Effect of Diameter of Reinforced Bar in Various Fiber Reinforced Concretes

Alwyn Varghese, Harikrishnan T P, Haritha K, Mohammed Razeem S M

Abstract*: An experimental investigation has been carried out to determine the effect of fibers on the bond strength of different grades (M20 and M50) of concrete by using reinforced bars of different diameters(10mm and 12mm). Different types of fibers such as glass, polypropylene, basalt were used in the preparation of concrete mix with 0.25% of volume proportion. Then the bond strength was determined by the pull-out test as per IS 2770 (part 1). Based on the test results of the study, grade of concrete, type of fibers and different diameter of reinforcement bar are the key parameters that affect the bond strength of concrete. The contribution of basalt fiber in enhancing the bond strength was found to be more significant compared to other fibers (8.227 N/mm^2 for M20 concrete and 9.323 N/mm^2 for M50 concrete). The bond strength has been improved slightly by increasing the diameter of the reinforcement bar. Durability analysis was carried out by curing specimens in HCl and H_2SO_4. Fibers don't have sufficient influence in the durability of concrete.

***Index Terms*: Bond Strength, Durability, FRC, Pull out test.**

I. INTRODUCTION

Concrete is one of the cheapest material with desired strength in the construction industry. Advancements were done in the concrete to develop its manufacture and utilization. Being a weak tensile material, several cracks formed during loading and so on. These cracks are formed because of the internal micro cracks, resistance of material to resist the tensile forces and environmental factors. Some researchers found some fiber which are effective with concrete to reduce the crack propagation. Fibers which are added in concrete will act as a tensile member and transfer load on these micro-cracks propagated area [1-4]. Fiber Reinforced Concrete (FRC) can also improve the bond strength between concrete and reinforcement [5-6].

Inclusion of Basalt Fiber (BF) will improve the toughness, reduce brittleness, tensile strength, resistance to deform and rupture modulus of concrete [7]. BF has better tensile strength than the E-glass fiber as well as greater failure strain than carbon fiber. BF also resist chemical attack, impact load and fire [7-8].

Shrinkage cracking can be controlled by adding Glass Fiber (GF). It will also improve flexural strength of concrete. GF also possess post-peak ductility in compression [9]. Glass Fiber Reinforced Concrete (GFRC) prepared with high strength, alkali-resistance glass fiber embedded in concrete matrix [10]. GF can be used as either in continuous or chopped lengths. GF are comparatively available in local market with low prize. Studies have shown that the addition of glass fibers in concrete can control shrinkage cracking, improve flexural and tensile strength [6] [11-12]

Addition of Polypropylene Fiber (PPF) in concrete will improve its ductility toughness, and impact resistance [13]. PPF utilized in concrete mix at relatively low volume fractions which helps to control plastic shrinkage cracking of concrete [13-14].

Environment has a greater impact on durability of a concrete structures. The constituents present in environment that includes chemicals, gases, dust particles and so on are the major causes of corrosion in the reinforcement that leads to deterioration in concrete structures [2].

Pull out tests is an important test for evaluating bond strength between concrete and embedded reinforcement and for durability chemical attack test by immersing the concrete cubes in an acid solution is conducted [1-2].

In reinforced concrete structure, bond strength is one of the most important and significant factor as it is dealt with the overall strength and serviceability of a structure. Bond strength is defined as the effective grip or adhesive forces between the reinforced bars and embedded concrete whereas durability is associated with the environmental impacts. The effect of fibers in plain concrete for the bond strength and durability is analyzed in this paper. The objective of this investigation is to analyze bond strength characteristics and durability aspects of FRC with BF, GF, and PPF in various cases such as changes in grade of concrete and changes in diameter of the reinforcing bar.

II. MATERIALS AND METHODS

A. Materials

Table 1: Properties of fibers

Property	GF	PPF	BF
Length (mm)	12	12	12
Diameter (mm)	0.012	0.022	0.009
Specific gravity	2.74	0.91	2.7
Tensile strength (MPa)	2450	350	550
Density (g/cm2)	2.55	0.903	2.8
Young's modulus (GPa)	78.51	1.3	89

Revised Manuscript Received on June 15, 2019.

Alwyn Varghese, Asst. Prof., Civil Department, Ahalia School of Engineering and Technology, Palakkad, Kerala, India.,

Harikrishnan T. P, Haritha K. & Mohammed Razeem S M, B-tech student, Civil Department, Ahalia School of Engineering and Technology, Palakkad, Kerala, India.

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

Ordinary Portland Cement (OPC) of 53 grade, Artificial sand (M Sand) of zone III having specific gravity of 2.6 is used as fine aggregate and 12mm sized crushed stones were used as coarse aggregates. Chopped fibers of basalt, glass and polypropylene were used in a specified mix proportions to cast the specimens. Table 1 shows the properties of fibers, which used in this study and fig. 1 is the images of used fibers.

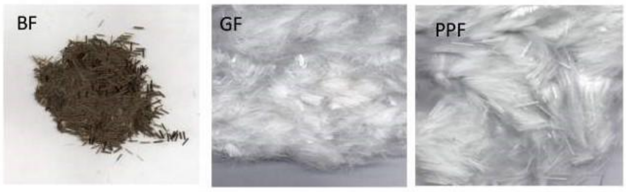

Fig. 1 Types of fibers used

B. Specimen Preparation

Materials were tested for calculating mix design and prepared mix proportions for two different grades (M20 and M50). Three trial specimen samples were casted for each testing. Table 2 shows the mix proportions of concrete used in this study. The concrete specimens were prepared by mixing cement, artificial sand, coarse aggregates and fibres as per the codal provision IS 2770: 1967 part (1). Superplasticizer of Fosroc Auramix V200 was used to adjust the workability of the concrete mix. The optimum dosage were determined by trials using the materials and conditions that will be experienced in use. The normal dosage range is in between 0.1 to 0.5 by cementitious materials.

Table 2: Mix Proportion for specimens

Mix	Water Cement ratio	Cement	Fine aggregate	Coarse aggregate
M20	0.5	1	1.95	2.95
M50	0.34	1	1.66	2.5

Fig. 2 Specimens for pull out test

A total of 96 specimens were casted for both pull out tests and durability tests that includes cubes with and without fibers. 48 Concrete cubes sized 100×100×100mm cubes without reinforcement were casted and cured in water for 28 days. Three trials of specimen were casted for each fiber mixes for each grade of concrete. The concrete cube specimens of 100×100×100 mm along with steel reinforcement were cast and kept in a curing tank for 28 days. Reinforcement of diameter 10 mm and 12 mm was inserted into fresh concrete specimen for a length of 100 mm. And also 10 mm projection of reinforcement at the bottom of cube was provided as per coded provision (IS 2770: 1967 part (1)).

After curing the specimens were subjected to pullout test and durability tests. Fig 2 shows the samples of prepared specimens for pull out tests.

C. Test Setup

Pull-out test

As per IS 2770: 1967 part (1), pullout test was carried out using Universal Testing Machine (UTM). A total of forty eight specimens were prepared with three types of fibers (GF, BF and PPF) and without fiber, for different grades of concrete (M20 and M50), and for different diameters of bars (10mm and 12mm). The specimen was placed in the UTM in such a way that the bar could be pulled axially from the cube. In this study, load and slip of reinforcing bar were noted in a number of intervals throughout the test up to a slip of 2.5 mm. For each intervals slip values are noted by using deflection meter with a least count of 0.002 mm. Fig 3 and fig 4 are the images of deflection meter connected to the UTM setup. Bond stress for each specimen was calculated by dividing the applied load at the end specified and the surface area of the embedded length of the bar.

Fig. 3 UTM

Fig. 4 Deflection meter

Durability test

Chemical resistance of concrete was studied through chemical attack by immersing them in $H2SO_4$ and HCl acid solutions. 100 mm x 100mm x100mm sized cube specimens were casted as per IS 2770-PART 1: 1967. Twenty four cubes of M20 and M50 grades of concrete (with and without fibers) were immersed in water for 28 days. Then the specimen weighed and inserted into 5% acid solution. The P¬H of the solution is maintained continuously for the entire curing period. Each cube is taken out after 28 days of acid curing and weighed again. Durability was analyzed by the weight loss of cubes.

III. METHODOLOGY

Bond strength of different grades of reference concrete (Rc), i.e.; specimen without fibers and FRC were determined by using pull-out test. Fig. 5 shows the methodology of the entire work.

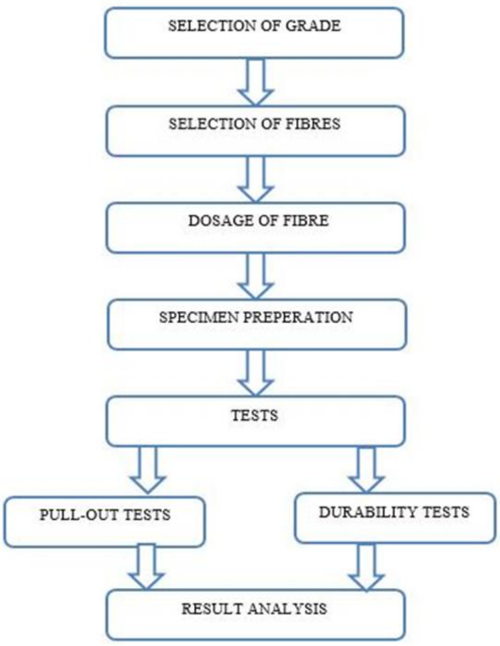

Fig. 5 Methodology

The bond stress values of different grades of concrete (M20 and M50) were compared to find the difference in bond stress. Also specimens with different diameter of bars were compared for analysis. Fig. 6 shows the actual view of experimental setup on UTM. The slip at the loaded end of bar was calculated by the average of reading given by the dial gauges for three trials of specimens. The average bond stress value for each specimen was calculated by dividing the applied load by the surface area of the embedded length of bar. The increase in bond strength when adding different fibers was calculated. And the effect in bond strength when changing the diameter of steel bar was found out.

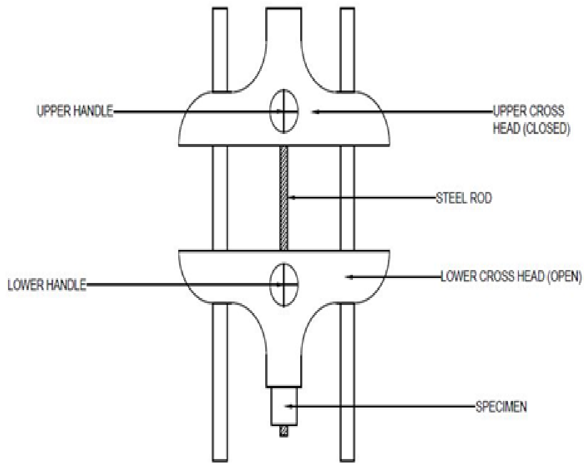

Fig. 6 Pullout test set up

The weight of specimen after 28 days of water curing before acid test was noted. The weight of specimen was again noted after 28 days of acid curing. Then the loss of weight of specimen after acid curing was calculated by determine the difference between two weights and then found out the percentage of weight loss.

IV. RESULTS AND DISCUSSIONS

A. Pull- out Test

All specimens failed by vertical crack formation when subjected to pull-out test as shown in fig. 7. It can be seen that fibers assist in reducing the cracks in concrete elements. Addition of fibers in concrete can make an improvement in tensile properties of concrete in all directions.

Fig. 7 Crack pattern

Fig. 8 shows the deflection of M20 specimens under 10 mm bar up to 2.5mm slip. M20 grade of Basalt Fiber Reinforced Concrete (BFRC) has higher bond strength of 7.183 N/mm2. M20 grade of concrete without fiber (Rc) specimen was the least among the FRC with a value of 5.116 N/mm2.

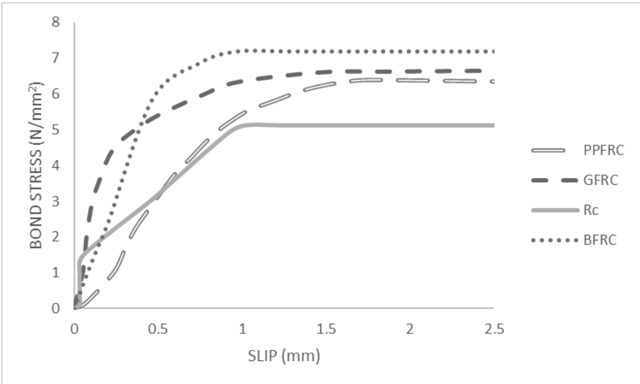

Fig. 8 Bond Strength of M20 R_C and M20 FRC (10mm bar) up to 2.5mm

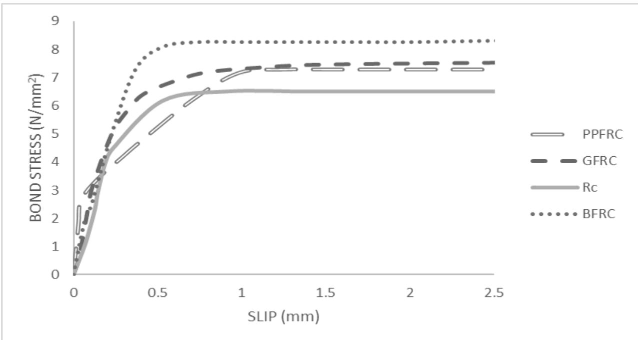

Fig. 9 Bond Strength of M20 R_C and M20 FRC (12mm bar) up to 2.5mm

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Fig. 9 shows the deflection of M20 specimens with 12mm reinforced bar. Also BFRC shows the highest bond strength of 8.227 N/mm2 followed by Glass Fiber Reinforced Concrete (GFRC), Polypropylene Fiber Reinforced Concrete (PPFRC) and Rc

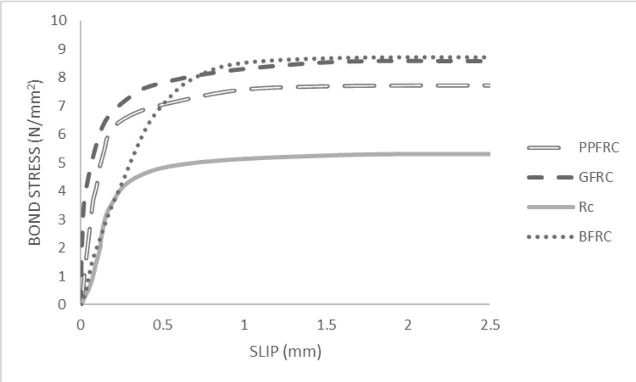

Fig. 10 Bond Strength of M50 R_C and M50 FRC (10mm bar) up to 2.5mm

Fig. 10 shows the bond strength of M50 grade of concrete specimens with 10mm reinforcement bar up to 2.5mm slip. M50 specimens have a higher bond strength than M20 specimens for each mixes. Also bond stress of BFRC has a high value of 8.639 N/mm2. Other mixes also followed the similar mode of increase.

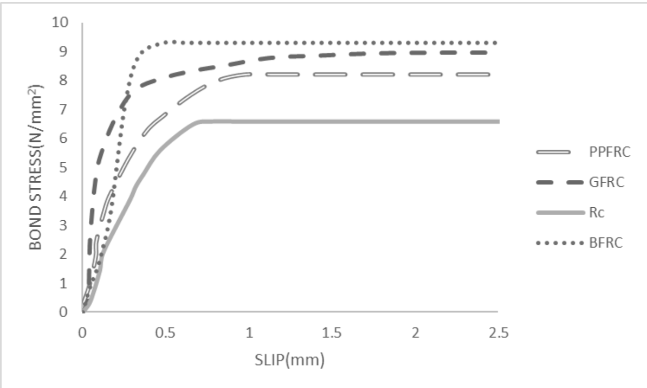

Fig. 11 Bond Strength of M50 R_C and M50 FRC (12mm bar) up to 2.5mm

Fig. 11 shows the deflection of M50 specimens with 12mm bar up to 2.5 mm slip. Concrete with BF had the highest strength and that was followed by GF and PPF. The bond strength of the concrete without fiber was the least among the FRC's. The bond strength of specimen was increased when adding fiber having high young's modulus [15].

From the experiments, it is observed that bond strength of BFRC is higher than that of concrete with GF, PPF and Rc for all grades of concrete. BF does not possess chemical reaction with other materials. It may be the reason for the high bond strength of BFRC [16-17]. GFRC possess more bond strength than PPFRC and Rc. Higher elastic modulus of GF than PPF may be responsible for its high bond strength [15].

It is found that PPFRC specimens have more bond strength than Rc specimens. Flexural ductility and long-term durability of concrete can improve by adding PPF [18]. It can reduce the plastic shrinkage of concrete [19]. Propagation of micro cracks of concrete can be reduced by adding PPF. It will fills the holes within the mortar and thus reduces porosity [20].

The difference of bond strength of M20 concrete specimens with 10 mm bar and 12 mm bar is shown in fig. 12. Final value of bond stress is the final crack load of the specimen in the apparatus. From the fig. it is clear that the bond strength of M20 grade of concrete specimen with 12 mm reinforced bar is higher than that with 10 mm reinforced bar. The BFRC specimen shows a higher bond stress than that of other FRCs.

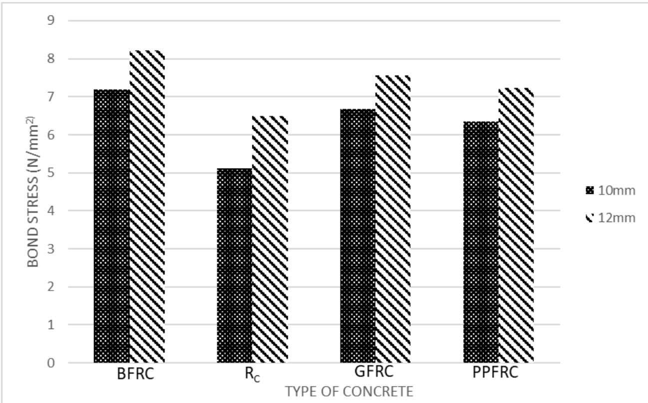

Fig.12 Bond Strength Comparison of M20 grade concrete with 10mm and 12mm bar

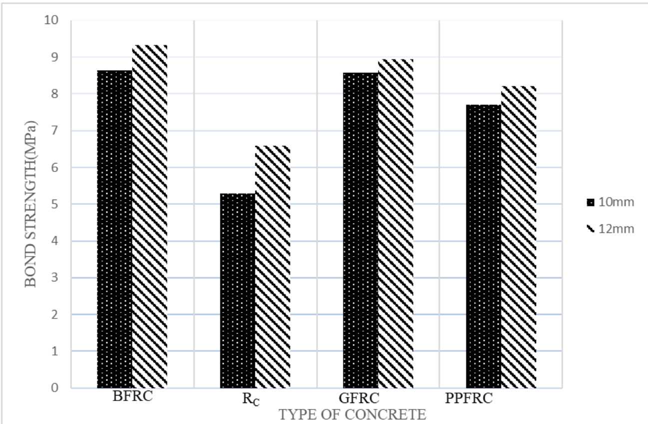

Fig.13 Bond Strength Comparison of M50 grade concrete with 10mm and 12mm bar

Bond strength of different M50 grade of concrete specimens with 10 mm and 12 mm diameter reinforced bars is shown in fig. 13. M50 grade of concrete specimens had comparatively higher bond strength than M20 grade of concrete specimens. BFRC had higher bond strength than that of other FRC's. Bond strength is improved slightly for specimens with 12 mm diameter reinforced bar.

The diameter of steel reinforcement used in a Pullout test specimen has an important role in the improvement of bond stress. From Table 3, it is clear that bond strength increases with increasing the diameter of reinforced bars. According to IS 2770:1967 (part 1)

Bond stress = $P/\pi D l$

Where P is the load acting on the specimen,
D is the diameter of the reinforcement,
l is the length of reinforcement bar inside the specimen.

Table 3: Percentage increase in bond strength based on diameter of bar

Mix	Type of concrete	Bond strength (N/mm^2)		% Increase in bond strength
		10mm	12mm	
M20	BFRC	7.183	8.227	10.43
	GFRC	6.672	7.556	8.83
	PPFRC	6.339	7.241	9.01
	R_C	5.116	6.502	13.86
M50	BFRC	8.639	9.323	6.83
	GFRC	8.568	8.934	3.65
	PPFRC	7.710	8.206	4.95
	R_C	5.288	6.597	13.08

The specimen with 12mm reinforced bar can withstand more pullout load than specimen with 10mm reinforced bar. Table 3 shows the percentage of increase in bond strength with increase in the diameter of bars. For M20 grade of concrete BFRC shows 10.43% increase in bond strength when using 12 mm bar whereas the bond strength of R_c specimen is increased by 13.86%. GFRC has comparatively less value of 8.83%. For M50 grade of concrete, bond strength of R_c specimen is increased by 13.08%. GFRC has the least value of 3.65%. The increase in the diameter of reinforced bar is more affects the M50 grade of concrete specimens than M20 grade of concrete specimens.

B. Durability Test

The loss of weight for different grades of FRC is given in Table 4. Cubes subjected to H_2SO_4 curing shows higher weight loss than cubes subjected to HCl solution. It is also analyzed that FRC specimens had comparatively high weight loss after 28 days of acid curing than Rc specimen. For M20 grade of concrete specimens, BFRC has 1.75% weight loss in HCl and 1.94% weight loss in H_2SO_4, which is higher among other FRCs. R_C specimen has 1.23% and 1.34% weight loss for HCl and H_2SO_4 respectively. For M50 grade of concrete specimens, R_C specimens have a less weight loss of 1.68% for HCl and 1.84% for H_2SO_4. Weight loss increase in an order of PPFRC, GFRC and BFRC. Percentage of weight loss was increased with addition of fibers [16]. Fiber addition reduced the weight of all specimens, when subjected to durability test. More over weight loss of FRC specimens were increased by increase in fiber dosage [21].

Table 4: Durability test results

Grade of concrete	Mix	Initial weight		Weight after 28 days (kg)		% Weight loss after 28 days (%)	
		HCl	H_2SO_4	HCl	H_2SO_4	HCl	H_2SO_4
M20	R_C	2.43	2.24	2.4	2.21	1.23	1.34
	GFRC	2.33	2.45	2.295	2.395	1.50	2.24
	BFRC	2.285	2.58	2.245	2.53	1.75	1.94
	PPFRC	2.415	2.425	2.375	2.38	1.66	1.86
M50	R_C	2.385	2.45	2.345	2.405	1.68	1.84
	GFRC	2.47	2.58	2.425	2.525	1.82	2.13
	BFRC	2.55	2.855	2.495	2.78	2.16	2.63
	PPFRC	2.4	2.15	2.36	2.11	1.67	1.86

V. CONCLUSIONS

From the experimental study, the following conclusions can be drawn.

- BFRC shows higher bond strength than other FRCs, in both grades of concrete.
- M50 FRCs have higher bond strength than M20 FRCs.
- Specimens made up of 12mm reinforcing bars have higher bond strength than that of specimens with 10mm reinforcing bars.
- M20 grade of BFRC specimen shows 10.43% increase in bond strength when increasing the diameter of reinforcing bar from 10mm to 12mm. It is comparatively higher than that of other M20 grades of FRCs.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

- M50 grade of BFRC specimens shows 6.83% increase in bond strength when increasing the diameter of reinforcing bar from 10mm to 12mm.
- The addition of fiber in concrete has no significant influence in its durability.
- Durability reduces with the addition of fiber in concrete in both grades subjected to acid curing for 28 days.
- Specimens cured in H_2SO_4 solution have higher weight loss than specimens cured in HCl.
- The addition of BF in concrete shows higher weight loss than other fibers and PPF is the least.
- Weight loss of specimens cannot be reduced by improving the grade of concrete.

REFERENCES

1. Varghese, A., R., Sajal, K., Sooraj, & K., Sanand. (2018). Study of bond strength on various fibre reinforced concrete. International Journal of Current Engineering And Scientific Research (IJCESR), 5(4), 70-76.
2. Vijayalakshmi, M., & Sekar, A. S. S. (2013). Strength and durability properties of concrete made with granite industry waste. Construction and Building Materials, 46, 1-7.
3. Achillides, Z., & Pilakoutas, K. (2004). Bond behavior of fiber reinforced polymer bars under direct pullout conditions. Journal of Composites for construction, 8(2), 173-181.
4. P., Amritha, Dandapani, A., Joy, K., Varghese, A., K. & Viswanath, V., (2017). Mechanical properties of glass powder and tin strips based concrete under accelerated curing. International journal of advanced technology in engineering and science, 5(4), 439-448.
5. Malkapur, S. M., Divakar, L., Narasimhan, M. C., Karkera, N. B., Goverdhan, P., Sathian, V., & Prasad, N. K. (2017). Fresh and hardened properties of polymer incorporated self compacting concrete mixes for neutron radiation shielding. Construction and Building Materials, 157, 917-929.
6. Varghese, A., & N, Anand. (2016). Role of fibers on fire endurance of concrete - a literature review. International journal of innovative research in science and engineering, 2(5), 349-356.
7. Kizilkanat, A. B., Kabay, N., Akyüncü, V., Chowdhury, S., & Akça, A. H. (2015). Mechanical properties and fracture behavior of basalt and glass fiber reinforced concrete: An experimental study. Construction and Building Materials, 100, 218-224.
8. Varghese, A., Jasper Selva Samuel, D., N, Anand. & Arulraj G, P., (2018). Studies on behaviour of fire affected reinforced concrete. International Journal of Civil Engineering and Technology, 9(10), 1668–1675.
9. Tassew, S. T., & Lubell, A. S. (2014). Mechanical properties of glass fiber reinforced ceramic concrete. Construction and Building Materials, 51, 215-224.
10. Rahmani, T., Kiani, B., Sami, F., Fard, B. N., Farnam, Y., & Shekarchizadeh, M. (2011, April). Durability of glass, polypropylene and steel fiber reinforced concrete. In Proceedings of the International Conference on Durability of Building Materials and Components, Porto, Portugal (pp. 12-15).
11. Rabadiya, S. R., Vaniya, S. R., Rabadiya, S. R., & Vaniya, S. R. (2015). Effect of Recycled Aggregate with Glass Fiber on Concrete Properties. International Journal, 2, 257-265.
12. Varghese, A., N., Anand. & Arulraj G, P., (2019). Effect of fiber on stress strain behaviour of concrete subjected to elevated temperature. Journal of Engineering Technology, 8(1), 291-301.
13. Varghese, A., N., Anand. & Arulraj G, P., (2019). Investigation on Impact Strength of Fiber Reinforced Concrete Subjected To Elevated Temperature. International Journal of Innovative Technology and Exploring Engineering, 8(4), 397-402.
14. Alhozaimy, A. M., Soroushian, P., & Mirza, F. (1996). Mechanical properties of polypropylene fiber reinforced concrete and the effects of pozzolanic materials. Cement and Concrete Composites, 18(2), 85-92.
15. Varghese, A.,N, Anand., Arulraj G, P., & Johnson Alengaram, U. (2019). Influence of fibers on bond strength of concrete exposed to elevated temperature. Journal of Adhesion Science and Technology, 1-23.
16. Wei, B., Cao, H., & Song, S. (2010). RETRACTED: environmental resistance and mechanical performance of basalt and glass fibers.
17. Singha, K. (2012). A short review on basalt fiber. International Journal of Textile Science, 1(4), 19-28.
18. Hannant, D. J. (1998). Durability of polypropylene fibers in Portland cement-based composites: eighteen years of data. Cement and Concrete Research, 28(12), 1809-1817.
19. Toledo Filho, R. D., & Sanjuan, M. A. (1999). Effect of low modulus sisal and polypropylene fibre on the free and restrained shrinkage of mortars at early age. Cement and Concrete Research, 29(10), 1597-1604.
20. Van Gemert, D., Czarnecki, L., Maultzsch, M., Schorn, H., Beeldens, A., Łukowski, P., & Knapen, E. (2005). Cement concrete and concrete–polymer composites: Two merging worlds: A report from 11th ICPIC Congress in Berlin, 2004. Cement and Concrete Composites, 27(9-10), 926-933.
21. Rao, D. P. S., Sravana, D., Rahim, D. Z. A., & Sekhar, D. T. S. Durability studies on steel fibre reinforced metakaolin blended concrete. AKGEJC International Journal of Technology, 3(1), 38-43.

AUTHORS PROFILE

Alwyn Varghese graduated from VLBJECT, Coimbatore in the year 2009. He completed his master degree in structural engineering from KCT, Coimbatore in the year 2013. Presently, Working as asst prof. in Ahalia School of engineering, Kerala, India. And he is pursuing Ph.D in the area of Fire resistance of fiber reinforced concrete under Department of Civil Engineering, KITS, Coimbatore. He has published more than 7 research papers in International Journals and Conferences. His areas of interest are Fire resistance of fiber reinforced concrete, Bond strength of concrete.

Harikrishnan T P Final year B-tech Civil Engineering student in Ahalia School of Engg. and Tech., Palakkad..

Haritha K Final year B-tech Civil Engineering student in Ahalia School of Engg. and Tech., Palakkad.

Mohammed Razeem S M Final year B-tech Civil Engineering student in Ahalia School of Engg. and Tech., Palakkad.