

# An Experimental Study on Use of Recycled PET Plastic Waste and Mineral Admixtures in Concrete – An Eco-Friendly Approach

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**ABSTRACT:** Concrete is indispensable in modern society's fascination with new roads, buildings and other constructions. Replacement of fine aggregate with recycled PET plastic is a tentative solution to problems like shrinking natural resources (e.g. sand) and disposal of non-biodegradable materials (e.g. plastic). The strength properties of M30 grade concrete were studied with varying plastic percentages of 0%, 5%, 10%, 15% and 20% of fine aggregate. Investigations were carried out to study various properties like workability, unit weight and compressive, tensile and flexural strengths of these mixes. There is a decrease in compressive strength with an increase in percentage of plastic. Silica Fume has been added to the mix with the least compressive strength, in varying percentages of 5%, 10% and 15% of cement. Again the mix with the least compressive strength has been chosen. Fly ash of 25% of cement is added to that mix. This resulted in improvement of compressive strength in concrete.

**KEYWORDS:** PET plastic, Silica fume, Fly ash, Water absorption capacity, Unit Weight, Compressive strength, Tensile strength, Flexural strength.

## I. INTRODUCTION

Concrete is the second most consumed material, after food and water. Its popularity and versatility can never be overstated. It is a common practice to use naturally-occurring materials like gravel and sand as constituent materials in conventional concrete. This leads to depletion of natural resources. A variety of plastic products are being consumed in the modern society. However, enormous volume of plastic waste is imposing pressure on the environment, owing to very low biodegradability of plastic. It is essential to evolve a rational solution to the problems like crunch on natural resources and also the disposal of plastic waste. Utilization of plastic waste as a replacement of fine aggregate is a step towards cleaner environment. Concrete containing plastic as partial aggregate possesses lower strength, but have other advantages. There is a decrease in unit weight of concrete, which results in reduced dead loads. If used as aggregate, plastic can stop or divert propagation of micro cracks and improves the toughness of concrete. Also, the cost of concrete is reduced to some extent.

The reduction in strength can be compensated by addition of mineral admixtures like silica fume and fly ash. Mineral admixtures are used to replacement partially. Reduced use of cement will directly result in reduced CO<sup>2</sup> emissions and lesser consumption of energy resources. Silica fume is a by-product obtained during manufacture of ferrosilicon alloys; whereas fly ash is a by-product of thermal power plants. Enormous amounts of these wastes are produced in our country. They are contributing to various forms of environmental pollution and their disposal is a big challenge. Even though, the popularity of such bye-products is rapidly increasing, the utilization is still below 20%. By replacement of cement with such pozzolanic materials, the cement and concrete industry can meet the growing demand in the construction industry. At the same time, the reduction of environmental pollution can be achieved.

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The main objective of this study is to investigate the properties of concrete in wet and hardened states after replacement of fine aggregate with plastic of varying amounts. In the present investigation, M30 grade concrete is designed; water-cement ration being 0.4. Properties of constituent materials were evaluated. Workability, compressive, tensile and flexural strengths and unit weight of concrete were calculated.

## II. RELATED WORK

**Simiha Akcozoglu (2009)** had made investigation by using PET plastic, concluded that use of shredded PET granules due to its low unit weight reduces the unit weight of concrete which results in reduction in dead weight of building will help to reduce the seismic risk of building the earth quake forces linearly dependent on dead weight .

**Mariaenrica Frigione (2010)** had conducted an investigation on using recycled PET bottles as fine aggregate in concrete and concluded the workability, compressive strength and split tensile strength are slightly lower than reference concrete and moderately higher ductility.

**Michael Thomas (2010)** had conducted an investigation on optimizing the use of fly ash in concrete and concluded that the use of good quality fly ash with high fineness and low carbon content reduces the water demand of concrete. A well –proportioned fly ash concrete mixture will have improved workability when cokpared with OPC concrete of the same slump. The ultimate strength achieved by the concrete increases with increasing fly ash content.

**Semiha Akcaozoglu (2011)** had conducted an investigation on mortars by using PET as aggregate and studied the effect of Granulated Blast Furnace Slag and fly ash .Both increased carbonation depths of specimens .For this reason carbonation reducing measures must be taken when using these mineral admixtures .

**R.V.Silva (2012)** had conducted an investigation on concrete containing paste waste as aggregate and influence of curing conditions on the durability related performance of concrete. He concluded that workability decreases with increasing amount of coarse, flakier and irregular shaped plastic aggregates. The gap between these values widened as all concrete specimens wore cured in progressively drier environments with reductions varying between 11.1%,28.3% of coarser plastic aggregate specimens cured .

**Brahim Safi (2013)** had conducted an investigation by using plastic waste a fine aggregate in self compacting mortars. He concluded that this plastic waste type can be used successfully as fine aggregate in self compacting mortars (or concrete). Fluidity is significantly improved by the presence of these waste. Reduction in Compressive strength was between 15 % and 33% for mortar containing 20 % to 50% plastic waste.

## IIIMATERIALS AND THEIR PROPERTIES

The materials used in this investigation are

1. ZUARI OPC 53 grade cement confirming to IS 12269:1987
2. Silica Fume confirming to ASTM C1240 and IS 15388:2003
3. Fly ash Class C confirming to IS 3812-2003
4. Natural river sand
5. Recycled PET Plastic
6. Coarse aggregate
7. Water
8. Master Glenium sky 8233 formerly B-233 as admixture of BASF company

### Cement

The fineness modulus of cement is 3%, specific gravity of cement is 3.13, standard consistency of cement is 31%, Initial setting time is 60 minutes and final setting time is 250 minutes.

### Silica Fume

Silica Fume is also known as micro silica. Its colour of silica fume is white, specific gravity is 2.3 and size of silica fume is 10 µm.

### Fly Ash

Class C fly ash has been used. The colour of fly ash is grey, specific gravity is 2.6.

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## Natural river sand

Uncrushed natural river sand is used as fine aggregate in this investigation .As per IS 383:1970 fine aggregate properties were tested and concluded that the fine aggregate in this investigation falls in zone-II .The water absorption capacity is 1%, fineness modulus is 2.60,specific gravity is 2.65.

## Plastic

Plastic used in this investigation is PET (polyethylene terephthalate ) .The water absorption capacity is 0.12%, specific gravity is 1.32, size is below 4.75 mm

## Coarse aggregate

As per IS 383:1970 the nominal size is 20 mm is used .The shape of coarse aggregate is angular, water absorption capacity is 0.5%, fineness modulus is 4.60, specific gravity is 2.73

## Water

Tap water which is potable is used in this investigation.

## Admixture

Master Glenium SKY 8233 has been used. It is a super plasticizer (based on polycarboxylic ether) which is a water-reducing admixture. This free from chloride and low in alkali content. It is compatible with most types of cements. The aspect of admixture is light brown; relative density is  $1.08 \pm 0.01$  at 25. Its PH is  $\geq 6$  and specific gravity is 1.08.

## IV. EXPERIMENTAL RESULTS

### Mix proportion

The mix design was made confirming IS 10262:2009. Ten mixes were made in this investigation including reference mix other than the reference mix, the mixes were made by partially replacing plastic to fine aggregate of percentage 5%, 10%, 15% and 20%, by volume. By taking the mix with least compressive strength was enhanced it with silica fume as partial cement replacer of percentage 5%, 10% and 15%, by weight. Among above three mixes, the mix with least compressive strength was enhanced with fly ash as partial cement replacer of percentage 25%by weight. The w/c ratio is 0.40. The mix proportions are shown in table 1.

Table 1: Mix proportion of M30 grade with w/c of 0.40

Mix name	CEMENT (Kg/m <sup>3</sup> )	SILICA FUME (Kg/m <sup>3</sup> )	FINE AGGREGATE (Kg/m <sup>3</sup> )	PLASTIC (Kg/m <sup>3</sup> )	COARSE AGGREGATE (Kg/m <sup>3</sup> )	WATER (Kg/m <sup>3</sup> )	ADMIXTURE (Kg/m <sup>3</sup> )
H1	394	0	662.027	0	1212.644	157.6	2.758
H2	394	0	628.97	16.610	1212.644	157.6	2.758
H3	394	0	595.86	33.22	1212.644	157.6	2.758
H4	394	0	562.76	49.83	1212.644	157.6	2.758
H5	394	0	529.66	66.44	1212.644	157.6	2.758
H6	374.3	19.7	529.66	66.44	1212.644	157.6	2.758
H7	354.6	39.4	529.66	66.44	1212.644	157.6	2.758
H8	334.9	59.1	529.66	66.44	1212.64	157.6	2.758
H9	275.8	19.7	98.5	66.44	1212.64	157.6	2.758

### Workability

In this investigation workability was measured in terms of slump. Increases in the plastic materials have resulted in easy workability of concrete. The slump results are shown in table 2.

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Table 2: Slump values

Mix name	Slump in mm	Degree of workability
H1	120	High
H2	130	High
H3	142	High
H4	145	High
H5	150	High
H6	150	High
H7	150	High
H8	150	High
H9	152	High

## Compressive strength

By increasing the waste plastic content, the results show a tendency for compressive strength values of waste plastic concrete mixes to decrease below the plain mixes at each curing age. The probable reason is poor adhesive strength between the surface of the waste plastic and the cement paste. The results of compressive strength of waste plastic concrete with no mineral admixtures are shown in table 3 and figure 1.

Table 3: Compressive strength of waste plastic concrete for 7 days and 28 days

Mix no	Average compressive strength for 7 days in N/m <sup>2</sup>	Average compressive strength for 28 days in N/m <sup>2</sup>
H1	28.2	47
H2	27.66	46.1
H3	26.52	44.2
H4	25.26	42.1
H5	24	40

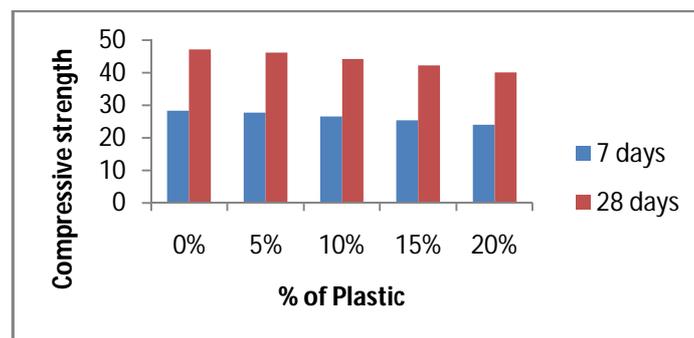


Fig 1 Compressive strength versus percentage of plastic for 7 days and 28 days

The mix with lowest compressive strength (i.e. H5) is chosen. A mineral admixture, silica fume, is added in varying percentages. By increasing the silica fume content, the results show a tendency for compressive strength values of mixes to increase as compared to the mixes with no silica fume. The results of compressive strength tests are shown in table 4 and figure 2.

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Table 4: Compressive strength of concrete with silica fume for 7 days and 28 days

Mix no	Average compressive strength for 7 days in N/m <sup>2</sup>	Average compressive strength for 28 days in N/m <sup>2</sup>
H5	24	40
H6	27.108	45.18
H7	28.8	48
H8	29.4	49

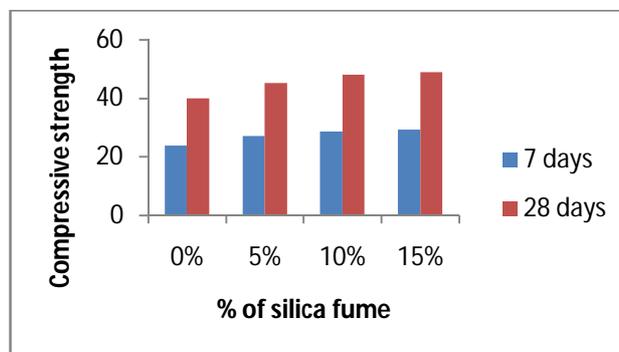


Fig 2 Compressive strength versus percentage of silica fume for 7 days and 28 days

The mix with lowest compressive strength (i.e. H6) is chosen. Fly ash (25% by weight of cement) is added. Addition of fly ash resulted in an increase of compressive strength. The results of compressive strength tests are shown in table 5 and figure 3.

Table 5: Compressive strength of concrete with silica fume and fly ash for 7 days and 28 days

Mix no	Average compressive strength for 7 days in N/m <sup>2</sup>	Average compressive strength for 28 days in N/m <sup>2</sup>
H6	27.108	45.18
H9	29	48.6

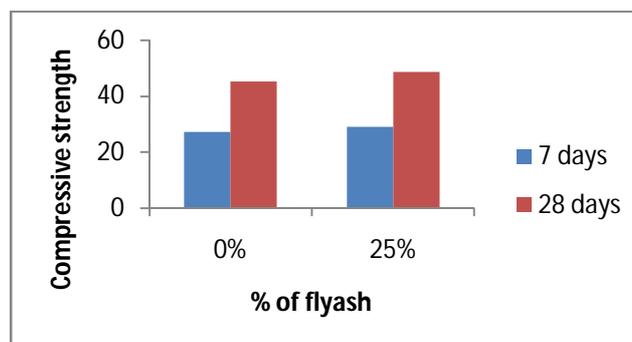


Fig 3 Compressive strength versus percentage of Fly Ash for 7 days and 28 days (SilicaFume = 5%)

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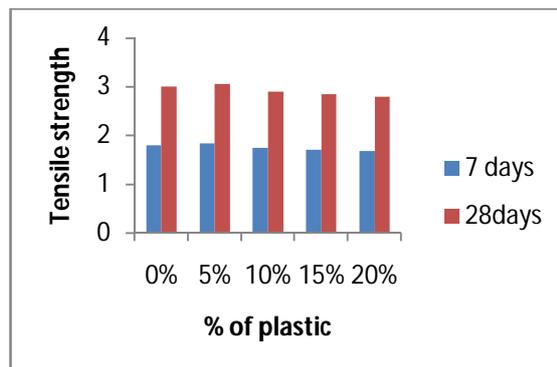
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**Tensile strength:** To understand the influence of the replacement percentage of fine aggregate with plastic aggregate at 7 days and 28 days on tensile behavior of concrete, the concrete specimens were tested for split tensile strength. The results show that the tensile strength of waste plastic concrete mixes at each curing age is prone to decrease with the increase of the waste plastic ratio in these mixes. This can be attributed to the decrease in adhesive strength between the surface of waste plastic particles and the cement paste.

The results of the tensile strength tests for the plastic concrete mixes (with no mineral admixtures) are shown in tables 6 and figure 4.

**Table 6. Tensile strength of concrete for 7 days and 28 days**

Mix no	Average tensile strength for 7 days in N/m <sup>2</sup>	Average tensile strength for 28 days in N/m <sup>2</sup>
H1	1.8	3
H2	1.832	3.05
H3	1.74	2.900
H4	1.71	2.85
H5	1.68	2.80



**Fig 4 Tensile strength versus percentage of plastic for 7 days and 28 days**

The results show that the tensile strength of concrete mixes increase with the increase of the silica fume content. The results of the tensile strength tests for the plastic concrete mixes, with varying percentages of silica fume are shown in tables 7 and figure 5.

**Table 7. Tensile strength of concrete with silica fume for 7 days and 28 days**

Mix no	Average tensile strength for 7 days in N/m <sup>2</sup>	Average tensile strength for 28 days in N/m <sup>2</sup>
H5	1.68	2.80
H6	2.037	3.945
H7	2.052	3.72
H8	2.18	3.642

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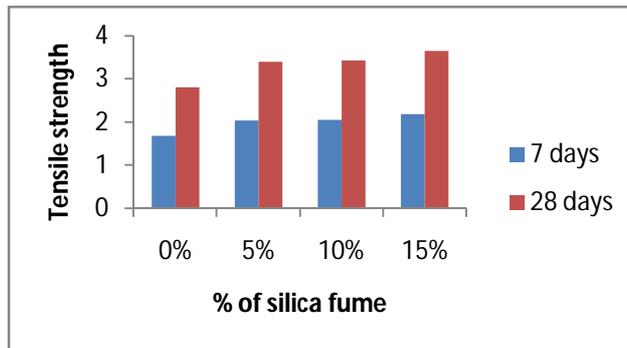


Fig 5 Tensile strength versus percentage of silica fume for 7 days and 28 days

The results show that the tensile strength of concrete mixes increased with the addition of fly ash. These results of the tensile strength tests for the plastic concrete mixes, with 5% silica fume and 25% fly ash are shown in tables 8 and figure 6.

Table 8. Tensile strength of concrete with silica fume and fly ash for 7 days and 28 days

Mix no	Average Tensile strength for 7 days in N/m <sup>2</sup>	Average tensile strength for 28 days in N/m <sup>2</sup>
H6	2.037	3.945
H9	2.4	3.96

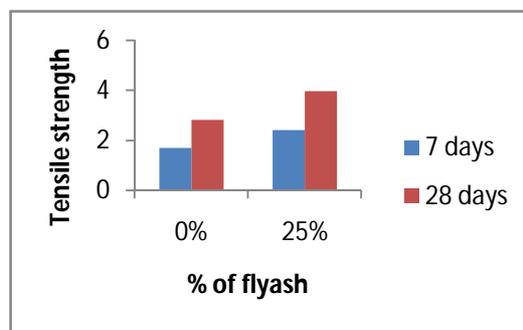


Fig 6 Tensile strength versus percentage of fly ash for 7 days and 28 days (Silica Fume = 5%)

## Flexural strength

The results show that the flexural strength of waste plastic concrete mixes at each curing age is prone to decrease with the increase of the waste plastic ratio in these mixes. This can be attributed to the decrease in adhesive strength between the surface of waste plastic particles and the cement paste, and the hydrophobic nature of plastic material which may limit the hydration of cement. The results of the flexural strength tests for the plastic concrete mixes (with no mineral admixtures) are shown in tables 9 and figure 7.

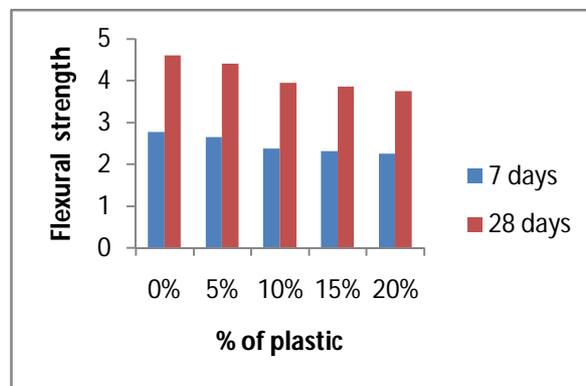
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**Table 9 Flexural strength of concrete for 7 days and 28 days**

Mix no	Average flexural strength for 7 days in N/m <sup>2</sup>	Average flexural strength for 28 days in N/m <sup>2</sup>
H1	2.76	4.6
H2	2.64	4.4
H3	2.37	3.95
H4	2.31	3.85
H5	2.25	3.75

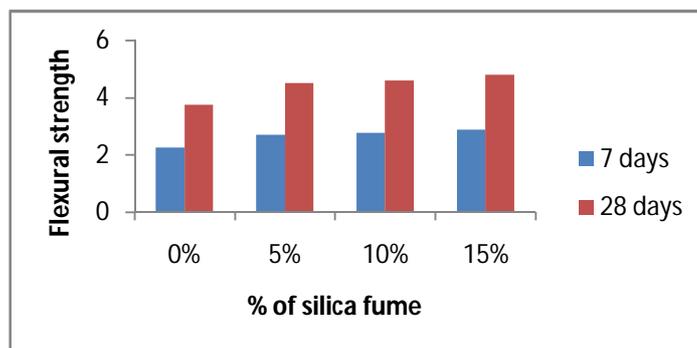


**Fig 7 Flexural strength versus percentage of plastic for 7 days and 28 days**

The results show that the flexural strength of concrete mixes increase with the increase of the silica fume content. The results of the flexural strength tests for the plastic concrete mixes, with varying percentages of silica fume are shown in tables 10 and figure 8.

**Table 10 Flexural strength of concrete with silica fume for 7 days and 28 days**

Mix no	Average flexural strength for 7 days in N/m <sup>2</sup>	Average flexural strength for 28 days in N/m <sup>2</sup>
H5	2.25	3.75
H6	2.7	4.4
H7	2.76	4.6
H8	2.88	4.8



**Fig 8 Flexural strength versus percentage of silica fume for 7 days and 28 days**

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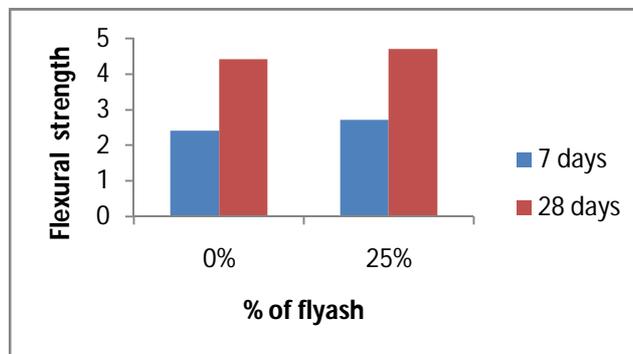
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The results show that the flexural strength of concrete mixes increased with the addition of fly ash. These results of the flexural strength tests for the plastic concrete mixes, with 5% silica fume and 25% fly ash are shown in tables 11 and figure 9.

**Table 11** Flexural strength of concrete with constant silica fume and varying fly ash for 7 days and 28 days

Mix no	Average flexural strength for 7 days in N/m <sup>2</sup>	Average flexural strength for 28 days in N/m <sup>2</sup>
H6	2.7	4.4
H9	2.4	4.5



**Fig 9** Flexural strength of concrete with constant silica fume and varying fly ash for 7 days and 28 days

### Unit Weight

The weights of waste plastic concrete specimens have been determined before conducting the destructive tests. Volume of each of the specimen is  $(0.15)^3 \text{ m}^3$ . Unit weight of the specimen is calculated as weight per unit volume. The results indicate that the unit weight tends to decrease with an increase in the plastic content. The values of unit weights are shown in table 12 and fig 10.

**Table 12** Unit weight of concrete

Mix name	Percentage of PET Plastic in Fine Aggregate	Unit weight in kg/m <sup>3</sup>
H1	0%	2412
H2	5%	2395
H3	10%	2380
H4	15%	2370
H5	20%	2345

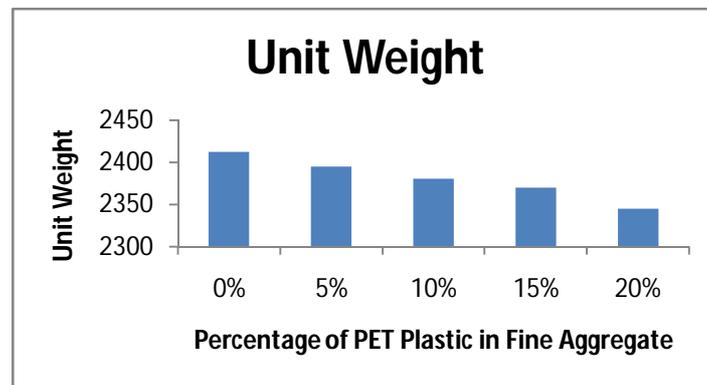


Fig 10 Unit weight versus Percentage of PET Plastic in Fine Aggregate

## V. CONCLUSIONS

1. Replacement of natural river sand (fine aggregate) with recycled PET plastic conservation of natural resources can be achieved.
2. By using recycled plastic waste, the environmental issues related to land fills can be reduced to some extent.
3. Plastic has low water absorption capacity, so the workability of concrete increases when the amount of plastic increases.
4. Decrease in unit weight of concrete has been observed with increase in plastic content.
5. By partially replacing fine aggregate with 20% plastic in concrete, the compressive strength has been decreased by 14.89% when compared to the reference mix.
6. For the mix with least compressive strength with 20% plastic aggregate (i.e. mix H5), we added silica fume as a replacement to cement (5%, 10% and 15% of weight of cement). For the mix with 15% silica fume as binder, the compressive strength increased by 22.5% when compared to the mix with no silica fume (mix H5).
7. Between mixes having 0% and 25% fly ash (both with 5% silica fume), the later mix showed an increase of compressive strength by 7.57% .
8. Decrease in tensile strength of concrete has been observed with increase in plastic content. When mineral admixture is added to the mix, tensile strength increased.
9. Decrease in flexural strength of concrete has been observed with increase in plastic content. . When mineral admixture is added to the mix, flexural strength increased.

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