Durability Study on Fly Ash Aggregate Concrete with Respect to Carbonation Test

Dr. Manorama Kumari Talla

Assistant Professor in Civil Engineering,

Manuu Polytechnic, Suwarnabadavani Layout, Nagarabhavi, Bangalore, Karnataka

Email: tmk.jntu@gmail.com

Abstract:

In this project, the durability of concrete with fly ash aggregates (FAA) is studied. M20 Grade concrete is selected and designed as per IS method. The project's major goal is to use (FAA) fly ash aggregates to replace traditional fine and coarse aggregates. Cement and fly ash are mixed in proportions of 10:90, 12.5:87.5, 15:85, 17.5:82.5, 20:80, and 22.5:77.5 to make fly ash aggregates. The specimen cubes will be caste and tested for corrosion depth, workability, pull out strength and pH value of concrete at the end of 7, 14 and 28-days curing. Fine aggregate and coarse aggregates were substituted with fly ash aggregates in all of these experiments. From the results, the conclusions were drawn.

Keywords: Fly Ash Aggregates, Fine Aggregate, Coarse Aggregates, Strength.

I. Introduction

Concrete is a combination of cement, sand, aggregate, and water that is homogeneous. It is extremely strong in bearing compressive pressures, and as a result, it is becoming increasingly popular as a building material across the world. As the circumstance requires, use of available materials for concrete production and their characteristics in both fresh and hardened phases. In the past, most structures were built out of brick, steel, or wood, depending on the resources available and the nature of the job; however, concrete has recently become a popular building material.

Concrete has achieved such prominence in such a short time that it now accounts for more than 65 percent of all new structures being built across the world. Similar to other constituents, coarse aggregate is an essential factor to consider when producing better concrete; it has an impact on concrete strength, and this report will track the importance and impact of coarse aggregate on concrete strength.

Fly Ash

Fly ash is one of the wastes produced during coal burning. Fly ash is usually collected from power plant chimneys, although it can also be found at the bottom of the furnace. Fly ash used to be discharged into the atmosphere through the smoke stack, but pollution control technology specified in recent decades now requires it to be collected before being released. Most electric power production facilities in the United States store it on-site.

Fly ash is made up of silica (silicon dioxide, SiO_2) (both amorphous and crystalline) and lime (calcium oxide, CaO). Besides its usage in concrete, where it offers both technological and economic advantages to manufacturers, fly ash is increasingly being employed in the synthesis of geopolymers and zeolites.

II. Literature Review

The results of a study on a sintered fly ash aggregate are given. Material orthogonal testing and a short chilled firing schedule test were used to create the aggregate. It had a high tensile strength (7.8 MPa) and a low water absorption rate (4.2 percent). This light weight aggregate concrete has a compressive strength of more than CL60, a slump of more than 20cm, a 60-minute slump loss of less than 2cm, and an expansibility of more than 50cm. Such characteristics fulfil the contemporary concrete's high strength and pumpability criteria. This innovative technique has significant economic and social implications for the use of industrial waste residues as well as environmental conservation.

Concrete's mechanical properties and durability were examined in an experimental study. These ratios were utilised in self-compacting concretes (0.40 and 0.36 for water/binder) as well as ordinary Portland Concrete (OPC) (0.58 and 0.48 for water/cement) (SCC). There were several methods used to analyse the properties of concrete including compressive and splitting strengths as well as electrical resistivity as well as rapid chloride penetration (RCPT) and the open circuit potential technique and AC impedance. Concrete's compressive strength and splitting strength, for example, can be improved by carbonation.

Concrete's mechanical properties and durability were examined in an experimental study. These ratios were utilised in self-compacting concretes (0.40 and 0.36 for water/binder) as well as ordinary Portland Concrete (OPC) (0.58 and 0.48 for water/cement) (SCC). There were several methods used to analyse the properties of concrete including compressive and splitting strengths as well as electrical resistivity as well as rapid chloride penetration (RCPT) and the open circuit potential technique and AC impedance. Concrete's compressive strength and splitting strength, for example, can be improved by carbonation. Carbonation, on the other hand, increased the rate of corrosion of reinforcing steel in corrosion tests. The following conclusions may be derived from the scope of this investigation.

(1) As exposure duration rises, the carbonation depth increases, and greater CO2 concentrations result in increased carbonation depth for all combinations.

(2) At the age of 28 days, the compressive and splitting strengths of carbonated concrete are somewhat greater than those of uncarbonated concrete.

(3) As the exposure duration rises, the electrical resistance of concrete increases, whereas the quantity of charge transferred reduces considerably as the carbonation depth increases.

III. Fly Ash Concrete

Engineered concrete systems that use fly ashes as a partial substitute for fine and coarse particles are known as fly ash concrete. Fly ash concrete is defined as concrete with a fly ash content of more than 35% by mass of the cementation's materials content. Typically, FAC is suggested to get all of the benefits of fly ash concrete.

The FAC is defined by the following characteristics:

- Very low water to cementitious materials ratio
- Low cement and High fly ash content
- Requires the application of a superplasticizer to obtain the appropriate properties

In order to get the necessary workability, this form of concrete frequently requires the application of a super plasticizer. The amount of fly ash produced is maximised by careful material selection, proportioning, and the use of chemical admixtures.

Fly Ash Properties

1) Workability

When Portland cement is partially replaced with fly ash in concrete, the amount of water required to achieve a particular consistency is reduced, and the workability and slump for a given water content are increased.

2) Slump

Slump is a measure of the concrete's workability or fluidity. The slum of FAC is low because of the lower water content in this type of concrete. This low water content is a result of the water reducing property of fly ash. If a higher slump is required for placement

of concrete it is essential to use a super plasticizer. The dosage of this super plasticizer used will depend on the characteristics of Portland cement and fly ash used for preparing the concrete mix.

3) Bleeding

Bleeding depends upon the concrete mixture proportioning. Due of its relatively low water content, FAC bleeds at insignificant to low levels. Therefore curing of the concrete should commence as soon as possible.

4)Setting

The use of fly ash as replacement in conventional concrete has a retarding influence on the setting time of concrete. The extent of retardation depends on several factors such as the type of fly ash, the fly ash content, the type of chemical admixtures and curing temperature of concrete.

When compared to traditional Portland cement concrete, the ultimate setting time of FAC is two to three hours longer. This is advantageous in hot weather since it gives you more time to transport and place concrete. Excessive set retardation can be prevented in cold weather by increasing the temperature or utilising set accelerating admixtures.

IV. Details of Aggregate Forming

Production of Aggregate from Fly Ash

Fly ash aggregates are made out of ingredients such as cement, fly ash, and water. Water is the binding ingredient that allows the aggregate to form with good bond properties. The topic of this project is the creation of FAA. It is described in full below.

1) *Proportion for fly ash aggregates*

Water is the binder, which is used to enhance the workability of the aggregates. Cement and fly ash are components for aggregate preparation. The proportions of 15:85 are obtained and put through the 'Pelletisation' procedure.

2) *Preparation of FAA*

a) *Pelletisation*

It is the agglomeration of moistened particles in a spinning drum or disc to generate a "fresh pellet" that may be handled further. The processes involved in the balling phenomena of powdered materials are used to form pellets. When a fine-grained substance is moistened, a thin liquid film forms on the grain's surface, and bridges form where the moistened particles come into touch with one another. Bonding forces emerge gradually when the particles spin into balls. A water bridge or meniscus is responsible for the first bonding forces between particles.

Droplets encase the concave moisturising particle clusters, which tend to create huge, irregular structures. The effectiveness of the palletisation process is influenced by grain size distribution and material surface roughness. Green pellets were made in the present investigation using a concrete mixer as a pelletiser and a combination of fly ash, regular Portland cement, and water as a binder.

b) *Trial selection for preparing FAA*

Each trial is selected separately for the preparation of aggregates. The cement and fly ash are weighted accordingly to meet the proportions appropriate for cubes, slices. The quantity of aggregates needed for casting is derived from the mix design of concrete of grade M20. Desired proportions such as cement, fly ash and water are mixed together in the concrete mixer. 'Green Pellets' are formed by the process called 'pelletisation'. The water is mixed thoroughly until a bonding takes place between the cement and fly ash.

Processing and Curing of Fly Ash Aggregates

The prepared 'Green Pellets' is allowed to dry for a day. Fly ash aggregates are then put for 7 days curing. The fly ash aggregates were weighted before and after curing process. It was found that no change was observed.

Table 1. Sieve analysis

IS CODE	Fine Aggregates	Coarse Aggregates
	<4.75mm	4.75mm to 20mm

Water

- Water lubricates the fine and coarse aggregates and reacts chemically with cement to produce the aggregate binding paste. It is also utilised to cure the concrete after it has been cast into the forms.
- Water used for both miming and curing should be free of a variety of harmful contaminants.
- Portable water is typically regarded as adequate for concrete mixing and curing.
- Water should not be utilised if it includes sugar, acid, or salt in excess.
- For concrete preparation, ordinary tap water is utilised.

Fig. 1. Formation of fly ash aggregates

V. Preliminary Test On Materials

Fineness Test on Cement

Procedure:

Take 100gms of cement.

- Transfer the cement into I.S. Sieve No. 9 and sieved it by rotational motion for 15 minutes
- Take the residue retained on I.S. Sieve No. 9 and determine its weight.
- On the same cement sample, the experiment is repeated three times and the average weight of residue is determined.

TABLE 2. OBSERVATION AND CALCULATION FINENESS OF CEMENT

Types of cement	Cement sample	Wt. of sample W_1(g)	Wt. of residue W_2(g)	Percentage Wt. of residue W_2/W_1x100	Average percentage of residue
Chettinadu cement	1	100	12.0	12.0	12.33
	2	100	10.0	10.0	
	3	100	15.0	15.0	

Result:

Average fineness of cement = 12.33%

Consistency Test on Cement

Procedure:

- The nonporous plate and the mould are washed, cleaned, and dried.
- On the nonporous plate, 400g of the specified cement sample is maintained.
- To make a smooth cement paste, 30 percent water by weight of cement is carefully added to the dry cement and properly mixed. From the time the water is added, the mixing takes 3 to 5 minutes to finish.
- Fill the vicat mould with the produced cement paste and set it on the nonporous plate. The surface is smoothed with a trowel until it is level with the mould.
- Any air from the sample is removed by gently shaking the mould.
- Place the nonporous plate and the mould beneath the plunger.
- The plunger is gradually lowered until it touches the paste's surface, and then the indicator is set to zero.
- The plunger is immediately released, allowing the paste to enter.
- Take note of the index scale reading when the plunger comes to a stop.
- Several trial pastes with various percentages of water are produced, and the test is carried out until the needle pierced 5mm to 7mm above the bottom of the mould. The outcomes are tallied.

TABLE 3. OBSERVATION AND CALCULATION CONSISTENCY TEST ON CEMENT

Trial	Wt. of Cement taken (g)	Quantity of water added		Penetration index reading (mm)
		%	ml	
1	400	30	120	32
2	400	31	124	19
3	400	31.5	126	12.5
4	400	32	128	10.0
5	400	32.5	130	5.0

Result:

Standard consistency of given sample of cement = 32.5%

Fine Aggregate Test – Specific Gravity Of Sand

Procedure:

- Weigh a clean, dry pycnometer with the cover on it (W1g).
- Fill the pycnometer with 200g of dry sand and calculate the weight of the pycnometer with sand (W2g).
- Shake the pycnometer to remove the air by filling it with distilled water up to the hole in the conical cap. Then, using sand and water, calculate the weight of the pycnometer (W3g).
- Empty and carefully clean the pycnometer. Then, up to the conical cap's grip, fill it with pure water and weigh it (W4g).
- The specific gravity of sand is determined using the aforementioned weights.

Observation and calculation:

Weight of empty pyconometer (W_1g) = 667gm

Weight of pyconometer + dry sand (W_2g) = 1120gm

Weight of pyconometer + sand + water(W_3g) = 1833gm

Weight of pyconometer + water (W_4g) = 1552gm

Specific gravity of sand = Dry weight of sand/ Weight of equal volume of water

$= [W_2-W_1]/ [(W_4-W_1)-(W_3-W_2)]$

$= [1120-667]/ [(1552-667)-(1833-1120)]$

$= 2.63$

Result:

Specific gravity of sand is = 2.63

Coarse Aggregate Test

Procedure:

- Weigh a clean, dry pycnometer with the cover on it (W1g).
- In the pycnometer, put roughly 200g of coarse aggregate that has passed through a 10mm screen, and calculate the weight of the pycnometer with coarse material (W2g).
- Shake the pycnometer to remove the air by filling it with distilled water up to the hole in the conical cap. Then, using coarse material and water, calculate the weight of the pycnometer (W3g).
- Empty and carefully clean the pycnometer. Then, up to the conical cap's grip, fill it with pure water and weigh it (W4g).
- Calculate the specific gravity of coarse aggregate using the provided weights.

Observation and calculation:

Weight of empty pyconometer (W_1g) = 667gm

Weight of pyconometer + coarse aggregate (W_2g) = 1140gm

Weight of pyconometer + coarse aggregate + water (W_3g) = 1843gm

Weight of pyconometer + water (W_4g) = 1545gm

Specific gravity of coarse aggregate =

$$\frac{\text{Dry weight of coarse aggregate}}{\text{Weight of equal volume of water}}$$

$= [W_2-W_1]/ [(W_4-W_1)-(W_3-W_2)]$

$= [1120-667]/ [(1552-667)-(1833-1120)] = 2.68$

Result:

Specific gravity of coarse aggregate = 2.68

Concrete Mix Design

3) *General*

Mix design is the process of calculating the proportional amount of material in order to get the required characteristics of concrete. As a result, mix design is defined as the process of selecting acceptable concrete components and establishing their relative amounts in order to produce concrete with the specified characteristics in the most cost-effective manner feasible. The goal of mix design is to determine the material proportions that will result in concrete with the desired characteristics. The proportions of the mix should be chosen such that the resultant concrete has the necessary workability while still being fresh and can be easily put and compacted for the intended use.

4) Types of Mix Design

- Mix design technique according to Indian Standard suggested guidelines for concrete mix design.
- British mix design method
- User mix design method
- Mix design method according to Indian Standard recommended guidelines for concrete mix design.
- ACI mix design method

TABLE 4. CONVENTIONAL CONCRETE TEST RESULTS

Curing days	Strength in N/mm^2	Average strength in N/mm^2
7 DAYS	12.42	12.95
	12.89	
	13.53	
14 DAYS	15.36	15.97
	15.92	
	16.64	
28 DAYS	20.12	20.71
	20.53	
	21.49	

VI. Conclusions

When carbon dioxide from the air penetrates concrete and mixes with calcium hydroxide to form calcium carbonate, a chemical reaction happens. As we observed earlier, the conversion of $Ca(OH)_2$ to $CaCO_3$ by the action of CO_2 results in a little shrinkage.

- FAAs appear to have a low specific gravity, indicating that they are light aggregates.
- M20 grade concrete cubes will be made with OPC 43 grade cement.
- Material orthogonal testing and a rapid chilled firing schedule test revealed good strength and low water absorption in sintered fly ash lightweight aggregate.
- This aggregate has a compressive strength of more than CL60, a slump of more than 20cm, a 60-minute slump loss of less than 2cm, and an expansibility of more than 50cm in lightweight aggregate concrete. Such characteristics fulfil the contemporary concrete's high strength and pumpability criteria.
-

REFERENCES

[1] R.V. Raikar, V.V. Karjinniand, and V.D., Gundakalle, Study on strength parameters of steel fiber reinforced high strength concrete, Journal of Applied Sciences and Engineering Research, 1(4) (2012).

[2] A.A. Al-Azzawi, A.S. Ali, and H.K. Risan, Behavior of ultra-high performance concrete structures, ARPN Journal of Engineering and Applied Sciences, 6(5), (2011) 95-109.

[3] J.H. Xie, Y.C. Guo, L.S. Liu, and Z.H. Xie, Compressive and flexural behaviours of a new steel-fibre-reinforced recycled aggregate concrete with crumb rubber, Construction and Building materials, 79, (2015) 263-272

[4] T. Alagunatrayan, P. Mohanraj, S. Manishankar et al., Engineered cement composite enhanced reinforced concrete beams usingflexural response: An experimental study, Materials Today: Proceedings,https://doi.org/10.1016/j.matpr.2021.07.130

[5] P. Parthiban, S. Kar, A. Kumar Mondal et al., Stress–strain behaviour of (hpfrc) high-performance fibre reinforced concrete: Anexperimental study, Materials Today: Proceedings,https://doi.org/10.1016/j.matpr.2021.07.175

[6] Asok, G., & George, S. (2016). Investigation on hybrid concrete using steel and polypropylene fiber. International Journal of New Technology and Research, 2(5).

[7] Parthiban, P. M. E., ME, M. R., MIE, D., & George, S. Comparative Study on Strength Enhancement of Concrete Using Magnetic and Normal Water. International Journal of New Technology and Research, 2(5).