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Effect of Fly Ash and Silica Fume as A Partial Replacement of Cement on Compressive Strength of Concrete in Rigid Pavement Construction

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ABSTRACT

Due to growing environmental awareness and stern regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial wastes and finding solutions on using their valuable component parts so that those might be used as secondary raw material for other industrial applications. Silica fume is the bi- product of the ferrosilicon alloy production and Fly ash is by-product of coal thermal power plants. To date, these by-products are being used in other industrial branches and in the field of civil constructions, such as in cement manufacturing along with clinker and in masonry work for civil works. Considering the specificity of physical and chemical properties of fly ash and silica fume and a series of possibilities for their use in concrete, this research work demonstrates the possibilities of using fly ash and silica fume together as partial replacements of cement in concrete. It has been observed from the 28 days tests of compressive strength of concrete that compressive strength in fly ash modify concrete 20FA has maximum strength. In silica fume modify concrete 10SF has maximum strength value. While the combination of fly ash and silica fume 20FA10SF has maximum strength value. As the percentage of fly ash increases in the mix when compared with controlled concrete it increase up to 20% and then decreases. The compressive strength analysis carried out in this work gives a deeper insight into the cementitious properties and pozzolanic behavior of such by-products when used for construction purposes. The results show that the strength properties of concrete vary significantly when cement is partially replaced by silica fume and Fly ash.

Keyword- Fly ash, silica fume, cement, Curing and compressive strength.

INTRODUCTION

In building industry and pavement design control, concrete is a most widely used material. Cement is used as a basic building component in construction works of civil engineering. By investigation and research from many researchers, it was found that every year, on an average there is 1-Ton of concrete produced for an individual person. Therefore, Concrete (i.e. cement) is a significant and valuable material in manufacturing works. It was found that, India is the second largest cement producer country in this word. Indian cement industry also has a significant and a vital role in its economic growth. In past decades, the manufacture rate of cement has grown rapidly all over the world. Fresh concrete is mixed with fresh materials which can be molded into various types of shapes that can harden the constructed job as a rock like material. Hardening of the produced job is a result of chemical reaction of cements and water that lasts for a long duration of time and leads stronger with age. It is composed of cementitious material, coarse aggregate, fine aggregate, water and sometimes admixtures in required proportion. Cement is widely used in concrete. As per IRC - 44 - 2008, when we design M40 as per their guideline recommend for Ordinary Portland Cement 43 grade conforming to IS: 8112 minimum of cement content is 325 kg/m^3 and maximum of cement content is 425 kg/m^3. In 1m^3 volume of concrete of grade M40, cement is 416 kg/m^3, fine aggregate is 668 kg/m^3 and coarse aggregate is 1242 kg/m^3 is used. According to this the quantity coarse aggregate is used maximum in concrete, but the cost of coarse aggregate is less than cement that's why we partially replaced cement As the cement is costly material. It has a heavy impact on the cost of the project so for the economic purpose we have need to partially replacement of cement by cementitious material. Generally, if we compare the cost of all material used in concrete, cost of cement is more.

LITERATURE REVIEW

The relevant literature pertaining to the use of Fly ash and silica fume in concrete carried out in India and abroad has been reviewed and presented as under:

Raghavendra Y. B et al. (2019). The construction industry plays a vital role in India's development and it contributes about 8-10 per cent to GDP on an average. Developing nations like India need to have faster construction with high quality, durability and a pollution-free environment, which can be achieved only with Ready mix concrete (RMC). The usage of GGBS is very high in RMC industry. Compressive strength and workability are the most important and basic properties of concrete for any applications. An experimental investigation is carried out on optimum usage of GGBS in Ready Mix concrete industry. This paper presents the experimental test results of 27 types of concrete mixes made with 10% to 80% replacement of ordinary Portland cement. Slump retention for 180 minute which is a basic requirement for an RMC industry is carried out. Compressive strength testing of all the specimens was carried out at 7, 28, 56, 90 and 180 days. The test results proved that the compressive strength of concrete mix containing GGBS increases but after 50% of the total binder content, the addition of GGBS does not improve the strength of concrete. The reason could be GGBS may act as fine aggregate.

Wan et al. (2018) examined the usage of waste materials in definite proportion to make light weight self compacting concrete. Different samples were made by using perlite, scoria, and polystyrene lightweight aggregates in varying proportion. After conducting different tests of compressive and tensile strength it was concluded that more waste is added to mix will result in the lesser compressive strength of concrete.
Silva et al. (2014) measure the properties of recycled aggregates obtained from C& D waste. After demolition four forms of concrete were identified namely first is recycled concrete aggregates (RCA), second is recycled masonry aggregate (RMA), third is mixed recycled aggregates (MRA) and last one is construction and demolition recycled aggregates (CDRA). The density of RMA was found lower than the RCA due to high porosity value. It was also conclude that these materials can be utilized in the construction of sub-base layer of roads.

Huda et al. (2014) investigated the property of recycled course aggregate up to 3 generation of usage by replacing 100% of them. Small sample of 100 X 200mm of cylinder and 150 X 150 X 500 mm were casted and randomly tests were examined to know the physical and mechanical properties of aggregates. Compressive and splitting tensile strength was getting reduced a little when RA was used as the substitution of aggregate. Usage of recycled aggregate was showing the similar maximum stress and axial strain value (i.e. 50 MPa and 0.0027 respectively) as shown by the normal mix (i.e. using natural aggregate). Test for Modulus of elasticity and Poisson's ratio showed that recycled aggregate can be reused thrice

MATERIALS

1.1.1 A. Cement

Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three types: 33 grade, 43 grade, 53 grade. One of the important benefits is the faster rate of development of strength. Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportion and grinding the mixture to get a thorough and intimate mixture between the constituents. This type of cement can be used for all purposes just like OPC. It has lower heat of evolution and is more durable and can be used in mass concrete production.

1.1.2 B. Coarse Aggregate

The normal maximum size is gradually 10-20 mm; however particle sizes up to 40 mm or more have been used. Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of lower internal friction the flow is improved by the rounded aggregates and angular particles interlocking. Locally available coarse aggregate having the maximum size of 40 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 383-1970.

C. Fine aggregate

The aggregate passing through the IS sieve 4.75 mm called fine aggregate. Fine aggregate is natural sand, crushed stone and the crushed gravel sand. The fine aggregate used in the concrete mix are procured from Alakhnanda River (Uttarakhand). Fine Aggregate confirm to be Zone-III (IS 383 1970).

Fig.1 Ordinary port land cement

Fig.2 Coarse Aggregate

Fig.3 Fine aggregate

1.1.3 D. Fly ash

2. A by-product of the thermal power plant industry fly ash is generally of two types one is the coal ash that is captured from coal-fired power plant's chimneys and second one is bottom ash which is collected from bottom of the coal furnaces. The composition of fly ash is not uniform and depends on the type and quality of the coal that is being used in the thermal power plants. Its main constituents are silicon dioxide (SiO_2) (amorphous as well as crystalline also) and calcium oxide (CaO). Class F and Class C are two main classes of the fly ash. The utilization of fly ash in concrete production was mainly performed to remove the Greenhouse gases of the concrete as one tone of Portland cement produces one tone of CO_2 while zero CO_2 is being

produced by the fly ash. It is estimated that Portland cement production will nearly reach 2 billion tons by 2010; utilization of fly ash can significantly minimize carbon emission associated with construction.

2.1.1 E. Silica fume

3. While the production of ferrosilicon alloys or silicon in electric arc furnaces that used to reduce high quality quartz with coke, silica fume is obtained as a by-product. By using nitrogen adsorption technique the surface area of silica fumes arises to be in the order of 215,280 ft²/lbs (20,000 m²/kg), with the average size of the particle is hundredth size of cement. Silica fume is considered to be one of the most effective pozzolanic materials because of its high silica content and extreme fineness. The use of silica fumes tends to increase the bond strength, compressive strength, and abrasion resistance of the concrete. The silica fume used in the concrete mix are collected from Mirzapur (U.P).

Fig. 4: Fly ash

Fig. 5: Silica fume

F. Super plasticizer

A substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability is known as Super Plasticizing Admixture. A high range water reducing admixture (HRWRA) is also referred as Super plasticizer, which is capable of reducing water content by about 20 to 40 percent has been developed. These can be added to concrete mix having a low to- normal slump and water cement ratio to produce high slump flowing concrete. The effect of super plasticizers lasts only for 30to 60 minutes, depending on composition and dosage and is followed by rapid loss in workability.

METHODOLOGY

A. Test Procedure

The experimental program included the following:

- Testing the properties of materials used for making concrete.
- Casting and curing of cubes of dimension 150×150×150 mm for compressive strength
- Tests to determine the compressive strength.

The Experimental work is carried out in three stages:

Stage.1: In this stage experimental is work carried out with different percentage of fly ash along with cement concrete.

Stage.2: In this stage experimental work carried is out with different percentage of silica fume along with cement concrete.

Stage.3: In this stage experimental work is carried out with different combination percentage of fly ash and silica fume along with cement concrete.

3.1.1 B. Curing

Curing of concrete is carried out keeping the samples in the curing tank. The concrete samples were carefully removed from the mould and immersed into the clean water at the room temperature. Sample is then carried out after specified days for testing.

C. Scanning electron microscope (SEM)

It is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. The electron beam is scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum in conventional SEM, or in low vacuum or wet conditions in variable pressure or environmental SEM, and at a wide range of cryogenic or elevated temperature with specialized instruments. SEM tests of samples are performed in the Instrumentation lab of HNBGU Garhwal Srinagar Uttarakhand as shown in figure 6.

Fig. 6: SEM testing machine **Fig.7: Compression testing machine**

RESULTS AND DISCUSSION

In most structural applications, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place in its vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains.

A. Compressive strength

Table 1: Compressive strength of different % of fly ash mixed in concrete

Sr. No.	Mix type	Compressive Strength (N/mm^2)			Average Compressive Strength (N/mm^2)
		TRIAL 1	TRIAL 2	TRIAL 3	
1	CM	41.37	42.38	43.11	42.30
2	5FA	42.40	43.42	43.95	43.25
3	10FA	43.85	44.35	43.15	43.78
4	15FA	44.13	44.84	42.48	43.83
5	20FA	45.02	44.80	43.28	44.36
6	25FA	40.26	41.51	42.04	41.27
7	30FA	39.02	38.93	39.73	39.22

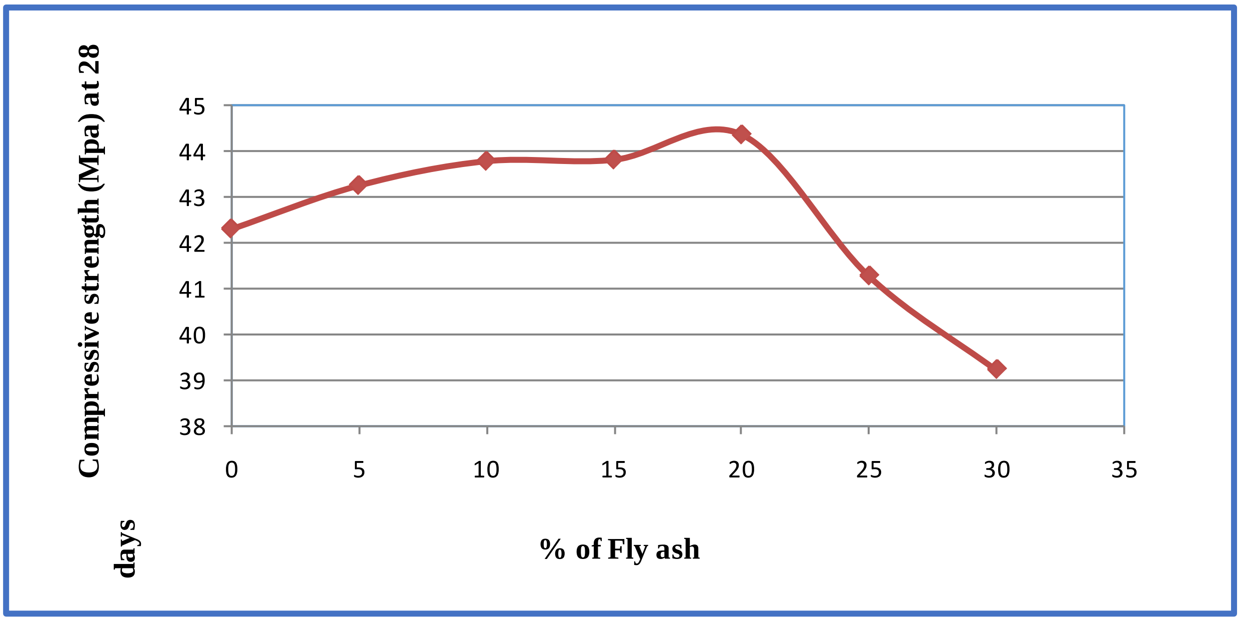

Fig.8: Compressive strength of different % of fly ash mixed in concrete

Table 2: Compressive strength of different % of silica fume mixed in concrete

Sr.No.	Mix type	Compressive Strength (N/mm^2)			AVERAGE Compressive Strength in (N/mm^2)
		TRIAL 1	TRIAL 2	TRIAL 3	
1	CM	41.37	42.38	43.11	42.30
2	5SF	42.88	43.64	42.00	42.84
3	10SF	43.02	43.37	44.66	43.68

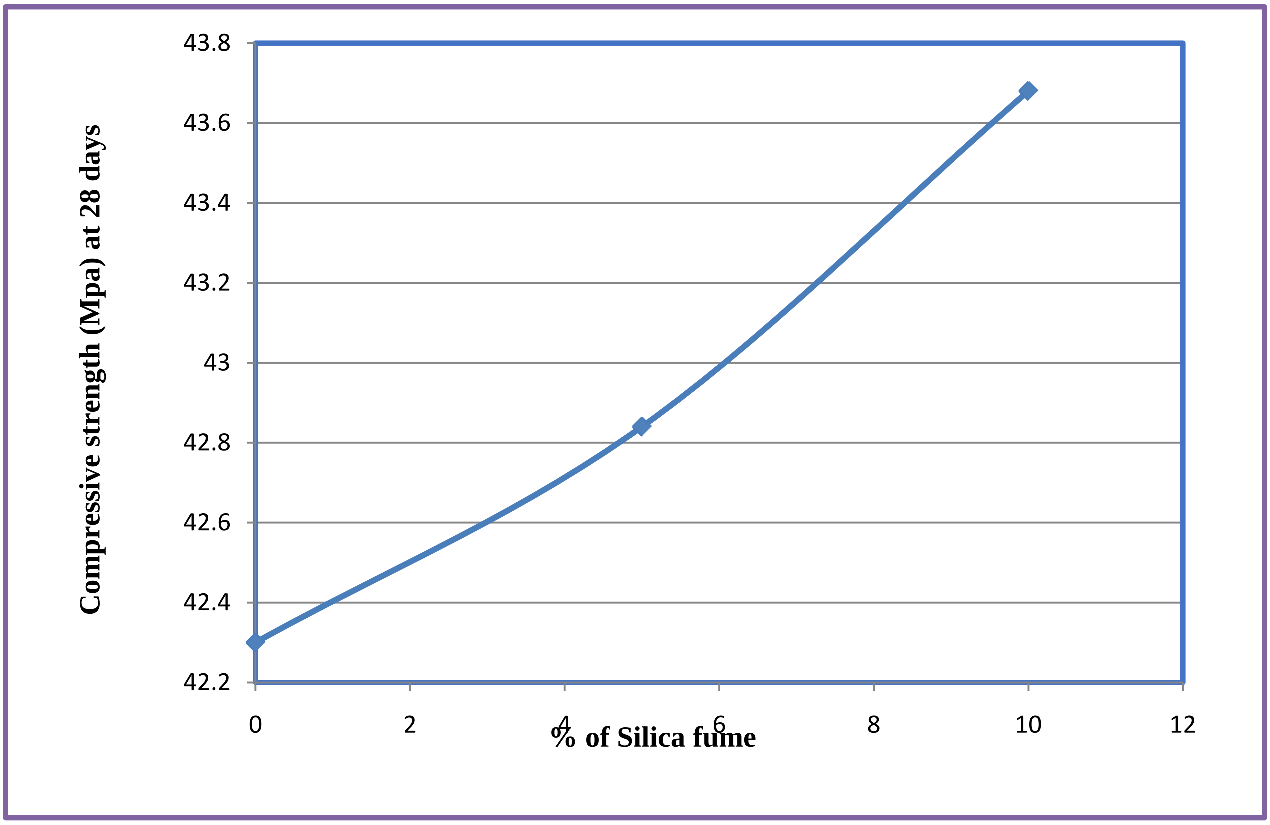

Fig.9: Compressive strength of different % of Silica fume mixed in concrete

Table 3: Compressive strength of different % fly ash and silica fume in concrete

Sr.No.	Mix type	Compressive Strength (N/mm^2)			AVERAGE Compressive Strength (N/mm^2)
		TRIAL 1	TRIAL 2	TRIAL 3	
1	CM	41.37	42.38	43.11	42.30
2	5FA5SF	45.15	45.33	44.84	45.10
3	5FA10SF	45.51	45.11	46.00	45.54
4	10FA5SF	45.73	45.86	47.06	46.21
5	10FA10SF	46.13	46.22	46.44	46.26
6	15FA5SF	44.35	46.66	47.55	46.18
7	15FA10SF	46.84	47.11	46.57	46.84
8	20FA5SF	47.55	46.88	46.97	47.13
9	20FA10SF	47.64	48.00	47.91	47.85
10	25FA5SF	44.22	43.77	42.91	43.55
11	25FA10SF	42.00	41.77	42.13	41.96
12	30FA5SF	41.42	41.15	39.55	40.70
13	30FA10SF	39.82	39.46	38.66	39.31

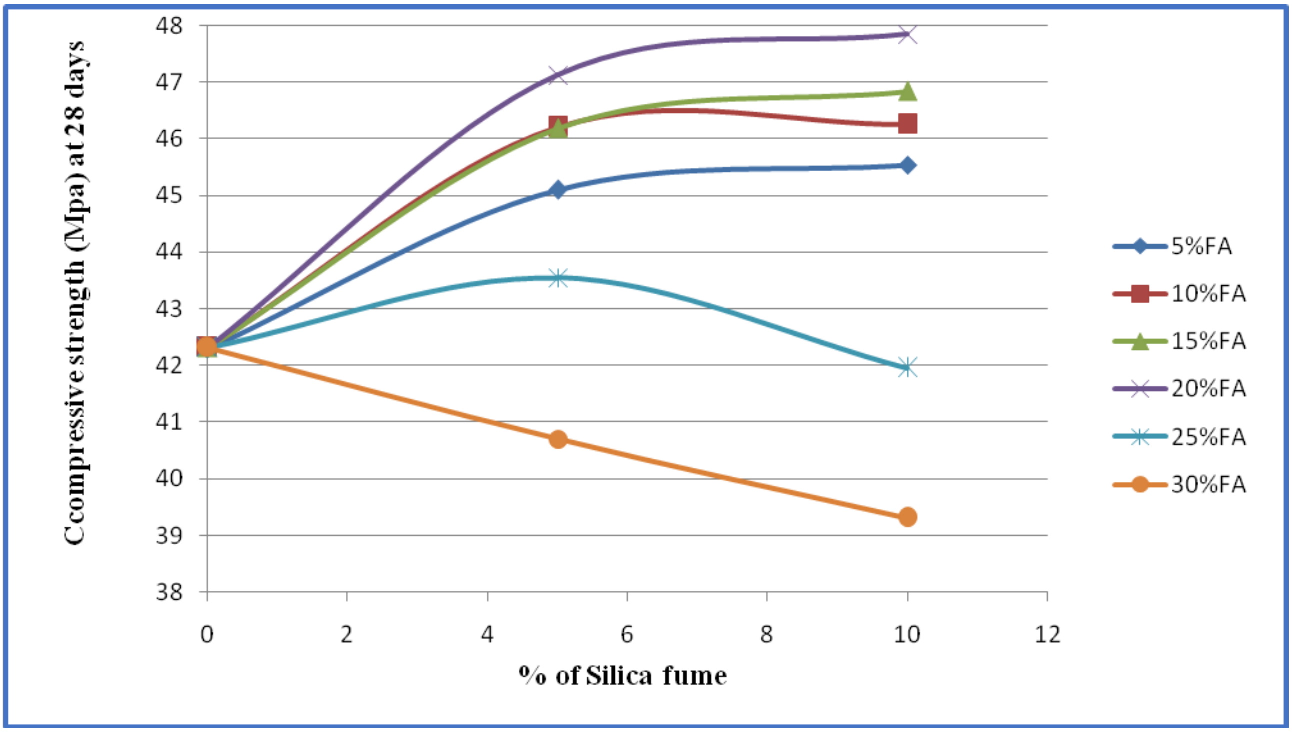

Fig.10.Compressive strength of different % of fly ash and silica fume in concrete

A. Scanning electron microscope (SEM)

Figure 4.11 shows the image of concrete mix incorporated with both silica fume and fly ash having 10 and 20% silica fume and fly ash respectively. Image shows that silica fume and fly ash have occupied the empty part of the control mix. The combination of fly ash and silica fumes have shown the best compressive among all the mixes used in the investigation. This may be due to the increase in bulk density of control mix. Images are in good agreement with the work done by **Nochaiya et al. (2013).**

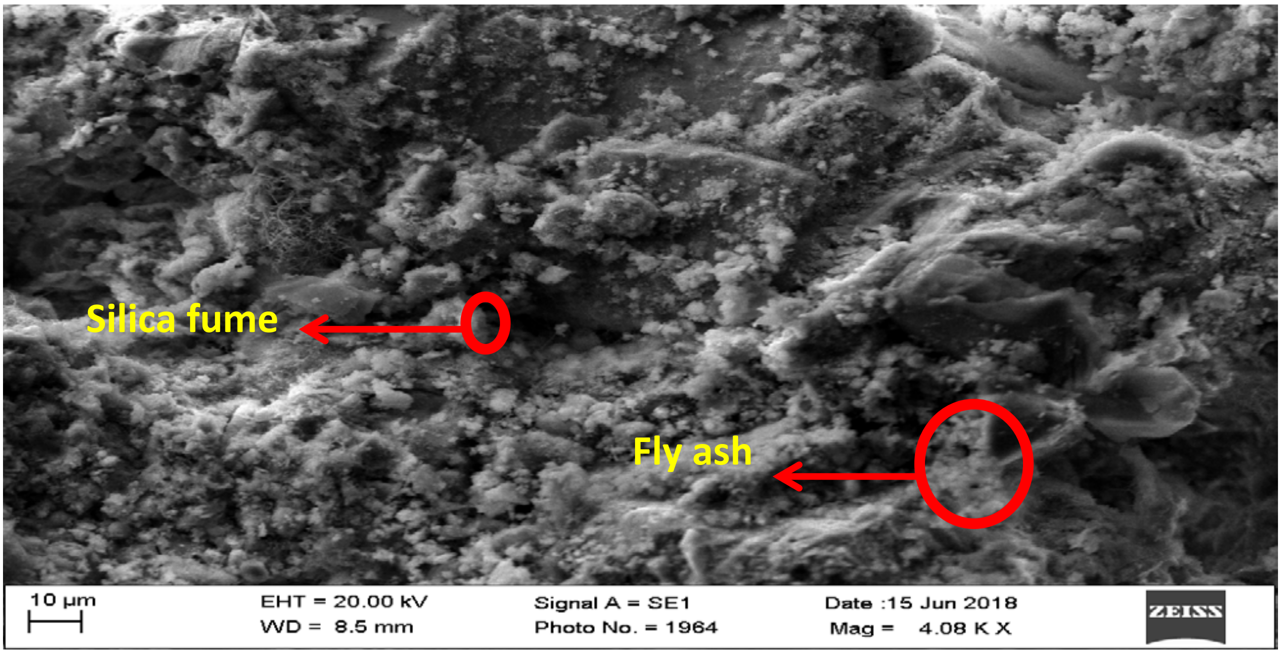

Fig.11: SEM images of concrete mix with silica fume and fly ash

CONCLUSION

- Compressive strength of fly ash modifies concrete decreases when 30% of cement is replaced by fly ash.
- Compressive strength of fly ash modifies concrete increases when 20% of cement is replaced by fly ash and give 5% increase in strength as compare to control mix.
- There is a trend of increase in strength up to 20% and the decrease in fly ash modify concrete mixtures
- There is an increase in strength of M-40 grade of concrete when 30% cement is replaced with 20% fly ash and 10% silica fume as compared with control mix and give 14% increase in strength.
- Also silica fume modify concrete upto 10% give increase strength as compare to control mix.
- There is a trend of increase in strength up to 20% and the decrease in fly ash modifies concrete mixtures.
- There is an increase in flexural strength of M-40 grade of concrete when 30% cement is replaced with 20% fly ash and 10% silica fume as compared with control mix and give 39 % increase in strength.

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