EFFECT OF FILLER MATERIAL ON PHYSICAL, MECHANICAL AND MICROSTRUCTURAL STUDIES ON SELF COMPACTING CONCRETE

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Abstract - *This work represent experimental study on strength of SCC with the filler material by dolomite powder. SCC is a highly flowable type of concrete that spreads in to the form without the need for mechanical vibration. Now a days self-compacting concrete is being widely used in construction over normal concrete due to its high workability, economy, less noise pollution, speedy construction etc. In the future works for strengthening concrete structure elements, it is preferred to use the dolomite powder especially when using self-compacting concrete. Dolomite, one of the type of Lime stone was employed is composed of calcium magnesium carbonate* $CaMg(CO_3)_2$. *However dolomite provides highest resistance to fire. The M40 grade of concrete mix and dolomite powder at volume of 2.5%, 5% and 7.5% will be added for this research. Hence using the dolomite powder with ultra-fine particles can fill the voids and make better resistance to permeability because of better bonding. It was proposed to study the Physical, Mechanical and Micro structural study for all specimens with different percentages of dolomite powder.*

Key words: self compacting concrete, Filler material, Dolomite powder, M40 grade, Microstructural study.

1. INTRODUCTION

Self-compaction is often described as the ability of the fresh concrete to flow under its own weight over a long distance without segregation and without the need to use vibrators to achieve proper compaction. This saves time, reduces overall cost, improves working environment and opens the way for the automation of the concrete construction Self compacting concrete (SCC) mixes always contain a powerful superplasticizer and often use a large quantity of powder materials and/or viscosity-modifying admixtures. The superplasticizer is necessary for producing a highly fluid concrete mix, while the powder materials or viscosity agents are required to maintain sufficient stability/cohesion of the mixture, hence reducing bleeding, segregation and settlement. Benefits of using SCC also include: improving homogeneity of concrete production and the excellent surface quality without blowholes

In self compacting concrete, introduction of high volume of mineral admixture to concrete mixtures is limited due to their negative effects on water demand and strength of the hardened concrete. However, these mineral admixture can be efficiently utilized as viscosity enhancer particularly in powder-type SCC. Thus, successful utilization of Dolomite powder (DP) in SCC could turn these materials into a precious resource. Moreover, these mineral admixtures can significantly improve the workability of self-compacting. When used in SCC, these mineral admixtures can reduce the amount of superplasticizer necessary to achieve a given property. It should be noted that the effect of mineral admixture on admixture requirements is significantly dependent on their particle size distribution as well as particle shape and surface characteristics. From this viewpoint, a cost effective SCC design can be obtained by incorporating reason- able amounts of DP. The addition of DP is the best mineral admixture to improve the properties of fresh SCC such as slump-flow, T50 time, L-box ratio, air content and unit weight. All the mineral admixtures have shown significant performance differences and the highest compressive strength has been obtained for the DP mixtures. Incorporation of mineral admixtures reduced the cost per unit compressive strength of these SCC

A lot of researches were performed to study the effects of filler materials on the properties of SCC. These studies showed that the use of filler materials improves workability with re- duced cement content. By this way, low heat of hydration and decreased thermal and shrinkage cracking can be achieved . M. Shahul Hameed et al .MSP can be used as filler and it helps to reduce the total voids content in concrete. Consequently, this contributes to improve the strength of concrete. An experimental investigation has been carried out to study the combined effect of addition of MSP and CRD on the durability of SCC. Water absorption, water permeability (flow), Ionic flow (Rapid Chloride ion penetrability) tests were conducted to measure the permeability of SCC and the results were compared with the normal concrete made up of river sand (NCRS) and the normal concrete made up of CRD (NCCRD). Test results indicate that the replacement of river sand with MSP and CRD in SCC reduces the permeability and does not affect the compressive strength. Thus, it is recommended that the replacement of natural sand with 85% CRD and 15% MSP, as replacement in SCC.

Akhila S et al, This paper summarizes the research work on the experimental study on strength of SCC with partial replacement of cement by dolomite and addition of para aramid fibres. Compressive strength, split tensile strength and flexural strength of concrete increased with the partial replacement of cement by dolomite and addition of Para aramid fibre with certain percentages. For this study result obtained as the maximum compressive strength, split tensile strength and flexural strength of concrete is 43.45N/mm2, 5.50N/mm2 and 12.55N/mm2 respectively. Addition of Para aramid fibre may improve the thermal stability of the entire structures.

Kosmas K. Sideris et al, Addition of LFS improved the fresh properties of SCC mixtures, contributed toward more viscous SCC mixtures. When LFS was used as sand replacement compressive strength of SCC mixtures was increased after the age of 28 days. The mixture produced with addition of 25% slag performed high compres-sive strength at the age of 28 days and may be consider that it belongs to the higher strength category. The durability of ladle furnace slag produced SCCs was improved when LFS was used as sand replacement. In the cases where LFS replaced cement at 10% percentage, durability against carbonation performed smaller increase while other durability indicators remained either almost stable (Dnssm values) or slightly decreased (mass loss due to freeze-thaw attack). There was a clear trend that higher dosage of LFS resulted to more durable mixtures when LFS was added as sand replacement and the w/c ratio remained constant. In such case all durability indicators in LFS produced mixtures were improved

Paweł Niewiadomskia et al, Based on the conducted studies, it can be concluded that the addition of nanoparticles improves the microstructure of self-compacting concrete. Analysis of the porosity results proved that concretes modified with the addition of nanoparticles are characterized by lower porosity in relation to pore size of up to 0.015mm in comparison to concrete which does not contain nanoparticles in its composition. The positive influence of the addition of nano-powders on the microstructure of the tested concretes is also confirmed by the results of the total porosity of the samples. In addition, the conducted studies have shown that nano-powders can positively influence both the hardness and elastic modulus of the cement matrix of concrete. The obtained results enable the assumption that the appropriate usage of nano-materials as an additive for the production of self-compacting concrete can improve its widely understood microstructure, and thus result in its increased durability.

Mahmoud Khashaa Mohammed et al, Production, microstructure and hydration characteristics of sustainable self-compacting concrete (SCC) are investigated with two types of filler having significant differences mainly in chemical composition and physical properties. The purpose is to show how different fillers at high cement replacement levels can affect the composition, microstructural and hydration characteristics at early age. Several techniques, comprising X-ray diffraction, scanning electron microscopy (SEM) linked with energy-dispersive X-ray (EDX) analysis, image analysis, mercury intrusion porosimetry and thermo-gravimetric analysis, were used in order to demonstrate the effect of these two fillers at high replacement proportions. The two types of sustainable SCC produced had a compressive strength of 50–60 MPa and used the same water to binder ratio. The replacement rate of both limestone powder (LP) and fly ash (FA) was about 33% of the total binder (450 kg/m3). In spite of the equal water to binder ratio and approximately the same compressive strength grade at 28-days, limestone powder self-compacting concrete (LP–SCC) had a different microstructure and hydration products from the fly ash self-compacting concrete (FA–SCC). The results indicate that the fly ash was the more suitable for the production of sustainable SCC.

Micro-scale porosity was deduced for the matrix of the both types of SCC. It seems that the filler type had no effect on the nature of the porosity (micro or macro) of the SCC whereas it did influence the critical pore diameter especially at 28-days. The microstructural investigation revealed that the FA–SCC had a relatively dense matrix with an approximately constant distribution of the Ca/Si ratio across the aggregate–matrix interface. In comparison, the LP–SCC had a less dense matrix with varied Ca/Si ratio across the thickness of the ITZ.

2. EXPERIEMENTAL PROGRAM

The present work aims to study the effect of filler type on fresh and hardened properties of self compacting concrete. Fresh and hardened concrete properties such as slump flow , T50 slump flow, J ring , V funnel , Compressive test, Tensile test ,Flexure test and Microstructure test were considered in this study

2.1 MATERIALS

A materials of OPC 53 grade cement, Fine aggregate as M sand (passing through 4.75mm and retained on 2.36mm sieve), coarse aggregate less than 10mm , super plasticizer as Auramix 400 and water used . The filler material as dolomite powder is used. Dolomite is an anhydrous carbonate mineral composed of calcium magnesium carbonate, ideally CaMg(CO3)2. The term is also used for a sedimentary carbonate rock composed mostly of the mineral dolomite. An alternative name sometimes used for the dolomitic rock type is dolostone Dolomite is a common rock-forming mineral. It is a calcium magnesium carbonate with a chemical composition of $CaMg(CO_3)_2$. It is the primary component of the sedimentary rock known as dolostone and the metamorphic rock known as dolomitic marble. Limestone that contains some dolomite is known as dolomitic limestone.

Table 1 Chemical composition of cement and dolomite powder

Chemical composition %	Cement	Dolomite powder
Sio_2	21.92	0.20
Al_2O_3	3.30	0.85
Fe_2O_3	1.20	0.15
CaO_2	63.2	32.2
SO_3	2.1	22.0
Loss of ignition	1.2	43.5

TABLE 2 PHYSICAL PROPERTIES OF CEMENT

S.No	Properties	Test Results	Requirement as per IS 4031:1996 part I
1	Fineness modulus of Cement	3.46%	Upto 5% OPC
2	Specific gravity of Cement	3.15	3-3.15
3	Consistency of cement	36%	
4	Initial setting time	30min	30min
52	Final setting time	10hrs	10hrs

TABLE 3 PHYSICAL PROPERTIES OF FINE AGGREGATE

S.No	Properties	Test Result	Requirement as per IS 383-1971
1.	Fineness Modulus of fine aggregate	2.80	2.6-3.0
2.	Specific Gravity of sand	2.73	Medium sand (2.6-2.9)
3.	Bulk density of fine aggregate	1777.3 kg/m^3	1520-1780 Kg/m^3

TABLE 4 PHYSICAL PROPERTIES OF COARSE AGGREGATE

S.No	Properties	Test result	Requirement as per IS:2386 (part III) 1963
1	Bulk density of coarse aggregate	1550.66 kg/m^3	1520 to 1680 kg/m^3
2	Specific gravity of coarse aggregate	2.69	2.4 to 2.9
3	Impact test	10.09%	

TABLE 5 PROPERTIES OF AURAMIX 400

Appearance	Light yellow coloured liquid
Ph	Minimum 6.0
Volumetric mass @ 20^{0}C	1.09kg/lit
Chloride content	Nil to IS:456
Alkali content	Typically less than 1.5g Na_2O equivalent/ litre of admixture

2.2 MIX PROPORTIONS

The used water/cement ratio for self compacting concrete was kept constant as 0.4 while the dosage of super plasticizer was constant as 0.5%. For all the used concrete mixes, the coarse aggregate as 805 kg/m^3 and fine aggregate as 891.75kg/m^3. For cement content of 528.03kg/m^3, the additional percentages of used filler material as 2.5%, 5% and 7.5%. By using different percentages of filler material twelve cubes and cylinders were cast and table shows the mixture proportions of these mixes

TABLE 6 MIX PROPORTIONS OF CONCRETE MIXES

Type of concrete	Mix no	Filler Type	Mixture proportions (kg/m^3)					
			Cement	Filler content	Water	Coarse aggregate	Fine aggregate	Admixtures (LIT)
Self compacting concrete	Scc	Dolomite powder (DP)	528.03	0	211.21	805.58	891.75	2.64
	Scc1		528.03	13.2	224.41	805.58	891.75	2.64
	Scc2		528.03	26.4	237.61	805.58	891.75	2.64
	Scc3		528.03	39.6	250.81	805.58	891.75	2.64

The mix design of self compacting concrete is a trial and error method. Many references available for mix proportioning of SCC. Here we use mix proportioning based on previous investigation strength data using Japanese method and also based EFNARC guidelines. The Japanese method was suggested by Okamura in 1993, after extensive trials in laboratory and at sites. In the Japanese method coarse and fine aggregate contents are initially fixed so that self compact ability is achieved by adjusting the water/powder ratio and super plasticizer dosage. Strength requirement are assessed from field trials of SCC at a large stage.

In this investigation we incorporate the procedures of EFNARC guidelines. These guidelines gives the range for coarse aggregate and fine aggregate content and based on the limit the approximate mix design for M40 grade of concrete is obtained. The mix ratio of M40 grade concrete is

Cement	Fine aggregate	Coarse aggregate	W/C	W/P	Super plasticizer
1	1.72	1.52	0.3	1	0.5%

Slump flow T50 Jring Vfunnel and Lbox tests according to ACI 237R-07 were performed on fresh concrete, also compression tension and flexural tests is carried out on hardened concrete.

The hardened properties included cube compressive strength, tensile and flexural tests carried out. concrete compressive strength was deter- mined according to BS 1881: Part 3. 150 mm cubes were used. Tensile strength was determined in cylinder where diameter as 150mm and height as 300mm. Each results represented in this section is the average of three tested specimens.Flexural strength of concrete is carried out in 1500x150x200mm beam.In addition, scanning electronic microscope (SEM) were performed to investigate morphological features in concrete.

3. TEST RESULTS AND DISCUSSIONS

3.1 FRESH CONCRETE

Slump, slump flow and T 50 cm

Results of fresh concrete properties of all self compacting concrete mixes are illustrated in Table. Slump flow and T 50 cm were used to measure the workability performance of SCC while slump test was considered for self compacting concrete. Comparing the obtained results of slump flow and T 50 cm with the SCC criteria, it can be concluded that all mixes satisfy the requirement of SCC limits.

V funnel tests carried out by 12 liters of sample and poured the sample in v funnel. Close the trap door and place the bucket underneath. Open within 12 sec filling the trap door and allow the concrete to flow under gravity. Calculate the time for discharge to complete flow

L box test carried out by 14 liters of sample. Set the apparatus level on firm ground ensure the sliding gate can open freely and then close it . Moisten the inside surface of the apparatus, remove any surplus water. Fill the vertical section of the apparatus with the concrete sample leave it for 1minute . Simultaneously start the stop watch and record the time taken for concrete to reach 200 and 400mm marks and the concrete stop flowing the distances H1 and H2 are measured. Calculate the H2/H1, the blocking ratio. The whole test has to be performed within 5 minutes. The table shows that the result value of workability test on different mixtures.

TABLE 7 WORKABILTY TEST RESULTS

S.NO	Test method	Results				Typical range of value (as per EFNARC)
		SCC	SCC1	SCC2	SCC3	
1	Slump flow	750mm	730mm	720mm	700mm	650 to 800mm
2	T50 slumpflow	2sec	3sec	3.3sec	4sec	2 to 5 sec
3	J ring	4	4.2	4.3	4.5	<10mm
4	Vfunnel	10sec	10sec	9sec	9sec	6 to 12 sec
5	L box	0.12	0.10	0.9	0.8	>=0.8

3.2 HARDENED CONCRETE

3.2.1 COMPRESSIVE STRENGTH

Testing of hardened concrete plays an important role in controlling and confirming the quality of concrete works. Its most common test conducted on hardened concrete and an easy test to perform. Most desirable characteristics properties of concrete are qualitative related to it compressive strength. The test were carried out on 150x150x150mm sixe cube as per IS 516-1959. The test conducted in 7th and 28 days and the results shows in the table

TABLE 8 COMPRESSIVE STRENGTH RESULTS

S.No	Specimens	Compressive strength in N/mm^2	
		7days	28 days
1	SCC	28	48
2	SCC1	29	52
3	SCC2	31	53
4	SCC3	32	56

3.2.2 SPLIT TENSILE STRENGTH FOR SCC

One of the important properties of concrete is "tensile strength" as structural loads make concrete vulnearable to tensile cracking. Tensile strength of concrete is much lower than its compressive strength. The split tensile test of self compacting concrete with various percentages of dolomite powder adding.

TABLE 9 TENSILE STRENGTH RESULTS

S.No	Specimens	Tensile strength in N/mm2
1	SCC	2.83
2	SCC1	3.2
3	SCC2	3.29
4	SCC3	3.31

3.2.3 EXPERIEMENTAL STUDY ON BEAMS

In this proposed study, the ductile behavior of reinforced self compacting concrete is studied. The beam is designed as over reinforced beam. In over reinforced beam, the amount of steer is provided more than the balanced section. So the neutral axis tends to move downward direction and strain stress is keep on increases. The steel is well with an elastic limit, such a beam is called as a over reinforced beam and this failure called as compression failure.Hence four beams were casted, in which first one is control beam and other three beam is adding dolomite powder in different percentages as 2.5%, 5% and 7.5%. These beams made up of M40 grade concrete beam

3.2.3.1 Non DESTRUCTIVE TEST ON BEAMS

Table 10 REBOUND HAMMER TEST

s.no	Beam SCC CS		Beam 2.5% Dolomite		Beam 5% dolomite	
	Rebound number (vertical direction)	Compressive strength in MPa	Rebound number (vertical direction)	Compressive strength in MPa	Rebound number (vertical direction)	Compressive strength in MPa
1	32	28.74	34	29.43	31	24.53
2	31	28.45	37	33.35	32	28.74

3	34	29.43	35	30.41	34	29.43
4	33	28.94	36	31.88	35	31.39
5	28	25.51	36	31.88	32	28.74
6	30	27.96	33	28.94	34	29.43
7	36	32.37	35	30.41	30	23.05

2. ULTRASONIC PULSE VELOCITY TEST

Table 11 Ultra Sonic Pulse Velocity Test Direct Method

s.no	Beam cs SCC		Beam 2.5% Dolomite		Beam 5% dolomite	
	Velocity KM/s	Quality of concrete	Velocity KM/s	Quality of concrete	Velocity KM/s	Quality of concrete
1	3.05	Good	3.7	Good	4.27	Good
2	3.5	Good	3.93	Good	3.26	Good
3	4.52	Good	4.43	Good	3.3	Good
4	3.61	Good	4.9	Good	4.2	Good

Table 12 Ultra Sonic Pulse Velocity Test SemiDirect

s.no	Beam cs SCC		Beam 2.5% Dolomite		Beam 5% dolomite	
	Velocity KM/s	Quality of concrete	Velocity KM/s	Quality of concrete	Velocity KM/s	Quality of concrete
1	4.29	Good	4.33	Good	4.33	Good
2	4.57	Good	3.26	Good	3.98	Good
3	3.89	Good	4.17	Good	3.93	Good
4	3.48	Good	3.3	Good	4.2	Good

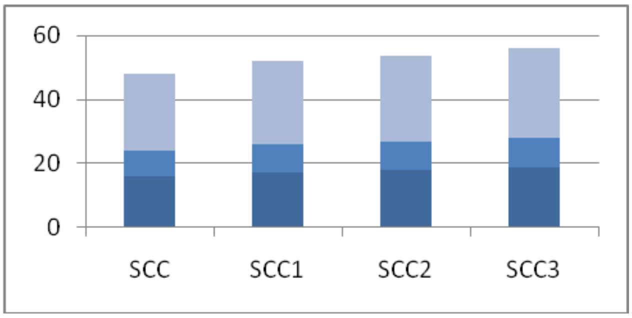

CHART 1 COMPRESSIVE STRENGTH IN N/mm²

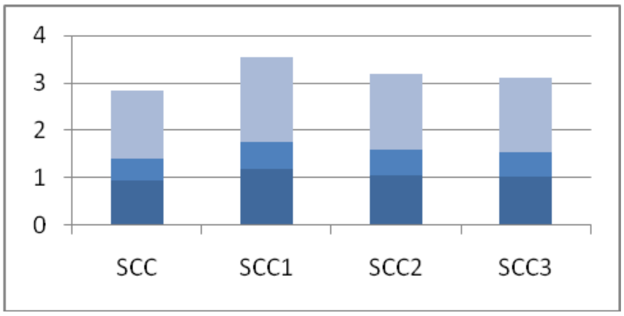

CHART 2 TENSILE STRENGTH IN N/mm²

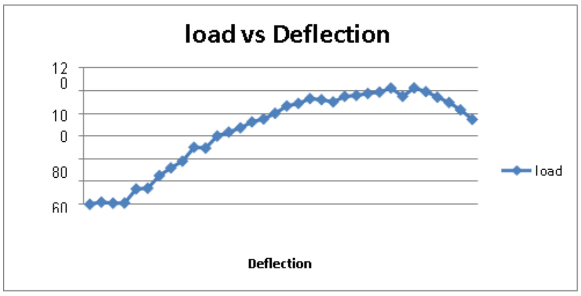

CHART 3 Load vs Deflection in CS SCC

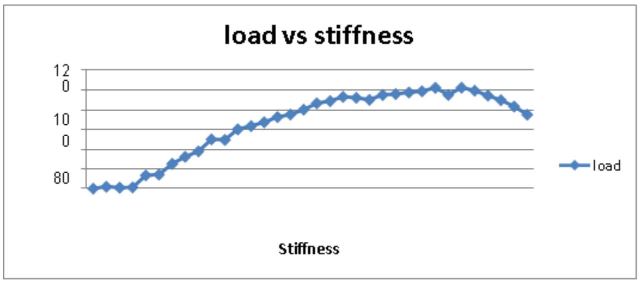

CHART 4 load vs stiffness in CS SCC

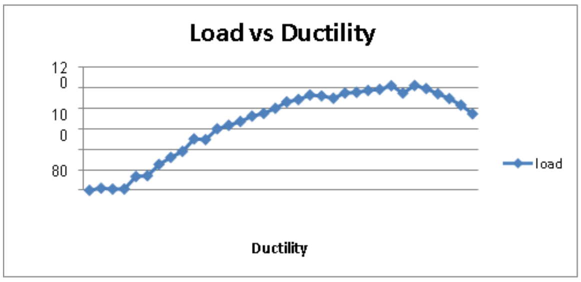

CHART 5 load vs Ductility in CS SCC

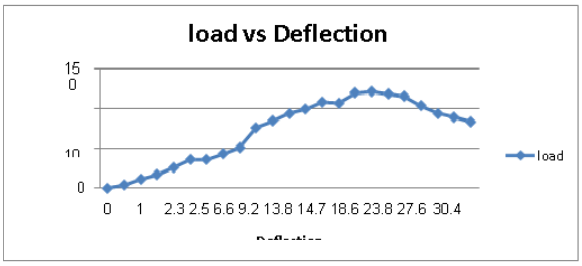

CHART 6 Load vs Deflection in CS 2.5% SCC

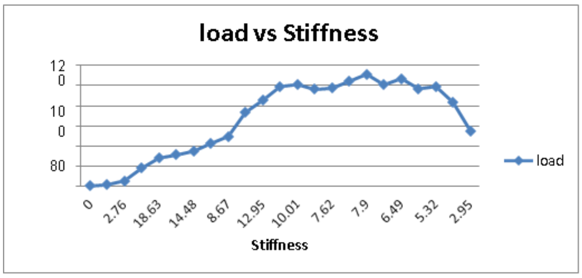

CHART 7 load vs stiffness in CS 2.5% SCC

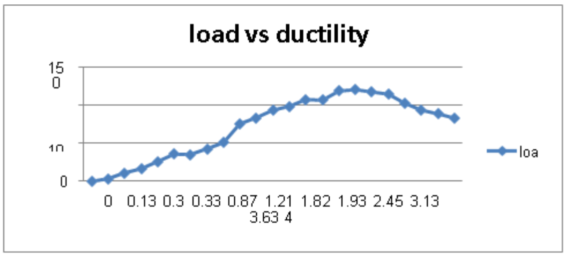

CHART 8 load vs Ductility in CS 2.5% SCC

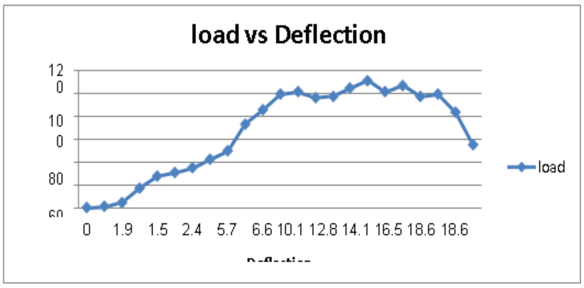

CHART 9 Load vs Deflection in CS 5% SCC

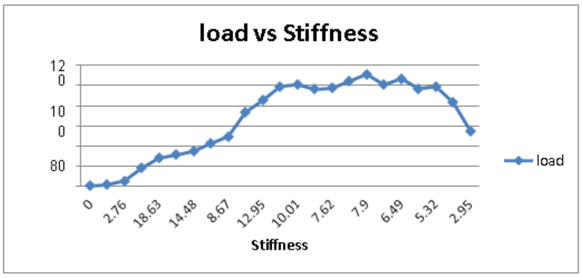

CHART 10 load vs stiffness in CS 5% SCC

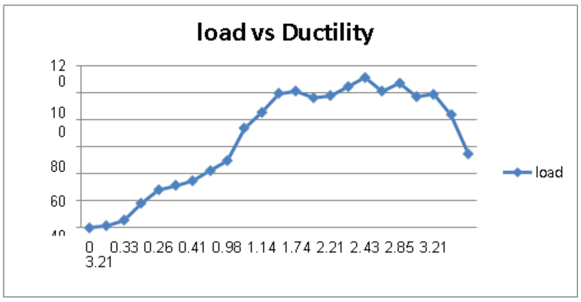

CHART 11 load vs Ductility in CS 5% SCC

SEM analysis

Figure shows the microstructure of the investigated pastes. The sample containing silica fume shows a refined pore struc- ture. The infinitesimal volume of silica fume particles reduces the porosity of the paste as a result of filler effect. The sample containing metakaolin or granite shows a well defined ettring- ite fibers which match with the aforementioned result of X-ray diffraction analysis. Moreover, the comparison between these images shows that the ettringite needled are clearly observed in limestone, granite and marble cement pastes whereas traces of ettringite are observed in silica fume and metakaolin cement pastes. The micrograph showed a good agreement with XRD, TGA and mechanical test results previously shown.

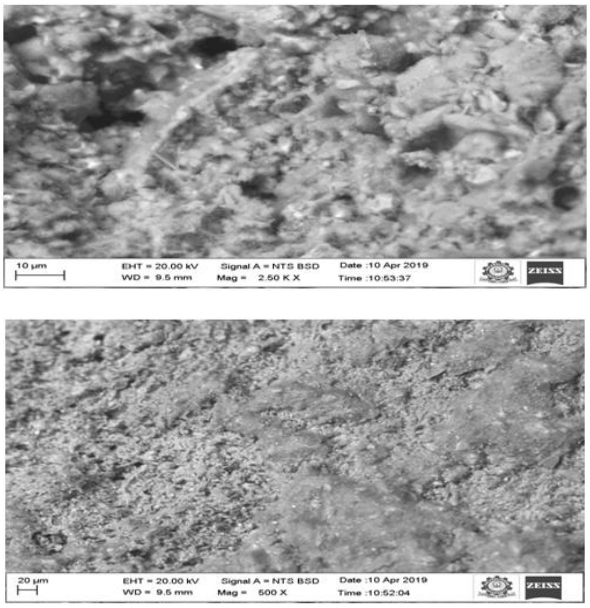

FIGURE 1 SEM ANALYSIS OF CEMENT PASTE MODIFIED WITH DOLOMITE POWDER

4. Conclusions

Based on the findings of the current study, the following con- clusions may be drawn:

- Filler type has a significant effect on segregation resistance and bleeding resistance of Self compacting concrete. The use of n filler materials (dolomite powder) decreases the segregation and bleeding in concrete.

- The increase in filler content improves bleeding resistance of SCC. The significant effect of filler type on bleeding resistance is obvious at high level of filler content, 5%, whereas there is no obvious effect of filler type on bleeding resistance at lower filler content.

- Filler type and content have significant effect on hardened SCC water absorption. For self compacting concrete, the use of 5% filler reduces significantly the water absorption of Flow-able hardened concrete. In addition, filler type has insignificant effect on water absorption.

- There is no negative effect of fillers on concrete compressive strength.

- Scanning electron microscope showed that there is no obvious change in the tested samples where type of filler, generally, has insignificant effect. The only clear effect is the low calcium hydroxide and ettringite in silica fume and metakaolin cement pastes, pozzolanic fillers compared with non-pozzolanic fillers.

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