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Studies on Relationship Between Water/Binder Ratio And Compressive Strength Of High Volume Fly Ash Concrete

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Abstract: - Pozzolanic admixtures are generally being used along with the cement in concrete mixes so as to derive certain benefits like economy, durability, Chemical resistance in permeability etc. The use of high volumes of fly ash has become on of the current topics of research possibility promoted by the availability of a wide range of chemical and mineral admixtures. In the present experimental investigation fly ash has been used in large volumes as an additional ingredient in concrete mixes. The present experimental investigations was carried out to study the relationship between Water /Binder Ratio to Compressive strength of high volume fly ash concrete using fly ash as an additional material in the cement concrete. The studies have indicated that the high volumes fly ash used in concrete as an additional material would lead to enhanced properties in concrete and contribute towards development of high performance and high strength concrete which is the need of the hour.

Keywords: - *Water/Binder Ratio, High Volume Fly Ash Concrete, Compressive Strength.*

INTRODUCTION

The challenge for the civil engineering community in the near future will be to realize projects in harmony with the concept of sustainable development, and this involves the use of high-performance materials and products manufactured at reasonable cost with the lowest possible environmental impact. Concrete is the most widely used construction material worldwide. However, the production of Portland cement, an essential constituent of concrete, releases large amounts of CO_2 which is a major contributor to the greenhouse effect and the global warming of the planet and the developed countries are considering very severe regulations and limitations on CO_2 emissions. In this scenario, the use of supplementary cementing materials (SCMs), such fly ash, slag and silica fume, as a replacement for Portland cement in concrete presents one viable solution with multiple benefits for the sustainable development of the concrete industry. The most commonly available SCM worldwide is fly ash, a by-product from the combustion of pulverized coal in thermal power stations. Fly ash, if not utilized has to be disposed of in landfills, ponds or rejected in river systems, which may present serious environmental concerns since it is produced in large volumes. Far to be considered as a “Waste” product, research and development has shown that fly ash actually represents a highly valuable concrete material. In order to considerably increase the utilization of fly ash as replacement for cement, such concrete must meet engineering performance requirements that the comparable to those for conventional Portland cement concrete, and be cost effective. This is a particularly important issue for India, which currently produces over 100 million tons of Portland cement and 100 million tons of fly ash annually. Disposal of fly ash is a growing problem in India, only about fifteen percent of this amount is currently used; the remainder goes to landfill. The World Bank has reported that by 2015, disposal of fly ash will require 1,000 square kilometers, or 1 square meter of land per person. The Indian government has begun to take positive steps in the utilization of fly ash in construction, such as mandating the use of fly ash in road and building construction projects within a 100 km radius of a coal fired power plant.

NECESSITY AND AIM OF THE PRESENT STUDY

Mineral admixtures such as silica fume, fly ash, and ground granulated blast- furnace slag improve the engineering properties and performance of concrete when they are used as mineral additives or as a partial cement replacements. Economic (lower cement requirement) and environmental considerations have also played a great role in the rapid increase in usage of mineral admixtures. Compared with the rapid increase in usage of mineral admixtures , Compared with the Portland cement, cement with pozzolana helps to have concrete with less permeability and denser calcium silicate hydrate (C-S-H). Ground granulated blast furnace slag, silica fume, metakaolin, and rice-husk ash can be used in concrete as supplementary cementing materials (SCM) in addition to fly ash. Compared to fly ash, the availability of other materials is rather limited. One of the major institutional barriers against the use of fly ash and other supplementary cementing materials is the prescriptive type of specifications and standards.

LITERATURE REVIW:

ACI COMMITTEE REPORT NO. 226 [(1)] discussed the specifications for material testing, quality assurances for fly ash concrete and making use of good proportion of fly ash.. **ANDRE BISAILLON et.al** [(2)] presented the comparative data on high-volume fly ash concrete made with ASTM Type 1 cement, and control concrete for mass concrete applications made with ASTM Type 1 and a modified version of ASTM Type 11 cements. **ALAIN BILOIDEAU et.al**[(3)] discussed the challenge for the civil engineering community in the near future e to realize projects in harmony with the concept of sustainable development, and involving the use of high-performance materials produced at reasonable cost with the lowest possible environmental impact. **ALBERT N. NOUMOWE** [(4)] carried out investigations on the behavior of three concretes (high– strength concrete with and without polypropylene fibers and light weight aggregate concrete). The three groups of specimens were subjected to identical testing conditions. After a heating – and – cooling cycle at 200^0C, mechanical tests were carried out. Thermal gradient and concrete thermal stability during heating, compressive strength, modulus of elasticity, and splitting tensile strength were analyzed. **FRANCIS A.OLUOKUN** [(5)] investigated the applicability of Abram's law to concrete mixes containing fly ash. As initially expected, it was found that Abram's water cement ratio law is not directly applicable to mixes with fly ash. An alternative augmented water-cementitious material ratio law is proposed for designing concrete mixes containing fly ash. **DUNSTAN M.R.H** [(6)] in their investigations on fine aggregate proportions to aid pumping. This may require a higher cement to maintain an equal slump and water cement ratio and hence strength. Use of fly ash may reduce the amount of fine aggregate needed in these mixtures and allow better balance of fine and coarse aggregate. Today there are few mass concrete dams built in part of the world that contain fly ash in the concrete.

OBJECTIVES OF STUDY:

To develop relationship between water / binder ratio and compressive strength of High volume Fly Ash Concrete.

MATERIALS

Cement

Ordinary Portland cement of 53 grade which meets the physical requirements in accordance with IS: 12269-1987 and for chemical requirements in accordance with IS: 4032-1977 was used as Cement

Fly Ash

The Fly Ash obtained from Vijayawada thermal power station having the specific gravity of 2.12 and Blaine's fineness 577 m^2/kg and confirming with the IS requirements as per IS 3812-1981was used.

Fine Aggregate

The locally available river sand is used as fine aggregate in the present investigation. The sand is free from clay, silt and organic impurities. The sand is tested for various properties like specific gravity, bulk density etc., in accordance with IS 2386-1963

Coarse Aggregate

Machine crushed angular granite metal of 20mm nominal size from the local source is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc. The course aggregate is also tested for its various properties. The specific gravity, bulk density and fineness modulus of coarse aggregate were found to be 2.62, 1580 kg/m^3 and 7.17 respectively.

Super plasticizer
Sulphonated naphthalene formaldehyde (SNF) superplasticizer Complying with IS: 9103 -1999, BS 5075, ASTM C- 494 was used.

Fibres
The fibres used in present investigation is mild steel wire of diameter 0.8 mm. Length of fibres is 40 mm and aspect ratio 50.

DISCUSSION OF RESULTS

Workability
The quantities of materials for one cubic meter of ordinary and high volume fly ash concrete along with compaction factor are shown in Table 1.0 and 2.0 . It can be seen from the table that a medium workability was maintained for almost all the mixes by addition of suitable quantities of super plasticizer.

Variation of Compressive Strength
From table 3.0 It can be seen that the strength various from 39.90 to 66.6 Mpa for ordinary concrete, with decrease in water/cement ratio . For the corresponding high volume fly ash concrete mixes the strength varies from 35.15 to 70.66 Mpa. From Table 3.0 the percentage variation of compressive strength of ordinary and high volume fly ash concrete at 28 days. The percentage increase in compressive strength in ordinary concrete is in between 10% to 15% for w/c 0.55 to 0.40. For lesser w/b ratios the high volume fly ash concrete have better strength compared to ordinary concrete.

Compressive strength and water/binder ratio
The variation of compressive strength with water/binder ratio is shown in Fig. 1-9, for both ordinary concrete and high volume fly ash concrete. It can be seen from Fig. 2, that the high volume fly ash concrete strength decreased as the water/binder ratio increased from 0.27 to 0.55. Fig. 3 shows the best fit curve for high volume fly ash concrete and ordinary concrete for different water/binder ratio. Fig. 4 shows the relationship between the compressive strength and water/cementitious material ratio (30% replacement fly ash) as suggested by R.K. Dhir, university of Dundee. Fig. 5 and 6 show the predicted compressive strength from the equation for various water/binder ratio for ordinary and high volume fly ash concrete. Fig. 7 represents the predicted compressive strength for both ordinary and high volume fly ash concrete. Fig. 8 shows the compressive strength at 28 days for ordinary and high volume fly ash concrete and also predicted compressive strength of ordinary and high volume fly ash concrete. Fig. 9 represents the relationship between the water/cement ratio and compressive strength from Bureau of Indian standards.

Equations for Compressive Strength of High Volume Fly ash Concrete
Mathematical equations were obtained expressing compressive strength in terms of water/binder ratio for ordinary concrete and high volume fly ash concrete. These are given below. Plot of these equations is shown in Fig. 7 for both ordinary concrete and high volume fly ash concrete.
The relationship between water/cement ratio and compressive strength is given by the equation

$$fc = \frac{111.37}{(5.86)^{(w/c)}}$$

For high volume fly ash concrete (50% fly ash used as additional material) the equation is

$$fc = \frac{155.02}{(15.08)^{(w/cm)}}$$

It can be seen that in both ordinary concrete and high volume fly ash concrete, equation for compressive strength is in the same form.

$$fc = \frac{a}{b^{(w/c)}}$$

This relation is similar to that given by Duff Abrams in 1918 relating compressive strength and water/cement ratio. The relation is also valid for high volume fly ash concrete with fly ash used as additional material.
Alternatively water/binder ratio of high volume fly ash concrete can be expressed as

$$w/b = \frac{12.60}{(fc)^{0.88}}$$

CONCLUSIONS

The fly ash used in these investigations exhibits good Pozzolanic properties and can be used in the production of high strength high volume fly ash concrete. High volumes of fly ash up to 50% can be used as additional material without sacrificing strength at lower w/b ratios. Further, addition of fly ash makes the concrete more impermeable due to micro filler action.

The relation between compressive strength and water binder ratio of high volume fly ash concrete is

$$fc = \frac{155.02}{(15.08)^{(w/cm)}}$$

Alternatively, the water/binder ratio can be expressed in terms of compressive strength of high volume fly ash concrete as

$$w/b = \frac{12.60}{(fc)^{0.88}}$$

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Table 1.0 Quantities of Materials for One Cubic Meter of Ordinary Concrete with Workability

w/c	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Water (liters)	Super Plasticizer (ml)	Compaction Factor
0.55	320.0	684.0	1079.0	178	--	0.96
0.53	335.0	670.0	1080.0	178	--	0.95
0.50	350.0	657.0	1081.0	178	--	0.94
0.48	370.0	634.0	1088.0	178	1110.0	0.94
0.46	388.0	612.0	1096.0	178	1161.0	0.92
0.44	404.0	640.0	1053.0	178	1212.0	0.94
0.42	425.0	568.0	1110.0	178	1275.0	0.87
0.40	445.0	563.0	1099.0	178	1335.0	0.88
0.38	470.0	524.0	1118.0	178	2350.0	0.92
0.36	472.0	517.0	1129.0	178	2472.0	0.94
0.34	524.0	494.0	1104.0	178	2618.0	0.87
0.32	556.0	477.0	1093.0	178	2781.0	0.94
0.30	593.0	460.0	1077.0	178	2967.0	0.95
0.27	659.0	436.0	1047.0	178	3296.0	0.92

Table 2.0 Quantities of Materials of High Volume Fly Ash concrete along with Workability

w/b	w/c	Cementi-tious material (Kg)	Cement (Kg)	Fly ash (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Water (liters)	Super Plasticizer (ml)	Compaction Factor
0.55	0.83	320.0	213.0	107.0	718.0	1134.0	178	--	0.96
0.53	0.79	335.0	223.0	112.0	706.0	1138.0	178	--	0.98
0.50	0.75	350.0	237.0	119.0	693.0	1140.0	178	--	0.95
0.48	0.72	370.0	246.0	124.0	672.0	1154.0	178	--	0.96
0.46	0.69	388.0	258.0	129.0	651.0	1165.0	178	--	0.95
0.44	0.66	404.0	270.0	134.0	630.0	1178.0	178	--	0.95
0.42	0.63	425.0	283.0	142.0	609.0	1190.0	178	--	0.91
0.40	0.60	445.0	296.0	149.0	588.0	1200.0	178	--	0.95
0.38	0.56	470.0	313.0	157.0	566.0	1209.0	178	--	0.90
0.36	0.54	472.0	330.0	165.0	553.0	1207.0	178	--	0.90
0.34	0.50	524.0	350.0	174.0	539.0	1205.0	178	--	0.90
0.32	0.48	556.0	370.0	186.0	525.0	1202.0	178	1112.0	0.90
0.30	0.45	593.0	396.0	198.0	511.0	1196.0	178	1188.0	0.95
0.27	0.40	659.0	440.0	220.0	491.0	1178.0	178	1320.0	0.95

Table 3.0 percentage variation of Ordinary And High Volume Fly ash Concrete

S.No.	w/c & w/b	Compressive Strength (MPa)		% Variation
		Ordinary concrete	High volume fly ash concrete	
1.	0.55	39.90	35.15	-11.90
2.	0.53	42.89	37.38	-12.85
3.	0.50	44.00	39.39	-10.47
4.	0.48	46.89	42.55	-9.26
5.	0.46	48.71	44.13	-9.40
6.	0.44	53.87	46.91	-12.92
7.	0.42	56.40	48.87	-13.35
8.	0.40	59.29	55.80	-5.88
9.	0.38	60.04	61.17	1.88
10.	0.36	61.65	62.66	1.64
11.	0.34	62.44	64.18	2.79
12.	0.32	63.42	66.40	4.69
13.	0.30	64.80	68.19	5.23
14.	0.27	66.60	70.66	6.10

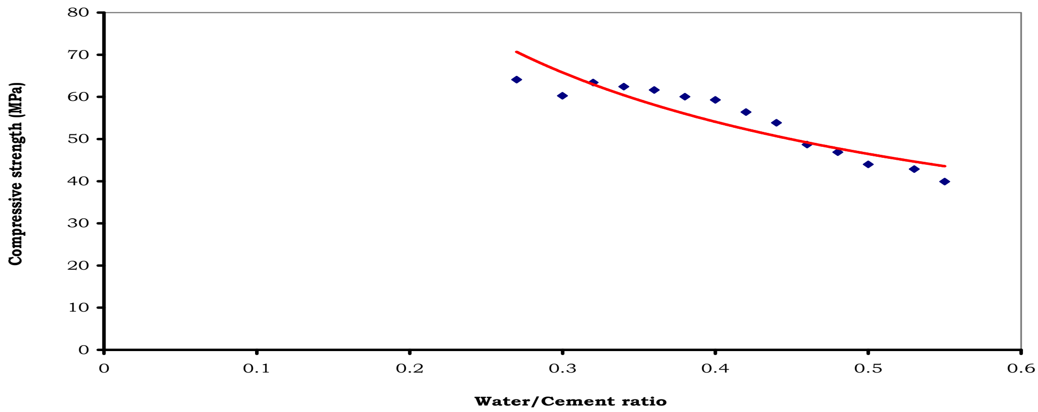

Fig 1.0 Compressive Strength Vs Water/ Cement Ratio for Ordinary Concrete

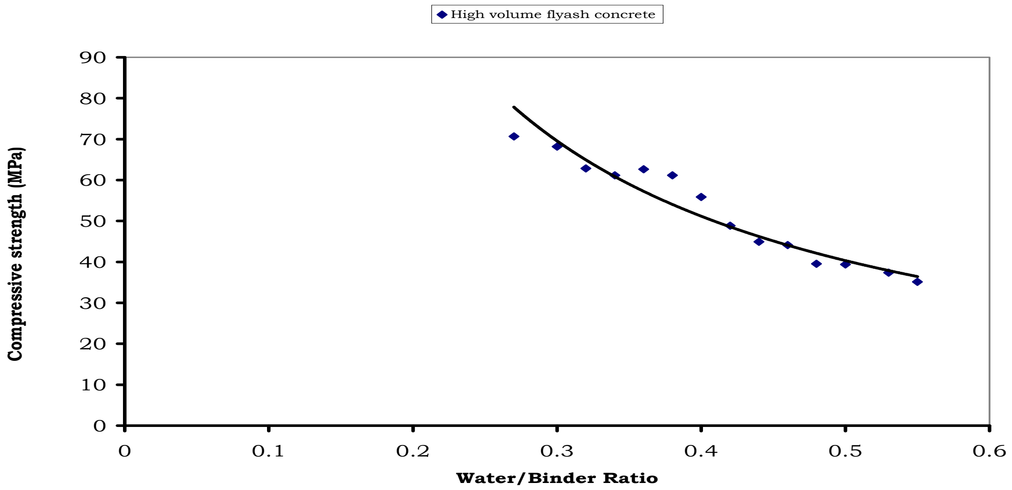

Fig 2.0 Compressive Strength Vs Water/Binder Ratio for High Volume Fly Ash Concrete

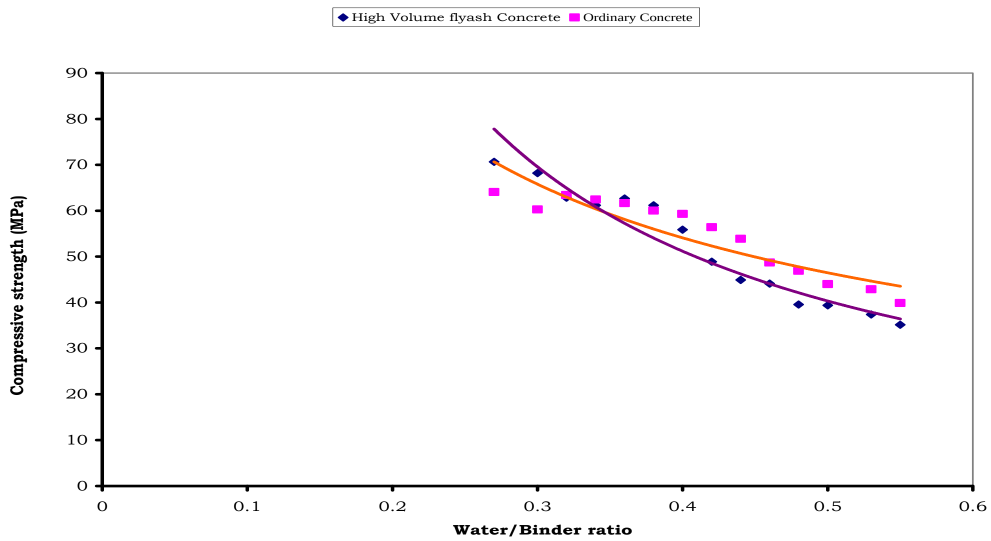

Fig 3.0 Compressive Strength Vs Water/Binder ratio

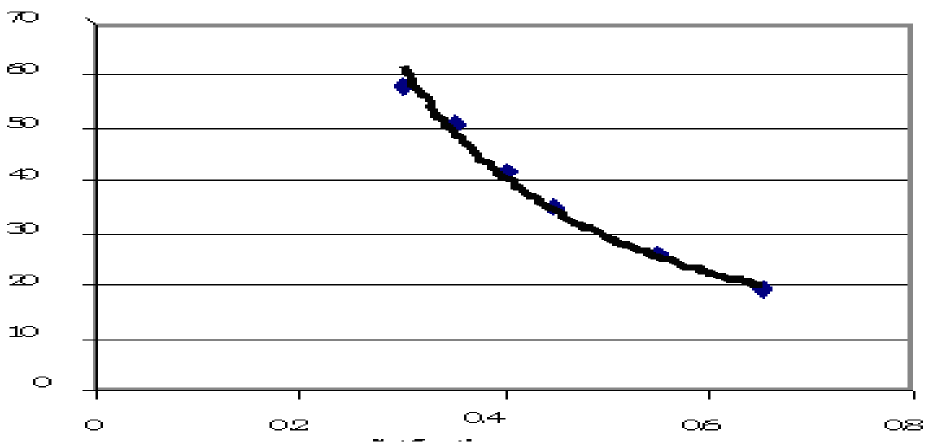

Fig 4.0 . Relation between water/ cement + flyash ratio 28 day cube strength (R.K.Dhir)

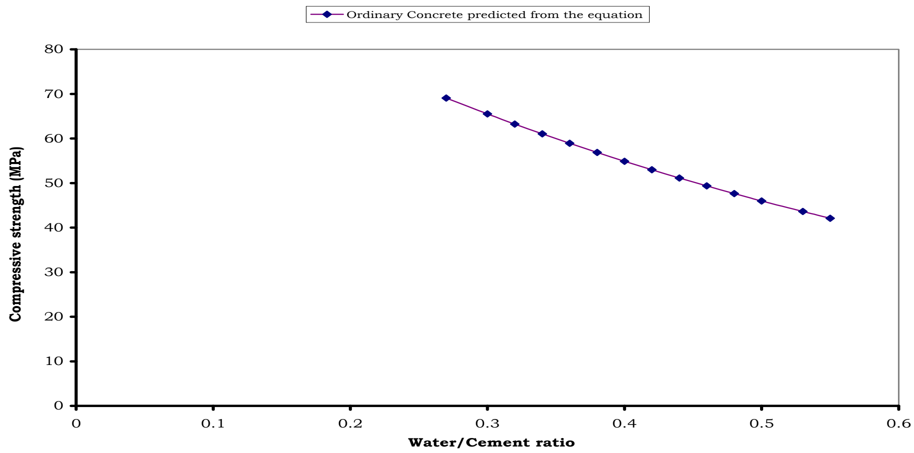

Fig 5.0 Compressive Strength Vs Water/ Cement Ratio For Ordinary Concrete

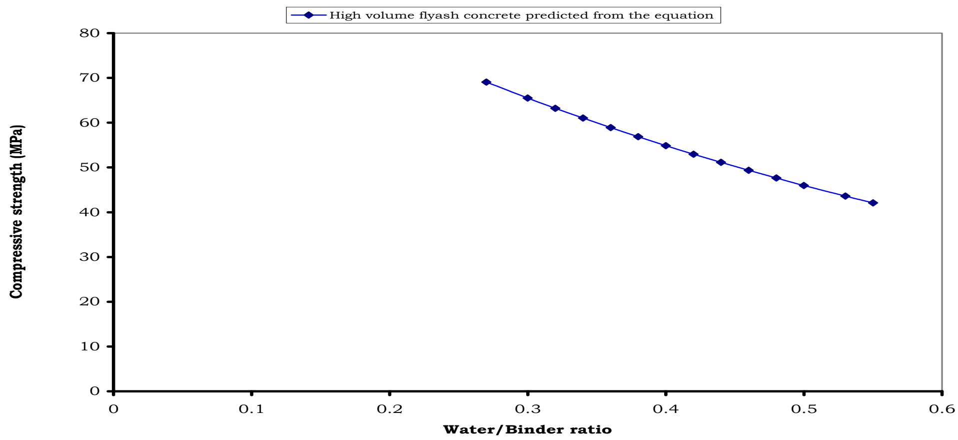

Fig 6.0 Compressive Strength Vs Water/ Binder Ratio for High Volume Fly Ash Concrete

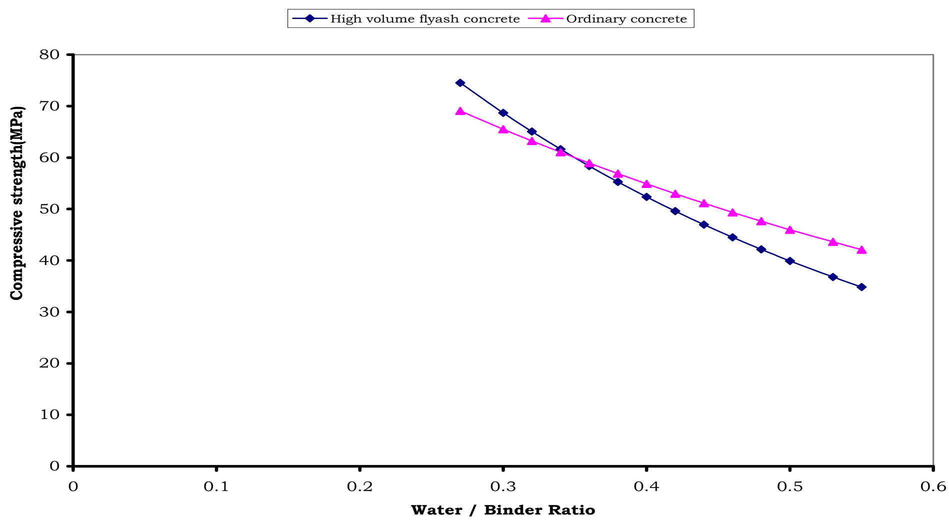

Fig 7.0 Compressive Strength Vs Water/ Binder ratio for Ordinary and High Volume Fly Ash Concrete

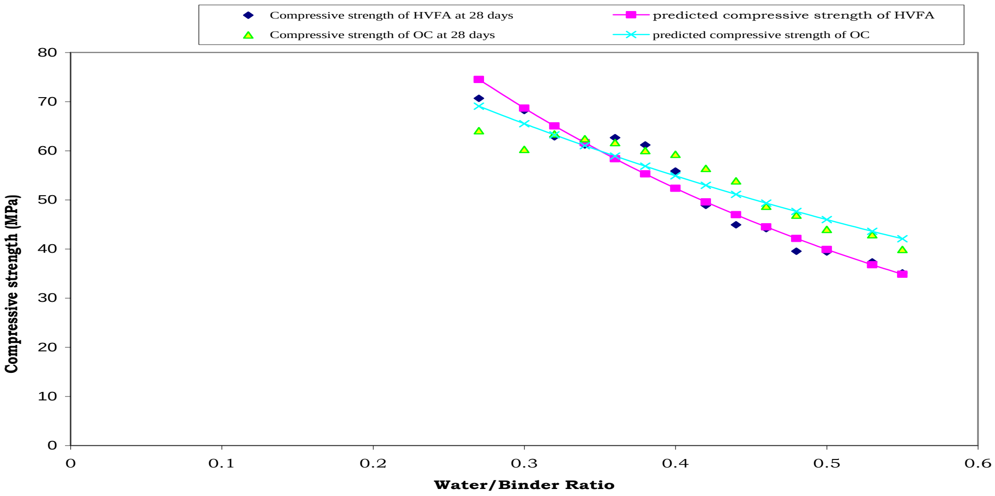

Fig 8.0 Compressive Strength Vs Water/ Binder ratio

Bibliography of Authors

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