Strength Properties of No-fines Concrete with Supplementary Cementitious Materials

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Abstract

No-fines concrete is a form of lightweight concrete. This concrete has zero-slump, uncluttered graded material consisting of Ordinary Portland Cement. This concrete only consists of coarse aggregate, water, and sometimes admixtures such as Silica Fume, GGBS, and Fly Ash. Because this type of concrete contains little sand or no sand, that why it is sometimes known as "no-fines" concrete. This type of concrete has a high void content ratio which is approximately about 30% of the total mass of its volume, this type of concrete is becoming prevalent now a day due to its probable decrease in the surface runoff to the drainage systems of surface or rainwater. No-fines concrete has large open pores within its body hence less heat transfer. This type of concrete has effective application in little loading intensity such as walkways, parking pavements, footpaths, and highways sub-base. This concrete is deliberated as an Eco-friendly Defender Agency (EPA) for as long as contamination control and underground recharging source. Hence, the no-fines concrete mix was prepared without sand, and cement was replaced with a dosage of Silica Fume 2.5%, 5%, 7.5%, 10%, and 12.5%, respectively. It has been found that the no-fines concrete's strength increased as soon as the dosage was increased. It was observed that concrete gained the maximum strength at 7.5% dosage of Silica Fume; after that dosage, strength decreased slowly and gradually. Hence while the silica fume is being used, its replacement should not be more than 7.5%.

Keywords—No-fines concrete; silica fume; strength properties.

1 Introduction

No -fines concrete is also well-known as the previous [1], gap-graded [7], porous, permeable concrete, and increases porosity to make it reliable concrete for rainstorm water-controlling sources [2]. By characterization, no-fines concrete is known as a mixture of cement, pebbles, or gravel water [9, 11], and little or no fine aggregates are added [5, 8] or adding admixtures sometimes. It voids allow the storm water to recharge underneath the soil when it is used for paving [11].On the other hand, no-fines concrete aids in defending the surface of the pavement and its surrounding environment. As defined above no-fines concrete assistances in similar basic ingredients as conventional concrete in that it has an interconnected voids ratio of about 15% to 30% of its total volume, which permits water to flow from its body[4]. From no-fines concrete 11 to 15 liters can permit a square foot of surface area; this percolation quantity is much more than most rainfall. When this type of concrete is used to exclude the need for far-reaching retaining pools, these technic inventors and other private firms are also using this type of concrete to free up appreciated real land for improvement, it is still used in the pavement of parks [3].In current ages, investigators have been attentive to the upgrading of concrete properties concerning their hardened and fresh properties. These can be attained by using various types of cementitious materials such as partially replacing cement with silica fume by adding 0%, 5%, 7.5%, 10%, and 12.5% [14] by weight of cement in concrete[15,16].

No-fines concrete is produced by coating thick

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cement paste on the surface of coarse aggregates [6], to prevent the runoff of the cement paste at the time of mixing and placing of concrete. It should ensure that adequate cement paste should be coated with the particles to preserve a system of interconnected voids ratio. Nonexistence of fine aggregates in concrete results in difficulty in mixing, delivery, and pouring. Due to the high void ratio, it has a lighter weight of 1600 kg/m3 to 1900 kg/m3.

No-fines concrete has many applications some of which are discussed here, its primarily used in residential road pavements, low-volume traffic, and pedestal because in most areas its use should completely limit the need for the imprisonment and retaining tarns, swales, and other more customary stormwater managing the plans that are then required for amenabilities with the federal stormwater conventions on profitable spots of one acre or more. This type of concrete can reduce the ambient temperature of the air, when this concrete is used in the partition wall of buildings, it will reduce the internal temperature of the building that's less power will be required to cool inside the buildings. There is no need to build costly structures for stormwater storage, such as underground tanks, outlets, and inlets, all these will exclude. Manufacturing arrangements will also be upgraded as the boulder drain bed will be set up at the start of construction, improving destruction-resisting processes and avoiding rain interruptions due to severe site situations. Deceptively, when no-fines concrete is compared to conventional concrete it has lower mechanical strength properties and has a lower unit weight approximately 70% of normal-weight concrete. However, this concrete has many advantages as comparing the ordinary concrete.

2 Objectives

To optimize the dosage of Silica Fume material as a partial replacement of cement based on mechanical strength properties such as:

1) Compressive Strength.
2) Splitting Tensile Strength.
3) Flexural Strength.

3 Materials and Method

3.1 Materials

3.1.1 CEMENT:

Cement is a binder material used for construction purposes that adhere to other materials like filler used for concreting and binding them together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is only behind water as the planet's most-consumed resource. OPC Ordinary Portland Cement 'lucky' product by lucky cement manufacturing was used during this experimental work/ study.

TABLE 1: Percentage of the chemical composition of Cement and Silica

S. #.	Major Component	Cement %	Silica fume %
1	Calcium oxide (Cao)	60	0.13
2	Aluminium oxide (Al2O3)	3.75	0.07
3	Iron oxide (Fe2O3)	3.12	0.03
4	Magnesium oxide (MgO)	2	0.12
5	Silicon dioxide (SiO2)	19.22	85.23
6	Sulphur trioxide (SO3)	2.45	0.15
7	Carbon	0.03	0.23
8	Loss on ignition (LOI)	2.25	3.45
9	Tricalicum silicate (C3S)	43.45	0
10	Dicalicum silicate (C2S)	30.34	0
11	Tricalicum Aluminates(C3A)	8.56	0
12	Tetracalicum aluminates ferrite(C4AF)	8.55	0

3.1.2 AGGREGATES:

Crushed old concrete, or iron blast-furnace slag, used with a hydraulic cementing medium to produce either concrete. Types of aggregates include natural stone coarse aggregate and recycled coarse aggregate. The aggregate of each type is further subdivided into many types and classified based on its size. The technique of Sieve Analysis is used for the gradation of aggregate for use in concrete and other applications. For preparing the concrete crushed stones of size 5mm to 20mm were used during the experimental work.

3.1.3 WATER:

The quality of water used for concrete is an important factor that determines the strength of the concrete. Ph value is an important criterion, if the pH value of water is lying from 6 to 8, then this water is free from organic matter. This water can be adopted for construction purposes. So we should check the ph of the water. Mostly drinking water was used for preparing samples and curing purposes. All properties of water were checked before use for this experimental study.

3.1.4 SILICA FUME:

Constant ratio 1:6 cement to coarse aggregates uniform mix proportion was used. The different size of coarse aggregates having size 20mm-10mm, 10mm-5mm, 20mm-13mm 20mm-5mm, and a water-cement ratio of 0.42 was used during experimental work.

3.1.5 MIX PROPORTION:

This cementitious material can be achieved from the blast Furnessas inorganic material in desiccated form. This is one of the reproduction Pozzolanic materials, usually used as a mineral admixture. Silica fume is actual adequate-crystalline silica, manufactured in an electric arc blast furnace, by production silica fume is also known as micro silica fume or summarized as silica.

3.2 Size and Shape of Specimens

3.2.1 CUBES SIZE:

A standard size (150 x 150 x 150) mm cubes were cast and tested to achieve the average compressive strength of concrete.

3.2.2 SIZE OF CYLINDERS:

Standard size (150 x 300) mm cylinders werecast and tested to achieve an average splitting tensile strength of concrete.

3.2.3 PRISMS:

Standard-size prisms (100x100x500) mm were cast for concluding flexural strength.

3.2.4 Preparation of Raw material:

The raw material (Silica Fume) was added to the concrete mix by the weight of the cement. The silica fume was mixed with cement before the cement was used for the preparation of the samples. The dry weight of concrete was calculated and after that weight was converted to wet weight. The cement to aggregate ratio 1:6 is used for all batches before selecting this ratio many trial ratios were cast and tested and ultimately it was investigated that 1:6 has given more strength properties than other ratios, ratios used are (1:6 to 1:10). Such as for calculating cement is that cement / total ratio x volume of specimens x density of NFC and for coarse aggregates is that coarse aggregates / total ratio x volume of specimens x density of NFC, this method was used for calculating the quantity of cement and coarse aggregates. The silica fume was calculated by the weight of the cement used for specimens. The % of silica fume used varies from 2.5% to 12.5% by the weight of cement used for specimens.

3.3 Curing of Specimens

After 24 hours casted specimens were demoulded and samples were removed with great care to avoid the breaking of edges of specimens. All the specimens were put in the water tank for curing up to the testing age i.e. 28days.

TABLE 2: Compressive strength of no-fines concrete with Silica Fume

S. No.	***Size of coarse aggregates***	***Replacement of silica fume***	***Average compressive strength***	
			MPa	***psi***
1	20mm-10mm	0%	13.2	1914
2	10mm-5mm	0%	10.2	1479
3	20mm-13mm	0%	9.2	1334
4	20mm-5mm	0%	8.6	1247
5	20mm-10mm	2.5%	14.2	2059
6	10mm-5mm	2.5%	11.7	1697
7	20mm-13mm	2.5%	11	1595
8	20mm-5mm	2.5%	10.6	1537
9	20mm-10mm	5%	16.6	2407
10	10mm-5mm	5%	13	1885
11	20mm-13mm	5%	12	1740
12	20mm-5mm	5%	11.5	1668
13	20mm-10mm	7.5%	17.8	2581
14	10mm-5mm	7.5%	16	2320
15	20mm-13mm	7.5%	14.6	2117
16	20mm-5mm	7.5%	13.8	2001
17	20mm-10mm	10%	16.9	2451
18	10mm-5mm	10%	12.8	1856
19	20mm-13mm	10%	11.3	1639
20	20mm-5mm	10%	10.6	1537
21	20mm-10mm	12.5%	15.6	2262
22	10mm-5mm	12.5%	11.7	1697
23	20mm-13mm	12.5%	10.4	1508
24	20mm-5mm	12.5%	9.68	1404
[(20-10) mm & (10-5)mm] has max: Comp: = 17.8 MPa & 16MPa at 7.5% Silica fume.				

4 Results and Discussion

4.1 Compressive Strength Test

The standard size of cubes was used for determining the compressive strength of no-fines concrete. The cubes were cast without fine aggregates. Controlled samples and other samples by replacing cement with silica fume with dosages 2.5 %, 5 %, 7.5 %, 10 % 12.5 % and tested at age of 28 days. The cubes of standard size 150mm x150mm were cast and tested. The compressive strength can be computed by using the following formula.

$$fcu = P/A \tag{1}$$

From the results of normal no-fines concrete, it is observed that 0.42 water-cement ratio and 1:6 cement to aggregate gradation gave better results therefore using these parameters and replacement of cement with silica fume in dosage of 2.5% - 12.5% by weight is used to cast. The replacement of cement is used in increments of 2.5%. Coarse aggregate gradation 20–10 mm, 10 − 5 mm, 20 − 13 mm, and 20 − 5 mm. Additionally, one batch of the samples with 0% replacement of cement is also cast to compare the results. 28-day cured samples are tested for compressive strength using a universal load testing machine. The obtained results are given in Table 1. The compressive strength of no-fines concrete with silica fume is recorded in the range of 9.68 MPa – 17.8 MPa. The maximum strength is recorded at the dosage of silica fume equal to 7.5%. It is noted that above and below this dosage of silica fume the compressive strength remained less than the maximum recorded value. Therefore, a 7.5% replacement of cement with silica fume may be treated as the optimum dosage. The maximum strength of control specimens is recorded as equal to the already reported value in the previous section (13.2 MPa). In comparison to the maximum compressive strength of control specimens, the no-fines concrete with silica fume attained a 34.8% increase in strength. The percentage difference between the compressive strength of no-fines concrete and to maximum compressive strength of normal no-fines concrete (control specimen) is computed and listed in the last column of Table 2. Although the dosage of silica fume has an impact on the compressive strength yet the introduction of silica fumes improves the compressive strength in all batches if compared with the relevant results of normal no-fines concrete specimens. It may be observed that the trend of compressive strength for all batches is almost similar. However, compressive strength with 7.5% dosage shows higher values of compressive strength. Although the dosage of silica fume has an impact on the compressive strength yet the introduction of silica fumes improves the compressive strength in all batches if compared with the relevant results of normal no-fines concrete specimens. The impact of coarse aggregate gradation on the compressive strength of no-fines concrete with silica fume is plotted in Figure1. It may be observed that the trend of compressive strength for all batches is almost similar. However, compressive strength with 7.5% dosage shows higher values of compressive strength. The same is also evident from Figure 2, which shows the impact of the dosage of silica fume on compressive strength.

4.2 Splitting Tenstile Strength Test

The standard size of cylinders was used to determine the splitting tensile strength of no-fines concrete. The cylinders were cast without fine aggregates. Controlled samples and other samples by replacing cement with silica fume with dosages 2.5 %, 5 %, 7.5 %, 10 % 12.5 % and tested at age of 28 days. The cylinders of standard size 150mm x 300mm were cast and tested. The splitting tensile strength can be computed by using the following formula

$$ft = 2P/\pi LD \tag{2}$$

TABLE 3: Splitting tensile strength of no-fines concrete with Silica Fume

S. No.	Size of coarse aggregates	Replacement of silica fume	Average splitting tensile strength	
			MPa	PSI
1	20mm-10mm	0%	2.3	333.5
2	10mm-5mm	0%	1.9	275.5
3	20mm-13mm	0%	1.7	246.5
4	20mm-5mm	0%	1.6	232
5	20mm-10mm	2.5%	2.4	348
6	10mm-5mm	2.5%	2	290
7	20mm-13mm	2.5%	1.9	275.5
8	20mm-5mm	2.5%	1.8	261
9	20mm-10mm	5%	2.7	391.5
10	10mm-5mm	5%	2.25	326.25
1	20mm-13mm	5%	2.	290
12	20mm-5mm	5%	1.9	275.5
13	20mm-10mm	7.5%	3.5	348
14	10mm-5mm	7.5%	2.9	290
15	20mm-13mm	7.5%	2.6	275.5
16	20mm-5mm	7.5%	2.5	261
17	20mm-10mm	10%	3.4	391.5
18	10mm-5mm	10%	2.6	326.25
19	20mm-13mm	10%	2.2	290
20	20mm-5mm	10%	2	275.5
21	20mm-10mm	12.5%	2.8	507.5
22	10mm-5mm	12.5%	2.2	420.5
23	20mm-13mm	12.5%	1.9	377
24	20mm-5mm	12.5%	1.7	362.5
[20mm-10mm &10mm-5mm] has max: Splitting T: = 3.5MPa& 2.9MPa @ 7.5% Silica fume.				

The results of splitting tensile strength are given in Table 3. The maximum and minimum tensile strength of concrete without silica fume is recorded in the range of 2.3 MPa – 1.6 MPa. Whereas, the same for samples with silica fume is recorded in the range of 3.5 MPa – 1.7 MPa. In both groups of specimens, maximum tensile strength is recorded for (20 – 10) mm coarse aggregate gradation. Further, the optimum dosage of silica fume is observed equally to 7.5%. This additionally confirms the conclusion of the parameter while dealing with the compressive strength. The addition of silica fume increased the maximum splitting tensile strength of no-fines concrete by 52.17%. If (10 – 5) mm coarse aggregate gradation is considered then the maximum tensile strength is 1.9 MPa for conventional no-fines concrete and 2.9 MPa for no-fines concrete with silica fume. In this case, the increase in tensile strength is equal to 52.63%. Although the percentile increase of tensile strength is for this group of coarse aggregate gradation, the maximum value is 45.71% less than the maximum tensile strength of no-fines concrete with (20 – 10) mm

TABLE 4: Flexural strength of no-fines concrete with Silica Fume

S. No.	Size of coarse aggregates	Replacement of silica fume	Average Flexural strength	
			MPa	PSI
1	20mm-10mm	0%	4.4	638
2	10mm-5mm	0%	3.4	493
3	20mm-13mm	0%	2.6	377
4	20mm-5mm	0%	2.4	348
5	20mm-10mm	2.5%	4.5	652.5
6	10mm-5mm	2.5%	3.5	507.5
7	20mm-13mm	2.5%	2.7	391.5
8	20mm-5mm	2.5%	2.5	362.5
9	20mm-10mm	5%	4.7	681.5
10	10mm-5mm	5%	3.6	522
1	20mm-13mm	5%	3	435
12	20mm-5mm	5%	2.8	406
13	20mm-10mm	7.5%	5.2	754
14	10mm-5mm	7.5%	4.2	609
15	20mm-13mm	7.5%	3.3	478.5
16	20mm-5mm	7.5%	3.3	478.5
17	20mm-10mm	10%	6	870
18	10mm-5mm	10%	4.3	623.5
19	20mm-13mm	10%	3.2	464
20	20mm-5mm	10%	2.9	420.5
21	20mm-10mm	12.5%	5.2	754
22	10mm-5mm	12.5%	4	580
23	20mm-13mm	12.5%	3	435
24	20mm-5mm	12.5%	2.7	391.5
[20mm-10 mm & 10mm-5mm] has max: Flexural S: = 5.2 MPa& 4.2 MPa @ 7.5 % Silica fume.				

coarse aggregate gradation. It may be observed from the results that the trend of strength reduction with the change in coarse aggregate gradation is almost similar in both cadres of the samples. It may also be observed from the results that a 7.5% dosage of silica fume gives maximum tensile strength results. The effect of the dosage of silica fume on the tensile strength of no-fines concrete along with conventional no-fines concrete is plotted in Figure 3 and figure 4. The figure also gives the details of the impact of coarse aggregate gradation on average splitting tensile strength. It may be observed from this figure that the trend of strength reduction with the change in coarse aggregate gradation is almost similar in both cadres of the samples. It may also be visualized from this figure that a 7.5% dosage of silica fume gives maximum tensile strength results.

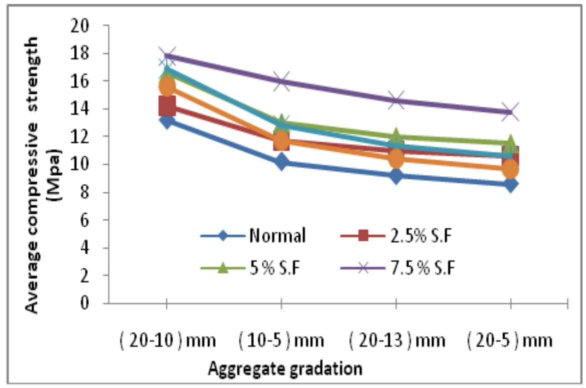

Fig. 1: . Compressive strength of no-fines concrete with silica dosage (2.5% to 12.5%) and various sizes of coarse aggregate.

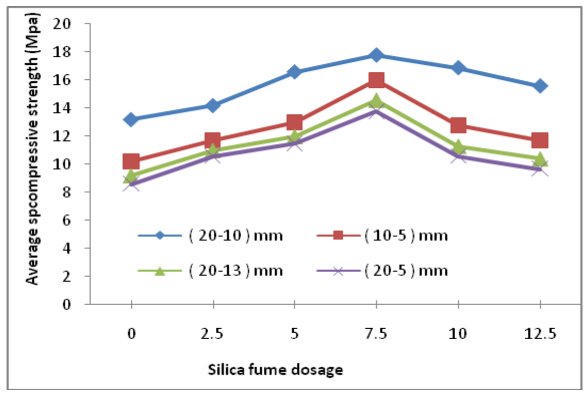

Fig. 2: Compressive strength of no-fines concrete with silica fume dosage (2.5 % to 12.5 %).

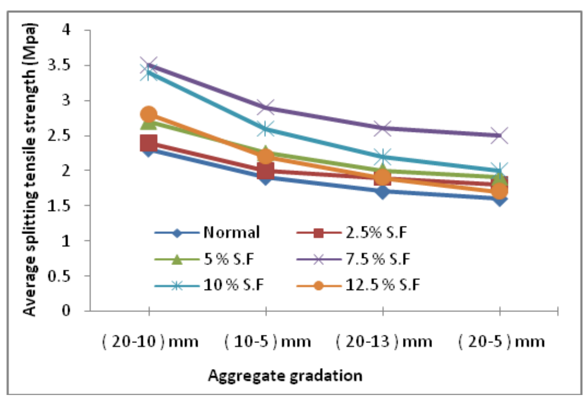

Fig. 3: Splitting tensile strength with various sizes of coarse aggregates.

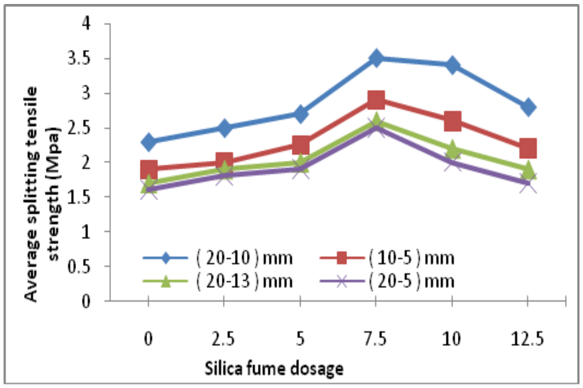

Fig. 4: Effect of silica fume dosage (2.5 % to 12.5 %) with various aggregate gradations on splitting tensile strength

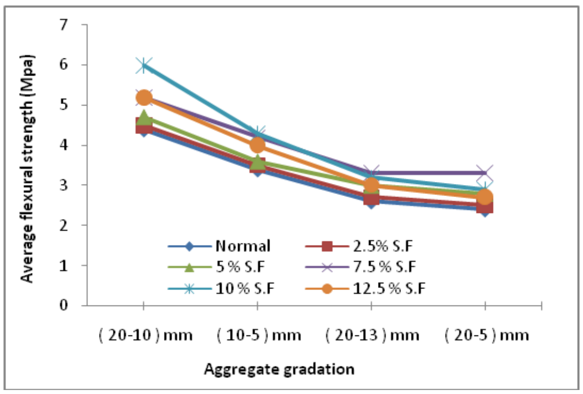

Fig. 5: Flexural strength of no-fines concrete with various sizes of coarse aggregate gradation with silica fume dosage (2.5% to 12.5%).

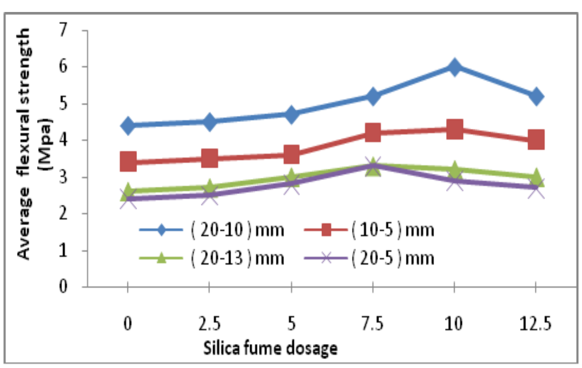

Fig. 6: . Effect of various sizes of aggregate gradation on flexural strength of no-fines concrete with silica fume

4.3 Flexural Strength Test

This test aimed to calculate the flexural behavior of prisms. When concrete is used in the beam due to externally applied load, the beam will fail under the flexural behavior; hence it is necessary to check the flexural strength of the concrete. The flexural strength was calculated by the following formula.

$$f_f = MC/I \tag{3}$$

Silica fume is used as cement replacement with different dosages of 0 – 12.5%. 0% samples with dosage to as of the control specimens are sued to compare the results. The obtained results for all batches of no-fines concrete are given in Table 3. It may be observed that in all batches of coarse aggregate gradation, maximum values are attained by (20 – 10) mm and (10 – 5) mm coarse aggregate gradation. Control specimen cast with (20 – 10) mm coarse aggregates attained maximum flexural strength equal to 4.4 MPa whereas those cast with (10 – 5) mm attained maximum flexural strength equal to 3.4 MPa. It may also be observed from Table 3 that the addition of silica fume has improved the flexural strength of all batches of no-fines concrete for all dosages of silica fume but the maximum strength of 6 Mpa achieved with the silica fume dosage equal to 7.5% (20 – 10) mm coarse aggregate gradation whereas, the maximum flexural strength attained by samples cast with (10 – 5) mm coarse aggregate gradations. Whereas equal to 4.3 MPa. The values in comparison to control specimens are 36.36% and 30.30% higher. Hence the optimum dosage of silica fume for flexural strength is equal to 10%. Although (20 – 5) mm coarse aggregate gradation takes a jerk and shows im-provement in strength it remained less than the results of other coarse aggregate gradations. Figure 5 and Figure 6 give the graphical representation of the flexural strength of no-fines concrete with various coarse aggregate gradation and dosage effects on the flexural strength of NFC respectively.

5 Conclusion

From the experimental investigation the following conclusions are drawn: The compressive strength of no-fines concrete with silica fume is recorded in the range of 9.68 MPa – 17.8 MPa. The maximum strength is recorded at the dosage of silica fume equal to 7.5%. Although the dosage of silica fume has an impact on the compressive strength yet the introduction of silica fumes improves the compressive strength in all batches if compared with the relevant results of normal no-fines concrete specimens. It may be observed that the trend of compressive strength for all batches is almost similar. However, compressive strength with 7.5% dosage shows higher values of compressive strength.

The addition of silica fume has increased in higher den-sity. The density was increased as the amount of silica fume was increased by replacing the cement with silica fume ie 2.5% to 7%. which is caused due to presence of a high amount of amorphous silica in silica fume, when it comes in contact with lime present in cement it will start a reaction and increase the density of concrete and as a result, the denser microstructure of concrete is formed. The maximum and minimum tensile strength of concrete without silica fume is recorded in the range of 2.5 MPa – 1.6 MPa. Whereas, the same for samples with silica fume is recorded in the range of 3.5 MPa – 1.7 MPa. In both groups of specimens, maximum tensile strength is recorded for (20 – 10) mm coarse aggregate gradation. Further, the optimum dosage of silica fume is observed equally to 7.5

It may be observed from the results that the trend of strength reduction with the change in coarse aggregate gradation is almost similar in both cadres of the samples. It may also be observed from the results that a 7.5% dosage of silica fume gives maximum tensile strength results.

It may be observed that in all batches of coarse aggregate gradation, maximum values are attained by (20 – 10) mm and (10 – 5) mm coarse aggregate gradation. Control specimen cast with (20 – 10) mm coarse aggregates attained maximum flexural strength equal to 5.2 MPa whereas those cast with (10 – 5) mm attained maximum flexural strength equal to 4.2 MPa.

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