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An Experimental Analysis of Sanative Concrete and Its Microscopic Properties

J. Sravani^[1], D. Nagaraju^[2]

PG Student (Structural Engineering), Narasarao Peta Engineering College, Narasaraopeta, AP, India ^[1]

Assistant Professor (Civil Engineering), Narasarao Peta Engineering College, Narasaraopeta, AP, India ^[2]

ABSTRACT: Concrete is a mixture of cement, aggregates and water, sometimes admixtures are also added. Cement is the costliest ingredient in concrete. The manufacturing of cement is a huge process in which several tons of carbon dioxide is released into the atmosphere. This is a serious problem to the environment to cause pollution. The use of flyash as a partial replacement of cement in concrete is tested as flyash has nearly the same chemical composition as that of cement. Many research works were carried out to study the property of concrete on addition of flyash and the results were noteworthy.

Flyash is an industrial waste product, which is formed from the combustion of coal in thermal power plants. Out of the available two types of flyash, Class C flyash is chosen in this experiment as it has the more amount of lime percentage and self cementitious compounds. The experimental work was carried at various percentage replacements of flyash i.e. 0, 5, 10, 15, 20, 25, 30, 35, 40, 50, 60 %. Flyash has the property of late strength formation. So the concrete attains a great amount of strength at 28 days rather than at earlier periods. Due to this property of flyash, concrete behaves as a self healing concrete.

Coir is an agricultural waste product, which has proved its use in many applications. The addition of coir into concrete is mainly to increase the tensile strength of concrete. As coir is a fibrous material it has good bonding properties with concrete and helps in crack resistance. Coir in concrete reduces the chance of corrosion occurrence to reinforcement. The specimens of concrete were casted at above mentioned percentages of flyash with constant amount of 0.5% by volume of cement in all the specimens. The concrete was tested for compressive strength and flexural strengths at 28 days. The optimum percentage of flyash and coir which gives the maximum compressive strength and flexural strength is reported. The self healing behaviour of sanative concrete is observed in all the specimens. The use of these waste materials in concrete comparatively reduces the overall cost of the project.

KEYWORDS: Flyash, Coir, Compressive strength, Self healing behaviour, Permeability.

I. INTRODUCTION

Concrete is a brittle material, which has very low tensile strength. As a result, plain concrete members could not resist tensile forces acting on the structures. So concrete members are reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength. The addition of steel reinforcement significantly increases the strength of concrete and results in concrete with homogenous tensile properties, however the development of micro cracks in concrete structures must be checked. Experiments are carried out to reduce the cost of concrete, which has satisfactorily high strength by using natural waste materials. The use of flyash is introduced as a partial replacement of cement in concrete to lower its cost and to observe the self healing behaviour. The introduction of fibers is generally taken as a solution to develop concrete in view of enhancing its flexural and tensile strength.

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Fly ash is the fine powder produced as a side product from the combustion of pulverized coal and is collected by mechanical and electrostatic separator from fuel gases of power plants. The disposal of fly ash is one of the major issues for environmentalists as dumping of fly ash as a waste material may cause severe environmental problem. Therefore, the utilization of fly ash as an admixture in concrete instead of dumping it as a waste material can have great beneficial effects. It can be used particularly in mass concrete applications where main emphasis is to control the thermal expansion due to heat of hydration of cement paste and it also helps in reducing thermal and shrinkage cracking of concrete at early ages. The replacement of cement with fly ash in concrete also helps to conserve energy.

Coconut fibre is extracted from the outer shell of a coconut. The scientific name of coconut fibre is Coir, *Cocos nucifera*. There are two types of coconut fibres, brown fibre extracted from matured coconuts and white fibres extracted from immature coconuts. There are many general advantages of coconut fibres e.g. they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean. The introduction of coir fibre into concrete is experimentally analyzed by checking the improvement of tensile strength and compressive strength of concrete.

The calcite precipitation induced by bacteria and bacterially produced carbonic anhydrate using X-ray diffractometer and Field Emission Scanning Electron Microscopy (FE-SEM) results showed that calcite was the dominant mineral phase [5, 6], Sanative concrete was quantified by strength tests, X-ray diffraction (XRD) analysis and by SEM. strength tests, XRD analysis and SEM evidenced that direct involvement of coir fiber in self-healing.

II. LITERATURE REVIEW

1. Dr. Nemkumar Banthia, University of British Columbia, (2016) did research program, which aims to contribute to the development of innovative pavements, enhance detection of corrosion in reinforced concrete bridges, undertake research in seismic strengthening for BC schools, and improve durability and performance of innovative materials. Hydrophilic fibres for use in concrete reinforcement have been developed, deployed in Thondebhavi pavements and have shown to increase durability, reduce GHG emissions and reduce costs in pavement construction.

2. K. Van Tittelboom et al, (2013) of Magnel Laboratory for Concrete Research, Ghent University worked on self healing in cementitious materials viz; autogenous healing and autonomous healing. Autogenous crack healing can be mainly attributed to hydration of unhydrated cement particles and dissolution and subsequent carbonation of calcium hydroxide. The study says that the slower reaction rate of flyash may result in a higher amount of unhydrated particles and thus an improved possibility for ongoing hydration.

3. Shreeshail.B.H et al, (2014) of St. John college of Engineering, Maharashtra worked on the study of strength properties of concrete on addition of coir and the deformation properties of concrete beams with fibres under static loading condition. The suitability of coir fibre reinforced concrete as a structural member is studied, in comparison with conventional concrete.

4. Daisuke Homma et al, (2009) of Japan Concrete Institute studied on investigation of self healing capability of fibre reinforced cementitious composites (FRCC), mechanical properties and surface morphology of crack in FRCC. The cracks were introduced in specimens of concrete by tensile test, were retained in water for 28 days. The self healing capability of the specimens was investigated by means of microscope observation, water permeability test and tension test.

5. D.M. Parbhane, S.B. Shinde, (2014) of JNEC, Aurangabad, studied on addition of coir fibre into concrete as the rising cost of construction material is a matter of concern. They observed that workability and tensile strength of

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concrete increased to some extent as the coir increased. Concrete produced by 1%, 2%, 3%, 4% & 5% addition attained 28 days tensile strength of 2.68, 2.90, 3.11, 3.25, 2.33 respectively. These results showed that Coir Fiber Concrete can be used in reinforced concrete construction. They reported that the usage of coir in concrete as ecofriendly.

6. Dhandhania VA* and Sawant S, (2014) of D.K.T.E. Society's Textile & Engineering Institute, Ichalkaranji, India, discussed the importance of coconut fiber as an ad-mixture for roofing, its advantages and scope in future. The study described the use of coconut fiber over Steel for the following reasons like low cost, recyclability, non corrosiveness, low thermal conductivity (natural cooling), high strength and low weight ratio. They reported that in earthquake prone areas where frequent damage to infrastructure takes place, the use of Natural fibers such as Coir instead of steel will prove advantageous.

7. Er. Amit kumar Ahirwar, Prof. Rajesh Joshi, (2015) of R.G.P.M, Bhopal conducted an experimental analysis of flyash and coir fiber mix cement concrete for rigid pavement. They studied and reported the compressive strength and flexural strength of flyash based coconut fibre reinforced concrete specimens were higher than conventional concrete at all the stages. They reported that the incorporation of flyash in concrete can save the coal and thermal industry disposal costs and produce a greener concrete for construction. The test specimens were casted by replacing cement with varying percentages of flyash and coir and the test results show an increase in compressive strength and tensile strength for the chosen mix proportion.

III. MATERIALS USED

1. Cement:

Ordinary Portland cement of 53 grade was generally used confirming to IS 12269: 1987.

Laboratory test property	Test Results	Requirements as per IS 12269:1987
Fineness	91.4 %	Should be > 90 %
Consistency	32 %	-
Setting time:		
Initial setting time	36.5 mins	Should be > 30 mins
Final setting time	360 mins	Should be < 10 hrs
Soundness	5 mm	Should be < 10 mm
Compressive strength at 28 days	54.016 N/sq.mm	Should be > 53 N/sq.mm
Specific gravity	3.15	3.15

Laboratory test report of OPC 53 grade cement

2. Flyash:

Flyash, also known as "pulverised fuel ash" is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Flyash is a pozzolan, a substance containing aluminous

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and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound similar to Portland cement.

The flyash produced by coal-fired power plants provide an excellent prime material used in blended cement, mosaic tiles, and hollow blocks among others. Fly ash can be an expensive replacement for Portland cement in concrete although using it improves strength, segregation, and ease of pumping concrete.

3. Coir:

Coir or coconut fibre is a natural fibre extracted from the husk of coconut and used in products such as floor mats, doormats, brushes and mattresses. Coir fibres are found between the hard, internal shell and the outer coat of a coconut. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature, but later become hardened and yellowed as a layer of lignin is deposited on their walls. Each cell is about 1 mm long and 10 to 20 μm in diameter. Fibers are typically 10 to 30 centimetres long. The two varieties of coir are brown and white. Brown coir harvested from fully ripened coconuts is thick, strong and has high abrasion resistance. It is typically used in mats, brushes and sacking. Mature brown coir fibres contain more lignin and less cellulose than fibres such as flax and cotton, so are stronger but less flexible. White coir fibres harvested from coconuts before they are ripe are white or light brown in color and are smoother and finer, but also weaker. They are generally spun to make yarn used in mats or rope.

The coir fibre is relatively waterproof, and is one of the few natural fibres resistant to damage by saltwater. Geotextiles made from coir are durable, absorb water, resist sunlight, facilitate seed germination, and are 100% biodegradable. These blankets have high strength retention and a slow rate of degradation meaning they last for several years in field applications. The introduction of coir into concrete has showed good results as it enhances the tensile strength of concrete and also shows resistant to cracks.

4. Aggregates:

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 important constituents in concrete. They give body to concrete, reduce shrinkage and effect economy. Earlier, aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregates and paste. The mere fact that the aggregates occupy 70 to 80% of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. To know more about the concrete it is very essential that one should know more about the aggregates which constitute major volume in concrete.

Coarse aggregates:

The aggregates of size more than 4.75mm are called coarse aggregates. Coarse aggregates make up the bulk of a concrete mixture. The presence of aggregate greatly increases the robustness of concrete above that of cement, which otherwise is a brittle material and thus concrete is a true composite material. Locally available crushed coarse aggregate was used.

Fine aggregates:

The aggregates of sizes less than 4.75 mm as per IS are called fine aggregates. Locally available dry aggregate satisfying the requirements of ASTM C33-03 was used in the concrete mixes. The sand obtained from river beds or quarries is used as fine aggregate. The fine aggregate along with the hydrated cement paste fill the space between the coarse aggregate. The specific gravity of the fine aggregate (natural sand) used in the investigation was found to be 2.74 and the fine aggregate use in this present investigation comes under ZONE – II i.e; normal sand.

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Property of aggregate	Obtained test result	Requirement as per IS
Size	20mm	Maximum 20mm
Flakiness index	11.344 %	Should be < 15%
Elongation index	9.865 %	Should be < 15%
Water absorption	0.12%	Should be < 0.6%
Specific gravity	2.74	Should be 2.6-2.8

Test Certificate of aggregates

5. Water:

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalies, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete. As a guide the following concentration represent the maximum permissible values:

- a) To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5ml of 0.02 normal NaOH.
- b) To neutralize 100ml sample of water, using mixed indicator, it should not require more than 25ml of 0.02 normal sulphuric acid.

IV. RESULTS AND ANALYSIS

Compressive strength test on cubes:

The compressive strength of concrete is one of the most important and useful properties of concrete. The compressive strength of concrete is generally determined by testing cubes or cylinders made in laboratory. The main function of the concrete in structure is mainly to resist the compressive forces. Compressive strength is also used as a qualitative measure for other properties of hardened concrete.

The compression test is carried on cube specimens of the size 150*150*150 mm. The casted specimens are given identity numbers and are left undisturbed for one day. Then the specimens are removed from the mould and are cured for 28 days. For testing in compression, no cushioning material should be placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Three cubes of conventional mix are tested at 7 days and three at 28 days. The obtained results are reported and analyzed.

Identity of mix (M30 Grade)	% Flyash	7 days strength (N/mm ²)	28 days strength (N/mm ²)
A ₀	0	28.4	39.99
A ₁	10	29.03	43.33
A ₂	15	30.96	43.89
A ₃	20	28.87	42.24
A ₄	25	27.06	41.11

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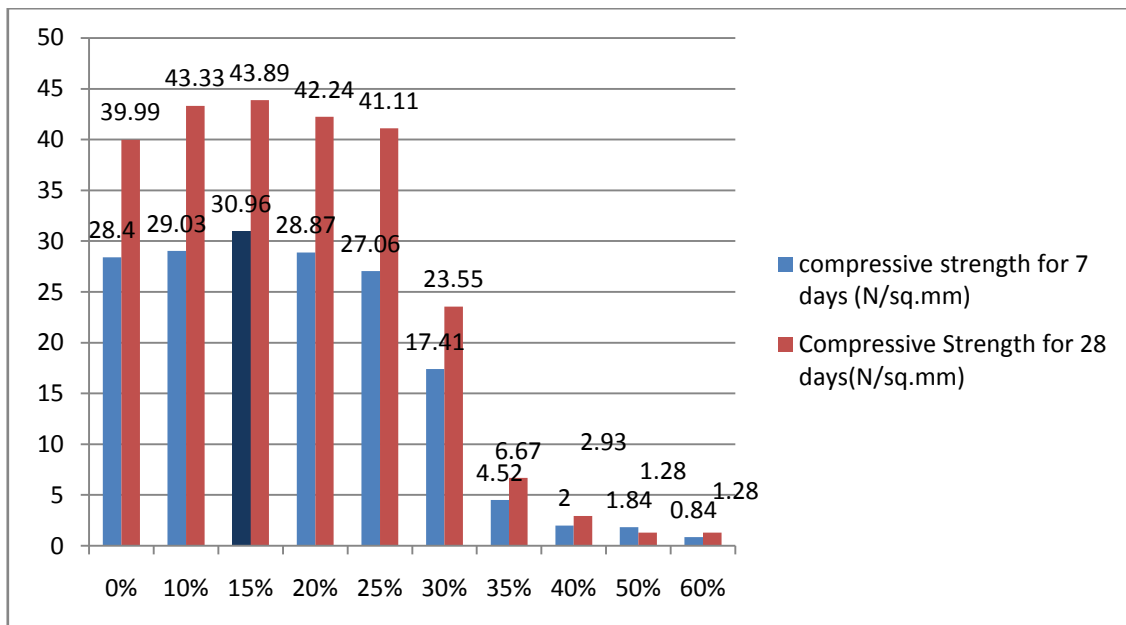
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A ₅	30	17.41	23.55
A ₆	35	4.52	6.67
A ₇	40	2	2.93
A ₈	50	1.84	1.28
A ₉	60	0.84	1.28

Compressive strength test results



Comparative analysis for compressive strength for 7 and 28 days

Flexural strength test:

Concrete is relatively strong in compression and weak in tension. The tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Direct measurement of tensile strength of concrete is difficult. The systems of loading used in finding out the flexural tension are central point loading and third point loading. The two point loading system is carried out in this experiment. The standard size of the specimen is 150*150*700 mm. The mould is filled with concrete and is well compacted. After 24 hrs, it is allowed to cure for 28 days and then tested.

Identity of mix (M30 Grade)	% Flyash	Flexural strength for 7 days (N/mm ²)	Flexural strength For 28 days (N/mm ²)
A ₀	0	4.54	6.64
A ₁	10	4.66	6.91

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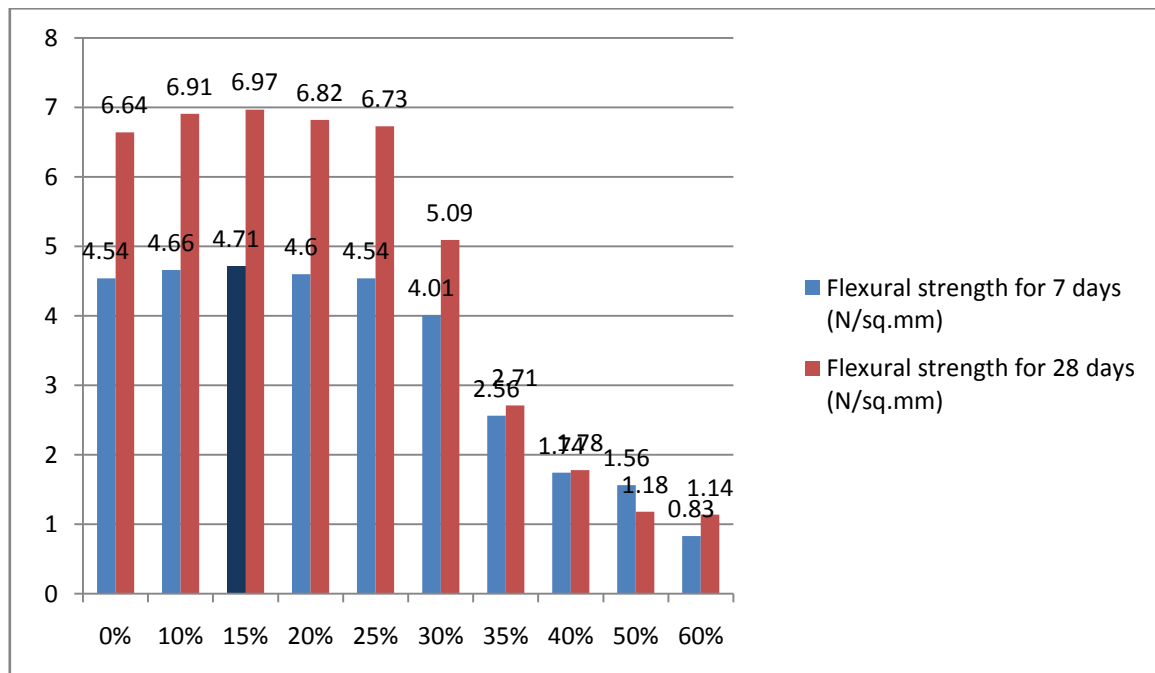
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A₂	15	4.71	6.97
A ₃	20	4.60	6.82
A ₄	25	4.54	6.73
A ₅	30	4.01	5.09
A ₆	35	2.56	2.71
A ₇	40	1.74	1.78
A ₈	50	1.56	1.18
A ₉	60	0.83	1.14

Flexural strength of concrete test results



Graphical representation of flexural strength of concrete

Self healing behaviour:

The self healing capacity of sanative concrete is observed by the curing of compressive strength tested cubes for a minimum period of 7 days. The casted specimens of sanative concrete are tested for compressive strength in CTM. The load is applied gradually until the first crack appears on the surface of concrete specimen. Then the tested specimen is again cured in water for atleast 7 days. It was observed that the crack formed on testing in CTM is healed completely by forming the cement paste within the crack. The cubes are again tested for compressive strength after self healing and the obtained results are reported.

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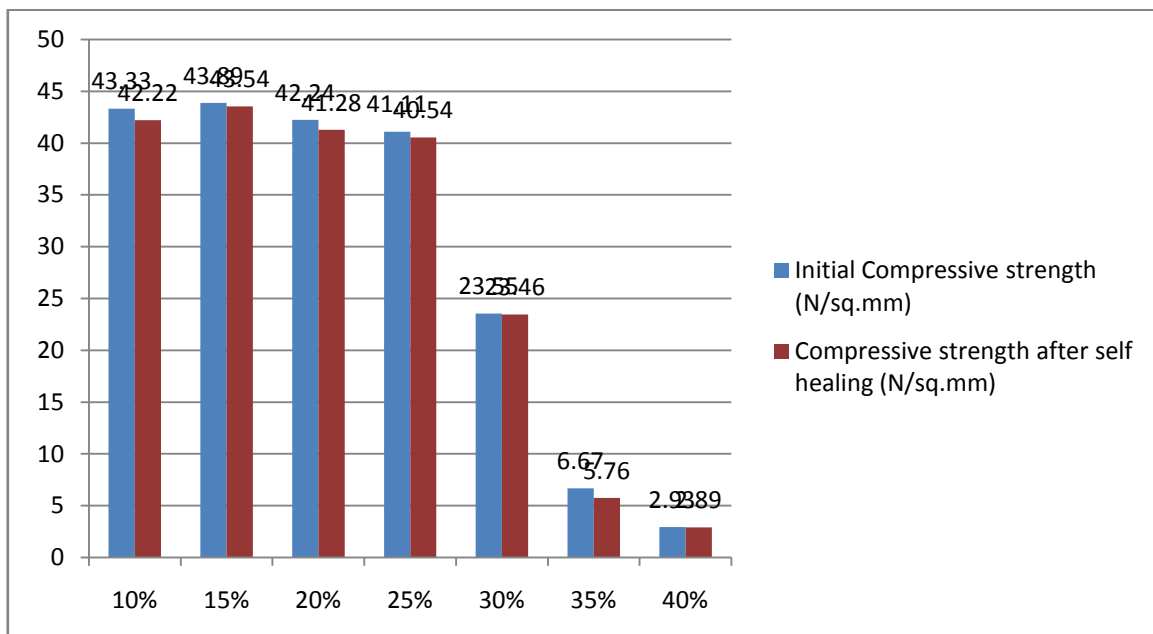
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It was observed that on increasing the amount of flyash the strength of concrete is increased upto certain level but after that the strength goes on decreasing. But in high percentage flyash concrete cubes, the self healing was observed completely. Also the permeability is observed to be more in such cubes. The crack width was measured as 0.2 mm and after self healing process, no cracks were observed open.

Identity of mix (M30 Grade)	Compressive strength at 1 st test (N/mm ²)	Compressive strength after self healing (N/mm ²)
A ₀	39.99	-
A ₁	43.33	42.22
A ₂	43.89	43.54
A ₃	42.24	41.28
A ₄	41.11	40.54
A ₅	23.55	23.45
A ₆	6.67	5.76
A ₇	2.93	2.89
A ₈	1.28	-
A ₉	1.28	-

Compressive strength test results before and after self healing



Graphical representation of compressive strength of initial and self healed cubes

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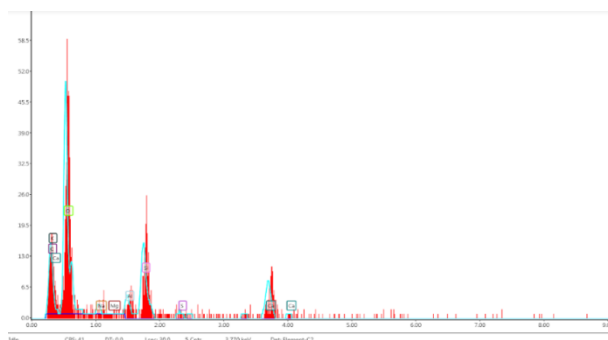
SEM ANALYSIS:

SEM means Scanning Electron Microscope. SEM is a type of electron microscope that produces images of a scanning the surface with a focussed beam of electrons. The electrons interact with atoms in the sample, producing various signals that contains information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern and the position of the beam is combined with the intensity of the detected signal to produce an image. SEM can achieve resolution better than 1nm. Specimens are observed in high vaccum in conventional SEM, or in kw vaccum or wet conditions in variable pressure or environmental SEM.

EDS ANALYSIS:

Energy-dispersive X-ray spectroscopy, is an analytical technique used for the elemental analysis or chemical characterization of a sample. It relies on an interaction of some source of X-ray excitation and a [sample](#). Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing a unique set of peaks on its electromagnetic emission spectrum (which is the main principle of spectroscopy).

To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as electrons or protons, or a beam of X-rays, is focused into the sample being studied. At rest, an atom within the sample contains ground state (or unexcited) electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where the electron was. An electron from an outer, higher-energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer. As the energies of the X-rays are characteristic of the difference in energy between the two shells and of the atomic structure of the emitting element, EDS allows the elemental composition of the specimen to be measured.



GRAPH OF EDS ANALYSIS

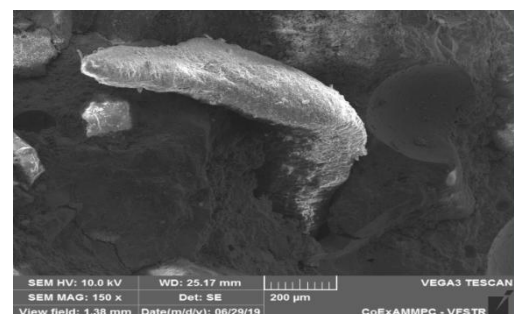


IMAGE OF SEM ANALYSIS

XRD ANALYSIS:

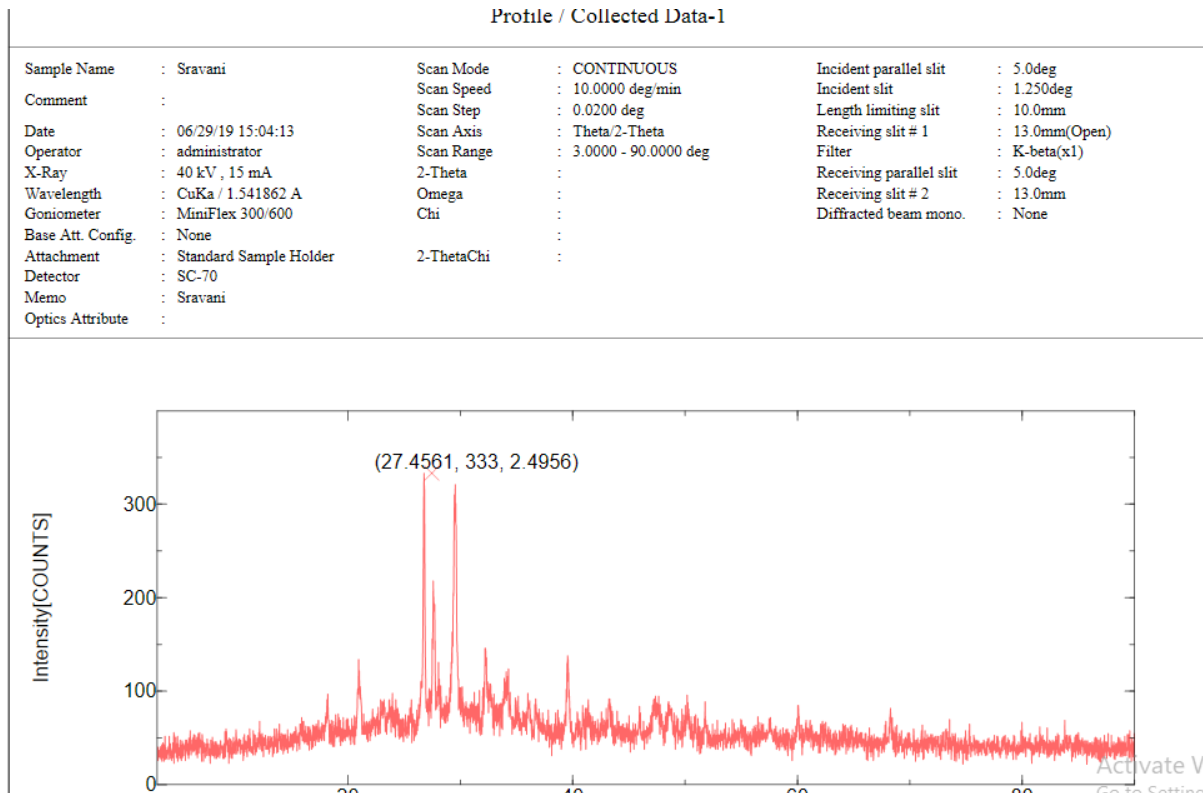
X-ray diffractometry was used to investigate the 28-day hardened paste of mix M5-8. Figure 18.8 shows the XRD pattern of the tested sample. The obtained pattern shows a mostly amorphous material with few crystalline phases including quartz, albite and diopside, in which quartz was originally present in the both preliminary raw materials. This indicates that the changes responsible for the differences in compressive strength originate and take place within the amorphous part of the/structure.

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GRAPHICAL REPRESENTATION OF XRD ANALYSIS

V. CONCLUSION

The following conclusions are reported from the experimental work carried out and from the results obtained from compressive strength, flexural strength and self healing capacities of casted specimens.

1. The optimum compressive strength of sanative concrete is obtained at 15% flyash and 0.5% coir i.e., 43.89N/mm² at 28 days.
2. The optimum flexural strength of sanative concrete is also observed at 15% flyash and 0.5% coir and is of value 6.97N/mm² at 28 days.
3. It is observed that the compressive and flexural strengths of sanative concrete are more than that of the conventional concrete, whose values are 39.99N/mm² and 6.64N/mm² respectively at 28 days.
4. At high percentage replacement of cement with flyash, the strength is very low but the permeability of such concrete is likely to be increased.
5. Use of flyash as a partial replacement of cement decreases the cost of construction and helps in self healing.
6. Use of coir as an additive in concrete increases the tensile strength of concrete and crack resistant.
7. The total cost of the project is reduced by using the natural waste materials, which yield good results too.
8. From the XRD, SEM analysis it was observed that the movement of moisture particles under the presence of cracking load had been influenced by the presence of coir fiber.
9. The hygroscopic moisture present in the interstices of the concrete had been absorbed by the coir fiber under the application of failure load for the specimen and making the concrete as sanative in nature as the fiber are undergoing for expansion and contraction due to the presence of moisture.

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