GEO-POLYMERISATION OF INDUSTRIAL WASTEUSING CONSTRUCTION AND DEMOLISION WASTE AS FINE AND COARSE AGGREGATE

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Abstract:

The reduction of Carbon emission has recently become a global concern. The use of Portland cement has been responsible for the main global warming effects in the construction industry, In order to introduce zero carbon emission, Geo-polymer have emerged as a new generation of alternatives.Construction has been most important human activity since early ages.The main aim is to study strength characteristics and flexural behavior of Geo-polymer concrete with Construction Demolision Waste. In this study, Geo-polymer concrete is produced with fly ash, GGBS,and sodium hydroxide and sodium silicate is used as a binder. The mix design is carried out for 12M concentration of sodium hydroxide. Alkaline activator solution ratio of 2.5 and alkaline liquid to fly ash ratio 0.4 is selected for this investigation. The specimen of size 100x100x100mm cubes 100x200mm cylinders and 1200x150x100mm beam were casted and the specimens of Geo-polymer concrete are cured at ambient temperature for 3days, 7 days and 28 days. The cured specimens were then tested for compressive strength, split tensile strength and flexural strength respectively.

Keywords:*Geo-polymer, C &D Waste, Alkaline solution,Compressive Strength, Split Tensile Strength, Flexural Strength.*

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1. Introduction

In past century we developed cement concrete as material for construction work. In 1902 August Perret, first designed building in Paris with structural components beams, slabs and columns. Construction sort of infrastructure and industrial sector by concrete makes it's an important product. It is produced by natural materials; it is reliable material, gives architectural freedom. After water most widely consumed material is concrete as more than ton produced every year for each person in the world. But, the environmental hazard caused by production of concrete material has concerned to form an eco-friendly material for construction. It is been studied that embodied carbon dioxide ranges from 700-800 kg CO_2 for a tone of concrete. The embodied carbon dioxide varies depending upon methods and type of mix design. In cement industry, research has been administered in collection of latest material and up gradation of technology. In India 93% of the cement industry uses dry process technology which is environment friendly. The old dry process technology and semi dry process technology is being used by 7% of cement industry.

The global warming is caused by the emission of the green house gases, CO_2 contributes about 65 % of Global warming.It is estimated that the production of cement will increase from about 1.5 billions tons in 1995 to 2.2 million tons in 2015.The cement industry is held responsible for some of the CO_2emissions,because the production of one to of Portland cement emits approximately one ton of CO_2 into the atmosphere. The environment must be protected by preventing dumping of waste by products materials in uncontrolled manners. Several efforts are in progress to address these issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granular blast furnace slag, rice-husk ash and metakaolin and the development of alternative binders to Portland cement.

There is reduction in emission level of CO_2 due to the waste heat recovery in cement plant. After steel and aluminium, cement is that the next material which produces high energy. It also uses an ample amount of non - renewable materials, e.g. coal, lime stone etc. About 65% of global warming is caused by CO_2. The cement industry is not suitable for sustainable industry since it causes high pollution to the environment. So, there's necessity for alternate material for cement within the concrete which should be eco-friendly, should satisfy mechanical properties and sturdiness characteristics.

This new material should be more superior, preferable compared to conventional concrete based on cement.In 1978 Davidots introduced Geo-polymer as new material for cement and describes the composition of mineral binder which is similar to zeolites with amorphous micro-structure. The ordinary hydraulic cement doesn't require silicon silicate hydration process to urge homogeneous mix and mechanical properties to urge desired strength, there's need of polycondensation of silica and alumina.

Geo-polymer material and alkaline binder solutions are main constituent to form Geo-polymer. The Geo-polymer material should be rich in silicon and aluminium. Fly ash, red mud, GGBS and rice husk ash which are the source materials for Geo-polymer. To create three dimensional polymeric chain and structure it's necessary to possess silica and alumina of ash consisting of Si-O. The rate of concentration of solids is higher in aluminium silicate gel during Geo-polymerisation reaction.

The alkaline liquids help to activate minerals containing reactive silicon and aluminium which helps to get inorganic polymeric material. It is found that fly ash and GGBS are best source material for Geo-polymeric system to get satisfactory strength in Geo-polymer concrete. The alkaline activator solutions help to activate fly ash, GGBS in concrete, which are easily available in India. The preparation of Geo-polymer concrete is same as conventional concrete, which uses alkaline activator solution (AAS) instead of water which acts as binder for the concrete.

2. Experimental Program

A comprehensive experimental program was developed to evaluate the effects of construction and demolison waste replacement percentages on strength characteristics and flexural behavior of Geo-polymer concrete. Four replacement percentages of 0%,20%,40%,60% were investigated. Furthermore, to compare the performanc of normal Geo-polymer concrete and Construction And Demolision Waste mixed Geo-polymer Concrete.

2.1. Materials

2.1.1. Fly Ash

Fly ash is a fine powder that is a by - product of burning pulverized coal in electric generation power plants. Fly ash is a pozzolanic material, a substance containing aluminous and siliceous material that forms cement in the presence of water. *Class F* fly ash is used in this project

2.1.2. *GGBS (Ground Granulated Blast-furnace Slag)*

It is a cementitious material whose main use is in concrete and is a by-product from the blast-furnaces used to make iron.

2.1.3. Super plasticizer

Super plasticizers are mostly used where high strength of concrete will be required and this also gives higher slump value without the increment in amount of water content.

2.1.4. Fine aggregate

It is added to concrete to assist workability and to prevent bleeding and segregation of the cement paste and coarse aggregate during its transportation. Aggregate which passed through 4.75mm IS Sieve and retained on 75 micron (0.075mm) IS Sieve is termed as fine aggregate.

2.1.5. Coarse aggregate

It is used primarily for the purpose of providing bulkiness to concrete.Coarse aggregates containing flat,elongated or flaky pieces or mica should be rejected. The grading of coarse aggregates should be as per specifications of IS 383 (1970).

2.1.6. Construction Demolision Waste

C&D waste was been replaced in place of Coarse aggregate in various ratios (20%,40%,60%). C&D aggregates containing flat,elongated or flaky pieces or mica should be sieved and used. In this project, 20mm size aggregate is used.

2.1.7. Water

Water as per Ph standards- Ph range from 6.5 to 75.normally used for all construction purposes.

2.2. Prelminary Tests

2.2.1. Water Absorption

The pycnometer is dried thoroughly and its weight is taken as W_1. Fill two third part of pycnometer with sand and is weighed as W_2. The pycnometer is filled with water upto the top without removing the sand. Then it is shaken well and stirred thoroughly with the glass rod to remove the entrapped air. After the air has been removed, the pycnometer is completely filled with water upto the mark. Then outside of the pycnometer is dried with a clean cloth and is weighed as W_3. The pycnometer is cleaned thoroughly and then completely filled with water upto the top. Then the outside of the pycnometer is dried with a clean cloth and is weighed.

A. *Fine Aggregate*

Weight of the vessel containing sample and filled with distilled water only, A = 1849.2g

Weight of the vessel filled with distilled water only, B = 1540g

Weight of the Saturated Surface Dried Sample, C = 500g

Weight of oven dried sample, D= 488 g

$$\textbf{Specific Gravity} = \frac{D}{C-(A-B)} = \mathbf{2.62}$$

Water Absorption = $\frac{100(C-D)}{D}$ **= 2.67 %**

Coarse Aggegate

The test procedure is same as that of specific gravity of coarse aggregate.

For **20 mm size**, 600g of coarse aggregates were taken.

Weight of the vessel containing sample and filled with distilled water only, A = 1922

Weight of the vessel filled with distilled water only, B = 1540g

Weight of the Saturated Surface Dried Sample,C = 600g

Weight of oven dried sample,D=598 g

Specific Gravity = $\frac{D}{C-(A-B)}$ **= 2.74**

Water Absorption = $\frac{100(C-D)}{D}$ **= 0.42%**

B. Construction And Demolision Waste

The test procedure is same as that of specific gravity of construction and demolision waste.

For **20mm size**, 600g of construction and demolision waste were taken.

Weight of the vessel containing sample and filled with distilled water only, A = 2000 g

Weight of the vessel filled with distilled water only, B = 1640g

Weight of the Saturated Surface Dried Sample, C = 665g

Weight of oven dried sample,D= 600 g

2.2.2. Sieve Analysis

The sample is brought to an air-dry condition before weighing and sieving. This may be achieved either by drying at room temperature or heating at a temperature of 1000^0 C to 1100^0 C. The air-dry sample 1kg was taken and sieved successively on the appropriate sieves starting with the largest size sieve as stated in the table. Sieving is carried out manually.

Figure 2.2. *Course Aggergate Sieve*

A. *Fine Aggregate*

B. Coarse Aggregate

The sieve analysis procedure is similar to that of fine aggregate. In this test, 3kg of sample was taken. Weight of sample taken is 3000 grams

C. Construction And Demolision Waste

Table 2.2.3. Sieve Analysis of Construction And Demolision waste

IS SIEVE SIZE (mm)	WEIGHT RETAINED(g)	% RETAINED	CUMULATIVE % RETAINED	CUMULATIVE % PASSING
16	16	0.53	0.53	99.46
12.5	191	9.36	6.89	93.10
10	1555	51.83	58.72	41.27
4.5	1233	41.1	99.82	0.18
PAN	5	0.18	100	
TOTAL	3000		365.83	

$$\text{Fineness modulus} = \frac{\text{Sum of Cumulative Weight Retained}}{100}$$

= 365.83/100

= **3.65**

Fineness Modulus of 20 mm Construction And Demolision Waste 3.65

Geopolymer is an inorganic polymer which is prepared by mixing Sodium Hydroxide with Distilled Water for minimum 5 to maximum 24 hours and mixed with Sodium Silicate which produces Geopolymer Alkaline Solution.

$$\text{Fineness modulus} = \frac{\text{Sum of Cumulative Weight Retained}}{100}$$

= 367/100

= **3.67**

Fineness Modulus of M-Sand = 3.67

Table 2.2.2. Sieve Analysis of Coarse Aggregate

IS SIEVE SIZE (mm)	WEIGHT RETAINED(g)	% RETAINED	CUMULATIVE % RETAINED	CUMULATIVE % PASSING
20	0	0	0	100
16	13	0.43	0.43	99.57
12.5	181	6.03	6.46	93.54
10	1469	48.97	55.43	44.57
4.5	1326	44.2	99.63	0.37
PAN	11	0.37	100	
TOTAL	3000		261.95	

$$\text{Fineness modulus} = \frac{\text{Sum of Cumulative Weight Retained}}{100}$$

= 261.95/100

= **2.61**

Fineness Modulus of 20 mm Coarse aggregate = 2.61

3. Concrete Preparation

Table 2.2.1. Sieve Analysis of Fine Aggregate

IS Sieve Size (mm)	Weight Retained (g)	% Retained	Cumulative Weight Retained	Cumulative % retained	Cumulative % Passing
10	0	0	0	0	100
4.75	0	0	0	0	100
2.36	176	17.6	176	17.6	82.4
1.18	221	22.1	397	39.7	60.3
600	151	15.1	548	54.8	45.2
300	159	15.9	707	70.7	29.3
150	135	13.5	842	84.2	15.8
PAN	158	15.8	1000	100	0
TOTAL	1000			367	

The Coarse aggregate, Construction and Demolision waste Where seived in which 12mm downgraded aggregates is used. Fine Aggregate is seived in Seived is used. The Class V type Flyash and GGBS are mixed together to form Geopolymer Concrete at Room Temperature.

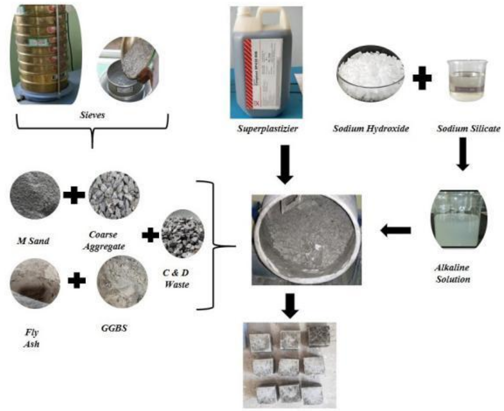

Figure3. *Preparation of Geopolymer*

4. Tests

4.1. ***Test on Fresh Concrete***

In order to determine the workability of fresh concrete for conventional concrete, the slump test and compaction factor test were conducted as per IS 1199 : 1959.

4.1.1. *Slum Cone Test*

Slump test is used to determine the workability of fresh concrete.The apparatus used for doing slump test are Slump Cone and Tamping rod.

The slump test is the most widely, primarily because of the simplicity of the apparatus required and the test procedure.

The slump test indicates the behavior of a compacted concrete cone under the action of gravitational forces.

The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test.

The mould is then filled in four layers, each 1/3 of the height of the mould, each layer being tamped 25 times with a standard tamping rod taking care to distribute the strokes evenly over the cross section.

After top layer has been damped, the concrete is struck off level with a trowel and tamping rod sample.

Themould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction.

This allowed concrete to subside. This subsidence is referred as slump of concrete. The difference in level between the height of the mould and that of the highest point of the subside concrete is measured.

This difference in height in mm and is taken as slump of concrete.

The slump value is 140 mm.

Figure 4.1.1 *Slump Cone Test*

4.2. Test on Harden Concrete

One of the purposes of testing hardened concrete is to confirm that the concrete used at site has developed the required strength. Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete works. Systematic testing of raw materials, fresh and hardened concrete are inseparable part of any quality control programs for concrete, which helps to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regard to both strength and durability. The test methods be simple, direct and convenient to apply. The controlled concrete is cast and cured for certain curing time and the tests for hardened concrete such as compressive strength, split tensile strength were done.

4.2.1. *Ultrasonic Pulse Velocity Test*

Ultrasonic pulse velocity test consists of measuring travel time, T ofultrasonic pulse of 50 to 54 kHz, produced by an electro-acousticaltransducer, held in contact with one surface of the concrete member undertest and receiving the same by a similar transducer in contact with thesurface at the other end.

With the path length L, (i.e. the distance between the two probes) and timeof travel T, the pulse velocity (V=L/T) is calculated.

The ultrasonic pulse velocity depends on the density and elastic propertiesof the material being tested.The influence of path length will be negligible provided it is not less than100mm when 20mm size aggregate is used.

Pulse velocity will not be influenced by the shape of the specimen,provided its least lateral dimension is not less than the wavelength of thepulse vibrations.

 The moisture content of the concrete can have a small but significantinfluence on the pulse velocity. In general, the velocity is increased withincrease in moisture content, the influence being more marked for lowerquality concrete.

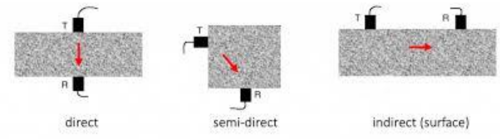

Figure4.2.1. *Ultrasonic Pulse Velocity Test*

Table 3.2.1. Concrete based on Ultrasonic Pulse Velocity Test

Pulse Velocity Concrete Quality	
>4.0 km/s	Very good to excellent
3.5 km/s – 4.0 km/s	Good to very good, slight porosity may exist
3.0 km/s – 3.5 km/s	Satisfactory but loss of integrity is suspected
<3.0 km/s	Poor and loss of integrity

4.2.2. Compressive Strength

The compressive strength test for cubes was conducted in compression testing machine as per IS 516: 1964. The cubes were tested in compressive testing machine at the rate of 140 kg/cm2 /min, and the ultimate loads were recorded. The bearing surface of machine was wiped off clean and the surface of the specimen was cleaned.

The specimen was placed in machine in such a manner, load was applied to opposite sides of the cubes such that casted side of specimen was not top and bottom.The axis of the specimen was carefully aligned at the center of loading frame.

The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. Maximum load applied on specimen was recorded.

Compressive strength = P / A

Where,

P = Maximum load applied (N)

A = Cross sectional area of specimen (mm^2)

Figure4.2.2. *Compression Test*

4.2.3. *Split Tensile Test*

The split tensile strength test for cylinders was carried out as per IS 516: 1964.This test was carried out by placing a cylinder specimen horizontally between the loading surfaces of a universal testing machine and the load was applied until failure of the cylinder along the vertical diameter.

When the load was applied along the generation element on the vertical diameter, the cylinder is subjected to a horizontal stress and the split tensile strength was found using subsequent formula.The split tensile strength of cylinders at 7 days and 28 days is as shown .

Split tensile strength, $f_{ck}(N/mm^2) = 2P/\pi LD$

Where,

P = Ultimate load (N)

L = Length of cylinder (mm)

D = Diameter of cylinder (mm)

Figure4.2.3. *Split Tensile Test*

5. Results And Discussions

5.1. Ultrasonic Pulse Velocity Test

In this, Geopolymer concrete with C & D waste 40% and 60% ratio has very good concrete quality when compared to othergeopolymer concrete mix. Out of this,Geopolymer concrete with C & D waste 20% good to very good, slight porosity may exist.

Table 4.1. Ultra Sonic Pulse Velocity Test

	SET O	SET A	SET B	SET C
Pulse Velocity	4.46	3.920	4.192	4.32

5.2. Compressive Strength

The compressive strength test results fordifferent duration period in ambient curing. The compressive strengthincreased with time for all the mixes.

Table 4.2.1. 3 Days Compressive Strength

Set	Sample Number	Weight Kg	Load kN	Area mm^2	Stress N/mm^2	Average N/mm^2
O	1 2 3	2.446 2.47 2.356	277.6 293.6 260	10000 10000 10000	27.7 29.36 26.0	24.9
A	1 2 3	2.49 2.67 2.55	174.4 209.6 140	10000 10000 10000	17.44 20.96 14.0	11.69
B	1 2 3	2.5 2.46 2.41	188 156.6 196	10000 10000 10000	18.8 15.66 19.6	15.019
C	1 2 3	2.39 2.46 2.39	89.6 160.4 174.4	10000 10000 10000	18.96 16.04 17.44	15.73

Table 4.2.2. 7 Days Compressive Strength

Set	Sample Number	Weight Kg	Load kN	Area mm^2	Stress N/mm^2	Average N/mm^2
O	1 2 3	2.42 2.435 2.464	389.6 396.0 325	10000 10000 10000	38.96 39.6 32.5	31.38
A	1 2 3	2.38 2.50 2.42	281.6 348 316.8	10000 10000 10000	28.16 34.8 31.6	26.118
B	1 2 3	2.41 2.37 2.48	353.6 329.6 343.6	10000 10000 10000	35.36 32.96 34.36	32.35
C	1 2 3	2.39 2.34 2.34	397.6 388 384	10000 10000 10000	39.76 38.8 38.4	37.58

Table 4.2.2. 28 Days Compressive Strength

Set	Sample Number	Weight Kg	Load kN	Area mm^2	Stress N/mm^2	Average N/mm^2

O	*1* *2* *3*	*2.48* *2.55* *2.54*	*476* *452* *502*	*10000* *10000* *10000*	*47.6* *45.2* *50.2*	*43.47*
A	*1* *2* *3*	*2.61* *2.54* *2.65*	*340* *382* *373*	*10000* *10000* *10000*	*34.0* *38.2* *37.3*	*33.3*
B	*1* *2* *3*	*2.53* *2.54* *2.56*	*381* *352* *364*	*10000* *10000* *10000*	*38.1* *35.2* *36.4*	*33.7*
C	*1* *2* *3*	*2.58* *2.50* *2.45*	*433* *445* *410*	*10000* *10000* *10000*	*43.3* *44.5* *41.0*	*40.2*

5.3. Split Tensile Strength

The split tensile strength testresults for different duration period in ambient curing (7,14 & 28 days).The tensile strength varies from 1.54 MPa from 7 days to 2.66 MPa at 28 daysfor 60 % partial replacement of C & D waste. The rate of increase ofstrength for all the mixes showed a similar trend of increase. This indicates that, the behaviour of Geo-polymer concreteis almost similar to the conventional concrete

Table 4.3.1. 7 Days Split Tensile Strength

Set	*Sample Number*	*Weight Kg*	*Load kN*	*Stress N/mm^2*	*Average N/mm^2*
O	*1* *2*	*3.814* *3.78*	*73.6* *61.6*	*2.34* *1.96*	*2.75*
A	*1* *2*	*3.76* *3.77*	*22* *48.8*	*1.0* *1.55*	*1.275*
B	*1* *2*	*3.67* *3.78*	*47.8* *60*	*1.52* *1.909*	*1.7145*
C	*1* *2*	*3.76* *3.64*	*44* *53.2*	*1.4* *1.69*	*1.545*

Table 4.3.2. 28 Days Split Tensile Strength

Set	*Sample Number*	*Weight Kg*	*Load kN*	*Stress N/mm^2*	*Average N/mm^2*
O	*1* *2*	*3.750* *3.750*	*110.6* *95.4*	*3.52* *3.036*	*3.278*
A	*1* *2*	*3.73* *3.75*	*58* *70*	*2.84* *2.22*	*2.53*
B	*1* *2*	*3.71* *3.54*	*54.4* *50*	*2.59* *2.08*	*2.56*
C	*1* *2*	*3.64* *3.67*	*50* *46.5*	*2.59* *2.73*	*2.66*

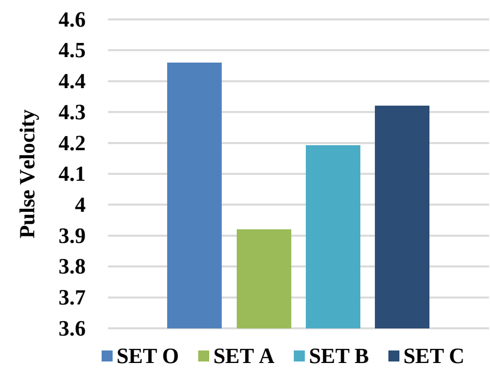

Fig 5.1. Ultrasonic Pulse Velocity Test

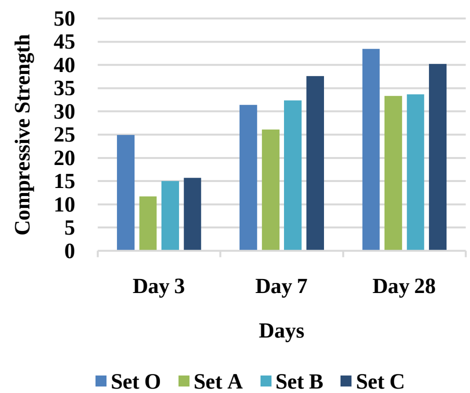

Fig 5.2. Compressive Strength

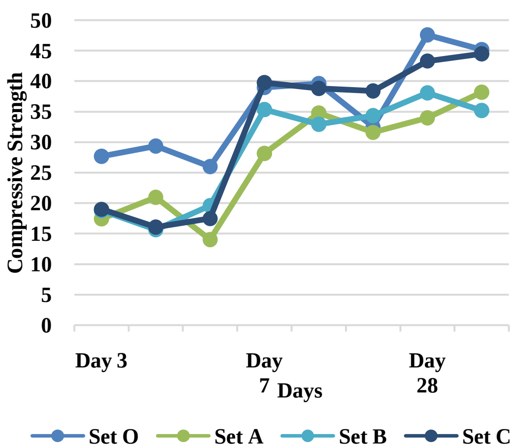

Fig 5.3. Compressive Strength

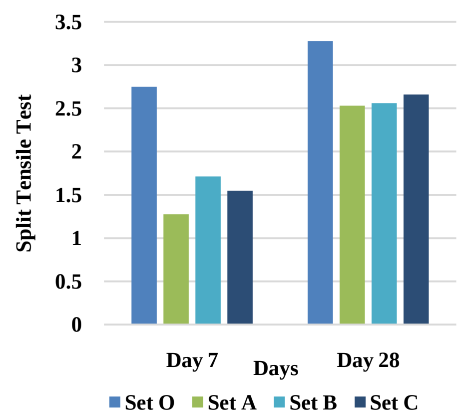

Fig 5.4. Split Tensile Test

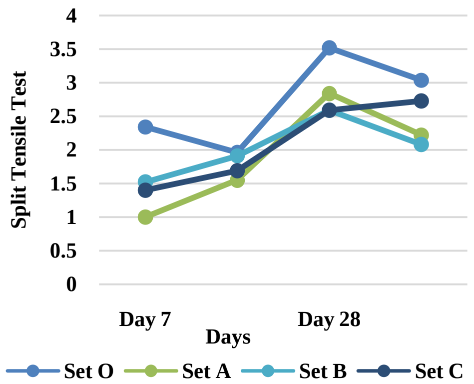

Fig 5.5.Graphical Representention of Split Tesile TestTitle

Set O - Normal Geo-polymer Concrete

Set A - 20% Replacement of C.A. With C& D waste

Set B - 40% Replacement of C.A. With C& D waste

Set C - 60% Replacement of C.A. With C& D waste

6. Conclusion

This paper presents preliminary study on the effect ofstrength characteristics and flexural behavior of Geo-polymer concrete with Construction DemolisionWaste. The Strength properties are measured at 7 and 28 days whilethe flexural properties are measured at 28 days. Based onlimited mechanical and durability properties the followingconclusions bemade:

1. The compressive strength of Geo-polymer Concrete showsgood resultswhen compared to Conventional Concrete at 28 days at ambient curing.
2. The partial replacement of 60% C & D waste to Coarse Aggregate gives the optimum value.
3. The compressive strength of Geo-polymer concrete 60% C & D waste to Coarse Aggregate of showshigh compressive strength values when compared to ConventionalConcrete specimens at 28 days.
4. There is an improvement in strength for the partial replacement levels of C & D waste to Coarse aggregate.
5. The Split Tensile Strength of Geo-polymer Concrete shows 72 % increase in resultswhen compared to Conventional Concrete at 28 days.
6. There was no Water Absorption in Geo-polymer Concrete as well as conventional concrete take place.
7. The Geo-polymer concrete with 60% C & D waste has very goodconcrete quality compared to other Geo-polymer concrete mixes.
8. From the fig 51. we can find out that Ultrasonic Pulse Velocity values for different mixproportions. In this, Geopolymer concrete with C & D waste 40% and 60% ratio has very good concrete quality when compared to othergeopolymer concrete mix. Out of this,Geopolymer concrete with C & D waste 20% good to very good, slight porosity may exist.

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