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Flexural Strength On Concrete For Acid Resistance Using Volcanic Ash, Silica Fume And GGBS

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Abstract- Corrosion of steel is challenging problem particularly in sewer environments. In many of the industries acid is used during procedure, which can lead to decrease of strength of the concrete structures. Then, it is very important to construct durable concrete structures in such procedures. An experimental study was under taken to improve concrete resistance against acid attack. Five concrete mixtures were used in the present project, first mix is a ordinary Portland cement (OPC) as a control mix and the second mix consists 10% replacement of cement with silica fume. Third mix consists ordinary Portland cement with 10% ground granulated blast furnace slag (GGBS) and forth mix consists OPC with 15% replacement of GGBS. Other mixes contain OPC with 10% and 15% replacement of volcanic ash. Concrete prism were immersed in 15% sulphuric acid of pH=1.0 for curing. They were tested for flexure up to 90 days. The strength of mix 2,3,4,5 was higher than the control mixture of OPC.

Index Terms- Flexural strength; sulphuric acid; volcanic ash; GGBS; silica fume.

1. INTRODUCTION

Portland cement concrete is the most commonly used construction material for sewer system. How-ever, deterioration of sewer pipes is not uncommon due acid attack on alkaline concrete by biogenic sulphuric acid, which is highly ionized mineral acid and may results in pH less than 2. The primary corrosion product formed on the concrete surface is gypsum, an expansive product, which results cracking and spalling of concrete. In addition, the reaction of gypsum with calcium aluminates phases in the cementitious matrix can form highly expansive ettringite, leading to micro- and macro-cracking in concrete. The main hydration product of calcium silicates, namely C-S-H gel, re-acts with the sulphuric acid to form silica gel.

2. LITERATURE REVIEW

"**R. Sri Ravindrarajah**" says, "Sulphuric acid attack resulted in concrete disintegration at an almost constant rate, the hydrochloric attack rate was reduced with time, whereas the lactic acid attack resulted leaching of corrosion products, at a slower rate under stagnant condition".

"**Anne-Mieke** in 1967" studied "the deformations in more detail, the applicability of traditional creep and shrinkage models test series as described, the following conclusions can be formulated with increasing c/p ratio, and consequently increasing cement content and decreasing w/c ratio, a decrease of the creep deformations is found. The fineness of the tested fillers has almost no influence on the deformations".

"**Audenaert K** in 1971" made "an extended experimental programme on chloride penetration of self compacting concrete mixtures and traditional concrete mixtures were determined. Based on these tests, the conclusion is that the penetration depth in real conditions is strongly influenced by water/cement and water/ (cement +filler) ratios. Decreasing one of these ratios or both is leading to as decreasing penetration depth".

"**Torii and Kawamura**", investigated the effect of using silica fume and fly ash as partial replacement for cement on the resistance of concrete to a 2% solution of sulphuric acid. They concluded that such a partial replacement for cement could not effectively prevent the acid-type deterioration involving surface scaling and softening of mortar.

"**Jirasit**" suggested that concrete made with a cementitious material content of 300 kg/m3 and incorporating 50% fly ash as partial replacement for cement could resist a 3% H2SO4 solution.

"**Daczko**" argued that partial replacement of OPC by 8% silica fume could reduce the mass loss of concrete specimens immersed in an H2SO4 solution with a pH of 1 by 30%. They also argued that using 8% metakaolin as partial replacement for OPC provided little contribution to the resistance of concrete to sulphuric acid attack.

3. MATERIALS

Different materials used in the work and their test results are presented below.

3.1 Materials Used

- Cement (53 Grade OPC)
- Fine aggregate (F.A)

- Coarse aggregate (C.A)
- Silica fume (S.F)
- Ground granulated blast furnace slag (GGBS)
- Volcanic Ash (V.A)
- Water

3.1.1 Cement:

Ultra-tech OPC 53 grade was used. Cement procured from single source, properties of which are tested in the laboratory.

Some of the Properties of cement are given below [IS: 12269-1987.]

- ❖ Specific gravity 3.1
- ❖ Normal consistency 34%
- ❖ Fineness 2% (Should not exceed 10%)
- ❖ Initial setting time 40 minutes (Should not be less than 30 minutes)
- ❖ Final setting time 190 minutes (Should not exceed 600 minutes)

3.1.2 Fine Aggregate (F.A):

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification.

In the present study good quality zone-II fine aggregates were used of Specific gravity=2.61and Bulk density=1710 Kg/m^3.

3.1.3 Coarse Aggregate (C.A):

It is the aggregate most of which is retained on 4.75 mm IS sieve and contains only so much finer material as is permitted by specification.

In the present investigation aggregate available from local crusher was used. Two size fraction i.e. 20mm and 10mm size coarse aggregate was used and its specific gravity=2.8, bulk density=1480 Kg/m^3.

3.1.4 Silica Fume (S.F):

Silica fume not only provides an extremely rapid pozzolanic reaction, but it’s very fine size also provides a beneficial contribution to concrete. Silica fume tends to improve both mechanical properties and durability.

Silica fume concretes continue to gain strength under a variety of curing conditions, including unfavourable ones. Thus the concretes with silica fume appear to be more robust to early drying than similar concretes that do not contain silica fume.

3.1.5 Ground Granulated Blast Furnace Slag (GGBFS):

Ground-granulated blast furnace slag is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminates impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation

Typical chemical composition:
Calcium oxide = 40%
Silica = 35%
Alumina = 13%
Magnesia = 8%
Typical physical properties:
Colour : off white
Specific gravity : 2.9
Bulk density : 1200 Kg/m^3
Fineness: 350 m^2 /kg

3.1.6 Volcanic Ash (V.A)

Volcanic ash consists of particles with diameters <2 mm (particles >2 mm are classified as lapilli) and can be as fine as 1 μm. The density of individual particles varies with different eruptions. The density of volcanic ash varies between 700–1200 kg/m^3. The main chemical elements contained in volcanic ash, are siliceous and oxygen, which constitute the main components of minerals and rocks in the Earth’s crust and mantle.

4. SULPHURIC ACID ATTACK

Sulphuric acid attack is very damaging to mortar as it combines an acid attack and a sulphate attack. At the first stage, deterioration of Ca $(OH)^2$ results in an expansive gypsum formation. The gypsum then reacts with C3A in aqueous environment and forms a more expansive product called ettringite. These very expansive compounds cause internal pressure in the mortar, which leads to the formation of cracks and the transformation of the mortar into a mushy or a non-cohesive mass.

Sulphuric acid may also cause the decalcification of Calcium silicate hydrates C-S-H and will ultimately transform the C-S-H into amorphous hydrous silica.

The following equations express these reactions
$Ca(OH)^2 + H_2SO_4 \rightarrow CaSO_4.2H_2O$ (Gypsum)
$3(CaSO4.2H2O)+3CaO.Al2O3.12H2O+14H2O \rightarrow 3 CaO.Al2O3.3CaSO4.32H2O3$ (Ettringite)
$CaO.SiO2.2H2O+H2SO4 \rightarrow CaSO4+ Si(OH)^4$ (Hydrous silica) + H_2O

5. DIFFERENT MIXES:

Following are different mixes used for the project where the control mix is used for comparing the strength with different mixes

Table 1: Different Mix Used For Project

Mix	TYPE OF MIX
I	Control Mix
II	10% Replacement Of Cement With Silica Fume
III	10% Replacement Of Cement With GGBS
IV	15% Replacement Of Cement With GGBS
V	10% Replacement Of Cement With Volcanic Ash
VI	15% Replacement Of Cement With Volcanic Ash

6. PREPARATION OF SPECIMENS

Moulds of standard size 100 mm X 100 mm X 500 mm were used for casting prisms. The internal surfaces of moulds are cleaned and one coat of cutting oil is applied.

The moulds are filled in three layers and the height of each layer is about 1/3rd height of mould, each layer is compacted by giving 25 blows with a tamping rod over the entire cross section of the mould uniformly. After filling and compacting the moulds, the top surface are made smooth and kept for a period of 24 hours.

Then the mould is removed prisms are kept under water for 7, 14, 28, 56, and 90 days. The curing of specimens is done by pounding method of curing. Water should be clean and free from impurities and 15% of ph 1 sulphuric acid is added to the water. Then after completing the curing period all the specimen were removed and kept for drying for one day.

The surface of the specimens should be cleaned and the test is carried out. 30 numbers of prisms were being cast for flexural strength tests for M40 grade concrete.

7. FLEXURAL STRENGTH RESULTS

From the test results, it is found that the flexural strength has increased with the increase in volcanic ash content by 15% then the strength decreased because of curing in sulphuric acid. It is found that the optimum percentage dosage of volcanic ash which gives the maximum flexural strength for concrete is 15%.

Following table shows the flexural strength in Mpa for different mixes upto 90 days

Table 2: Flexural Strength of Concrete

MIX	FLEXURAL STRENGTH OF CONCRETE (MPA)				
	7 DAYS	14 DAYS	28 DAYS	56 DAYS	90 DAYS
I	8.23	10.4	13.5	13.2	8.56
II	9.41	11.2	14.5	14.1	13.7
III	9.92	11.8	14.6	13.9	10.94
IV	10.21	12.1	13.7	12.9	11.46
V	10.86	12.9	14.12	13.7	13.00
VI	11.2	12.7	14.9	13.9	13.5

Graph 1: Comparison Of Flexural Strength

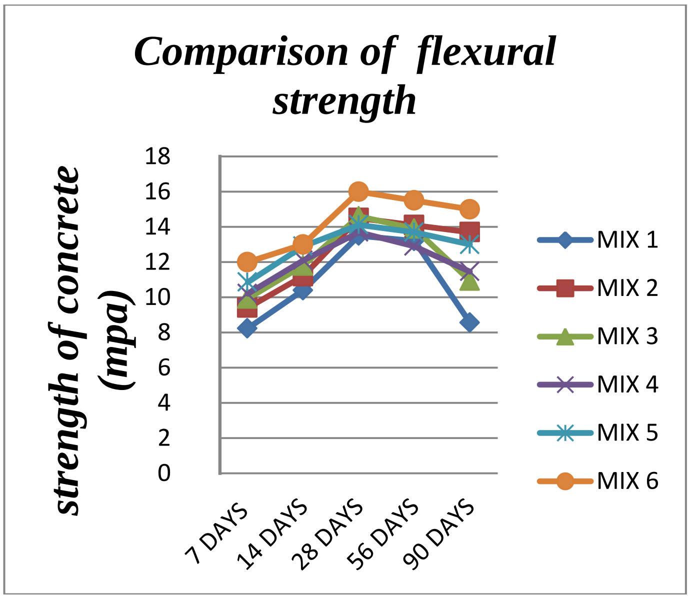

Fig 1: Flexural Strength Testing

8. CONCLUSION

1. For replacing cement by silica fume, ground granulated blast furnace slag, volcanic ash the optimum value is given by 15% replacement of volcanic ash.
2. It is found that there was 18 % increment in flexural strength for M40 grade concrete 7 days of curing.
3. It is found that there was 16 % increment in flexural strength for M40 grade concrete at 28 days of curing.
4. It is found that degradation of concrete due to curing in sulphuric acid was high for control mix where as when cement is replacement with 10% of silica fume, 10% and 15% of ground granulated blast furnace slag and volcanic ash was more durable.

9. FUTURE SCOPE

Following are the scope for future work.

1. In the present work m40 grade of concrete is studied further work can be carried out on the higher grades of concrete and also m20, m25, m30, m35 grade.
2. Ground granulated blast furnace slag can be used as a partial replacement for fine aggregates.
3. Flexure behaviour of larger size beams can be studied.
4. Durability studies like water absorption, porosity, resistance to abrasion etc can be carried out.
5. Admixtures like silica fume, ground granulated blast furnace slag, and volcanic ash can also be further replaced partially by 20%, 25%, 30%, 35%, 40% etc.

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