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STUDY ON COMPRESSIVE STRENGTH OF CONCRETE BY USING FLY ASH AND NANOSILICA

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Abstract – *The aim of this experimental investigation is to find the influence of fly ash and nanosilica on compressive strength of concrete and analyze its microscopic nature by SEM .Cement is partially replaced by fly ash and nanosilica replaces the total binding materials. Fly ash is pozzolanic material and abundant in India causing a lot of pollution and also enhances the durability of concrete. Nanosilica is used because of its large surface area to improve compressive and flexural strength at early ages. For the experiment we have replaced cement partially by 10%, 20% and 30% fly of ash and 1%, 2% and 3% of nanosilica of total binder by weight for M_{30} concrete. It has been observed that there is a significant gain in the fly ash mixed concrete when nanosilica has been added. The cause of it being more C-S-H phase and $Ca(OH)^2$ produced due to addition of nanosilica as observed by SEM.*

Key Words: Fly ash, pozzolanic, nanosilica, M_{30}, SEM.

1. INTRODUCTION

Concrete is a construction material composed of cement, fine aggregate and coarse aggregate mixed with water which hardens with time. Concrete has comparatively high compressive strength but significantly lower tensile strength. In a building construction, concrete is used for the construction for the foundations, columns, beams, slabs and other load bearing elements.

2. SCOPE OF THE PROJECT

Following procedure to be done for this work:

- Preliminary tests to be conducted on materials to find out physical properties.
- Materials to be mixed in proper proportion and molded in cubes.
- M30 cement concrete with maximum replacement of cement by fly ash by 10%, 20% and 30% and nanosilica with 1%, 2%, 3% of total binder.
- These various specimens of fly ash and nanosilica cement concrete are to be tested 7 days, 14 days and 28 days to find compressive strength and also analyze through SEM.
- Analysis of compressive strength and SEM results.

3. OBJECTIVES

The main objective of this work is an attempt to make fly ash as a source material for replacement of cement in structural concrete by enhancing with optimum nanosilica.

4. LITERATURE REVIEW

Shaik, Supit, Sarker (2014), Addition of nanosilica was found to yield higher strength, 2% nanosilica gives best results, rate of strength development indicates high reactivity of nanosilica, for 40%, 50% fly ash mortar, 7 days strength improved but later did not.

Garcia, Zapata, Suarez (2015), Nanosilica accelerates hardening, increases density, reduces porosity, improves binding among cement paste and aggregates. More than 6% nanosilica not recommended due to chemical incompatibility.

Mistry, Patel & et. all (2015), The percentages of nanosilica used for replacement where 0%, 1%, 1.5%, 2%, 2.5% by weight of cement and fly ash content were 55%, of all the mix. The compressive strength of concrete were tested for M50 and M60 grade of concrete. Results shows that as the day's increases compressive strength increases but as the percentage of replacement of nanosilica increases beyond 1.5%, compressive strength decreases.

Reddy, Meena, & et. all (2018), Use of nanosilica gives stronger concrete with minimum pores.M30 concrete has been tested. Fly ash, nanosilica concrete sets quickly than that of conventional concrete. They are superior to conventional concrete. Addition of replacement materials leads to ecofriendly and sustainable concrete. There is reduction of overall cost of manufacture of concrete.

Nagabhushana (2015), The grades of concrete selected for the study are M20, M35 and M50. The fly ash replacements considered for the study are 0%, 20%, 35% and 50% of cement by weight. The results of this study indicates that for M20 and M35 grades of concrete, there is increase in strength with 35% cement replacement by fly ash. For M50 grade of concrete, there is decrease in strength for all replacement levels selected for the study.

Reddy, Swetha, Dhani (2015), The project studies the effect on properties of concrete with M-sand by replacement in proportions 0%, 20%, 40%, 60%, 100%. M20 and M30 grade 450 specimen were studied. Compressive strength, split tensile strength and flexural strength increases with replacement in Msand. 60% replacement is most suitable. M-sand is best alternative for natural sand in terms of strength and durability. 60% replacement gave overall best results.

Parida (2015), The experiment has been carried out by replacing the cement with nanosilica of 0.3%, 0.6% and 1% by weight of cement. The test shows there is considerable increase in early age compressive strength and a small increase in overall compressive strength of concrete.

Meghashree. M, Gowda, Roopa (2016), M-sand has been found as viable substitute which gives better strength than or equal to natural sand. Physical tests were also carried out on sand for comparison. Specific gravity, bulking of fine aggregates, bulk density, sieve analysis were carried out. Specific gravity of M-sand was found to be higher. Percentage bulking was higher in M-sand. M-sand has higher bulk density, M-sand is slightly coarser than natural sand, both natural sand and M sand both fall under zone 2.

Padhye, Deo (2016), historically, fly ash has been used in concrete at level ranging from 15% to 25% by mass of cementation material component. The paper aim to study the effect of fly ash as partial replacement of cement in concrete and ascertain the optimum proportion of fly ash for different grades of concrete which is acceptable, applicable and economical. It was found that fly ash up to replacement of 40% would be safe.

Parmeswaran, Varghese (2019), Nanosilica improves the concrete quality by filler effect, nucleation effect, pozzolanic effect. It is limited to 3%-5% by weight. Microstructure of the nanosilica modified concrete is more uniform and compact than the normal concrete. The hydration process accelerates in the presence of nanosilica. Initial reactivity of fly ash also increases.

5. MATERIALS

- Cement: The cement we used was Birla Super 53 Grade
- M-sand: M sand is a substitute of river sand for concrete construction. It is produced from hard granite stone by crushing.
- Coarse Aggregates: The particles that are predominantly retained on the 4.75 mm are called coarse aggregate. The aggregate used were sourced locally.
- Fly ash (Class F): Fly ash is most used pozzolanic material all over the world. The fly ash we used was sourced from Jindal Steel.
- Nanosilica: It is composed of silicon oxide. The nanosilica used in this project is bought from a local vendor in BDA complex near Dr Ambedkar Institute Of Technology.
- Water: The water was clean and did not contain sugar, molasses or gur or their derivatives, or sewage, oils, organic substances.

6. METHODOLOGY

The following are the steps followed in carrying out the project.

6.1. **Preliminary tests on cement, aggregates and fly ash:** Various standard tests were done on the materials for their physical properties.

6.2. **Mix design:** The designed concrete is M30 and with variance of fly ash is 0%, 10%, 20% and 30% and the variance of nanosilica is 0%, 1%, 2% and 3%.

6.3. **Weigh batching:** All the materials are weighted according to their proportion in mix design. Fly ash was replaced by weight of cement in the concrete and the nanosilica by weight of total binder (cement and fly ash).

6.4. **Preparation of moulds:** Before casting the specimens, all cube moulds were cleaned, screwed tightly and oil was applied to all surfaces to prevent adhesion of concrete during casting.

6.5. **Mixing:** The cementitious materials were mixed in a pan first then with aggregates in a lab concrete mixer.

6.6. **Compaction and slump test**: Compaction of concrete in oiled cubical moulds was done in three layers, each layer was tamped at least 25 times with the tamping rod. Subsequently slump test for each variation was done.

6.7. **Curing:** Curing was done for 7, 14 and 28 days in a pond.

6.8. **Tests:**

Compressive strength test: Specimens were taken out from the curing tank after 7, 14 and 28 days to perform compressive strength test. Three numbers of specimens were tested and average value was calculated.

SEM analysis: The specimen was broken into small pieces and air dried for 24 hours then analyzed by SEM.

7. RESULTS

7.1. PRELIMINARY TESTS

Table-1: Preliminary Tests

Cement		
S.N	Test	Result
1	Fineness Of Cement	7%
2	Specific Gravity	3.04
3	Standard Consistency	32%
4	Initial setting time of cement	50 min
5	Soundness test	4mm
M-Sand		
S.N	Test	Result
1	Sieve Analysis	2.85
2	Moisture Content	1.8%
3	Specific Gravity Test	2.60
4	Water Absorption Test	3.45%
5	Zone Test	
6	Bulking of sand	4%
Coarse Aggregate		
S.N	Test	Result
1	Sieve Analysis	6.42
2	Specific Gravity	2.78
3	Water Absorption	0.95%
Fly ash		
S.N	Test	Result
1	Specific Gravity	2.70

7.2. Mix Design: The following mix designs were obtained from above preliminary tests using IS 12062.

Table-2: Mix Design

0% Nanosilica			
S.N	Variation (Fly ash %)	Mix Design	w/c used
1	0	1:1.53:2.72	0.45
2	10	1:1.36:2.40	0.41
3	20	1:1.34:2.38	0.45
4	30	1:1.35:2.36	0.45
1% Nanosilica			
S.N	Variation (Fly ash %)	Mix Design	w/c used
1	0	1:1.52:2.71	0.45
2	10	1:1.35:2.37	0.43
3	20	1:1.34:2.37	0.43
4	30	1:1.34:2.37	0.43
2% Nanosilica			
S.N	Variation (Fly ash %)	Mix Design	w/c used
1	0	1:1.52:2.70	0.45
2	10	1:1.35:2.39	0.43
3	20	1:1.33:2.36	0.43
4	30	1:1.32:2.34	0.43
3% Nanosilica			
S.N	Variation (Fly ash %)	Mix Design	w/c used
1	0	1:1.51:2.69	0.45
2	10	1:1.34:2.37	0.43
3	20	1:1.33:2.35	0.43
4	30	1:1.32:2.33	0.43

7.3. Compressive Strength Test

The compressive strength test was done in 7, 14 and 28 days for all variation.

7.3.1. 7 days test

Table-3: 7 days test

0% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	30.15
2	10	30.74
3	20	21.58
4	30	18.10
1% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	29.73
2	10	27.21
3	20	21.36
4	30	18.88
2% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	30.3
2	10	25.46
3	20	22.21
4	30	16.54
3% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	30.09
2	10	29.88
3	20	26.45
4	30	22.22

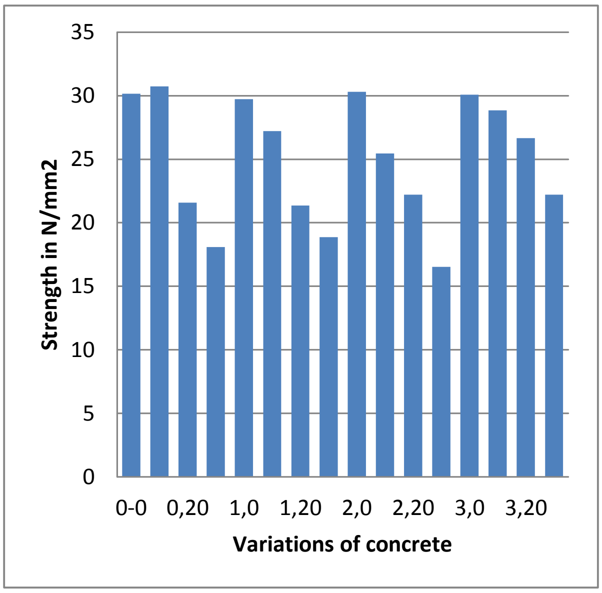

Chart-1: 7 days test

Table-3: 14 days test

0% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	35.35
2	10	36.84
3	20	25.86
4	30	21.69
1% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	39.27
2	10	32.40
3	20	29.00
4	30	24.90
2% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	41.77

2	10	33.86
3	20	29.58
4	30	21.98
3% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	36.06
2	10	35.81
3	20	31.72
4	30	32.21

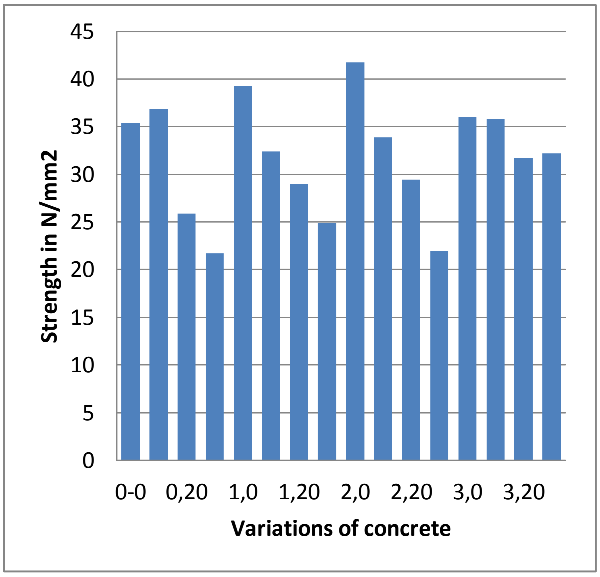

Chart-2: 14 days test

Table-4: 28 days test

0% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	41.12
2	10	43.61
3	20	34.89
4	30	30.44
1% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	46.67
2	10	41.22
3	20	41.34
4	30	37.11
2% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	47.74
2	10	40.82
3	20	42.57
4	30	32.36
3% Nanosilica		
S.N	Variation (FA %)	Avg Compressive Strength (N/mm²)
1	0	50.44
2	10	48.89
3	20	43.31
4	30	44.30

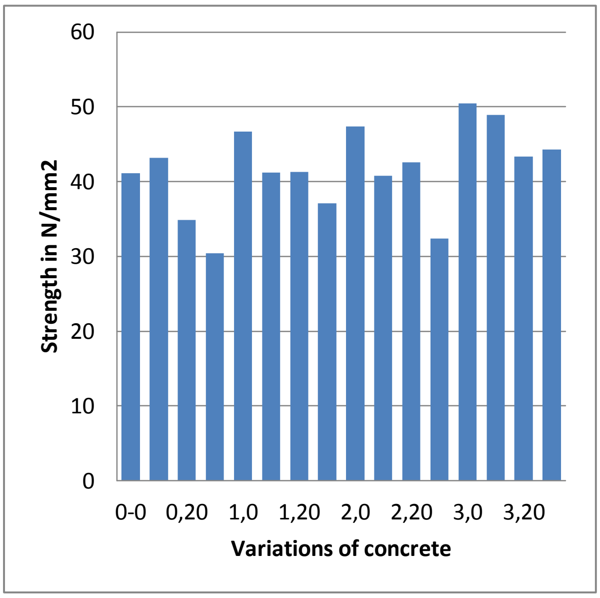

Chart-3: 28 days test

7.4. SEM analysis

Due to constraints in the pandemic only 7 days SEM photographs of 0%, 10% and 20% fly ash variation could only be taken.

7.4.1. 0% Fly ash

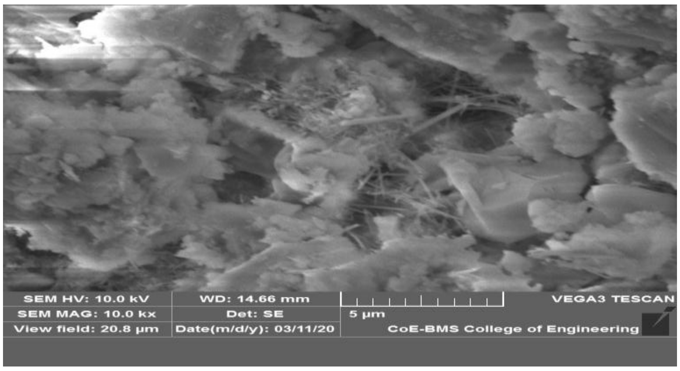

Fig-1: 0% Nanosilica 0% Fly ash

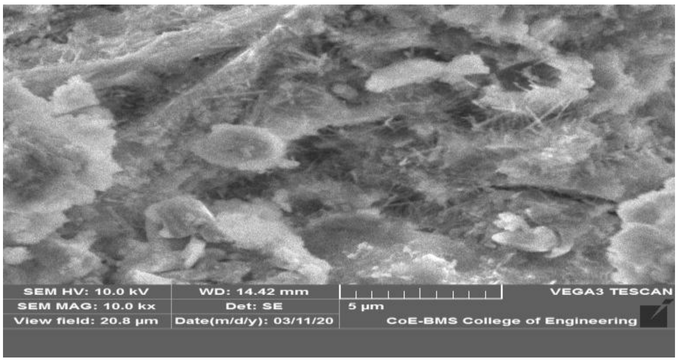

Fig-2: 1% Nanosilica 0% Fly ash

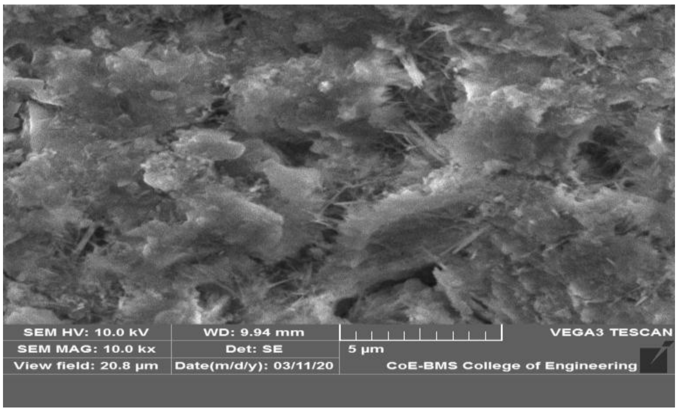

Fig-2: 2% Nanosilica 0% Fly ash

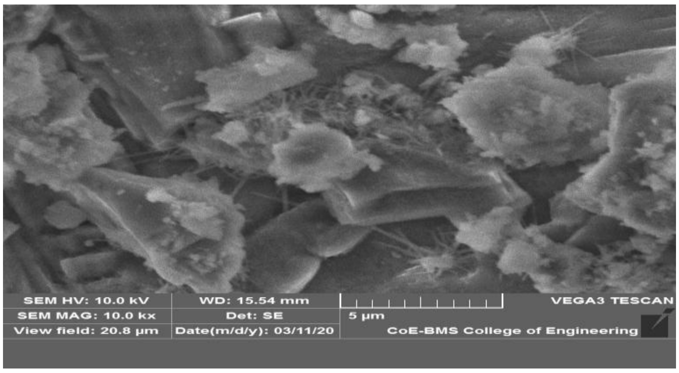

Fig-2: 3% Nanosilica 0% Fly ash

From the above analysis, it can be clearly seen that the ettringite content has decreased on subsequent addition of nanosilica. Also, in 3% nanosilica 0% fly ash variation more $Ca(OH)^2$ content can be seen.

7.4.2. 10% Fly ash

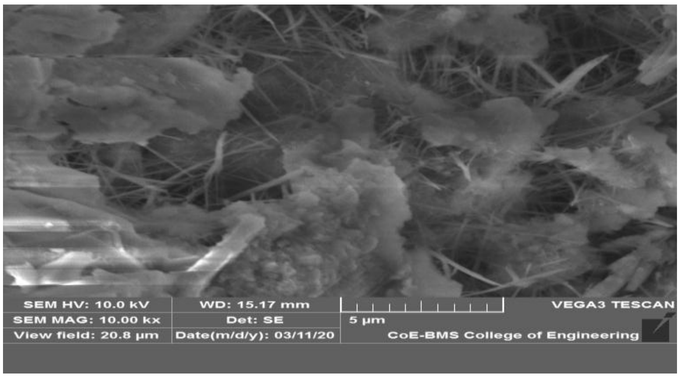

Fig-5: 0% Nanosilica 10% Fly ash

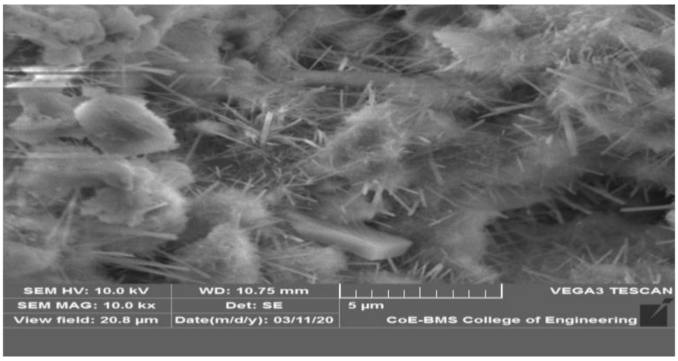

Fig-6: 1% Nanosilica 10% Fly ash

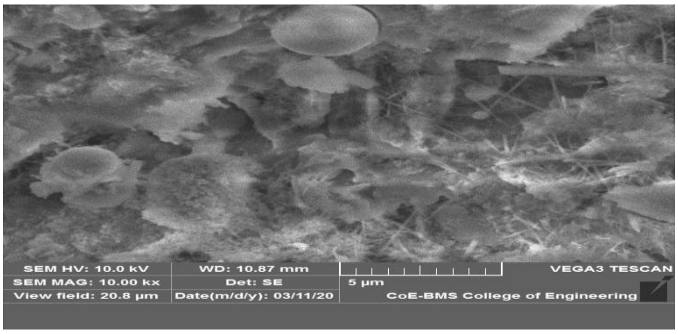

Fig-7: 2% Nanosilica 10% Fly ash

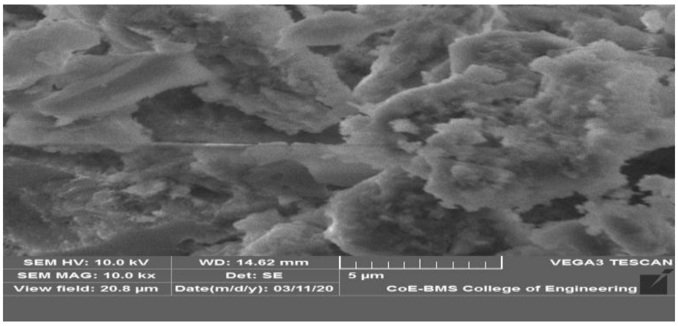

Fig-8: 3% Nanosilica 10% Fly ash

Here, the ettringite has decreased on subsequent addition of nanosilica on the samples with 10% fly ash whereas there is increase in C-S-H phase and $Ca(OH)^2$.

7.4.3. 20% Fly ash

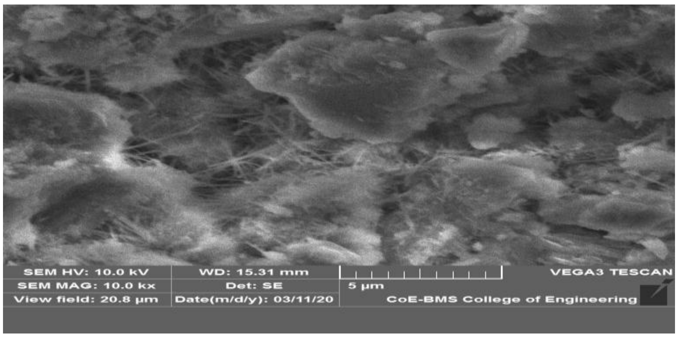

Fig-9: 0% Nanosilica 20% Fly ash

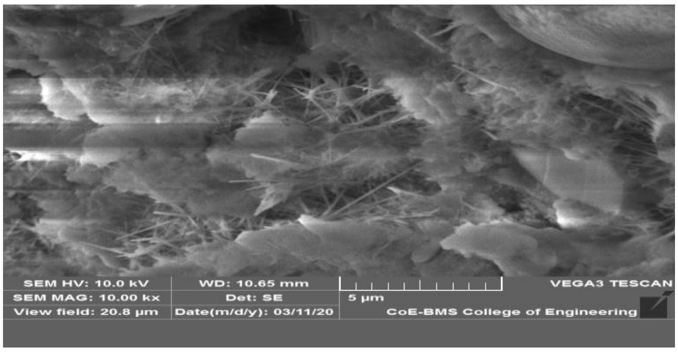

Fig-10: 1% Nanosilica 20% Fly ash

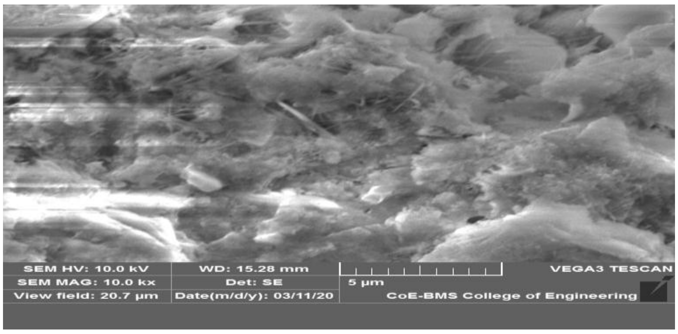

Fig-11: 2% Nanosilica 20% Fly ash

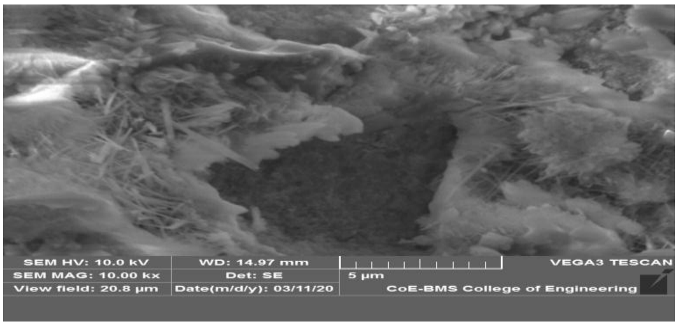

Fig-12: 3% Nanosilica 20% Fly ash

Here, the ettringite has decreased on subsequent addition of nanosilica on the samples with 20% fly ash whereas there is increase in C-S-H gels and $Ca(OH)^2$. But compared to previous samples with less fly ash the ettringite is more.

7. CONCLUSIONS

- Compared to the concrete with fly ash and OPC, the strength gained is more with the mixture including nanosilica. Even the maximum of 30% of fly ash can be mixed with 1% and 3% nanosilica.
- At all the cement replacement levels of fly ash; there is gradual increase in compressive strength with different variation of nanosilica from reaching the designed characteristic strength at 28 days except the 2% nanosilica and 30% fly ash variation.
- The gain in the strength of the concrete when nanosilica is added is significant. This may be considered to develop high strength concrete.
- The SEM analysis clearly shows the increase in C-S-H phase and Ca(OH)2 in the nanosilica enhanced fly ash concrete which can be seen significantly more in samples with 3% nanosilica, which causes the increase in strength of the concrete.
- Nanosilica being used increases the cost of the concrete but gives the advantage of high strength and pollution abatement of fly ash.

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