IJE TRANSACTIONS A: Basics Vol. 30, No. 7, (July 2017) 964-971

International Journal of Engineering

Journal Homepage: www.ije.ir

Durable Glass Fiber Reinforced Concrete with Supplimentary Cementitious Materials

B. Rath*, S. Deo, G. Ramtekkar

Civil Engineering Department, NIT, Raipur, India

PAPER INFO

Paper history:
Received 29 January 2017
Received in revised form 15 March 2017
Accepted 21 April 2017

Keywords:
Fly Ash
Pond Ash
Glass Fiber
Shrinkage Test
Electrical Resistivity Test
Ultrasonic Pulse Velocity Test

ABSTRACT

Durability of concrete structure in marine environments is a big issue for many decades due to chloride attack. Chloride penetrates the concrete structure and accelerates the corrosion process of reinforcement which decreases the life of those structures. Also shrinkage cracks in concrete play main role for chloride penetration through concrete surface. Many researchers tried to find easy and economical ways to obtain durable concrete in such marine region by use of supplementary cementitious material with proper curing regime. Also use of fiber in concrete may arrest the shrinkage cracks, decreasing the chloride permeability and increasing the durability of concrete. Durability of concrete with glass fiber and by replacement of cement and sand partially by supplementary cementitious material such as fly ash and pond ash, respectively is measured by conducting shrinkage test, bulk electrical resistivity, SEM and ultrasonic pulse velocity test. Based on various test result present research proposes an economical durable concrete with desired compressive strength by use of glass fiber and supplementary cementitious material.

***doi**: 10.5829/ije.2017.30.07a.05*

1. INTRODUCTION

Durability of concrete is one of its most important properties aside from its compressive strength. Nowadays many researchers are trying to develop concrete with enhanced durability and strength by adding fibres and supplementary cementitious material. Several investigations carried on concrete containing fly ash have reported to exhibit excellent mechanical and durability properties [1-5]. It has been reported that 20-30% replacement of cement with activated fly ash improved the corrosion-resistance, electrical resistivity and strength of concrete [6, 7]. Soleimanzadeh and Mydin [8] concluded that flexural strength exposed to high temperature increased due to replacement of cement with fly ash up to 30%. Also fly ash can be used as sand replacement partially using minimum voids method for higher compressive strength, flexural strength and workability at lower cost [9]. Non activated and coarse fly ash reduces the twenty eight days strength of concrete when used as replacement of cement. In present fly ash disposal system fly ash from all hoppers is collected in silos and distributed for further use. Coarse fly ash particles require longer curing period before they achieve compressive strength. In this view, coarser combined fly ash available from silos used for the study and required curing days for achievement of comparable compressive strength was found. On the other hand, pond ash is collected as combination of fly ash and bottom ash at bottom of the boiler, mixed in slurry form and deposited in a pond by pumping. Since size of pond ash is higher than fly ash and cement and disposed with water for long time, it has a very low amount of binding property [10]. Hence many researchers used it as sand replacement material. Literatures have shown increase in compressive strength and decrease in workability in concrete due to addition of pond ash as partial replacement of sand.

Fly ash and pond ash complement each other as reduction in compressive strength as partial replacement of cement may be compensated by partial replacement of sand with pond ash. Also loss of workability due to partial replacement of sand with pond ash may be improved by partial replacement of cement with fly ash. Use of fly ash in concrete improves the micro structure and in turn improves the performance of fiber [11]. Inclusion of fiber in concrete influences matrix greatly

*Corresponding Author's Email: *rath_rcpit@rediffmail.com* (B. Rath)

and improves the engineering properties of the concrete such as the tensile strength, flexural strength, impact, fatigue and abrasion resistance, shrinkage, deformation capability, toughness and load bearing capacity after cracking [12, 13]. The use of high strength materials requires that the concrete members perform satisfactorily under high stress levels. Due to high tensile strength of glass fibre it is reported that compressive strength increases by 20-25%, flexural strength and splitting tensile strength increase by 15-20% [14]. The durability related problems in concrete structures due to environmental causes include steel corrosion, cracking, carbonation, sulphate attack, scaling, abrasion and cavitations etc. The protection of concrete against corrosion of steel, which is mainly due to the ingress of chloride ions, oxygen, carbon dioxide or water is greatly decreased with reduction of cracks. By increasing the period of curing and addition of fly ash and fiber shrinkage cracks may be greatly reduced. In order to achieve low permeability and chloride penetration proper curing is essential in concrete making [15]. Though the rapid chloride permeability test gives the corrosion risk, it is not always consistent and differs by up to 51.2% in different laboratories [ASTM Committee C09]. Therefore, a faster and more reliable testing method is required to determine the corrosion risk of reinforcement [16]. Hence electrical resistivity test fulfill the requirement because the electrical resistivity of water saturated concrete is an indirect measurement of the concrete pore connectivity. In addition ultra pulse velocity (UPV) test is used for assessment of deterioration. In UPV test an ultrasonic sound velocity is created by transmitting transducer and sent through the concrete block and receives this stress waves by receiving transducer. This velocity depends upon the density and packing arrangement of the material. Hence UPV evaluates the qualitative assessment of homogeneity of concrete, which is correlated with compressive strength indirectly.

2. RESEARCH SIGNIFICANCE

In recent years the research has been focused on increasing the durability of high performance concrete incorporating supplementary cementitious material (SCM). There are limited researches on durability of concrete for cement and sand replacement simultaneously with fly ash and pond ash, respectively. Cement companies while manufacturing Portland Pozzolana Cement (PPC), generally replace up to 25% cement with fly ash. Also construction industry is always demanding of alternate material for partial replacement of sand due to shortage of good quality natural sand. In view of this a detailed study on concrete with up to 40% replacement of cement with fly ash and 20% sand replacement with pond ash is necessary to know its effect on strength and durability of concrete before use at site. For various researches finer fly ash as replacement of cement is used, however present paper studies the effect of coarse fly ash as available from combined silo. Inclusion of fly ash improves the performance of fiber in concrete due to better matrix. Hence effect of glass fiber along with fly ash and pond ash on durability and strength needs to be checked. Present research shall propose possible economical durable concrete with required compressive strength for further practical use.

3. MATERIALS AND METHODS

The work presented in this paper is a detailed investigation effect of addition of fiber, SCM into concrete on the behavior of shrinkage, bulk electrical resistivity, ultrasonic pulse velocity test and compressive strength at various curing ages.

3. 1. Materials

In this research, cement, sand, coarse aggregates, coal ash, glass fiber and super plasticizer were used to produce concrete and their specifications are shown in Table 1.

FM= Fineness Modulus

V_f = Volume of Fraction

Cement and glass fiber were purchased from local supplier. The sand was collected from Mahanadi River Basin and used as fine aggregate. Locally available crushed stone were used as coarse aggregate. Both fly ash and pond ash were selected as supplementary cementitious materials and collected from NSPCL, Bhilai. Addition of fiber decreases shrinkage and slump and reduction of slump could increase the voids hence optimum value of fiber dose was decided with in limit of shrinkage and workability. Physical properties of glass fiber is shown in Table 2.

3. 2. Mix Proportions

The mix design was prepared using water cement ratio of 0.35 with and without glass fiber as shown in Table 3.

TABLE 1. Properties of materials

S.N.	Materials	Specifications
1	Cement	OPC 43 Grade
2	Sand	Zone-II, FM=2.67
3	Aggregate	10 mm size, FM=5.9
4	Fly ash	Retained 91% fly ash in 150 μm sieve
5	Pond ash	Zone-IV, FM=1.41
6	Glass fiber	Length=12 mm, Dia=14μm, V_f=0.1%
7	Super plasticizer	Water soluble sulphonated polymers, Dose of Use = 0.75%

TABLE 2. Physical properties of glass Fiber (as per data sheet of supplier)

S.N.	Properties	Test Result
1	Appeareance	White
2	Physical state	Solid
3	Softening point	860 ^{0}C
4	Specific gravity	2.6
5	Tensile strength	1700 MPa
6	Modulus of elasticity	72 GPa

Two types of concrete were prepared named as controlled concrete i.e. without fiber (C) and with fiber (F). Cement is replaced with fly ash by weight 20 and 40% where sand is replaced with pond ash by volume 10 and 20%. The cement was replaced by fly ash 20 and 40% by weight; and sand is replaced with pond ash in 10 and 20% by volume. It is suggested by I.S. code that mix design of concrete is to be prepared on volume basis. Hence sand is replaced up to 20% with pond ash by volume. But mix design of PPC I.S. code suggests replacing the cement partially with fly ash by weight. Hence the cement is replaced with fly ash up to 40% by weight. The control concrete mix is denoted as C_{x-y} and fiber reinforced concrete is denoted as F_{x-y}. Here 'x' denotes cement replacement and 'y' denotes sand replacement in percentage. The ingredients of concrete were mixed in 0.04 m^3 capacity mixer. Weighed quantities of cement, sand and coarse aggregate were dry mixed until a uniform colour was obtained. Measured quantity of water was added with adding admixture of 0.75% of cementitious materials.

Prepared concrete of each concrete mixture was filled in shrinkage cone to measure the early shrinkage and 216 numbers of cubes of size 100 × 100 × 100 mm were cast for determining the bulk electrical resistivity and ultrasonic pulse velocity. The specimens were de-molded after 24 hours and cured in water for 7, 28, 56 and 119 days to know the effect of longer days of curing on strength and durability of concrete.

3. 3. Fresh Concrete Test

Slump and shrinkage found for fresh concrete are shown in Table 3.

TABLE 3. Mix proportions of materials for both non fiber and fiber reinforced concrete

Mix	Cement (kg/m^3)	Sand (kg/m^3)	Aggregate (kg/m^3)	Fly Ash (kg/m^3)	Pond ash (kg/m^3)	Water (kg/m^3)	Admixture (kg/m^3)	Fiber (kg/m^3)	Slump (mm)	Shrinkage (µm)
Non fiber reinforced concrete										
C_{0-0}	450	917	959	0	0	157	3.4	0	36	256.42
C_{20-0}	360	917	959	90	0	157	3.4	0	42	189.19
C_{40-0}	270	917	959	180	0	157	3.4	0	47	135.34
C_{0-10}	450	841	959	0	76	157	3.4	0	34	217.96
C_{0-20}	450	765	959	0	152	157	3.4	0	31	197.45
C_{20-10}	360	841	959	90	76	157	3.4	0	39	179.50
C_{20-20}	360	765	959	90	152	157	3.4	0	37	164.11
C_{40-10}	270	841	959	180	76	157	3.4	0	44	123.08
C_{40-20}	270	765	959	180	152	157	3.4	0	42	97.44
Fiber reinforced concrete										
F_{0-0}	450	917	959	0	0	157	3.4	2.65	25	110.26
F_{20-0}	360	917	959	90	0	157	3.4	2.65	29	80.49
F_{40-0}	270	917	959	180	0	157	3.4	2.65	32	57.34
F_{0-10}	450	841	959	0	76	157	3.4	2.65	24	93.72
F_{0-20}	450	765	959	0	152	157	3.4	2.65	22	84.90
F_{20-10}	360	841	959	90	76	157	3.4	2.65	27	77.18
F_{20-20}	360	765	959	90	152	157	3.4	2.65	26	70.57
F_{40-10}	270	841	959	180	76	157	3.4	2.65	31	52.93
F_{40-20}	270	765	959	180	152	157	3.4	2.65	29	41.90

In case of replacement of cement by 40% fly ash, slump height was about 30% lower than the control concrete. Similarly for fiber reinforced concrete, workability decreases compared to non fiber reinforced concrete. Workability of concrete with cement replacement by fly ash was always higher due to ball bearing effect of fly ash. Addition of pond ash and fiber reduced workability; however it was compensated by partial replacement of cement with fly ash. In all combinations of fly ash and pond ash slump was more than the control concrete. Addition of 0.1% fiber considerably reduced workability loss of up to 40%.

3. 4. Harden Concrete Test After curing for stipulated period, the cubes were taken out from the tank and tested for bulk electrical resistivity followed by ultrasonic pulse velocity test. The saturated wet cubes were placed in between two parallel metal plates with moist sponge of electrical resistivity meter. The voltage between two ends of the concrete specimen was measured by applying small alternating current at intended frequency. The impedance Z was displayed on the monitor of electrical resistivity meter. Concrete resistivity was then determined using that impedance value as follows:

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

where, ρ is the resistivity of concrete (Ωcm), A is the cross sectional area of the specimen (cm^2), L is the length of specimen (cm) and Z denotes the impedance measured by device (Ω). In UPV test the time interval (T) between the onset of a pulse generated at the transmitting transducer and the onset of its arrival at the receiving transducer were measured and displayed on monitor. The pulse velocity is given by:

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

where V is the ultra pulse velocity, L represents the length of specimen and T is the transit time. By using the above formula the ER and UPV of eighteen mixes were calculated and plotted as shown in Figures 6 and 7. The compressive strength test is conducted for all 216 cubes after 7, 28, 56 and 119 days curing. By using the above formula the ER and UPV of eighteen mixes are calculated. The compressive strength test is conducted for all 216 cubes after 7, 28, 56 and 119 days of curing.

4. RESULT ANALYSIS

By using the above formula the ER and UPV of eighteen mixes were calculated. The compressive strength test is conducted for all 216 cubes after 7, 28, 56 and 119 days of curing.

4. 1. Workability Test All mixes of fiber and non fiber reinforced concrete were prepared in low water cement ratio like 0.35 and maximum size of aggregate was 10 mm. Hence the slump values of all mixes are less than 50 mm. It is noticed that when cement is replaced with fly ash by 20%, slump value increases by 16% and when cement is replaced by 40%, slump value increases by 30%. This occurs due to the small spherical size of fly ash particle and also fly ash inside the voids of cement, pronouncing lubrication effect and ball bearing action in the concrete. Coarse fly ash has also worked very well to improve workability. But when sand is replaced with pond ash by 10%, slump value decreases by 5% and when it is replaced with pond ash by 20% by volume, slump value decreases by 14%. Pond ash increases the water demand and hence decreases the workability. For both replacement of cement and sand partially with fly ash and pond ash slump value lies in between C_{40-0} and C_{0-20} for non fiber reinforced concrete and F_{40-0} and F_{0-20} for fiber reinforced concrete. Hence it is concluded that addition of fly ash compensates the loss of workability due to replacement of sand by pond ash or addition of fiber.

4. 2. Shrinkage Test The shrinkage test of eighteen mixes fresh concrete was carried on shrinkage cone. Shrinkage of control concrete was noted as 161.4 µm. When 0.1% fiber is introduced in control concrete the shrinkage value decreases by 40% as compared to control concrete. When 20% cement is replaced with fly ash by weight shrinkage decreased by about 8% and when cement replacement increases to 40%, shrinkage of concrete decreases by about 23%. On the other hand, the replacement of sand with pond ash by volume does not affect the shrinkage properties. The shrinkage value slightly decreases i.e 2 for 10% sand replacement and 3.5 for 20% sand replacement. Among both replacement of cement and sand with fly ash and pond ash, 40% cement replacement and 20% sand replacement shows better result.

4. 3. Electrical Resistivity Test Bulk Electrical Resistivity Test (ER) was carried with resistivity meter as per guide lines of ASTM C 1202. Data was generated on for all 18 mixes of fiber and non fiber reinforced concrete at the age of 7, 28, 56 and 119 days. ER value of control concrete without replacement (C_{0-0}) at age 7 days and 28 days of curing is less than 10 kΩ cm, while 56 and 119 days lies within 10-20 kΩ cm. When glass fiber of 0.1% of volume of fraction was introduced in plane concrete, electrical resistivity increased 40% as compared to the control concrete which is more than 10 kΩ cm at 28 days of curing and 20 kΩ cm at 119 days of curing indicating good capacity of resistance against corrosion. When cement is replaced with fly ash by 20 and 40% by weight, ER value increased by 20 and 50%, respectively over control concrete. But when 10% sand is replaced with pond ash by volume, ER value increases by 5%, but when sand replacement increases by 20%, ER value decreases by 12% for both fiber and non fiber reinforced concrete. Hence from durability and workability point of view, 20% replacement of sand with pond ash may not be recommended. For both replacement of fly ash and pond ash with cement and sand simultaneously mix C_{40-10} and F_{40-10} shows better durability compared to other mixes of non fiber and fiber reinforced concrete. Hence it is concluded that the higher replacement of cement with fly ash shows more durability compared to higher replacement of sand with pond ash. This is due to spherical nature of fly ash which acts like ball bearing and improves the packing density of concrete. At 28 days, ER value is about 35% more in all cases and at 119 days, ER value is about double the 28 days value and 2.5 times that of 7 days value. Hence proper curing for 28 days is a must for durable concrete. Maximum ER for concrete with and without fiber was observed with 40% replacement of cement with fly ash. Though a drop in ER was observed with pond ash, same was higher than control for fly ash and pond ash combination.

It is also seen that the curing period has a great influence on the value of Bulk Electrical Resistivity Test (ER). ER values of fiber reinforced concrete at 7 days of curing achieve the ER values of non fiber reinforced concrete at 28 days for all 9 mixes. The values of electrical resistivity of fiber reinforced concrete is more than control concrete and also increases gradually with curing age.

4. 4. Ultrasonic Pulse Velocity Test From Figures 6 and 7 it is noticed that both electrical resistivity and ultrasonic pulse velocity behave similar with fly ash, pond ash and fiber. Due to addition of 0.1% of fiber, UPV value increases 5% of control volume. Again UPV increases 2.5 and 6.3% for cement replacement by fly ash as 20 and 40%. Sand replacement with pond ash does not affect more on UPV value.

4. 5. Importance of Fiber and Curing Period on Severity of Corrosion The coarse fly ash is used in present study supplied by thermal power plant to public. Hence the pozzolanic reaction continues up to 119 days. It is seen that the severity of corrosion of control concrete without replacement at 28 days of curing is high. It changes from moderate to low in control concrete without fiber when cement is replaced with fly ash up to 40 or 0.1% glass fiber is introduced in control concrete. Similarly type of chloride penetration is moderate in control concrete at 28 days of curing and it is converted to low for fly ash concrete up to 40% replacement of cement or 0.1% glass fiber reinforced concrete. Hence glass fiber reinforced concrete improves resistance of both chloride penetration and severity of corrosion. The rating of corrosion 'high' gradually improves at long term curing days and it shows 'moderate' value at 119 days of curing for control concrete without replacement. The 119 days of curing also improves the ER value of glass fiber reinforced concrete. Ultrasonic pulse velocity value is more than 4.5 for all mixes of concrete at all curing ages. Hence all mixes are excellent category with water cement ratio of 0.35. Ultrasonic pulse velocity also improves as the curing age extends. Also compressive strength has higher value at 119 days of curing for all types of mix. Hence curing is strongly recommended for achieving high durability and strength of concrete. Also ER could better differentiate between different concrete than UPV.

4. 6. SEM Analysis of Concrete with Replacement Materials To know the effect of SCM material like fly ash and pond ash on microstructure, SEM (Scanned Electron Microscope) observations were examined on 119 days old hardened concrete with back scattered scanning electron microscope.

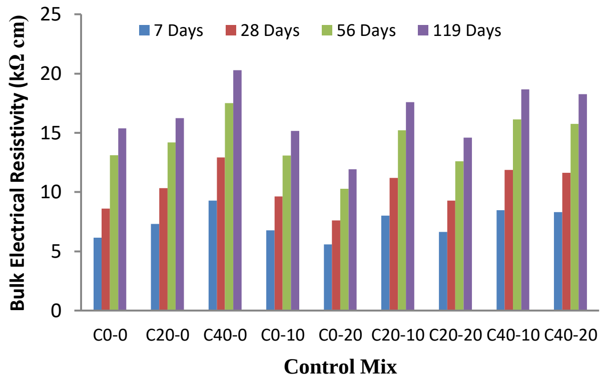


Figure-6(a). Bulk electrical resistivity test of controlled concrete of different w/c for different curing ages

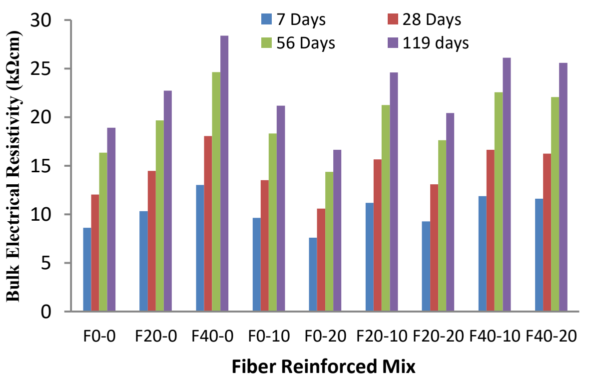


Figure-6(b). Bulk electrical resistivity test of FRC of different w/c for different curing ages

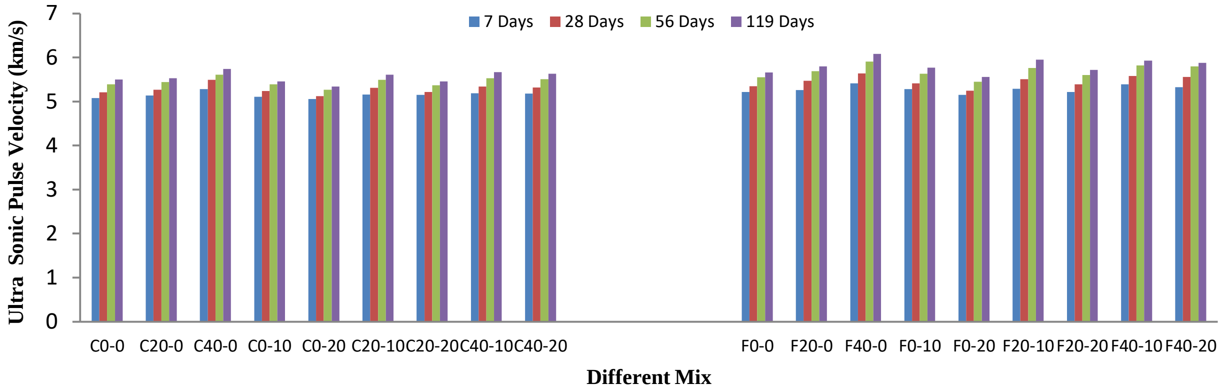
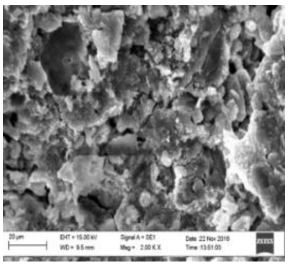


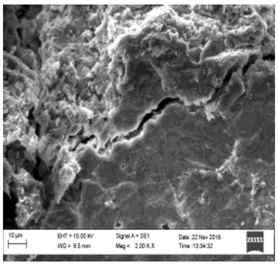
Figure 7. Ultrasonic pulse velocity test of controlled and fiber reinforced concrete

The specimens were extracted from concrete cubes of 100 mm^2 with approximate thickness of 5 mm.

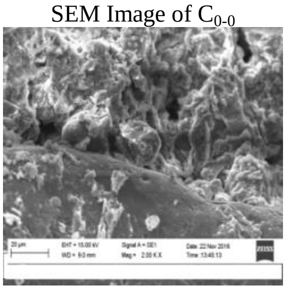
Top portion of the specimen was polished and mounted on gold splutter coater for gold coating and mounted on aluminum stub for scanning the image at high resolution. All the images of different mixes were found from the screen at 2000X magnification as shown in Figure 8. According to Ramchandran and James [11] hydrated cement paste consists of 50 to 60% CSH gel,



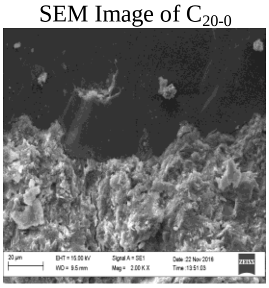
SEM Image of C_{0-0}



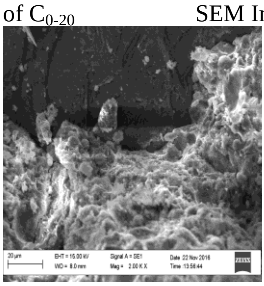
SEM Image of C_{20-0}



SEM Image of C_{0-20}



SEM Image of C_{20-20}



SEM Image of C_{40-20}

Figure 8. SEM images of different mixes

20 to 25% calcium hydroxide and remaining portion is occupied by ettringite, monosulfate incompletely hydrated particle and voids (or paste porosity).

From above scanned images it can be noticed that the voids presenting inside the controlled concrete (i.e. C_{0-0} Mix) are more and the amount of CSH gels and ettringite needles are less than other mixes. The ettringite (i.e. needle like structure) and CSH gel (fibrous type structure) are seen in more amounts when 20% of cement is replaced with fly ash (C_{20-0}) or 20% of sand with pond ash (C_{0-20}) or both replacements (C_{20-20} & C_{40-20}).

Also fly ash and pond ash increased the compaction factor hence shows dense structure in SEM image. According to Ramchandran and James [11] the shape of calcium hydrates are platy crystals with distinctive hexagonal prism. It can be noticed that platy crystals structures are more amounts in control concrete (C_{0-0} mix). When fly ash or pond ash was introduced in concrete calcium hydrates it reacts with silica present in fly ash and pond ash formed CSH gel and etterngite. Hence in Mix C_{20-0} and C_{0-20} the amount of calcium hydrate crystal are very less as compared to control concrete. The amounts of etterngite and CSH gels are more in case of simultaneous replacement of cement and sand with fly ash and pond ash (i.e. C_{20-20} & C_{40-20}).

5. CONCLUSIONS

1. The introduction of 0.1% glass fiber of total volume decreased the shrinkage by 40% and improved both electrical resistivity and ultrasonic pulse velocity values by 40 and 5%, respectively.
2. When cement is replaced with fly ash up to 40% in concrete by weight the electrical resistivity increases by 50%, UPV increases by 6.3%, shrinkage reduces by 23% but compressive strength decreases by 23% at this replacement. Hence durability increases at high volume fly ash concrete.

3. Replacement of 20% sand with pond ash affect the durability of concrete adversely. Both ER and UPV value of sand replacement concrete is nearer to control concrete. But the compressive strength increases by 20% for 10% replacement of sand with pond ash by volume. Beyond that replacement compressive strength decreases.
4. The achieved compressive strength is 23 and 50% more than control concrete, when 20% cement is replaced with fly ash and 10% sand is replaced with pond ash simultaneously for both non fiber and fiber reinforced concretes, respectively. It is recommended that 20% replacement of cement with fly ash by weight and 10% replacement of pond ash by volume should be followed for better durability and strength with low cost.
5. Both electrical resistivity and ultrasonic pulse velocity showed higher values for C_{40-10} and F_{40-10} for non fiber and fiber reinforced concrete. The compressive strength and cost per unit strength of F_{40-10} and C_{0-0} mixes are almost same; however ER value was double for F_{40-10}. Hence cement can be replaced up to 40% without hampering durability, strength and cost of concrete in general practice with addition of 0.1% fiber. This will save cement and consume high volume of fly ash.
6. Hence 40% cement replacement with fly ash and 10% sand replacement with pond ash along with 0.1% glass fiber is highly recommended for durable concrete at comparable strength and cost with control concrete without fiber.
7. Replacement of cement and sand with fly ash and pond ash respectively save the natural resources and reduces the construction cost and keeps the environment green and hence is highly recommended.
8. It is noticed that fly ash, pond ash and fiber help to increase the durability of concrete by reducing the shrinkage and increasing the ER and UPV values.
9. ER, UPV and compressive strength values for both fiber and non fiber reinforced concrete show higher values at long term curing age i.e. 119 days for all mixes. Electrical resistivity, ultrasonic pulse velocity and compressive strength value gradually increased and chloride diffusivity gradually decreased as the curing period increased. Hence proper curing of concrete with fly ash should be strictly followed by local contractor and builder.
10. Addition of fiber to concrete increases the durability at higher cost. Higher use of fly ash and reduction of cement is required for sustainable concrete. However partial replacement of cement with higher volume of fly ash reduces 28 days compressive strength which is highly desired by contractors. Partial replacement of sand with pond ash is also very important but reduces workability of concrete. Proper combination of fiber, fly ash and pond ash produces a high 28 days strength and durable concrete at lower cost. Hence it is recommended to use a combination of fiber, fly ash and pond ash as discussed in this research to produce sustainable concrete.

6. REFERENCES

1. Han, S.-H., Kim, J.-K. and Park, Y.-D., "Prediction of compressive strength of fly ash concrete by new apparent activation energy function", ***Cement and Concrete Research***, Vol. 33, No. 7, (2003), 965-971.
2. Langley, W., Carette, G.G. and Malhotra, V., "Strength development and temperature rise in large concrete blocks containing high volumes of low-calcium (astm class f) fly ash", ***Materials Journal***, Vol. 89, No. 4, (1992), 362-368.
3. V.M., M., "High performance, high-volume fly ash concrete: A solution to the infrastructure needs of india", ***Indian Concrete Journal***, Vol. 76, (2002), 103-108.
4. Shafabakhsh, G. and Ahmadi, S., "Evaluation of coal waste ash and rice husk ash on properties of pervious concrete pavement", ***International Journal of Engineering-Transactions B: Applications***, Vol. 29, No. 2, (2016), 192-201.
5. Zhang, P., Li, Q. and Zhang, H., "Fracture properties of high-performance concrete containing fly ash", ***Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications***, Vol. 226, No. 2, (2012), 170-176.
6. Saraswathy, V., Muralidharan, S., Thangavel, K. and Srinivasan, S., "Influence of activated fly ash on corrosion-resistance and strength of concrete", ***Cement and Concrete Composites***, Vol. 25, No. 7, (2003), 673-680.
7. Thomas, M., "Chloride thresholds in marine concrete", ***Cement and Concrete Research***, Vol. 26, No. 4, (1996), 513-519.
8. Soleimanzadeh, S. and Mydin, M.O., "Influence of high temperatures on flexural strength of foamed concrete containing fly ash and polypropylene fiber", ***International Journal of Engineering***, Vol. 26, No. 1, (2013), 365-374.
9. Pofale, A. and Deo, S., "Comparative long term study of concrete mix design procedure for fine aggregate replacement with fly ash by minimum voids method and maximum density method", ***KSCE Journal of Civil Engineering***, Vol. 14, No. 5, (2010), 759-764.
10. Sofi, A. and Phanikumar, B., "An experimental investigation on flexural behaviour of fibre-reinforced pond ash-modified concrete", ***Ain Shams Engineering Journal***, Vol. 6, No. 4, (2015), 1133-1142.
11. Ramachandran, V. and Beaudoin, J.J., "Handbook of analytical techniques in concrete", (2001).
12. Jiang, C., Fan, K., Wu, F. and Chen, D., "Experimental study on the mechanical properties and microstructure of chopped basalt fibre reinforced concrete", ***Materials & Design***, Vol. 58, (2014), 187-193.
13. Mehta, P.K. and Monteiro, P.J., *Concrete: Microstructure, properties, and materials.* (2006), New York: McGraw-Hill.
14. Chandramouli, K., Srinivasa Rao, P., Pannirselvam, N., Seshadri Sekhar, T. and Sravana, P., "Strength properties of glass fiber concrete", ***ARPN journal of Engineering and Applied sciences***, Vol. 5, No. 4, (2010), 1-6.
15. Chia, K.S. and Zhang, M.-H., "Water permeability and chloride penetrability of high-strength lightweight aggregate concrete", ***Cement and Concrete Research***, Vol. 32, No. 4, (2002), 639-645.
16. Teo, D.C., Mannan, M. and Kurian, V., "Durability of lightweight ops concrete under different curing conditions", ***Materials and Structures***, Vol. 43, No. 1, (2010), 1-13.

Durable Glass Fiber Reinforced Concrete with Supplimentary Cementitious Materials

B. Rath, S. Deo, G. Ramtekkar

Civil Engineering Department, NIT, Raipur, India

PAPER INFO

Paper history:
Received 29 January 2017
Received in revised form 15 March 2017
Accepted 21 April 2017

Keywords:
Fly Ash
Pond Ash
Glass Fiber
Shrinkage Test
Electrical Resistivity Test
Ultrasonic Pulse Velocity Test

چکیده

دوام ساختار بتن در محیط های دریایی به علت حمله کلر مسئله مهمی برای چند دهه است. کلرید به ساختار بتن نفوذ می کند و روند خوردگی را تقویت می کند که دوام این سازه ها را کاهش می دهد. همچنین ترک های کوچک در بتن نقش اصلی را برای نفوذ کلرید از طریق سطح بتن بازی می کنند. بسیاری از محققان سعی داشتند روش های آسان و اقتصادی برای به دست آوردن بتن پایدار در چنین ناحیه دریایی با استفاده از مواد افزودنی سیمانی و دوره تیمار مناسب را توسعه دهند. استفاده از فیبر در بتن می تواند ترک های کوچک را کاهش دهد، نفوذپذیری کلرید را کاهش داده و دوام بتن را افزایش دهد. استحکام بتن با فیبر شیشه ای و با جایگزینی سیمان و شن و ماسه به طور جزئی با مواد سیمانی مکمل مانند خاکستر با انجام آزمون چروکیدگی، مقاومت الکتریکی توده ای، SEM و آزمون سرعت پالس اولتراسونیک اندازه گیری می شود. بر اساس نتایج آزمون های مختلف، با استفاده از فیبر شیشه ای و مواد سیمانی مکمل، بتن با دوام اقتصادی و با مقاومت کمپرسی مطلوب حاصل شد.

***doi**: 10.5829/ije.2017.30.07a.05*