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Performance of Geopolymer Concrete Incorporating Manufactured Sand as Find Aggregate

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Abstract **- Geo binder is a sustainable binding material that produces no emissions of carbon dioxide during curing and after curing. Aggregates contribute more than 65% for producing geopolymer concrete. The Eco-friendly sand material and cost effective material called manufacture sand was used as a partial replacement material for fine aggregates by various percentages. Manufacture sand is generally produced by crushing, screening and washing a rock in desired shapes and sizes. Manufacture sand was partially replaced by fine aggregates in 10%, 20%, 30%, 40%, 50% 60%, 70%, 80%, 90%, and 100%. Mix designs were prepared and casted separately and then tests were carried out and then the results were compared with respect to conventional geopolymer concrete and concrete made by replacement materials.**

Keywords: Geo polymer, fly ash M-Sand, River Sand, Alkaline solution, Sem XRD.

INTRODUCTION

Concreting is very important in construction activities all over the world. Binding material is necessary for concrete. Generally cement is used as binding material in all concrete applications. Construction is going on everywhere due to this the demand for cement is increased. To overcome this, fly ash has been introduced in place of cement. Manufacture of cement in cement industries emits large amount of pollutantswhich cause environmental pollution. During at the time of production of cement, carbon dioxide is released into atmosphere. One ton production of cement approximately release one ton of CO2 into the atmosphere. By taking that into consideration we are using fly ash as a binding material for concrete along with alkaline solutions, which is named as "Geo polymer concrete". As a result of this we can reduce demand for cement and also decrease the emissions of pollutants into the atmosphere which are releasing by cement industries. That to fly ash is a by product of which is obtained from thermal power plant, and it is also the most abundant industrial waste in the environment. The use of geo polymer concrete significantly decreases CO2 emission and reduces environmental pollution. Utilization of natural river sand is increasing day by day with an increasing of construction activities. It is becoming a scarce material now a day. It is the second major component in the concrete mix. Since it is a natural product; it has organic and inorganic matter. Organic matter if we use such sand. There were many issues rising on extraction of natural sand like decrease of underground water table which impacts on agriculture, effect on aquatic life, erosion of river banks and loss of water holding capacity are the problem associated with natural sand extraction. To overcome all these causes synthetic man made sand called manufacture sand can also be used in place of course aggregates and fine aggregates. Due to even size of all particles in M-sand, high content of reactive silica in M-sand and higher density of M-sand give better properties to the concrete mix compared to conventional concrete.

Kolli Ramujee and M.Potharaju [1] experimented geopolymer concrete and stated that it can more resistant to attack by magnesium and higher sulphuric acids. Geopolymer concrete is more resistant to OPC concrete.

Nirav Shah, et.al [2] investigated concrete with fly ash and determined the compressive and flexural strength of concrete in normal and acidic environment.

L.Krishnan, et.al [3] experimented geopolymer concrete and test results of compressive strength and stated that geopolymer concrete is an eco-friendly construction material.

Vanchai Sata, et.al [4] experimented geopolymer concrete with using recycled aggregates and made relationships of density and compressive strength, splitting tensile and compressive strength.

MATERIALS AND METHODS

Alkaline Liquids

A combination of sodium hydroxide and sodium silicate was used in this study to prepare the alkaline solution. Both the chemicals are commercially available in the local market.

Characteristics of sodium silicate (Na_2SiO_3)

Sodium silicate also known as water glass or liquid glass, available in viscous translucent liquid form, was purchased from the local suppliers. Its reactivity with sodium hydroxide depends upon the Na_2O/ SiO_2 ratio which

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was maintained as 2.2. The mass of soluble silicate (SiO_2) and sodium oxide (Na_2O) present in sodium silicate liquid is 33% and 15% respectively.

Characteristics of Sodium hydroxide (NaoH)

Sodium hydroxide is one of the alkalis commonly used in producing geopolymer concrete. It is usually prepared in concentration ranging between 8M and 16M. In this investigation, sodium hydroxide concentration of 8M, 12M and 14M were considered to manufacture various specimens. 320 grams of sodium hydroxide in flake form was dissolved in 820ml of potable water of make 8M solutions.

Handling the flakes with bare hands gave a sense of irritation, and it necessitated the use of gloves. Initially, the solution was prepared and kept in metal containers. Due to the exothermic heat developed during dissolution, the metal containes started to melt. So, the solution was mixed and kept in plastic containers. The picture of NaOH flakes and the composition of sodium hydroxide flakes is presented in table.

Composition of sodium hydroxide flakes

Chemical compound	Composition
Sodium Hydroxide (NaOH)	99% by weight, min.
Sodium carbonate (Na_2CO_3)	0.5% by weight, max.
Sodium Chlorides (NaCl)	0.1% by weight, max.
Iron (Fe_2O_3)	0.004% by weight, max.
Heavy metals	20ppm, max.

Sand

The sand is collected by a local area. The sand has been sieve in 1.18mm (passed) and retained in 600µ, taken the 500 grams of sand and the sieve plates are used in 1.18mm, 600µ, 300µ, 212µ, 106µ and 53µ. The sand is passing through the 1.18 sieve plate weighted retained in 600µ. After that the retained sand was weighted. The procedure was continued with in half hours and find out the fineness modulus of sand is 2.73.

Coarse Aggregate

The Aggregate is the major ingredients of concrete constituting 70-75 %. They provide a rigid skeleton structure for concrete and act as economical space fillers. The clean river sand is available locally complying with the requirements of grading zone – II specified by IS 383- 1970 of fine aggregate is used for the investigation. Similarly, fineness modulus of fine aggregate 2.73, locally available well-graded granite aggregate of maximum size 20 mm was used along with 12 mm sized aggregate and 6 mm chips as coarse aggregate.

Water

Bore well water collected from the Institution used to cost the concrete specimens. The water was acids and alkalis and more soluble chloride content of 150 mg/lit, sulfate 20 mg/ L, TDS 926 mg/ L, Total hardness 600 mg/lit which is high compared to permissible limit these results are testing from CIRT- water analysis Lab Salem, Tamil Nadu, India. As per IS 456-2000, the permissible limit for chloride is 500 mg/ lit of reinforced concrete.

Alkaline liquid

The most common alkaline liquid used in geopolymerisation is a combination of sodium silicate or potassium silicate and sodium hydroxide (NOAH) or potassium hydroxide (KOH). The use of a single alkaline activator has been reported. Type of alkaline liquid is plays a crucial role in the polymerization of geopolymer concrete. The molarity of the liquid increases with increase the compressive strength of concrete and it gives more stiffness to the materials in the concrete. The father of geopolymer found that generally the KOH solution caused a lower dissolution of minerals compare to NAOH solution. So in this research we were used NAOH pellet form.

Coarse and fine aggregates

In total concrete volume more than 70% place is occupy by the aggregates and it increases the workability of concrete. Most of the body is covered with coarse aggregates and fine aggregates. In this experimental work the coarse aggregates which are retained in 10mm I.S Sieve and passed in 20mm I.S Sieve are consider as per I.S 383-1970. The size of aggregate is less than 4.75mm are called as fine aggregates. Normally sand contains silica material and it is useful to give proper bonding to the concrete. The bonding between the materials are only gives the good strength to the concrete. The physical properties of fine aggregates are shown in below.

Table – Properties of fine aggregates

Characteristic	Value
Type	Uncrushed (shape)
Specific gravity	2.69
Fineness modulus	2.58
Water adsorption	1.08
Grading zone	II

Design mix

G25 grade of concrete is designed by using various design codes and considerations are like geopolymer concrete -1 and geopolymer concrete -2 by using this design considerations we are casted different percentages of concrete by using different materials. In this paper we were used binder ratio (i.e. sodium silicate and sodium hydroxide ratio) is 2.5 and 16M solution is used for getting the good results. To the total volume of concrete 79% of aggregates were taken for design considerations. Manufacture sand are partially replaced in geopolymer concrete instead of fine aggregates. The various replacing percentages are like 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. The design mix propositions are shown in table.

Table – Design mix propositions (kg/ m3) and ratios of G25 grade of concrete

Coarse aggregate	Fine aggregate	Sodium silicate	Sodium hydroxide	fly ash
1344	528	121.71	50.28	392
3.8	1.5	2.5	2.5	1.5

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Table - Mix propositions of F.A andM.S

Mixes	Partial replacement of M-sand as fine aggregates	
	F.A	M.S
Nominal mix	100%	0%
Mix - 1	90%	10%
Mix – 2	80%	20%
Mix – 3	70%	30%
Mix – 4	60%	40%
Mix – 5	50%	50%
Mix – 6	40%	60%
Mix – 7	30%	70%
Mix – 8	20%	80%
Mix – 9	10%	90%
Mix - 10	0%	100%

Experimental work

The evaluation of concrete with electronic waste material and manufacture sand as a partial replacement of fine aggregates has done through testing the specimens. Concrete contains coarse aggregates, fine aggregates, alkaline solution, waterand admixtures for geopolymer concrete are in the ratio of 1:1.5:3.8 before one day of the casting prepare the alkaline solution. For the preparation of solution using plastic bucket and steel rod the solutions are sodium hydroxide and water. The manufacture sand are used as a partial replacement of fine aggregate with various percentages like 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. In this research we were used polyprolyne fibers to decrease the sudden failure of the structure. These fibers are added to the concrete by volume of the cement. For testing the compressive strength for cubes, cylinders and beams of conventional and other mix percentages are totally 90 – cubes and size of specimen is (150 x 150 x 150)mm were casted for strength of geopolymer concrete. As per mix prepositions 15 – cylinders were casted for split tensile test of geopolymer concrete and size of specimen is 150mm X 300mm from the date of casting specimens are kept in oven curing for 24 hours. In 60^{o}C with conceal curing purpose method only. Next day de-mould the concrete specimens and kept in room temperature. The specimens are tested on compressive testing machine for 7th day, 28th day, 56th day, 90th day and 180th day of that alkaline solution added to concrete. For split tensile test 28 days curing is required to test the concrete specimens. For beam flexural test 28 days ambient curing is required to test the concrete specimens.

Compressive strength test

Compression test is the most common test conducted on concrete. It decided the characteristic strength of the concrete. Concrete is weak in tension and strong in compression. The quality of concrete is related to its compressive strength. So the concrete should be strong in compression to attain a high compression values. In this paper we were casted 3- samples for each mix and tested on the machine. From that test results average value is taken and compare to normal geopolymer 25 grade of concrete. Totally casted 50 cubes. Size of each cube is 150mm X 150mm X 150mm and tested at 7days and 28 days. The size of aggregate is 20mm and 10mm for 15cms cubes. Size of aggregates are varies for 10cms cubes. For testing the cube and cylinders uniformly load is applied on the particular specimen, it forms a crack on the surface (or) inside the specimen that cracks on specimen is called the failure load of the cubes and cylinders. The compressive strength of concrete is calculated by using the below expression.

Compressive Strength of concrete (N/mm2) = Applied load (N) / Cross section area (mm2)

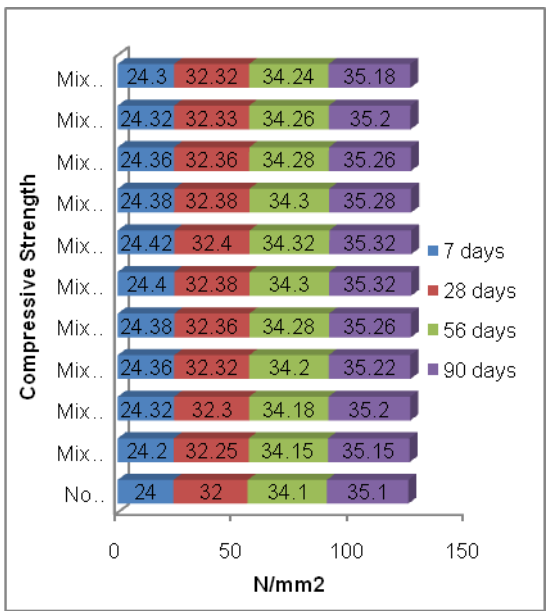
The above figure shows the uniformly load applied on the specimen at the top surface and plate is fixed at the bottom of the specimen. The failure of the specimen is shown in above fig.

Table – Compressive strength values for geopolymer concrete with M.SAND

Mix	Compressive strength values of M-sand (N/MM2)			
	7th day	28th day	56th day	90th day
Nominal mix	24.00	32.00	34.10	35.10
Mix – 1	24.20	32.25	34.15	35.15
Mix – 2	24.32	32.30	34.18	35.20
Mix – 3	24.36	32.32	34.20	35.22
Mix – 4	24.38	32.36	34.28	35.26
Mix – 5	24.40	32.38	34.30	35.32
Mix – 6	24.42	32.40	34.32	35.32
Mix – 7	24.38	32.38	34.30	35.28
Mix – 8	24.36	32.36	34.28	35.26
Mix – 9	24.32	32.33	34.26	35.20
Mix - 10	24.30	32.32	34.24	35.18

The above test results are shown 7th day and 28th day of different mix propositions by replacing M-sand and E-waste as a fine aggregates. The compressive strength of concrete is slightly increasing while adding M-sand as a fine aggregate and for E-waste 32.2 N/MM2 is the maximum compressive strength of concrete while E-waste is added as a fine aggregate up to 20% replacement.

Bar chart No.1 Compressive Strength of concrete



SPLIT TENSILE TEST

In this test we were tested cylindrical specimens. The size of each cylinder is 150mm X 300mm tested at 28th days. The specimen is placed in the machine in a proper manner that the load is applied top surface of the section

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with 2 line spaced a part. The load is applied at the top surface of the cylindrical specimen and increased continuously until the specimens fails, the maximum load of the specimen is recorded. Totally 30 cylinders we were casted for different mix propositions of normal geopolymer 25. For each mix 3- samples were casted and tested. From that testing samples average value is taken as a split tensile strength of concrete. The different mix ratio values of split tensile test and normal mix as shown in below table and those values are clearly shown in the bar graph. There is the formula to calculate the split tensile test as shown below.

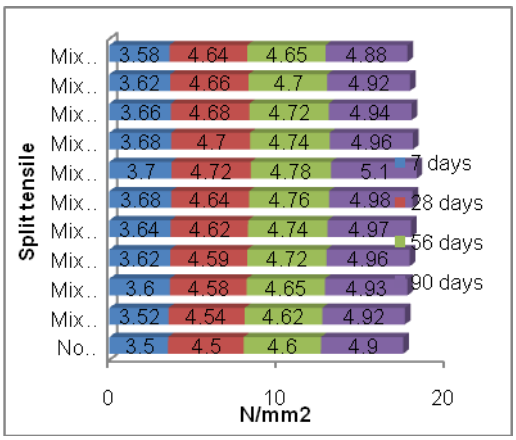
Split tensile test = 2P/ (3.14dl)
Where p – Applied load (KN)
d – Diameter of the cylinder in mm
L–Length of the cylinder in mm

Table- Split tensile test values of geopolymer concrete

Mix	Split tensile test values of M-sand (N/MM2)			
	7th day	28th day	56th day	90th day
Nominal mix	3.50	4.50	4.60	4.90
Mix – 1	3.52	4.54	4.62	4.92
Mix – 2	3.60	4.58	4.65	4.93
Mix – 3	3.62	4.59	4.72	4.96
Mix – 4	3.64	4.62	4.74	4.97
Mix – 5	3.68	4.64	4.76	4.98
Mix – 6	3.70	4.72	4.78	5.10
Mix – 7	3.68	4.70	4.74	4.96
Mix – 8	3.66	4.68	4.72	4.94
Mix – 9	3.62	4.66	4.70	4.92
Mix - 10	3.58	4.64	4.65	4.88

From the above test results maximum value getting at mix-2 i.e. 4.8 at 20% replacement of replacing fine aggregates as a M-sand it increases the split tensile strength of concrete. All values are compared to nominal concrete as shown in below bar chart.

Bar chart No.2 Split tensile strength of concrete



Flexural Strength of Concrete

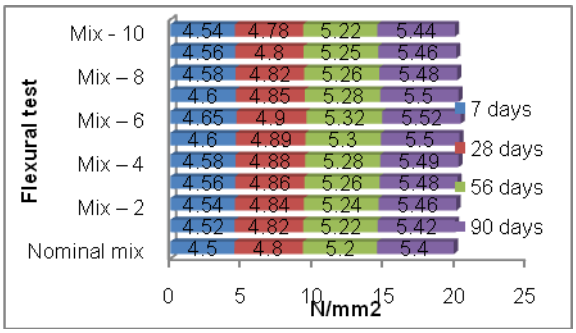
Concrete as relatively weak in tension and strong in compression. in steel reinforced concrete member"s dependence is placed on the tensile strength of concrete. Rebars and steel reinforcement is provided to resist the tensile forces in the concrete specimens. Tensile stress is develop in concrete due to rusting of steel reinforcement bars, drying shrinkage, and other reasons. The concrete beam is placed on two adequate subgrade supports. Point load is applied at the center of the beam maximum fiber stress are developed while bending. In case of two point loading crack will be appear at any section of the beam ,not strong to resist the stress in the middle. The bending moment of the section is maximum. While applying the two point load the modulus of rupture is lower compare to point loading .the size of the specimens are 100mm X 100mm X 500mm. Totally 10 cylinders were casted and tested.

Table 8 Flexural test values of geopolymer concrete

Mix	Flexural strength values of M-sand (N/MM2)			
	7th day	28th day	56th day	90th day
Nominal mix	4.50	4.80	5.20	5.40
Mix – 1	4.52	4.82	5.22	5.42
Mix – 2	4.54	4.84	5.24	5.46
Mix – 3	4.56	4.86	5.26	5.48
Mix – 4	4.58	4.88	5.28	5.49
Mix – 5	4.60	4.89	5.30	5.50
Mix – 6	4.65	4.90	5.32	5.52
Mix – 7	4.60	4.85	5.28	5.50
Mix – 8	4.58	4.82	5.26	5.48
Mix – 9	4.56	4.80	5.25	5.46
Mix - 10	4.54	4.78	5.22	5.44

From the above test results increase flexural strength values by replacing fine aggregate as an M-sand in different mix propositions and other replacing material. As a fine aggregates up to 20% strength values are increases more than that percentage decrease the flexural strength values. This test results are compared to nominal mix and that values are shown in bar chart.

Bar chart No.3 Flexural Strength of Concrete



The compressive strength, split tensile and flexural tests of concrete has done. The strength behaviour of geopolymer concrete is calculated by replacing M-sand as fine aggregates. We were replacing different percentages like 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. That test result values are shown in table 6, table 7 and table 8. In this research the compressive strength of concrete is increases while adding M-sand as a fine aggregates and strength of concrete is decreases while adding fine aggregates. By re-placing 30% in concrete

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increases the strength value and it slightly decreases by adding more than 30%. Bar chart 1,bar chart 2 and bar chart 3 shows the Different mix prepositions of various percentage replacing in concrete and compressive strength ,split tensile test and flexural test values are shown in table6,table7 and table8 for 7 days, and 28 days.

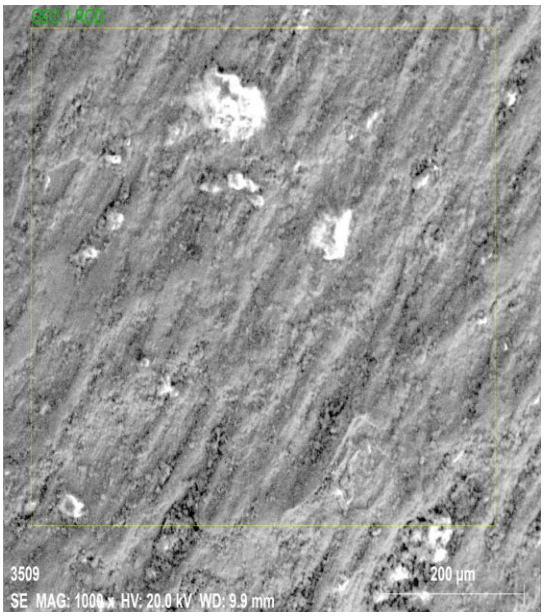
CONCLUSION

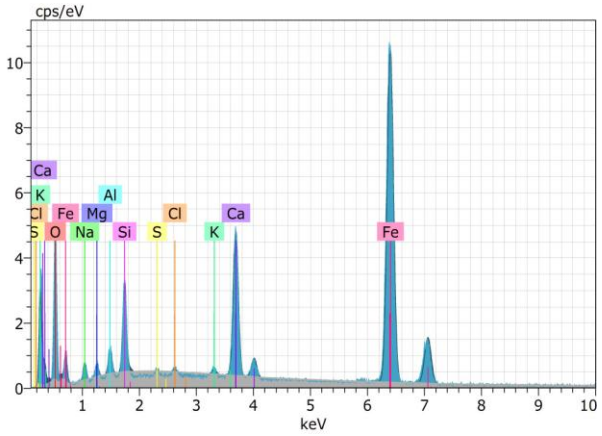
The main aim of this research is to improve the characteristic strength of geopolymer concrete, replaced with 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% of M-sand as a fine aggregates and find out the optimum percentage replacement.

Based on the experimental investigation presented, the following results are drawn:

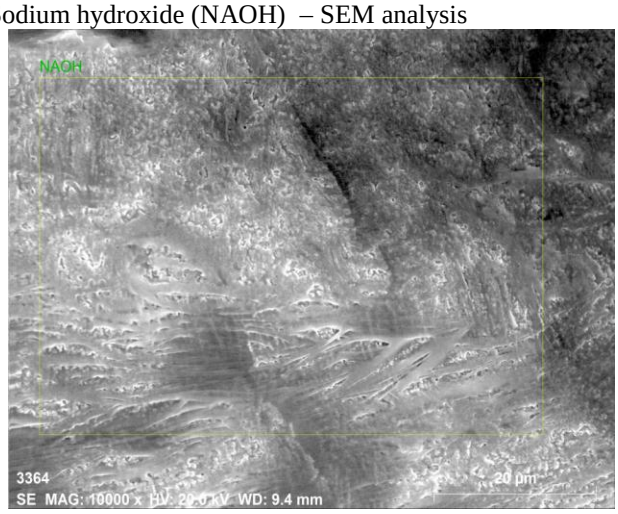
- The strength of geopolymer concrete was increased with increase in percentage of M-sand in various percentages.
- The strength of geopolymer concrete was increased¬ with increase in percentage up to 40%.
- More than 40% replacement the strength of concrete is slightly decreases compare to nominal mix and its effects on the structure.
- The maximum strength obtained for M-sand at 56 days is 36.8Mpa and the maximum strength is obtained for 28 days is 32.2Mpa.
- From the test results as mentioned above we observe that the compressive strength of concrete using as a partial replacement for sand shows decrease in compressive strength when compared with control mix.
- In split tensile test the maximum strength is obtained for 20% replacement in concrete at 28 days. For M-sand the split tensile strength is increased up to 50% replaced in concrete. By adding the polypropylene fibres to concrete it reduces the water permeability and shrinkage.
- To overcome the low tensile strength of concrete by adding polypropylene fibres to concrete. Increase in the amount of proportion in geopolymer concrete requires higher dosage of super plasticizer to get good work ability.

Geo polymer concrete – SEM Analysis





Sodium hydroxide (NAOH) – SEM analysis



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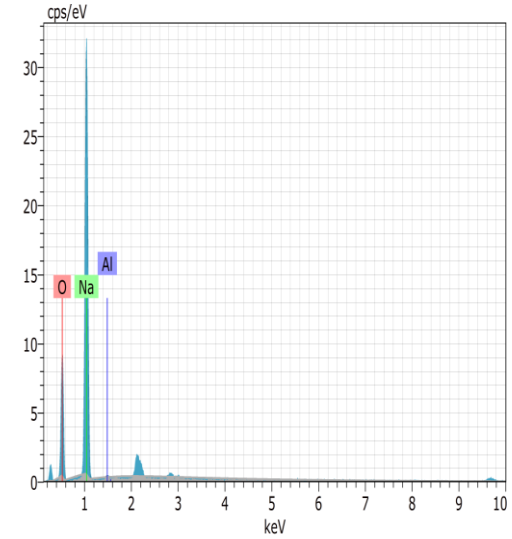
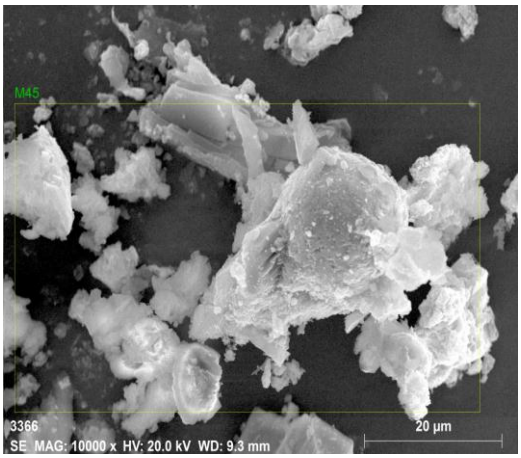
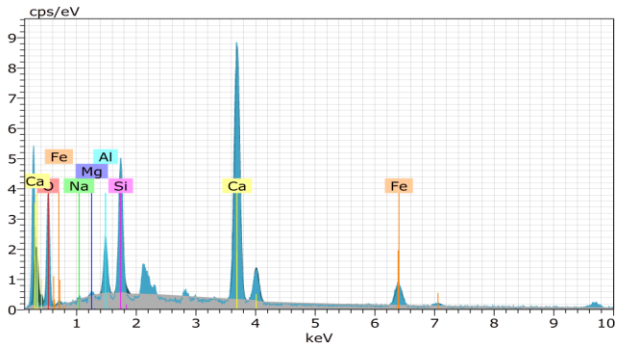


Plain concrete image – sem analysis





XRD REPORT