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International Journal of Innovative Research in Technology, Science & Engineering (IJIRTSE)
ISSN: 2395-5619, Volume – 1, Issue – 6. August 2015

EXPERIMETNAL INVESTIGATION ON FUNCTIONALY GRADED MATERIAL IN HPC WITH FLY ASH

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***Abstract*— Generally, concrete is used in the construction field suffers from lack of durability and homogeneity. Cement is the only binding material in concrete and due to increasing price, researchers have been looking for apt substitute for that. By consideration of economy, strength and anti-corrosion, functionally graded material (FGM) has developed. FGM having one layer of high performance concrete and another of flyash concrete. The flexural behavior FGB has analyzed experimentally with variation in interface as 0, 50, 75 and 100mm from bottom. In this study, Flyash has prepared with replacement of cement by 35 and 55 % with fly ash for M60 grade of concrete. It has seemed that there is increase in compressive and flexural strength of FGM. The bond strength FGM cube is optimum at neutral axis i.e, 50 mm depth. As FGM is economical, having better performance of durability and strength, so it enables more sustainability in concrete industry.**

Keywords: Functionally graded material, bond strength, anti corrosion

I. INTRODUCTION

High Performance Concrete is generally cement based composite material and it is produced by using the mineral admixture and chemical admixtures. HPC can be considered as an appropriate material for the construction of vast infrastructural facilities. With the availability of mineral and chemical admixtures in the country, use 0f HPC is expected rapidly in the future development. High Strength Concrete with water cement ratio of 0.35 to 0.45 and compressive strength in the range of 40 MPa to 60 MPa are usually made by using super plasticizer with or without mineral admixtures. This type of concrete finds its applications in heavily reinforced sophisticated structural elements such as tall buildings, offshore structures, long span bridges and heavy pavements. Advance in material amalgamation technologies, the development of a new type of materials called functionally graded materials (FGM), with promising applications in aerospace, infrastructure, energy electronics and biomedical engineering. Due to hike of cement, Fly-Ash enhances the workability, compressive strength, flexural strength, pumpability, durability and concrete finishing. So its use in designing of FGM makes it more economical as compared to normal high performance concrete or fly ash concrete. Structural Engineering Research Institute reported that HVFAC exhibited higher strength at later ages and the flexural strength is higher for HVFAC whereas the bond strength for embedded rebar is nearly same for both the concretes but it shows very low chloride permeability and low water absorption and reduced water permeability, however better abrasion resistance as compared to OPC based concrete which increases the age of the concrete. Later many investigations were carried out to realize the full potential of FGM in the field of construction. As the concrete is weak in tensile strength, so it is economical to use FGB. FGM beam is designed with M60 grade above the interface and below with the HVFAC having 35 and 55 % replacement of cement with fly ash. The weakness of concrete such as shrinkage during coagulation and hardening, low tensile strength, poor crack resistance, brittleness, small ultimate extension and bad impact endurance, which prevails in concrete and limits its application, has been thoroughly dealt with in FGM.

II. MATERIALS USED

The details of materials used in the present investigation are shown below.

A) Cement

The properties of the cement used are given in Table 1.

B) Aggregates

Locally available river sand and crushed stone aggregates were used as fine and coarse aggregate respectively. The properties of these aggregates are given in Tables 2 & 3 respectively.

Table 1 Physical properties of cement

1 **SI NO**	2 **PHYSICAL PROPERTIES OF OPC 53 CEMENT** 3	4 **RESULT**	5 **REQUIREMENTS AS PER IS:8112-1989** 6
7 *1*	8 *Specific gravity*	9 *3.15*	10 *3.10-3.15* 11
12 *2*	13 *Standard consistency (%)*	14 *31.5%*	15 *30-35* 16
17 *3*	18 *Initial setting time (hours, min)*	19 *91min*	20 *30 mins (minimum)* 21
22 *4*	23 *Final setting time (hours, min)*	24 *211 mins*	25 *600 mins (maximum)* 26
27 *5*	28 *Compressive strength N/mm2 at 28 days*	29 *58 N/mm2*	30 *53 N/mm2 minimum* 31
32 *6*	33 *Fineness (m^2/kg)*	34 *337*	35 *225* 36

Table 2 Properties of fine aggregate

PARAMETER	**OBTAINED**	**CODAL**	**REMARKS**
Specific Gravity	*2.65*	*2.60-2.80*	*IS 2386 Part 3*
Materials Finer than 75 micron (% by weight)	*1.00*	*3 Max*	*Satisfied*
Water absorption	*1.01%*	*0.1-2%*	*IS 2386 Part 3*

Table 3 Properties of coarse aggregate

PARAMETER	***OBTAINED***	***CODAL SPECIFICATION***	***REMARKS***
Specific gravity	2.71	2.5-3	IS 2386 Part 3
Water absorption	0.53	0.1-2%	IS 2386 Part 3

C) FLYASH

A class 'C' flyash was used in this present investigation and the properties are given in Table 4.

Table 4 Properties of flyash

SI NO	***COMPONENTS***	***IS: 3812 (1981) Specifications, %***	***Fly ash used, %***
1	*SiO2 + A1203 + Fe203*	*70min*	*99 . 0 - 99.1*
2	*SiO, (alone)*	*35min*	*58,8 . - 59.1*

3	*MgO*	*5max*	*0.22-0.34*
4	*Total sulphur as SO3*	*2.75 max.*	*-*
5	*Alkalies as Na,O*	*1.5mx*	*0.5*
6	*CaO*	*-*	*0.86 - 1.02*
7	*K20*	*-*	*0.05-0.71*
8	*Specific gravity*	*2.31*	*-*

D) MIX PROPORTION

After conducting tests on trial mixes, the final proportion arrived at was 0.35:1.12:3.43 to get a compressive strength of 60 MPa without fly ash.

Table 5 Mix proportion of M60 grade of concrete

Material	**Requirement per m^3**	**Mix Proportion**
Cement	*423 kg*	*1*
Fine aggregate	*474 kg*	*1.12*
Coarse aggregate	*1453 kg*	*3.43*
Water	*185 litres*	*0.35*
Chemical admixture	*9 kg*	*0.02*

E) EXPERIMENTAL DETAILS

Table 6 Designation of concrete mix

37 **SI NO**	38 **MIX IDENTIFICATION**	39 **CONCRETE MIX PROPORTION** 40
41 *1*	42 *M61*	43 *M60 GRADE OF CONCRETE WITH 100% CEMENT + 0% FLY ASH* 44
45 *2*	46 *M62*	47 *M60 GRADE OF CONCRETE WITH 65% CEMENT + 35% FLY ASH* 48
49 *3*	50 *M63*	51 *M60 GRADE OF CONCRETE WITH 45% CEMENT + 55% FLY ASH* 52

Table 7 Details of FGM cubes

53 **M60 GRADE OF CONCRETE** 54			
55 *M62A*	56 *M62A1* 57	58 *M62A2*	59 *M62A3*
60	61 *M61 (100mm) + M62 (50mm)* 62	63 *M61 (75mm) + M62 (75mm)*	64 *M61 (50mm) + M62 (100mm)*
65 *M63A*	66 *M63A1* 67	68 *M63A2*	69 *M63A3*
70	71 *M61 (100mm) + M63 (50mm)* 72	73 *M61 (75mm) + M63 (75mm)*	74 *M61 (50mm) + M63 (100mm)*

III. EXPERIMENTAL RESULTS

In this investigation, the compressive strength of FGM cubes was determined at an interval of 7 and 28 days with the replacement of cement @ (35 and 55 %) with fly ash with changing an interface as 50, 75 and 100mm. Besides this flexural strength of 750x 150 x 150 mm3 prism of M60 Grade with above replacement of cement with FA had tested with variation in interface as 25, 50 and 100 mm. The bond strength with concrete cube is also tested at interface. The compressive strength and flexural strength of normal concrete, high volume fly ash concrete and FGM.

Figure 1 Position of interface

Figure 2 Concrete cubes with variying interface

1) Compressive Strength of Cubes

The compressive strength of cube dimension 150x150x150 mm3 of M60 grade of concrete is tested by the variation in interface from bottom. It has been shown that M62A1, M62FA2 have more compressive strength as compared to other cubes of M60 grade as per Table 8. It has been also seem that the cube having interface at the middle has more compressive strength as compared to other concrete cubes.

Table 8 Compressive strength of cubes (35% replacement of cement)

75 SI NO	76 DEPTH VARIATION FROM BOTTOM (mm)	77 COMPRESSIVE STRENGTH(N/mm2)	
		78 7DAYS	79 28DAYS
80 *1*	81 *M61*	82 *37.9*	83 *65.75*
84 *2*	85 *M62FA1*	86 *36.3*	87 *65.48*
88 *3*	89 *M62FA2*	90 *34.9*	91 *66.22*
92 *4*	93 *M62FA3*	94 *33.5*	95 *64.26*

Figure 3 Compressive strength of concrete M62 cubes

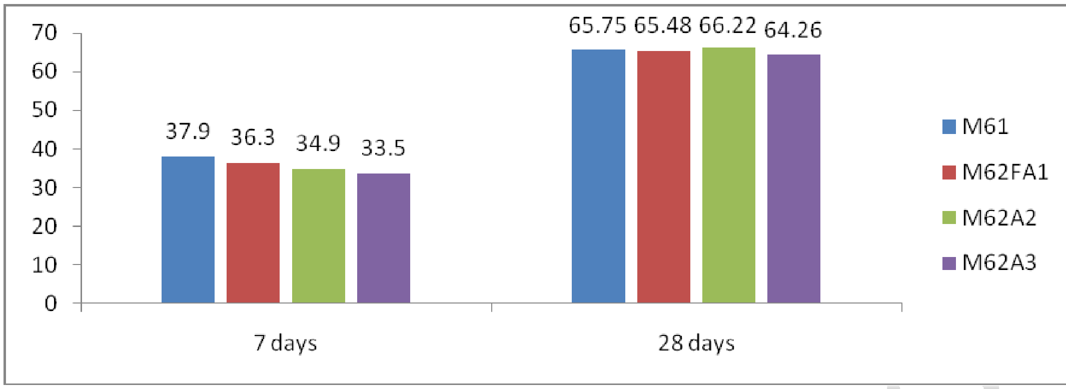

Table 9 Compressive strength of cubes (55% replacement of cement)

96 SI NO	97 DEPTH VARIATION FROM BOTTOM (mm)	98 COMPRESSIVE STRENGTH(N/mm2)	
		99 7DAYS	100 28DAYS
101 1	102 M61	103 37.9 104	105 65.75
106 2	107 M63FA1	108 34.8 109	110 65.1
111 3	112 M63FA2	113 33.1 114	115 65.22
116 4	117 M63FA3	118 31.6 119	120 63.2

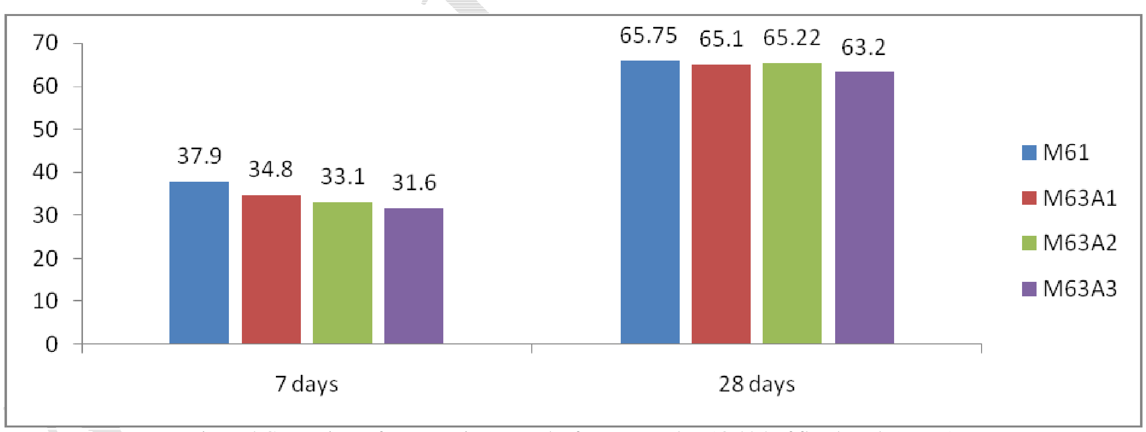

Figure 4 Comparison of compressive strength of concrete cubes (@55% of flyash replacement)

2) *SPLIT TENSILE STRENGTH*

Table 10 Tensile strength of cylinders (@35% replacement of cement)

SI NO	**DEPTH VARIATION FROM BOTTOM (mm)**	**SPLIT TENSILE STRENGTH (N/mm2)**	
		7DAYS	**28 DAYS**
1	*Conventional(0 mm)*	*2.35*	*4.45*
2	*100 mm*	*2.44*	*4.87*
3	*150 mm*	*2.3*	*4.42*
4	*200 mm*	*2.1*	*4.3*

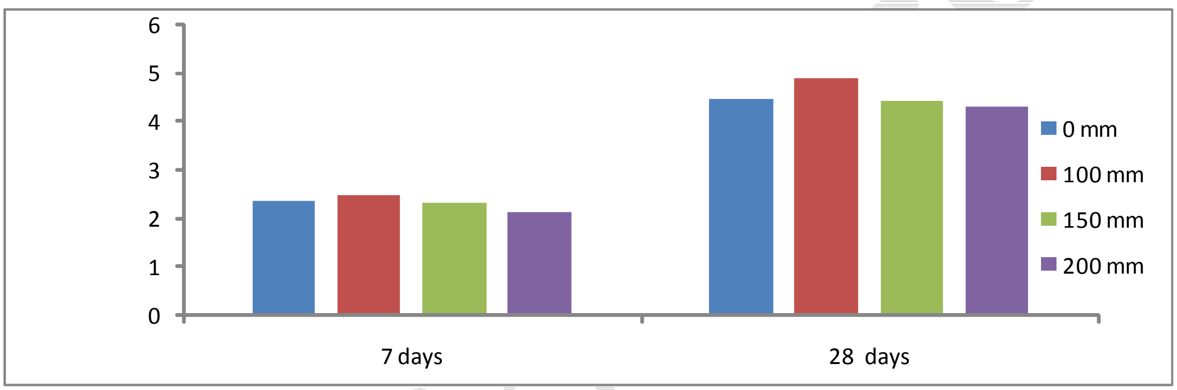

Figure 3 Comprasion of split tensile strength of cylinder (@35% replacement of cement)

Table 11 Split tensile strength of M63 cylinders

SI NO	**DEPTH VARIATION FROM BOTTOM (mm)**	**SPLIT TENSILE STRENGTH (N/mm2)**	
		7DAYS	**28 DAYS**
1	*Conventional(0 mm)*	*2.63*	*4.45*
2	*100 mm*	*2.51*	*4.42*
3	*150 mm*	*2.38*	*4.87*
4	*200 mm*	*2.08*	*4.32*

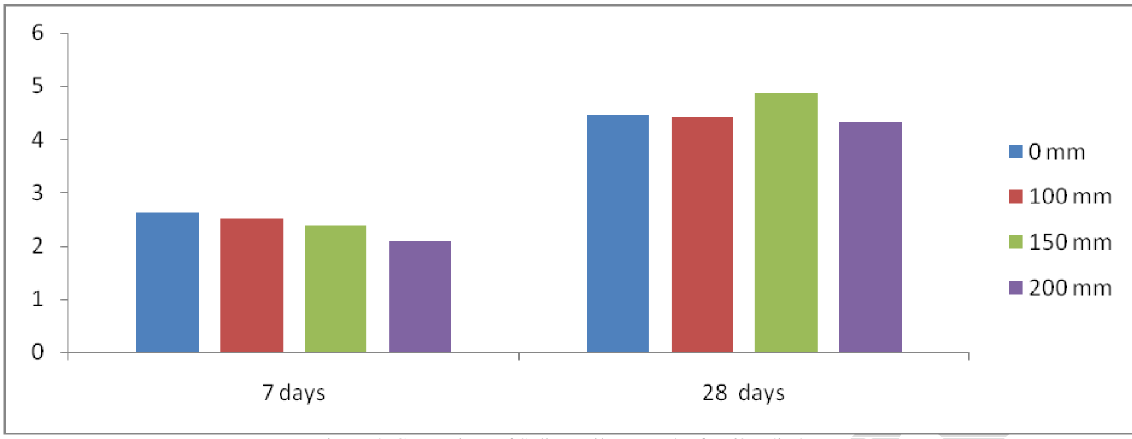

Figure 4 Comparison of Split tensile strength of M63 cylinders

3) FLEXURAL STRENGTH OF PRISM

The prism of dimension 750 X 150 X 150 mm was casted to find the flexural strength of the concrete and it has been resulted that 35% replacement of flyash with 50 mm depth has maximum flexural strength and it has been reduced with increase in amount of fly ash in FGM and also decreases with increase in the position of interface from bottom of prism.

Table 12 Flexural strength of M62 prism

173 **SI NO**	174 **AREA (mm2)**	175 **DEPTH VARIATION FROM BOTTOM(mm)**	176 **FLEXURAL STRENGTH(28 DAYS)**
177 *1*	178 *112500*	179 *M61* 180	181 *7.95*
182 *2*	183 *112500*	184 *M62A1* 185	186 *6.7*
187 *3*	188 *112500*	189 *M62A2* 190	191 *6.2*
192 *4*	193 *112500*	194 *M62A3* 195	196 *5.7*

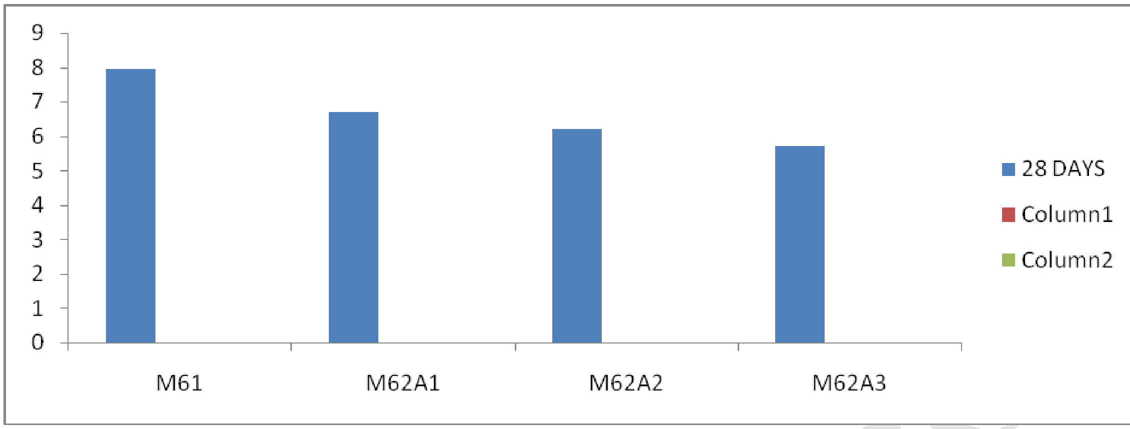

Figure 5 Flexural strength with position of interface of M62 mixes

Table 13 Flexural strength of M63 Mix of prism

197 SI NO	198 AREA (mm2)	199 DEPTH VARIATION FROM BOTTOM(mm)	200 FLEXURAL STRENGTH(28 DAYS)
201 *1*	202 *112500*	203 *M61* 204	205 *7.95*
206 *2*	207 *112500*	208 *M63A1* 209	210 *5.7*
211 *3*	212 *112500*	213 *M63A2* 214	215 *5.1*
216 *4*	217 *112500*	218 *M63A3* 219	220 *4.4*

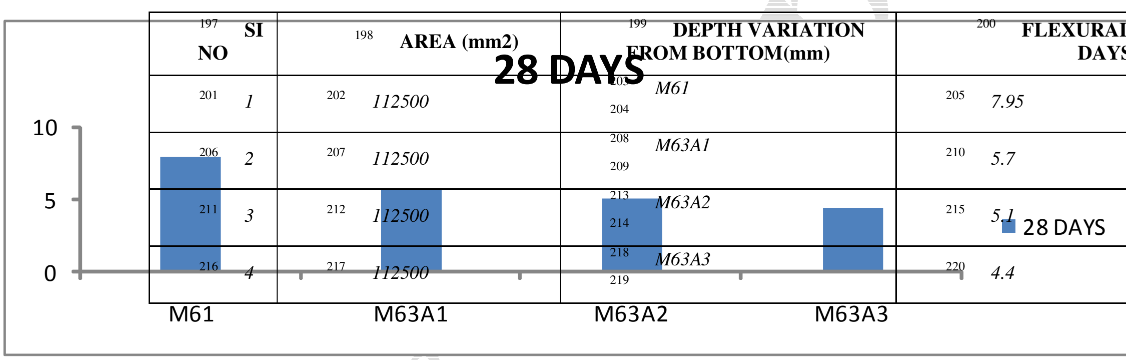

Figure 6 Comparison of Flexural strength of prism with position of interface M62 mixes

Figure 7 Testing of specimen

Figure 8 Testing of cubes (2000kN capacity)

Figure 9 Tesing of flexural strength of prism

Figure 10 Placing of prism in UTM

IV. CONCLUSION

1) HPC mixes using 53 grade cement and class 'C' flyash as cement replacement @35% having mean compressive strength greater than 65 MPa at 28 days, have been made and studied .
2) The paper suggest that FGM cubes having interface at the middle have more compressive strength as compared to conventional concrete.
3) And it has also been seem that the flexural strength decrease with increase in interface from bottom, it could not have sufficient strength to resist the loading.
4) So it has been determined that the FGM concrete having interface at the middle and fly ash concrete formed by replacement of 35 % of cement by fly ash is having better result as compared to others but for concrete having 55 % replacement of cement with fly ash have same compressive strength as that of normal grade of concrete. So, for FGM concrete high volume fly ash concrete can be used at half of the depth.
5)

V. SCOPE OF WORK

To improves economy in cement production & construction by partial substitution of cement by fly ash.

Also improves the fresh and hardened properties of concrete.

And enhances the durability characteristics

Safe disposal of industrial waste material and Protecting the environment from pollution.

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