iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** III **Month of publication:** March 2019

DOI: http://doi.org/10.22214/ijraset.2019.3069

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue III, Mar 2019- Available at www.ijraset.com

Experimental Investigation on Strength and Durability of Concrete using High Volume Flyash, GGBS and M-Sand

P. Priya Rachel
Professor, Department of Civil Engineering , St. Peter's College of Engineering and Technology, College Road, Avadi, Chennai - 600 054, Tamil Nadu, India

Abstract: The study focuses on the partial replacement of concrete with industrial by products such as High volume flyash and Ground granulated blast furnace slag with full replacement of aggregate with M-Sand. Studies have been carried out on the characteristics compressive strength, tensile and flexural strength of concrete, produced using HVFA and GGBFS in the ratio of 0%, 30%, 40% and 50% by the weight of the cement and 100% replacement of M-Sand. Based on the trial method a suitable mix proportion was arrived. Mix designs for M40 grade concrete as per Indian code specifications (IS10262-2007) was carried out. The durability property such as Rapid Chloride Penetration Test, Sorptivity Test and Water Penetration Test were studied for a period of 56 days. The optimum compressive strength with 30% HVFA in 56 days is 53.83N/mm^2 and the optimum compressive strength with 50% GGBS in 56 days is 58.17 N/mm^2.The investigation also showed that the other mechanical property such as flexural strength, split tensile strength gives better results with optimum replacement of High Volume Flyash and Ground Granulated Blast furnace slag. The durability properties like Rapid Chloride Penetration Test, Sorptivity Test and Water Permeability Test showed good results. The promotional use of manufactured sand, High Volume Flyash and Ground Granulated Blast furnace slag will conserve the natural resources for the sustainable development of the concrete in construction industry.
Keywords: M-Sand, High Volume Flyash, Ground Granulated Blast furnace slag, Strength, Durability.

I. INTRODUCTION

The suitable and widely used construction material is concrete which is composed of Portland cement, Aggregates and Water. The production of cement is an energy intensive process and it results in emission of carbon di oxide polluting the atmosphere and depleting the raw material (limestone). Various attempts have been made to reduce the carbon di oxide emission relating to concrete by partial replacement of cement with by products such as flyash and GGBFS. The usage of industrial by products as additives increases the strength and decrease the environmental impact of concrete. Fly Ash is one of the pozzolanic materials generated by burning coal in thermal power plants and Ground Granulated blast furnace slag (GGBFS) is a byproduct obtained by the manufacture of pig iron in blast furnace. Instead of disposing this huge amount of fly ash and GGBFS in land, it can be effectively used as a replacement in concrete. The utilization of natural river sand depletes the resources and restriction due to environmental consideration has made concrete manufactures to go for suitable alternative fine aggregate. One such alternative is "Manufactured sand". Previous studies by Jayeshkumar Pitroda et.al[11], Rafat Siddique et.al[17]; Yogendra O.Patil et.al[21], Mahesh Patel et. al [13], has shown that HVFA and GGBS are suitable replacement for cement**.** M-Sand has been tried as a fine aggregate in the production of concrete**.** In the present research attempt has been made to partial replace concrete with industrial by products such as High volume flyash and Ground granulated blast furnace slag with full replacement of aggregate with M-Sand.

II. EXPERIMENTAL PROGRAMME

A. Materials Used

1) *GGBS and Flyash:* High volume flyash of Class F Fly ash conforming to IS 3812-1999[31] from ennore Thermal Power Plant and GGBFS is used as mineral admixture for partial replacement of cement. Class F Fly Ash is normally produced from burning anthracite or bituminous coal that meets the applicable requirements. Specific Gravity of flyash was performed using Le-chatelier flask apparatus. The specific gravity of flyash is found to be 2.14 and the specific gravity of GGBFS is 2.85. The properties of material are shown in Table 1.
2) *M-Sand:* Sand which is also known as factory sand or artificial sand is a type of sand used as a replacement for natural sand in

every construction industry today. Manufacture sand for the experimental program was locally procured.

3) *Cement:* Ordinary Portland cement of grade 53 confirming to IS8112:1989[30] with specific gravity 3.15 was used. The properties of cement are tested by referring IS 12269-1987[29] specification of 53 grade Ordinary Portland Cement. The cement replacement was in the ratio 0%, 30%, 40% and 50%.
4) *Fine Aggregate:* Fine aggregate used is manufacture sand. Manufacture sand for the experimental program was locally procured and confirmed to Indian Standard Specification IS: 383-1970[28]. The manufacture sand confirming to zone II was used.
5) *Water:* Portable water from local area was used for mixing and curing.

TABLE 1
Properties Of Material

Property	Cement	M Sand	Coarse Aggregate(12mm)	Coarse Aggregate(20mm)
Specific Gravity	3.15	2.55	2.73	2.76
Normal Consistency	30%	-	-	-
Initial setting time	30min	-	-	-
Final Setting Time	600min	-	-	-
Water Absorption	-	2.67%	0.50%	0.33%
Bulk Density	-	1903Kg/m^3	1556Kg/m^3	1612 Kg/m^3
Fineness Modulus	-	3.52	2.42	3.08
Grading Zone	Zone II	Zone II	Graded Aggregate	Single size Aggregate

6) *Mix Proportion:* The concrete mix was designed as per IS 10262-2009[32]. The grade of concrete adopted was M40 with the water cement ratio of 0.36 and 0.38. The target mean compressive strength was 48.25 MPa. The mix proportions is shown table 2. The ordinary Portland cement was partially replaced with High volume flyash in various proportions (i.e.) 30%, 40%, and 50% and 100% M-sand was used to replace ordinary river sand. Similarly ordinary Portland cement was partially replaced with GGBFS in various proportions (i.e.) 30%, 40%, and 50% and using 100% replacement of M-sand for Ordinary river sand. The concrete mixes and cubes were prepared with reference to IS 516:1959[33] and tested for their compressive strength, split tensile strength and flexural strength.

TABLE 2
MIX PROPORTIONS (FOR 1M^3)

Mineral Admixture	HVFA				GGBFS			
Grade	M40				M40			
Mix Designation	Mix1 (0%)	Mix 2 (30%)	Mix3 (40%)	Mix4 (50%)	Mix1 (0%)	Mix 2 (30%)	Mix 3 (40%)	Mix 4 (50%)
OPC	475	335	285	240	450	315	270	225
Flyash /GGBFS	-	140	190	235	-	135	180	225
Coarse Aggregate (12mm)	443	430	425	420	449	445	444	443
Coarse Aggregate (20mm)	673	653	646	638	721	714	712	711
M-Sand(Kg)	675	654	647	636	685	678	677	676
W/C ratio	0.36	0.36	0.36	0.36	0.38	0.38	0.38	0.38

7) *Durability of Concrete:* Durability of concrete may is the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Specimens were also fabricated in order to evaluate the durability performance of HVFA concrete and GGBS concrete. Rapid Chloride Penetration Test, Sorptivity Test and Water Permeability were performed using the concrete mix.

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III.RESULTS AND DISCUSSION

A. *Compressive Strength of Concrete*:

The compressive strength of concrete is not significantly affected by the presence of fly ash at low and moderate levels of replacement[15]. Also a good fly ash can act as a superplasticizing admixture when used in high-volume[12,15,17]. The value of compressive strength of HVFA concrete and GGBS concrete is shown in figure 1 and 2. The compressive strength variation for conventional concrete specimen was found to be 40.10 N/mm^2 to 48.50 N/mm^2 for 14, 28 and 56 days of testing. The replacement of cement with HVFA resulted in a strength variation of 37.82N/mm^2 to 50.76 N/mm^2. The ultimate strength achieved by the concrete increases with increasing fly ash content, with replacement levels up to 30%.The strength at 30% replacement of HVFA is found to be 53.73 N/mm^2. High early strength and optimum strength was achieved by replacing with 30 % HVFA and 100% M-Sand. However, as the HVFA content increased beyond 30%, the compressive strength decreased.

Similarly for 30%, 40% and 50% replacement with GGBFS and M-Sand the compressive strength varies from 29.81N/mm^2 to 58.17 N/mm^2. The strength properties of concrete increases as the GGBS content increased up to an optimum point. The optimum level of GGBS content for maximizing strengths is about 50% of cement content. As the curing period increases the strength of specimen increase and this is due to the slow pozzolonic reaction (Abhijeet Kosht et al., 2018).

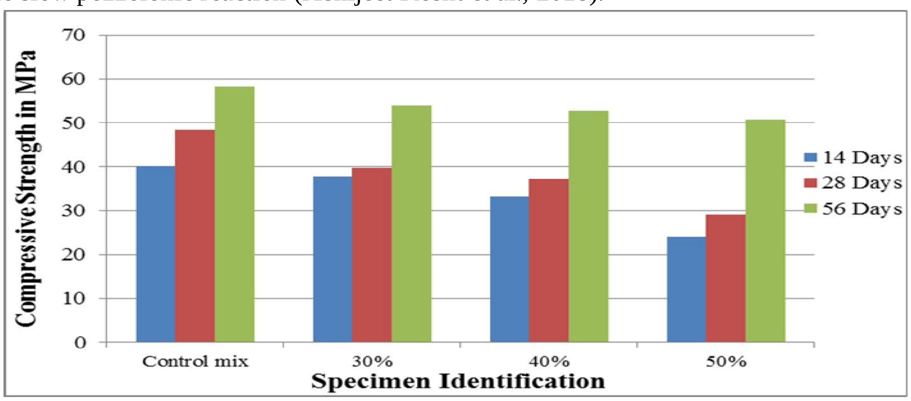

Fig1 Compressive strength results for replacement with HVFA and M Sand

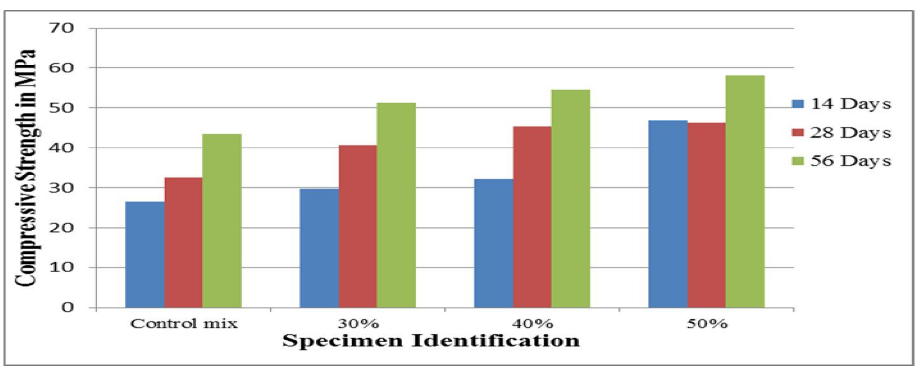

Fig 2 Compressive strength results for replacement with GGBFS and M Sand

B. *Split Tensile Strength of Concrete*

The splitting test is believed to give a close representation of the true tensile strength of concrete (Zhou et al., 1998). The split tensile strength decreased with the increase fly ash (Soni et al., 2014). Figure 3 and 4 shows the split tensile strength variation for HVFA and GGBS. It can be observed that there is a gradual decrease in the split tensile strength as the percentage of fly ash increases. With 30% replacement of fly ash in cement and M Sand as fine aggregate the average split tensile strength of the specimen is 6.04 N/mm^2. Gradually the split tensile strength of the specimens decreases with 40% and 50% replacement of fly ash in cement as 4 N/mm^2 and 3.49 N/mm^2 respectively. The optimum replacement of fly ash is 30% in cement with M Sand as fine aggregate. Similarly with 50% replacement of GGBFS the split tensile strength of specimen varies from 2.85 N/mm^2 to 5.0 N/mm^2. From Figure 4, it is observed that at about 50% replacement of cement with GGBS, concrete attains its maximum split tensile strength for M40 grade, when the replacement exceeds 40%, the compressive strength is found to be decreasing slightly (Santosh Kumar Karri et al., 2015). The variation in strength was comparable to that of the strength obtained for control mix.

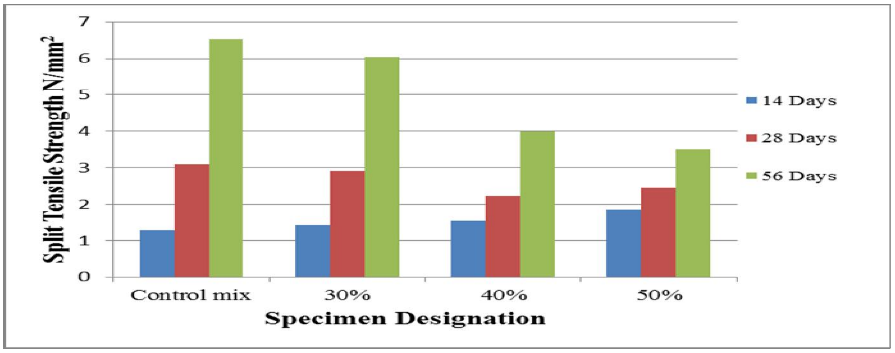

Fig 3 Split Tensile strength results for replacement HVFA and M Sand

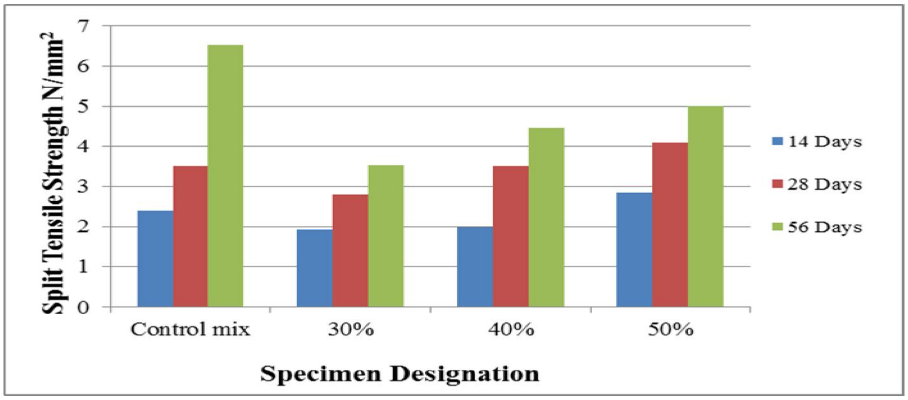

Fig 4 Split Tensile strength results for replacement GGBS and M Sand

C. Flexural Strength of Concrete

The flexural test is one measure of the tensile strength of unreinforced concrete to resist failure in bending (T. Ch. Madhavi et al., 2014). From the study of Tamilarasan V. S., P. Perumal it is found that 30% replacement of cement with GGBS gives maximum increase in strength. When super plasticizer was added to concrete, it was found that 40% replacement of cement gives maximum increase in strength for M20 and M25 grade concrete .With an optimum replacement level of 30% fly ash in cement and M Sand as fine aggregate the average flexural strength of the specimen is 6.11 N/mm^2. Decrease in flexural strength is observed from Figure 5 for a replacement of 40% and 50% HVFA. The flexural strength observed for 50% replacement with GGBS is found to be optimum with an strength of 9.8 N/mm^2 .From Figure 6 it is observed that the variation in strength was greater than that of the strength obtained for control mix**.**

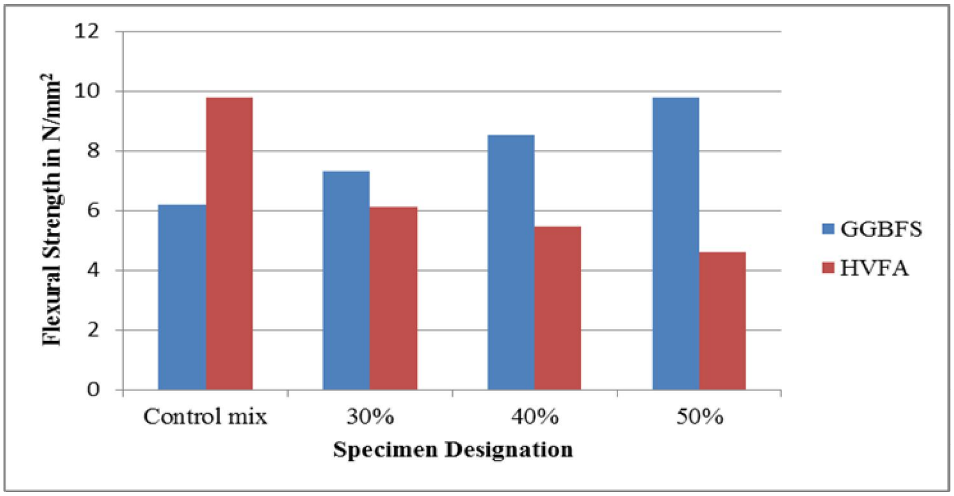

Fig 5 Flexural Strength results for concrete specimen at 56 days.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
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D. Sorptivity Study

The measurement of sorptivity could be used as an indicator of durability [8, 10, 15]. The lower the sorptivity value, the higher the resistance of concrete towards water absorption. It mainly depends on the pore distribution and micro structural properties of concrete i.e. water could be transported through the pores by capillary action or by diffusion in both capillary and gel pores[1]. The sorptivity values are least due to lower amount of water in the mix, resulting in lower porosity. The observed range of sorptivity from Figure 6 for mixes replaced with HVFA lies between 0.0178 to 0.1336 mm/sec and the range of sorptivity for GGBS replaced concrete is found to be between 0.0496 to 0.2928 mm/sec. This shows that the concrete has less number of interconnected pores .The sorptivity is found to decrease as the cement replacement by flyash increases. Based on the results from Figure 6 with partial replacement of GGBS and M- Sand the sorptivity for control mix, 30% and 40% replacement is found to be low. It is clear that the unsaturated flow of fluids into the concrete for all mixes showed better results. The specimen shows less pores and hence the water absorption percentage will also be low.

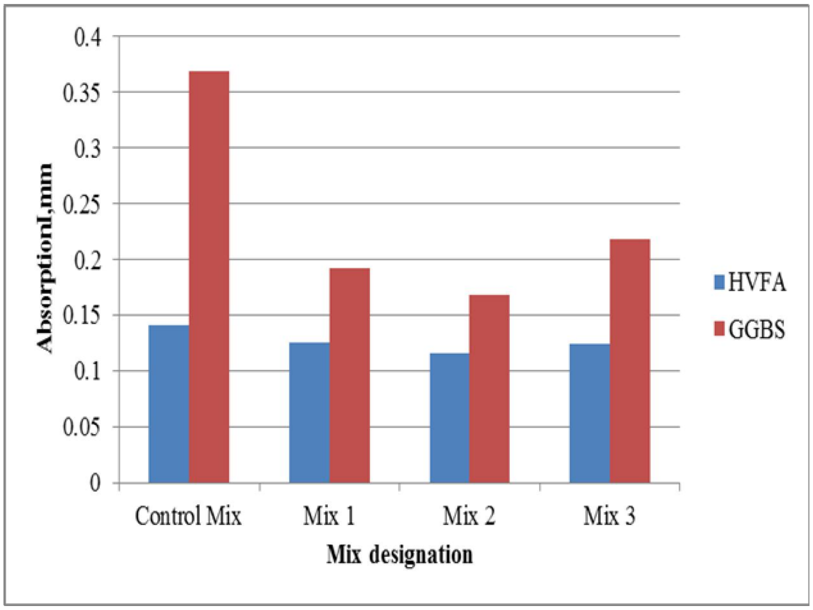

Fig 6 Sorptivity results for HVFA Concrete and GGBS Concrete with M Sand

E. Rapid Chloride Penetration Test

The chloride penetration causes a serious damage to the reinforcement present in the concrete (Christina Mary et al., 2015).The diffusion rate of chloride ions can be found out by RCPT apparatus. Based on the results from RCPT graph for HVFA and GGBS in Figure 7 and 8, the chloride diffusion range is in between 1000 – 2000 Coulomb and found to be low as per ASTM C1202[25].

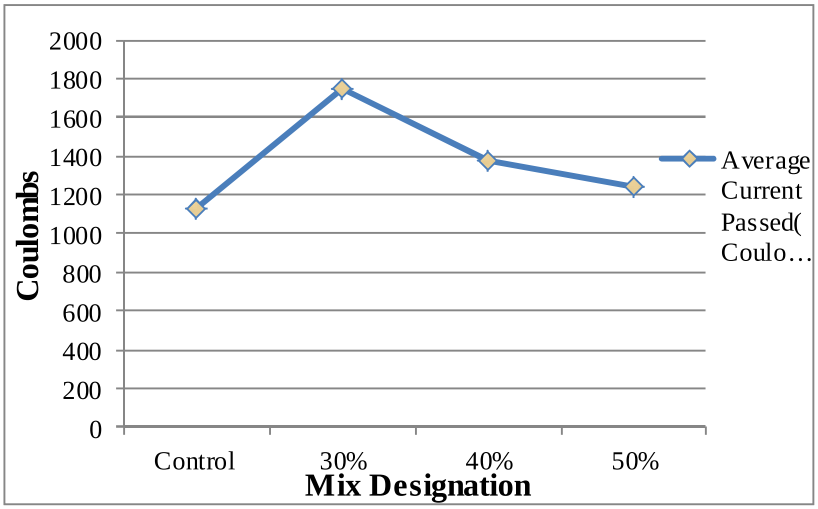

Fig 7 RCPT results for replacement with HVFA and M Sand

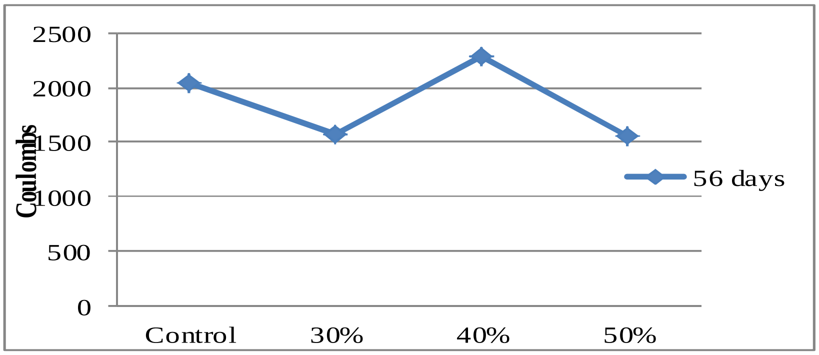

Fig 8 RCPT results for replacement with GGBS and M Sand

F. Water Absorption

This test is used to determine the permeability of concrete by evaluating the resistance of concrete against the penetration of water under hydrostatic pressure. The study of Zhao.Y et al (2014) shows that the water front moves deeper into the porous material with increasing applied pressure and with increasing duration of the sustained pressure. Applied pressure of 0.1 MPa has hardly any influence on water penetration .The concrete samples are subjected to 0.5 MPa (72.5 psi) of hydrostatic pressure over a period of three days and results observed are listed in Table 3. The maximum depth of penetration of water into the sample is measured. The results observed shows that hydrostatic pressure of 0.5 MPa has very little influence on the penetration, thus the specimen shows higher resistance to water under hydrostatic pressure. The replacement of part of the Portland cement by HVFA and GGBS in concrete resulted in much higher resistance with respect to water penetration. This can be due to the finer cementitious grains and the pozzolanic reaction.

TABLE 3

Water Permeability Results For Replacement With Hvaf And Ggbfs

S.NO	Specimen Identification	Penetration in mm	
		HVFA	GGBS
1	Control	7	7
2	Mix 1(30%)	5	6
3	Mix 2(40%)	7	5
4	Mix 3(50%)	9	8

IV. CONCLUSION

Following conclusions have been drawn from the experimental results of this study:

A. The compressive strength of HVFA with M-Sand as fine aggregate is 53.83 N/mm^2 for 56 days, which is much higher than the minimum requirement. The optimum compressive strength is achieved by adding 30% HVFA which saved the cement content by 30%.

B. The compressive strength of GGBS concrete with M-Sand as fine aggregate increases with the increase in % of GGBS and the optimum replacement observed from the result is 50% replacement of cement with GGBS and 100% replacement of fine aggregate with M-Sand.

C. The split tensile strength of HVFA concrete for 56 days is 6.04N/mm^2 at 30% replacement of fly ash. It can be observed from the results that there is a gradual decrease in the split tensile strength as the percentage of fly ash increases. The Split tensile strength of GGBS Concrete for 56 days is 5.0 N/mm^2. The optimum split tensile strength is achieved by adding 50% GGBS which saved the cement content by 50% and fine aggregate by 100%.

D. The optimum percentage replacement for flexural strength of HVFA and GGBS concrete based on the experimental results is 30% and 50% respectively .The flexural strength observed was 6.11N/mm^2 and 9.8N/mm^2 respectively. When the percentage of replacement of HVFA goes beyond 40% and 50% the strength considerably decreases. It is found that by partial replacement of cement with GGBS and full replacement of fine aggregate with M Sand helped in improving the strength of concrete compared to normal mix concrete.

E. The observed range of sorptivity from Figure 6 for mixes replaced with HVFA lies between 0.0178 to 0.1336 mm/sec and the range of sorptivity for GGBS replaced concrete is found to be between 0.0496 to 0.2928 mm/sec. The sorptivity value is found to be low and the resistance of concrete towards water absorption is higher.

F. The RCPT test results reveals that M40 grade concrete shows lower permeability when compared to conventional concrete with partial replacement of HVFA and GGBS and full replacement of M-sand.

G. The results show that an applied water pressure of less than 0.1 MPa has no influence on the water permeability. The replacement of part of the Portland cement by HVFA and GGBS in concrete resulted in a higher resistance with respect to water penetration.

H. Hence this research work concludes that, M-sand can be used as an alternative material for river sand and thereby the sustainability can be achieved. The usage of industrial by products increases the strength and decreases the environmental impact of concrete.

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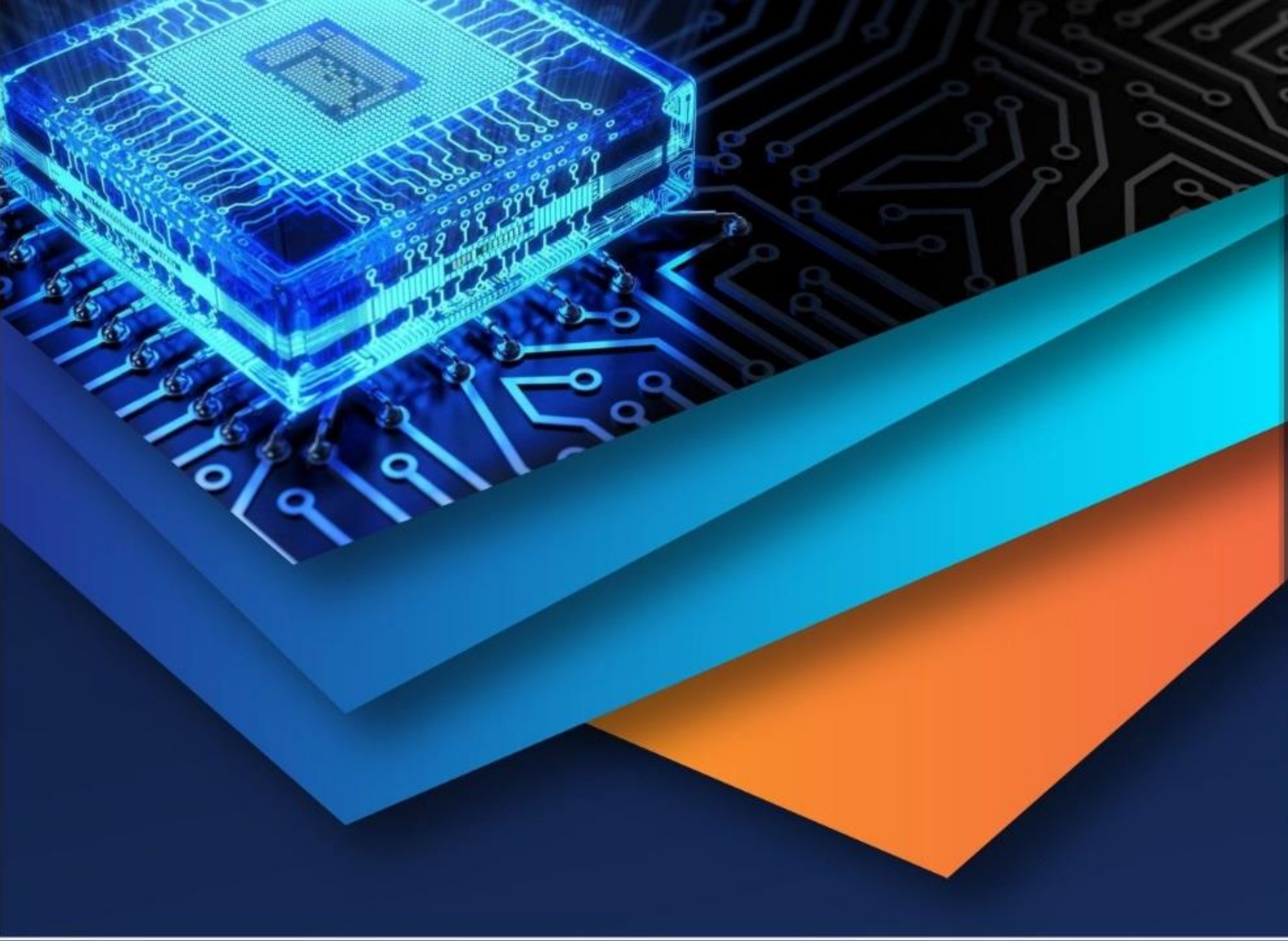

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