International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

Strength and Durability Characteristics of Steel Fibre Reinforced Concrete with Mineral Admixtures

N. Sanjeev, K. Harish Kumar, Kaza Prem Rakshit Kumar

Abstract: ***The present investigation is carried out to study the strength and durability characteristics of steel fibre reinforced concrete, by replacing Ordinary Portland cement with Fly Ash, Ground Granulated Blast Furnace Slag (GGBS) and Metakaolin. In this study, cement is replaced by 30% and 40% with Fly Ash, GGBS and Metakaolin for M30 and M35 grades of concrete. Steel fibres @ 1% by weight of binder is used in all the mixes. Strength characteristics like compressive strength and split tensile strength are tested at 7 days and 28 days age. Additionally, durability tests such as water absorption and Sorptivity tests are conducted after 28days curing. The test results have shown that 30% replacement is optimum for strength criteria. And when metakaolin is used with fly ash, durability properties were improved and workability reduced.***

Keywords: ***Concrete, Fly Ash, GGBS, Steel fiber, M-Sand, Compressive Strength, Sorptivity and Water Absorption***

I. INTRODUCTION

Concrete is a composite material, comprising of coarse aggregate, fine aggregate, binder material to hold the aggregate matrix and water which is added proportionately. The utilization of concrete is increasing day by day in construction field which intern increasing production of cement and depletion of natural sand. Every tonne of cement production produces one tonne of CO_2 and which lead to cause global warming and environmental pollution. Hence it became imminent to explore alternatives for cement and natural sand. Fly ash, GGBS, metakaolin, silica fume and rice husk ash are the mineral admixtures which could act as pozzolanic and cementitious material. and manufactured sand is a suitable alternative material for natural sand as fine aggregate. Manufactured sand is a crushed granite stone which is sieved to required size. In recent days, usage of M-sand becoming popular in concrete. Fly ash and GGBS are the by-products obtained in thermal power stations and steel manufacturing industries respectively. However, Ground Granulated Blast Furnace Slag is obtained as the result of quenching the molten iron slag in the water and then it is grounded to powdered form. And Metakaolin is a product that is manufactured for use rather than a by-product and is formed when china clay, the mineral kaolin, is heated to high temperatures.

Revised Manuscript Received on October 30, 2019.

* Correspondence Author

Dr. N. Sanjeev, Civil Engineering Department, Gokaraju Rangraju Institute of Engineering and Technology (GRIET) Hyderabad, Telangana, India. Email: drnsanjeev@gmail.com

K. HarishKumar, Civil Engineering Department, GRIET Hyderabad, Telangana, India. Email: kattaharishkumar@gmail.com

Kaza Prem Rakshit Kumar, Civil Engeering Department, GRIET Hyderabad, Telangana, India. Email: premrakshitkumarkaza@gmail.com

The utilization of these by-products as replacements of cement will help in retarding the global warming and environmental pollution and their disposal problems to some extent. Fibres are generally added to improve strength, impact resistance, toughness and cracking resistance due to plastic and drying shrinkage. Some of them are steel, glass and poly propylene fibres. These fibres are available in different forms, shapes and sizes. Fibres are basically defined or adapted based on their aspect ratio (i.e. L/d ratio) and in most of the cases steel fibres are used for structural applications.

The objective of the present study is to determine strength and durability characteristics of M30 and M35 grade Steel Fibre reinforced Concrete on replacing OPC with Fly Ash, GGBS and Metakaolin, and natural sand by M- Sand.

II. MATERIALS USED

A. Cement:

In this study for all the Concrete mixes, the cement used was Ordinary Portland Cement (OPC) of 53 grade in accordance with IS 12269:1987.

Table-1: Properties of Cement

Cement	Grade	Specific Gravity	IS Code
OPC	53	3.15	IS 12269:1987

B. Fine Aggregate:

M-sand is used as fine aggregate conforming to zone II IS 383:1970. The physical properties such as specific gravity and water absorption were tested are in accordance with IS 2386:1963.

Table-2: Properties of Fine Aggregate

Fine Aggregate	Specific Gravity	Water Absorption	IS Code
M - Sand	2.6	2.5%	IS 2386:1963.

C. Coarse Aggregate:

Crushed angular aggregates are used and these aggregates are of size 20mm in accordance with IS 383:1970. The specific gravity and water absorption were tested conforming to IS 2386:1963.

Table-3: Properties of Coarse aggregate

Coarse Aggregate Size	Specific Gravity	Water Absorption	IS Code
20mm	2.64	0.5%	IS 2386:1963

D. Fly Ash:

Fly ash of Class F is used as the mineral admixture in this study according to ASTM C 618-2003. The fly ash is acquired from RANK RMC Plant.

Table-4: Properties of Fly Ash

Type	Colour	Bulk Density	Specific Gravity	Fineness
Class-F	Dark Grey	1024 Kg/m^3	2.1	336 m^2/Kg

E. GGBS:

In Accordance with ASTM C989-06, GGBS serves as mineral admixture in concrete. The GGBS is acquired from LAFARGE RMC PLANT.

Table-5: Properties of GGBS

Colour	Bulk Density	Specific Gravity	Fineness	Water Absorption
Off white	1281 Kg/m^3	2.81	342 m^2/Kg	NIL

F. Metakaolin:

Metakaolin is a pozzolanic material used in concrete in replacement of cement. It is a product that is manufactured for use rather than a by-product and is formed when china clay, the mineral kaolin, is heated to high temperatures.

Table-6: Properties of Metakaolin

Colour	Bulk Density	Specific Gravity	Fineness	Water Absorption
Off white	786 Kg/m^3	2.71	352 m^2/Kg	NIL

E. Steel Fibre:

Hooked end steel fibres are used. Length - 30mm, diameter-0.75mm and aspect ratio - 40.

F. Super Plasticizer:

Master Rheobuild 920SH is used as super plasticizer and its properties are as in Table VII below.

Table-7: Properties of Super Plasticizer

State	Colour	Density	Chemical Name	pH
Liquid	Dark Brown	1.2	Naphthalene Formaldehyde polymer	8.40

III. EXPERIMENTAL INVESTIGATION

A. General

Strength properties test such as compressive strength test, split tensile strength test and durability properties tests like water absorption test and Sorptivity test were done to study the behavior of fibre reinforced concrete of M30 and M35 grades by author-2 and author-3 respectively. In this study, steel fibres of 1% by weight of binder is used in each and every mix and replacement of cement is varied by 30% and 40% with fly ash and GGBS for M30 grade concrete and by fly ash and metakaolin for M35 grade concrete. The samples were casted and tested at 7 days and 28 days age to analyse mechanical properties and at 28 days age to analyse durability properties. The tests carried out to study mechanical and durability properties of all the mixes are as below.

B. Compression Test

Cubes of size 150mm x 150mm x 150mm are casted and are used to test the compressive strength of concrete in accordance with IS 516-1969. Three samples are tested at each of 7 days and 28 days curing.

C. Split Tensile Strength Test

Split tensile strength of concrete is determined in indirect way and this standard test is done in accordance with IS 5816-1970.

D. Water Absorption Test

The aim of this test is to establish the water absorption rate of steel fibre reinforced Concrete of M30 and M35 grades. 100mm x 100mm x 100mm size concrete cube specimens are casted and treated with water for 28 days as per ASTM C 642-97. In order to eliminate powdered material from the surface of specimen, it should be washed with deionized water. After curing of specimens with water for 28 days, the specimens are oven dried at 110° C for a duration of 24hrs. And then the specimens are submerged in water such a way as to ensure the height of water above the specimen after submersion is 2 cm. Withdraw the specimen at programmed interval and blot the surface with damp cloth to remove surface water and then record weight specimen. Re-immerse the specimen after measuring the weight at each interval of time. This is continued until the weight difference between two successive 24hr interval measurements is less than 1%.

Amount of water absorbed with respect to the mass of dry specimen is stated as below:

$$M_i\% = \frac{m_i - m_0}{m_0} \times 100$$

Where, m_i = weight of the specimen at time t;
m_o = weight of dry specimen.

Concrete samples should be weighed a few minutes after immersion, and then at increasing intervals (15min, 30min, 1 hr, etc.) for first three hours. All the specimens should be weighed at 8 hours after the beginning of the test and then at 24 hours until the weight difference between two successive 24hr interval measurements is less than 1% of the total mass.

Amount of water absorbed with respect to the mass of dry specimen at each interval is recorded on data sheet and a graph is plotted with the values with respect to the time.

D. Sorptivity Test

The intention of this test is to estimate the sorptivity of steel fibre reinforced concrete of M30 and M35 grades as per ASTM C 1585. Sorptivity is the accumulated change in volume of water absorbed per unit area against the square root of time. Cylindrical specimens of size 100mm diameter and 50mm thickness are used for this sorptivity test. Following the 28 days of curing, the specimens are oven dried at 110° C for 24hrs. The specimen sides are sealed with electricians' tape or sealant. Suction face and the face opposite to it should be kept unsealed. The specimens were positioned as illustrated in the figure below.

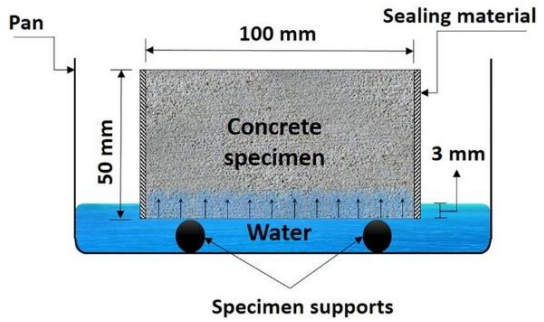

Fig 1: Representation of Sorptivity Test

The rate of water absorption or sorptivity = K = is the slope of I vs √t graph

$$I = \frac{W}{A \times d}$$

Where, W = the amount of water absorbed in kg
A = area of the cross section of the specimen that is in contact with water,
d = density of the medium in which specimen was immersed (1000kg/m^2 in case medium is water).

E. Mix Proportion:

The mix proportioning of cement, fine aggregate and coarse aggregate for the present work is done as per the guidelines of IS 10262-2009. For M30 grade by author-2 mix proportion is is 1:2.17:3, with a binder ratio of 0.43. Whereas, for M35 grade by author-3 mix proportion is 1:2.13:2.86, with water binder ratio of 0.42.

F. Concrete Mixes

AUTHOR-2

Table-8: For M30 Grade of Concrete

MIX	OPC	FLY ASH	GGBS	STEEL FIBRE
M1	100%	0%	0%	1%
M2	70%	15%	15%	1%
M3	60%	20%	20%	1%

AUTHOR-3

Table-9: For M35 GRADE CONCRETE

MIX	OPC	FLY ASH	METAKAOLIN	STEEL FIBRE
P1	100%	0%	0%	1%
P2	70%	15%	15%	1%
P3	60%	20%	20%	1%

IV. TEST RESULTS

A. Workability

The workability for different mixes of M30 and M35 grade concrete is shown Fig-2 and Fig-3 respectively. From these Figures it is observed that when OPC is replaced with fly ash and GGBS workability got increased whereas, it is decreased by replacing with fly ash and metakaolin.

Workability of M30 grade concrete

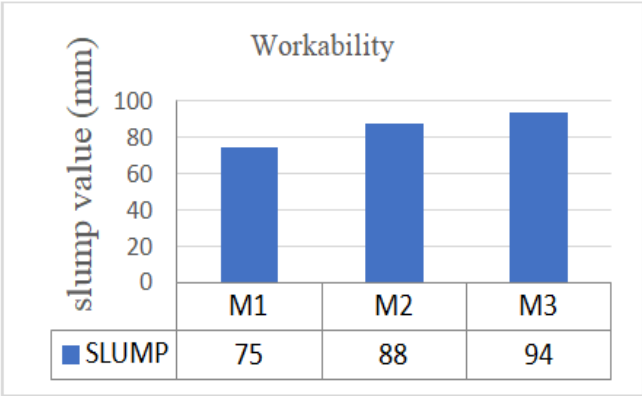

Fig-2: Workability of M30 grade concrete

Workability of M35 grade concrete

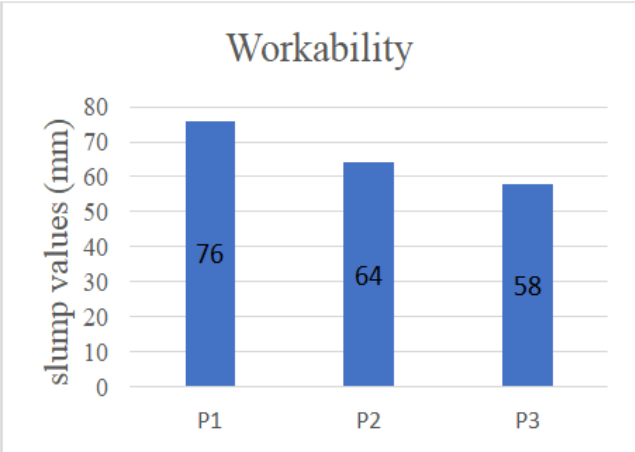

Fig-3: Workability of M35 grade concrete

B. Compressive Strength

7 days and 28 days age compressive strength values of all mixes are shown in graphical form in Fig-4 for M30 grade concrete and in Fig-5 for M35grade concrete. From the graphs below, it is noted that 30% replacement is ideal amongst all the replacements.

Compressive Strength of M30 grade concrete

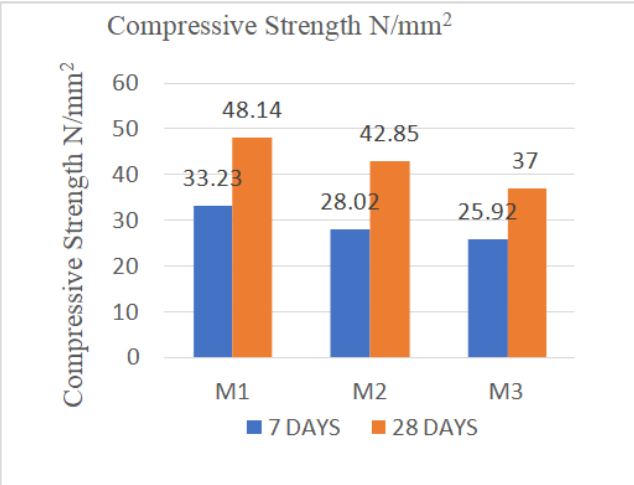

Fig-4: Compressive Strength of M30 grade concrete mixes

Compressive Strength of M35 grade concrete

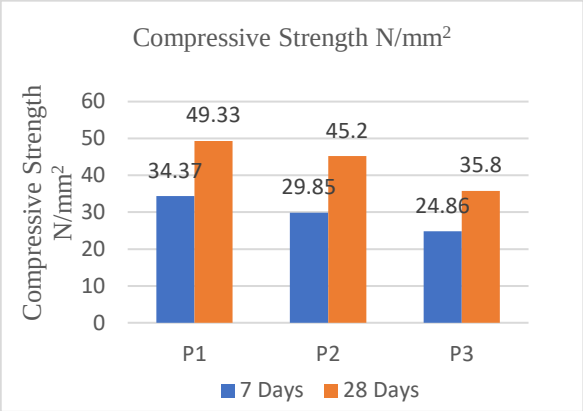

Fig-5: Compressive Strength of M35 grade concrete mixes

C. *Spilt Tensile Strength*

7 days and 28 days split tensile strength values for all mixes are shown in graphical form in Fig-6 for M30 grade concrete and in Fig-7 for M35 grade concrete. From the graphs below it is observed that 30% replacement is ideal amongst all the replacements.

Split Tensile Strength of M30 grade concrete

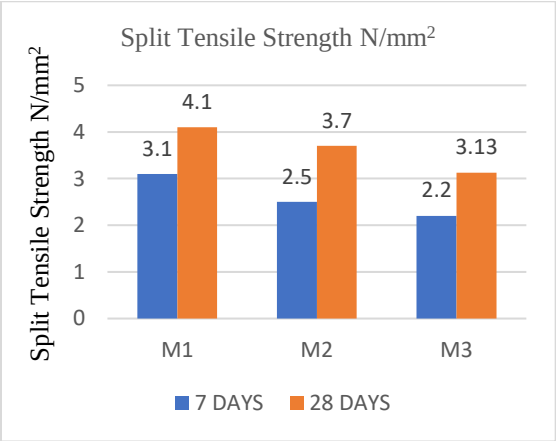

Fig-6: Split Tensile Strength of M30 grade concrete mixes

Split Tensile Strength of M35 grade concrete

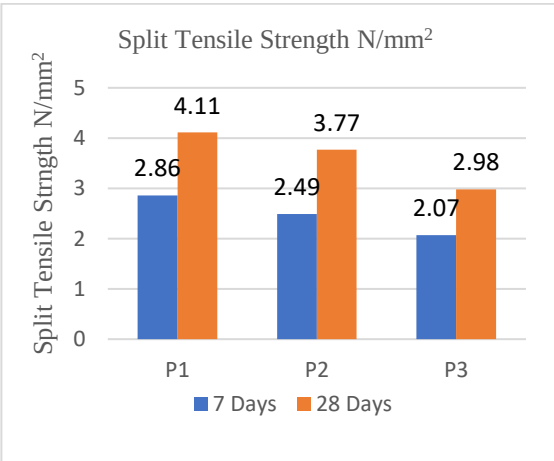

Fig-7: Split Tensile Strength of M35 grade concrete mixes

D. *Sorptivity*

Sorptivity for all mixes are obtained from the graph shown below in Fig 8 and Fig (9). It was found that sorptivity of the concrete is improved when metakaolin is used with fly ash instead of GGBS

SORPTIVITY of M30 (Fly ash+GGBS) Grade Concrete

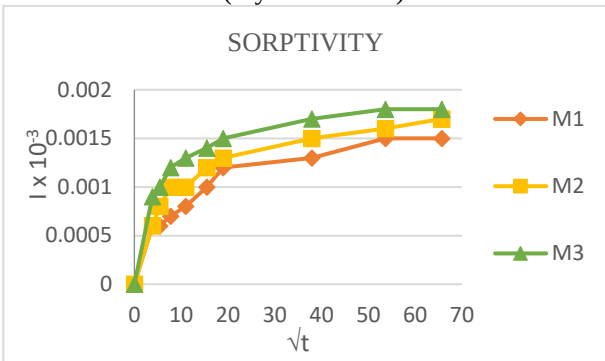

Fig-8: Sorptivity values of M30 grade concrete mixes M1, M2 and M3

SORPTIVITY of M35 (Fly Ash+ Metakaolin) Grade Concrete

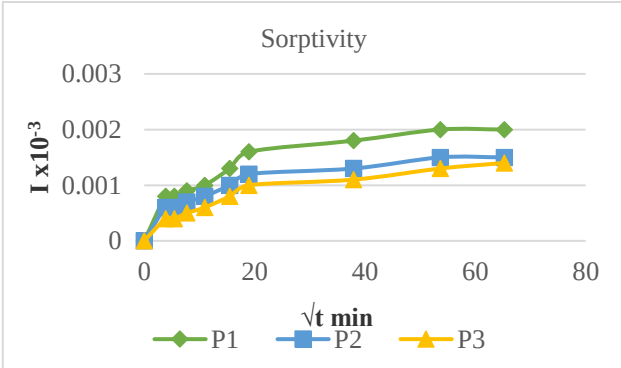

Fig-9: Sorptivity values of M35 grade concrete mixes P1, P2 and P3

E. *Water Absorption*

Results for water absorption test for all mixes are represented graphically in Fig 10 and Fig 11. It was found that water absorption rate of the concrete is improved when metakaolin is used with fly ash instead of GGBS

Water absorption of M30 grade concrete

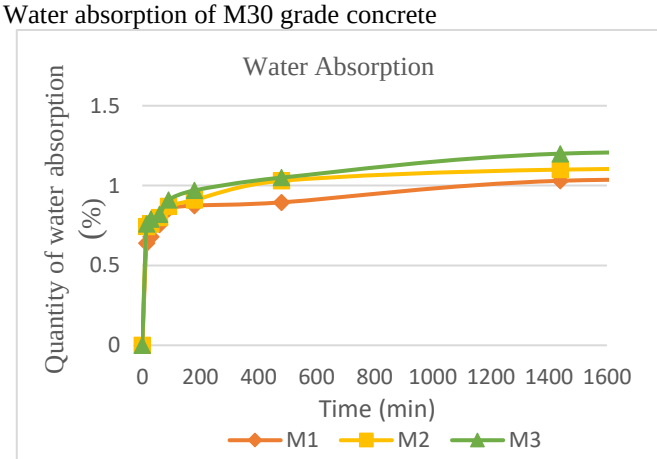

Fig-10: Water absorption values of M30 grade concrete mixes M1, M2, M3

Water Absorption of M35 grade concrete

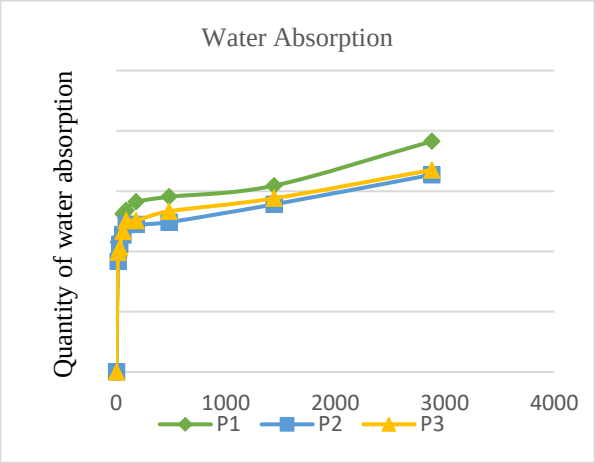

Fig-11: Water absorption values of M35 grade concrete mixes P1, P2 and P3.

V. CONCLUSIONS

Based on the experimental investigation, the following conclusion are made

A. The workability of the Concrete was increased from 75mm to 94 mm when the 40% of Cement was replaced by Fly Ash and GGBS together by the author-2; However, workability of the Concrete was decreased from 76 mm to 58 mm when the 40% of Cement was replaced by Fly Ash and Metakaolin together by the author-3.

B. In the study by author-2, 30% replacement of Cement was found to be ideal since 28-day compressive strength was about 13% more than by the target mean strength. However, in the Study by author-3, same 30% replacement of Cement was found to be ideal as 28-day compressive strength was about 6% more than the target mean strength,

C. In the experimental investigation conducted by both the authors-2 and 3, the split tensile strength was noted to be maximum for 30% replacement when compared to other replacement (40%) of OPC with mineral admixtures.

D. In the present study by the author-2, there was no considerable improvement in the durability properties such as water absorption and sorptivity. However, these properties were improved with replacement of cement by fly ash and metakaolin together in the study of author-3.

REFERENCES

1. P. Priya Rachel (2019) "Experimental Investigation on Strength and Durability of Concrete using High Volume Flyash, GGBS and M-Sand", International Journal for Research in Applied Science & Engineering Technology, Vol 7, Issue III, PP 396-403.
2. Dumpati Mamatha, T Ajay and Kiran H P (2018) "An experimental investigation on partial replacement of Cement with GGBS and Fly Ash in Rigid pavements", International Research Journal of Engineering and Technology, Vol 5, Issue 4, PP 3452-3455.
3. P. R. Nagarajan (2018) "Workability and compressive strength of Concrete with M-Sand and Fly Ash", International Research Journal of Engineering and Technology, Vol 5, Issue 7, PP 2005- 2008.
4. M.Mohanraj, S.Gayathri (2018), "A Study on Mechanical Properties of Concrete using Fly Ash and Metakaolin", International Journal of Advanced Research in Science, Engineering and Technology (IJARSET), Volume 6, Issue 11, , ISSN(O): 2319-8753, pp.21543-21550.
5. Jayeshkumar Pitroda and Dr F S Umrigar (2013) "Evaluation of sorptivity and water absorption of Concrete with partial replacement of Cement by thermal industry waste (Fly Ash)", International Journal of Engineering and Innovative Technology, Vol 2, Issue 7, PP 245-249.

LIST OF CODES

1. ASTM C1585 Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes
2. ASTM C 642-97. Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

AUTHORS PROFILE

Dr.N.Sanjeev, got his first degree from NIT Warangal in 1983. Joined government of India through UPSC Engineering Services (so called IES)-1983 batch and was Engineer in Charge for the construction of longest runway in Asia near Chennai. After 21 years of service retired from government service. Served private and corporate construction industries for 6 years up to level of Vice President. Worked as professor in KLU for 2 years and presently professor in civil engineering department in Gokaraju Rangaraju Institute of Engineering and Technology since November 2014.

Kaza Prem Rakshit Kumar, completed Bachelor of Technology (Civil Engineering) in Institute of Aeronautical Engineering (IARE) College (Hyderabad), 2009-2013 batch with first class degree. Presently pursuing Master of Technology (Structural Engineering) in Gokaraju Rangaraju Institute of Engineering and Technology (Hyderabad), participated in some of the considerable conferences conducted by The Institute of Engineers (India) and also took part in workshops conducted by Indian Concrete Institute New Delhi Centre and very much interested to carry out experimental investigation on concrete incorporating various mineral admixtures.

K. Harish Kumar, completed Civil Engineering at Institute of Aeronautical Engineering College (IARE), Dundigal, Hyderabad in 2017. Btech project was on "Effect of organic admixtures on compressive strength of concrete under elevated temperatures". Presently pursuing Master of Technology in Structural Engineering at Gokaraju Rangaraju Institute of Engineering and Technology (GRIET), participated in some of the major conferences conducted by The Institute of Engineers (India) and also participated in workshops like Modern developments in concrete and building technology keenly interested to conduct experimental investigation on mechanical properties and some durability properties of fiber reinforced concrete made with different mineral admixtures under the guidance of Dr N Sanjeev.