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Research paper

Mechanical properties of triple blended concrete using fly ash and GGBS as cement replacement material for rigid pavements

T. Vijaya Gowri [1] *, B. Manjunath [2], C. Krishna Raju [3]

[1] *Associate Professor, BVRIT, Narsapur, Telangana State, India*
[2] *Assistant Professor, BVRIT, Narsapur, Telangana State, India*
[3] *Professor BVRIT, Narsapur, Telangana State, India*
**Corresponding author E-mail: vijayagowri.t@bvrit.ac.in*

Abstract

In the present investigations, Conventional Triple blended concrete (TBC)of 8 mixes were designed for M40 grade using w/b as 0.4 and tested for Compressive Strength and Flexural Strength. In these concrete mixes, Cement was replaced with 15% of Fly ash (FA)and with 10%, 20%, 30%, 40%, 50%, 60%, 70% and 80% of Ground Granulated Blast Furnace Slag (GGBS), tested for 7 days and 28 days strength and compared with the strength of Conventional Concrete (CC). From the results, it was observed that, the strength of TBC is maintaining appropriate strength up to 50% GGBS replacement level and drastic decrease in strengths above 50% GGBS replacement level. The results are analyzed and the relations also developed between Compressive Strength and Flexural Strength of TBC for 7 days and 28 days.

Keywords: *Triple Blended Concrete; Conventional Concrete; Fly Ash; Ground Granulated Blast Furnace Slag; Compressive Strength and Flexural Strength.*

1. Introduction

Concrete is a versatile material used in construction, from the flooring of a hut to a multi-storied high-rise structures from pathway to airport runway. Cement is main constituent as a binder to the concrete. Cement production leaves so many effluents to the environment and key material which causes pollution.

Presently, tremendous research is going on for thereduction of cement content in concrete by replacement of mineral admixture is added to the concrete. These mineral admixtures are slag or waste generated from industries. The utilization of Ground Granulated Blast Furnace Slag brought about from strict authorization of air pollution measures outlined to halt discharge of that material into atmosphere. In the present study an attempt has been made to assess the suitability of Ground granulated blast furnace slag as cement replacement material in concrete making. The presence of Fly ash (FA), Ground Granulated Blast Furnace Slag (GGBS) mineral admixture helps to improve mechanical properties to the concrete and environment friendly. These mineral admixtures are economical compare to cement.

1.1. Literature survey

Strength properties are increased at 20% GGBS replacement when compared to Conventional Concrete, due to the finer size of GGBS (Arivalagan, 2014, p. 269). The High Volumes of slag concrete gains appreciable amount of strength at later ages (90 days onwards) and it increases with decrease in water-binder ratios & hydration of slag with Ca(OH)2 and water (Vijaya & Sravana, 2014, p.237). The setting time of concrete can be delayed by using ground granulated blast-furnace slag (GGBFS).

This property depends on factors like the amount of Portland cement, the type of GGBS, water requirement, and reactivity of the slag or dosage of pozzolan, and the temperature of the concrete (Rajesh Kumar, 2014, p.100). Partial replacement of Portland cement with GGBF slag is found to improve the sulfate resistance of concrete (Atul & Chandak, p.4.). The effect of ground granulate blast furnace slag as cementitious material improved the strength, binding property towards polyvinyl alcohol fiber which causes ductility of engineered cementitious composite (ECC) (Ing Lim, 2012, p. 324).

The surface declamation and spalling due to gypsum were observed less when the concrete with GGBS exposed to sulphate environment (Ciaran, 2011, p.12). The saturation dosage of superplasticizer is almost same for the specific surface of GGBFS changes from 350 to 550 m2/kg. The strength of concrete with GGBS is more when the curing temperature rose when comparing with concrete with OPC (Wang & Tian, 2004, p.312 & 317). The heat of hydration of concrete, pH value and alkali -silica reaction can be controlled by using fly ash and GGBS along with OPC (Maiti & Raj, 2006, p.27). At 10-40% of GGBS replacement of cement in concrete, it increases the workability properties, Sulfate and Chloride resistance and strength is observed more in later ages (Magandeep & Ravi, 2015, p.72).

The GGBS concrete with 40% replacement of cement exhibited good strength among all GGBS concrete mixes for later ages (56 days) (Shariq and Prasad, 2008, p.73). GGBS improves the strength of the concrete for lower water-binder ratios. Pozzolans improve the pozzolanic activity in early days as well as reduces chloride permeability (Ozkan & Mehmet, 2009, p.500). Concrete with OPC and GGBS show highest strength at 20oC whereas concrete with fly ash shows at 35oC (Even, 2002, p.540). The progressive release of alkalis by the GGBS, together the formation of calcium hydroxide by Portland cement, resulting in continuing reaction of GGBS over a long period. Thus, there is a long term gain in strength. However, the later rate of hydration of blended cement containing GGBS is accelerated. Thus heat of hydration is reduced by inclusion of GGBS mix. (Neville, 2011).

1.2. Research significance

From the experimental results in our laboratory, it is found that Fly ash and GGBS can be used as cement replacement material and also 15% of fly ash as the optimum percentage as substituting binder to cement (Pratap & Bhasker, 2014). There is no literature found for different percentages of GGBS (from 10% - 80%) with 15% Fly Ash. As per IRC 58-2015, Flexural Strength of concrete is significant parameter in designing of rigid pavement. Accordingly, some relations are developed between Compressive Strength and Flexural Strength of CC and TBC for 7 days and 28 Days for all concrete mixes.

1.3. Objective of present investigations

The scope of present study is to identify the suitable mix for the rigid pavement. The main objectives of the present investigations are

a) To determine percentage variation between CC and TBC,
b) To know the influence of combinations of Fly Ash and GGBS on strength of concrete.
c) To propose empirical equations for Compressive strength and w/b and Flexural Strength for all concrete mixes.

2. Experimental investigations

Experimental Investigations are conducted to determine the property of ingredients of concrete mixes.

2.1. Materials

The materials used in the present investigations are 53 grade Ordinary Portland Cement, GGBS, Fly Ash, River Sand (Fine Aggregate) and 20 mm Crushed Granite Stones (Coarse Aggregate) and Water. Specific gravity of all the ingredients are shown Table 1 and Particle Size Distribution Curve of Combined Aggregate is shown in Fig. 1.

Table 1: Property of Ingredients

S. No.	Material	Specific Gravity
1	Cement (Ultratech)	3.1
2	Ground Granulated Blast Furnace Slag (from Visakhapatnam)	2.86
3	Fly ash	2.2
4	Fine Aggregate (River Sand)	2.55
5	Coarse Aggregate (Crushed Granite Material)	2.60

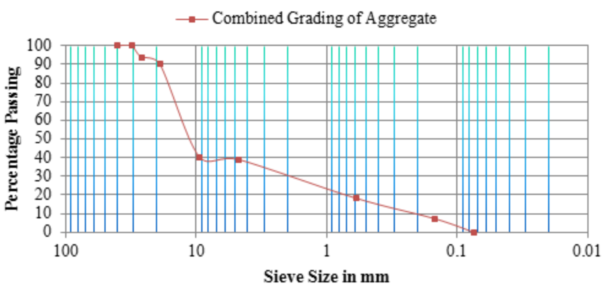


Fig. 1: Particle Size Distribution Curve of Combined Aggregate.

3. Mix proportioning

Mix Proportioning of CC and TBC with Fly ash as 15% of cement replacement had been prepared. CC and TBC mixes were prepared for various with 0% to 80% GGBS as replacement material for cement are shown in Table 2.

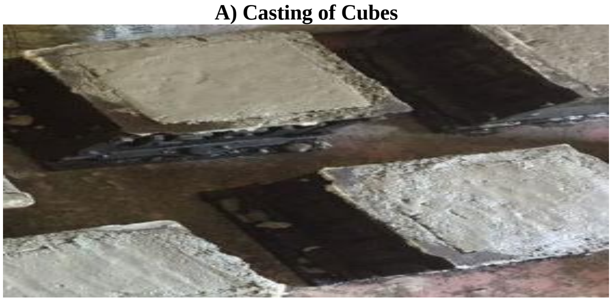
Table 2: Mix Proportions of Conventional Concrete and Triple Blended Concrete with Fly Ash as 15% of cement replacement

Mix	CC	TBC10	TBC20	TBC30	TBC40	TBC50	TBC60	TBC70	TBC80
Cement (Kg)	440	330	286	242	198	154	110	66	22
GGBS (Kg)	0	44	88	132	176	220	264	308	352
Fly Ash(Kg)	0	66	66	66	66	66	66	66	66
FA(Kg)	639	629	628	627	626	625	624	622	621
CA(Kg)	1216	1205	1202	1200	1198	1196	1194	1192	1190
Slump (mm)	20	25	30	35	35	40	40	45	45

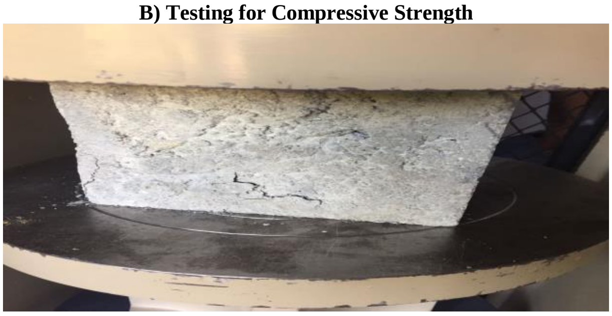
3.1. Preparation, casting and testing of specimen

The specimens of CC and TBC were cast, cured and tested for Compressive Strength and Flexural Strength as per IS: 516-1959 are shown in Fig.2.

A) Casting of Cubes



B) Testing for Compressive Strength



C) Testing for Flexural Strength

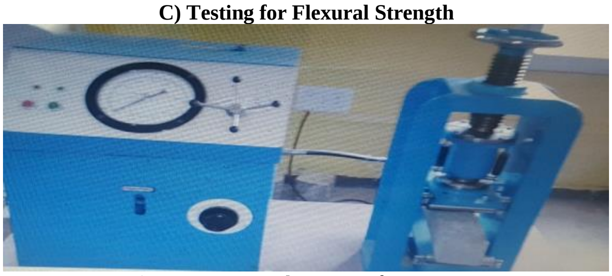


Fig. 2: Casting and Testing of Specimens.

3.2. Compressive strength test

Concrete cube specimens of size 150 mm are used to determine the Compressive Strength of Conventional and Triple Blended Concrete as per IS 516-1959 for 28 days.

4. Experimental results

Compressive Strength of CC and TBC for 7 days and 28 days
The Compressive Strength of Concrete mixes for 7 days and 28 days are given in Table 3 and Fig. 3.

Table 3: Compressive Strength of CC and TBC for 7 Days and 28 Days

S.No.	Mix	Compressive Strength in MPa		Percentage increase
		7 Days	28 Days	
1	CC	43.70	70.20	60.63
2	TBC10	42.10	56.72	34.73
3	TBC20	37.99	48.45	27.53
4	TBC30	31.82	45.94	44.37
5	TBC40	29.68	44.57	50.17
6	TBC50	29.60	44.26	49.55
7	TBC60	22.20	28.70	29.31
8	TBC70	16.84	25.80	53.21
9	TBC80	8.06	14.30	77.51

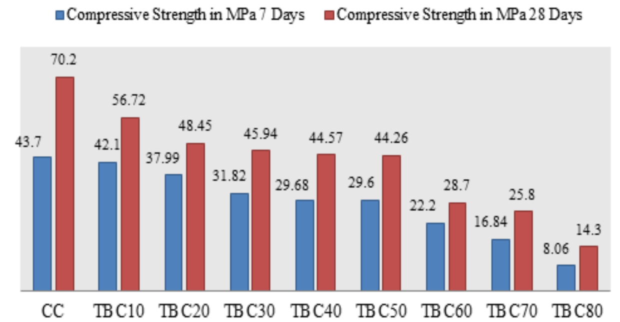


Fig. 3: Compressive Strength of CC and TBC Mixes for 7 Days and 28 Days.

From the Table 3, it is observed that, the percentage increase in Compressive Strength of all mixes for 28 days varies from 27.53 to 77.51% when comparing with 7 days strength. The Compressive Strength of the CC is having higher value than all TBC mixes. However, the Compressive Strength values of TBC up to TBC20 achieved target mean strength for which it is designed. Moreover the concrete mixes of TBC from TBC30 to TBC50 also showing appreciable strength for 28 days when comparing with the 7 days. The mixes of TBC from TBC60 to TBC80 were showing very less strengths for 7days as well as 28 days. However, the percentage improvements were exhibited in higher values. It is also observed that percentage improvements of all TBC mixes were increased with the increasing the replacement of binder content due to pozzolanic action of Fly Ash and GGBS.
The recommended average 7 day Compressive Strength of lean concrete for Dry Lean Concrete (DLC) layer is 7 MPa determined as per IRC SP: 49 over GSB for highways. Hence, TBC50 to TBC80 mixes are recommended for DLC layer for Highways.The 7 day strength of DLC should not be less than 10 MPa for a PQC bonded to DLC as per IRC 58-2015. Hence TBC50 to TBC70 are recommended for DLC layer for a PQC bonded to DLC.
Flexural Strength of CC and TBC for 7 days and 28 days and percentage increase in strength with age
The Flexural Strength of Concrete mixes for 7 days and 28 days are given in Table 4 and Fig. 4.

Table 4:

S. No.	Mix	Flexural Strength in MPa		Percentage increase
		7 Days	28 Days	
1	CC	6.02	9.18	52.49
2	TBC10	4.33	5.90	36.26
3	TBC20	3.92	5.03	28.32
4	TBC30	3.27	4.65	42.20
5	TBC40	2.98	4.56	53.02
6	TBC50	2.92	4.43	51.71
7	TBC60	2.20	3.05	38.64
8	TBC70	1.63	2.43	49.08
9	TBC80	0.81	1.42	75.31

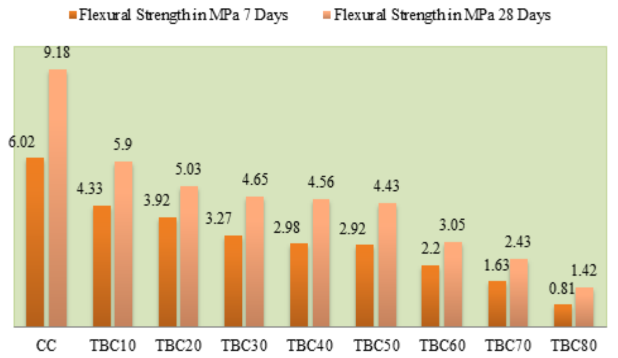


Fig. 4: Flexural Strength of CC and TBC Mixes for 7 Days and 28 Days.

The Flexural Strength of CC and TBC mixes up to TBC40 were exhibiting good Flexural Strength for 28 days curing. The Flexural Strengths of CC and TBC mixes from TBC10 to TBC80 were 6.02MPa and 4.33MPa to 0.81 MPa for 7 days respectively.The 28 days Flexural strengths of CC and TBC mixes from TBC10 to TBC80 were 9.18MPa and 5.90MPa to 1.42MPa for 28 days respectively. The percentages increase in Flexural Strength for 28 days were varying from 28.32 to 75.31 with respect to 7 days Flexural Strength.
As per IRC 58-2015, the minimum Flexural Strength for 28 days for Pavement Quality Concrete (PQC) is 4.5MPa. Hence the concrete mixes of TBC10 to TBC40 can be recommended for PQC.
Empirical relations between Compressive Strength and Flexural Strength of all Concrete Mixes. The relation between Compressive Strength and Flexural Strength of concrete mixes as per IS 456-2000 (p.16) the following:

$f_r = 0.7 * \sqrt{f_{ck}}$

Where

f_r =Flexural Strength or Modulus of Rupture in MPa.

f_{ck} = Characteristic Compressive Cube Strength of Concrete in MPa.

Empirical relation between Compressive Strength and Flexural Strength of TBC mixes:

For 7 days, $f_f = 0.094\ f_c^{\ 1.0207}$ with R^2 value = 0.998

For 28 days, $f_f = 0.0895\ f_c^{\ 1.0347}$ with R^2 value = 0.995

The above relations are shown in Fig. 5 and Fig. 6.

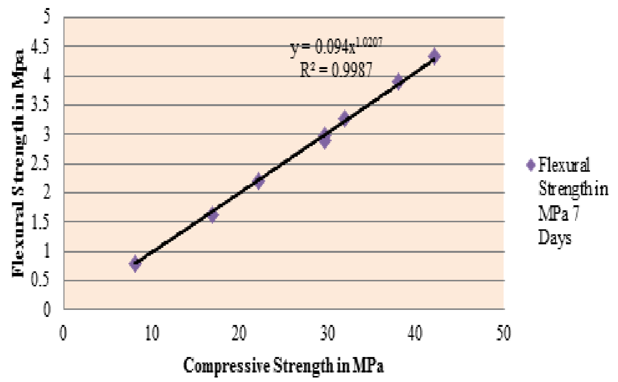


Fig. 5: Empirical Relation between Compressive Strength and Flexural Strength of TBC Mixes for 7 Days.

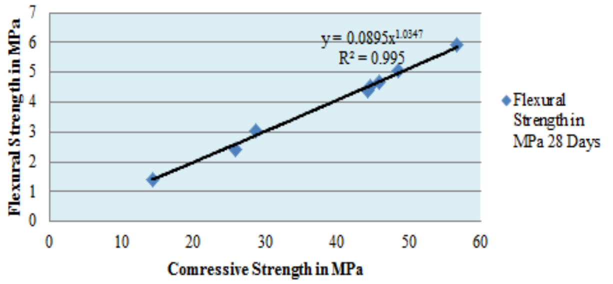


Fig. 6: Empirical Relation between Compressive Strength and Flexural Strength of TBC Mixes for 28 Days.

5. Conclusions

The following Conclusions are drawn from the experimental results.

The Compressive Strength of the CC is having higher value than all TBC mixes. However, the Compressive Strength values of TBC up to TBC20 achieved target mean strength for which it is designed.

The concrete mixes of TBC from TBC30 to TBC50 also showing appreciable Compressive Strength for 28 days when comparing with the 7 days. The mixes of TBC from TBC60 to TBC80 were showing very less CompressiveStrengths for 7days as well as 28 days. However, the percentage improvements were exhibited in higher values.

The Flexural Strength of CC and TBC mixes up to TBC40 were exhibiting good Flexural Strength for 28 days curing. The concrete mixes of TBC10 to TBC40 can be recommended for PQC.

TBC50 to TBC80 mixes are recommended for DLC layer for Highways. TBC50 to TBC70 are recommended for DLC layer for a PQC bonded to DLC.

References

[1] Arivalagan.S. (2014), Sustainable Studies on Concrete with GGBS As a Replacement Material in Cement, Jordan Journal of Civil Engineering, Volume 8, No. 3, pp. 263-270.

[2] Even. Ö. (2002), Strength Development of Concretes with Ordinary Portland Cement, Slag or Fly Ash Cured at Different Temperatures, Materials and Structures/ Materiaux et Constructions, Vol.35, November 2002, pp. 536-540.

[3] Ing Lim, Jenn-Chuan Chern, Tony Liu, and Yin-Wen Chan (2012), Effect of Ground Granulated Blast Furnace Slag on Mechanical Behavior of PVA-ECC, Journal of Marine Science and Technology, Vol. 20, No. 3, pp. 319-324.

[4] IRC SP: 49: Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement (First Revision).

[5] IRC 58 (2015): Guidelines for the Design of Plain Jointed Rigid Pavements for Highways.

[6] IS 456 (2000): Indian Standard Plain and Reinforced Concrete – Code of Practice.

[7] IS 516 (1959): Method of Tests for strength of Concrete [CED 2: Cement and Concrete].

[8] Magandeep, Ravi Kant Pareek and Varinder Singh (2015), Utilization of Ground Granulated Blast Furnace Slag to Improve Properties of Concrete, International Journal on Emerging Technologies 6(2): 72-79 ISSN No. (Print): 0975-8364.

[9] Martin O'Connell, Ciaran McNally, and Mark G.Richardson. (2012), Performance of Concrete Incorporating GGBS in Aggressive Wastewater Environments, Construction and Building Materials, 27 (1), 368-374.

[10] Ozkan Sengul and Mehmet Ali Tasdemir (2009), Compressive Strength and Rapid Chloride Permeability of Concretes with Ground Fly Ash and Slag, Journal of Materials in Civil Engineering © ASCE / September, 21:494-501.

[11] Pratap.K.V. Bhasker.M., Teja. P.S.S.R. (2014), Triple Blending of Cement Concrete With Fly Ash and Ground Granulated Blast Furnace Slag, IJEAR Vol. 4, Issue Spl-2, pp.54-58.

[12] Neville A.M Properties of Concrete. Noida Pearson Education Limited. 2011.

[13] Rajesh Kumar, Amiya K. Samanta and D. K. Singha Roy (2014), Characterization and development of ecofriendly concrete using industrial waste –a review, Journal of Urban and Environmental Engineering, v.8, n.1 p. 98-108.

[14] Roy.D.M.and Idorn.G.M. (1982), Hydration, structure and properties of blast-furnace slag cementmortals, and concrete, ACI journal (79) 444-457.

[15] Sonali K. Gadpalliwar, R. S. Deotale, Abhijeet R. Narde (2014), To Study the Partial Replacement of Cement by GGBFS & RHA and Natural Sand by Quarry Sand in Concrete, IOSR of Mechanical and Civil Engineering (IOSR-JMCE) E ISSN: 2278-1684,P-ISSN:2320-334X, Volume 11, Issue 2 Ver. II, PP 69-77.

[16] Shariq. M, Prasad.J and Ahuja.A.K. (2008), Strength Development of Cement Mortar and Concrete Incorporating GGBFS, Asian Journal Of Civil Engineering (building and housing) vol. 9, no. 1, pp 61-74.

[17] Vijaya Gowri.T, Sravana.P, Srinivasa Rao.P. (2014), Studies on strength behavior of high volumes of slag concrete, IJRET Volume: 03 Issue: 04, pp.1-12.

[18] Wang Ling, Tian Pei, and Yao Yan (2004), Application of Ground Granulated Blast Furnace Slag in High-Performance Concrete in China, International Workshop on Sustainable Development and Concrete Technology China Building Materials Academy, PRC, 309-317.