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Strength and Durability Studies of Ternary Concrete

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Abstract

This thesis presents a study conducted on mechanical and durability properties of concrete. The investigation covered concrete mixes at water cementitious material with ratio of 0.4. Ordinary Portland cement of 53-grade was used in this study. The percentage of cement that partially replaced by weight were Silica Flume is 10% and varying the GGBS replacement from 0% to 50% . Concrete cubes and cylinders were casted and tested in laboratories. The optimum proportion of replacement was found by conducting tests on mechanical properties like Compressive strength test and Split tensile strength test.

The results show that the optimum replacement of cement with silica flume 10% and 40% GGBS, it is possible to gain the same strength as conventional concrete. The durability of concrete was done by curing with 5% Hydrochloric acid (HCL) and 5% Sulphuric acid (H_2SO_4). The effect of acids on compressive strength, Split tensile strength and durability characteristic property was determined for 7, 28, 60, 90 and 180Days.

INTRODUCTION

For a long time concrete was considered to be very durable material requiring. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments, harmful sub-soil water in area and many other hostile conditions where other materials of construction are found be non –durable. Since the use of concrete in recent years have spread to highly harsh and hostile conditions, the earlier impression that concrete is a very durable material is being threatened, particularly on account of premature failures of number of structures.

In the past only strength of concrete was considered in the concrete mix design procedure assuming strength of concrete in all pervading factor for all other desirable properties of concrete including durability. In the recent revision of IS 456 of 2000, one of the points discussed, deliberated and revised is the durability aspects of concrete, in line with codes of practice of other countries, which have better experiences in dealing with durability of concrete structures. One of the main reasons for deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength. As a matter of fact advancement in concrete technology has been generally on the strength of concrete. It is now recognized that strength of concrete alone is not sufficient, the degree of harshness of the environment condition to which concrete is exposed over its entire life is equally important. Therefore, both strength and durability have to be considered explicitly at the design state. It is interesting to consider yet another view point regarding strength and durability relationship. Durability of concrete is its Resistance to deteriorating agencies to which the concrete may be exposed during its service life. When one deals with the durability aspects of concrete, the chemical attack, which results in loss of weight, cracking of concrete and the consequent deterioration of concrete, becomes an important part of investigation. Ordinary Portland cement concrete usually does not have good resistance to acid attack. The addition of FA improves the micro structural properties of concrete like porosity, permeability and sorptivity. The reduction of porosity and permeability implies the improvement in chemical attack and corrosion resistance. The experimental investigation of this aspect is to find compressive strength and durability of concrete by partial replacement of cement with quarry dust.

Durability is an important engineering property of concrete, which determines the service life of concrete structures significantly. Due to the interactions of concrete with external influences, the mechanical and physical properties of concrete may be threatened and lost. ACI Committee Report 201(2001) has classified chemical attacks into several types that include acidic attack, alkali attack, carbonation, chloride attack, and leaching and sulfate attack. Acidic attack usually originates from industrial processes, but it can even be due to urban activity. Even natural exposure conditions may cause acid attacks. Free acids in natural waters are rare. Exceptions are carbonic waters and sulfurous and sulfuric acids in peat waters. Soils may contain huminous acids. Several organic and inorganic acids may occur in shallow regions of sea-water as a consequence of bacteriological activity. Significant quantities of free acids in plants and factories may be found. In these cases, the concentration of acid, which comes in contact with concrete structures, may reach to high value. The degree of aggressive of an acid is dependent on the chemical character of anions present. The strength of acid, its dissociation degree in solutions and, mainly, the solubility of the calcium salts formed are dependent on the chemical character of anion. The acidic attack is affected by the processes of decomposition and leaching of the constituent of cement matrix.

The objective of the present project work is to study the behavior of concrete in partial replacement for cement with quarry dust in proportions. It includes a brief description of the materials used in the concrete mix, mix proportions, the preparation of the test specimens and the parameters studied. In order to achieve the stated objectives, this study is carried out in different stages. In the initial stage, all the materials and equipment needed must be gathered or checked for availability. Once the characteristics of the materials selected have been studied through appropriate tests, the applicable standards of specification are referred. The properties of hardened concrete are important as it is retained for the remainder of the concrete life. In general, the important properties of hardened concrete are strength and durability. An experimental program is held to measure strength of hardened concrete.

AIM AND OBJECTIVES

The main objectives of the present study are as mentioned below:

- To study the effect of silica fume and GGBS on the compressive strength of concrete.
- To study the microstructure of the hardened cement concrete.
- To explain the change in properties of concrete, if any, by explaining the microstructure.
- Investigations were carried out on OPC mixes for M40, M60, M80 grade using 20mm maximum size of aggregates to ascertain the workability and durability properties of concrete made with partial replacement of cement with Silica fume from H_2So_4, HCL immersion test the effect of acids on design concrete is same as the effect for ordinary Portland cement concrete.
- Hence in the present investigation more emphasis is given to study the OPC using silica fume so as to achieve better concrete composites and also to encourage the increased use of byproducts to maintain ecology.

MATERIALS AND MIX DESIGN

The present chapter deals with the presentation of results obtained from various tests conducted on material used for developing pavement quality concrete. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of marble dust and steel fiber on compressive strength, split tensile strength, flexural strength and durability of concrete

Materials

The properties of materials used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were Cement, Coarse aggregates, Fine aggregates, Silica fume, Steel fibers and super-plasticizer. The aim of a study of various properties of material is used to check the appearance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below

Portland cement

Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and non-specialty grout. It was developed from other types of hydraulic lime in England in the mid 19th century, and usually originates from limestone. It is a fine powder, produced by heating limestone and clay minerals in a kiln to form clinker, grinding the clinker, and adding 2 to 3 percent of gypsum. Several types of Portland cement are available. The most common, called ordinary Portland cement (OPC), is grey in colour, but white Portland cement is also available. Its name is derived from its similarity to Portland stone which was quarried on the Isle of Portland in Dorset, England. It was named by Joseph Aspdin who obtained a patent for it in 1824. However, his son William Aspdin is regarded as the inventor of "modern" Portland cement due to his developments in the 1840s.

Portland cement is caustic, so it can cause chemical burns. The powder can cause irritation or, with severe exposure, lung cancer, and can contain some hazardous components, such as crystalline silica and hexavalent chromium.

Environmental concerns are the high energy consumption required to mine, manufacture, and transport the cement, and the related air pollution, including the release of greenhouse gases (e.g., carbon dioxide), dioxin, NO_x, SO_2, and particulates.

Ordinary Portland cement (OPC) of 53 Grade (UltraTech cement) from a single lot was used throughout the course of the investigation. It was fresh and without any lumps. The physical properties of the cement are determined from various tests conforming to Indian Standard IS: 8112:l1989 are listed in table below Cement is carefully stored to prevent deterioration in its properties due to contact with moisture.

Table 3 .1 Properties of OPC 53 Grade cement

Sr.No.	Characteristics	Values Obtained Experimentally	Values Specified By IS 8112:1989
1.	Specific Gravity	3.10	-
2.	Standard Consistency, percent	27	-
3.	Initial Setting Time, minutes	149	30 (minimum)
4.	Final Setting Time, minutes	257	600 (maximum)
5.	Compressive Strength 3 days 7 days 28 days	 27.8 N/mm² 36.5 N/mm² 48.6 N/mm²	 23 N/mm²(minimum) 33 N/mm²(minimum) 43 N/mm²(minimum)

Aggregates

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. To increase the density of resulting mix, the aggregates are frequently used in two or more sizes. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture. The fine aggregate assist the cement paste to hold the coarse aggregate particles in suspension. This action promotes plasticity in the mixture and prevents the possible segregation of paste and coarse aggregate, particularly when it is necessary to transport the concrete some distance from the mixing plant to placement. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable and economical. The aggregates must be proper shape, clean, hard, strong and well graded.

Coarse aggregates

Those particles that are predominantly retained on the 4.75 mm (No. 4) sieve and will pass through 3-inch screen are called **coarse aggregate.** The coarser the aggregate, the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstructions within a concrete form. That allows the area below to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area.

The coarse aggregates used were a mixture of two locally available crushed stone of 20mm and 10mm size in 70:30 proportion. The aggregates were washed to remove drit, dust and then dried to surface dry condition.

Specific gravity and other properties of coarse aggregates are given in below tables.

Table 3. 2 Properties of Coarse aggregates:

Characteristics	Value
Colour	Grey
Shape	Angular
Maximum Size	20 mm/10mm
Specific Gravity	2.73/2.72
Water Absorption	0.20%/0.35%

Table 3. 3 Sieve analysis of Coarse aggregates (20mm)

Weight of sample taken = 3000gm					
Sr. No	IS-Sieve (mm)	Wt. Retained (gm)	%age retained	%age passing	Cumulative % retained
1	80	0.00	0.00	100.00	0.00
2	40	0.00	0.00	100.00	0.00
3	20	53.00	1.77	98.23	1.77
4	10	2938.50	97.95	0.28	99.72
5	4.75	5.50	0.18	0.10	99.90
6	Pan	3.00	0.10	0.00	
	Total	**3000.00**		**SUM**	**201.38 + 500 = 701.38**
				FM =	*7.01*

Table 3. 4 Sieve analysis of Coarse aggregates (10mm)

Weight of sample taken = 3000gm.					
Sr. No	IS-Sieve (mm)	Wt. Retained (gm)	%age retained	%age passing	Cumulative % retained
1	100	0.00	0.00	100.00	0.00
2	80	0.00	0.00	100.00	0.00
3	40	0.00	0.00	100.00	0.00
4	20	0.00	0.00	100.00	0.00
5	10	2012.00	67.07	32.93	67.07
6	4.75	958.00	31.93	1.00	99.00
7	Pan	30.00	1.00	0.00	
	Total	**3000.00**		**SUM**	**166.07 + 500 = 666.07**
				FM =	*6.66*

Fine aggregates

Those particles passing the 9.5 mm (3/8 in.) Sieve, almost entirely passing the 4.75 mm (No. 4) sieve, and predominantly retained on the 75 µm (No. 200) sieve are called fine aggregate. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. According to the size, the fine aggregates may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fne aggregates into four grading zones (Grade I to IV).

Table 3. 5 Sieve analysis of Fine aggregates

Weight of sample taken =1000 gm.					
Sr. No.	IS-Sieve (mm)	Wt. Retained (gm)	%age retained	%age passing	Cumulative % retained
1	4.75	6	0.6	99.4	0.6
2	2.36	59	5.9	93.5	6.5
3	1.18	220	22	71.5	28.5
4	600 µ	159	15.9	55.6	44.4
5	300 µ	316.5	31.65	23.95	76.05
6	150 µ	196.5	19.65	4.3	95.70
7	Pan	43	4.3	0.0	
	Total	**1000.00**		**SUM**	**251.75**
				FM =	*2.51*

Silica fume

Silica fume, also known as microsilica, (CAS number 69012-64-2, and EINECS number 273-761-1) is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

It is sometimes confused with fumed silica (also known as pyrogenic silica, CAS number 112945-52-5). However, the production process, particle characteristics and fields of application of fumed silica are all different from those of silica fume.

Silicon dioxide nanoparticles, also known as silica nanoparticles or nanosilica, are the basis for a great deal of biomedical research due to their stability, low toxicity and ability to be functionalized with a range of molecules and polymers.

GGBS

Granulated Blast Furnace Slag is obtained by rapidly chilling (quenching) the molten ash from the furnace with the help of water. During this process, the slag gets fragmented and transformed into amorphous granules (glass), meeting the requirement of IS 12089:1987 (manufacturing specification for granulated slag used in Portland Slag Cement). The granulated slag is ground to desired fineness for producing GGBS.

The chemical composition of JSW's GGBS contributes to the production of superior cement. Over the period of time, its load-bearing properties continue to increase as it absorbs surplus lime released during hydration to form more calcium silicate hydrates. These hydrates add to the strength of the cement.

Water:

Generally potable water ought to be used. This is to make sure that the water is cheap unfastened from such impurities as suspended solids, organic depend and dissolved salts, which may additionally adversely affect the residences of the concrete, especially the placing, hardening, energy, sturdiness, pit fee, and many others.

Admixture

To acquire workability of clean Geopolymer Concrete, Sulphonated napthalene polymer based totally wonderful plasticizer Conplast SP430 in the shape of a brown liquid right away dispersible in water, Use of superplasticizer lets in the discount of water to the quantity up to 30 percentage without lowering the workability, in assessment to the feasible reduction up to fifteen percentage in case of plasticizers. The use of superplasticizer is practiced for production of flowing, self leveling, self compacting, and for production of excessive strength and high performance concrete.

Mix design

Design of M40 as per IS: 10262:2009.

Table 3. 6 Final Mix of M40 Grade concrete

W	C	FA	CA
180	450	605	1188
0.40	1	1.35	2.64

Concrete mix design (grade m60)

Table 3.7 Final Mix of M60 Grade concrete

Material	Cement	Sand	12.5mm aggregates	Water
Proportions	1	1.35	2.19	0.29

Mix design for m80 grade concrete

Table 3.8 Final Mix of M80 Grade concrete

Material	Cement	Sand	12.5mm aggregates	Water
Density	450	837.45	1023.55	140
Proportions	1	1.861	2.275	0.31

NUMBER OF SPECIMENS REQUIRED FOR THE STUDY

The details of number of blocks to be tested while the experimentation process is given in the below table

Table 4. 1 No Blocks Required For the Experiment

<table>
<tr><th rowspan="2">Sl.No</th><th rowspan="2">% Replacemet (Mix ID)</th><th colspan="3">Compressive strength of concrete</th><th colspan="2">Split tensile strength of concrete</th><th colspan="2">Flexural strength of concrete</th><th>Durability of concrete</th></tr>
<tr><th>7days</th><th>14days</th><th>28days</th><th>7days</th><th>28days</th><th>7days</th><th>28days</th><th>90 days</th></tr>
<tr><td>1</td><td>0%SF+0%GGBS (M0)</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>2</td><td>10%SF+0%GGBS (M1)</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>3</td><td>10%SF+10%GGBS (M2)</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>4</td><td>10%SF+20%GGBS (M3)</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>5</td><td>10%SF+30%GGBS (M4)</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>6</td><td>10%SF+40%GGBS (M5)</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>7</td><td>10%SF+50%GGBS (M6)</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Total</td><td colspan="3">63 cubes</td><td colspan="2">42 Cylinders</td><td colspan="2">42 prisms</td><td>18 cubes</td></tr>
</table>

In each batch 3 cubes, 3 cylinders and 3 prisms were casted. Totally 81 cubes, 42 cylinders and 42 prisms were casted during entire experimentation.

Shape and Dimensions of the Blocks

The shape and dimensions specified for the blocks for different tests are given below table Fig 4. 2 Shape and Dimensions of Blocks

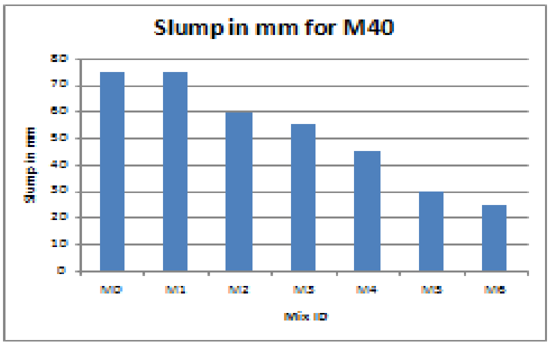
Type of test	Shape of block	Length (m)	Breadth(m)	Height (m)	Diameter (m)	Volume of Block (m^3)
Compressive strength	Cube	0.15	0.15	0.15	--	0.00375
Split tensile strength	Cylinder	--	--	0.30	0.15	0.00530
Flexural strength	Square prism	0.1	0.1	0.7	--	0.00700

RESULTS AND ANALYSIS

M40 Grade concrete

Table 5. 1 Slump cone test for M40 Grade

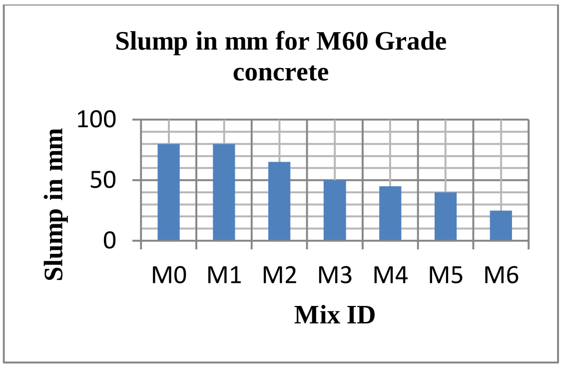
s.no	% Replacemet (Mix ID)	Slump in mm for M40
1	0%SF+0%GGBS (M0)	75
2	10%SF+0%GGBS (M1)	75
3	10%SF+10%GGBS (M2)	60
4	10%SF+20%GGBS (M3)	55
5	10%SF+30%GGBS (M4)	45
6	10%SF+40%GGBS (M5)	30
7	10%SF+50%GGBS (M6)	25



Graph 5.1 Slump in mm for M40 Grade concrete

Table 5.2 Slump cone test for M60 Grade

S.no	% Replacemet (Mix ID)	Slump in mm for M60
1	0%SF+0%GGBS (M0)	80
2	10%SF+0%GGBS(M1)	80
3	10%SF+10%GGBS(M2)	65
4	10%SF+20%GGBS(M3)	50
5	10%SF+30%GGBS(M4)	45
6	10%SF+40%GGBS(M5)	40
7	10%SF+50%GGBS(M6)	25

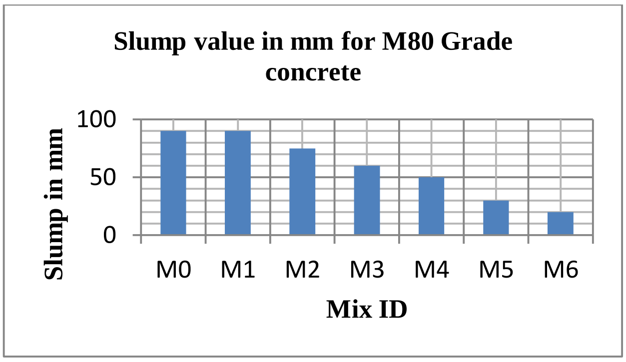


Graph 5.2 Slump in mm for M60 Grade concrete

M80 Grade of concrete

Table 5. 3 Slump cone test for M80 Grade

S.no	% Replacemet (Mix ID)	Slump in mm for M80
1	0%SF+0%GGBS (M0)	90
2	10%SF+0%GGBS (M1)	90
3	10%SF+10%GGBS (M2)	75
4	10%SF+20%GGBS (M3)	60
5	10%SF+30%GGBS (M4)	50
6	10%SF+40%GGBS (M5)	30
7	10%SF+50%GGBS (M6)	20



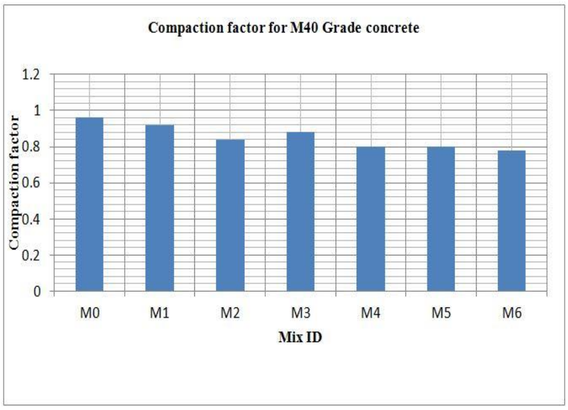
Graph 5. 3 Slump in mm for M80 Grade concrete

Compaction factor test

M40 Grade concrete

Table 5. 4 Compaction factor for M40 Grade

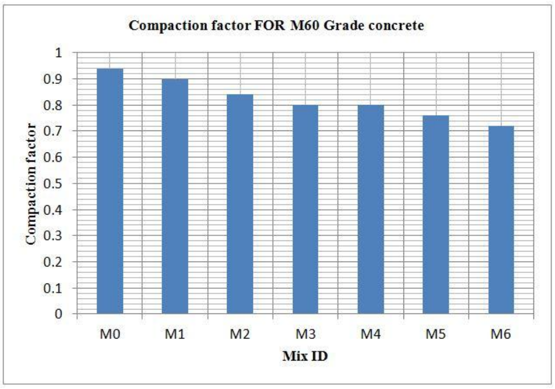
S.no	% Replacemet (Mix ID)	Compaction factor
1	0%SF+0%GGBS (M0)	0.96
2	10%SF+0%GGBS (M1)	0.92
3	10%SF+10%GGBS (M2)	0.84
4	10%SF+20%GGBS (M3)	0.88
5	10%SF+30%GGBS (M4)	0.80
6	10%SF+40%GGBS (M5)	0.80
7	10%SF+50%GGBS (M6)	0.78



Graph 5.4 Compaction factror for M40 Grade concrete

Table 5. 5 Compaction factor test for M60 Grade concrete

s.no	% Replacemet (Mix ID)	Compaction factor
1	0%SF+0%GGBS (M0)	0.94
2	10%SF+0%GGBS (M1)	0.90
3	10%SF+10%GGBS (M2)	0.84
4	10%SF+20%GGBS (M3)	0.80
5	10%SF+30%GGBS (M4)	0.80
6	10%SF+40%GGBS (M5)	0.76
7	10%SF+50%GGBS (M6)	0.72

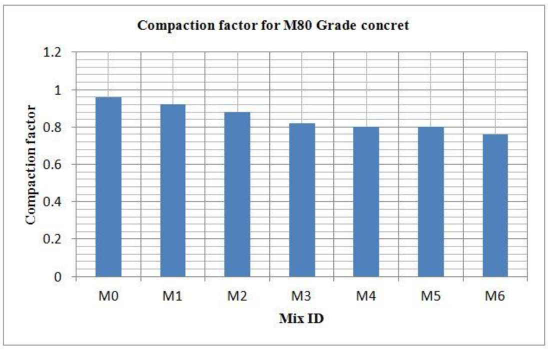


Graph 5. 5 Compaction factror for M60 Grade concrete

M80 Grade of concrete

Table 5. 6 Compaction factor test for M80 Grade concrete

s.no	% Replacemet (Mix ID)	Compaction factor
1	0%SF+0%GGBS (M0)	0.96
2	10%SF+0%GGBS (M1)	0.92
3	10%SF+10%GGBS (M2)	0.88
4	10%SF+20%GGBS (M3)	0.82
5	10%SF+30%GGBS (M4)	0.8
6	10%SF+40%GGBS (M5)	0.8
7	10%SF+50%GGBS (M6)	0.76



Graph 5. 6 Compaction factor for M80 Grade concrete

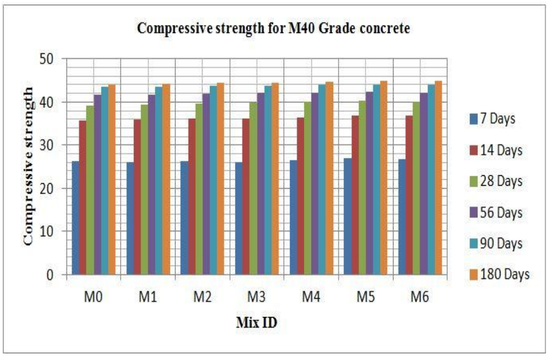
Harden concrete tests

Compressive strength of concrete

M40 Grade concrete

Table 5.7 Compressive strength for M40 Grade

S.no	% Replacement (Mix ID)	7 Days	14 Days	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	26.3	35.6	39.2	41.6	43.56	44.1
2	10%SF+0%GGBS (M1)	26	36	39.4	41.8	43.64	44.24
3	10%SF+10%GGBS (M2)	26.2	36.24	39.52	41.92	43.76	44.38
4	10%SF+20%GGBS (M3)	26.1	36.16	39.82	42.06	43.82	44.54
5	10%SF+30%GGBS (M4)	26.54	36.42	40.12	42.14	43.9	44.72
6	10%SF+40%GGBS (M5)	26.86	36.9	40.22	42.32	44.06	44.92
7	10%SF+50%GGBS (M6)	26.78	36.84	40.16	42.24	43.96	44.86

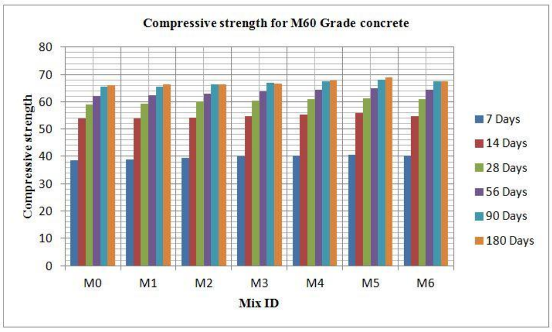


Graph 5.7 Compressive strength for M40 Grade concrete

M60 GRADE OF CONCRETE

Table 5.8 Compressive strength for M60 Grade

S.no	% Replacement (Mix ID)	7 Days	14 Days	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	38.6	53.8	59.04	62.1	65.4	66.12
2	10%SF+0%GGBS (M1)	39	54	59.2	62.4	65.52	66.32
3	10%SF+10%GGBS (M2)	39.42	54.26	60.14	63.08	66.22	66.46
4	10%SF+20%GGBS (M3)	39.86	54.68	60.48	63.78	66.96	66.74
5	10%SF+30%GGBS (M4)	40.16	55.32	60.96	64.26	67.47	67.88
6	10%SF+40%GGBS (M5)	40.58	55.86	61.24	64.94	68.18	68.94
7	10%SF+50%GGBS (M6)	40.24	54.63	61.02	64.38	67.6	67.52

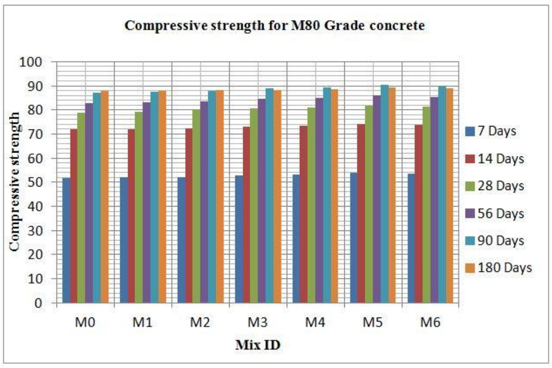


Graph 5.8 Compressive strength for M60 Grade concrete

M80 GRADE OF CONCRETE

Table 5.9 Compressive strength for M80 Grade

S.no	% Replacement (Mix ID)	7 Days	14 Days	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	51.6	71.8	78.8	82.8	87.2	87.8
2	10%SF+0%GGBS (M1)	52	72	79.2	83.2	87.36	87.88
3	10%SF+10%GGBS (M2)	52.26	72.3	80.14	83.62	87.7	88.12
4	10%SF+20%GGBS (M3)	52.88	72.94	80.56	84.6	88.84	88.34
5	10%SF+30%GGBS (M4)	53.2	73.46	81.04	85.12	89.38	88.62
6	10%SF+40%GGBS (M5)	53.74	74.1	81.68	86.02	90.28	89.2
7	10%SF+50%GGBS (M6)	53.42	73.8	81.32	85.48	89.76	88.96



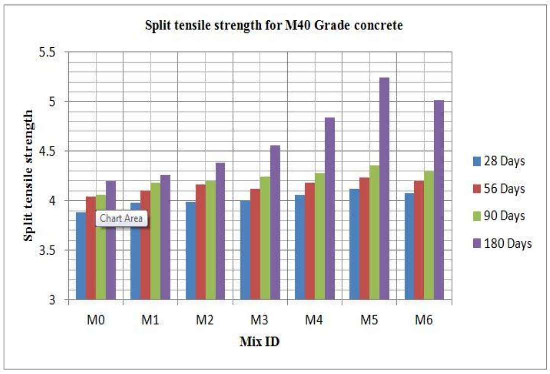
Graph 5.9 Compressive strength for M80 Grade concrete

SPLIT TENSILE STRENGTH OF CONCRETE

M40 Grade concrete

Table 5.10 Split tensile strength for M40 Grade

S.no	% Replacement (Mix ID)	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	3.88	4.04	4.06	4.2
2	10%SF+0%GGBS (M1)	3.98	4.1	4.18	4.26
3	10%SF+10%GGBS (M2)	3.99	4.16	4.2	4.38
4	10%SF+20%GGBS (M3)	4	4.12	4.24	4.56
5	10%SF+30%GGBS (M4)	4.06	4.18	4.28	4.84
6	10%SF+40%GGBS (M5)	4.12	4.23	4.36	5.24
7	10%SF+50%GGBS (M6)	4.08	4.2	4.3	5.02

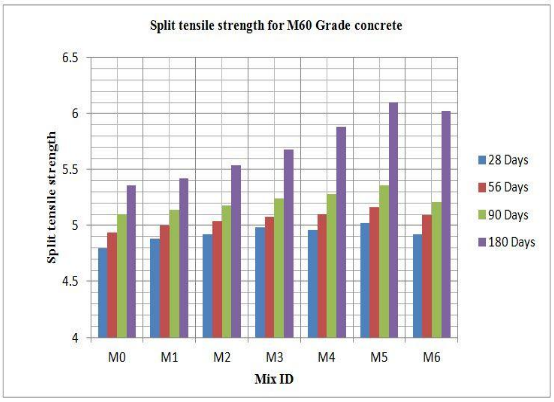


Graph 5.10 Split tensile strength for M40 Grade concrete

M60 Grade of concrete

Table 5. 11 Split tensile strength for M60 Grade concrete

S.no	% Replacement (Mix ID)	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	4.8	4.94	5.1	5.36
2	10%SF+0%GGBS (M1)	4.88	5	5.14	5.42
3	10%SF+10%GGBS (M2)	4.92	5.04	5.18	5.54
4	10%SF+20%GGBS (M3)	4.98	5.08	5.24	5.68
5	10%SF+30%GGBS (M4)	4.96	5.1	5.28	5.88
6	10%SF+40%GGBS (M5)	5.02	5.16	5.36	6.1
7	10%SF+50%GGBS (M6)	4.92	5.09	5.21	6.02

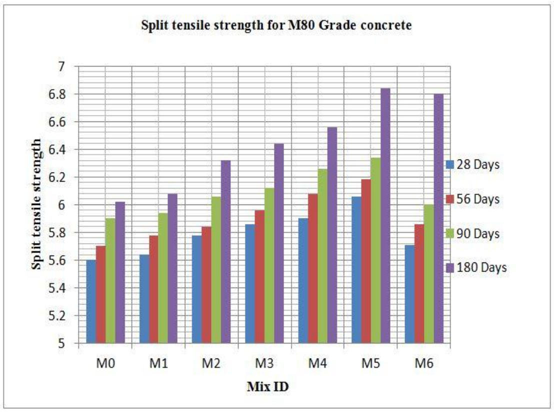


Graph 5. 11 Split tensile strength for M60 Grade concrete

M80 Grade of concrete

Table 5. 12 Split tensile strength for M80 Grade concrete

S.no	% Replacement (Mix ID)	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	5.6	5.7	5.9	6.02
2	10%SF+0%GGBS (M1)	5.64	5.78	5.94	6.08
3	10%SF+10%GGBS (M2)	5.78	5.84	6.06	6.32
4	10%SF+20%GGBS (M3)	5.86	5.96	6.12	6.44
5	10%SF+30%GGBS (M4)	5.9	6.08	6.26	6.56
6	10%SF+40%GGBS (M5)	6.06	6.18	6.34	6.84
7	10%SF+50%GGBS (M6)	5.71	5.86	6	6.8



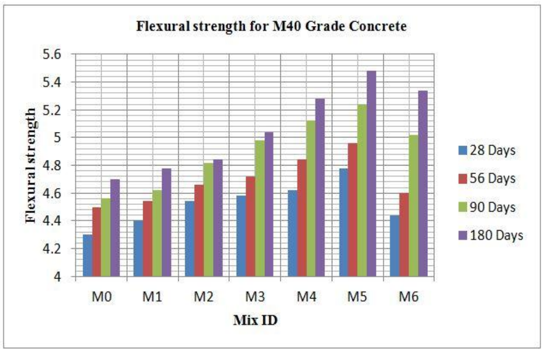
Graph 5. 12 Split tensile strength for M80 Grade concrete

FLEXURAL STRENGTH OF CONCRETE

M40 Grade concrete

Table 5.13 Flexural Strength of M40 Grade concrete

S.no	% Replacement (Mix ID)	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	4.3	4.5	4.56	4.7
2	10%SF+0%GGBS (M1)	4.4	4.54	4.62	4.78
3	10%SF+10%GGBS (M2)	4.54	4.66	4.82	4.84
4	10%SF+20%GGBS (M3)	4.58	4.72	4.98	5.04
5	10%SF+30%GGBS (M4)	4.62	4.84	5.12	5.28
6	10%SF+40%GGBS (M5)	4.78	4.96	5.24	5.48
7	10%SF+50%GGBS (M6)	4.44	4.6	5.02	5.34

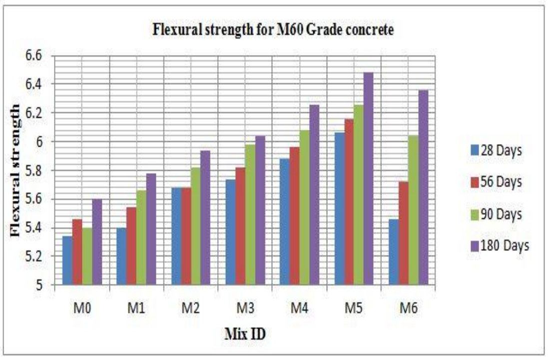


Graph 5. 13 Flexural strength for M40 Grade concrete

M60 Grade of concrete

Table 5.14 Flexural Strength of M60 Grade concrete

S. no	% Replacement (Mix ID)	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	5.34	5.46	5.4	5.6
2	10%SF+0%GGBS (M1)	5.4	5.54	5.66	5.78
3	10%SF+10%GGBS (M2)	5.68	5.68	5.82	5.94
4	10%SF+20%GGBS (M3)	5.74	5.82	5.98	6.04
5	10%SF+30%GGBS (M4)	5.88	5.96	6.08	6.26
6	10%SF+40%GGBS (M5)	6.06	6.16	6.26	6.48
7	10%SF+50%GGBS (M6)	5.46	5.72	6.04	6.36

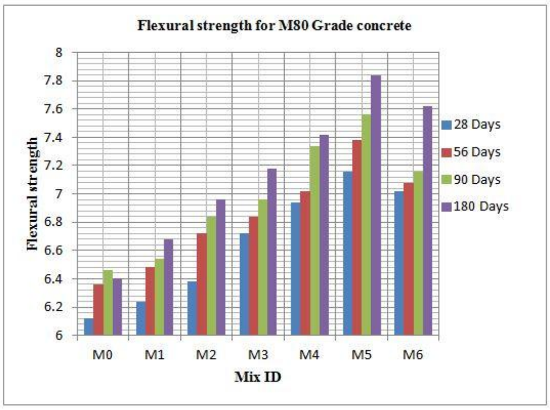


Graph 5. 14 Flexural strength for M60 Grade concrete

M80 Grade of concrete

Table 5.15 Flexural Strength of M80 Grade concrete

S.no	% Replacement (Mix ID)	28 Days	56 Days	90 Days	180 Days
1	0%SF+0%GGBS (M0)	6.12	6.36	6.46	6.4
2	10%SF+0%GGBS (M1)	6.24	6.48	6.54	6.68
3	10%SF+10%GGBS (M2)	6.38	6.72	6.84	6.96
4	10%SF+20%GGBS (M3)	6.72	6.84	6.96	7.18
5	10%SF+30%GGBS (M4)	6.94	7.02	7.34	7.42
6	10%SF+40%GGBS (M5)	7.16	7.38	7.56	7.84
7	10%SF+50%GGBS (M6)	7.02	7.08	7.16	7.62



Graph 5. 15 Flexural strength for M80 Grade concrete

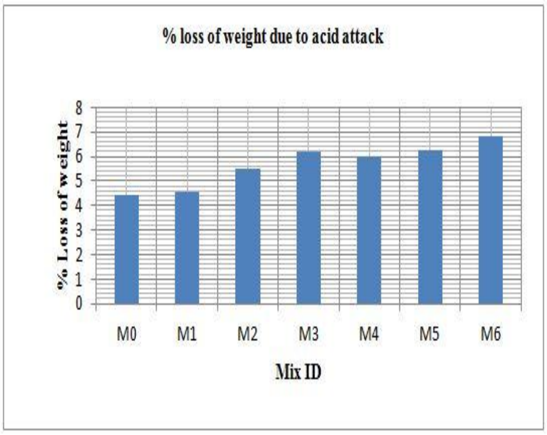
Durability of concrete

Acid attack

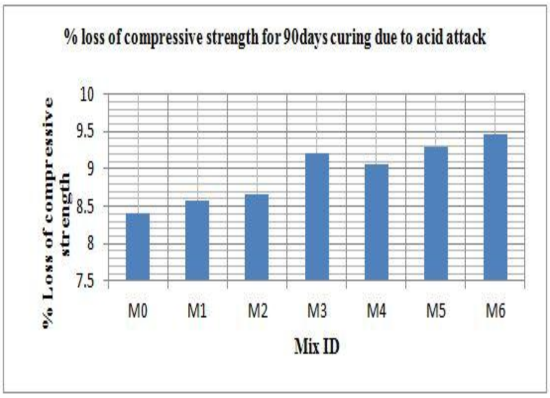
M40 Grade Concrete

Table 5. 16 Acid attack for M40 Grade

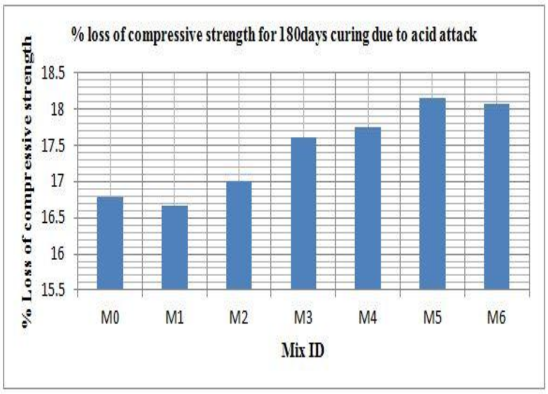
Sl.no	% replacement (Mix ID)	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to acid attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	Compressive strength of cubes after 180days curing	% loss of compressive strength for 90days curing due to acid attack	% loss of compressive strength for 180days curing due to acid attack
1	0%SF+0%GGBS (M0)	2355	2248	4.54	39.4	36.02	32.84	8.58	8.84
2	10%SF+0%GGBS (M1)	2335	2206	5.52	39.52	36.1	32.82	8.65	9.05
3	10%SF+10%GGBS (M2)	2265	2124	6.22	39.82	36.16	32.78	9.2	9.36
4	10%SF+20%GGBS (M3)	2230	2096	6	40.12	36.48	33	9.07	9.56
5	10%SF+30%GGBS (M4)	2394	2244	6.26	40.22	36.38	32.92	9.3	9.48
6	10%SF+40%GGBS (M5)	2425	2260	6.8	40.16	36.36	32.9	9.46	9.5
7	10%SF+50%GGBS (M6)	2325	2184	6.06	61.02	54.88	55.02	10.06	9.82



Graph 5. 16 Percent loss of weight due to acid attack



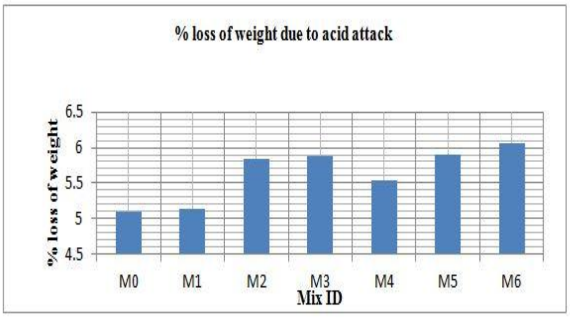
Graph 5. 17 Percentage loss of compressive strength for 90 days curing



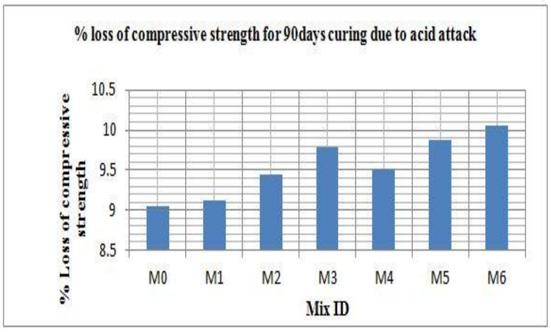
Graph 5. 18 Percentage loss of compressive strength for 180 days curing

Table 5.17 Acid attack for M60 Grade

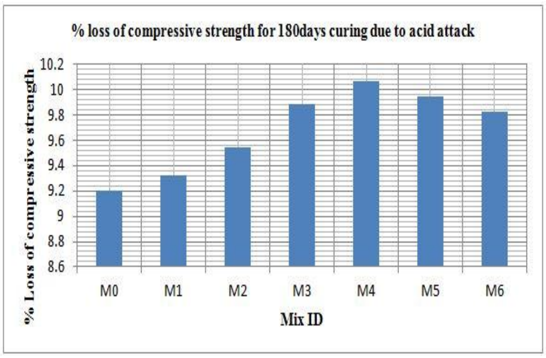
Sl.no	**% replacement** (Mix ID)	**Initial weight of cube after 28days curing in grams**	**Final weight of cubes after 90days curing in grams**	**% loss of weight due to acid attack**	**Compressive strength of cube after 28days curing**	**Compressive strength of cubes after 90days curing**	**Compressive strength of cubes after 180days curing**	**% loss of compressive strength for 90days curing due to acid attack**	**% loss of compressive strength for 180days curing due to acid attack**
1	0%SF+0%GGBS (M0)	2390	2268	5.1	59.04	53.7	53.6	9.04	9.2
2	10%SF+0%GGBS (M1)	2370	2248	5.14	59.2	53.8	53.68	9.12	9.32
3	10%SF+10%GGBS (M2)	2320	2190	5.84	60.14	54.46	54.46	9.44	9.54
4	10%SF+20%GGBS (M3)	2225	2094	5.89	60.48	54.56	54.5	9.78	9.88
5	10%SF+30%GGBS (M4)	2280	2154	5.53	60.96	55.15	54.82	9.52	10.06
6	10%SF+40%GGBS (M5)	2334	2196	5.91	61.24	55.19	55.14	9.88	9.94
7	10%SF+50%GGBS (M6)	2325	2184	6.06	61.02	54.88	55.02	10.06	9.82



Graph 5. 19 Percent loss of weight due to acid attack



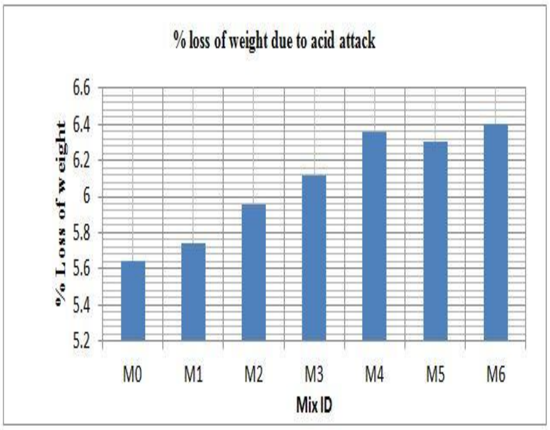
Graph 5. 20 Percentage loss of compressive strength for 90 days curing



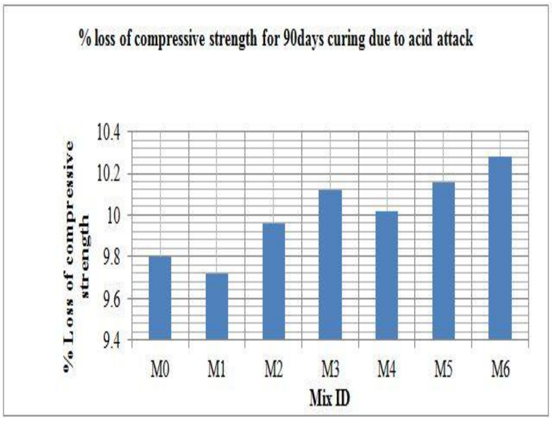
Graph 5. 21 Percentage loss of compressive strength for 180 days curing

Table 5.18 Acid attack for M80 Grade

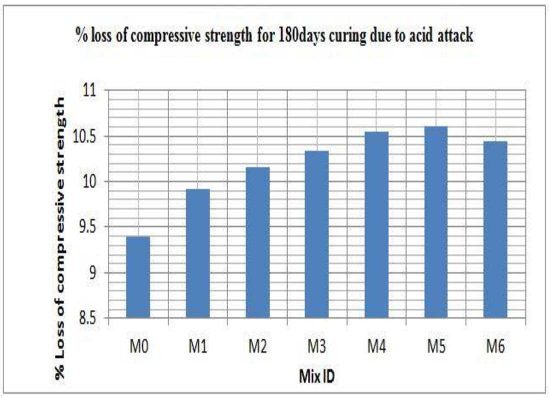
Sl.no	% replacement (Mix ID)	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to acid attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	Compressive strength of cubes after 180days curing	% loss of compressive strength for 90days curing due to acid attack	% loss of compressive strength for 180days curing due to acid attack
1	0%SF+0%GGBS (M0)	2290	2160	5.64	78.64	70.92	71.24	9.8	9.4
2	10%SF+0%GGBS (M1)	2284	2154	5.74	79.2	71.5	71.34	9.72	9.92
3	10%SF+10%GGBS (M2)	2528	2378	5.96	80.14	71.16	72.38	9.96	10.16
4	10%SF+20%GGBS (M3)	2286	2146	6.12	80.56	72.4	72.24	10.12	10.34
5	10%SF+30%GGBS (M4)	2356	2206	6.36	81.04	72.92	72.5	10.02	10.54
6	10%SF+40%GGBS (M5)	2456	2302	6.3	81.68	73.38	73.02	10.16	10.6
7	10%SF+50%GGBS (M6)	2388	2236	6.4	81.32	72.96	72.3	10.28	10.44



Graph 5. 22 Percent loss of weight due to acid attack



Graph 5. 23 Percentage loss of compressive strength for 90 days curing



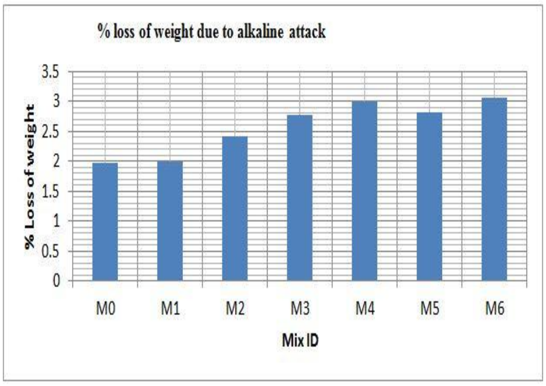
Graph 5. 24 Percentage loss of compressive strength for 180 days curing

Alkaline attack

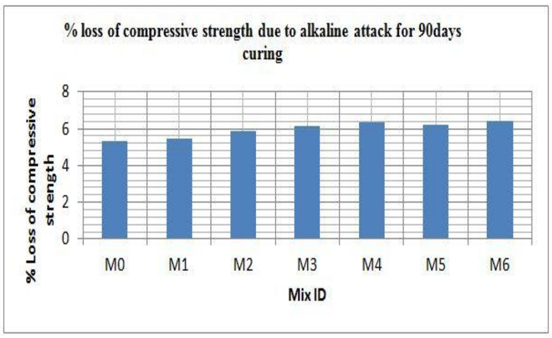
M40 Grade concrete

Table 5. 19 Alkaline attack for M40 Grade concrete

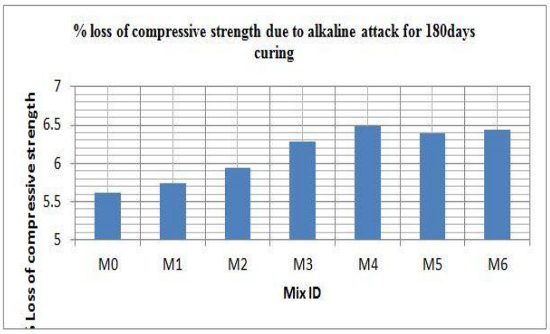
Sl. No	% replacement (Mix ID)	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to alkaline attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	Compressive strength of cubes after 180days curing	% loss of compressive strength due to alkaline attack for 90days curing	% loss of compressive strength due to alkaline attack for 180days curing
1	0%SF+0%GGBS (M0)	2280	2235	1.98	39.2	37.12	37	5.3	5.62
2	10%SF+0%GGBS (M1)	2245	2200	2	39.4	37.24	37.14	5.46	5.74
3	10%SF+10%GGBS (M2)	2365	2308	2.41	39.52	37.22	37.18	5.84	5.94
4	10%SF+20%GGBS (M3)	2458	2390	2.766	39.82	37.36	37.32	6.16	6.28
5	10%SF+30%GGBS (M4)	2468	2394	2.99	40.12	37.58	37.52	6.34	6.48
6	10%SF+40%GGBS (M5)	2538	2466	2.83	40.22	37.72	37.64	6.24	6.4
7	10%SF+50%GGBS (M6)	2680	2598	3.06	40.16	37.58	37.58	6.42	6.44



Graph 5.25 Percent loss of weight due to acid attack



Graph 5. 26 Percentage loss of compressive strength for 90 days curing

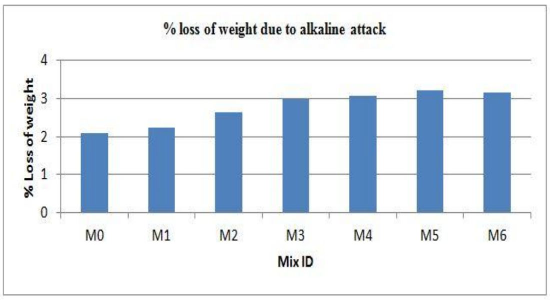


Graph 5. 27 Percentage loss of compressive strength for 180 days curing

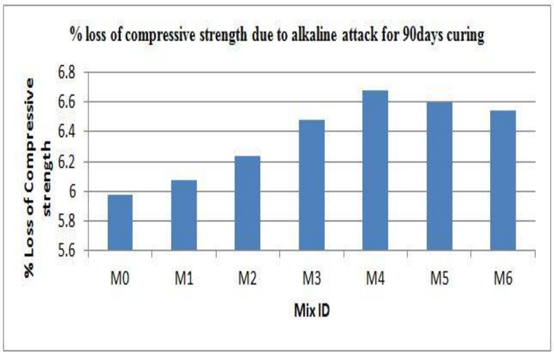
M60 Grade concrete

Table 5. 20 Alkaline attack for M60 Grade

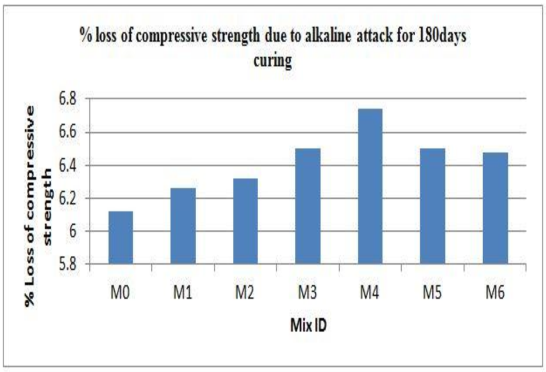
Sl. No	**% replacement** (Mix ID)	**Initial weight of cube after 28days curing in grams**	**Final weight of cubes after 90days curing in grams**	**% loss of weight due to alkaline attack**	**Compressive strength of cube after 28days curing**	**Compressive strength of cubes after 90days curing**	**Compressive strength of cubes after 180days curing**	**% loss of compressive strength due to alkaline attack for 90days curing**	**% loss of compressive strength due to alkaline attack for 180days curing**
1	0%SF+0%GGBS (M0)	2320	2272	2.1	59.04	55.5	55.42	5.98	6.12
2	10%SF+0%GGBS (M1)	2248	2198	2.24	59.2	55.6	55.5	6.08	6.26
3	10%SF+10%GGBS (M2)	2316	2254	2.64	60.14	56.38	56.34	6.24	6.32
4	10%SF+20%GGBS (M3)	2456	2382	2.98	60.48	56.56	56.54	6.48	6.5
5	10%SF+30%GGBS (M4)	2688	2606	3.08	60.96	56.44	56.86	6.68	6.74
6	10%SF+40%GGBS (M5)	2468	2390	3.2	61.24	57.2	57.26	6.6	6.5
7	10%SF+50%GGBS (M6)	2546	2466	3.16	61.02	57.02	57.06	6.54	6.48



Graph 5. 28 Percent loss of weight due to acid attack



Graph 5. 29 Percentage loss of compressive strength for 90 days curing

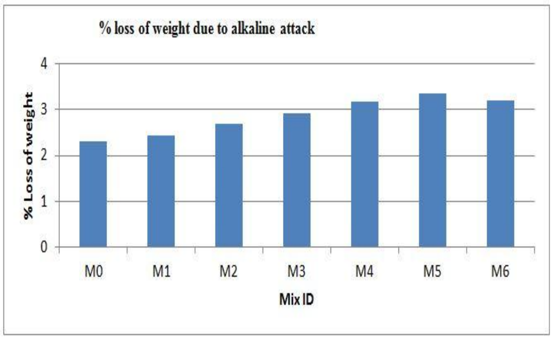


Graph 5. 30 Percentage loss of compressive strength for 180 days curing

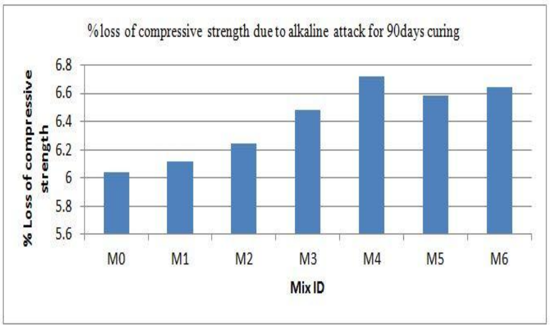
M80 Grade concrete

Table 5. 21 Alkaline attack for M80 Grade Concrete

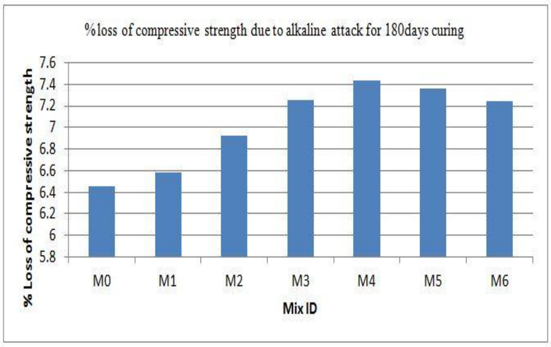
Sl. No	**% replacement** (Mix ID)	**Initial weight of cube after 28days curing in grams**	**Final weight of cubes after 90days curing in grams**	**% loss of weight due to alkaline attack**	**Compressive strength of cube after 28days curing**	**Compressive strength of cubes after 90days curing**	**Compressive strength of cubes after 180days curing**	**% loss of compressive strength due to alkaline attack for 90days curing**	**% loss of compressive strength due to alkaline attack for 180days curing**
1	0%SF+0%GGBS (M0)	2340	2286	2.3	78.8	74.04	73.7	6.04	6.46
2	10%SF+0%GGBS (M1)	2364	2306	2.44	79.2	74.36	73.98	6.12	6.58
3	10%SF+10%GGBS (M2)	2584	2514	2.68	80.14	75.14	74.6	6.24	6.92
4	10%SF+20%GGBS (M3)	2684	2606	2.92	80.56	75.34	74.72	6.48	7.25
5	10%SF+30%GGBS (M4)	2568	2366	3.16	81.04	75.6	69.98	6.72	7.43
6	10%SF+40%GGBS (M5)	2444	2362	3.36	81.68	76.3	75.66	6.58	7.36
7	10%SF+50%GGBS (M6)	2458	2380	3.2	81.32	75.94	75.44	6.64	7.24



Graph 5. 31 Percent loss of weight due to acid attack



Graph 5. 32 Percentage loss of compressive strength for 90 days curing



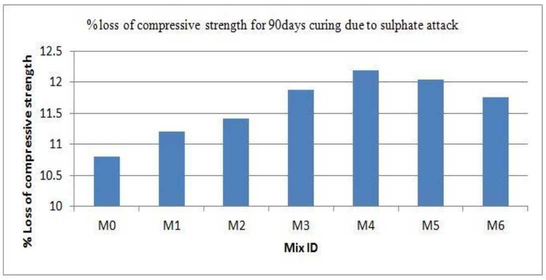
Graph 5. 33 Percentage loss of compressive strength for 180 days curing

Sulphate attack

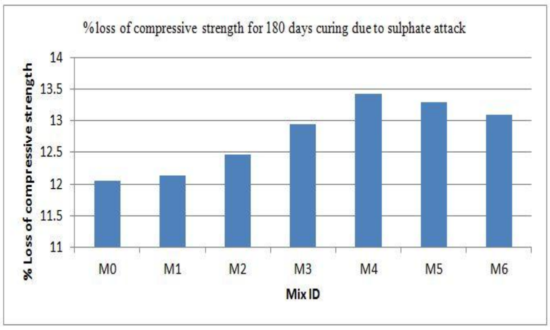
M40 Grade concrete

Table 5. 22 Sulphate attack for M40 Grade concrete

Sl.no	% replacement (Mix ID)	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	Compressive strength of cubes after 180days curing	% loss of compressive strength for 90days curing due to sulphate attack	% loss of compressive strength for 18days curing due to sulphate attack
1	0%SF+0%GGBS (M0)	39.2	35	34.48	10.8	12.05
2	10%SF+0%GGBS (M1)	39.4	34.98	34.62	11.2	12.14
3	10%SF+10%GGBS (M2)	39.52	35	34.6	11.42	12.46
4	10%SF+20%GGBS (M3)	39.82	35.08	34.66	11.88	12.94
5	10%SF+30%GGBS (M4)	40.12	35.22	34.74	12.2	13.42
6	10%SF+40%GGBS (M5)	40.22	35.38	34.88	12.05	13.3
7	10%SF+50%GGBS (M6)	40.16	35.44	34.9	11.76	13.1



Graph 5. 34 Percentage loss of compressive strength for 90 days curing

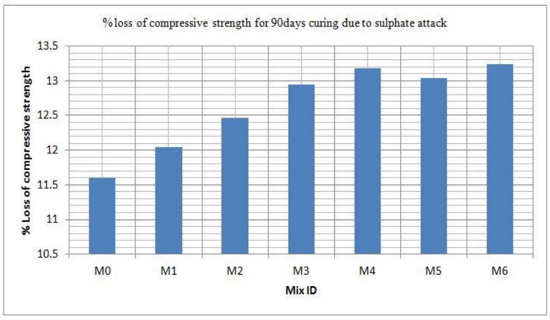


Graph 5. 35 Percentage loss of compressive strength for 180 days curing

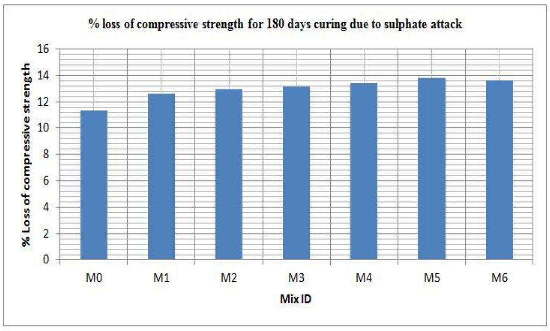
M60 Grade concrete

Table 5. 23 Sulphate attack for M60 Grade concrete

Sl.no	% replacement (Mix ID)	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	Compressive strength of cubes after 180days curing	% loss of compressive strength for 90days curing due to sulphate attack	% loss of compressive strength for 180days curing due to sulphate attack
1	0%SF+0%GGBS (M0)	59.04	52.2	52.36	11.6	11.32
2	10%SF+0%GGBS (M1)	59.2	52.08	51.72	12.04	12.64
3	10%SF+10%GGBS (M2)	60.14	52.64	52.38	12.46	12.92
4	10%SF+20%GGBS (M3)	60.48	52.66	52.54	12.94	13.12
5	10%SF+30%GGBS (M4)	60.96	52.92	52.76	13.18	13.44
6	10%SF+40%GGBS (M5)	61.24	53.25	53.26	13.04	13.82
7	10%SF+50%GGBS (M6)	61.02	52.94	52.7	13.24	13.64



Graph 5. 36 Percentage loss of compressive strength for 90 days curing



Graph 5. 37 Percentage loss of compressive strength for 180 days curing

CONCLUSIONS

From the above study the following conclusions were made

- The material properties of the cement, fine aggregates and coarse aggregates are within the acceptable limits as per IS code recommendations so we will use the materials for research.
- Slump cone value for the combination of silica fume and GGBS concrete Decreases with increasing in the percentage so the concrete is workable.
- Compaction factor value for the combination of silica fume and GGBS concrete increases with increase in the percentage of Silica fume and GGBS.
- The compressive strength of concrete is maximum at 10%SF+40%GGBS and is the optimum value for 7days curing, 28days curing, 56days curing, 90days curing and 180days curing.
- Split tensile strength for the cylindrical specimens is maximum at 10%Ssf+40%GGBS 28days curing, 56days curing, 90days curing and 180 days curing.
- The flexural strength of copper slag concrete is also maximum at at 10%Ssf+40%GGBS 28days curing, 56days curing, 90days curing and 180 days curing
- The percentage loss of weight and percentage loss of compressive strength is increases with in increasing the percentages in all cases in durability studies in 10%SF+40%GGBS concrete. So, the concrete is durable upto 10%SF+40%GGBS.So the replacement of 10%SF+40%GGBS concrete is generally useful for better strength values in ,M40,M60,M80 grades of concrete.

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