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# SCRUNITY ON DURABILITY PROPERTIES OF HIGH PERFORMANCE CONCRETE

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**ABSTRACT:** This paper deals with an experimental study on High Performance Concrete (HPC) with partial replacement of cement by Fly Ash and fine aggregate by Glass Powder. The use of glass powder and fly ash in high performance concrete as a supplementary cementitious material was an alternative to traditional concrete. The research work is carried out on M80 grade concrete with constant water cement ratio 0.33 and partial replacements of fine aggregate by Glass Powder and cement by Fly Ash with different percentages (i.e., 0%, 10%, 20%, and 30%).Compressive strengths for different proportions were tested by considering the replacement of fine aggregate and then followed by replacement of cement separately. The proportions at which higher compressive strength in replacement of fine aggregate by glass powder was taken and similarly incase of replacement of cement by fly ash considered as base for combined replacement of fine aggregate and cement simultaneously. Properties like compressive strength, split tensile strength, flexural strength, workability and durability for M80 grade concrete at 7days and 28days are studied. The materials like waste glass powder and fly ash using this experiment to reduce the CO2 and sand mining.

**Key Words:** High performance concrete, compressive strength, durability, glass powder and fly ash.

## 1. INTRODUCTION

Concretes of strengths above 40 Mpa are generally confirmed to produce high strengths. HPC is nothing but high strength concrete not only gives high ultimate strength but performs better in many aspects like durability, abrasion resistance and sulphate attack etc. According to ACI High performance concrete is defined as a material meeting special combinations and uniformity requirements and performance that cannot be always be achieved by Normal mixing, placing and using conventional materials. High Performance concrete plays an important role in present constructional activities. High rise buildings and off shore structures and long span bridges, structures at marine environment are requires high strength concrete for its more stability and durability for lifetime. There is a possibility of obtaining required high performance characteristics for concrete with low water cement ratios and

superplastisizers.

The developing country like India facing shortage of good quality natural sand and particularly in India, natural sand deposits are being used up and creating serious problem to environment and society. Hence

sand mining from riverbeds is being restricted or banned by the authorities. With the advent of revolution in infrastructure industry, there is enormous hike in the demand of fine aggregate. Due to the poor availability of natural sand, alternatives are to be investigated. To fulfill this problem, sand can be replaced with glass powder and cement by fly ash to achieve economical and better performance.fly ash replaced with concrete improves durability, workability, lowers heat of hydration hence elimination of cracks. The main problem in using crushed glass as aggregate in Portland cement concrete are expansion and cracking caused by the glass aggregate due to alkali silica reaction.

The usage of cement in constructions and the cement manufacturing industries are releasing large amount of $CO_2$ into the atmosphere. This results in increasing the global warming there by increasing the environmental pollution. So the need of alternatives for cement is necessary.

To produce high performance concrete in economical way, need of alternatives is necessary for the sustainable growth. Due to the increasing the demand of conventional materials.

**GLASS POWDER:**

The glass is a mixture of a number of metallic silicates, one of which is usually that of an alkali metal. It is an amorphous, transparent or translucent. It may also be considered as a solidified super cooled solution of various metallic silicates having infinite viscosity.

**PREPARATION**: Waste glass was collected from autonagar Green House glass industry, Vijayawada, AP, consisting of waste automobile glass. It was pulverized and then sieved through 2.38mm IS sieve. The specific gravity of waste glass was found to be 2.41

**PROPERTIES AND APPLICATIONS OF GLASS POWDER**:

- Consuming the glass powder in concrete saves landfills and concrete price.
- Glass powder enhances mechanical properties at later age due to its pozzolanic activity.
- Glass powder improves pore structure and durability of concrete.
- Glass is a uniform amorphous solid material.
- The most familiar form of glass is the silica-based material used for windows, containers and decorative objects.
- Glass is a biologically inactive material that can be formed with very smooth and impervious surfaces

**ADVANTAGES OF GLASS POWDER:**

- The reuse of very finely ground waste glass in concrete has economical and technical advantages.
- If the glass could be ground to a very fine size, it could satisfy the active pozzolanic behaviour.
- Glass waste is recognized to be

increasing year by year in a large volume from shops, construction areas and factories.

- These waste storage disposals are becoming a serious environmental problem.
- Thus usage of waste glass in construction sector is advantageous as the construction cost decreases.

**FLY ASH**

Fly ash is a by–product obtained by burning coal from the thermal power plants. Form the power plants, for every year around 85 million tons of fly ash is producing as a waste product. There is only 10 – 15 % is using for constructions. Some of the brick manufacturing industries are using fly ash.

The Class – C fly ash and slag will contain 35% of silica and low calcium oxide content than ordinary Portland cement. Because of its low calcium oxide content it gives better durability. So many re- searches have had done on fly ash to its extended usage in concrete. ACI committee has also done re-search and concluded that; fly ash can be used as a cement replacement up to 35% in constructions.

**PROPERTIES OF FLY ASH:**

Fly ash is a pozzolanic material means it is a silicious or silicious - aluminous material that reacts with calcium oxide to form cement. When Portland cement reacts with water and produces calcium silicate and lime. This reaction of fly ash will improves strength in concrete.

Some of the important properties of Fly ash are

- The spherical shape and particle size distribution of fly ash will increases the flowability and fluidity. So the amount of water can be reduced, this will helps in producing high strengths.
- Fly ash has excellent water tightness of the concrete will increases the durability.
- Fly ash reduces the alkali aggregate reaction, which reduces the harmful expansion in concrete.

**ADVANTAGES OF FLY ASH:**

- High ultimate strength
- Improved workability
- Reduced bleeding
- Reduced heat of hydration
- Reduced permeability
- Increased resistance to sulphate attack
- Lowered costs
- Reduced shrinkage
- Increased durability
- Cold weather resistant
- Can be used as good substitute for Portland cement
- It reduces the emission of $CO_2$ content
- Fills microscopic voids to increase strength

## 2. HIGH PERFPRMANCE CONCRETE

Concrete meeting special combinations and uniformity requirements that cannot be always achieved by regular mixing and placing conditions is generally known as High performance concrete.

High performance concrete is also defined a material which is designed to give optimized performance characteristics for the given set of materials, usage and exposure conditions, consistent with requirement of cost, service

life and durability. Generally High performance concrete means that the concrete with High strength and high durability.

Concrete is exposed to problems in coastal regions and marine environments. In these places the durability of concrete is reducing very much and life of structure is also reducing. To overcome this problem re-searches are began to find a new material in place of conventional concrete that results in the invention of High performance concrete. HPC generally contains mineral and chemical admixtures. So the rate of strength development is quite different from conventional concrete.

**PROPERTIES:**

**1.Workability:** High performance concrete has good workability. High performance concrete pumps very well due to its volume of cementing material and presence of chemical admixtures such as High range water reducers.

**2.Strength:** High performance concrete will shows superior strength due to less porosity and good bonding property. The development of strength is depends mainly on the presence of constituent materials, bond b/w cement paste and aggregates, presence of voids.

**3.Stres- strain behavior:** High performance concrete exhibits less internal micro cracks than normal concrete. So there is a less development of axial strain in High performance concrete.

4.**Modulus of elasticity**: The modulus of elasticity of concrete will increase with increase in compressive strength and elastic modulus of Coarse aggregates. Generally at wet condition concrete has 15% high elastic modulus than in dry condition.

**5.Poisons ration**: With the increase in water cement ratio poisons ratio deceases. Generally High performance concrete ranges from M50 to M80 grades will have poisons ratio in between 0.2 and 0.28.

**6.shrinkage:** The shrinkage of high performance concrete is similar to that of Low performance concrete and shrinkage is unaffected by water cement ratio. Compared with normal concrete, shrinkage is less in high performance concrete.

**ADVANTAGES:**

- By using HPC the member size can be reduced so that unusable area can be increased there by reducing cost of construction by reducing the concrete volume.
- High performance concrete will have low creep and shrinkage problem will be less.
- Due to the greater stiffness of HPC, the modulus of elasticity will be high.
- Resistance to Freezing and Thawing, chemical attack will be high. So there is a significant improvement in long term durability and crack propagation will be less.
- The maintenance and repairing costs will be reduced.
- The compaction is good and will be without segregation.
- The heat of hydration will be less in using HPC.

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**APPLICATIONS:**

**Areas where high performance concrete needed:**

- For producing High strength and high durable concrete
- In the construction of Underwater structures
- Structures under Marine environment
- For the construction of Nuclear power plants
- Structures of underground constructions

**Major applications where High performance concrete used in india:**

- M75 grade concrete used in **J. J Flyover in Mumbai** for the first time in India.
- Concrete grades of M50, M60 and M70 are used in the spillway structure of **Tehri Dam Project in Uttaranchal.**
- M70 grade concrete used to reduce the Abrasion loss in spillway of **Tala Dam in Bhutan.**
- M75 grade concrete was used in most of the flyovers constructed by **AFCONS CONSTRUCTIONS in PUNE.**
- **Tala head race tunnel** is constructed by using High performance concrete.
- **Vidyasagar Sethu in Kolkata** is the longest cable strayed bridge built by using High performance concrete.

## 3. EXPERIMENTAL PROGRAM

**PROPERTIES OF MATERIALS:**

Various tests have conducted on the Raw materials to obtain the physical and mechanical properties. The detailed test results are given below.

**DETAILED PROPERTIES OF CEMENT:**

Table : 1 test results of cement

| TEST | Natural sand |
|---|---|
| Fineness of cement | 97% |
| Normal consistency of cement | 28% of water and initial distance 40mm and final distance 5mm |
| Specific gravity | 3.16 |
| Initial setting time | 53min |
| Final setting time | 222min |

**FINE AGGREGRATE:** Tests on aggregates are confirming to IS 383 specifications.

Table : 2 test results of fine aggregate

| TEST | Natural sand | Glass powder |
|---|---|---|
| Sieve analysis | Zone II | _ |
| Fineness modulus | 2.60 | _ |
| Specific gravity | 2.64 | 2.41 |
| Water Absorption | 0.9% | _ |
| Bulk density | 1656.0 Kg/$m^3$ | _ |

**COARSE AGGREGATE:** The maximum size of coarse aggregate used in this process is 20 mm.

Table:3 test results of coarse aggregate

| Property | Result |
|---|---|
| Specific gravity | 2.80 |
| Water absorption | 0.1% |
| Fineness modulus | 3.28 |
| bulk density loosely loaded | 1664.0 kg/$m^3$ |
| Bulk density compacted | 1717.0 kg/$m^3$ |

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**FLY ASH**: Specific gravity of fly ash = 2.0

Table :4 chemical composition of fly ash

| Constituent | Percentage |
|---|---|
| SiO2 | 45.31 |
| Al2O3 | 28.73 |
| Fe2O3 | 3.89 |
| CaO | 20 |
| MgO | 1.26 |
| K2O | 0.73 |
| Na2O | 0.97 |

**GLASS POWDER**

Table 5 Chemical composition of Glass powder

| Composition(%weight of mass) | Percentage |
|---|---|
| Silica(SiO2) | 72.5 |
| Alumina(Al2O3) | 0.4 |
| Iron oxide(Fe2O3) | 0.2 |
| Calcium oxide(Cao) | 907 |
| Magnesium oxide(Mgo) | 3.3 |
| Sodium oxide(Na2O) | 13.7 |
| Potassium oxide(K2O) | 0.1 |
| Sulphur trioxide(SO3) | - |
| Loss of ignition | 0.36 |
| Fineness % passing | 80($45\mu m$) |
| Unit weight,kg/m3 | 2579 |
| Specific gravity. | 2.58 |

## 4. MIX DESIGN

Mix design is an essential part in manufacturing of concrete. Proper Mix design method gives better properties to the concrete. In this experimental work, the mix design method used is of ACI 211.1 – 1991

**DESIGN STIPULATIONS FOR MIX DESIGN:**

- Grade of concrete = M80
- Size of aggregates used = 12.5mm,20mm
- Fine aggregate confirming to = Zone-2
- Degree of quality control = good
- Type of exposure = moderate
- Cement used = OPC 53 grade
- Type of aggregate = crushed angular aggregate
- Specific gravity of coarse aggregate = 2.80
- Specific gravity of fine aggregate = 2.68
- Dry rodded bulk density of C.A = 1700 kg/$m^3$
- Fineness modulus of fine aggregate = 3.09
- Super plasticizer used = Glenium B233 (BASF chemicals)

**MIX PROPOTION DETAILS:**

Cement: Fine Aggregate: Coarse Aggregates: water

1 : 0.93 : 1.81 : 0.33

## 5.COMPOSITION OF TRAIL MIXES

The trail mixes were prepared according to the obtained mix proportion for M80 grade. The process of detailing includes the replacement of cement by fly ash and sand with Glass powder. Initially Control mixes with replacement of cement by fly ash 0%, 10%, 20%, 30%, and sand by glass powder individually. Compressive strengths for different proportions were tested by considering the replacement of fine aggregate and then followed by replacement of cement separately. The proportions at

which higher compressive strength in replacement of fine aggregate by glass powder was taken and similarly incase of replacement of cement by fly ash considered as base for combined replacement of fine aggregate and cement simultaneously.

**CASTING OF SPECIMENS:**

After completing the mix proportioning of materials concreting is done to represent the characteristics. Three types of concrete specimens are prepared in respective moulds in casting procedure. The types of specimens are Cubes, Beams and Cylinders

**CASTING PROCEDURE:**

**Preparation of moulds:**The moulds for concreting are need prepare carefully before casting. All the moulds should be fitted properly. Oiling is done on the surface of the moulds for an easy removal of specimens.

**Calculation of materials**: The required materials are calculated for casting. The materials should be dry and well graded.

**Measuring the fresh properties:** Before pouring concrete into the moulds we need to observe the fresh properties of concrete by slump cone method.

**Naming of the trials:** The casted moulds are named and set for undisturbed for 24 hrs for setting.

**Demoulding:** The specimens should be removed after proper setting concrete. The specimens are removed and processed for curing.

**CASTING OF CUBES:**

For each trail 6 cube specimens were casted for calculating 7 days and 28 days strengths. The dimensions of specimen for cube are of 150mm x 150mm x 150mm.

**CASTING OF CYLINDERS:**

For each trail 6 cylinder specimens were casted for calculating 7 days and 28 days strengths. The dimensions of the cylindrical specimen are of

Height = 300mm Diameter = 150mm

**CASTING OF BEAMS:**

For each trail 6 beam specimens were casted for calculating 7 days and 28 days strengths. The dimensions of the beam specimen are of 500mm x 100mm x 100mm

**CURING OF SPECIMENS:**

Curing is most important process in concreting. Concrete strength increases with age of curing. The specimens should keep in curing tank for better improvement in strength. Generally curing is done by ponding curing tanks. We need to change the water for every 7 days of curing. The specimens are tested for 7 days and 28 days curing

**TESTING OF SPECIMENS:**

SLUMP CONE METHOD

Slump cone method consist a cone of 300mm height, 200mm bottom diameter and 100mm top diameter. For doing slump test concrete is poured into the cone in 3 layers and tamped at 24 times for each layer with a tamping bar. After total compaction the cone will removed and height of cone will measured. The difference between actual height and formed cone height will give slump value.

COMPRESSIVE STRENGTH

Compressive strength or crushing strength is the main property observed in testing the cubes. Cubes are tested to calculate compressive strength by applying gradual loading in Compression Testing Machine.

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The reading of the failure load is occurred on the top of the machine in the indicator

Compressive strength ($f_{ck}$) = applied load/cross sectional area

**($f_{ck}$) = P/A**

**SPLIT TENSILE STRENGTH**

Split tensile strength is the most important property of concrete. So to improve tensile behavior of concrete, split tensile strength is important. It is also important in reducing formation of cracks in concrete. Cylinders are casted for calculating split tensile strength.

FLEXURAL STRENGTH

Most of the beam failures are occurred due to their failure in flexural strength. It is important that prediction of flexural strength by calculating modulus of rupture for reducing failure problems in beams. The calculation of modulus of Rupture in terms of Flexural strength is the main aim in casting beam specimens.

The modulus of rupture is denoted by "$f_{cr}$".

## 6. RESULTS AND DISCUSSIONS

The results are tabulated by calculating Fresh and Hardened properties of concrete. The research work is carried out on M80 grade concrete with constant water cement ratio 0.33 and partial replacements of fine aggregate by Glass Powder and cement by Fly Ash with different percentages (i.e., 0%, 10%, 20%, and 30%).Compressive strengths for different proportions were tested by considering the replacement of fine aggregate and then followed by replacement of cement separately. The proportions at which higher compressive strength in replacement of fine aggregate by glass powder was taken and similarly incase of replacement of cement by fly ash considered as base for combined replacement of fine aggregate and cement simultaneously. Properties like compressive strength, split tensile strength, flexural strength, workability and durability for M80 grade concrete at 7days and 28days are studied.

**WORKABILITY OF CONCRETE**

The workability of concrete is observed by the Slump Cone method. The range of slump was selected from the Table A1.5.3.1 of ACI 211.1-91. The slump range was 25-100mm

Table:6 slump obtained for M80

| Mix name | Slump(mm) |
|---|---|
| | M80 |
| CM | 71 |
| HPC1 (FA10%+GP30%) | 68 |
| HPC2 (FA15%+GP35%) | 65 |
| HPC3 (FA20%+GP40%) | 63 |
| HPC4 (FA25%+GP45%) | 59 |

**COMPRESSIVE STRENGTH: (IS 516-1959)**

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing strength. Compressive strength of concrete is calculated by casting 150mm x 150mm x 150mm cubes. The test results are presented here for the compressive strength of 7 days and 28 days of testing.

Table:7 compressive strength cement by fly ash for M80

| Cement by fly ash | Compressive strength(N/mm2) | |
|---|---|---|
| | 7days | 28days |
| 0% | 53.11 | 76.91 |

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| | | |
|---|---|---|
| **10%** | **54.23** | **79.15** |
| 20% | 51.06 | 74.52 |
| 30% | 51.58 | 75.34 |

Table:8 Compressive strength sand by glass powder for M80

| Sand by Glass powder | Compressive strength(N/mm2) | |
|---|---|---|
| | 7days | 28days |
| 0% | 53.21 | 78.91 |
| **10%** | 55.56 | 80.31 |
| 20% | 56.34 | 82.30 |
| 30% | **58.95** | **84.28** |

Table:9 Compressive strengths for M80

| Mix name | Compressive strength(N/mm2) | |
|---|---|---|
| | 7days | 28days |
| CM | 52.90 | 78.91 |
| HPC1 | 53.21 | 82.66 |
| HPC2 | 60.89 | 86.15 |
| **HPC3** | **66.50** | **91.52** |
| HPC4 | 70.14 | 89.72 |

**FLEXURAL STRENGTH: (IS 516-1959)**

The modulus of rupture is the main property for the flexural members. To improve the flexural strength of concrete is one main task in present construction activities. The beam dimensions are of 500mm x 100mm x 100mm. The test results are presented here for the compressive strength of 7 days and 28 days of testing.

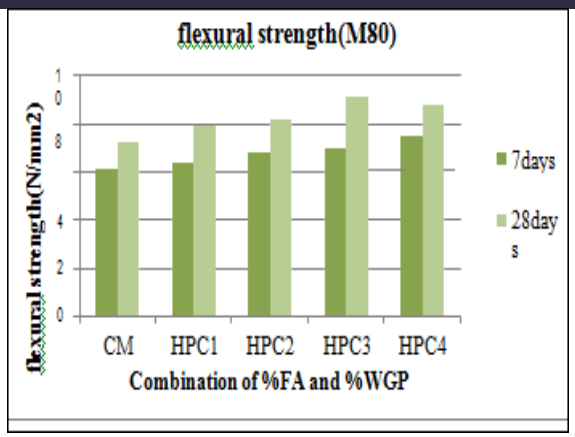


Fig 1. Flexural strength variation for M80 grade at 7 & 28days

**SPLIT TENSILE STRENGTH: (IS 516-1959)**

Out of all the properties of concrete, tensile strength is very important one. The tensile strength is calculated by testing cylindrical specimens of size 300mm height and 150mm diameter. Here each set of specimens are tested for 7 days and 28 days of curing.

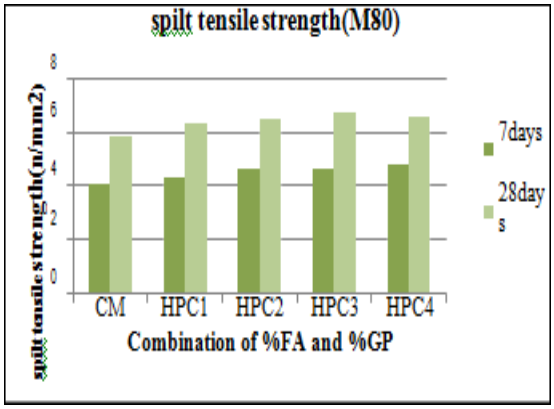


Fig.2 Spilt tensile strength variation for M80 grade at 7 & 28days

## 7. DURABILITY STUDIES

Concrete with Ordinary Portland cement is the major composition in present constructional activities. A concrete structure was good in strength can also be

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good in providing service life. Durability is of concrete structure is justified only when it shows reliability in its life time. More durability means more service life of structure. The concrete under marine environment and exposed to aggressive chemical attack through water are the major problems in reducing the life time of structure

ACID ATTACK TEST ON DURABILITY

To check the Acid resistance of concrete Hydro Chloric acid (HCL), Sulphuric Acid (H2SO4) is selected. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516- 1959 and ASTM C666-1997.The durability properties of concrete are examined with the help of Acid attack test for calculation for % weight loss and % strength loss.

**DETAILED PROCEDURE ADOPTED**

- Cubes of size 100mm x 100mm x 100mm are casted for each trail of M80 and M90 grades
- The specimens are placed in a undisturbed curing period of 60 days.
- After the completion of curing, cubes are taken out of water.
- Initial measurements are taken for each cube in terms of weight and dimensions
- The initial weight and diagonal dimensions of each set of cubes were carefully taken.
- The prepared cubes are placed in acid curing for 60days
- The solutions are prepared by taking 8 litres of water with 5% HCL and 5% H2SO4
- After the completion of acid curing period 60 days the cubes are processed for Acid attack factor and Acid durability factor.

**SUMMARY OF DURABILITY REQUIEMENTS**

| | |
|---|---|
| Acids used | HCL, H2SO4 |
| Concentrations for trails | 5% in water |
| Termination period | 60days |
| Properties comparing | Acid Attack Factor % of weight loss and strength loss |

## 8. DURABILITY RESULTS

In this experimental work, the properties of durability in concrete studies such as Acid Attack test, % weight loss and % strength loss for before immersing and after 60days immersing in HCL, H2SO4 are carefully observed and the results are tabulated as follows

**PERCENTAGE OF WEIGHT LOSS**

**Weight loss of cubes immersed in 5% HCL and 5% H2SO4**

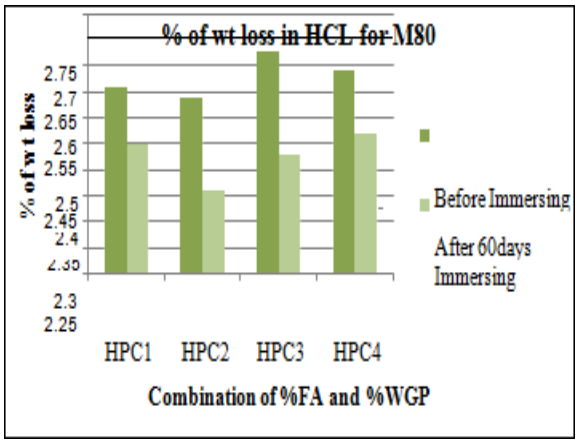


Fig.3 Weight loss in 5% HCL for M80 grade

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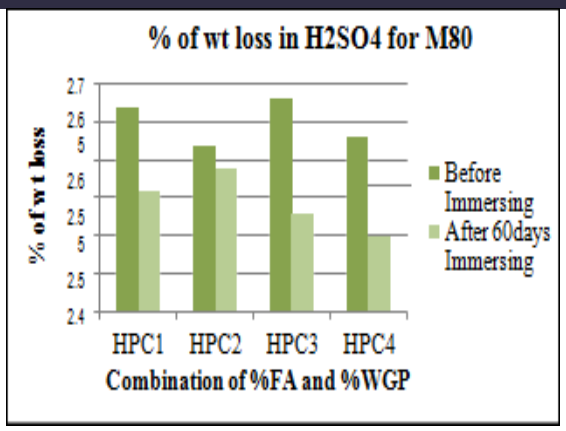


Fig.4 Weight loss in 5% $H_2SO_4$ for M80 grade

**PERCENTAGE OF COMPREESIVE STRENGTH LOSS**

The percentage compressive strength loss of cubes immersed in HCL and $H_2SO_4$ for M80 grade have shown below

immersed in 5% HCL and 5% $H_2SO_4$ Table no.9.2 Compressive strength loss in cubes for M80 Grad

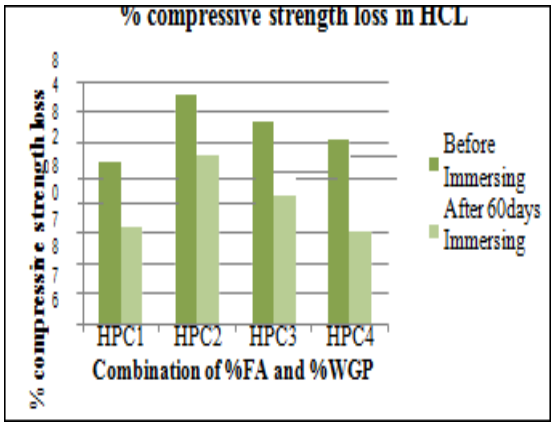


Fig.5 Compressive strength loss in 5% HCL for M80 grade

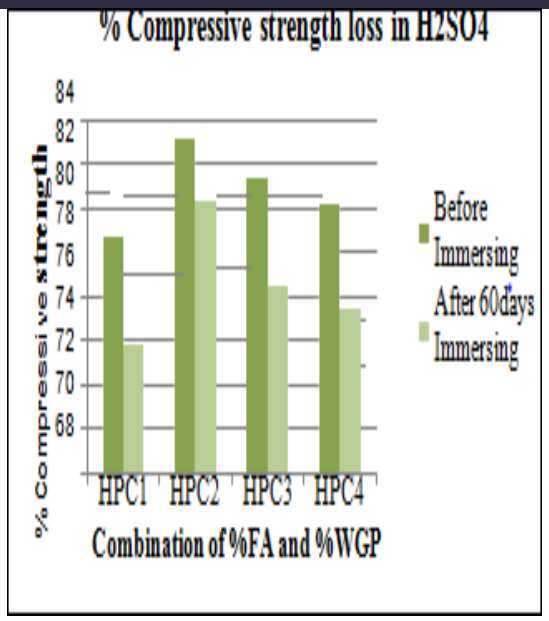


Fig.6 Compressive strength loss in 5% $H_2SO_4$ for M80 grade

## 9. CONCLUSIONS

These following conclusions are given based on the above experimental results

- In the present investigation possibility of high strengths are observed for M80 grade that are successfully achievedThe material Glass powder is a good alternative to replace River sand that it satisfied all the requirements as well as natural sand and it can be used for all constructional purposes in place of sand for sustainable constructions.
- The coarse aggregates of maximum size of 20mm are used to reduce the amount of area occupied by 12.5mm aggregates, thereby reducing amount of voids and gives better bonding.
- By using Glenium B233 as superplastisizer at a dosage of 0.3% shows better workability and uniformity in mixing of concrete. It is a

good water reducing agent.

- In this experimental study it was identified that the higher strength is achieved at partial replacement of cement by fly ash in 20% and river sand by glass powder in 30% individually.
- For M80 grade, maximum compressive strength of 91.52 Mpa, Split tensile strength of 6.7 Mpa and Flexural strength of 9.1Mpa had occurred for cement by fly ash 20%and sand by glass powder 40%.
- In case of durability the HPC2 mix replacement of cement by fly ash and sand by glass powder has shown better results in attaining resistance when compared with other mixes.
- Acid attack test for M80 concrete is more for cubes immersed in $H_2SO_4$ when compared with HCL.
- It was concluded that the weight loss and strength loss due to acid attack is less for combined replacement of 15% cement by fly ash and 35% of river sand by glass powder.
- Minimum percentage loss of weight and strength occurred for M80 grade is 0.03% and is 4.12% obtained in HPC2 mix.
- The replacement of F.A with Glass powder proportions exceeding 45% and cement by fly ash proportion 25% found to have a negative impact on compressive strength.

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