Studies on Special Behaviours of SCC using Fibre and Sand Resources

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Abstract- **The thesis represents an investigation on mechanical behaviour and microstructural analysis of self-compacting concrete. Concrete materials were weighed batched and casted for M30 grade. A total of 8 cubes (150mm x 150mm x 150mm) and cylinder (150mm x 300mm) were casted. All these cubes and cylinders were casted with partial replacement levels of calcite powder and quartz powder of varying proportions instead of using cement. Along with total replacement of foundry sand and 0.75%of basalt fibre were added. The use of large amount of quartz powder in combination with cementitious additions in concrete along with foundry sand has several practical and ecological advantages by reducing carbon dioxide emissions. The fresh properties of SCC were discussed using slump flow test, V-funnel test, L-box test and U-box test were conducted. The specimens were cured and then tested for 7 days, 28 days. The microstructural properties were examined using SEM analysis (scanning electron microscopic). It was concluded that it holds good parameter on durability and fresh property test. It also increases the strength of hardened property. In this investigation it helps in reducing segregation resistance as it holds to be homogeneous and reduces the emission of carbondioxide.**

I. INTRODUCTION

Self-Compacting Concrete or Self- Consolidating Concrete was developed to improve the durability of concrete structures. It is a highly flowable type of concrete that spreads into the form without the need for mechanical vibration. In order to increase the volume of paste, cohesiveness of paste, stability of the concrete and to enhance deformability, the powder content is incorporated along with supplementary cementitious materials. Self-Compacting Concrete contributes a remarkable role on modern architectural and complex indeterminate structural construction.

A. DEVELOPMENT OF SELF-COMPACTINGCONCRETE

In 1983, there occurred a problem on durability of concrete structures. In order to overcome the problem "Self-Compacting Concrete" was created by okamura in 1986 who is known as the father of SCC technology.

Manufacturing of Self-Compacting Concrete requires three main aspects to be fulfilled.

- In order to obtain high flowing characteristics, high amount of water reducers or super plasticizers were added.
- A type of aggregate mixture is added to gain the desiredcompactness.
- Alteration of fluid properties ensures a cohesive mix which will keep the aggregate and pastetogether.

B. APPLICATIONS OF SELF-COMPACTINGCONCRETE

- Self-Compacting Concrete is used for repairs, restoration and renewal construction.
- It is helpful in constructing highly stable and durable retainingwalls.
- Self-Compacting Concrete is employed in the construction of raft and pile foundations.

C. OBJECTIVE OF THEPROJECT

- To determine the mechanical behaviour of Self-Compacting Concrete by using foundrysand.
- To determine better flow-ability, filling ability and passing ability of self-compactingconcrete.

D. LITERATUREREVIEW

T.Parthiban (2017) investigated on the Durability of Concrete by adding Basalt fibre which do not contain any otheradditives. In this study trial test for the concrete with cement, fine aggregate, coarse aggregate and basalt fibre with 0%, 1%, 2% are conducted to prove the difference in durability parameters. Rapid chloride penetration test, Water permeability test, Sorptivity test were conducted for the concrete mix. In this experimental investigation it was concluded that fibre arrests the formation of micro cracks and thus in RCPT, WPT, ST the optimum value attained at 1% of fibre replacement. The test results found that 1% replacement holds good for durability parameter.

Neelam Pathak and Rafat Siddique (2012) carried their study on Effects of elevated temperatures on self-compacting concrete containing fly ash and spent foundry sand which usually consists of ordinary Portland cement with 43 grade, classF-flyash, fine and coarse aggregate and polycarboxylic ether-based superplasticizer. In this research the influence of class F fly ash with three percentages of 30%, 40%, 50% as cement replacement and replacing 10% of fine aggregate with spent foundry sand. Forvarious percentages compressive strength test, split tensile strength test, RCPT, modulus of elasticity and fresh property tests, SEM analysis and X - ray diffraction tests have been evaluated and all these were heated up to27^{0}C, 100^{0}C, 200^{0}C and 300^{0}C. From this study it was found that increase in strength attributes bending property of cement paste and thus the compressive strength increases between 200^{0}C and 300^{0}C.

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Augustine Uchechukuru Elinwa (2014) an evaluationontheuseofSpentFoundrySand as partial replacement of fine aggregate in concrete production. The material spent foundry sand was replaced in the proportions of 0%,10%.20%,30% and 40% by weight of fine aggregate and with a total of 5 mixes M-0, M- 10, M-20, M-30 and M-40 were prepared and cured for 3, 7, 28, 60 and 90 days. Tests were carried under compressive strength test, water absorption and density and thus the results obtained that spent foundry sand can reduce the effects of absorption in concrete by 8% to 28% at 90 days of curing and also found that compressive strength reduces with increase in replacement levels and 10% replacement shows best behaviour.

HafezE.Elyamany(2014)et.alevaluatesthe Effect of filler types on physical, mechanical and microstructure of self-compacting concrete and Flow-able concrete. It consists of cement with two groups of filler materials of 7.5%, 10%, 15% and tests on hardened properties along with X-ray diffraction analysis, SEM analysis,thermo-gravimetric analysis were performed. It was evaluated that increase in filler type decrease segregation and bleeding and no negative effect occurs on non-pozzolanic filler materials.

Aravinth S.N. (2014) developed High Strength Self Compacting Concrete using Mineral and Chemical Admixture. In this

study consists of cement, fine aggregate, coarse aggregate, water and the use of Mineral admixture Silica Fume and viscous modifying agent with Chemical admixture Glenium B233 were used. An Experimental investigation were carried out for fresh concrete and hardened concrete using EFNARC guidelines. Results obtained that reduction of W/P ratio increases compressive strength and optimum dosage of chemical admixture maintains the self-compacting concrete.

K. Senthil et.al, carried out an experimental investigation on the Influence of Basaltfibre and Recycled concrete aggregate on Self- Compacting Concrete through Mechanical and Durability tests. In this study the durability properties of self-compacting concrete elements were studied in carbonation depth. It has been observed high water absorption capacity, durability along with the behaviour of RAC is lower than the normal concrete due to lack of bonding between recycled aggregate and cement mix.In order to overcome these deficiencies, can be eliminated by reinforcing it with discrete fibres. Special type of limitations is followed in fibrous self-compacting concrete. Basalt fibre was varied as 0, 2 and 4kg/m^3 by replacing recycled concrete aggregate with various levels at 0%, 50% and 100% and compressive strength test, split tensile strength test, flexural strength test was carried out. Simultaneously further modifications were done using Natural aggregate along with recycled concrete aggregate and tests on fresh concrete, hardened concrete was done. It was concluded that basalt fibre along with recycled concrete aggregate decreases in case of compressive strength. Similarly increase of basalt fibre increases the split tensile strength, flexural strength and in carbonation depth.

Gurpreet Singh and Ankush Thakur (2018) Incorporation of Waste foundry sand in concrete. Waste foundry sand is utilized as partial replacement of cement or partial replacement of natural aggregate or fully substituted as natural aggregate and as a supplementary addition for different properties of cement concrete. In this study Compressive strength test, split tensile strength test, Flexural strength test and Modulus of elasticity of cement concrete of M30 grade and also the homogeneity of concrete ultrasonic pulse velocity method and water permeability is considered. Foundry sand is replaced as

fine aggregate with five different replacement ratios 0%, 10%, 20%, 30% and 40%. Thus, it was concluded that waste foundry sand with 30% replacement of fine aggregate gives maximum results and it reveals that water absorption values decreases with increase in replacement levels.Thus,the increase in waste foundry sand increases in ultrasonic pulse velocity.

Aylin Ozodabas (2018) carried their study on Investigation of the effect of Basalt fibre on Self Compacting Concrete. Self- compacting concrete compared to the amount of binder in which it is insisted of blast furnace slag 10% and 30%, Plasticizer additive 2.7%, basalt fibre with 1.6% in samples A and 3.2% in samples B.Slump flow test,V-funnel test,L- box test, compressive strength test, ultrasonic pulse velocity,water absorption and weight per unit of volume tests were performed. It was observed from the experiments that the basalt fibre decreased the workability of fresh concrete and increased the compressive strength values.

Sakthi Ganesh G (2017) conducted study on Mechanical and durability properties of self- compacting concrete in order to reduce the amount of cement content in concrete mix. Along with fly ash and superplasticizer an Viscosity modifying agent (VMA) have been added to enrich the quality of workability. Fly ash with 15%, 20% and 25% of cement replacement and tests on fresh concrete(Filling ability, passing ability and Segregation Resistance) and tests on hardened concrete have been evaluated. It was further concluded that 15% replacement of fly ash shows greater strength and suffers from chloride penetration.

D.Indu and R.Elangovan(2016) conductan experimental investigationon Optimum Mix Proportioning of High strength self- compacting concrete for different grades (30MPa-80MPa). In this study fly ash were added along with chemical admixtures. Numerous trials with increase in fly ash and decrease in water-cement ratio were done. Fresh concrete tests were observed and after casting, the compressive strength test, split tensile strength test and flexural strength test were obtained at 1, 7, 14, 28, 56 and 90thdays respectively. It comes into conclusion that the flow ability, passing ability and segregation resistance is within the limits. SYSTAT which used for the empirical

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relationship investigates the selected range of combination of ingredients for the desired characteristics and the mathematical model predicts the proportions of concrete constituents strength and workability.

M.Nithya (2017) investigated on Properties of concrete containing Waste Foundry Sand for partial replacement of fine aggregate in concrete in which it is insisted of Ordinary Portland cement, coarse and fine aggregate. Eight mixtures of fine aggregate were replaced using foundry sand in range of 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%. Tests such as Acid resistance test, Alkalinity test, Compressive test, split tensile test and Flexural test have been done on 28thday. It was concluded that mechanical properties of concrete with waste foundry sand increases for 35% replacement and decreases for 40% replacement of fine aggregate.

R. Vasumitha and Dr. P. Srinivasa Rao (2013) an experimental investigation on Strength and Durability study of High Strength Self Compacting Concrete with different materials like Quartz sand, Quartz powder, Viscous modifying agent for Rheodynamic concrete, Modified Polycarboxylated ether based Super plasticizer and Micro Silica were used. However, it is more emphasised to the need of test on RCPT, Slumpflow, L-box,V-funnel tests, and tests on hardened concrete. It made into remarkable result which indicates that chloride penetration of HSSCC shows less permeability of chlorides and reduces the cracks.

Gawande Y.B, Prof. P.B. Autade (2017) demonstrates Self Compacting Concrete with partial replacement of sand by waste foundry sand. In this investigation waste foundry sand was carried out in the range of 0%, 10%, 20%, 30%, 40% by weight of M35 grade which was tested with compressive strength test, split tensile strength test, flexural strength test of self-compacting concrete and were compared with ordinary self-compacting concrete. It was observed that 20% of waste foundry sand shows maximum decrease in workability. Hence it was concluded that increase of waste foundry sand decreases the density of self-compacting concrete.

Saurabh D. et.al (2018) have manufactured Self Compacting Concrete using Calciteand Fly Ash. This paper consists of cement, coarse aggregate, fine aggregate, fly ash and calcite where the calcite is an inorganic and

filler material which improves the hydration rate of cement compound. Compressive strength test, Flexural strength test and workability were conducted with 0%, 5%, 10%, 15% of calcite proportions. The results obtained that it overcomes the acid attack by using calcite and fly ash and increase in powder content increases workability of self-compacting concrete.

K.SathesKumaret.al.,(2017)experimented a study on the "Strength and Analysis of Basalt Fibre in Concrete". In this present experimental study, it aims to investigate the compressive, flexural, split tensile strengthand the effects of different proportions of basalt fibre of length 12mm in the mix. Test for the concrete is conducted with basalt fibre and without basalt fibre to show different proportions for M25 grade. The mix design for the fibre reinforced concrete is same as that of conventional concrete in case of small fibre volume of less than 0.5%.The addition of 0.5% of basalt fibre increases the compressive strength and further more addition of 1% of basalt fibre gives maximum compressive strength but basalt fibre with addition of 1.5% decreases the compressive strength. In thecase of split tensile, flexural the basalt fibre with 0.5% and 1% increases the
strength and further more addition of basalt fibre leads to decrement ofstrength.

Pendhari Ankush R. (2017) represents the current utilization of fine sand in construction and mostly focuses on the amount of foundry sand used as a cementitious material. In order to overcome the disposal problem of industrial waste and to reduce the construction cost, the wastefoundry sand have been used. This paper gives the remarkable results which indicates that the foundry sand is economical and found that 30% replacement of waste foundry sand gives maximum compressive strength and flexural streng that 28 days.It was concluded that waste foundry sand is a good replacement of fine aggregate and helps in preparing green concrete.

II. MATERIALSUSED

A. CEMENT

The cement and water form a paste that binds the other materials together as the concrete hardens.
The ordinary cement contains two basic ingredients namely argillaceous and calcareous. Ordinary Portland Cement with 53 grade was used for casting all the specimens.Selection of the type of cement will depend on the overall requirements for the concrete such as strength, durability, and etc.,

PROPERTIES OF CEMENT

Table I Properties of Portland cement

Properties	Test results
Specific gravity	3.15
Initial setting time	30min
Final setting time	600min

B. QUARTZPOWDER

Quartz is a hard, crystalline chemical compound consisting of one-part silicon and two-part oxygen atoms which are linked in a continuous framework of SiO_2 silicon-oxygen tetrahedral. Quartz is commonly known as silica sand for producing float glass, fibre glass, automotive glass and othertypes.

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Quartz has its important applications in the electronic industry. The specific gravity of quartz powder is 2.61.

CHEMICAL COMPOSITION OF QUARTZPOWDER

Table II Chemical Composition of Quartz Powder

COMPOSITION	QUARTZ (%)
SiO_2	99.5%
Al_2O_3	0.08%
TiO_2	0.04%
CaO	0.01%
MgO	0.01%
L.O.I.	0.28%
Alkalies	0.29%
Fe_2O_3	0.04%
MESH	100M

C. CALCITEPOWDER

Calcite is a carbonate mineral and the most stable polymorph of calcium carbonate ($CaCO_3$). Calcium carbonate powder is the filler material improves the hydration rate of cement compound and consequently increases the strength at early ages. A beneficial influence on calcite powder on sulphate resistance. Calcite controls bleeding of concrete with low cement content and low susceptibility.

CHEMICAL COMPOSITION OF CALCITEPOWDER

Table III Chemical Composition of Calcite Powder

COMPOSITION	CALCITE (%)
$CaCO_3$	93% - 97%
MgO	1.5%
Silica	1% - 2%

D. BASALT FIBRE

Basalt fibre is made from a single material, crushed basalt, from extremely fine fibres of basalt and having better physic mechanical properties than fibre glass. Its characteristics vary from the source of lava, cooling rate and historical exposure to the elements.Basalt fibre is used in Fibre Reinforced Polymer and in Structural composites which has high potential and getting lot of attention due to its high temperature and abrasion resistance. Basalt of high acidity (over 46% silica content) and low iron content is considered desirable for fibre production.

CHEMICAL COMPOSITION OF BASALTFIBRE

Table IV Chemical Composition of Basalt Fibre

COMPOSITION	BASALT (%)
SiO_2	51.6% - 59.3%
Al_2O_3	14.6% - 18.3%
TiO_2	0.8% - 2.25%
CaO	5.9% - 9.4%
MgO	3.0% - 5.3%
$FeO + Fe_2O_3$	9.0% - 14.0%
$Na_2O + K_2O$	0.8% - 2.25%
Others	0.09% - 0.13%

E. SUPERPLASTICIZER

Sika Viscocrete 20HE is a thirdgeneration High Performance super plasticizer which is especially suitable for the production of concrete and mortar mixes. It gives high early strength development, powerful water reduction and excellent flowability.

APPLICATIONS OF SIKA VISCOCRETE

- It is useful in Precastconcrete.
- It is mainly used in Fast trackconcrete.
- In situ concrete requiring fast striping time.
- It is used in Self-compacting concrete.

F. COARSEAGGREGATE

In order to obtain a good concrete quality, aggregates should be hard and strong, free of undesirable impurities and chemically stable.

Coarse aggregate conforming to EN 12620 are appropriate for the production of SCC. The amount of coarse aggregate used in self- compacting concrete is much lower when compared to the normal vibrated concrete. In the present study Coarse aggregate of 10mm size is used for Self-Compacting Concrete as per standard specifications. In order to avoid the aggregate blocking and to ensure the flow- ability, passing ability of SCC mix.

PROPERTIES OF COARSE AGGREGATE

Table V Properties of Coarse aggregate

Properties	Test results
Specific gravity	2.95
Bulk density	
1,) Compacted bulk density	1.5kg/l
2.) Loose bulk density	1.37kg/l
Water absorption	11.11%
Impact factor	24.18%

G. FOUNDRYSAND

Foundry sand is a by-product from the production of both ferrous and nonferrous metal castings. It is high quality silica sand with uniform physical characteristics. By foundry sand casting process, the metals are casted into particular shapes by melting into a liquid and then pouring it to the mold. Then the mold material is been removed after the metal has solidified as it cools. It is basically a fine aggregate that can be used in many ways as natural sands and manufactured sands.

In the present study Fine aggregate is totally replaced by using Foundry sand in order to increase its mechanical strength parameters and to hold good flow-ability, passing ability, filling ability and segregation resistance.

PROPERTIES OF FOUNDRYSAND

Table VI Properties of Foundry sand

Properties	Test results
Specific gravity	2.306
Fineness modulus	4.33

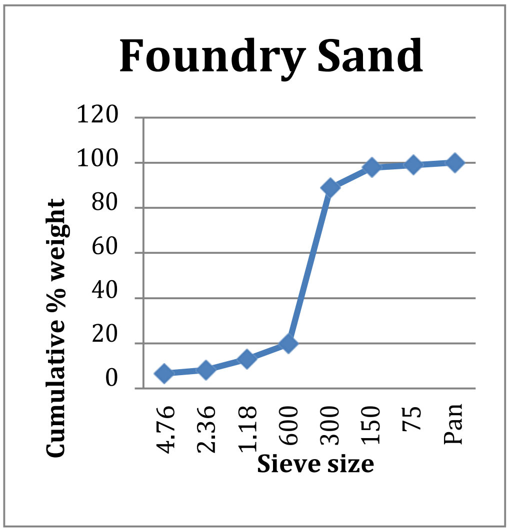

Fig. 1. Foundry sand

III. MIX PROPORTIONS

REPLACEMENT RATIO OF CALCITE POWDER AND QUARTZ POWDER

In this study cubes of (150mm x 150mm x 150mm) and cylinder of (150mm x 300mm) were casted with 100% replacement of foundry sand 0.75% of basalt fibre.

Table VII Mix Proportions for self-compacting concrete

Percentag e Replacem ent of Calcite	Percentag e Replacem ent of Quartz	Ceme nt (kg)	Calcit e Powd er (kg)	Quar tz Powd er (kg)
2.5%	15%	6.65	0.22	1.33
2.5%	20%	6.875	0.22	1.77
5%	10%	7.5	0.5	0.97
10%	10%	7.08	0.97	0.97

IV. RESULTS AND DISCUSSION

A. FRESHPROPERTIES

SCC containing 100% of foundry sand was tested for Slump flow, V-funnel, L-Box, U- box. The results of fresh properties of Self- compacting concretes with foundry sand are included in table below.

- The V-funnel flow times were in therange of 6–10seconds.
- Test results of this investigation indicated that all SCC mixes meet the requirements of allowable flowtime.
- In the above results the L-box ratioH2/H1 for the mixes was above 0.8 which is as per EFNARC standards.
- U-box difference in height of concrete in two compartments was in Properties of Self-Compacting Concrete.
- In terms of slump flow, all SCCs exhibited satisfactory slump flows within the prescribed range which is an indication of a good deformability
- All the fresh properties of concrete values were in good agreement for the flow- ability and passing ability to that of the values given by European guidelines.

Table VIII Fresh properties

COMBINATIONS	SLUMP FLOW	V-FUNNEL	L-BOX (cm)		U-BOX (cm)	
			H1	H2	H1	H2
SCC	5	6	120	110	18	49
			0.9		31	
MIX-1	6	7	125	105	20	53
			0.84		33	
MIX-2	8	6	115	105	21	54
			0.9		33	
MIX-3	9	10	110	100	22	56.5
			0.93		34.5	
MIX-4	11	11	110	103	22.5	58
			0.9		35.5	

B. HARDENEDPROPERTIES

a) COMPRESSIVE STRENGTHTEST

Compressive Strength of M30 grade concrete mixes with 100% replacement of fine aggregate using foundry sand and 0.75% of basalt fibre. Mix-1 (2.5% C.P +15% QP),Mix- 2 (2.5% C.P +20% QP), Mix-3 (5%C.P+10%QP), Mix-4 (10%C.P+10%QP) at 7th and 28th days strength is given below.

Table IX Compressive strength results

Percentage replacement of Calcite Powder	Percentage replacement of Quartz Powder	Compressive strength (N/mm^2)	
		7th day	28th day
2.5%	15%	22.67	32.89
2.5%	20%	24.89	34.2
5%	10%	21.3	31.5
10%	10%	19.1	29.77

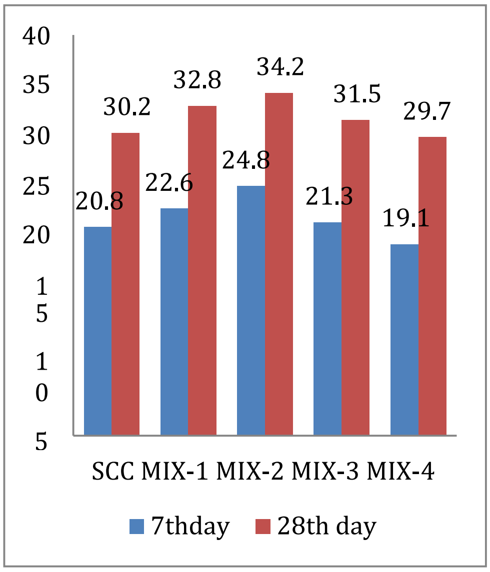

Fig. 2. Compressive Strength

- When the cement is replaced with 2.5% Calcite Powder along 15% Quartz Powder there is an increase in compressive strength.
- Further replacement with cement as 2.5% calcite powder along with the addition of 20% quartz powder gives maximum compressivestrength.
- When the cement is replaced with 5% calcite powder and 10% quartz powder there is decrease in compressivestrength.
- When the cement is again replaced with addition of 10% calcite powder and 10% quartz powder results in decrement of compressivestrength.

b) SPLIT TENSILE STRENGTHTEST

Split Tensile Strength of M30 grade concrete mixes with 100% replacement of fine aggregate using foundry sand and 0.75% of basalt fibre. Mix-1 (2.5% C.P +15% QP),Mix- 2 (2.5% C.P +20% QP), Mix-3(5%C.P+10%QP),Mix-4 (10%C.P+10%QP) at 7thand 28thdays strength is given below.

Table X Split tensile strength

Percentage replacement of Calcite Powder	Percentage replacement of Quartz Powder	Split Tensile strength (N/mm^2)	
		7th day	28th day
2.5%	15%	2.12	3.4
2.5%	20%	2.4	3.67
5%	10%	1.69	3.25
10%	10%	1.4	2.97

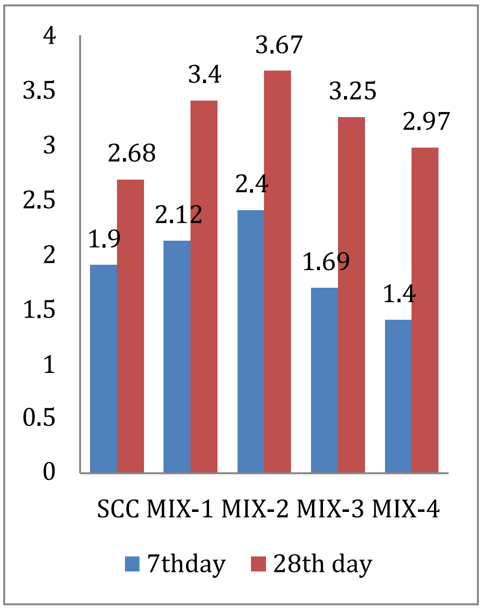

Fig. 3. Split tensilestrength

- When the cement is replaced with 2.5% Calcite Powder along 15% Quartz Powder there is an increase in split tensile strength.
- Further replacement of 2.5% calcite powder along with the addition of 20% quartz powder gives maximum split tensile strength.
- When the cement is replaced with 5% calcite powder and 10% quartz powder there is decrease in split tensile strength.
- When the cement is again replaced with addition of 10% calcite powder and 10% quartz powder results indecrement of split tensile strength.

C. ICROSTRUCTURAL PROPERTIES

a) SEM ANALYSIS

SEM (Scanning electron microscopic) observations were examined on the self- compacting concrete mixtures with 100% of foundry sand and 0.75% of basalt fibre. Self-compacting concrete mixtures in SEM images which contains a cementitious material of 2.5% calcite powder and 20% quartz powder.

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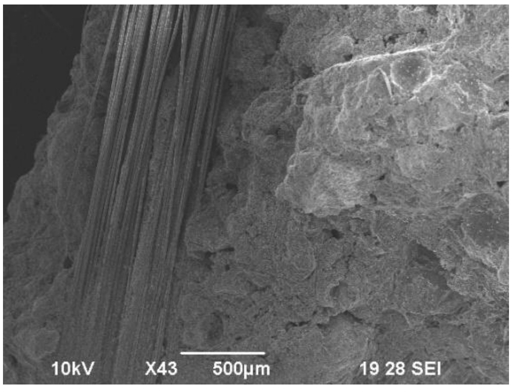

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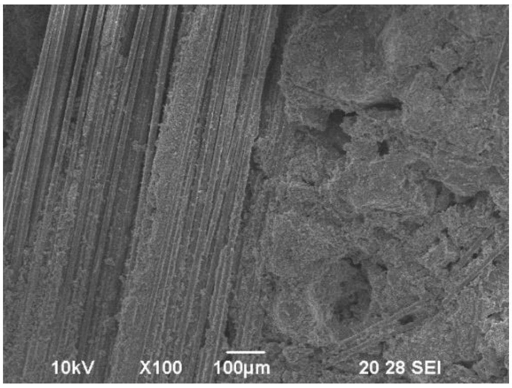

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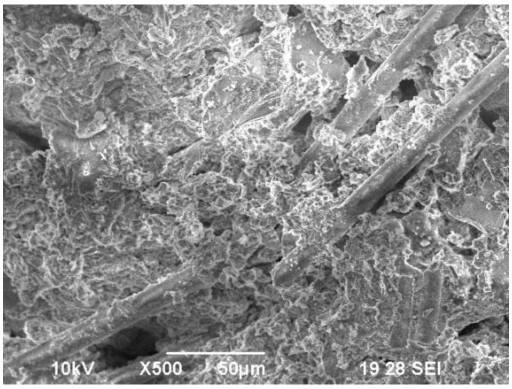

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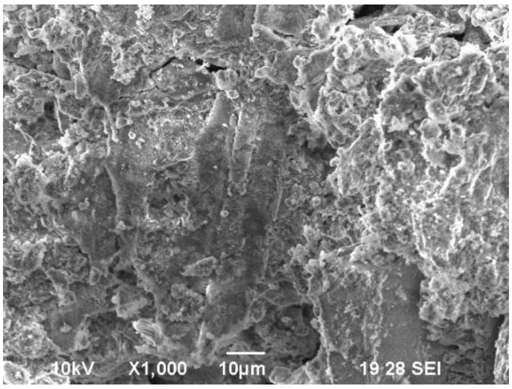

d.

Fig. 4. SEM Properties

V. CONCLUSION

On the basis of the results and discussions of this investigation following conclusions canbe inferred:

- For M30 grade concrete mix the compressive strength and split tensile strength increases with 100% of foundry sand and 0.75% of basalt fibre.
- The Compressive strength increases from 20.8N/mm^2 to 24.89N/mm^2 at 7thday and from 30.2 N/mm^2 to 34.2 N/mm^2 at 28thday by replacing cement with 2.5% calcite powder and 20% quartz powder.
- The Split tensile strength increases from 1.9N/mm^2 to 2.4N/mm^2 at 7th day and from 2.68 N/mm^2 to 3.67 N/mm^2 at 28thday by replacing cement with 2.5% calcite powder and 20% quartz powder.
- Further increase of calcite powder and decrease of quartz powder results in the decrement of compressive strength and split tensile strength.
- It was concluded that the strength increases at 2.5% of calcite powder and 20% of quartz powder with the incorporation of 100% foundry sand.

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