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Studies on Compressive Strength Of Ternary Blended Concretes At Different Water Binder Ratios

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Abstract: - The Present experimental investigation is carried out in the optimisation of a Ternary Blended Cementitious system based on Ordinary Portland Cement (OPC)/ Fly Ash / Micro Silica for the development of high- performance concrete. Compressive Strength of Ternary Blended Concrete at the ages of 28, 90, 180 days for various combinations of Fly Ash and Micro Silica mixes were investigated. Fly Ash was replaced by 0%, 15% and 20% along with Micro Silica of 0%, 5%, and 10%. All the mixes were studied at three water binder ratios of 0.55, 0.45 and 0.35.

I. INTRODUCTION

Now a day the world is witnessing the construction of very challenging and difficult structures, concrete being the most important and widely used structural material is called upon to possess very high strength. The main ingredient in the conventional concrete is Portland cement. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. To overcome the above ill effects, the advent of newer material and construction techniques and in this drive, admixture has taken newer things with various ingredients has become a necessity. The addition of pozzolanic materials with OPC a century old practice is an alternative in the construction industry. Fly ash one of the byproducts of thermal power plants is one of the most common mineral admixture used in concrete world wide. Fly ash largely improves the durability of concrete. One of the greatest drawbacks while using fly ash as pozzolanic material in concrete is the early age performance of concrete. The early age strength development of fly ash blended binary concretes shows poor performance than the ordinary concrete. Researchers all over the world are developing Ternary Blended Concretes by adding a superfine mineral admixture like Micro Silica to the binary blended concretes of fly ash. Micro Silica in the ternary blend improves the early age performance of concrete and fly ash improves the properties at the later age.

II. LITERATURE REVIEW

Shweta Goyal [1] et.al investigated on the role of Fly Ash addition on the superplasticiser dosage, slump, and 28 day and 90 day Compressive Strength of Micro Silica concrete .It was concluded that in the binary mixes Micro Silica increased the superplasticiser demand while Fly Ash decreased the optimum dosage of superplasticiser for constant workability. Three component systems can be designed for high workability with low superplasticiser dosage without impairing much in strength. **Murthi [2] et.al** in their experimental study intended to identify the relationship ofCompressive Strength and splitting tensile strength of Ternary Blended Concrete. For this purpose, the applicability of 0.5 power relationship as per IS 456-2000 and then a similar kind of relationship developed for Ternary Blended Concrete. Two kinds of binary blended concrete systems were considered in this study using the optimum replacement of cement by ASTM class Fly Ash (FA) and rice husk

ash (RHA). The Ternary Blended Concrete was developed by replacing the cement content in the binary system using Micro Silica (MS). The replacement of cement in the binary system by MS was suggested as 4%, 8% and 12% of total powder content by weight. **Khan [3] et.al** investigated on the optimization of a ternary blended cementitious system based on ordinary Portland cement (OPC)/ pulverized Fly Ash (PFA)/ Micro Silica (MS) for the development of high performance concrete. Cement pastes covering a wide range of PFA/MS blending proportions were investigated. Compressive Strength at ages of 7,28 and 90 days for cement paste containing 0%, 15%, 20%, 25%, 30%, 35%, 40% and 45% PFA along with 0%, 5%, 10% and 15% MS as partial replacement at a water binder ratio of 0.30 were investigated. **Tahir kemal erdem [4] et.al** investigated on the combinations of cement additions to provide more benefits for concrete than a single one. In this study, 80 high strength concretes containing several types and amounts of additions were produced. In the first stage Micro Silica contents in the binary blends that gave the highest strength were determined for different binder contents. The amount of Micro Silica that was used as replacement was 5%, 10% and 15% by mass of cement. In the second stage a third binder(class F or class C Fly Ash or ground granulated blast furnace slag) was introduced to concretes already containing Portland cement and Micro Silica in the amounts found in the first stage. Results indicated that ternary blends almost made it possible to obtain higher strengths than binary blends provided that the replacement by additions were chosen properly. The performance of slag in the ternary blends was better than class F Fly Ash but worse than class C Fly Ash. **Murthi [5] et.al** investigated on an essential assumption that porosity variation plays a role in influencing Compressive Strength of hardened concrete. The normal strength concrete with W/C ratio of 0.55 was used for this experimental investigation. The partial replacement of cement by Fly Ash was done to reduce the porosity and make concrete with a dense microstructure. The initial strength development of Fly Ash based blended concrete was less compared to the normal concrete. An attempt has been made to overcome the delay in strength development of concrete during the early ages by making the Ternary Blended Concrete. Fly Ash (FA) and Rice Husk Ash (RHA) were used for preparing the binary blended concrete and Micro Silica (MS) was used for developing the Ternary Blended Concrete. The results of the porosity of the concrete obtained from absorption tests showed that the porosity of blended concrete was less than that of the normal concrete. The Compressive Strength of the blended concrete was determined and it was observed that the early strength of Ternary Blended Concrete improved more than that of binary blended concrete. **Anwar [6]** presented the results from laboratory studies on properties of concrete that contain ternary blends of Portland cement, Micro Silica and Fly Ash. Selected four concrete mixes were prepared with water to cementitious material ratio of 0.4. The different combinations that were studied were 5%MS + 15% FA, 5%MS + 25% FA, 10% MS + 15% FA and 10% MS + 15% FA. The concrete mixes were designed to have the same degree of workability and percentage of air content. The results indicated that the concrete made with these systems generally showed good fresh and hardened properties since the combination of Micro Silica and Fly Ash is somewhat synergistic. Fly Ash appears to compensate for some of the workability problems associated with the Micro Silica where as the Micro Silica appears to compensate for the low early age strength of Fly Ash concrete.

III. EXPERIMENTAL INVESTIGATION

The present investigation is aimed to study the combination of Micro Silica and Fly Ash that is required that produces the maximum Compressive Strength. The cement was replaced from a minimum of 0% to a maximum of 30% in the Ternary blends. A total of five combinations were studied. 5% Micro Silica + 15% Fly Ash, 5% Micro Silica + 20% Fly Ash, 10% Micro Silica + 15% Fly Ash , 10% Micro Silica + 20% Fly Ash and 0% Micro Silica + 0% Fly Ash by weight of cement with different W/B ratios of 0.55,0.45 and 0.35 were studied. The Compressive Strength was calculated at the age of 28, 90 and 180 days.

IV. MATERIALS

Cement

Ordinary Portland cement of 53 grade having specific gravity of 3.02 and fineness of 3200cm^2/gm was used . The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of 12269-1987.

Coarse Aggregate

Crushed angular granite metal of 10 mm size having the specific gravity of 2.65 and fineness modulus 6.05 was used .

Fine Aggregate

River sand having the specific gravity of 2.55 and fineness modulus 2.77 was used .

Fly Ash
Type-II fly ash confirming to I.S. 3812 – 1981of Indian Standard Specification was used .

Micro Silica
The Micro silica having the specific gravity 2.2 was used .
Superplasticizer:
Superplasticizer CONPLAST 430 was used as water reducing admixture. It increases workability.

V. DISCCUSSION OF RESULTS

Workability of Ternary Blended Concrete

When Fly Ash and Micro Silica are used in combination the beneficial effect of Fly Ash on fluidity can be used to compensate for the loss of workability with Micro Silica addition. Further for the same Micro Silica content (5% Micro Silica) increasing the Fly Ash content from 15% to 20% resulted in decrease in dosage of superplasticizer dosage indicating the positive influence of Fly Ash on the optimum superplasticizer dosage in the ternary mixes. The trend was reversed when the Micro Silica content increased from 5% to 10% for the same Fly Ash percentage (15%). For water to binder ratios the combination of 5% Micro Silica + 20% Fly Ash exhibited the least superplasticizer dosage while the mix 10% Micro Silica + 15% Fly Ash exhibited the highest optimum superplasticizer dosage. It was observed that as the water to binder ratio decreases the optimum dosage of superplasticiser increases. With the decrease in water to binder ratio, more superplasticiser molecules are required for adsorption on the surface of cement and mineral admixture particles to increase the fluidity of the mix. The optimum dosage increased sharply as the water to binder ratio decreased from 0.45 to 0.35. For control mixes superplasticiser was not required for water to binder ratios of 0.55 and 0.45 but for water to binder ratio of 0.35, 7% of cementitious material was required to get medium workability. For the combination of 10% Micro Silica + 15% Fly Ash the cementitious material increased from 5% to 8.5% as the water to binder ratio decreased from 0.45 to 0.35 to attain medium workability. This is because at very low water to binder ratio, cement particles are very closely placed and to overcome inter particle friction and inter particle forces of attraction, additional quantum of superplasticiser is required to arrive at the optimum dosage.

Compressive Strength Studies on Ordinary and Ternary Blended Concrete

The combination of Micro Silica and Fly Ash leads to increase in Compressive Strength as compared to control mix proportions given in tables 1.0 to 5.0 irrespective of water to binder ratios at the age of 90 and 180 days . The combination of 5% Micro Silica, 15% Fly Ash and 80% cement represents the optimum among the four combinations studied for all the water to binder ratios. It was noticed that replacing the cement by more than 20% tended to lower the efficiency of mineral admixtures. The other combination i.e. 5% Micro Silica + 20% Fly Ash and 10% Micro Silica + 15% Fly Ash that used 25% of mineral admixtures as replacement of cement did not show significant increase in strength. The combination of 10% Micro Silica + 20% Fly Ash showed a decrease in strength compared to control concrete at the age of 28 days for W/B ratios of 0.55 and 0.45.
From Table 6.0, 7.0 and 8.0 we observe the variation in Compressive Strength from 35.20 to 73.24 MPa for Ordinary Concrete , 40.64 to 96.70MPa for Ternary Blended Concrete(TBC) (5% Micro Silica + 15% Fly Ash) , 38.47 to 90.00 MPa for Ternary Blended Concrete(TBC) (5% Micro Silica + 20% Fly Ash) , 39.11 to 94.82 MPa for Ternary Blended Concrete(TBC) (10% Micro Silica + 20% Fly Ash) , 34.10 to 80.12 MPa for Ternary Blended Concrete(TBC) (10% Micro Silica + 20% Fly Ash) with W/B ratios of 0.55, 0.45, 0.35 respectively

The addition of Micro Silica to Fly Ash based binary blended concrete resulted in increase in compressive strength. The improved performance of Micro Silica concrete could be attributed to the improvement in bond between the hydrated cement matrix and aggregate. This in turn is due to the combined effect of secondary pozzolanic reaction and the fineness of Micro Silica particles.

Increase of Compressive Strength of Ternary Blended Concrete (5% Micro Silica + 15% Fly Ash) compared with Ordinary Concrete
From graph 1.0 the increase in Compressive Strength of Ternary Blended Concrete compared to Ordinary Concrete from 28 days to 180 days is observed to be 15% to 32 % for all W/B ratio
Increase of Compressive Strength of Ternary Blended Concrete (5% Micro Silica + 20% Fly Ash) compared with Ordinary Concrete
From graph 2.0 the increase in Compressive Strength of Ternary Blended Concrete compared to Ordinary Concrete from 28 days to 180 days is observed to be 9% to 23 % for all W/B ratio

Increase of Compressive Strength of Ternary Blended Concrete (10% Micro Silica + 15% Fly Ash) compared with Ordinary Concrete

From graph 3.0 the increase in Compressive Strength of Ternary Blended Concrete compared to Ordinary Concrete from 28 days to 180 days is observed to be 11% to 29 % for all W/B ratio

Increase of Compressive Strength of Ternary Blended Concrete (10% Micro Silica + 20% Fly Ash) compared with Ordinary Concrete

From graph 4.0 the increase in Compressive Strength of Ternary Blended Concrete compared to Ordinary Concrete from 28 days to 180 days is observed to be 3.0% to9.0 % for all W/B ratio

Increase of Compressive Strength of Ternary Blended Concrete(5% Micro Silica + 15% Fly Ash) at the age of 90 and 180 days with its 28 day strength.

From graph 5.0 the increase in Compressive Strength of Ternary Blended Concrete with its 28 day strength is observed from 10% to 30% for all W/B ratios.

Increase of Compressive Strength of Ternary Blended Concrete(5% Micro Silica + 20% Fly Ash) at the age of 90 and 180 days with its 28 day strength.

From graph 6.0 the increase in Compressive Strength of Ternary Blended Concrete with its 28 day strength is observed from 10% to 29% for all W/B ratios.

Increase of Compressive Strength of Ternary Blended Concrete(10% Micro Silica + 15% Fly Ash) at the age of 90 and 180 days with its 28 day strength.

From graph 7.0 the increase in Compressive Strength of Ternary Blended Concrete with its 28 day strength is observed from 11% to 30% for all W/B ratios.

Increase of Compressive Strength of Ternary Blended Concrete(10% Micro Silica + 20% Fly Ash) at the age of 90 and 180 days with its 28 day strength.

From graph 8.0 the increase in Compressive Strength of Ternary Blended Concrete with its 28 day strength is observed from 13% to 31% for all W/B ratios.

VI. CONCLUSIONS

1 The combination of 5% Micro Silica + 20% Fly Ash required the least dosage of superplasticiser for all the three W/B ratios studied.

2 The combination of 5% Micro Silica + 15% Fly Ash performed the best at all ages and at all the W/B ratios studied in terms of Compressive Strength among the four combinations studied.

3 The combination of 10% Micro Silica + 20% Fly Ash gave the least Compressive Strength among the ternary mixes at all ages and at all W/B ratios.

4 The percentage increase in Compressive Strength of Ternary Blended Concrete (5% Micro Silica + 15% Fly Ash) for various W/B ratios compared with Ordinary Concrete is observed to be 15% to 32%.

5 The percentage increase in Compressive Strength of Ternary Blended Concrete (5% Micro Silica + 15% Fly Ash) at the age of 90 and 180 days with its 28 day strength is observed to be 10% to 30%.

6 The percentage increase in Compressive Strength of Ternary Blended Concrete is found to be higher at higher ages for all water to binder ratios.

7 Results show that Ternary Blended Concrete offer significant advantages over control concrete. Such Concretes show generally good properties and offset the problems associated with using Fly Ash and Micro Silica when these materials are used individually. More attention must be given to the development of a new types of cements incorporating combination of the cementitious material in the Ternary cementitious systems.

8 The combination of Micro Silica and Fly Ash is complimentary. The Micro Silica improves the early age performance of concrete with the Fly Ash continuously refining the peoperties of hardened concrete as it matures.

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Table 1.0 Quantities of Materials required per 1 m^3 of Ordinary Concrete

S.No	W/C	Cement	Fine Aggregate.	Coarse Aggregate	Water	Super Plasticizer
1	0.55	324	736	1084	178	0
2	0.45	391	697	1070	176	0
3	0.35	497	629	1050	174	3480

Table 2.0 Quantities of Material required per 1 m^3 of Ternary Blended Concrete (5% Micro Silica – 15% Fly Ash)

S.No	W/B	Cement	Micro Silica.	Fly Ash	Fine Aggregate.	Coarse Aggregate	Water.	Super Plasticizer
1	0.55	259	16.20	48.6	736.0	1084.0	178	0
2	0.45	312	`19.55	58.65	697.0	1070.0	176	0
3	0.35	397	24.85	74.55	629.0	1050.0	174	2980

Table 3.0 Quantities of Material required per 1 m^3 of Ternary Blended Concrete (5% Micro Silica – 20% Fly Ash)

S.No	W/B	Cement	Micro Silica	Fly Ash.	Fine Aggregate.	Coarse Aggregate	Water	Super Plasticizer
1	0.55	243	16.20	64.8	736.0	1084.0	178	0
2	0.45	293	19.55	78.2	697.0	1070.0	176	0
3	0.35	373	24.85	99.4	629.0	1050.0	174	2798

Table 4.0 Quantities of Material required per 1 m^3 of Ternary Blended Concrete (10% Micro Silica – 15% Fly Ash) **Table 4.0 Quantities of Material required per 1 m^3 of Ternary Blended Concrete (10% Micro Silica – 15% Fly Ash)**

S. No	W/B	Cement	Micro Silica	Fly Ash	Fine Aggregate.	Coarse Aggregate	Water	Super Plasticizer
1	0.55	243	32.4	48.6	736.0	1084.0	178	0
2	0.45	293	39.1	58.65	697.0	1070.0	176	1465
3	0.35	373	49.7	74.55	629.0	1050.0	174	3170

Table 5.0 Quantities of Material required per 1 m^3 of Ternary Blended Concrete (10% Micro Silica – 20% Fly Ash)

S.No	W/B	Cement	Micro Silica	Fly Ash	F.A.	C.A.	Water	Super Plasticizer
1	0.55	227	32.4	64.8	736.0	1084.0	178	0
2	0.45	274	39.1	78.2	697.0	1070.0	176	1370
3	0.35	348	49.7	99.4	629.0	1050.0	174	3132

Table 6.0 Compressive Strength of Ordinary and Ternary Blended Concrete at 28, 90, 180 days at W/B ratio of 0.55

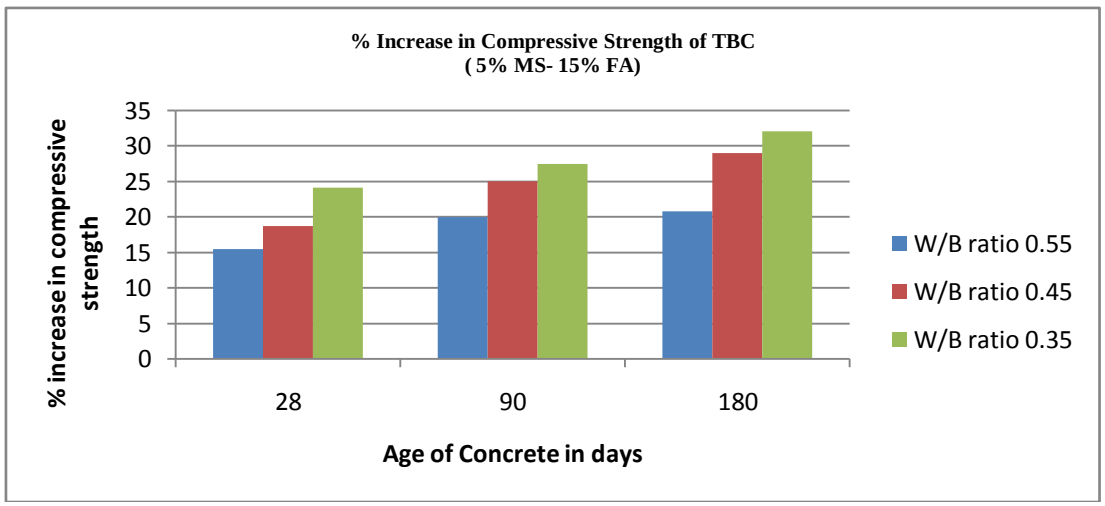
Sl. No	W/B	Mineral Admixture ,% replacement of cement		Compressive Strength (MPa)		
		Micro Silica	Fly Ash	28 Days	90 Days	180 Days
1	0.55	0%	0%	35.20	37.42	40.44
2		5%	15%	40.64	44.87	48.81
3		5%	20%	38.47	42.35	46.80
4		10%	15%	39.11	43.56	47.64
5		10%	20%	34.10	38.60	42.00

Table 7.0 Compressive Strength of Ordinary and Ternary Blended Concrete at 28, 90, 180 days at W/B ratio of 0.45

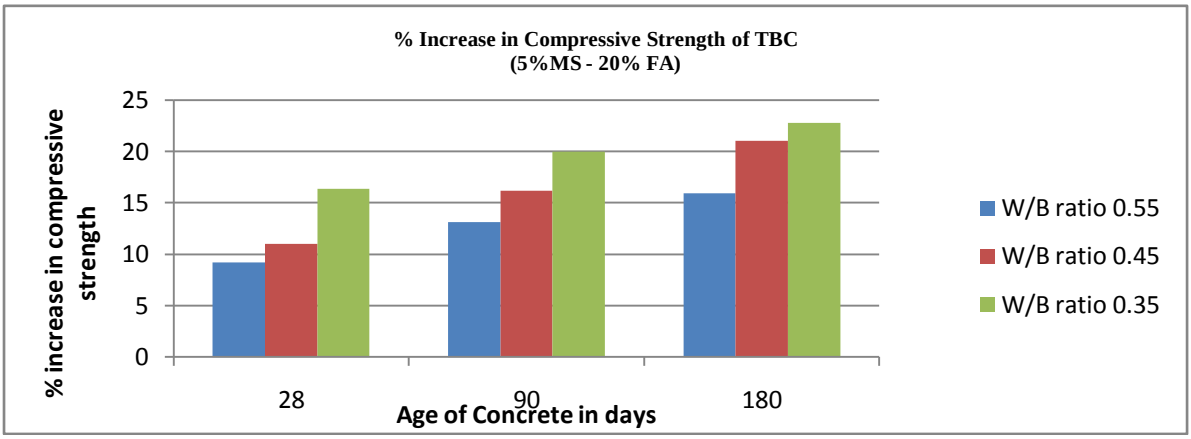
Sl. No	W/B	MA, % replacement of cement		Compressive Strength (MPa)		
		Micro Silica	Fly Ash	28 Days	90 Days	180 Days
1	0.45	0%	0%	42.32	45.61	49.42
2		5%	15%	50.22	57.00	63.73
3		5%	20%	47.00	52.90	59.84
4		10%	15%	48.75	55.51	61.63
5		10%	20%	41.12	47.78	51.98

Table 8.0 Compressive Strength of Ordinary and Ternary Blended Concrete at 28, 90, 180 days at W/B ratio of 0.35

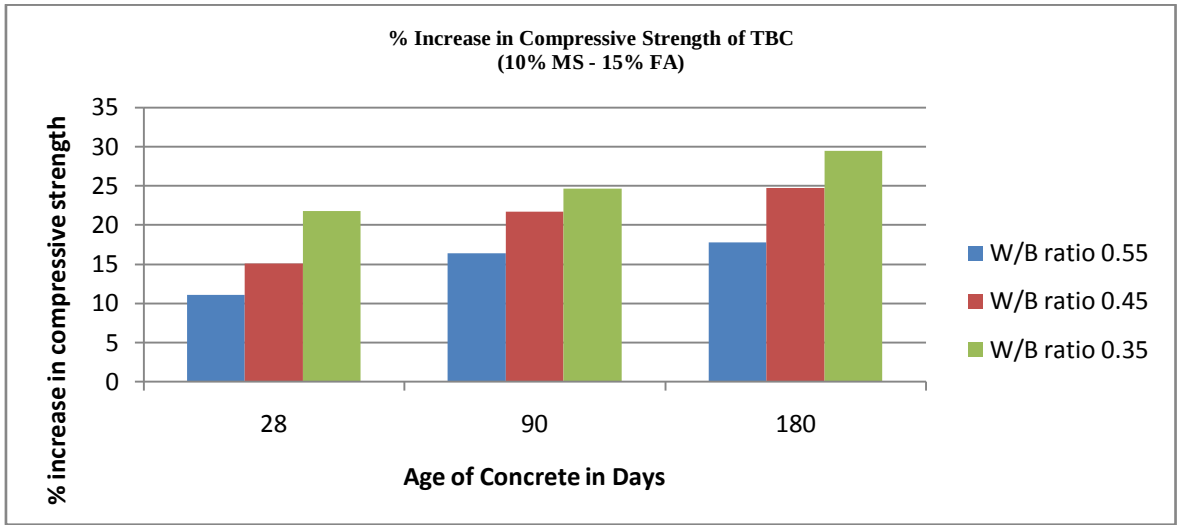
Sl. No	W/B	MA, % replacement of cement		Compressive Strength (MPa)		
		Micro Silica	Fly Ash	28 Days	90 Days	180 Days
1	0.35	0%	0%	60.04	66.72	73.24
2		5%	15%	74.78	85.00	96.70
3		5%	20%	69.88	80.04	90.00
4		10%	15%	73.08	83.14	94.82
5		10%	20%	61.30	72.20	80.12



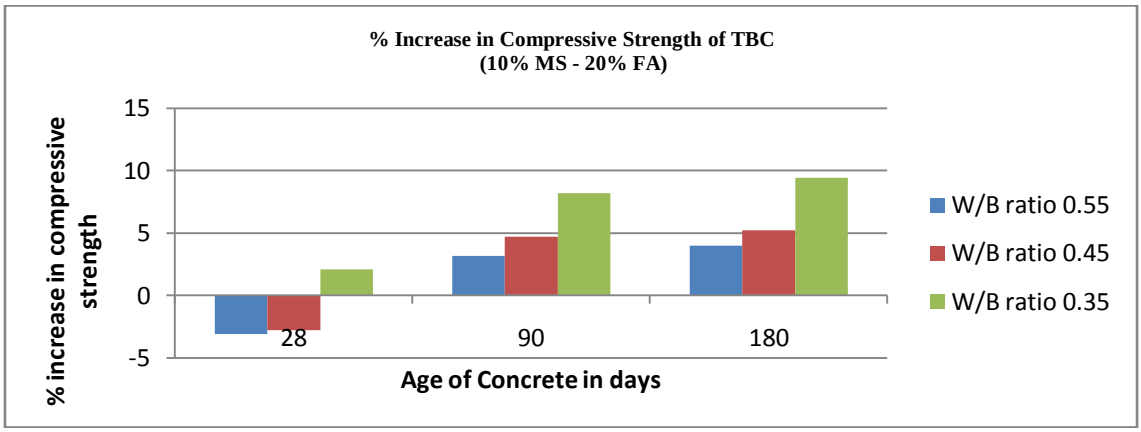
Graph 1.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (5% MS + 15% FA) with respect to Ordinary Concrete at the age of 28,90,180 days



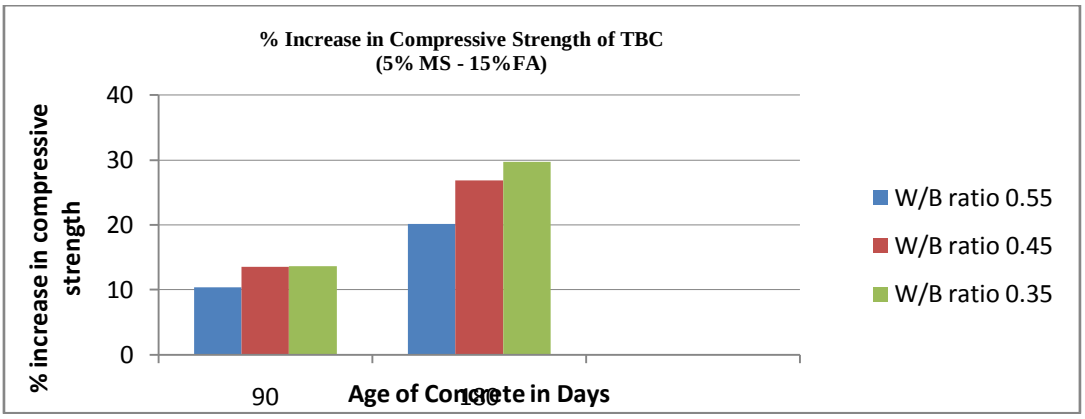
Graph 2.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (5% MS + 20% FA) with respect to Ordinary Concrete at the age of 28,90,180 days.



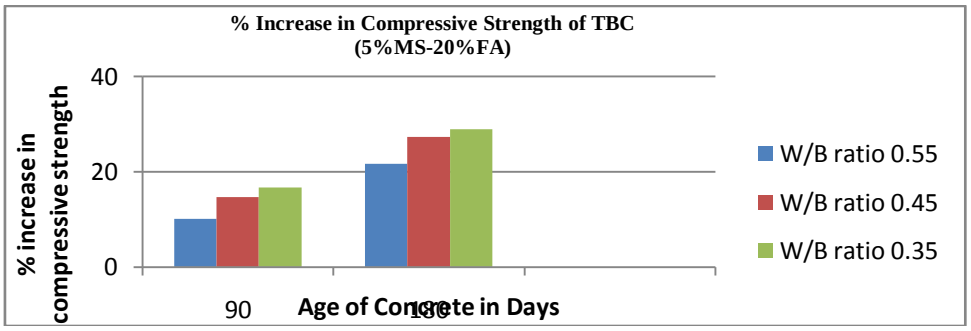
Graph 3.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (10% MS + 15% FA) with respect to Ordinary Concrete at the age of 28,90,180 days.



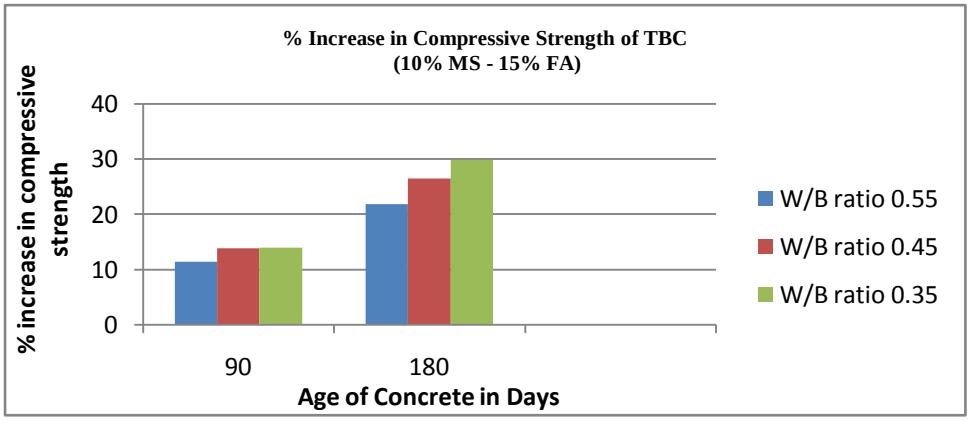
Graph 4.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (10% MS + 20% FA) with respect to Ordinary Concrete at the age of 28,90,180 days



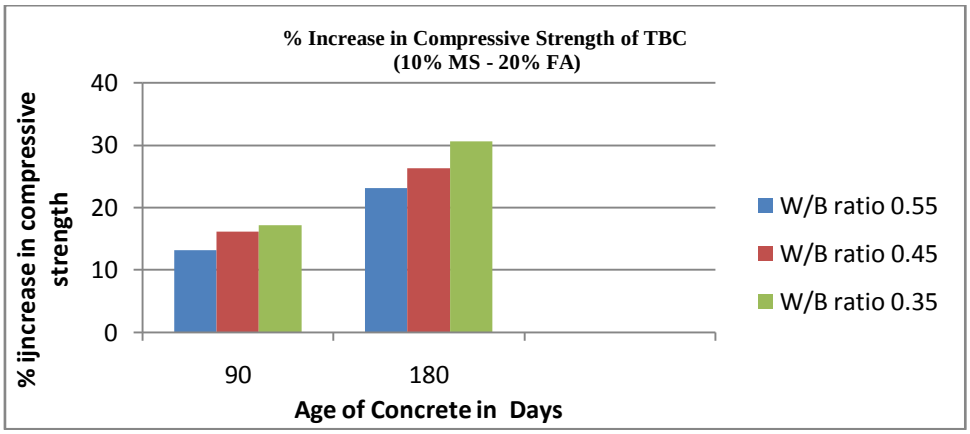
Graph 5.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (5% MS + 15%FA) at the age of 90 and 180 days with its 28 day strength.



Graph 6.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (5% MS + 20% FA) at the age of 90 and 180 days with its 28 day strength.



Graph 7.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (10% MS + 15% FA) at the age of 90 and 180 days with its 28 day strength.



Graph 8.0 Percentage increase in Compressive Strength of Ternary Blended Concrete (10% MS + 20% FA) at the age of 90 and 180 days with its 28 day strength.

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