Study on Properties of Concrete After Incorporating Waste Materials

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STUDY ON PROPERTIES OF CONCRETE AFTER INCORPORATING WASTE MATERIALS

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Abstract:

This study investigates the compressive strength effects of fly ash, ACBFS, and silica fume in cement concrete. The effect of fly ash, ACBFS and silica fume on compressive strength of concrete proportioned with various levels of cement replacement i.e; 25%, 22.5%, 20% and 17.5% by fly ash and fly ash partially replaced i.e. 2.5%, 5% and 7.5% by silica fume while coarse aggregate replaced by 20%, 40% and 60% ACBFS was studied. For contrast, M30 was mixed without fly ash. 7- and 28-day-old cube and beam concrete samples were examined for compressive strength.

Key words: cement, silica fume, fly ash, air cooled blast furnace slag, plasticizer, optimum moisture content, compression strength test.

1. INTRODUCTION:

With ageing infrastructure globally, we build structures that can last. Current research focuses on creating buildings that can adapt to environmental changes and function better. This philosophy can help redesign reinforced concrete [1].

The least quantity of cement possible that maintains the mix's quality should be used in the production of an economical concrete mixture. Fresh concrete needs to be easy to work with, but the finished product needs to be tough, appealing, and long-lasting. If fresh concrete is difficult to work with, it will be impossible to accomplish full compaction, which will have a negative impact on the durability and strength of the hardened concrete. The ratio of water to cement that is used in the design of concrete mix has a direct impact on the strength of the concrete. A number of other factors can have an impact, including the aggregate-to-cement ratio, the aggregate grading, the aggregate particle shape and texture, and the amount of entrained air [3].

Fly ash, ACBFS (Air Cooled Blast Furnace Slag), and Silica Fumes are all taken into consideration in this study. Air-entraining admixtures, water-reducing admixtures, plasticizers, accelerating admixtures, retarding admixtures, hydration-control admixtures, corrosion inhibitors, shrinkage reducers, and alkali-silica reactivity inhibitors are all examples of admixtures that are included in this category [2].

Literature review c shows that most studies focused on fly ash in concrete. Several studies have examined how adding ACBFS, fly ash, or silica fume affects concrete strength. Studies on ternary and quaternary mixtures are sparse. Also, studies on the combined effects of ACBFS, fly ash, and silica fume on concrete flexural and compressive strength are limited.

This study examines the feasibility and effect of replacing coarse natural aggregates with blast furnace slag and cement with silica fume and fly ash in varied percentages. This would assist conserve natural resources and maintain ecological balance to meet the rising demand for building materials in infrastructure development. Reducing the usage of natural aggregates and cement to fulfil future demand will increase the usability of waste materials and lower the demand for natural aggregates and cement.

This study aims to determine how fly ash affects concrete's compressive strength. This research examines how replacing air-cooled blast furnace slag with natural aggregates affects the compressive strength of fly ash concrete. To examine the effect of partial cement replacement with fly ash and silica fume on concrete compressive strength. To compare fly ash, blast furnace slag, and silica fume concrete compressive strengths.

2. Methodology:

2.1. Physical Properties of Materials Used

According to rules of practice, concrete materials' qualities are determined in the lab. Cement, fine aggregate, coarse aggregate, water, fly ash, air-cooled blast furnace slag, super plasticizer, and silica fume were employed in the investigation. The next sections reflect the results of laboratory testing on various materials.

Table 1: Physical Properties of Cement

Properties	Cement Consistency	Sp. gr.	(IST) Initial setting time	(FST) Final setting time	Compressive Strength (N/mm^2)		
					3days	7days	28days
Experimental value	30%	3.12	110 Minutes	265 Minutes	30.4	41.16	48.82
Specified Value as per IS: 8112-1989	-	3.15	>30 minutes	< 600 minutes	>23	>33	>43

Table 2: Sieve Analysis of Fine Aggregates

IS Sieve Designation (in mm)	10	4.75	2.36	1.18	0.6	0.3	0.15	Pan
Wt. Retained on Sieve (gm)	-	0	30	100	280	290	210	90
Cumulative Wt. Retained (gm)	-	0	30	130	410	700	910	1000
Cumulative Percentage Wt. Retained	0	0	3	13	41	70	91	-
%age Passing	100	100	97	87	59	30	9	-
IS 383-1970 standards	100	90-100	75-100	55-90	35-59	8-30	0-10	-

Fineness Modulus (F.M.) = 2.18

Table 3: Physical Properties of Fine Aggregates

Characteristics	Grading	Fineness Modulus	Sp. Gr.	Water Absorption (%)	(FMC) Free Moisture Content (%)

Results	Zone II	2.18	2.63	0.52%	Nil

Table 4: Proportioning of Coarse Aggregate

IS Sieve Designation (in mm)			80	40	20	10	4.75
Cumulative Percentage Passing of	10 mm Agg.		100	100	100	85.24	1.24
Cumulative Percentage Passing of	20 mm Agg.		100	100	99.82	2	0.2
Proportion	40:60	(10mm:20 mm)	100	100	99.892	35.29	0.616
IS 383-1970 requirements			100	100	95-100	25-55	0-10

Table 5: Sieve Analysis of Proportioned Coarse Aggregates

Sieve (in mm)	80	40	20	10	4.75	Pan
Wt. Retained on Sieve (10mm Agg.) (gm)	0	0	0	738	4200	62
Wt. Retained on Sieve (20mm Agg.) (gm)	0	0	9	4891	92	8
Proportioned Wt. Retained	0	0	5.4	3229.8	1735.2	29.6
Cumulative Wt. Retained (gm)	0	0	5.4	3235.2	4970.4	5000
Cumulative %age Wt. Retained (gm)	0	0	0.108	64.704	99.408	-
%age Passing	100	100	99.89	35.29	0.592	-

Fineness Modulus (F.M.) = 6.64

Table 6: Physical Properties of Coarse Aggregates

Characteristics	colour	Type	Shape	Sp. Gr.	Water Absorption	(FM) Fineness Modulus	(MC) Moisture Content (%)

Results	Grey	Crushed	Angular	2.65	1%	6.64	Nil

Table 7: Index properties of fly ash

Property	Bulk density in kg/m^3	Surface area in m^2/kg	Specific gravity	Lime reactivity in N/mm^2	Compressive strength as percent of corresponding plain cement concrete (P.C.C.)
Value	1000	400.6	2.03	4.8	85
Requirements as per IS: 1727-1967 (reaffirmed 2004)		Min 320		Min 4.5	80% of ordinary cement mortar strength

Table 8: Physical properties of Silica fume (source: from supplier)

Characteristics	Appearance	Specific gravity	Chloride content	Toxicity
Value	Grey Powder	2.2	Nil	Non-Toxic

Table 9: Properties of Super plasticizer

Test	Specific Gravity	pH	Dry Material Content	Chloride Content
Values Obtained	1.24	7.4	44	0.03
Limit as per IS 9103:1999	Manufacturer's value plus/minus 0.02	Min. 6.00	Plus/minus 5% of the manufacturer's value)	Manufacturer specifies tolerances of 10% or 0.2%. (percent by mass)

2.2.Mix Design Report

Determining concrete materials' characteristics based on the IS technique, three sample mixes were created with 0.43 water-cement ratio, casting 6 cubes for each mix, and examined at 7 and 28 days. Trial mix no. 3 of Table 3.18 produced slightly more than the desired mean compressive strength (38.25 N/mm2) and was used in this investigation.

Table 10: Trial Mix for M30 Grade

Trial Mix	Mix 1	Mix 2	Mix 3
Coarse Aggregates (kg)	0.42	0.42	0.42
Fine Aggregates (kg)	166	171	166
Cement (kg)	380	431	386
Water (litres)	700	666	720
W/C Ratio	1185	1132	1150
Super-plasticizer (kg)	2.67	2.67	2.67

Table 10 shows the test results for trial mixes 1, 2, and 3. Trial mix 3 at w/c ratio 0.43 achieves the required mean strength of 38.48MPa. The investigation used trial mix 3 with 385 kg/m3 cement. Reference mix components (by weight) (M0).

Table 11: 28-day compression tests

Grade of Concrete	M30		
Trial Mix	M1	M2	M3
Average Compressive Strength (N/mm^2)	40.5	32.5	39

Table 12: Proportioning M0 for 1m3 of mix

Coarse Aggregates (kg)	1140	2.95
Fine Aggregate (kg)	762	2
Cement (kg)	385	1
Superplasticizer (kg)	2.7	0.7
Water (litres)	165	0.43

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3. Compressive Strength:

Table 19: Compressive strength for varied cement-fly ash-ACBFS replacement levels

Sample		M0	M1	M2	M3	M4
Percentage Replacement by fly ash (%)		0	25	25	25	25
Percentage Replacement by ACBFS (%)		0	0	20	40	60
Compressive Strength (N/mm^2)	7 days	26	16	22	25	14
	28 days	39	29	25	29	30

Table 20: Variation of compressive strength for varied cement-to-fly ash and silica fume ratios and coarse aggregate-to-ACBFS ratios

Sample		M0	M5	M6	M7	M8
Percentage Replacement by fly ash (%)		0	22.5	22.5	22.5	22.5
Percentage Replacement by Silica Fume (%)		0	2.5	2.5	2.5	2.5
Percentage Replacement by ACBFS (%)		0	0	20	40	60
Compressive Strength (N/mm^2)	7 days	26	13	14	16	15
	28 days	39	28	28	27	26

Table 21: Compressive strength for varied cement replacement levels (fly ash, silica fume) and coarse aggregate replacement levels (ACBFS)

Sample		M0	M9	M10	M11	M12
Percentage Replacement by fly ash (%)		0	20	20	20	20
Percentage Replacement by Silica Fume (%)		0	5	5	5	5
Percentage Replacement by ACBFS (%)		0	0	20	40	60
Compressive Strength (N/mm^2)	7 days	26	22	18	16	25
	28 days	39	37	32	37	35

Table 22: Variation of compressive strength for varied cement-to-fly ash and silica fume ratios and coarse aggregate-to-ACBFS ratios.

Sample		M0	M13	M14	M15	M16
Percentage Replacement by fly ash (%)		0	17.5	17.5	17.5	17.5
Percentage Replacement by Silica Fume (%)		0	7.5	7.5	7.5	7.5
Percentage Replacement by ACBFS (%)		0	0	20	40	60
Compressive Strength (N/mm^2)	7 days	26	13	22	28	23
	28 days	39	28	36	39	34

4. Discussion:

4.1. Effect of fly ash and ACBFS on compressive strength of concrete

Fly ash-containing binary mixes had decreased 7-day compressive strength. Fly ash strengthened compression. At all ACBFS replacement levels, binary mixtures had lower 28-day compressive strength than concrete without fly ash. Binary concrete mixes with no silica fume and all ACBFS substitutes have a compressive strength of 25MPa after 28 days of wet curing, making them excellent for many structural purposes.

Reference mix had 38.48MPa 28-day compressive strength.

25 percent fly ash with 0%, 20%, 40%, and 60% ACBFS produced 28,92MPa, 34.52MPa, 38.47MPa, and 29.23MPa, respectively.

At 20% ACBFS, compressive strength is lowest. All ages loved the reference mix. Fly ash concrete gains strength in 28 days due to its pozzolanic effect.

Substituting cement with fly ash reduces initial compressive strength, cement paste cohesiveness, and aggregate adhesion. At maximum hydration, OPC contains around 75% mineralogical phases. Ca(OH)2, whose contribution to strength is small when fly ash substitutes cement, does not contribute to chemical reaction because adequate cementitious activity of fly ash is not activated at the earliest stages, and unreactive quantity of fly ash at this point represent insignificant influence.

Later ages boost strength because extra lime from OPC hydration contributes secondary hydrated mineralogy and strength. Refining pores and grains increases strength and transition zone strength. Hydrated mineralogy mechanism:

$$\text{OPC} + \text{H} \xrightarrow{\text{Fast}} \text{Primary hydrated mineralogy} + \text{CH}$$

$$\text{Pozzolona} + \text{CH} + \text{H} \xrightarrow{\text{Slow}} \text{Secondary hydrated mineralogy.}$$

Unreactive fly ash fills the matrix, increasing the microstructure of hydrated cement paste. Lewandowski observed 50 percent unreacted fly ash after one year because class F fly ash pozzolanic response is delayed. The unreactive component may be regarded a micro aggregate for strength. Reactive part of fly ash has a decisive and dominant role compared to unreactive portion's packing effect strength. Fly ash concrete's compressive strength should improve after 56 days.

4.2.Effect of silica fume on compressive strength of concrete:

After 7 days, ternary and quaternary mixes with fly ash and silica fume had lower compressive strength than the reference mix and binary mixes. Compressive strength increases with silica fume and fly ash. After 28 days, ternary mixes without ACBFS had lower compressive strengths than binary mixes with fly ash at all replacement levels. After 28 days of wet curing, the compressive strength of 22.5% fly ash and 2.5% silica fume concrete mixes with 0%, 40%, or 60% ACBFS substitution is over 20 MPa.

28.15 MPa, 27.66 MPa, 26.75 MPa, and 25.70 MPa were reached by ternary and quaternary concrete mixes using 22.5 percent fly ash and 2.5 percent silica fume at 0%, 20%, 40%, and 60% ACBFS. Tabulated results

5. Conclusion

1. After substituting cement with fly ash and coarse particles with ACBFS, the compressive strength of concrete decreased at 7 and 28 days. The 25% fly ash and 60% ACBFS combination exhibited the least compressive strength after 7 days. After 28 days, no mix had lost as much compressive strength as after 7 days.

2. Comparing silica fume to fly ash and ACBFS concrete, compressive strength improved at all ages. After 28 days, M16 with 17.5% fly ash and 7.5% silica fume had the maximum compressive strength.

3. A combination of 22.5% fly ash, 60% ACBFS, and 2.5% silica fume had the least compressive strength.

References

1. ACI Committee 232, 2003, Use of Fly Ash in Concrete, ACI Manual of Concrete, 232.2R- 96, American Concrete Institute, Farmington Hills, Michigan, 34 pages.

2. Alsanusi S., 2013, Influence of silica fume on the properties of self-compacting concrete, World academy of Science, Engineering and Technology, Vol. 7, pp 399-403.

3. American Society for Testing and Materials, 1975, Standard specification for blended hydraulic cements, Annual book of ASTM standards, Part 13. ASTM, Philadelphia, PA, pp. 353.

4. Berry, E.E., and Malhotra, V.M., 1986, Fly Ash in Concrete, Energy, Mines and Resources Canada, CANMET, Ottawa, Canada.

5. Bremner, T.W., and Thomas, M.D.A., 2004, Learning Module on Traditional and Non Traditional uses of Coal Combustion Products ,CCP , Vol 4 , pp 345-355.

6. Buitelaar P., 2004, Heavy Reinforced Ultra High Performance Concrete, Proceedings of the International Symposium on Ultra High Performance Concrete, Kassal, Germany, pp 25-35.

7. Cement Association of Canada, 2003, Plastic Shrinkage Cracking, www.cement.ca, December 21, 2003.

8. Davis, R.E., Carlson, R.W., Kelly, J.W. and Davis, H.E. , 1937, Properties of cements and concretes containing fly ash , Journal of the American Concrete Institute, Vol. 33, pp. 577-611.

9. Duval, R., Kadri, E.H., 1998, Influence of Silica Fume on the Workability and the Compressive Strength of High-Performance Concretes, Cement and Concrete Research, Vol. 28, Issue 4, January 1998.

10. Ghailan A. H., 2015, Modified concrete by using a waste material as a coarse aggregate, Construction Research Congress, pp-10. San Diego, California, United States.

11. Gopala Krishnan S., Rajemane N.P., Neelamegam M.M., Pelor J.A., Dattareya, J.K., 2001, Effect of partial replacement of cement with Fly ash on the strength and durability of HPC, The Indian Concrete Journal, May, pp. 335

12. Gunavant K. Kate, Pranesh B. Murnal., 2013, Effect Of Addition Of Fly Ash On Shrinkage Characteristics In High Strength Concrete, International Journal Of Advanced Technology In Civil Engineering, Volume-2, Issue-1.

13. Haque M.N., Langan B.W., Ward M.A., 1984, High fly ash Concretes, ACI journal, pg 54
14. Heba A Mohammad, 2011, Effect of fly ash and silica fume on compressive strength of Self-compacting concrete under different curing conditions, Ain Shams Engineering Journal, Vol. 2, pp 79-86
15. Hobbs, D.W. ,1983, Influence of Fly Ash on the Workability and Early Strength of Concrete, Proceedings, 1st International Conference on the Use of Fly Ash, Silica Fume, Slag and other Mineral By-Products in Concrete. ACI SP – 79, pp. 289-306.
16. Hooton, R.D.; Pun, P.; Kojundic, T.; Fidjestol, P., 1997, Influence of Silica Fume on Chloride Resistance of Concrete, Proceedings of the PCI/FHWA International Symposium on HPC, October 1997.
17. IS 10262:1982 (Reaffirmed 2009), Recommended guidelines for concrete mix design, Bureau of Indian Standards, New Delhi.
18. IS 4031:1988 (Part XI), Methods of tests for specific gravity of cement, Bureau of Indian Standards, New Delhi.
19. IS 4031:1988 (Part VI), Methods of tests for compressive strength of cement, Bureau of Indian Standards, New Delhi.
20. IS 4031:1988 (Part V), Methods of tests for determination of initial and final setting time of cement, Bureau of Indian Standards, New Delhi.
21. IS 4031:1988 (Part IV), Methods of tests for standard consistency of cement, Bureau of Indian Standards, New Delhi.
22. IS 3812-1981 (Reaffirmed 1999): Specifications for fly ash for use as pozzolona and admixture, Bureau of Indian Standards, New Delhi?
23. IS 2386:1963 (Part III), Methods of tests for sieve analysis of coarse and fine aggregates, Bureau of Indian Standards, New Delhi.
24. IS 2386:1963 (Part I), Methods of tests for specific gravity of aggregates, Bureau of Indian Standards, New Delhi.
25. IS 1199:1959, Methods of tests for workability of concrete, Bureau of Indian Standards, New Delhi.
26. IS 383:1970 (Reaffirmed 1997) Specification for coarse and Fine aggregates from natural sources for concrete, Bureau of Indian Standards, New Delhi.

27. IS 456:2000, Code of practice Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi?
28. IS 516:1959 (Reaffirmed 1999), Methods of tests for strength of concrete, Bureau of Indian Standards, New Delhi.
29. IS: 8112:1989 Specification for ordinary Portland cement grade 43, Bureau of Indian Standards, New Delhi.
30. Krishna P. Hari and Murthy Dr. V. Ramena, 2002, Fly ash as a construction material-problems and prospective, National conference on Advances in construction materials, AICM, Hamirpur (HP),India, pp. 57-62
31. Lame L., Wong y., and Poon C.S., 1989, Effect of fly ash and silica fume on compressive and facture behavior of concrete, Cement and Concrete research, Vol. 86, Issue 5, Sept-Oct, pp 507-514
32. Lane R.O. and Best G.F., 1982, Properties of use of fly ash in Portland cement, Concrete International, vol. 4, pp 81-82
33. Langley W.S., and Leeman G.H., 1998, Practical Uses for High-Volume Fly Ash Concrete Utilizing a Low Calcium Fly Ash, 6th International Conference on Fly Ash, Silica Fume, Slag & Natural Pozzolans in Concrete, ACI SP –178-30, pp.545-574.