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Influence of High Volume Fly Ash as a Replacement of Cement and Sand Along With Glass Fiber on the Durability of Concrete

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Abstract*: Dumping of fly ash is an emergent challenge in India day by day. The capacity of the landfill area decreases with continuously increasing the amount of fly ash. Due to restrictions of government on natural sand mining from a watercourse, contractors are demanding reliable partial replacement material for sand. Many Researchers carried out an investigation on durability properties of concrete by partially replacing cement with fly ash along with the different type of fibers. However, the influence of high volume fly ash as partly alternative for cement and sand along with glass fibers does not exist in the literature. The objective of this study is the use of alternative sustainable material such as fly ash as a partial substitute for cement and sand in concrete. Also, to check the effect on fresh and hardened properties of proposed concrete. A present study shall be a right action for reducing the utilization of cement and natural fine aggregate moreover consuming a higher amount of fly ash accessible in India for durable concrete. Based on the test result carried out in the present study indicate the improvement in compressive strength, electrical resistivity, ultrasonic pulse velocity and decrease the shrinkage in concrete

***Index Terms*: Compressive Strength, Durability, Fiber, Fly Ash, Sand, shrinkage.**

I. INTRODUCTION

In India, the generation of electricity mainly depends upon coal-based power plant which produces over 184 millions tonnes of fly ash per year with half of its in used [1]. However the production of cement increases rapidly all over the world, total emission from cement industry contribute to the extent that 8% of worldwide CO_2 emission [2]. The Author reported that for producing 1000 kg of cement nearly 900 Kg of Co_2 is emitted to the atmosphere [3], which creates major environmental issues for upcoming generations. So it is a crucial need to enhance the consumption rate of fly ash and reduce the production of cement to maintain a healthy environment. Durability is the principal properties of concrete aside from its strength. Researchers are annoying to improve the strength and durability by adding fibers and by-product from industries like fly ash in concrete. Numerous research carried out on concrete containing high volume fly ash have reported exhibiting tremendous durability properties such as high strength and low shrinkage [4]. Authors reported that the heterogeneities in the microstructure of the hydrated Portland cement paste, especially the existence of large pores and large crystalline products in the transition zone, were greatly reduced by the introduction of fine particles of fly ash [5]. Extensive research concludes that replacement of cement high volume fly ash decreases the chloride penetration of concrete specimens [6]. Study on partly replacing cement with 45% by fly ash the reduction in chloride diffusion was observed 39.1% and 76.67% at the ages of 28 and 90 days respectively [7]. Many researchers find out that the inclusion of high volume fly ash in the matrix increases the electrical resistivity. The author investigated by the inclusion of 50% fly ash as a cement replacement increases the electrical resistivity 4.8 times than normal concrete [8]. Researcher finds out by the addition of 60% fly ash as a cement replacement the improvement in electrical resistivity observed 9.1% than the normal concrete [9]. The author concludes that porosity, water absorption, and sorptivity coefficient values increased with the increases fly ash and fiber content [10]. Many researchers conclude that the addition of different types of fiber provide better performance of the concrete, while fly ash in the mixture may adjust the loss of workability due to an addition of fibers and improve the strength [11, 12]. The test result showed that the compressive strength, split tensile strength and flexural strength of fly ash concrete mixes with 10% to 50% fine aggregate replacement by fly ash were higher than control mix at all ages [13]. Also, reported that by replacement of 15% sand with fly ash by weight increased compressive strength by about 30% [14]. The most important finding by the author on the effect of high volume fly ash as a partly sand replacement in fiber reinforced concrete showed that the compressive and tensile strength values achieved more than double those of concrete without fly ash [15].

Fibers have been implemented in concrete structures to enhance tensile characteristics by inhibiting crack growth which generally occurs due to shrinkage and improving mechanical behavior. Fibers in concrete substantially improve toughness, tensile strength, flexural strength, fatigue resistance, load bearing capacity, ductility and shrinkage [16, 17]. The author concludes that the inclusion of a small amount of glass fiber in concrete increases the compressive and splitting tensile strength by 20-25% and 15-20% respectively [18].

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The researcher found that the addition of 600 gm/m^3 glass fiber in concrete reduced 50-95% crack area than normal concrete [19]. Generally, the microstructure of concrete improves using fly ash in concrete and turns improve the better performance of fiber [20]. The present challenge is to produce high volume and high-performance fly ash concrete with improved durability and life, at the least cost. Also, the concrete have a minimal harmful impact on the atmosphere that is green and sustainable concrete. This can be accomplished by decreasing the utilization of natural fine aggregates whose assets are limited and decrease very speedy day by day, by utilizing maximum probable industrial by-product such as fly ash in concrete while it would reduce huge land space, which is required for storing and dumping of fly ash.

II. RESEARCH SIGINIFICANCE

Nowadays all the attempt of the concrete technologist should be in the way of saving cement as it lowers the CO_2 production. Also, green agencies are suggested minor use of sand and higher utilization of fly ash. By using fly ash and fibers the structures will be more stable making them sustainable and expanding service life. Fly ash concrete with fibers fulfills these requirements however the issue of addressing lower workability due to the addition of fiber in concrete but use fly ash in the mixture may adjust the workability. Replacement of sand with fly ash using glass fiber effect on the durability of concrete, not well studies and hence need to study for recommending partly replacement of sand with fly ash along with glass fiber for practice use. Also, partly cement and sand alternative by fly ash along with glass fiber study not available and hence for the consumption of elevated volume fly ash in concrete such study is highly desired by the industry.

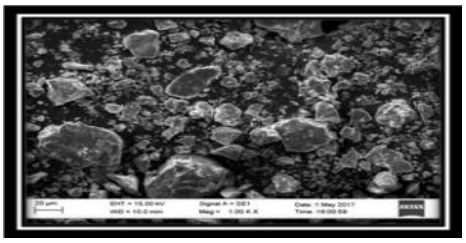
III. EXPERIMENTAL PROGRAME

The present research carried out the detail investigations of the impact of high volume fly ash and glass fibers on fresh and hardens properties of concrete like workability, early age shrinkage, ultrasonic pulse velocity, bulk electrical resistivity and compressive strength at different curing ages.

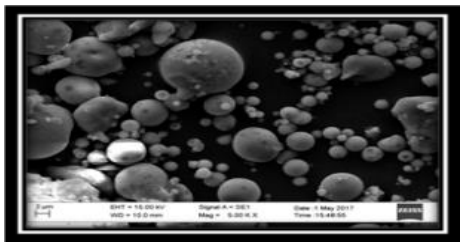
A. Materials

1. Cement The cement used in the present research was Ordinary Portland cement (OPC) 53 grade with the specific gravity of 3.16. The early and closing setting time of cement obtained 165 min and 210 min correspondingly. The normal consistency was 30.5% and soundness was 2 mm found in the test result. The Scanning electron microscope (SEM) and Energy dispersive X-ray (EDX) test done on cement and found to be the uneven shape of cement particles as displayed in figure 1(a) and their element content are given in table 1.

2. Fly Ash The fly ash (FA) was composed of NSPCL, Bhilai, located in Chhattisgarh India. The specific gravity of fly ash was 2.15 and fineness passing by 90-micron sieve was 89.7%. On fly ash, the SEM and EDX test was accomplished and found to be the spherical shape of fly ash particles shown in figure 1(b) and their element content are specified in the table 1.



(a) The irregular shape of OPC



(b) The spherical shape of FA

Fig. 1 SEM image of cement and fly ash particles

3. Aggregate The aggregate used in the mixture was dry and clean. The 20 mm and 10 mm coarse aggregate were purchased separately from a local supplier. For achieving the final grading of coarse aggregate as per IS 383-1970 the 20 mm and 10 mm aggregates were combined 60% and 40% respectively. The fine aggregate was collected from the Mahanadi River Basin. The physical properties were tested as per IS 2386-1963 which is given in table 2.

4. Glass Fiber As per data sheet available from a local supplier of glass fiber, the length was 12 mm and diameter was 14 micrometer, the physical properties such as tensile strength, modulus of elasticity and specific gravity were 1700 MPa, 72 GPa and 2.6 respectively. In the present study, 600 gm/m^3 of Anti-Crack high diffusion glass fiber was used for mixes.

5. Plasticizer A water Reducing Master Builders solutions were used to improve concrete durability. The dosage was kept constant by 1% of cementitious material

Table 1 Element content of OPC and fly ash (%)

Chemicals	OPC	Fly ash
Silica (Si)	15.70	63.78
Calcium (Ca)	68.51	1.12
Aluminum (Al)	4.65	24.44
Iron (Fe)	3.76	5.01
Magnesium (Mg)	1.66	0.48
Sulphur (S)	2.66	----
Potassium (K)	2.35	2.46
Sodium (Na)	0.37	0.11

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B. Mix Proportion

The mix design was prepared as per Indian Standard (I.S.) 10262: 2009 using 0.35 of water-cement ratio. Total ten mixes were cast i.e. control concrete, concrete along with glass fiber and remaining mixes in which cement and sand partially replaced by fly ash along with glass fiber as given in Table 2. To measure the significance of fly ash on initial age shrinkage each concrete mixture were filled in shrinkage cone. All the concrete sample of size 100 X 100 mm cube was cast and demoulding after 24 hours. For testing of compressive strength of the concrete mixture, the specimen was cured at 7, 28, 56 and 119 days. The mixture C_{0-0} denotes control concrete; F_{0-0} denotes concrete along with glass fiber. The F_{20-0} and F_{0-20} denotes partly 20% cement and sand replacement respectively and so on by fly ash in percentage.

Table 2 Mix proportion for concrete

Mix	Cement (Kg/m^3)	Fly Ash (Kg/m^3)	Sand (Kg/m^3)	Aggregate (Kg/m^3)	Fiber (gm/m^3)	Water (Kg/m^3)	Slump (mm)	Shrinkage (µm)
C_{0-0}	450	0	712	1117	600	157.5	31	261.27
F_{0-0}	450	0	712	1117	600	157.5	24	147.42
F_{20-0}	360	90	712	1117	600	157.5	29	103.38
F_{40-0}	270	180	712	1117	600	157.5	37	77.81
F_{0-20}	450	121	591	1117	600	157.5	25	127.34
F_{0-40}	450	242	470	1117	600	157.5	18	109.31
F_{20-20}	396	211	591	1117	600	157.5	28	98.30
F_{20-40}	396	332	470	1117	600	157.5	23	87.32
F_{40-20}	297	301	591	1117	600	157.5	32	64.32
F_{40-40}	297	422	470	1117	600	157.5	28	53.62

C. Test on fresh concrete

Properties of fresh concrete such as slump and early age shrinkage were determined and tabulated in table 2. Workability of concrete along with glass fiber without any replacement was found lower than all others mixes, as many researchers conclude that fibers hinder the flowability of concrete. Partly replacement of cement and sand by fly ash along with glass fiber found higher workability due to spherical shape and ball bearing effect of fly ash than control mix and concrete along with glass fiber mix. By using shrinkage meter the shrinkage of fresh concrete was measured in the present study. The shrinkage meter as shown in figure 2 consists of the cone for checking the shrinkage of concrete, mortar, cement paste, etc. The cone consists of a container having an 11 cm diameter and 9 cm height. For measuring the shrinkage of concrete the material is filled inside the container after laying separation foil on the internal face of the surface of the container. A laser that is seated on a beam set can be changed up and down by rack and pinion adjustment. By moving vertically up and down the laser beam is directed continuously on the specimen container and place on the functioning area. Shrinkage of every second can be measured in micrometer (µm) with the help of shrinkage meter which is attached to the computer. In the data logger box, the time and shrinkage are measured, for further analysis the measured reading extracted in an excel sheet. Figure 3 shows the simplified illustration of shrinkage cone. Location 1 denotes the cone formed specimen container, 2 shows the mix of concrete, 3 represent a laser unit, 4 stands for reflector and 5 denotes the computer. The proposed homogeneous mix was filled in three coats up to the edge of the shrinkage cone. To eliminate the complete air bubble in the mix shrinkage cone was slightly vibrated. A reflector was put up at the intermediate of the mixed surface.

Fig. 2 Model of shrinkage meter

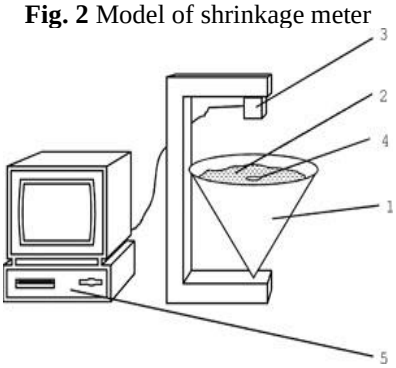

Fig. 3 Simplified illustration of shrinkage cone meter

The cone is stored indoors the shrinkage meter and laser ray concentrated at the peak center of the reflector. To record the shrinkage by data logger box the time interval of 30 minutes was set.

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By giving the required command to a computer the measuring of shrinkage was initiated at every 30 minutes of the period. The first 30 minutes result tabulated in table 2 for different mixes.

D. Test on harden concrete

After curing the concrete cubes were tested for compressive strength using the compressive testing machine at disparate curing ages. The cubes were also tested for electrical resistivity subsequently ultrasonic pulse velocity test. The soaked cubes were sighted among two similar metal plates with a wet sponge of electrical resistivity meter. By applying tiny irregular current at the proposed frequency the voltage among two ends of the concrete sample was measured. The monitor of electrical resistivity has displayed the value of impendence (Z), through that impendence value the resistivity of concrete was determined as the following equation (1)

$$\rho = \frac{A}{L} Z \quad (1)$$

Where, ρ is the resistivity of a concrete mixture (Ωcm), Z is the impendence (Ω), A denotes the cross-sectional area of the specimen (cm^2) and L denotes the length of the specimen (cm). The ultrasonic pulse velocity (UPV) consists of measuring the travel time (T) of the pulse of longitudinal ultrasonic waves passing through the concrete specimen. The travel times among the primary onset and reception of the pulse are measured electronically. The pulse velocity is given by using equation (2)

$$V = \frac{L}{T} \quad (2)$$

Where V denotes the ultra pulse velocity, L denotes the length of specimen and T is the travel time. By using the above equation the electrical resistivity and UPV of all ten mixes were calculated and shown in Fig. 3 and 4. The compressive strength of cubes for all the mixes was tested at the age of 7, 14, 28, 56 and 119 days of curing.

IV. RESULT AND DISCUSSION

A. Workability

All the mixes were set using 0.35 water-cement ratio, the effect of fly ash on the workability of concrete along with glass fibers was measured in terms of slump value as shown in Table 2. Concrete made with glass fiber without any replacement shows a reduction in workability as the addition of fibers in concrete hinder the flowability of a mix. The replacement of cement 20% and 40% by fly ash along with glass fiber increases the slump value of 20.83% and 35.13% respectively than concrete made with glass fiber (F_{0-0}). It can be concluded that increase in the fly ash content causes further increase in workability because the influence of fly ash on workability is primarily credited to the ball bearing property due to rounded shape of fly ash particles, these spherically shaped fly ash particles decreases the internal friction in fresh concrete, thus, improve the flowability of fresh concrete. It can be concluded that the failure of workability due to the addition of glass fiber may be adjusted by the incorporation of fly ash in concrete. The replacement of 20% sand by fly ash the workability slightly increased than concrete made with glass fiber. But when sand is replaced 40% by fly ash with glass fiber decreased the slump value 25% than concrete made with glass fiber. The reduction in a slump was due to more fineness in concrete by the inclusion of fly ash which increases the water demand.

B. Early age shrinkage

The early age shrinkage of all fresh concrete mixes was carried out by using shrinkage cone apparatus. The shrinkage of control concrete found to be 261.27 µm, whereas by addition of 600 gm/m^3 glass fiber (F_{0-0}) the reduction in shrinkage noted 43.57% than normal concrete. The reason is that the glass fiber has a high tensile strength which increases the tensile strength of concrete. Mainly cracks depend on the tensile strength of concrete, so that it can resist the cracking due to volume changes and reduced the shrinkage cracking of concrete. As the percentage replacement of cement by fly ash increases, the reduction in shrinkage also increases. The partial replacement of cement 20% (F_{20-0}) and 40% (F_{40-0}) by fly ash noted a reduction in shrinkage was 29.87% and 47.21% respectively than concrete along with glass fiber only. The reduction in shrinkage at an early age is due to the low amount of cement, which reduced almost 40% heat of hydration in the fly as concrete. Inclusion of fine fly ash in concrete bleeding reduces due to which shrinkage also decreases. The concrete made with 20% (F_{0-20}) and 40% (F_{0-40}) sand replacement by fly ash, the reductions in shrinkage were 13.62% and 25.85% observed than concrete along with glass fiber. The reduction may be due to minor bleeding on account of a high quantity of fine fly ash, and superior packing of material due to the inclusion of fly ash. Combine replacement of 40 % cement and 40% sand (F_{40-40}) by fly ash shows a higher reduction of shrinkage than all other mixes. The reduction is due to a large amount of finer material which reduced voids inside the concrete, liberate less heat, less bleeding and better packing effect.

C. Electrical resistivity (ER)

The Electrical resistivity tests of all 10 mixes were carried out by using resistivity meter at the age of 7, 28, 56 and 119 days. From figure 4 the ER value for control concrete (C_{0-0})) found to be less than 10 KΩcm at the age of 7 and 28 days. By the addition of glass fiber in plane concrete, the ER values increased by 23.81%, 25.36%, 31.78% and 37.61% at the age of 7, 28, 56 and 119 days respectively than control concrete, which illustrates the good ability of resistance at the side of corrosion. As a replacement of cement by fly ash along with glass fiber increased the ER values also increased than concrete made with glass fiber (F_{0-0}). The increment in ER value found to be 23.28% and 42.24% at the age of 28 and 119 days for 20% and 40% cement replacement. When sand is replaced 20% by fly ash (F_{0-20}) the ER values slightly increased than concrete made with glass fiber. The combined replacement of 40% cement and 20% sand (F_{40-20}) by fly ash got a better result than all other mixes except (F_{40-0}). Hence it is concluded that the higher replacement of cement by fly ash shows more durability. This is due to the spherical shape of fly ash which improves the packing density of concrete.

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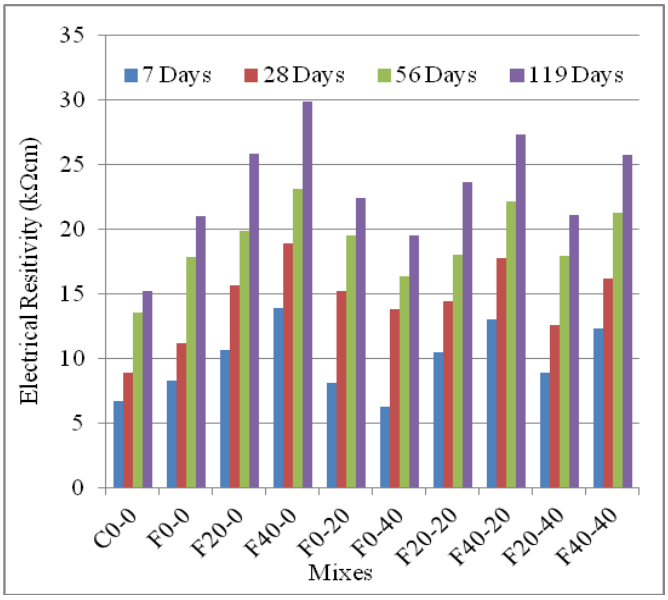

Fig. 4 Electrical Resistivity result for different mixes

D. Ultrasonic pulse velocity (UPV)

Figure 5 shows that the addition of 600 gm/m^3 of glass fiber, UPV values increased by 3.27% of control concrete at the age of 28 days. For replacement of cement 20% (F_{20-0}) and 40% (F_{40-0}) by fly ash, the UPV value increased by 2% and 4.10% respectively than fiber reinforced concrete (F_{0-0}). The increment in UPV is due to the formation of extra C-S-H gel by addition of finer fly ash, which increased the microstructure of concrete. When 20% of sand is replaced by fly ash (F_{0-20}) the UPV values nearly the same or slightly increased than glass fiber concrete (F_{0-0}) up to the period of 119 days. But when 40% of sand is replaced by fly ash (F_{0-40}) the UPV values decreased by nearly 1.23% at the age of 119 days than concrete along the glass fiber (F_{0-0}). For combine replacement (F_{40-20}) by fly ash shows a better result than all other mixes except (F_{40-0}). The increment in UPV is due to proper packing and formation of extra C-S-H gel which increased the microstructure of concrete.

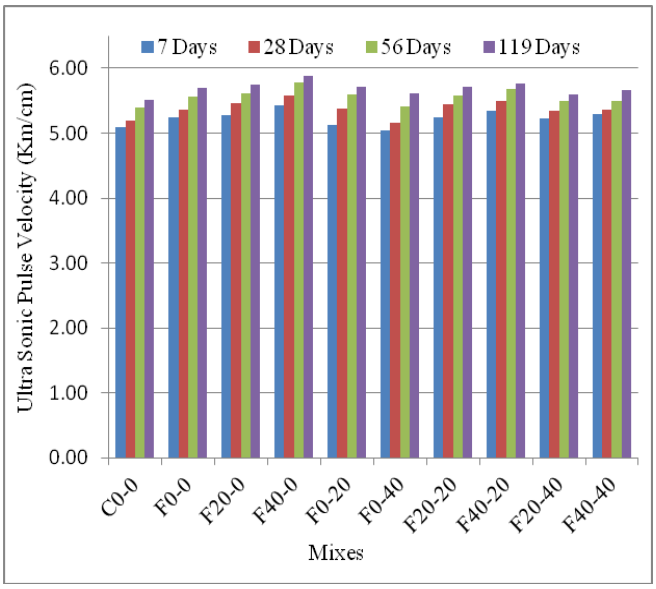

Fig. 5 Ultrasonic Pulse Velocity result for different mixes

E. Compressive Strength

The compressive strength was calculated for all 10 concrete mixes on 160 cubes for 0.35 water-cement ratio after testing on electrical resistivity and ultrasonic pulse velocity test. Figure 6 shows the result of compressive strength of various mixes at the period of 7, 28, 56 and 119 days.

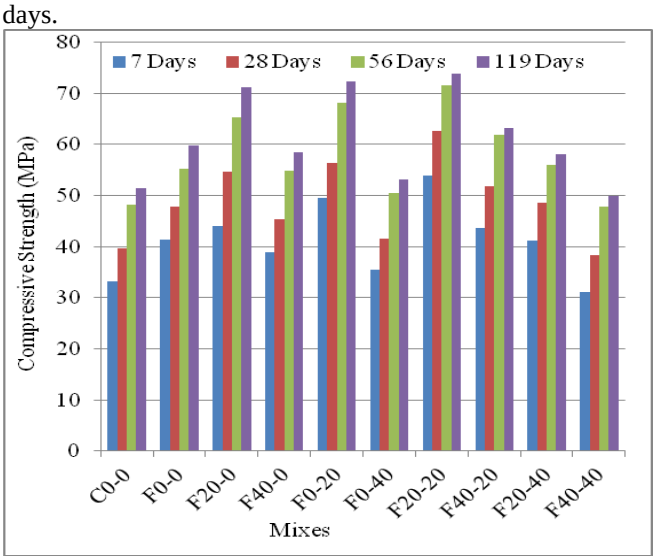

Fig. 6 Compressive strength result for different mixes

The result shows that by addition of 600 gm/m^3 of glass fiber in concrete the average compressive strength increases up to 20% at all the ages than normal concrete. The reason is that the fiber arrest the cracks in concrete which increase the strain hardening property and increases the extra compressive strength.

When 20% cement replaced by fly ash along with glass fiber (F_{20-0}) the strength increased by 37.83% & 14.42% than normal concrete (C_{0-0}) and concrete made with glass fiber (F_{0-0}) respectively at the duration of 28 days. The increase in strength was observed at 38.50% and 19.05% at the age of 119 days. The presence of fly ash in concrete create the extra C-S-H gel than normal concrete, due to the creation of extra C-S-H gel the microstructure of mix improved which improve the compressive strength. But when cement replaced 40% by fly ash (F_{40-0}) the compressive strength decreases than concrete made with glass fiber.

When sand replaced 20% by fly ash (F_{0-20}) the compressive strength increased by 18.14% than concrete along with glass fiber at the age of 28 days. Also, the slight increment in strength was observed when cement replaced 20% by fly ash (F_{20-0}). The strength is increased may be due to better packing effect and reduction in voids in concrete when sand replaced by fly ash.

In present study combine replacement of 20% cement & 20% sand with fly ash (F_{20-20}) shows the best outcome than all another mix at all the ages. Also, combine substitute of 40% cement and 20% sand (F_{40-20}) by fly ash got an exceptional result than standard concrete and concrete made with glass fiber (F_{0-0}). Present result shows that by incorporating high volume fly ash in concrete can achieve more or the same strength than control concrete and concrete made with glass fiber respectively. Hence for better strength and durability of concrete, combine alternative up to 40% cement & 20% fine aggregate with fly ash can be suggested in practice use.

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V. CONCLUSION

1. The loss of workability due to the addition of glass fiber can be regulated by the involvement of fly ash in the mix.
2. Addition of 600 gm/m3 of glass fiber of total volume reduced the shrinkage by 43.57%, also increased electrical resistivity (ER), ultrasonic pulse velocity (UPV) and compressive strength by 25.36%, 3.27% and 20.47% at the period of 28 days respectively than normal concrete.
3. When 40% cement replaced by fly ash along with glass fiber the shrinkage reduce by 47.21%, ER values increased by 60% and UPV increased by 4.10% than concrete made with glass fiber only (F_{0-0}), but compressive strength decreased by 5.33%. Hence durability point of view adoption of high quantity fly ash can be proposed in concrete.
4. When 20% of sand replaced by fly ash ER increased by 36.07%, the value of UPV nearly same and compressive strength increased by 18.26% than concrete along with glass fiber respectively. But a reduction in shrinkage was observed 13.62% for the same mix.
5. Replacement of sand 40% by fly ash affects the adverse effect on ER, UPV, and compressive strength compared to concrete along with glass fiber (F_{0-0}). But the reduction in shrinkage was observed 26.00% for the same replacement.
6. The combined replacement of 20% cement and 20% sand with fly ash got the best outcome than all the additional mixes. The ER, UPV and compressive strength increased by 28.91%, 30.93%, and 33.31% respectively at 28 days compared to concrete along with glass fiber.
7. Also, combine substitution of 40% cement and 20% sand by fly ash observed increment in ER by 52.35%, UPV by 6%, compressive strength by 9% and reduction in shrinkage by 56.36% compare to concrete along with glass fiber.
8. From the result, it is noticed that the use of fly ash and glass fiber help to increased the durability by increasing ER, UPV, compressive strength and reducing the shrinkage.
9. Hence without hampering durability, strength and cost of concrete, merge replacement up to 40% cement and 20% fine aggregate with fly ash along with 600 gm/m^3 of glass fiber will be highly recommended in general practice use. This will consume a large amount of fly ash and reduce the quantity of cement.
10. Consuming high volume fly ash in concrete as a partial replacement material for cement and sand, we can save natural resources, keep the environment green and increasing the service life of structure at the lowest possible cost.

REFERENCES

1. Report on Fly-ash generation at coal/lignite based thermal power station and its utilization in the country (2018, December). *Central Electricity Authority* India. Available: http://www.cea.nic.in
2. Robbie M. Andrew (2018, January). Global CO_2 emission from cement production. *Earth Science Data* 10, 195-217. Available: https://www.earth-syst-sci-data.net
3. E. Benhelal, G. Zahedi, E. Shamsaei, A. Bahodori (2013, July). Global strategies and potentials to curb CO_2 emission in cement industry. Journal of Cleaner Production, Elsevier. 51, 142-161.
4. Cengiz duran atis (2003, April). High volume fly ash concrete with high strength and low drying shrinkage. Journal of Material in Civil Engineering, ASCE, 15, 153-156.
5. V. M. Malhotra, and P. K. Mehta, (2002, Augest). High-Performance, High-Volume Fly Ash Concrete. Materials, Mixture Proportioning, Properties, Construction Practice and Case Histories. Ottawa, Canada.
6. W. Chalee, M. Teekavanit, K. Kiattikomol, A. Siripanichgorn, C. Jaturapitakkul (2007, May). Effect of W/C ratio on covering depth of fly ash concrete in marine environment. Construction and Building Materrial, Elsevier. 21, 965–971.
7. C. S. Poon, L. Lam, Y. L. Wong (2000). A study on high strength concrete prepared with large volumes of low calcium fly ash. Cement and Concrete Research, Elsevier. 30, 447–455.
8. J. Hoppe Filho, M. H. F. Medeiros, E. Pereira, P. Helene, M. ASCE, G. C. Isaia (2013, March). High-Volume Fly Ash Concrete with and without Hydrated Lime: Chloride Diffusion Coefficient from Accelerated Test. Journal of Materials in Civil Engineering, ASCE. 25 (3), 411–418.
9. M. Gesoglu, E. Guneyisi, E. Ozbay (2009). Properties of self-compacting concretes made with binary, ternary, and quaternary cementitious blends of fly ash, blast furnace slag, and silica fume. Construction and Building. Materials, Elsevier. 23, 1847–1854.
10. O. Karahan, C. D. Atis (2011, February). The durability properties of polypropylene fiber reinforced fly ash concrete, Materials and Design, Elsevier. 32, 1044–1049.
11. I. B. Topcu, M. Canbaz (2007, July). Effect of different fibers on the mechanical properties of concrete containing fly ash, Construction and Building Materials, Elsevier. 21, 1486–1491.
12. C. D. Atis (2002, May). Heat evolution of high-volume fly ash concrete. Cement and Concrete Research, Elsevier. 32, 751–756.
13. R. Siddique (2003). Effect of fine aggregate replacement with Class F fly ash on the mechanical properties of concrete. Cement and Concrete Research, Elsevier. 33, 539–547.
14. K. Rebeiz, S. Serhal, A. Craft, (2004, February). Properties of Polymer Concrete using Fly Ash. Journal of Materials Engineering, ASCE. 16(1) 15-19.
15. O Kayali (2004, June). Effect of high volume fly ash on mechanical properties of fiber reinforced concrete. Materials and Structure, Springer. 37, 318-327.
16. C. Jiang, K. Fan, F. Wu, D. Chen (2014, June). Experimental study on the mechanical properties and microstructure of chopped basalt fibre reinforced concrete. Materials & Design, Elsevier. 58, 187-193.
17. P. K. Mehta, P. J. Monteiro, (2006). Concrete: Microstructure, properties, and materials. New York: 3rd Edition, McGraw-Hill.
18. K. Chandramouli, P. S. Rao, N. Pannirselvam T. S. Seshadri, P. Sarvana (2010, April). Strength properties of glass fiber concrete. ARPN journal of Engineering and Applied sciences, 5(4), 1-6.
19. G. Barluenga, F. Hernández-Olivares (2007, August). Cracking control of concretes modified with short AR-glass fibers at early age. Experimental results on standard concrete and SCC. Cement and Concrete Research, Elsevier. 37, 1624–1638.
20. V.S. Ramachandran, J. J. Beaudoin, (2001). Handbook of analytical techniques in concrete. NOYES publications, New Jersey, U.S.A.

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He published 20 research papers in reputed journals like SCI and Scopus Indexed. Also nearly 19 papers contribution in national journals and international conferences. He invited as a guest lecturer in government and reputed engineering colleges. He is an associate member of The Institution of Engineers, a life member of ISTE, Member of American Concrete Institute and member of Indian Concrete Institute.

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