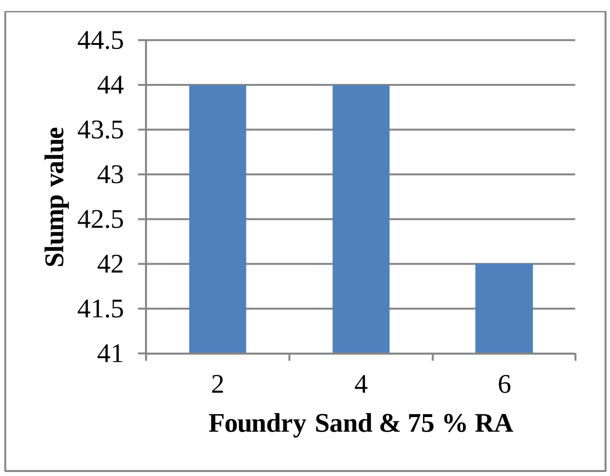

Figure 5.3 Slump Value at Varying % Found Sand and 75 % of Recycled Aggregate

D. Compressive Strength Test

Comparative study of Compressive strength and flexural strength of Geopolymer Concrete with replacement of different percentage of foundry sand and recycled aggregate by normal sand and fresh aggregate under a ambient temperature of 50 ^{0}C at 7 days and 28 days curing periods.

Table 5.6 Compressive Strength of Concrete With 25 % Recycled Aggregate and Varying Percentage of Foundry Sand after 7 and 28 days

Mix designation	% of Recycled aggregate	% of Foundry sand	Compressive Strength (N/mm^2) 7 days	Compressive Strength (N/mm^2) 28 days	Average Compressive Strength (N/mm^2) 7 Days	Average Compressive Strength (N/mm^2) 28 days
RA0 FS0	0	0	35.60 36.48 37.14	43.33 44.23 44.57	36.40	44.04
RA25 FS0	25	0	31.72 32.92 33.00	40.28 40.30 40.50	32.54	40.36
RA25 FS2	25	2	32.75 33.92 34.10	41.30 41.35 41.52	33.59	41.39
RA25 FS4	25	4	33.80 34.95 35.12	42.34 42.38 42.55	34.62	42.42
RA25 FS6	25	6	34.92 35.98 36.18	43.36 43.40 43.58	35.69	43.44

Table 5.7 Compressive Strength of Concrete With 50 % Recycled Aggregate and Varying Percentage of Foundry sand after 7 and 28 days

Mix designation	% of Recycled Aggregate	% of Foundry sand	Compressive Strength (N/mm^2) 7 Days	Compressive Strength (N/mm^2) 28 Days	Average Compressive Strength (N/mm^2) 7 Days	Average Compressive Strength (N/mm^2) 28 Days
RA0 FS0	0	0	35.60 36.48 37.14	43.33 44.23 44.57	36.40	44.04
RA50 FS0	50	0	30.80 31.12 32.90	39.18 39.24 39.36	31.60	39.26
RA50 FS 2	50	2	31.84 32.18 33.95	40.20 40.28 40.40	32.65	40.29
RA50 FS4	50	4	32.92 33.25 34.98	41.30 41.36 41.48	33.71	41.38
RA50 FS6	50	6	33.98 34.28 36.00	42.32 42.42 42.53	34.75	42.42

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Table 5.8 Compressive Strength of Concrete With 75 % Recycled Aggregate and Varying Percentage of Foundry sand after 7 and 28 days

Mix designation	% of Recycled Aggregate	% of Foundry sand	Compressive Strength (N/mm^2) 7 Days	Compressive Strength (N/mm^2) 28 Days	Average Compressive Strength (N/mm^2) 7 Days	Average Compressive Strength (N/mm^2) 28 Days
RA0 FS0	0	0	35.60 36.48 37.14	43.33 44.23 44.57	36.40	44.04
RA75 FS0	75	0	30.64 30.70 30.76	38.05 38.12 38.20	30.70	38.12
RA75 FS 2	75	2	31.68 31.72 31.78	39.16 39.20 39.31	31.72	39.22
RA75 FS4	75	4	32.72 32.79 32.82	40.24 40.26 40.28	32.77	40.26
RA75 FS6	75	6	33.78 33.86 33.90	41.26 41.32 41.34	33.84	41.30

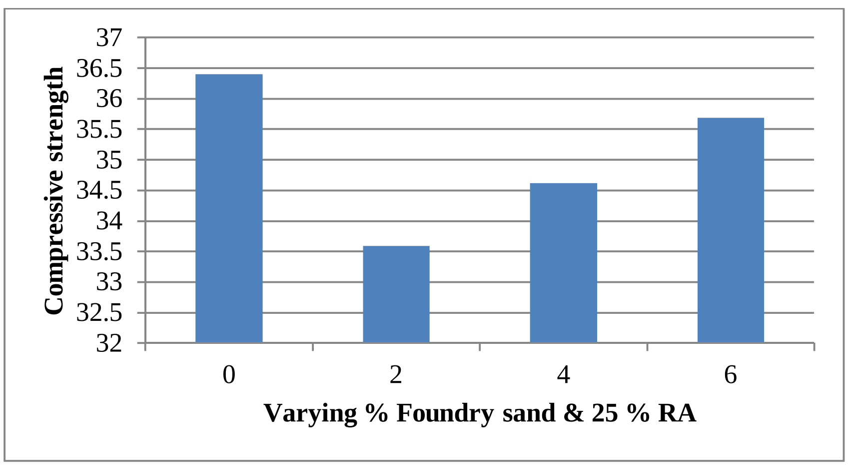

Figure 5.4 Compressive strength with 25 % of recycled aggregate and varying % of foundry sand

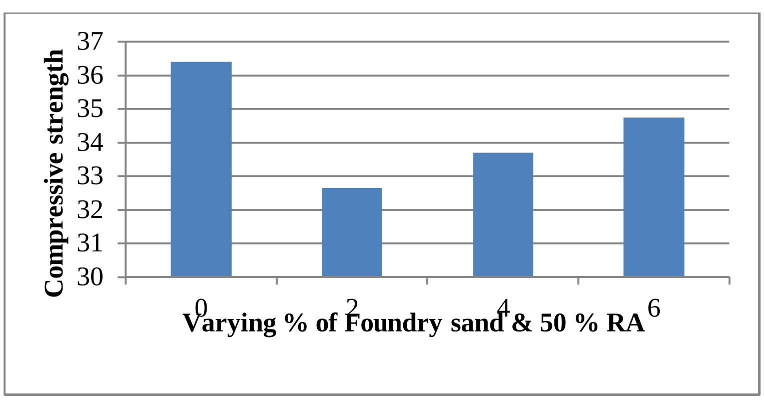

Figure 5.5 Compressive strength with 50 % of recycled aggregate and varying % of foundry sand

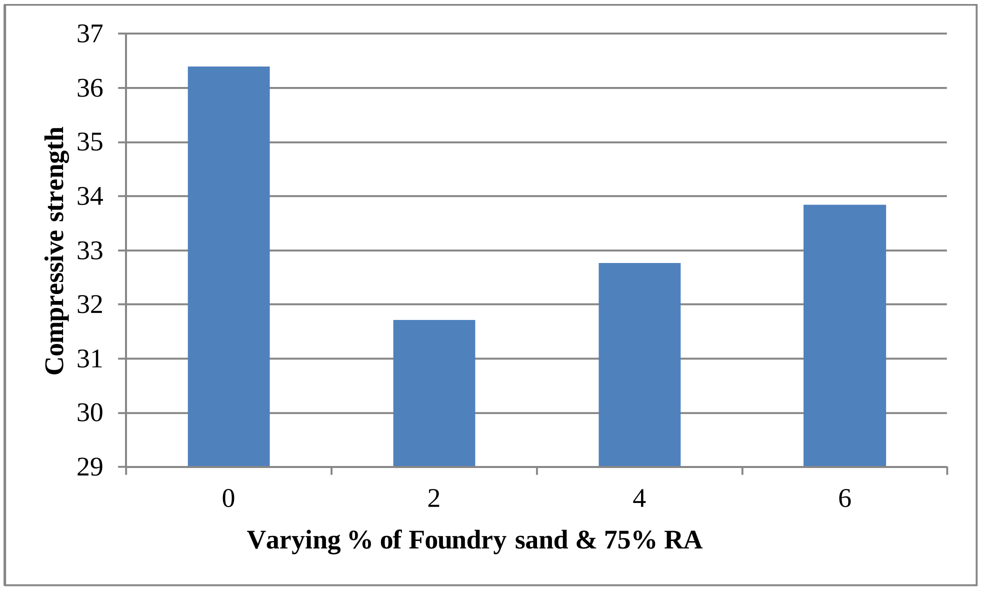

Figure 5.6 Compressive strength with 75 % of recycled aggregate and varying % of foundry sand

E. Flexural Strength

The Flexural strength and compressive strength of all the samples are given in table below. The graphs were plotted with corresponding tables shown in figure below for different combinations of foundry sand and recycled aggregate at different curing temperatures. In this study, compressive strength and flexural strength was measured as per recommendation of IS code. For testing the compressive strength of concrete cubes of 150mm X 150 mm X 150 mm dimensions were casted and tested for each parameter for 7 days curing and other for 28 days curing. The compressive strength of concrete is measured at 7 and 28 days. Flexural strength test was carried out by casting beams of size 100mm X 100mm X 500mm.

The Discussion of all the investigation works have been divided into following phase:-

Table 5.9 Flexural strength of concrete with 25 % recycled aggregate and varying percentage of foundry sand after 7 and 28 days

Mix Designation	% of Recycled Aggregate	% of Foundry Sand	Flexural Strength (N/mm^2) 7 Days	Flexural Strength (N/mm^2) 28 Days	Average Flexural Strength (N/mm^2) 7 Days	Average Flexural Strength (N/mm^2) 28 Days
RA0 FS0	0	0	4.72 4.82 4.93	5.75 5.82 5.88	4.82	5.81
RA25 FS0	25	0	4.50 4.57 4.70	5.02 5.08 5.12	4.59	5.07
RA25 FS2	25	2	4.54 4.60 4.76	5.08 5.12 5.15	4.63	5.11
RA25 FS4	25	4	4.58 4.64 4.79	5.11 5.15 5.19	4.67	5.15
RA25 FS6	25	6	4.61 4.68 4.82	5.16 5.22 5.24	4.70	5.20

Table 5.10 Flexural strength of concrete with 50 % recycled aggregate and varying percentage of foundry sand after 7 and 28 days

Mix Designation	% of Recycled Aggregate	% of Foundry Sand	Flexural Strength (N/mm^2) 7 Days	Flexural Strength (N/mm^2) 28 Days	Average Flexural Strength (N/mm^2) 7 Days	Average Flexural Strength (N/mm^2) 28 Days
RA0 FS0	0	0	4.72 4.82 4.93	5.75 5.82 5.88	4.82	5.81
RA50 FS0	50	0	4.46 4.50 4.58	5.00 5.03 5.09	4.51	5.04
RA50 FS2	50	2	4.49 4.54 4.61	5.05 5.08 5.12	4.54	5.08
RA50 FS4	50	4	4.52 4.58 4.65	5.08 5.10 5.16	4.58	5.11
RA50 FS6	50	6	4.56 4.60 4.69	5.12 5.16 5.19	4.61	5.15

Table 5.11 Flexural strength of concrete with 75 % recycled aggregate and varying percentage of foundry sand after 7 and 28 days

Mix Designation	% of Recycled Aggregate	% of Foundry Sand	Flexural Strength (N/mm^2) 7 Days	Flexural Strength (N/mm^2) 28 Days	Average Flexural Strength (N/mm^2) 7 Days	Average Flexural Strength (N/mm^2) 28 Days
RA0 FS0	0	0	4.72 4.82 4.93	5.75 5.82 5.88	4.82	5.81
RA75 FS0	75	0	4.44 4.48 4.55	4.90 4.99 5.05	4.49	4.98
RA75 FS2	75	2	4.46 4.50 4.59	5.00 5.05 5.09	4.51	5.04
RA75 FS4	75	4	4.48 4.55 4.62	5.06 5.09 5.14	4.55	5.09
RA75 FS6	75	6	4.51 4.58 4.66	5.10 5.12 5.16	4.58	5.12

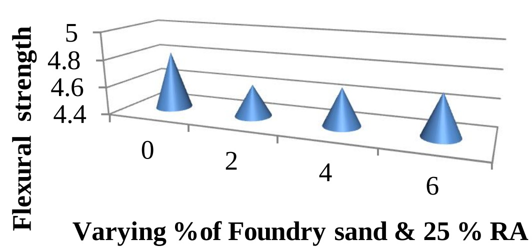

Figure 5.5 Flexural strength at 25 % of recycled aggregate and varying % of foundry sand

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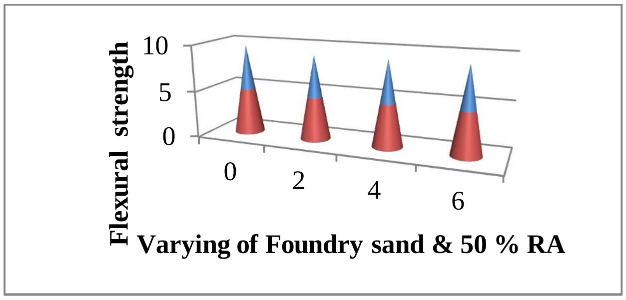

Figure 5.7 Flexural strength at 50 % of recycled aggregate and varying % of foundry sand

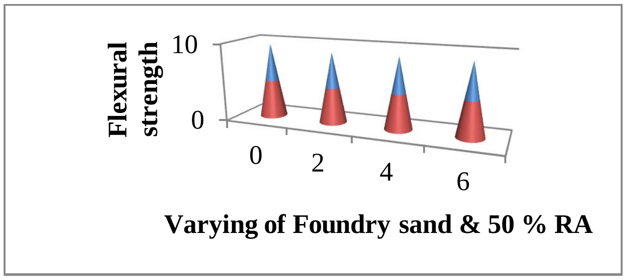

Figure 5.8 Flexural strength at 75 % of recycled aggregate and varying % of foundry sand

VI. CONCLUSION

The present investigation was undertaken to study the effect of foundry sand and recycled aggregate on strength characteristic strength of geopolymer concrete. To achieve the objectives of the present study the sand replaced with foundry sand at 2, 4 and 6 % and fresh aggregate replaced with recycled aggregate at 25, 50 and 75 %. The compressive strength and the flexural strength test were determined for the mixes at the curing age of 7 days and 28 days. Also the various properties of aggregate are also found. The results obtained for the above mixes were compared to investigate the effects of partial replacement of sand by foundry sand and fresh aggregate with recycled aggregate on the above strength parameters of concrete. The conclusion drawn from this study is presented in this chapter.

Based on the results obtained in the present investigation, the following conclusion can be drawn.

1) The results obtained in the present study indicates that it is feasible to replace the sand with foundry sand in geopolymer concrete, for improving the strength characteristics. Thus we can say that foundry sand used as a replacement material of sand upto 6 % in geopolymer concrete. It can be used as an alternative material of sand for the production of concrete to address the waste disposal problems and to minimize the cost of construction.
2) The Experimental work shows that properties of concrete M40 gets improved up to some extent due to incorporation of recycled aggregate and foundry sand.
3) M40 concrete produced from sand and aggregate replacement up to 6% foundry sand leads to increase in compressive strength of concrete at the end of 7days i.e 35.69 N/mm^2 & 28 days i.e 43.44 N/mm^2 respectively in case of compressive strength of concrete.
4) Compressive strength increases by adding foundry sand up to 6 % and then decreases by adding more foundry sand at 25, 50 and 75 % of recycled aggregate at 7 and 28 days.
5) M40 concrete produced from replacement of foundry sand up to 6% leads to increase in flexural strength of concrete at the end of 7 days i.e 4.70 N/mm^2 & 28 days i.e 5.20 N/mm^2 respectively in case of flexural strength of concrete.
6) Flexural strength increases by adding foundry sand up to 6 % and then decreases by adding more foundry sand at 25, 50 and 75 % of recycled aggregate.
7) Workability of concrete will not so increase by replacing cement with geopolymer, sand with foundry sand and fresh aggregate with recycle aggregate powder then further decrease.
8) Toughness of fresh aggregate is higher then recycled aggregate but there is no so much difference so we can use recycled aggregate where the loading condition is not so much increasing.

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