EXPERIMENTAL STUDY ON DURABILITY OF CONCRETE UNDER DIFFERENT ENVIRONMENTAL EXPOSURE CONDITIONS

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Abstract :

In India, most of the construction activities are made with concrete. Concrete is being used for all major constructions, like dams, towers, water tanks, houses, roadways, and railway sleepers etc. Concrete has been the major instrument for providing stable and reliable infrastructure and thus long-term performance of structures has become vital to the economies of all nations. Deterioration, long term poor performance, and inadequate resistance to hostile environment, coupled with greater demands for more sophisticated architectural form, led to the accelerated research into the microstructure of cements and concretes and more elaborate codes and standards. As a result, new materials and composites have been developed and improved. The major remarkable quality in making High Performance concrete is elimination of voids and reduced w/c ratio. To attain this quality pulverized fly ash is replaced with concrete as 30%, 40% and 50% and the compression strength obtained are compared with conventional concrete result. To reduce water cement ratio chemical admixture is added and the comparison is done with conventional strength result. The strength results on M20, M30 and M40 grade says that the replacement of fly ash satisfies the codal provision, reduces 30% of total cost of work and increases durability as years goes on.

IndexTerms: **Durability, flyash, Chemical Admixture, M20, M30, M40**

I. INTRODUCTION

Durable concrete will retain its original form, quality and serviceability when exposed to its environment. The inferior durability characteristics of concrete may be caused by the environment that the concrete is exposed to or by internal causes within the concrete such as Temperature, Moisture, Physical, Chemical and Biological factors. The degree of exposure anticipated for the concrete during its service life together with other relevant factors relating to mix composition workmanship design and detailing should be considered. The concrete mix to provide adequate durability under these conditions should be chosen taking account of the accuracy of current testing regimes for control and compliance as described in standard. The Factors helping concrete to have more lubricating effect for easy compaction by reducing internal friction are,

- Water content.
- Size and Surface texture of Aggregate.
- Mix proportion.
- Shape and Grading of Aggregate.
- Dosage of Chemical Admixture.

Table 1.1 Environmental Exposure Condition

Exposure	Plain concrete			Reinforced concrete		
	Minimum cement content (kg/m3)	Maximum free Water Cement ratio	Minimum grade of concrete	Minimum cement content (kg/m3)	Maximum free Water Cement ratio	Minimum grade of concrete
Mild	220	0.60	-	300	0.55	M20
Moderate	240	0.60	M15	300	0.50	M25
Severe	250	0.50	M20	320	0.45	M30
Very severe	260	0.45	M20	340	0.45	M35
Extreme	280	0.40	M25	360	0.40	M40

1.2 EXPOSURE CONDITION:

The general environment to which the concrete will be exposed during its working life is classified into five levels of severity.

Table 1.2 Specification for Different Exposure Conditions **(1S 456-2000)**

S.NO	ENVIRONMENT	EXPOSURE CONDITION
1	Mild	Concrete surfaces protected against weather except situated in coastal area.
2	Moderate	Concrete surfaces sheltered from severe rain and continuously under water.
3	Severe	Concrete surfaces exposed to severe rain and exposed to coastal environment.
4	Very Severe	Concrete surfaces exposed to sea water spray corrosive fumes or severe freezing.
5	Extreme	Concrete surface of members in tidal zone and in direct contact with liquid.

The minimum cement content, maximum water cement ratio and minimum grade of concrete for different exposures with normal weight aggregates of 20mm nominal maximum size as per IS 456-2000 is given in Table 1.2

1.3 WATER CEMENT RATIO:

The ratio of the volume of mixing water to that of cement is formed as water cement ratio. In case water used is more it would result in formation of laitance, segregation, voids formation, honey combing and thereby reduces the density, strength and durability of concrete. The lower the ratio the greater is the strength of the mix which results very good durability. The compression strength of workable concrete is governed by W/C ratio.

1.4 MINERAL ADMIXTURE:

One of the mineral admixtures is pozzolanic material. It is used as pulverized fuel ash conforming to IS 3812 as part replacement of ordinary Portland cement in 53 grade. This pozzolanic action is responsible for impermeability of concrete and secondly the removal of calcium hydroxide reduces the susceptibility of concrete to attack by magnesium sulphate. Fly ash increases concrete durability by two primary methods. The increased hydration from the fly ash with cement reaction creates a denser matrix and one that is much more impermeable. When water is prevented from entering the concrete structure, durability increases. The second means by which HVFA increases durability is by allowing an optimally low level of mixing water in the wet mix. The ball bearing effect of the fly ash increases the flowability and allows w/c ratios of 0.3 and less. With this level of water in the mix, the concrete can form a dense well-sealed matrix. Permeability and durability primarily depend on the amount of mixing water to the concrete mix.

1.5 CHEMICAL ADMIXTURE:

Chemical admixture is defined as one of the material that is used as an ingredient of concrete and is added to the batch for obtaining higher workability without using excess of water. The addition of excess of water will only improve the fluidity but not workability of concrete. The excess water will not improve the inherent good qualities such as homogeneity and cohesiveness of the mix which reduces the tendency for segregation and bleeding which results in impairs of the homogeneity and serviceability of the concrete. The excess mortar at the top causes plastic shrinkage cracks.

1.6 NEED FOR THE PRESENT STUDY:

The life of building as per Indian Standard is 80 years. But due to the environmental condition it is reduced to 40 years with maintenance cost. Normal concrete lacks required strength, workability and durability which are more often required for large concrete structures such as high rise buildings, bridges, and structures under severe exposure conditions. By increasing concrete strength, the required thickness of concrete members and the cost of concrete structures can both be reduced. Therefore, it is felt necessary to improve the strength and performance of concrete with suitable admixtures to cater present need. In this study, it is planned to replace some percentage of cement with pulverized fly ash and some percentage of chemical admixture is added to reduce water cement ratio and to increase workability.

1.7 OBJECTIVES:

The objectives of this project work are to study:

- The mix design of concrete with minimum grade of concrete for different environmental exposure conditions.
- The properties of pulverized fly ash with various per cent replacement with cement and their behaviour in high performance concrete.
- The effect of Chemical Admixture on workability of concrete and water cement ratio.
- The compression strength of concrete with and without fly ash and chemical admixture and to compare the result with conventional concrete.

1.8 SCOPE:

India is the first country in the production of fly ash with 200 MT per year but it is the last country in utilization up to 38%.The main purpose of this study is to develop confidence among user agencies in India to use higher volume fly ash concrete in the building construction to increase the life of structure.

2. MATERIAL PROPERTIES

The physiochemical and engineering properties of the materials used in this project were studied and the test results obtained are verified as per the requirements of IS codes. The source and the type of material are discussed in this chapter.

Cement is a building material in the form of powder made of calcined limestone and clay and mixed with water, sand or gravel to make concrete and mortar. Ordinary Portland cement (OPC) of 53 grade is used in this project. The source of cement is from "Penna cement Industries Limited" located in Anantapur District. Fly ash of Class F is used in this project. It is obtained from Ennore Thermal Plant.

Water is an important ingredient of concrete as it actively participates with chemical reaction with cement. Portable water is generally considered satisfactorily for mixing concrete. The source of water is from draw well located near Thillai Nataraja RMC Plant in Mayyambakkam. Aggregate are the important constituents in concrete. They give body to the concrete, reduce shrinkage, chemically active and occupy 70 to 80 per cent volume of concrete. It is classified into two types namely: Fine and Coarse aggregate. The aggregate fraction from 4.75mm to 150µ (4.75 mm, 2.36mm, 1.18mm, 600µ ,300µ ,150µ) are termed as fine aggregate. The source of fine aggregate is from Palaru River. The aggregate fraction from 80mm to 4.75mm (80mm, 40mm, 10mm, 4.75mm) are termed as coarse aggregate. It possess well defined edges formed at the intersection of roughly planar faces hence the shape of aggregate is angular as per IS 383:1970 code. The source of aggregate is from quarry in Senneerkuppam located near site.Chemical admixture is an additional ingredient which is used in concrete at the time of mixing. It is mainly added to increase workability by reducing water cement ratio to a considerable amount and the addition of this will not change the properties of concrete. The admixture of type superplasticizer **"KEMSUPLAST 101 S"** is used in this project. It is a high range water reducing, slump retaining admixture for concrete. The higher slump retention and pumping capacity of TB 101 S makes the product best suited for structural concrete, ready mix concrete industry, where there is a delay in transportation and placing with high ambient temperature. The source of admixture is from Chembond Chemicals Private limited located in Sennerkuppam. The admixture is of type Modified sulphonated naphthalene formaldehyde with selected water soluble co-polymers. As per ASTM C494 it is of Type-G.

3. MIX DESIGN FOR M20, M30 AND M40 GRADES

The mix design is done to know the quantity of the ingredients needed to cast the cube. The trial mixes are designed as per IS 10262 and modified based on observation with the intention of using minimum cement content, adopting low /c ratio and mineral admixture conforming to IS 3812 and used as part replacement of OPC.

Table 3.1 Mix Design for M20 Grade Concrete

Materials \ Trials	1	2	3	4	5
Cement Kg/m^3	300	235	196	180	160
Fly ash Kg/m^3	-	-	84	120	160
Total Cementitious Material Kg/m^3	300	235	280	300	320
% replacement of fly ash	-	-	30	40	50
Water in litres	171	140	151	153	170
$\frac{W}{C+FA}$	0.57	0.55	0.54	0.51	0.53
Fine Aggregate Kg/m^3	686.28	737.30	699.05	685.86	657.93

Coarse Aggreg-ate Kg/m^3	20 mm	782.47	830.35	787.28	772.43	740.96
	10 mm	518.64	553.57	524.86	514.95	493.98
	Total	1388.16	1383.92	1312.14	1287.38	1234.94
Chemical Admixture Gms		-	55	55	55	55
Mix Ratio		1:2.29:4.29	1:3.17:5.96	1:2.5:4.69	1:2.29:4.29	1:2.06:3.86
Exposure Condition		Moderate (P.C.C)	Mild (P.C.C)	Moderate (P.C.C)	Mild (R.C.C)	Mild (R.C.C)

Table 3.2 Mix Design for M30 Grade Concrete

Trials / Materials		1	2	3	4	5
Cement Kg/m^3		320	260	192	186	180
Fly ash Kg/m^3		-	-	83	120	180
Total Cementitious Material Kg/m^3		320	260	275	300	360
% replacement of fly ash		-	-	30	40	50
Water in litres		163	135	130	129	130
$\frac{W}{C+FA}$		0.51	0.52	0.47	0.42	0.35
Fine Aggregate Kg/m^3		687.76	733.07	721.03	708.83	680.53
Coarse Aggreg-ate Kg/m^3	20 mm	778.16	825.60	812.04	798.29	766.20
	10 mm	518.78	550.40	541.36	532.19	510.80
	Total	1296.94	1376.00	1353.40	1330.48	1277.00
Chemical Admixture Gms		-	55	55	55	55
Mix Ratio		1:2.15:4.05	1:2.82:5.29	1:2.62:4.92	1:2.29:4.29	1:1.79:3.46
Exposure Condition		Mild (R.C.C)	Moderate (P.C.C)	Severe (P.C.C)	Moderate (R.C.C)	Extreme (R.C.C)

Table 3.3 Mix Design for M40 Grade Concrete

Materials \ Trials		1	2	3	4	5
Cement Kg/m^3		360	300	255	252	235
Fly ash Kg/m^3		-	-	108	168	235
Total Cementitious Material Kg/m^3		360	300	360	420	470
% replacement of fly ash		-	-	30	40	50
Water in litres		162	129	137	147	155
$\frac{W}{C+FA}$		0.39	0.37	0.36	0.35	0.33
Fine Aggregate Kg/m^3		676.36	726.46	683.49	647.51	614.57
Coarse Aggreg-ate Kg/m^3	20 mm	761.73	818.15	769.75	729.23	692.14
	10 mm	507.83	545.44	513.17	486.16	461.43
	Total	1269.56	1363.59	1282.92	1215.39	1153.57
Chemical Admixture Gms		-	55	55	55	55
Mix Ratio		1:1.59:3.07	1:2.04:3.93	1:1.9:3.56	1:1.54:2.89	1:1.31:2.45
Exposure Condition		Very severe (R.C.C)	Moderate (R.C.C)	Extreme (R.C.C)	Extreme (R.C.C)	Extreme (R.C.C)

4. RESULTS AND DISCUSSIONS:

The compressive strength results of M20, M30 and M40 grades of concrete are discussed here. The graphical representation shows the variation of strength of concrete by adding mineral admixture and chemical admixture in the concrete.

4.1 COMPRESSIVE STRENGTH:

Compressive strength is taken as “An index of its quality in terms of durability, impermeability and water tightness and is easily measurable”. This test on hardened concrete plays an important role in controlling and confirming the quality of cement concrete works. The compression test is carried out on cubical specimens of size 150x150x150 mm.

4.2 COMPRESSION TEST RESULTS:

The compression test results for M20, M30 and M40 grade are listed from table 4.1 to table 4.3.compression test develops a rather more complex system of stresses. Due to compression load, the cube undergoes lateral expansion owing to the Poisson’s ratio effect. It is an easy test to perform because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

4.3 GRAPHICAL REPRESENTATION:

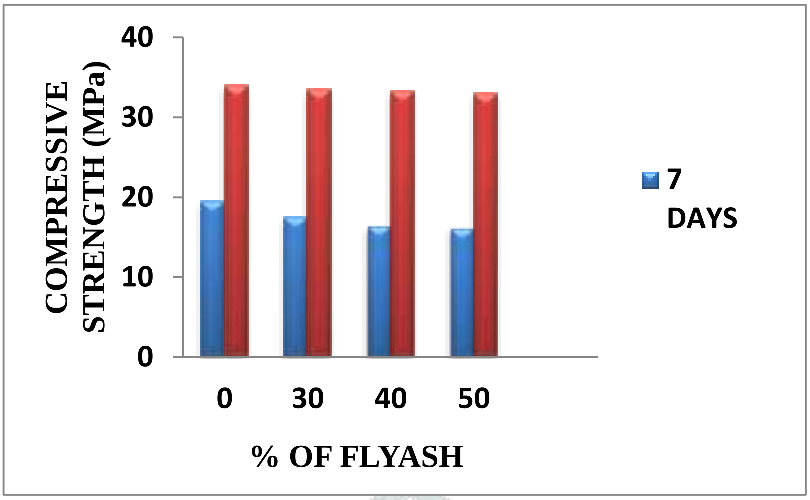

Figure 4.1 Compressive Strength for M20 Concrete

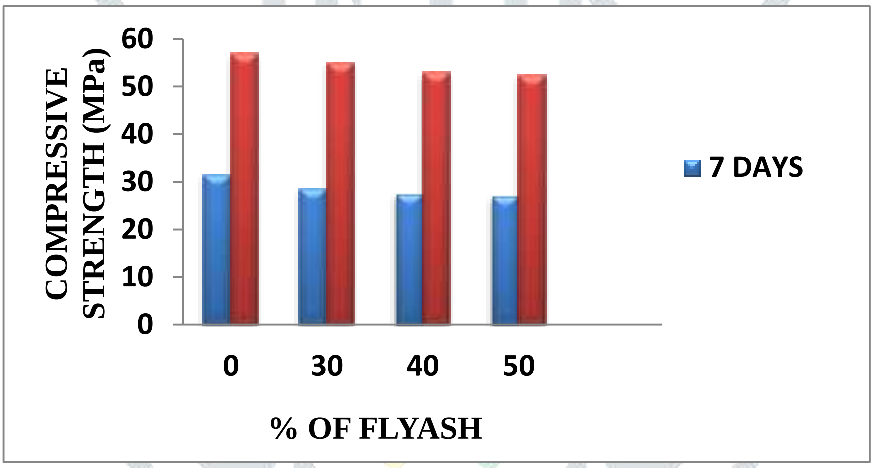

Figure 4.2 Compressive Strength for M30 Concrete

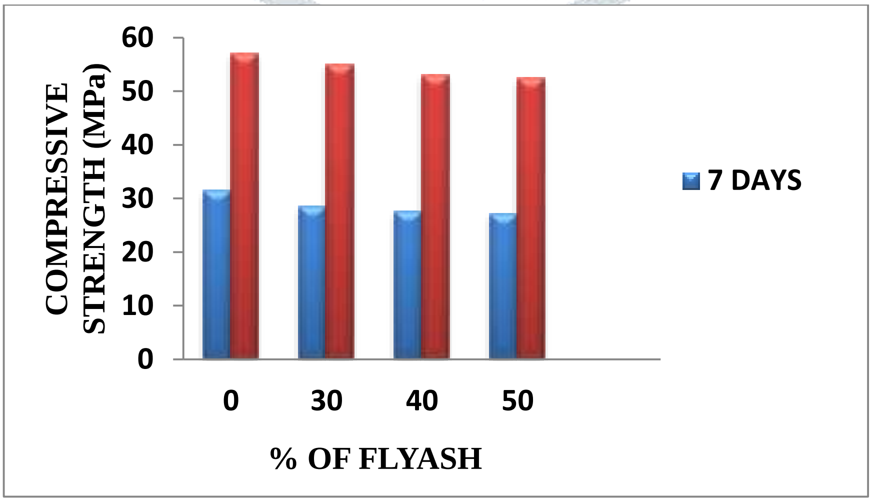

Figure 4.3 Compressive Strength for M40 Concrete

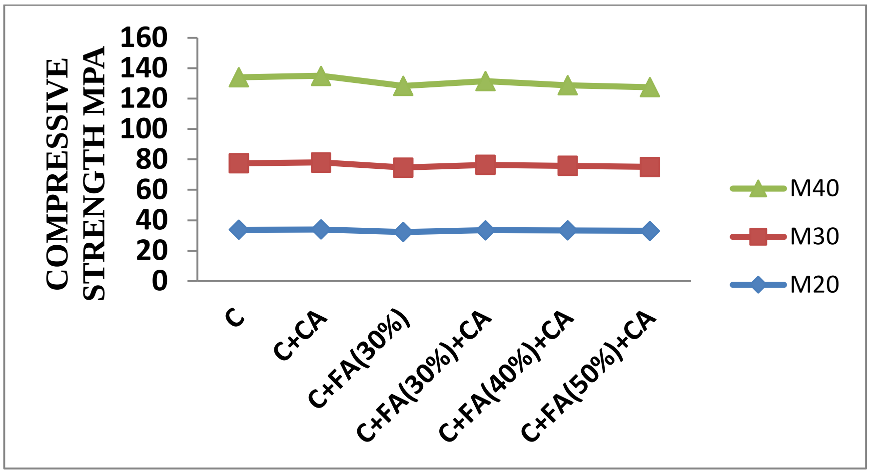

Figure 4.4

Compressive Strength for M20, M30 And M40 at 7 Days at Various Combinations

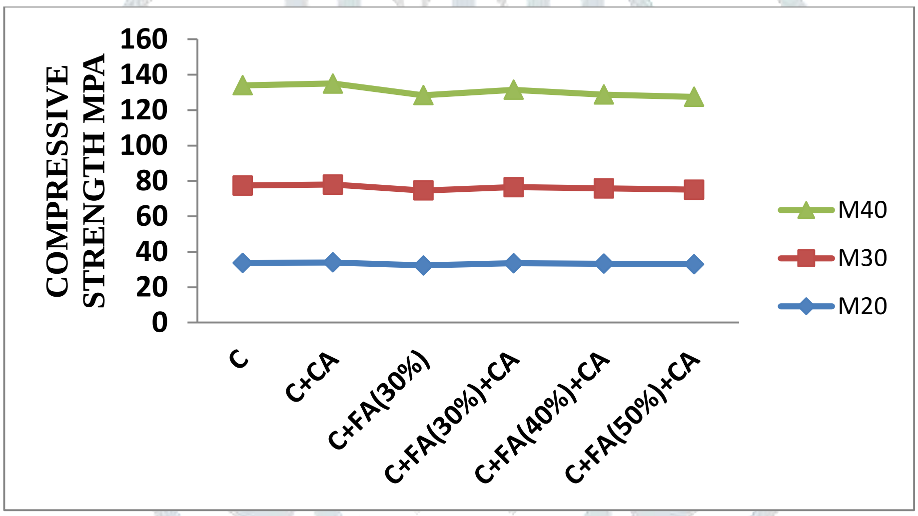

Figure 4.5 Compressive Strength for M20, M30 and M40 at 28 Days at Various Combinations

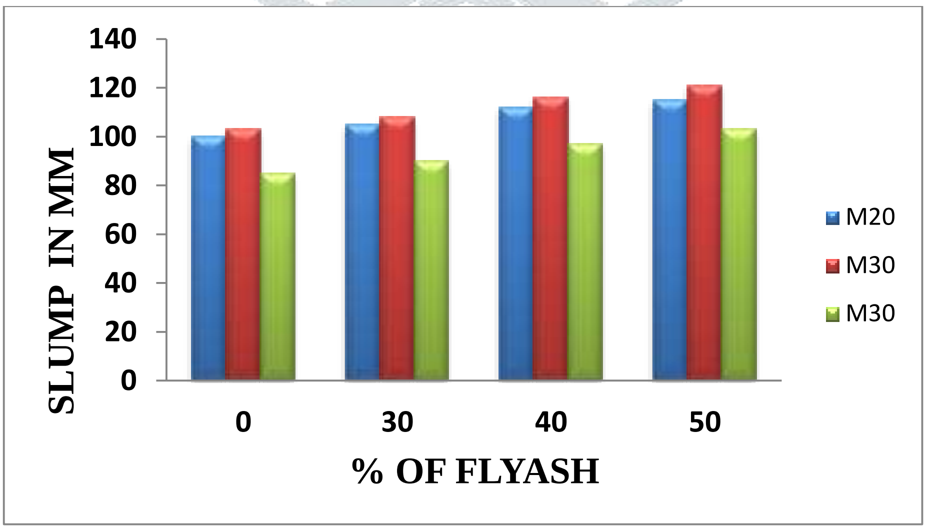

Figure 4.6 Comparison of Slump for M20, M30 And M40 Grades

5. CONCLUSION

From the results obtained in this project work, we concluded the following,

- The mix design for 15 trials of concrete satisfied the requirements as per IS 456:2000 for different environmental exposure conditions.
- Replacing a suitable percentage of cement by fly ash in all the three grades of concrete shows that 28 days strength can be achieved at minimum cost compared to conventional concrete strength.
- The use of fly ash influences the physic – chemical effects associated with pozzolanic and cementitious reactions that result in pore size reduction and grain size reduction. This affects the rheological behaviour of fresh concrete and the strength and durability of hardened concrete increases.
- The fly ash as supplementary cementing material gives more resistance to chloride ion penetration which reduces permeability and increases durability.
- From the strength result it is clear that the addition of chemical admixture increases workability with low w/c ratio and increases strength.
- From the strength results obtained we conclude that replacement of fly ash satisfies the codal provision, reduces 30% of total cost of work and increases durability as years goes on.

REFERENCES

1. Bandyopadhyay, D. (2000):"*The role of fly ash management in combating the global environmental pollution*", Proc. of the 2nd International Conference on fly ash disposal and utilization.
2. Dhir, R.K. (2005): *"Emerging trends in fly ash utilization: World Scenario",* Proc. of International Conference on fly ash utilization.
3. Gebler, S. H., *"The Effects of High-Range Water Reducers on the Properties of Freshly Mixed and Hardened Flowing Concrete"*,Research and Development Bulletin RD081, Portland Cement Association
4. IS 10262:1982- *Recommended Guidelines for Concrete Mix Design*
5. IS 12269:1987- *Specification for 53 Grade Ordinary Portland Cement*
6. IS 3812-1981- *Specification for Fly Ash Use as Pozzolana and Admixture*
7. IS 383:1970- *Specification for Coarse and Fine Aggregate from Natural Sources of Concrete.*
8. IS 456:2000 - *Code of Practice for Plain and Reinforced Concrete*
9. IS 516:1959 - *Method of Test for Strength of Concrete*
10. IS 7320:1974- *Specification for Concrete Slump Test Apparatus*
11. IS 9103:1999- *Specification for Admixtures for Concrete*
12. Koteeswaran, R., Pazhani, K., (2007) *"Developing the mix deign procedure for Slag cement Concrete,"* Thesis in Department of Civil Engineering, Anna University.
13. Krishnamoorthy, T., (2001) "*Investigations on durability characteristics of SFRC,"* The Indian Concrete Journal.
14. Kumar, V. (2006): *"Fly ash: A resource for sustainable development"*, Proc. of the International Coal Congress & Expo.
15. M.S.Shetty (2010): *"Concrete technology theory and practice".*
16. Mullick, A.,(2005) *"High Performance concrete in India - Development, Practices and Standardisation,"* Indian Concrete Journal..
17. Siddique, R. (2004). *"Performance Characteristics of High –Volume Class F Fly Ash Concrete".*