Behaviour of High Performance Concrete with Multi Compound Composite Cement

Manju Priyadharshini R, Sivakumar M, Mahendran S, Mohan M

Abstract*: *This study investigates about the behaviour of high performance concrete produced with multi component composite cements. Here, the cement is partially replaced with certain mineral admixtures. The mineral admixture used in the study are fly ash, rice husk ash, silica fume and ground granulated blast furnace slag in various percentages up to 50%. The mix proportion for fly ash and rice husk ash are kept constant thought the study as 25% and 7.5% respectively. The Mechanical properties such as (Compressive strength, split tensile strength, flexural strength and modulus of elasticity), Durability tests (Acid test, Sorptivity), permeability test and Non Destructive test are performed on M40 grade concrete cube* material property, *cylinder and prism. The outcomes were analyzed with the controlled mix. The results shown that the M3 mix (50% cement, 25% fly ash, 7.5% RHA,7.5 % silica fume and 10 % GGBS) obtained optimum strength, durability and other properties when analyzed with the other mixes.

Keywords : Acid test, Compressive strength, Flexural strength FA, RHA, GGBS, Modulus of elasticity, Nondestructive tests, Silica fume, Sorptivity, Spilt tensile strength and permeability.

I. INTRODUCTION

Concrete is the widely used material in nature, it is generally made of cement, fine aggregate, coarse aggregate and water. Due to demand of concrete, a new-flanged materials and methods were made for the production of concrete. The industrial and agricultural byproducts used in the construction has become a solution for economic and environmental problems. The Mineral amalgamation such as FA, RHA, SF and GGBS are used in advancement of High performance combinations which serve as pozzolanic materials and fillers. The pozzolans in combinations with the cement to obtain high performance concrete aims at improving the concrete microstructure. It encounter unique performance and homogeneity requirements that cannot be accomplished always by using the conventional materials alone. The use of pozzolans can accomplish not only the efficient benefit but also technical benefits. The use of chemical amalgamation diminish the water content, thereby reducing the porosity within the hydrated cement paste. It is commonly agreed that with proper selection of admixture, mixture proportioning, curing techniques and mineral additive can highly boost the strength, durability and other aspect.

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II. MATERIALS USED

A. Cement

The cement used for present study is Ordinary portland cement 53 grade confirming to Indian Standard specifications.

B. Fine aggregate

The usable river sand confirming to Indian Standard specifications was used as the fine aggregate for concrete preparation.

C. Coarse aggregate

Coarse aggregate of nominal size 20mm was obtained from the local quarry confirming to IS specifications was used.

D. Water

Water confirming to as per IS 456 – 2000 was used for all mixing as well as curing purpose.It should be free from acids or alternative organic contamination. The local consume water free from the contamination used in this experimental programme for mixing and curing.

E. Fly ash

Fly ash also known as pulverised fuel ash is a coal ignition product which is made of certain particulates such as fragment that are obtained of coal-fired boilers along the flue gases. FA is a byproduct of thermal power plants. Class F fly ash is used, this ash is pozzolanic in nature, and contains but 7% lime. Utilization of fly ash in concrete is now increased like common ingredient in concrete for producing high strength and high performance concrete. By utilizing this ash not only produces better properties by disposal.

Table- I: Chemical Properties of Fly Ash

S.No	Chemical composition	Percentage by weight
1	SiO_2	59.00
2	Al_2O	21
3	Fe_2O_3	3.70
4	CaO	6.90
5	MgO	1.40
6	SO_3	1.00
7	K_2O	0.90
8	LOI	4.62

F. Rice husk ash

Rice Husk Ash commonly assigned to an agricultural by-product of burning husk under controlled temperature. Rice plant consume silica from the soil, Rice husk is the exterior protecting layer of the rice plant with a high concentration of silica, broadly 81-86% and 5% alumina, confirming to large cementations.RHA required huge amount of H_2O because of inhale of biological characteristics. It is utilized as filler or pozzalanic materials for HPC it gives greater strength.

Table- II: Chemical Properties of Rice husk ash

S.No	Chemical composition	Percentage by weight
1	SiO_2	88.90
2	Al_2O	2.50
3	Fe_2O_3	2.19
4	CaO	0.22
5	$Na_2O + k_2O$	0.69
6	LOI	4.01

G. Ground granulated blast furnace slag

GGBS is a main component of alternative binder. It becomes a sustainable binder in concrete material. GGBS is a waste material which needs to proper method of disposal. It is a byproduct from blast furnace which is used to make iron. These furnaces operates at a temperature above 1500ºC. When mixed with water it will hydrate similar to portland cement. GGBS is slightly less expensive than Portland cement. Adding GGBS to the normal ratios of aggregates and water, cementations material becomes unchanged.

Table- III: Chemical Properties of GGBS

S.No	Chemical composition	Percentage by weight
1	SiO_2	40
2	Al_2O	13.5
3	Fe_2O_3	1.8
4	CaO	39.2
5	MgO	3.6
6	SO3	0.2
7	LOI	0.0

H. Silica fume

Silica fume referred to as micro silica, is an unstructured polymorph of SiO_2 and Si, owing to its chemical and physical properties it's a reactive Pozzolan. It is added to improve other properties, compressive strength, bond strength and abrasion resistance.

Table- IV: Chemical Properties of Silica fume

S.No	Chemical composition	Percentage by weight
1	SiO_2	99.886
2	Al_2O	0.043
3	Fe_2O_3	0.040
4	CaO	0.001
5	MgO	0.001
6	TiO_2	0.001
7	Na_2O	0.003
8	LOI	0.015

I. Super plasticizer

Super plasticizers are developed in 1960's. It enhance workability. The effects depend on type, dosage and time of addition. Water requirement is reduce by 15% to 30%, resulting concrete has higher strength and lower permeability. Super plasticizers produce than higher normal workability for 30 – 60 minutes and there will be rapid loss of workability, slump loss depends on initial slump, type of cement, time of addition, humidity, temperature, presence of other admixtures and super plasticizers. Generally bleeding is decreased. The use of SP allows improvement in the bond between hardened concrete and reinforcing steel. Water reduction allows producing high strength concrete.

Table- V: Properties of chemical admixture

S.No	Properties	Results
1	Colour	Brown liquid
2	Specific gravity	1.18
3	Chloride content	Nil to BS5075/BS:EN934
4	Air entrainment	Less than 2% additional air entrained at normal dosages
5	Compatibility	Conplast SP430 suitable for Portland cements

III MIX DESIGN

A. Concrete mix design

M40 grade of concrete was designed as per IS 10262 – 2019. Mix proportion of M40 grade concrete: 1:1.55:3.10. The mix designation and mix percentage are given in table VI and VII.

Table VI Mix Designation of various pozzolanic materials

MIX	CEMENT Kg/m^3	FLY ASH Kg/m^3	RICE HUSK ASH Kg/m^3	GROUN GRANULATED BLAST FURNACE SLAG Kg/m^3	SILICA FUME Kg/m^3	FINE AGGREGATE Kg/m^3	COARSE AGGREGATE Kg/m^3
M	412	0	0	0	0	636	1279
M1	206	103	30.9	20.6	51.5	636	1279
M2	206	103	30.9	30.9	41.2	636	1279
M3	206	103	30.9	41.2	30.9	636	1279
M4	206	103	30.9	20.6	20.6	636	1279

Table VI Mix Proportion of various pozzolanic materials

MIX	CEMENT %	FLY ASH %	RICE HUSK ASH %	GROUND GRANULATED BLAST FURNACE SLAG %	SILICA FUME %	FINE AGGREGATE %	COARSE AGGREGATE %
M	100	0	0	0	0	100	100
M1	50	25	7.5	5	12.5	100	100
M2	50	25	7.5	7.5	10	100	100
M3	50	25	7.5	10	7.5	100	100
M4	50	25	7.5	12.5	5	100	100

B. Test specimens

The standard cubes of size 150×150×150 mm, cylinders with size 150mm dia and 300mm height and prism of dimension 100×100×500mm are adapted for every type of mix to achived mechanical properties, durability, permeability and non-destructive tests.

IV RESULT AND DISCUSSION

Concrete cube, cylinder and prism are taken from the curing tank and dehydrated They were tested for compressive strength, Split tensile strength, Flexural strength and Modulus of elasticity, For Durability studies, Sorptivity and Acid attack test, permeability test and Non-destructive test were also conducted.

A. Compressive Strength Test

The compressive strength of cubes for mix M40 grade concrete is done by compressive testing machine. The values for 28 and 56 days are given in the figure 1.

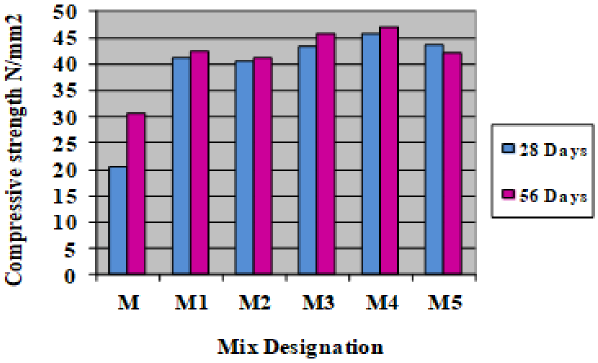

Fig.1. Compressive Strength at 28 and 56 days

Table- VIII: Compression strength test results

S.No	Mix Designation	Average Compressive strength N/mm^2	
		28 days	56 days
1	M	41.27	42.32
2	M1	40.29	41
3	M2	43.16	45.83
4	M3	45.78	47.12
5	M4	43.50	42.19

(a) Compressive strength of concrete

B. Split tensile strength

Split tensile strength was determined based on IS 5816-1999.The test was carried out in concrete cylinder , due to applying of load crack will occur. The value for 28 days and 56 days are given in figure 2.

Table- IX: Spilt tensile strength test results

S.No	Mix Designation	Average Split tensile strength N/mm^2	
		28 days	56 days
1	M	5.11	5.47
2	M1	5.25	5.85
3	M2	5.49	5.91
4	M3	5.60	6.17
5	M4	5.39	5.57

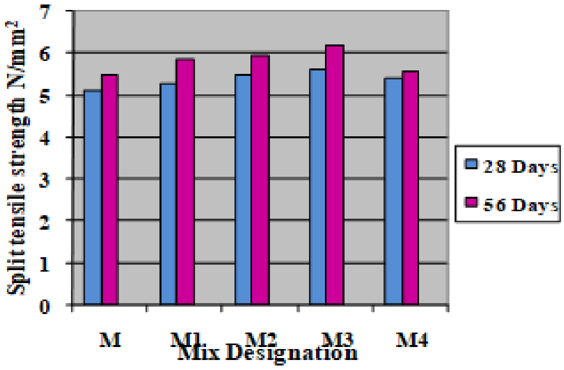

Fig.2. Split tensile strength at 28 and 56 days

(b) Spilt tensile strength

C. Flexural strength

The flexural strength of concrete prism was determined based on IS: 516 –1959 on 100mm × 100mm ×150mm concrete specimens. The load was applied at the rate of 4kN/min until failure of specimen and maximum load applies to specimen was recorded The results of 28 days and 56 days are given in figure 3.

Table- X: Flexural strength test results

S.No	Mix Designation	Average Split tensile strength N/mm^2	
		28 days	56 days
1	M	8.17	8.29
2	M1	8.20	8.37
3	M2	8.59	8.97
4	M3	9.10	9.23
5	M4	8.43	8.57

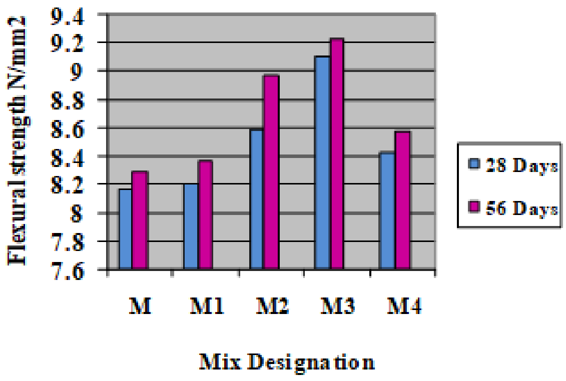

Fig.3. Flexural strength at 28 and 56 days

(c) Flexural strength

D. Modulus of Elasticity

Modulus of elasticity was determined as per IS 516 - 1959. Tested values are taken from average compared values of three specimens. The difference of experimental result and the values predicted as per IS 456:2000 have been evaluated and the results are shown in the fig 4.

Table- XI: Modulus of Elasticity results

S.No	Mix Designation	Experimental results (N/mm^2)	Predicted as per IS 456 -2000 (N/mm^2)
1	M	36102.8	35220.7
2	M1	35533.9	34604.9
3	M2	37908.14	38470
4	M3	40587.1	38900
5	M4	39511.4	38600.5

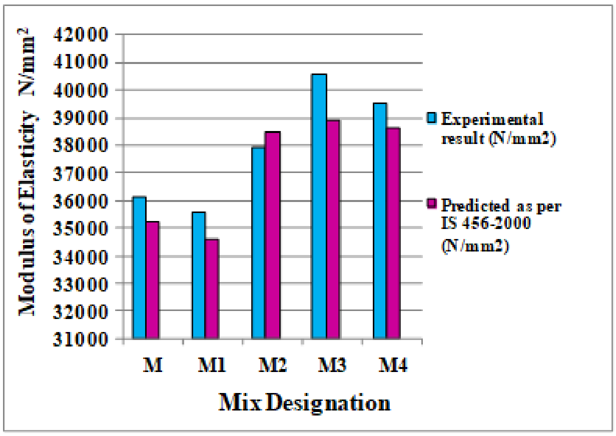

Fig.4. Modulus of Elasticity

E. Durability studies

1. Sorptivity

Sorptivity is a testing method which describe the tendency of a porous material to soak up by capillarity. It can be calculated by the given formula.

$$i = s\sqrt{t} \quad (4.2)$$

The comparison of Sorptivity values at 28 days is shown in fig 5.

Table- XII: Sorptivity results

S.No	Mix Designation	Sorptivity at 28 days ($mm/min^{0.5}$)
1	M	0.001146
2	M1	0.001401
3	M2	0.001019
4	M3	0.00051
5	M4	0.000892

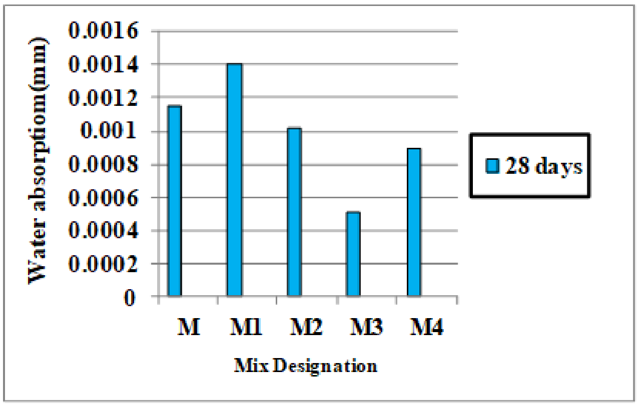

Fig.5. Sorptivity

2. Acid tests

The Acid attack test (H_2SO_4 Exposure) was determined based on ASTM C267-01(2012). Normality was uniformly maintained for acid throughout the period In H_2SO_4 surrounding, the maximum percentage weight loss and strength loss is observed for all the specimens at 28 days and the values are shown in fig 6 and fig 7.

Table- XIII: Percentage Weight loss

S.No	Mix Designation	5% H_2SO_4 Solution – Weight loss(%) (28 days)
1	M	9
2	M1	12.4
3	M2	9.6
4	M3	8.54
5	M4	9.2

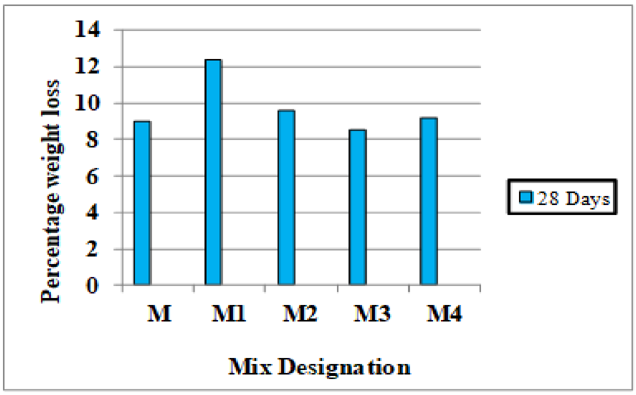

Fig.6. Percentage Weight loss

Table- XIV: Percentage Strength loss

S.No	Mix Designation	5% H_2SO_4 Solution – Strength loss(%)(28 days)
1	M	48
2	M1	59.21
3	M2	46.21
4	M3	42.3
5	M4	45.2

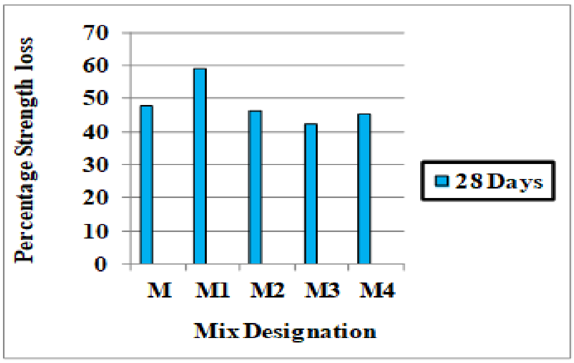

Fig.7. Percentage Strength loss

F. Void Permeability tests

The percentage of permeable voids was determined as per ASTMC 642-2006. This percentage of voids were was found in the cube. The test was conducted on 150mm cubes. The void permeability was calculate by the formula.

$$\text{Voidspermeability} = \frac{Wsat - Wdry}{V}$$

The comparison of void permeability values at 28 days is shown in fig 8.

Table- XV: Void Permeability results

S.No	Mix Designation	Volume of Permeable voids (%)(28 days)
1	M	3.2
2	M1	3.3
3	M2	3.1
4	M3	2.6
5	M4	2.9

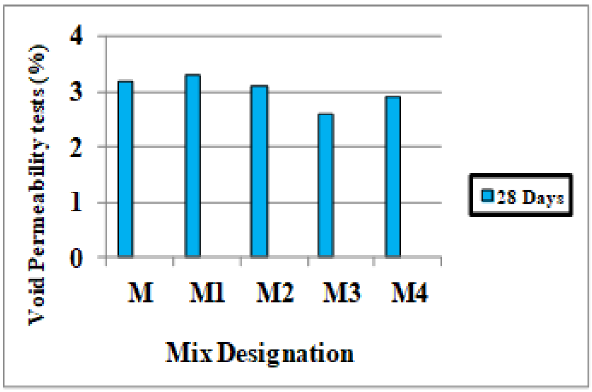

Fig.8. Void Permeability

G. Non-Destructive test

1. Rebound hammer test

Rebound hammer test is used to determine the quality and in-situ strength of concrete. It is conducted as per IS 13311-1992 part 2. The results of different concrete mixtures was found out at 28 days and are shown in fig 9.

Table- XVI: Rebound hammer test

S.No	Mix Design -ation	Travel time (μs)	Length travelled (mm)	Pulse velocity (mm/μs)	Remarks (as per IS 13311-1992 part 1) (28 days)
1	M	40	150	3.75	Good
2	M1	52	150	2.88	Good
3	M2	47	150	3.19	Good
4	M3	39	150	3.84	Good
5	M4	42	150	3.57	Good

(d) Rebound hammer

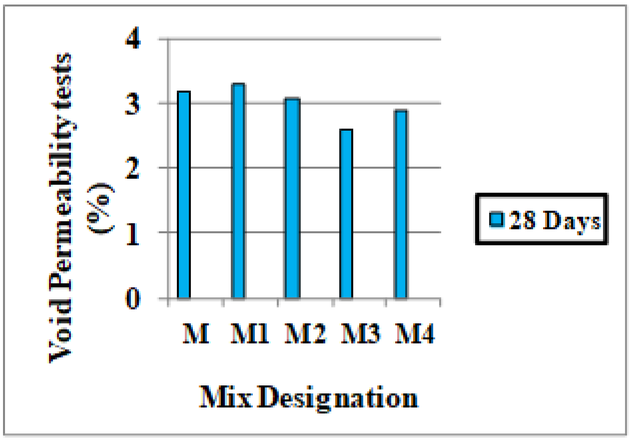

Fig.9. Rebound hammer test

2. Ultra sonic pulse velocity test

UPV is used to determined the quality of concrete. The test was conducted as per IS 13311-1992 (part 1) and the grade of concrete as excellent, good medium and doubtful. The results of different concrete mixtures was found out at 28 days and are shown in fig 10.

Table- XVII: Ultra sonic pulse velocity test

S.No	Mix Designation	Average Compressive strength N/mm^2	Remarks (as per IS 13311-1992 part 2) (28 days)
1	M	32.33	Good layer
2	M1	30	Good layer
3	M2	33	Good layer
4	M3	36	Good layer
5	M4	31.33	Good layer

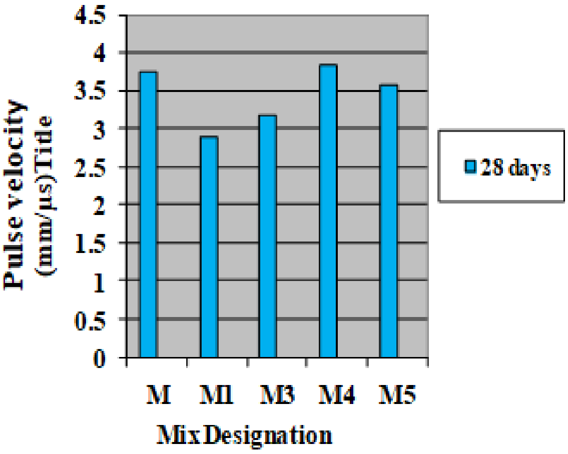

Fig.10. Ultrasonic pulse velocity test

V CONCLUSION

This work is mainly aimed at doing lot of trial an error method which give some ideas about High performance concrete. Replacing of Ordinary Portland Cement by industrial byproducts promote Eco safely disposal of byproduct which are produced in larger quantities by various manufacturing units.

1. The outcome shows that mixing (blend) of concrete doesn't give up the strength of concrete.
2. It is recognized that addition of 10% of ggbs have increased the strength at all ages.
3. Compressive strength of cubes shows that, the M3 (50% cement, 25% fly ash, 7.5% RHA,7.5 % silica fume and 10% ggbs) mix gives optimum strength at 28 and 56 days.
4. The optimum Split Tensile Strength has been increase from 5.11 to 5.60 N/mm^2 for 28 days and for 56 days from 5.47 to 6.17 N/mm^2 for at mix M3.
5. Flexural strength of concrete increases in mix M3.
6. There is a deviation after acid curing. The mix M3 strengthen to resistance H_2SO_4 acid attack.
7. Modulus of elasticity of concrete with mix M3 is Slightly higher than the controlled concrete.
8. In void permeability mix M3 get low percentage of permeability of voids compared to others.
9. In Non Destructive Tests all the mix gets good layer as per IS 33111- 1992 code part 1 and part 2, but the optimum value obtained for mix M3.

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