A Study on Strength Characteristics of Ternary Blended Concrete with Varying Percentages of Coarse Aggregate With Sintered Fly Ash Aggregate

Prabhu Siddaiah[1], Dr Shashishankar A[2], Mohiyuddin C S[3], Ravithej N[4], Ganesh SSY[5]
[2]Professor & Head, Dept of Civil Engineering
[3, 4, 5]Assistant Professor, Dept of Civil Engineering
[1]Jain University
[2, 3, 4, 5] AMCEC

Abstract- *In the present research work,OPC has been replaced with different percentage of pozzolanic materials viz. FA, GGBS, SF to arrive at targeted strength of concrete (M55). The lightweight aggregate i.e., SFA aggregate has been proposed to replace the conventional mineralogical coarse aggregate (CA) and study the strength characteristics of concrete.*

An array of results, characteristics data obtained after the laboratory experiments on concrete cubes, compiled, analyzed and inferences drawn. The results are critically examined vis-à-vis intended strength characteristics and its variations for different percentage of replacement of cement and coarse aggregate content.

The analyses of the experimental results indicate that the strength characteristics are reducing with increasing % of replacement of CA with LWSFA in all combination of TBC. However, the rate of reduction is more in C+FA+GGBS combination and least in C+FA+SF combination.

Keywords- Sintered Flyash Aggregate, Ternary Blended Concrete, Lightweight Sintered Flyash Aggregates (LWSFA)

I. INTRODUCTION

Higher grade of concrete finds application in many fields i.e., high rise structures, shielding membranes, transport sector-road pavement, railway sleepers, air strips, airport aprons etc., As many structural elements in roadways, railways and airways are subjected to cyclic loading of heavy axle loads; the assessment of surface characteristics and durability properties of discrete elements remain an important domain for research. Accordingly, it is envisaged, to use industrial waste, by-products in manufacturing the cement concrete with varying degree of different percentage of FA, GGBS, MK & SF as replacement to OPC viz., ternary blended combinations (TBC) of (**cement + fly ash + silica fume**). (**cement + fly ash + ground granulated blast furnace slag**) and (**cement + fly ash + metakaolin**).

In an attempt to consume abundantly available industrial waste, i.e., fly ash, it is envisaged to replace small percentage of natural coarse aggregate with coarse aggregate manufactured through sintering process of Fly ash i.e., *(LWSFA)*

II. OBJECTIVES OF RESEARCH WORK

1. To assess strength characteristics of ternary blended concrete such as compressive strength,flexural strength, impact strengthand split tensile strength.
2. The near surface characteristics of ternary blended concrete.

III. MATERIALS AND METHODOLOGY

1.Cement

The cement shall conform to IS 12269:1987 with amendment no VI of June 2000. The cement content of the mix shall not be less than 350kg/cu.m and not more than 480 kg/cu.m for M55.

2.Aggregates

The aggregates shall conform to IS 383:2016 and shall, before use, be got tested through an approved testing institute, and results submitted are in accordance with Appendix 'A' of IS 383:2016. CA and FA shall pass Sodium or Magnesium Sulphate accelerated soundness test specified in IS2386(part V):1963. The mineralogical CA used in the work was manufactured in crusher located (at Chalamatii village off Hubballi – Karwar NH, while Tungabhadra river sand from Harihar has been used as FA.

Table 1 – Aggregates Properties

Properties	Fine Aggregate River Natural Sand
Specific Gravity	2.7
Water Adsorption	1.7

Table 2 –Properties of Mineralogical Coarse Aggregates

Aggregate Properties	Mineralogical Coarse Aggregates
Specific Gravity	2.66
Water Adsorption %	0.32
Impact Value	17.0
Abrasion Value	20.0
Crushing Value	18.0
Elongation Value	16.0
Flakiness Index	12.0

Table 3 –Properties of Sintered Fly ash Aggregates

Aggregate Properties	Sintered Fly ash Aggregates
Size of Aggregate	8-12 mm
Specific Gravity	1.78
Water Adsorption	15.8%
Fineness Modulus	6.24
Type of Aggregate	Light Weight Aggregate
Bulk Porosity	35 – 40%
Bulk Density	800kg/m^3

3. Water

Water to be used in making and for curing concrete shall conform to IS 456:2000.

Equipment/Machines used

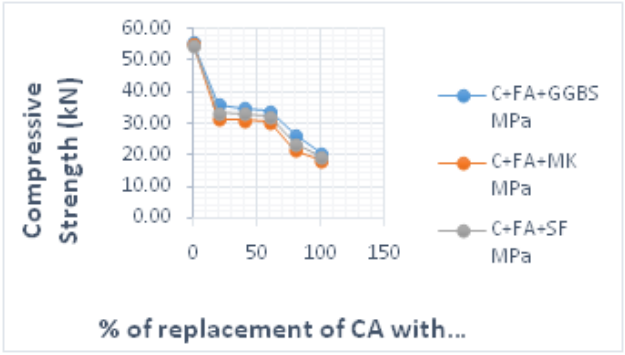
Weighing Balance,
Modern High-Speed machines
Moulds,
Vibrator,
Analyzing Chamber

Characteristics evaluated:

- Strength
  - Compressive
  - Flexural
  - Impact
  - Split tensile.
- Sorptivity Test
- Rapid Chloride Penetration Test.

Table 4 showing variation in **Compressive Strength** for different combination of Ternary blended concrete

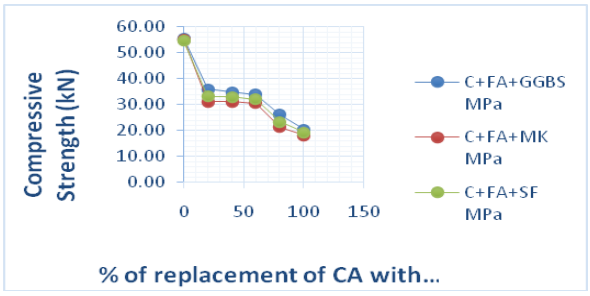
% of replacement of CA with SFA	C+FA+GGBS MPa	C+FA+MK MPa	C+FA+SF MPa
0	55.66	55.22	54.78
20	35.86	31.17	38.22
40	34.76	31.02	33.00
60	33.88	30.58	32.12
80	26.18	21.34	23.32
100	20.46	18.26	19.36



Graph 1 Showing variation in Compressive Strength

Table 5 showing variation in **Flexural Strength** for different combination of Ternary blended concrete

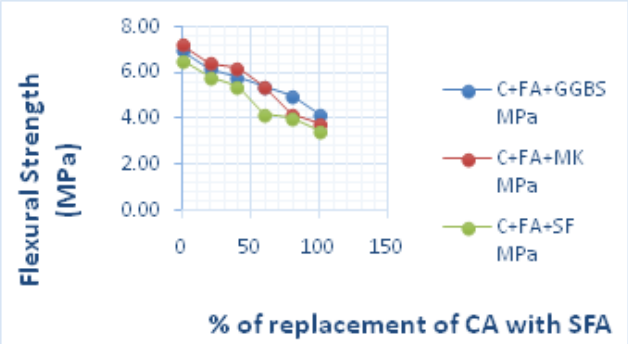
% of replacement of CA with SFA	C+FA+GGBS MPa	C+FA+MK MPa	C+FA+SF MPa
0	7.0	7.21	6.53
20	6.2	6.4	5.80
40	5.0	6.2	5.40
60	5.4	5.4	4.20
80	5.0	4.2	4.00
100	4.2	3.8	3.47



Graph 2 Showing variation in Flexural Strength

Table 6 showing variation in **Impact Strength** for different combination of Temary blended concrete

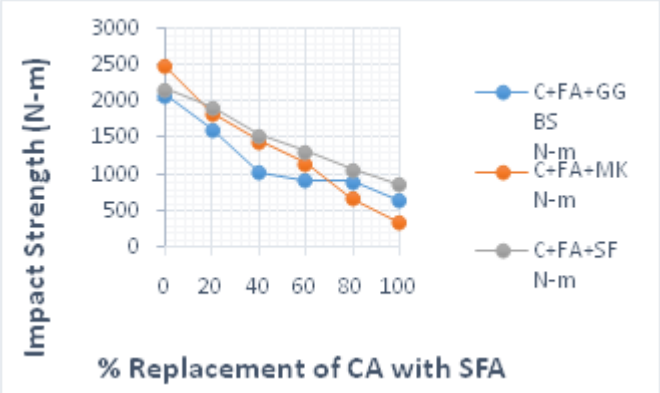
% of replacement of CA with SFA	C+FA+GGBS N-m	C+FA+MK N-m	C+FA+SF N-m
0	2097.63	2495.22	2179.89
20	1624.64	1850.85	1933.11
40	1028.25	1460.12	1549.23
60	925.43	1151.64	1316.16
80	904.86	671.79	1069.38
100	651.23	342.75	863.73



Graph 3 Showing variation in impact Strength

Table 7showing variation in **Split Tensile Strength** for different combination of Temary blended concrete

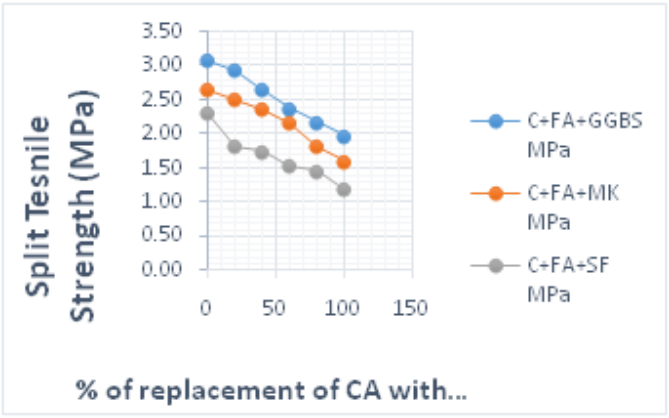
% of replacement of CA with SFA	C+FA+GGBS MPa	C+FA+MK MPa	C+FA+SF MPa
0	3.08	2.66	2.31
20	2.94	2.52	1.82
40	2.66	2.38	1.75
60	2.38	2.17	1.54
80	2.17	1.82	1.47
100	1.98	1.61	1.19



Graph 4 Showing variation in Split Tensile Strength

Table 8 Showing variation in **Sorptivity** for different combination of Temary blended concrete

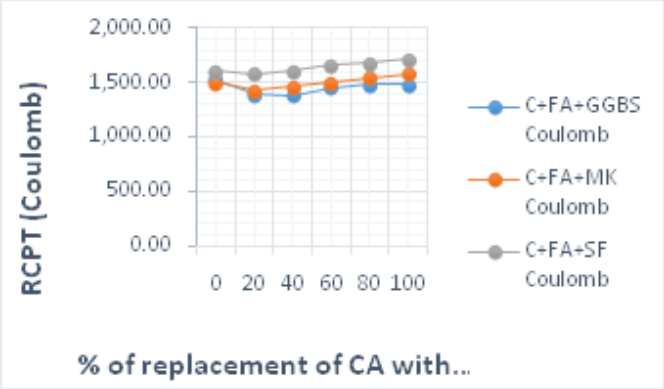
% of replacement of CA with SFA	C+FA+GGBS mm/Sec 0.5	C+FA+MK mm/Sec 0.5	C+FA+SF mm/Sec 0.5
0	3.24	3.34	2.93
20	3.65	3.43	3.10
40	3.80	3.54	3.17
60	3.84	3.58	3.45
80	4.11	3.91	3.51
100	4.55	4.06	4.57



Graph 5 Showing variation in Sorptivity

Table 9 Showing variation in **RCPT (Coulombs)** for different combination of Temary blended concrete

% of replacement of CA with SFA	C+FA+GGBS Coulombs	C+FA+MK Coulombs	C+FA+SF Coulombs
0	1521.27	1495.26	1604.52
20	1391.49	1421.10	1573.65
40	1382.22	1450.08	1606.23
60	1454.58	1495.80	1656.81
80	1481.13	1540.53	1678.95
100	1482.57	1573.83	1714.41



Graph 6 Showing variation in **RCPT (Coulombs)**

IV. RESULTS & DISCUSSION

1. The compressive strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 35.57, 36.55, 39.13, 52.96 and 63.24 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+GGBFS.
2. The compressive strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 43.43, 43.82, 44.62, 61.35 and66.93 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Metakaolin.
3. The compressive strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 33.36, 39.76, 41.37, 57.43 and 64.66 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Silica fume.
4. Among the various combination of ternary blended concrete, C+FA+MK and C+FA+GGBS have shown maximum and minimum reduction of compressive strength respectively.
5. The Flexural strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 11.43, 16.86, 22.86, 28.57 and 40.00 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+GGBFS.
6. The Flexural strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 11.11, 13.89, 25.0, 41.67 and 47.22percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Metakaolin.
7. The Flexural strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 9.38, 15.63, 34.38, 37.5 and 43.75 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Silica fume.
8. Among the various combination of ternary blended concrete, C+FA+SF and C+FA+GGBS have shown maximum and minimum reduction of Flexural strength respectively.
9. The Impact strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 22.55, 50.98, 55.88, 56.86 and 69.61 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+GGBFS.
10. The Impact strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 27.05, 41.80, 54.10, 73.77 and 86.07 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Metakaolin.
11. The Impact strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 11.32, 29.25, 39.62, 50.94 and 60.38 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Silica fume.
12. Among the various combination of ternary blended concrete, C+FA+MK and C+ FA+SF have shown maximum and minimum reduction of Impact strength respectively.
13. The Split tensile strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 4.55, 13.64, 20.45, 29.55 AND 36.36 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+GGBFS.
14. The Split tensile strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 2.63, 10.53, 18.42, 31.58 and 39.47 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Metakaolin.
15. The Split tensile strength shows the gradual deduction with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 21.21, 24.24, 33.33, 36.36 and 51.52 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Silica fume.
16. Among the various combination of ternary blended concrete, C+FA+SF and C+FA+GGBFS have shown maximum and minimum reduction of Split tensile strength respectively.

17. The Sorptivity shows the gradual increasing with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 12.65, 17.28, 18.52, 26.85 and 40.43 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+GGBFS.
18. The Sorptivity shows the gradual increasing with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 2.69, 5.99, 7.19, 17.07 and 21.56 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Metakaolin.
19. The Sorptivity shows the gradual increasing with increasing percentage of sintered fly ash aggregate (SFA) as replacement to coarse aggregate (CA) of 5.8, 8.19, 17.75, 19.80 and 55.97 percentage with 20%, 40%, 60%, 80% and 100% respectively for the ternary blended concrete of cement + FA+Silica fume.
20. Among the various combination of ternary blended concrete, C+FA+SF and C+FA+MK have shown maximum and minimum reduction of Sorptivity respectively.
21. As regards to chloride penetration test, among the various combination of ternary blended concrete, C+FA+SF and C+FA+GGBS have shown maximum and minimum resistance for chloride attack respectively.
22. In general, for different strength characteristics/properties, when compared among different combination of ternary blended concrete C+FA+GGBFS has shown maximum reduction for strength while C+FA+SF is least affected.
23. From above, it is noticed that partial replacement of blending material Silica Fume has shown better strength characteristic as against metakaolin/GGBS.

REFERENCES

[1] Allahverdi A and S H Salem, "Studies on Main Properties of Ternary Blended Cement with Limestone Powder and Microsilica", *International Journal of Chemical Engineering*, vol. 4, no.1 (Winter), IAchE, 2007.

[2] AbhijeetKoshti, OnkarJadhav, Shubham Yadav, Amar Tande, PrajyotFasale and AmarnathKadam, "Experimental Study of Concrete Made with GGBS and Granite Powder", *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, vol. 6, Issue III, March 2018.

[3] ACI Committee 211.1. Standard Practice for selecting proportions for Structural Light weight concrete, *(ACI 211.2.98), Vol. 98, no. Reapproved. 1998, pp. 1-18.*

[4] Adinarayna D, SeshadriSekhar and Srinivasa Rao. "Behaviour of Ternary Blended Concretes with different water binder ratios". *International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD),* vol. 3, issue 5, pp. 27- 36, Dec 2013

[5] AfidahBinti Abu Bakar,"Fracture Mechanics Analysis of prestressed sleepers containing Fibres", PhD thesis November 2010.

[6] Akira Aikawa, Fumihiro Urakawa, Kazuhisa Abe, Akira Namura. "Dynamic characteristics of Railway concrete sleepers using impact excitation techniques and model analysis". *9th World Congress Railway Research*, pp. 1-10, May-2011.

[7] Alex M Remennikov and SakdiratKaewunruen. "Resistance of Railway concrete Sleepers to impact loading". *7th International Conference on Shock & Impact Loads on Structures*, pp. 1-8, Oct-2017.

[8] Allan N. Scott and Michael Thomas D A,"Evaluation of fly ash from co-combustion of coal and petroleum coke for use in concrete". *ACI Materials Journal*, pp. 62-69, Jan-Feb 2007.

[9] Amnon Katz and Hadassa Baum, "Effect of high levels of fines content on concrete

[10] Palomo A, Fernandez-Jimenez A, Lopez-Hombrados, and Lleyda J. L, "Railway sleepers made of alkali activated fly ash concrete," Rev. Ing. Constr., vol. 22, no.l 2, pp. 78-80, 2007.