EXPERIMENTAL STUDY ON 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 which are used in this work have potential to reduce the CO2 emissions from cement industry and sand mining in addition to contributing high performance concrete. 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 for M80 concrete is more for cubes immersed in H2SO4 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.

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

I. INTRODUCTION

Production of concrete having high strength and showing high performance has become the need of the hour as construction industry is rapidly progressing. Such concrete is known as high performance concrete(HPC). Concretes of strengths above 40 MPa are generally considered 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 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 use of super-plasticizers. The developing country like India facing shortage of good quality natural sand and 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. Towards a solution to this problem, sand can be replaced with glass powder. In similar lines cement production becomes too expensive and also contributes a lot to the environmental degradation. The usage of cement in constructions and the cement manufacturing industries are releasing large amount of CO2 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. The chief green house gas, CO2 is mainly coming out from cement industries next to thermal power plants. Hence any work which reduces the emission of CO2 is the need of the hour. Hence from historical observations cement is partially replaced by fly ash for obtaining good quality concrete versions. The research shows that cement may be partially replaced by fly ash to achieve concrete which is economical and having better performance. Fly ash replacing the cement in concrete improves durability, workability, lowers heat of hydration hence helps in elimination of cracks. The main problems in using crushed glass as aggregate in Portland cement concrete are expansion and cracking caused by the glass aggregate due to alkali silica reaction. This may be tackled by the silica content of the fly ash which is a pozzolanic material. 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, search for alternatives to produce sustainable constructions is on the platform. So it is hoped that use of Glass powder and Fly ash to produce high strength concrete as a replacement of sand and cement will definitely becomes as a good alternative materials. Through this experimental study this is investigated.

OBJECTIVE IF THE PRESENT WORK

- To investigate the strength and durability properties of HPC by M80 grade.
- To investigate the maximum percentage partial replacement of Fine aggregate by glass powder and cement by Fly ash.
- To investigate how the Glass powder and Fly ash improves the pore structure and durability of concrete.
- To reduce the cost of HPC by using these materials.

II. MATERIALS USED

In this experimental program, the primary stage includes the preliminary research on selecting the raw materials. Number of conventional trails is prepared and the mix proportion for M80 grade is selected by choosing constant water cement ratio (0.33). By replacing the cement by fly ash and sand by glass powder in 0%, 10%, 20%, 30% individually and optimum percentage is selected for main trails. The main experimental work involves the replacement of fly ash and glass powder in 0%, 10%, 20%, 30% for cement and sand, the strength and durability properties are studied for M80 grade.

CEMENTITIOUS MATERIALS:

CEMENT

Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will be greatly affected by changing the cement content. The cement used in this project is Ordinary Portland cement of 53 grade confirming to IS 12269 – 1987.

FLY ASH

The fly ash used in the present work is supplied by VTPS power plant in Vijayawada and the fly ash is of class C-type. Fly ash is largely made up of calcium oxide and silicon oxide can be used as a substitute or as a supplement for ordinary port land cement. Normally Fly ash used concrete is also known as green concrete. The specific gravity of Fly ash is 2.04

FINE AGGREGATE

Aggregates of size ranges between 0.075mm – 4.75mm are generally considered as fine aggregates. In this experimental work two types of fine aggregate were used. They are River sand and Glass powder. The river sand was partially replaced by the Glass powder. The fine aggregates are selected as per IS-383 specifications.

RIVER SAND:

It is also called as natural sand. In this work a good quality of natural sand was used. The sand is medium sand and is confirming to Zone-II as per standard specifications.

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.

COARSE AGGREGATE

Aggregates of size more than 4.75mm are generally considered as coarse aggregate. The maximum size of coarse aggregate used in this experimental are 20 mm. A good quality of coarse aggregates is obtained from nearest crusher unit. The coarse aggregates are selected as per IS-383 specifications.

CHEMICAL ADMIXTURE

Chemical admixtures in concrete are confirms to ASTM C 494 Specifications. Chemical admixtures will gives required workability with low water contents. They improves the workability and concrete quality. In this Experimental work GLENIUM B233 is used as a super plasticizer.

GLENIUM B233:BASF GLENIUM B233 is a super plasticizing admixture. Glenium B233 is an admixture of a new generation based on modified poly-carboxylic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required.

PROPERTIES OF GLENIUM B233:

Table .1 Properties of GLENIUM B233

Type	Ploy-corboxylic ether
Colour	Light brown
Specific gravity	1.06
Dosage	500 – 1500 ml per 100kg of cement
Standard confirming	ASTM C494 Type-F

In this experimental work, the amount of Super Plasticizer used is of 0.3% by cement weight.

Advantages of Glenium B233

- Elimination of vibration and reduced labour cost in placing.
- Marked increase in early & ultimate strengths.
- Higher Young's modulus.
- Better resistance to carbonation and other aggressive atmospheric conditions.
- Increased durability.

III. MIX DESIGN FOR M80 GRADE

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.

This mix design is adopted after conducting several conventional trails. The final mix design procedure is tabulated as follows:

Target mean strength (F_t) = f_{ck} + k(s)

= 80 + 1.65(6)

= 89.9 Mpa
Water cement ratio = 0.33 [from Table A 1.5.3.4 (a) and Table A 1.5.3.4 (b) of ACI 211.1-91]
Range of slump = 25 – 100mm [from Table A 1.5.3.1 of ACI 211.1-91]
Actual water content = 199 lit/m^3 [from Table A 1.5.3.3 of ACI 211.1-91]
Cementitious materials = 199/0.33
= 603 kg/m^3, Take 600 kg/m^3.(Cementitious materials include cement, fly ash and silica fume).
Bulk density of coarse aggregate = 1700 kg/m^3,Volume of coarse aggregate required = 0.64 (from Table A 1.5.3.6 of ACI211.1-91)
Weight of Coarse aggregate = 1700x0.64 = 1088 kg/m^3
First estimate density of fresh concrete = 2450 kg/m^3
Required water content:
Cement = 600 kg/m^3 Water = 600x0.33 = 198 lit/m^3
Weight of fine aggregate required:
Fine aggregate content = estimate density – (cement + water + CA) = 2450 – (600 + 198 + 1088) FA = 563 kg/m^3
Ratio of materials:
Cement: fine aggregate: coarse aggregate: water
600: 563: 1088: 198 = 1: 0.93: 1.81: 0.33
Super plasticizer dosage = 0.3% by cement weight
Mix ratio = 1: 0.93: 1.81: 0.33
MIX PROPOTION DETAILS
Cement = 600Kg/m^3
Fine aggregate = 563 Kg/m^3
Coarse aggregates = 1088 Kg/m^3

IV. EXPERIMENTAL PROGRAM

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.

DETAILING OF TRAIL MIXES FOR M80

Table . 2 Mix proportion quantities of M80 grade

Mix name	Mix description	C (kg)	FA (kg)	CA (kg)	Fly Ash (kg)	W GP (kg)	W (lit/ m^3)	SP (kg)
CM	Control mix	600	563	1088	0	0	198	1.8
HPC1	FA10%+ GP30%	520	394	1088	60	169	198	1.8
HPC2	FA15%+ GP35%	510	366	1088	90	197	198	1.8
HPC3	FA20%+ GP40%	480	338	1088	120	225	198	1.8
HPC4	FA25%+ GP45%	450	310	1088	150	253	198	1.8

V. RESULTS AND DISCUSSION

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.

COMPRESSIVE STRENGTH:

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 .3 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

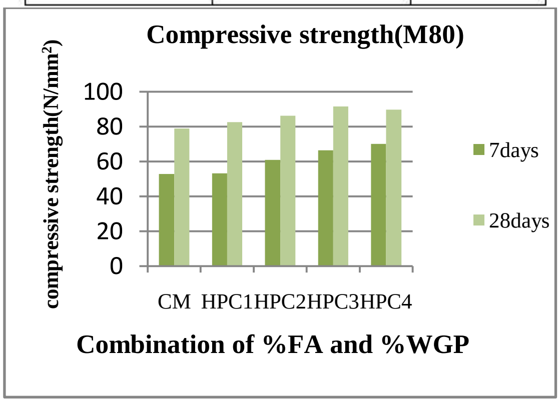

Fig .1 Compressive strength variation for M80 grade at 7 & 28 days

FLEXURAL STRENGTH:

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.

Table .4 Flexural strength for M80

Mix name	Flexural strength(N/mm^2)	
	7days	28days
CM	6.1	7.2
HPC1	6.4	7.9
HPC2	6.8	8.2
HPC3	**7.0**	**9.1**
HPC4	7.5	8.8

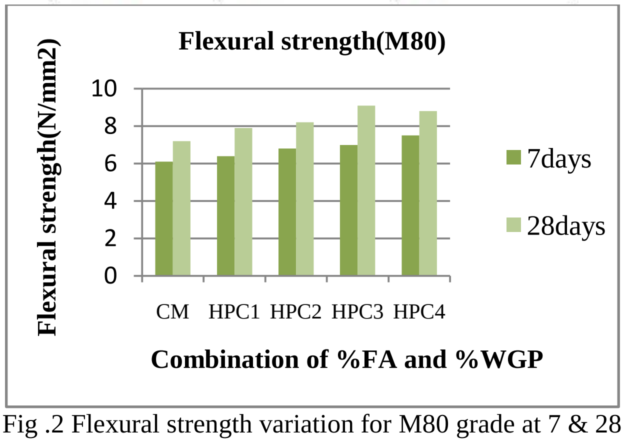

Fig .2 Flexural strength variation for M80 grade at 7 & 28 days

SPLIT TENSILE STRENGTH:

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.

Table .5 Split tensile strength for M80

Mix name	Spilt tensile strength(N/mm^2)	
	7days	28days
CM	4.1	5.8
HPC1	4.3	6.3
HPC2	4.6	6.5
HPC3	**4.6**	**6.7**
HPC4	4.8	6.6

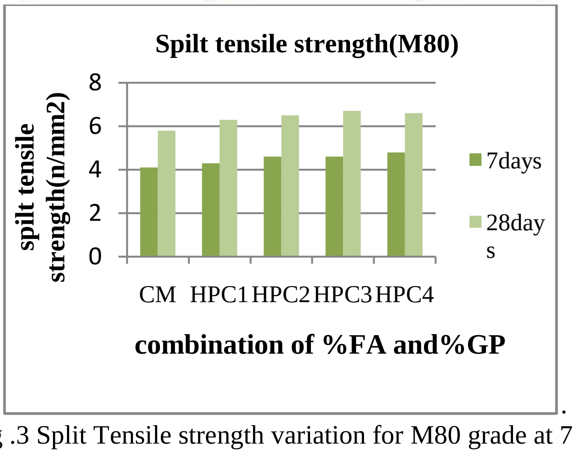

Fig .3 Split Tensile strength variation for M80 grade at 7 & 28 days

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 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 reducing the life time of structures.

ACID ATTACK TEST FOR DURABILITY

To check the Acid resistance of concrete, Hydro Chloric acid (HCL), Sulphuric Acid (H_2SO_4) is selected for testing concrete. 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.

ACID ATTACK TEST FOR % OF WEIGHT LOSS

- The cubes will be processed for Acid attack factor after completion of 60 days acid curing.
- Acid attack factor mainly deals with weight loss and dimension loss of specimens.
- The deteriorated surface dimensions are taken by calculating Diagonal dimensions of each struck face is taken eight corners of set of cubes.
- The final weight of cube was taken and to calculate the percentage of weight loss.
- Acid attack factor was calculated by the formula
  Acid attack factor = (loss in mm on 8 corners) / 4

ACID DURABILITY FACTOR FOR % STRENGTH LOSS

- In Acid durability factor test, the deteriorated cube was tested for compressive strength for before immersing and after 60days.
- The Relative strength (Sr) after ‘N’ days are calculated before immersing and after 60days.
- The acid durability factor was calculated by the formula
  Acid durability factor = Sr(N/M)
  Here Sr = relative strength at N days (%)
  N = Number of days at which acid durability factor is needed
  M = Number of days at which the acid durability factor is terminated.

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 an 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.

PERCENTAGE OF WEIGHT LOSS

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.

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

Table .6 Percentage weight loss in cubes for M80 Grade

Mix	Curing under 5% HCL		Curing under 5% H2SO4	
	Before Immersing wt of specimen (kgs)	After 60days Immersing wt of specimen (kgs)	Before Immersing wt of specimen (kgs)	After 60days Immersing wt of specimen (kgs)
HPC1	2.61	2.50	2.67	2.56
HPC2	2.59	2.41	2.62	2.59
HPC3	2.68	2.48	2.68	2.53
HPC4	2.64	2.52	2.63	2.50

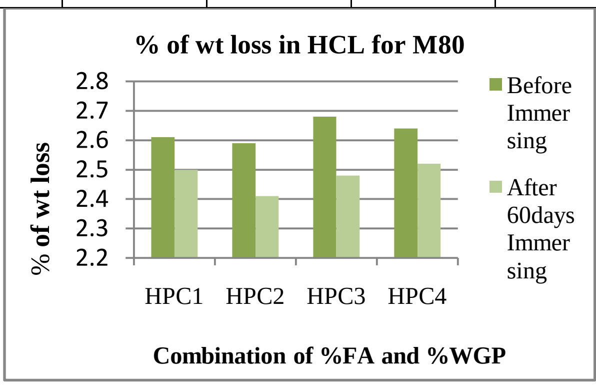

Fig .4 Weight loss in 5% HCL for M80 grade

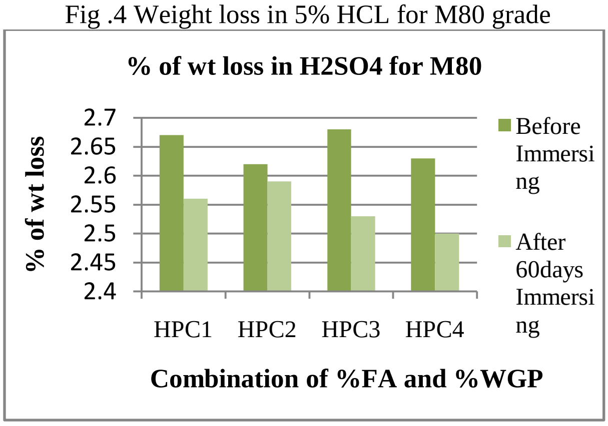

Fig .5 Weight loss in 5% H_2SO_4 for M80 grade

PERCENTAGE COMPREESIVE STRENGTH LOSS

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

Percentage Compressive strength of cubes immersed in 5% HCL and 5% H_2SO_4

Table.7 Compressive strength loss in cubes for M80 Grade

Mix	Curing under 5% HCL		Curing under 5% H_2SO_4	
	Before Immersing	After 60days Immersing	Before Immersing	After 60days Immersing
HPC1	78.72	74.32	78.72	73.89
HPC2	83.13	79.10	83.13	80.32
HPC3	81.42	76.54	81.42	76.57
HPC4	80.21	74.10	80.21	75.52

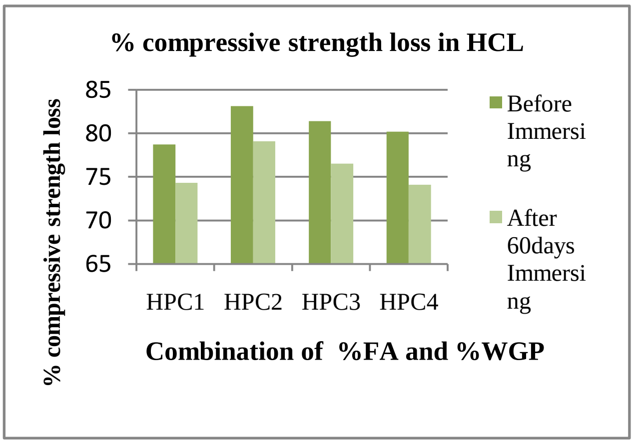

Fig .6 Compressive strength loss in 5% HCL for M80 grade

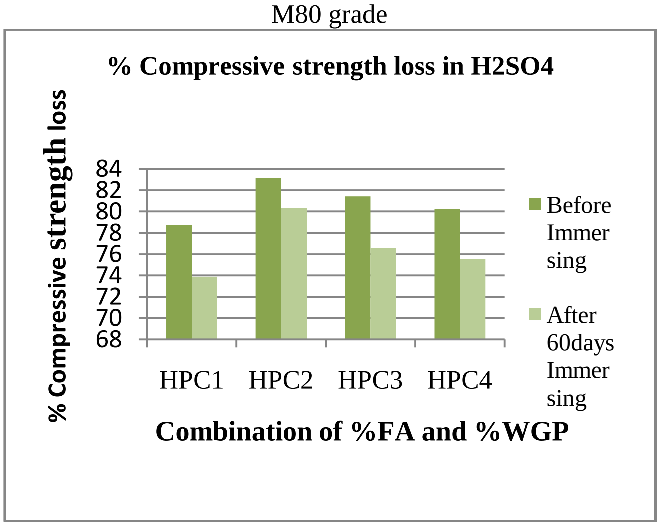

Fig .7 Compressive strength loss in 5% H2SO4 for M80 grade

VI. 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 achieved. The 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 super plastisizer 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 10% 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 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.

Scope for further study:
Different admixtures can be used in place of fly ash, and the strength and durability tests can be conducted for observing further improvement. Manufactured sand may be used to replace natural sand, and the strength and durability tests can be conducted for observing further improvement.

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