PERFORMANCE OF ADDITIVE BLENDED HIGH VOLUME FLY ASH CONCRETE- A SYSTEMATIC LITERATURE STUDY

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

This is to certify that the project report entitled **PERFORMANCE OF ADDITIVE BLENDED HIGH VOLUME FLY ASH CONCRETE- A SYSTEMATIC LITERATURE STUDY** is the bonafide record of training undergone by **R.K.SHOBAKIRUTHIKA (17CER167), S.SOWMINI(17CER174), M.SUBAASH(17CEL241)** in partial fulfillment of the requirements for the award of the degree of bachelor of engineering in Kongu Engineering College of Anna university, Chennai during the academic year 2020-2021.

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EXAMINER I **EXAMINER II**

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DECLARATION

We affirm that the project Report titled **PERFORMANCE OF ADDITIVE BLENDED HIGH VOLUME FLY ASH CONCRETE- A SYSTEMATIC LITERATURE STUDY** being submitted in partial fulfilment of the requirements for the award of the Bachelor of Engineering is the original work carried by us. It has not formed the part of any other project report or dissertation on the basis of which a degree or award was conferred on the earlier occasion on this or any other candidate.

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ABSTRACT

The replacing cement with fly ash has recently created huge popularity among the construction field because of its huge production, efficient resources and sustainability aspect in future. This study is made to determine the High-Volume fly-ash concrete (HVFC) performance by adding additives. The general use concrete mixture is prepared by proportioning fly ash (40-50%) as a replacement. The concrete specimen was found to have better compressive strengths and passed the strength tests. By incorporating additive Nano-SiO_2 and the superplasticizer the following compression, Flexural rigidity, splitting tensile strength and Elasticity modulus were observed in the specimen to establish the cement and fly ash bond. The concrete performance mix with replacement fly ash at different percent was found to have good compressive strength during test and stayed undamaged during the entire period of exposure.

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LIST OF SYMBOLS

Symbol	Description
M1	Mix proportion (0% fly-ash)
M2	Mix proportion (40% fly ash)
M3	Mix proportion (45% fly-ash)
M4	Mix proportion (50% fly-ash)
SiO_2	Silicon-dioxide
Al_2O_3	Aluminium-oxide
Fe_2O_3	Ferric-oxide
CA	Coarse aggregate
FA	Fine aggregate
SSD	Saturated-Surface-dry
MPa	Mega Pascal
GPa	Giga Pascal

CHAPTER 1

INTRODUCTION

1.1 HIGH VOLUME FLY ASH CONCRETE

Fly-ash, the remains collected from ignition of pummelled coal and gathered from electrostatic power stations wherein coal is used as main fuel source. The fly ash usage as opposed to unloading it as a non-use material can be mostly utilized on monetary grounds as cement for incomplete substitution of concrete and somewhat in view of its gainful impacts, for example, lower water interest for comparable usefulness, decreased dying and last lower development of warmth. It is being utilized especially in huge applications of solids cum enormous volume situation aiming at controlling development because of hydration warmth and furthermore helps at decreasing breaking at initial ages. HVFC has arisen as development material with its self-potential right. This sort of concrete typically contains over half fly-ash by a mass having absolute cement materials nature. Numerous specialists have utilized Class-C and Class-F fly-ash in concrete.

1.2 NEED FOR THE USE OF FLY-ASH IN CONCRETE

The gigantic increment of populace alongside the enormous improvement these days prompted the extraordinary demand for concrete these days. Kanvic's recommended that the Cement request will raise by around 660 MMT (million metric tons) in India by 2030. Cement which is the essential constituent of concrete contributes the significant CO_2 discharge into the climate and furthermore an unnatural weather change. To satisfy the emerging need, in this paper the high-volume fly ash solid execution joining added substances is to be broke down. To meet the need in future we use fly ash as a replacement of cement. Fly-ash is collected as residue of coal obtained from power stations. Cement is more expense and important part of concrete. The Cement cost for a unit can be decreased by fractional supplanting of concrete by fly-ash. Fly-ash removal is an important issue as unloading of fly ash as residue might lead to serious ecological issues/risks.

1.3 SOURCES OF FLY ASH

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue.

1.4 FACTORS AFFECTING HVFC

Workability-Slump Cone, addition of Fly ash increases workability when compared with conventional concrete with the same water content, Workability - Compaction Factor. In HVFAC, the compaction factor decreases with addition of fibres, Bleeding of Concrete. Setting Time. Age of exposure, Concrete mix design factors like Water to binder ratio, Binder and Fly ash content, Exposure conditions like CO_2 concentration and Relative humidity.

1.5 AIM AND OBJECTIVE

To make a systematic study on the performance of additive blended high volume fly ash concrete and to write a review paper. The objective of the project is that an exertion is carried out to introduce the consequences of conducting an examination completed to contemplate the impact of supplanting concrete with HVFC on the properties of cement and an exertion is made to examine the impact of nano-SiO_2 in improving the properties of high strength high HVFC.

1.6 SCOPE OF THE PROJECT

Analyzing and understanding the complete performance of additive blended high volume fly ash concrete. To write a journal paper by undertaking research on the performance of high-volume fly ash concrete under all circumstances. Undergoing the practical experimental works for the better results on high volume fly ash concrete.

CHAPTER 2

LITERATURE REVIEW

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Tarun.R.Naik, Shiw.S.Singh & Mohammad.M.Hossain, Abrasion resistance of concrete as influenced by inclusion of fly ash, 1994 - The difference between strength gain of fly ash and no-fly ash concrete diminished with age. Concrete mixture having 50% cement replacement with fly ash attained sufficient strength required for structural applications. The concrete mixtures showed excellent abrasion resistance. Abrasion resistance of concrete was primarily influenced by its compressive strength.

R. F. Feldman & G. G. Carette & V. M. Malhotra, Studies on Mechanism of Development of Physical and Mechanical Properties of High-Volume Fly Ash-Cement Pastes, 1990 - The blended cement pastes used in this work yielded relatively high mechanical properties at early times. Cement matrix and residual unreacted fly ash form a good mechanical bond. The formation of a relatively homogeneous hydrate product with low $Ca(OH)_2$ content or the formation of low c/s ratio CSH produces a stronger body.

V. Sivasundaram, G. G. Carette & V. M. Malhotra, Long-Term Strength Development of High-Volume Fly Ash Concrete, 1990 - The mass concrete block incorporating a low quantity of cement and a high volume of low calcium (ASTM Class F) fly ash has shown excellent results. The pulse velocity tests indicated the absence of internal cracks within the block, and the pulse velocity values were seen to increase gradually with age, with the development of strength. This type of concrete has excellent potential for use in massive concrete structures such as mat foundations, large retaining walls, piles, large columns and dams.

V. M. Malhotra, Durability of Concrete Incorporating High-Volume of Low-Calcium (ASTM Class F) Fly Ash, 1990 - Air entrained high-volume fly ash concrete has excellent durability characteristics as regards freezing and thawing cycling. The concrete offers considerable resistance to the passage of chloride ions and considerably reduces the expansion due to alkali-silica reaction.

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B. Balakrishnan & A.S.M. Abdul Awal, Durability properties of concrete containing high volume Malaysian fly ash, 2000 - Concrete without any fly ash has suffered the most deterioration in all the three chemical solutions. High volume fly ash had experienced some weight and strength loss, the values were much lower as compared to 0% fly ash concrete. The increased resistance of the high-volume fly ash concrete is suspected mainly due to consumption of the Ca (OH)2 which leads to reduced porosity and increased impermeability that prevented the migration of the detrimental chemical ions inside the concrete.

Serdar Aydın, Halit Yazıcı, Hu seyin Yigiter & Bulent Baradan, Sulfuric acid resistance of high-volume fly ash concrete, 2005 - The compressive strength at 1 day decreased sharply with the increasing amount of Class C fly ash replacement. Mechanical properties (splitting tensile strength and modulus of elasticity) of high-volume fly ash concrete at 28 days also decreased similar to compressive strength variation. Due to the progressive nature of pozzolanic reaction, all mechanical properties of high-volume fly ash concretes may improve at later ages.

Mustafa Sahmaran, Ismail O. Yaman & Mustafa Tokyay, Transport and mechanical properties of self-consolidating concrete with high volume fly ash, 2008 - The geometry and surface roughness of the fly ash affected the workability properties of SCC. Even though, replacing 60% and 70% Portland cement with fly ash resulted in considerable compressive and split tensile strength reductions at early ages, these reductions were partially off-set after 28 days. When evaluating the durability of

SCC by its transport properties as measured by all the tests, the addition of fly ash at high volumes seemed to be beneficial leading to a more durable concrete.

P. Van den Heede, E. Gruyaert & N. De Belie, Transport properties of high-volume fly ash concrete: Capillary water sorption, water sorption under vacuum and gas permeability, 2010 - For 28 and 91 days curing periods followed by preparatory drying at 105 C, capillary water sorption after 14 days for F50-4 is 32.6% and 44.4% lower than the value obtained. High quality HVFA mixtures mostly require a higher binder content and a lower W/B ratio, environmental benefit does not simply equal the cement replacement level applied.

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Halit Yazvcv, Serdar Aydvn, Hqseyin Yigiter & Bqlent Baradan, Effect of steam curing on class C high-volume fly ash concrete mixtures, 2004 - The compressive strength at 1-day decreased sharply with increasing content of Class C fly ash. At 50% of cement replacement with fly ash, the 3-day strength was 20 MPa, and, at 90-day, the strength was 60 Mpa. The setting times of high-volume fly ash cement pastes were somewhat prolonged; however, the set retardation was reduced by the use of superplasticizers. Steam curing will be required to develop adequate compressive strength for form removal at age 1-day.

Edward G. Moffatt, Michael D.A. Thomas & Andrew Fahim, Performance of high-volume fly ash concrete in marine environment, 2017 - High replacement levels of fly ash greatly increased the resistance to chloride-ion penetration. It is recommended that water-to-cementitious materials ratio of high-volume fly ash concrete must not exceed 0.40. HVFA concrete blocks with LWA showed significant surface deterioration, which resulted in a deeper chloride penetration than LWA (low weight aggregate) concrete and the HVFA concrete with normal-density aggregate. The decreases in chloride penetration in concrete containing high volumes of fly ash significantly outweigh any reported decreased in chloride threshold.

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Mahdi Arezoumandi, Michael H. Wolfe & Jeffery S. Volz, A comparative study of the bond strength of reinforcing steel in high-volume fly ash concrete and conventional concrete, 2012 - Load–deflection behavior of the HVFAC and CC beams was essentially identical. No significant difference between load-slip behavior of the HVFAC and CC specimens. Hence it appears that HVFAC possesses reinforcement bond strength comparable or slightly greater than CC.

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Peng Jiang, Linhua Jiang, Jie Zha & Zijian Song, Influence of temperature history on chloride diffusion in high volume fly ash concrete, 2017 - Different temperature histories were set to determine the chloride diffusion coefficient of HVFA concrete. For HVFA concrete, although the chloride diffusion coefficient was higher than ordinary concrete at early age, it would become small and even lower at 60 days. Higher accumulated temperature got higher compressive strength, better pore structure and lower chloride diffusion coefficient, but the difference became smaller after 28 days.

Okan Karahan, Transport properties of high-volume fly ash or slag concrete exposed to high temperature, 2017 - Transport properties of HVFA or slag concretes were studied after high temperature. Transport properties of concrete increased significantly after exposure to 400 C. Slag concrete behaved better than fly ash concrete for all high temperature. 30–50% fly ash or 50–70% slag replacement is optimal content for high temperature.

Hayder H. Alghazali & John J. Myers, Shear behavior of full-scale high volume fly ash-self consolidating concrete (HVFA-SCC) beams, 2017 - HVFA-SCC beams with low longitudinal reinforcement ratio possess superior shear strength capacity compared to CC beams. However, increasing the longitudinal reinforcement ratio does not show any obvious increasing trend on the normalized shear strength versus longitudinal reinforcement ratios; CC data from Ortega study. The lower aggregate fraction and aggregate size used in the HVFA-SCC, might affect the aggregate interlocking mechanism.

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Charith Herath, Chamila Gunasekara, David W. Law & Sujeeva Setunge, Performance of high-volume fly ash concrete incorporating additives, 2020 - HVFA concrete has low early age strengths above 60% cement replacements. HVFA concrete has a higher sulphate/acid/chloride resistance and a lower shrinkage. Higher the fineness of fly ash and additives, greater the reactivity and hydration. Nano silica significantly enhances the properties of HVFA concrete at all ages. Material combinations could be optimized to develop effective HVFA concretes.

Mahdi Arezoumandi & Jeffery S. Volz, Effect of fly ash replacement level on the shear strength of high-volume fly ash concrete beams, 2013 - Based on these findings, it appears that for reinforced concrete beams with 50% and 70% replacement of cement with Class C fly ash, the behavior is essentially identical to conventional concrete. The shape and progression of shear cracking was identical between the HVFAC and CC specimens, indicating a similar qualitative comparison between the response of the two materials.

Gengying Li, Properties of high-volume fly ash concrete incorporating nano-SiO2, 2003 – Fly ash has low initial activity, but the pozzolanic activity significantly increased after incorporating a little nanoSiO_2. This has been confirmed by the tests carried out on pozzolanic activity (weight change in lime solution) and hydration heat. According to the heating definition, concrete with 50% FA incorporating 4% nano-SiO_2 can reach ‘‘higher’’ about 61°C, which slightly lower than that of PCC about 65 jC and higher than that of HFAC about 51°C. It means an increase in temperature of 19% with respect to HFAC. The pozzolanic activity results (weight change) showed that nano-SiO_2 can activate fly ash, and the weight increment of fly ash incorporating nano-SiO2

(GSFA) at each tested age was higher than that of fly ash plus that of nano-SiO_2 (GS + GFA). Addition of nano-SiO2 to high-volume high-strength concrete leads to an increase of both short-term strength and long-term strength. SHFAC has an increase in 3-day strength of 81% with respect to HFAC, and the 2-year strength was 115.9 MPa higher than both of HFAC about 108 MPa and of PCC about 103.7 MPa. The addition of fly ash leads to higher porosity at short curing time, while nano-SiO_2, acting as an accelerating additive, leads to more compact structures, even at short curing times.

Rafat Siddique, Performance characteristics of high-volume Class F fly ash concrete, 2003 - The replacement of cement with three percentages of fly ash content reduced the compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of concrete at the age of 28 days, but there was a continuous and significant improvement of strength properties beyond 28 days. The strength of concrete with 40%, 45%, and 50% fly ash content, even at 28 days is sufficient enough for use in reinforced cement concrete construction. Abrasion resistance of concrete was strongly influenced by its compressive strength, irrespective of fly ash content. Abrasion resistance was found to increase with the increase in age for all concrete mixtures. Depth of wear was found to be maximum at 60 min of abrasion time for all mixtures.

CHAPTER 3

METHODOLOGY

3.1 PROCESS FLOW OF PROJECT

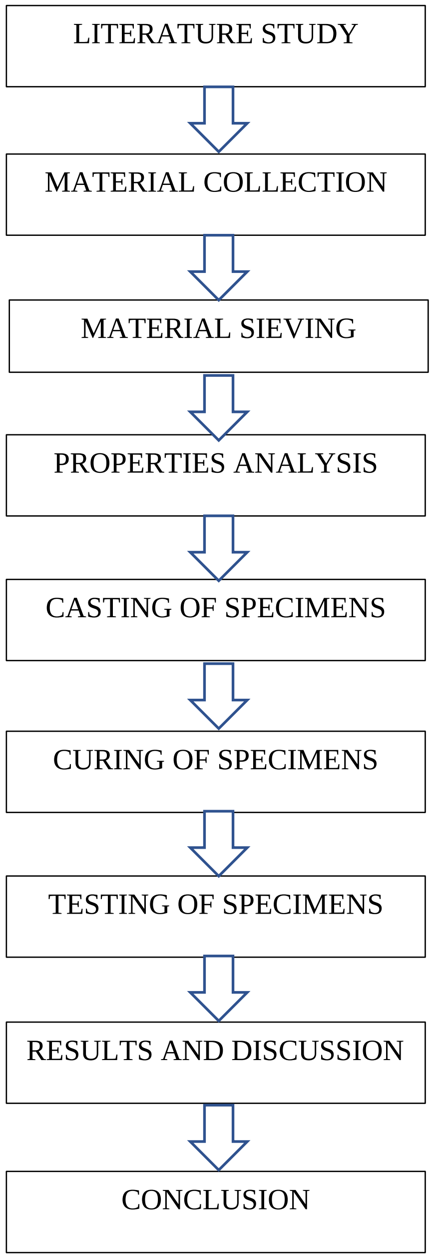


Fig: 3.1 Process flow of project

CHAPTER 4

MATERIALS USED AND ITS PROPERTIES

4.1 MATERIALS USED

- Ordinary Portland cement (grade 43)
- Fly-ash type Class-F
- Natural sand- 4.75-mm nominal
- Coarse aggregate- 12.5 mm nominal
- superplasticizer - melamine-based
- Nano-SiO_2 – additive (powdered form)

4.2 CEMENT

A **cement** is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is behind only water as the planet's most-consumed resource

Fig: 4.2 Cement

4.3 PROPERTIES OF CEMENT

Test conducted	Obtained Results	IS: 8112-1989 Requirements
Cement Fineness which is retained on 90-Am sieve	7.7	Maximum of 10
Cement Fineness: specific surface (m^2/kg)	266	Minimum of 225
Normal consistency	30 %	–
Vicat setting time (minutes) Initial time Final time	 107 197	 Minimum of 30 Maximum of 600
Strength due to Compression (MPa) 7 days 28 days	 34.9 45.1	 Minimum of 33.0 Minimum of 43.0
Specific gravity	3.15	–

TABLE 4.3: Cement properties

4.4 USES OF CEMENT

- To prepare cement mortar
- To prepare cement concrete
- To build fire proof and thermal proof structures
- To build hydrographic and frost resistant structures
- To build chemical proof structures
- As a grout material
- To construct Cement concrete roads
- To manufacture precast members
- For aesthetic concrete construction

4.5 FLY ASH

Fly ash or **flue ash**, also known as **pulverised fuel ash** or coal combustion residuals (CCRs), is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler's combustion chamber (commonly called a firebox) is called bottom ash. Together with bottom ash removed from the bottom of the boiler, it is known as **coal ash**. Depending upon the source and composition of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.

Fig: 4.5 Fly ash

4.6 PROPERTIES OF FLYASH

Chemical parameters	% of Fly ash	ASTM C 618 (%) Requirements
Silicon-dioxide, SiO_2	54.2	-
Aluminum-oxide, Al_2O_3	25.6	-
Ferric-oxide, Fe_2O_3	5.0	-
$SiO_2 + Al_2O_3 = Fe_2O_3$	84.7	Minimum of 70.0
Calcium-oxide	5.2	-
Magnesium-oxide	2.0	Maximum of 5.0
Titanium-oxide	1.27	-
Potassium-oxide	.58	-
Sodium-oxide	.43	Maximum of 1.5
Sulphur-trioxide	1.28	Maximum of 5.0
Ignition loss (1000 ºC)	1.68	Maximum of 6.0
Moisture	.26	Maximum of 3.0

Table: 4.6 Properties of Fly ash

4.7 PROPERTIES OF AGGREGATES

Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Aggregates collected is shown in fig 4.7.

Property	Fine aggregate	Coarse aggregate
Specific gravity of aggregate	2.61	2.79
Fineness modulus	2.27	6.59
SSD absorption	0.86%	1.10%
Voids	36.0%	39.8%
Unit-weight (kg/m^3)	1680	1613

Table: 4.7 Properties of aggregates

4.8 SIEVE ANALYSIS OF AGGREGATES

Fine aggregate			Coarse aggregate		
Sieve number	% passing	IS: 383-1970 Requirements	Sieve sizes	% passing	IS: 383-1970 Requirements
4.75 mm	95.4	90-100	12.5 mm	97	95-100
2.36 mm	92.7	85-100	10 mm	69	40-85
1.18 mm	77.0	75-100	4.75 mm	5	0-10
600 mm	61.1	60-79			
300 mm	34.3	12-40			
150 mm	5.7	0-10			

Table: 4.8 Sieve analysis of aggregates

4.9 PROPERTIES OF NANO-SiO_2

Silicon dioxide nanoparticles, also known as silica nanoparticles or nano-silica, are the basis for a great deal of biomedical research due to their stability, low toxicity and ability to be functionalized with a range of molecules and polymers. Nano-silica particles are divided into P-type and S-type according to their structure.

Type	Total surface area/unit mass (m^2/g)	pH-value	Average size of the particle (nm)	SiO_2 content (%)	Density of Surface (g/ml)
Class F	100±25	6.5-7.5	10-25	≥ 99.7	≤ 0.15

Table: 4.9 Properties of nano- SiO_2

Fig 4.7 Sieve analysis of aggregates

CHAPTER 5

MIX PROPORTION AND CASTING

5.1 MATERIAL MIXING

In the study, a combination M1 is planned per, IS:10262-1982 is casted and found with 28th day strength of compression as 37.2 MPa as a conventional concrete. The other three specimens are casted by substituting cement in concrete by 40, 45 and 50% mass of Class-F fly-ash with differing superplasticizer measurements for every example projecting. Maintaining the constant quantity of additive nano-SiO2 for every sample mixture ratio. In doing as such, water-cement material proportions were kept practically same, so as to explore concrete impacts due to the substitution with high Class-F fly-ash when different boundaries are nearly maintained same. The fig.5.1 represents the material mixing.

Fig 5.1: Materials mixing

5.2 CONCRETE MIX PROPORTION

Properties of Freshly casted concrete namely Slump, temperature, unit weight is determined per IS: 1199-1959.Table 5.2 represents the mix proportion of concrete. Fig 5.2 represents mixing of specimens.

Fig 5.2 Mixing of concrete

Mixture number	M1	M2	M3	M4
Fly-ash	0 %	40 %	45%	50 %
Cement in kg/m^3	405	230	210	200
Fly-ash in kg/m^3	0	170	185	190
Water in kg/m^3	165	161	165	161
W/ (FA+C)	.41	.40	.41	.40
SSD aggregate (kg/m^3)	615	613	609	615
CA (kg/m^3)	1227	1225	1227	1226
SP(Superplasticizer) (l/m^3)	2	2.2	2.4	2.5
Nano-Sio_2	20	20	20	20
Slump in mm	60	80	85	95
Air-content in %	3.1	3.5	3.4	3.5
Air-temperature in ^oC	26	25	27	25
Temperature of concrete (^oC)	29	27	28	29
Density of Concrete (kg/m3)	2405	2397	2401	2400

TABLE 5.2 Mix proportion of concrete.

5.3 SPECIMENS TO BE CASTED

Compression strength is tested with 150×150mm size concrete cubes. Cylinders of size 150×300-mm is tested for split tensile strength, beams of 101.4×101.4× 508-mm is tested for flexural strength and cylinders of size 150×300-mm is used for testing elasticity modulus. Every concrete example was set up as per IS: 516-1959. In the wake of projecting, specimens are covered using plastic sheets, they are left free in projecting space for a period 24 hrs with 24 ±1 ^oC temperature. They are demoulded after a day (24 hrs) and are immersed into the water-storing room till the test hour. The specimens casted is shown in fig 5.3.

Fig 5.3: Casted specimens

CHAPTER 6

RESULTS AND DISCUSSION

6.1 TESTS TO BE CONDUCTED

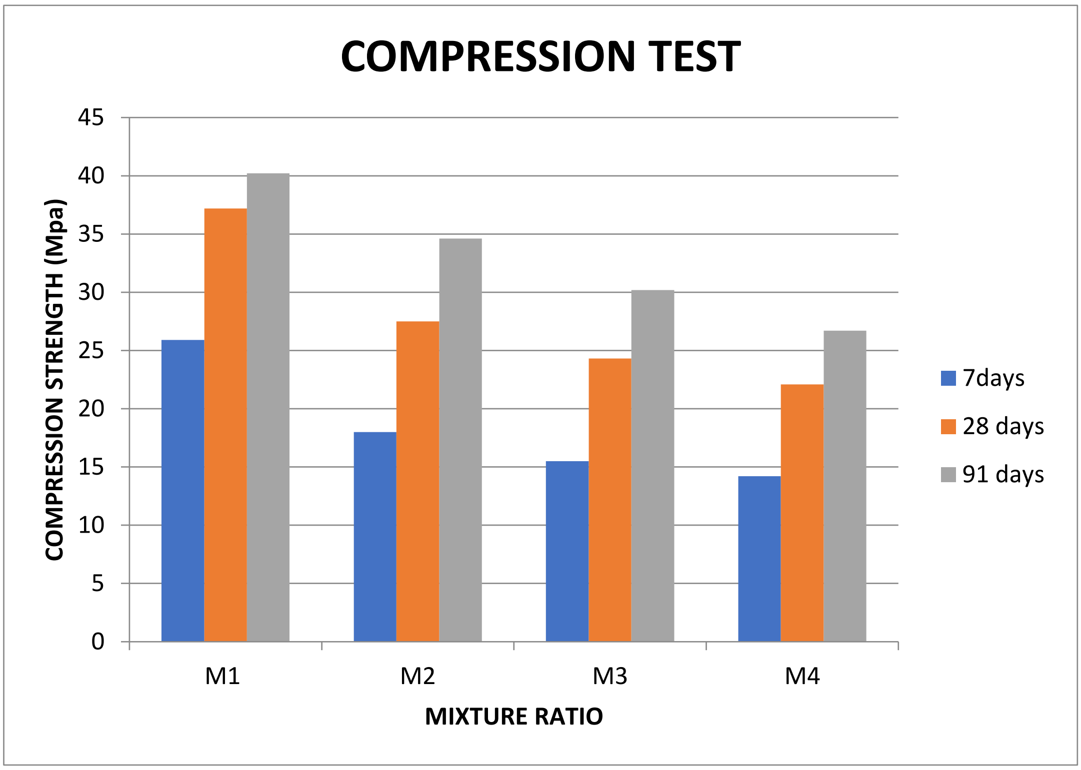
Compressive strength is tested for concrete cubes of 150 mm normal size, split tensile strength is tested with cylinders of size 150×300-mm, beams with size, 101.4×101.4× 508-mm is used for testing flexural strength, finally cylinder with size 150×300-mm is again used for testing the elasticity modulus in the concrete specimen as per IS:516-1959.

6.2 COMPRESSION TEST

Concrete mixture having various ages like 7,21 and 91 days were tested for compressive strength. Result obtained are tabulated in Table 6.2 and in fig.6.2. The specimen compressive strength was found to be 37.2 MPa at the 28th day followed by 27.5,24.3 and 22.1MPa at the fly-ash replacement with percent reduction of 26%,35% and 41% respectively comparing to the strength of the concrete of control mixture M1(with fly-ash 0%). Results of compressive strength by the day 91 was found to increase gradually beyond day 28 with a varying strength increase between 21% and 26%. The continued cement hydration is the main reason for the strength increase. The chemical reaction occurring by adding of pozzolans with fly-ash present in concrete is the main significant cause for the steady increase of compressive strength of HVFC. Though reduction of compressive strength occurs due to fly-ash replacement at end of 28 days the mixture M4(50% fly-ash) might be used for the construction of concrete, M3(45% fly-ash) and M2 (40% fly-ash) can be used well for the structural construction of concrete. This shows that the HVFC can maintain a very long-term retaining of strength.

Mix ratio	Compressive strength (MPa)		
	7th day	28th day	91th day
M1 (0% fly-ash)	25.9	37.1	40.2
M2 (40% fly-ash)	18	27.5	34.6
M3 (45% fly-ash)	15.5	24.3	30.2
M4 (50% fly-ash)	14.2	22.1	26.7

TABLE 6.2: Compression test result



M1(0% fly-ash) M3(45% fly-ash)

M2(40% fly ash) M4 (50% fly-ash)

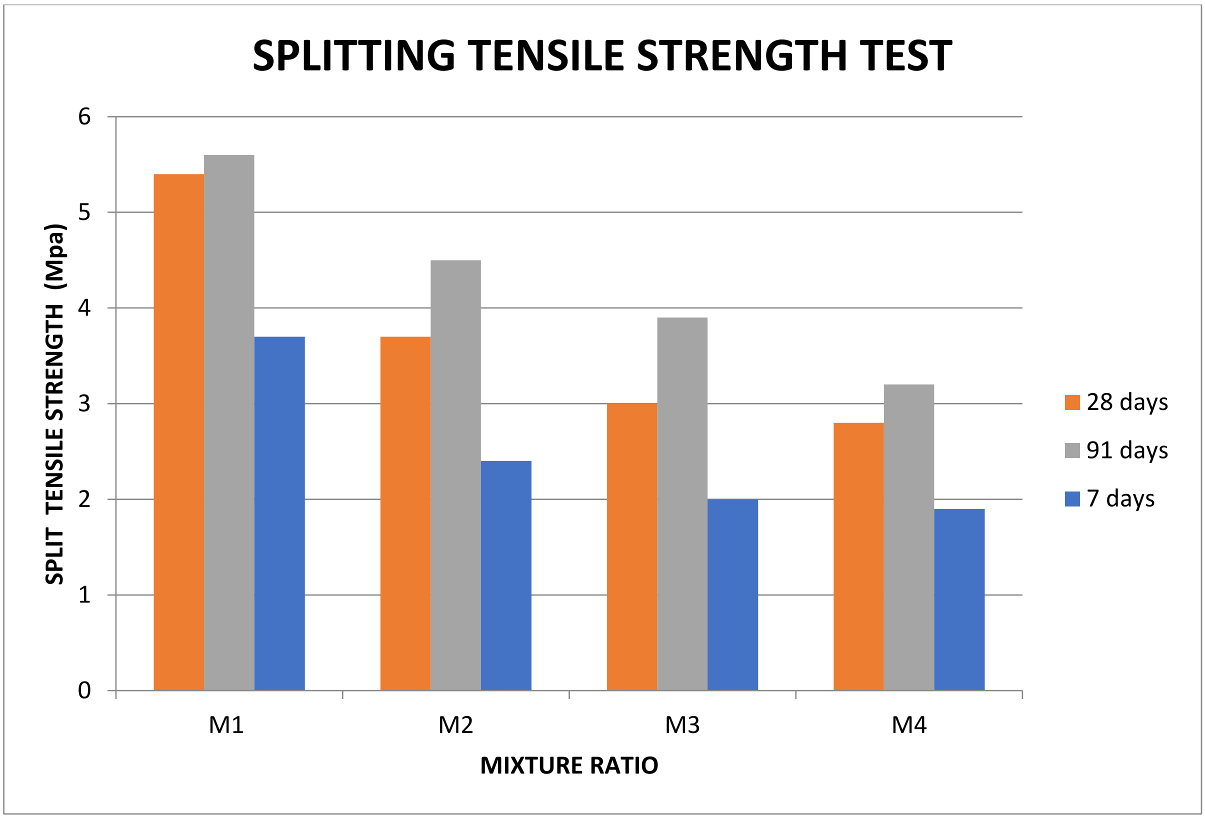
Fig 6.2: Compressive strength vs mix proportion

6.3 SPLITTING TENSILE TEST

The splitting tensile strength of the specimen is calculated for the ages 7th, 28th and 91st days and the results were tabulated in table 6.3 and fig 6.3. The strength difference depending on ages are analysed similar to the compressive strength analysis. At age 28 days the splitting tensile strength of the cylinders at M1(0% fly-ash) was found to be 4.1 MPa followed by 3.2,2.7 and 2.1MPa for M2(40% fly-ash), M3(45% fly-ash) and M4 (50% fly-ash) which shows the reduced strength of about 22%, 34% and 49% respectively. At 91th day the strength increased to be 4.3, 3.9, 3.4 and 2.7 for M1(0% fly-ash), for M2(40% fly-ash), M3(45% fly-ash) and M4 (50% fly-ash) respectively which showed an increase of about 5%, 21%, 26% and 29% respectively when compared to the age of 28th day. It can be observed there is a % increase in strength is much higher during 91 days and for concrete mixture M1 compared to early strength at 28th day. This can cause pozzolanic action because of the presence of fly ash.

Mix ratio	Splitting tensile strength (MPa)		
	7th day	28th day	91st day
M1 (0% fly-ash)	2.6	4.1	4.3
M2 (40% fly-ash)	1.7	3.2	3.9
M3 (45% fly-ash)	1.5	2.7	3.4
M4 (50% fly-ash)	1.4	2.1	2.7

Table 6.3: Splitting tensile strength Result



M1 (0% fly-ash) M3(45% fly-ash)

M2(40% fly ash) M4 (50% fly-ash)

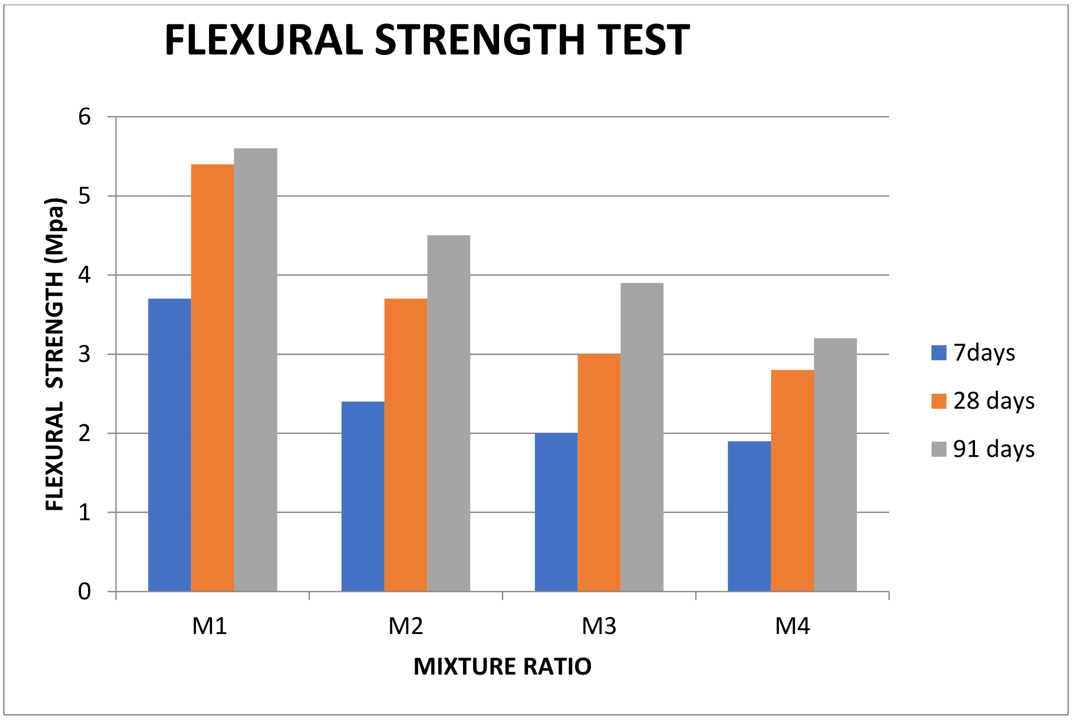
Fig 6.3: Splitting tensile strength vs mix proportion

6.4 FLEXURAL STRENGTH TEST

The flexural strength of the concrete specimen for 7th, 28th and 91st days are analysed and results are presented in table 6.4 and fig 6.4. Similar to the compressive and splitting tensile there is also an increase in the flexural strength with age. Control mixture M1(0% fly-ash) was observed to have a strength of 5.4 MPa at 28 days and %.6 MPa at 91 days which is an increase of strength. M2(40% fly ash), M3(45% fly-ash) and M4(50% fly-ash) were observed with 3.7, 3 and 2.6 MPa respectively at 28 days respectively. The strength of M2(40% fly-ash), M3(45% fly-ash) and M4 (50% fly-ash) was found to possess 4.5,4,3.2 MPa respectively at 91 days which is observed to have a successive increase of strength compared to the 28th day. It is finally observed from the results that there is a consecutive strength increase beyond 28th day. The flexural strength of concrete from day 28-91 were found to have continuous increase between 14% and 30%, depending on fly ash replacement.

Mix ratio	Flexural strength (MPa)		
	7th day	28th day	91th day
M1 (0% fly-ash)	3.7	5.4	5.6
M2 (40% fly-ash)	2.4	3.7	4.5
M3 (45% fly-ash)	2	3.0	3.9
M4 (50% fly-ash)	1.9	2.8	3.2

Table 6.4: Flexural strength results



M1 (0% fly-ash) M3(45% fly-ash)

M2(40% fly ash) M4 (50% fly-ash)

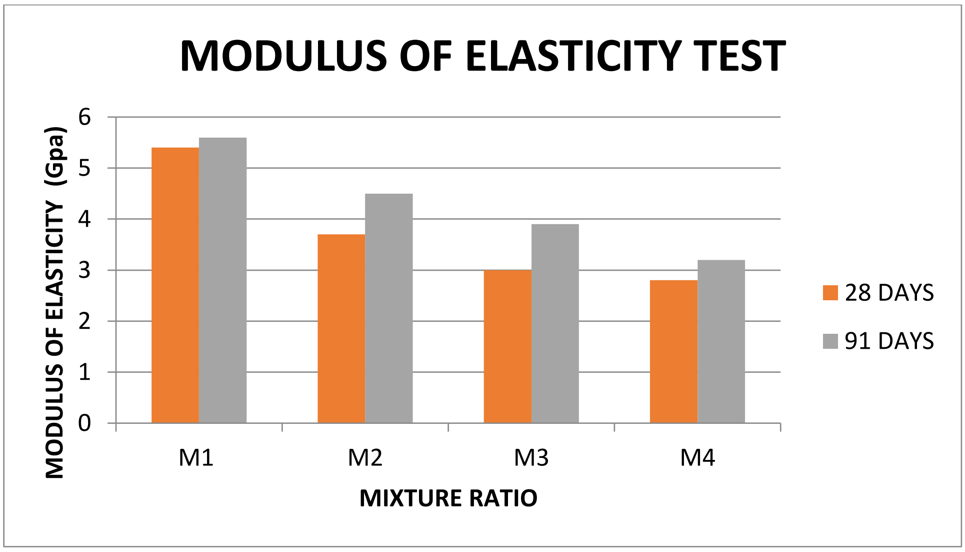
Fig 6.4: Flexural strength vs mix proportion

6.5 MODULUS OF ELASTICITY TEST

In the examination, the elasticity modulus, that additionally called secant modulus, is taken as the slant of harmony from cause to some discretionary point on the stress – strain curve. The secant modulus determined in this examination is for 33% of the most extreme pressure. Elasticity modulus for day 7,28 and 91 were observed and the results are presented in table 6.5 and fig 6.5. The test results indicated that the increasing amount of fly ash decreases the modulus strength compared to that of M1 concrete mixture. The modulus value of at age 28 for M1(0% fly-ash), M2(40% fly-ash), M3(45% fly-ash) and M4(50% fly-ash) was calculated to be 29.7, 19.8,19.6,18.9 MPa respectively. However, there is a successive increase in the modulus strength with ages.

Mix ratio	Modulus of elasticity (GPa)	
	28th day	91th day
M1 (0% fly-ash)	29.7	30.9
M2 (40% fly-ash)	19.8	22.2
M3 (45% fly-ash)	19.6	20.8
M4 (50% fly-ash)	18.9	19.1

Table 6.5: Modulus of elasticity results



M1 (0% fly-ash) M3(45% fly-ash)

M2(40% fly ash) M4 (50% fly-ash)

Fig 6.5: Modulus of elasticity vs mix proportion

CHAPTER 7

CONCLUSION

The replacement of fly ash in three different percentage at initial stage caused the decrease in strength of compression, Split tensile strength, Flexural strength and modulus of elasticity at 28^{th} day. But still strength gradually increased beyond 28^{th} day. Though the concrete strength gradually decreases at 40%,45% and 50% fly ash replaced concrete at 28 days has much good strength for construction of concrete structure. Incorporation of nano-SiO_2 into the HVFC increases both the short and long-term concrete strength. Fly-ash causes high porosity at short time of curing whereas the accelerating additive nano SiO_2 produce compact structure even at the shorter time of curing.

CHAPTER 8

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This is to certify that Mr .T.S.Mukesh of Kongu Engineering College has presented a paper titled "Performance of additive blended high volume fly ash concrete- A systematic literature study" at the Eighth National Conference on Recent Advancements in Geotechnical Engineering (NCRAG'21) in association with IGS Coimbatore Chapter organized by Bannari Amman Institute of Technology, Sathyamangalam during March 26, 2021

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