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"Experimental study on High-Performing Concrete Produced with Industrial Waste"

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ABSTRACT: The utilization of industrial wastes in concrete is becoming more and more common for producing high-performance concrete. Industrial waste materials serve as micro fillers and participate in hydration and pozzolanic processes in concrete. It provides an additional reduction in the porosity of the mortar matrix and improves the interaction with the aggregate. With the use of chemical admixtures, great strength can be obtained while significantly reducing the amount of mixing water. Silica fume, bottom ash, and steel slag aggregate are examples of industrial byproducts that are added to concrete to enhance its overall performance. Their use in high performance concrete (HPC) improves the strength and durability of the material. The goal of the current study is to determine the impact of replacing steel slag, bottom ash, and silica fume with coarse aggregate, fine aggregate, and, cement respectively, on the performance of HPC. Here, M30-grade High Performance Concrete using three different industrial by-product silica fume, bottom ash, and steel slag aggregate was attempted. The ratios of cement, fine aggregate, and coarse aggregate were 1:2.19:3.07 with a water/cement ratio of 0.45 and the addition of Super Plasticizer ECMAS HP 890. The mix design was based on the IS: 10262-2009 method. As cement substitutes, silica fume is used in replacement amounts of 5%, 10%, 15%, and 20%. As Fine aggregate substitutes, bottom ash is used in replacement amounts of 10%, 20%, 30%, and 40%. and As Coarse aggregate substitutes, steel slag aggregate is used in replacement amounts of 10%, 20%, 30%, and 40%.

KEYWORDS: high performance concrete, industrial by-products, silica fume, bottom ash, and steel slag, durability studies, Compressive and Split tensile strength.

I. INTRODUCTION

1.1 Role of Silica fume in High Performance Concrete

By adding silica fume to concrete, the mixture becomes stronger and more cohesive while also being more mobile. The foundation of contemporary high-performance concrete has been the combination of silica fume and superplasticizer. The use of a superplasticizer or water reducing agent is required because the addition of silica fume to concrete increases the water demand. This results from better cementitious particle dispersion and is caused by the smooth surface properties of silica fume particles, which absorb little water during mixing. The silica fume mixture has very little porosity, good resistance to chloride ion penetration, and minimal effects from freezing and thawing. A highly stable cementitious substance with a complex composition involving water, calcium, and silica was created when the calcium hydroxide and the siliceous compound, which was in a finely divided form, reacted. Pozzolanic reaction is characterised by its initial slowness, which causes the heat of hydration and strength development to be extremely high due to the curing days. The amount of calcium hydroxide in the concrete paste can be used to calculate a pozzolanic's reactivity.

1.2 Role of Bottom ash in High Performance Concrete

In the process of burning coal, bottom ash works alongside fly ash, making up roughly 20% of the total ash volume, depending on the type of boiler, dust collection system, burning temperature, and coal type. Compared to fly ash, its particles are porous, irregular, and coarser, but otherwise, their chemical makeup is very similar. Due to its similar particle size to that of regular sand, some studies on the use of bottom ash in concrete have concentrated on its potential ability to replace or partially replace fly ash. The most popular method for managing coal combustion residues is disposal in landfills and surface impoundment. In these profitable alternatives, the use of coal combustion residues has been steadily rising. Before these materials can be used safely and effectively, information about their physical, chemical, and engineering properties of coal combustion residues is needed. The majority of the researchers

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emphasised how easily bottom ash's physical, chemical, and engineering properties can be changed. It varies over time within a single plant not only from day to day but also from plant to plant.

1.3 Role of Steel slag aggregate in High Performance Concrete

In order to minimize shrinkage and have a positive economic impact on the production of concrete, aggregates are crucial components in the concrete mix. Although most coarse aggregates are made from naturally occurring materials, some synthetic aggregates can also be used to make concrete. These synthetic and organic aggregates interact chemically with the cement paste to enhance the mechanical properties of concrete.

The by-product of the steel-making process, steel slag is created in the steel-making furnaces when molten steel is separated from impurities. A lot of work has been put into using native by-products in concrete because of the negative environmental effects of extracting aggregate. The main benefits of adding by-products from different sources to concrete are the removal of scraps and a decrease in the overuse of quarries. An industrial product called steel slag aggregate is produced using strict quality control procedures and is free of organic impurities, clay, shells, and other similar substances. There is no reactive silica in this aggregate, which is one factor in chemical reactions with alkali aggregates. It lessens negative environmental effects, protects priceless natural resources needed to preserve ecosystems, and may use less energy during mining, stone crushing, and other processes. Steel slag is highly regarded as a recycled material that can lessen environmental impacts due to its resource-conservation and energy-saving effects as a result of rising environmental awareness.

II. OBJECTIVES OF THIS STUDY

1. The goals of the current study can be summed up as follows: utilising IS 10262:2009 to create the mix design for M30 grade concrete and using the slump cone test to determine the workability.
2. To determine the best mix proportions for both high performance concrete and conventional concrete using trial mixes and the proper selection of industrial by-products examine the physical and chemical characteristics of the industrial byproducts as well as the material properties of replacement concrete. to carry out a possibility study on concrete replacement using the chosen industrial by-products, including steel slag, bottom ash, and silica fume.
3. To determine the ideal replacement level of a single combination of replacement materials in concrete mixes by analyzing the mechanical properties of compressive strength, split tensile strength.
4. To investigate the impact of industrial byproducts on HPC in Binary and Ternary Combination mixes on mechanical properties like compressive strength at ages of 7,14 and 28 days in cube form 150mm x150mm 150mm.
5. To investigate the impact of industrial byproducts on HPC in Binary and Ternary Combination mixes on mechanical properties like Splitting tensile strength at ages of 14 and 28 days.

III. RESEARCH METHODOLOGY

The following methodology has been adopted in order to achieve the aforementioned goals.

The goal of this study is to find a productive method for making high performance concrete with aggregate made of industrial byproducts like silica fume, bottom ash, and steel slag.

Using the mix design in IS 10262:2009, an attempt will be made to determine the ideal mix proportion of the substitute materials in place of cement, fine aggregate, and coarse aggregate.

The specimens have the following dimensions: cubes measure 150 mm x 150 mm x 150 mm, cylinders measure 150 mm x 300 mm, and prisms measure 100 mm x 100 mm x 500 mm.

The results of the experimental tests can be used to determine the concrete's compressive strength, split tensile strength, and flexural strength.

The ideal replacement level mix for the concrete must be determined for further research based on the compressive strength of a single combination mix.

Comparative result analysis of conventional concrete between to making high performance concrete with aggregate made of industrial byproducts like silica fume, bottom ash, and steel slag.

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IV. RESULT AND DISCUSSION

4.1 Mix proportion M30 Grade of Concrete

Table 1: Mix Trial I of Mix Concrete in % and By Weight (kg/m3)

Mix designation	Cement	Silica Fume	Fine Aggregate	Bottom Ash	Coarse Aggregate	Steel Slag	Water	Super Plasticizer ECMAS HP 890
in %	100%	0%	100%	0%	100%	0%	0.47	0.4
By Weight kg/m3	359.00	0.00	788.00	0.00	1105.00	0.00	161.00	1.34

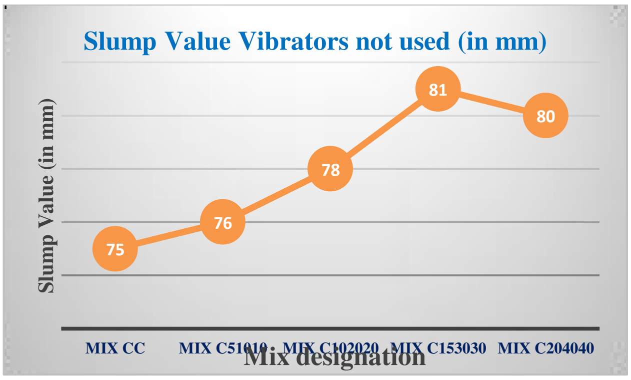
Table 2: Mix Concrete By Weight (kg/m3)

Mix designation	Cement	Silica Fume	Fine Aggregate	Bottom Ash	Coarse Aggregate	Steel Slag	Water /Cement	Super Plasticizer
Mix CC	359.00	0.00	788.00	0.00	1105.00	0.00	161.00	1.34
Mix C51010	341.05	17.95	709.20	78.80	994.50	110.50	161.00	1.34
Mix C102020	323.10	35.90	630.40	157.60	884.00	221.00	161.00	1.34
Mix C153030	305.15	53.85	551.60	236.40	773.50	331.50	161.00	1.34
Mix C204040	287.20	71.80	472.80	315.20	663.00	442.00	161.00	1.34

4.2 Experiment Work Fresh Concrete by Slump Cone Test

Table 3: Slump Cone Test

Mix designation	Slump Value Vibrators not used (in mm)
Mix CC	75 mm
Mix C51010	76 mm
Mix C102020	78 mm
Mix C153030	81 mm
Mix C204040	80 mm



Graph 1: Slump Cone Test

4.3 Compressive Strength of Concrete (IS: 516-1959)

Table 4: Compressive strength in N/mm² at 7 days

Mix design Code	Age of Cube	Load (KN)	Compressive Strength (N/mm^2)	Average	% Increase in strength at 7 days
Mix CC	7 Days	650.30	28.90	28.99	0.01
	7 Days	655.60	29.14		
	7 Days	651.20	28.94		
Mix C51010	7 Days	665.20	29.56	29.55	1.92
	7 Days	666.40	29.62		
	7 Days	662.80	29.46		
Mix C102020	7 Days	708.50	31.49	31.41	8.35
	7 Days	695.60	30.92		
	7 Days	716.20	31.83		

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Mix C153030	7 Days	725.20	32.23	32.22	11.14
	7 Days	731.25	32.50		
	7 Days	718.30	31.92		
Mix C204040	7 Days	662.80	29.46	30.62	5.63
	7 Days	708.50	31.49		
	7 Days	695.60	30.92		

Table 5: Compressive strength in N/mm² at 28 days

Mix design Code	Age of Cube	Load (KN)	Compressive Strength (N/mm^2)	Average	% Increase in strength at 28 days
Mix CC	28 Days	870.60	38.69	**38.70**	**0.00**
	28 Days	872.60	38.78		
	28 Days	869.30	38.64		
Mix C51010	28 Days	907.50	40.33	**40.35**	**4.25**
	28 Days	905.60	40.25		
	28 Days	910.20	40.45		
Mix C102020	28 Days	918.55	40.82	**41.03**	**6.03**
	28 Days	926.70	41.19		
	28 Days	924.55	41.09		
Mix C153030	28 Days	948.60	42.16	**42.26**	**9.19**
	28 Days	951.50	42.29		
	28 Days	952.30	42.32		
Mix C204040	28 Days	910.20	40.45	**40.82**	**5.48**
	28 Days	870.60	38.69		
	28 Days	872.60	38.78		

4.4 Tensile Strength Test

Concrete is inherently weak in tension, making tensile strength testing crucial. This can be performed through:

4.4.1 Split Cylinder Test

A cylindrical specimen (30cm x 15cm) is placed in a compression testing machine, and load is applied diametrically until it splits. Calculate the splitting tensile strength of each sample.

$$T = \frac{2P}{\pi LD}$$

Where:
T = splitting tensile strength in KN
P = maximum applied load indicated by the testing machine in KN
L = average sample length in mm
D = sample diameter in mm

Table no. 6 Splitting Tensile Strength (N/mm^2) at 28 days

Mix design Code	**Age of Cube**	**Load (KN)**	**Splitting Tensile Strength (N/mm2)**	**Average**	**% Increase in strength at 28 days**
Mix CC	28 Days	275.00	3.89	**3.88**	**0.00**
	28 Days	273.00	3.86		
	28 Days	275.00	3.89		
Mix C51010	28 Days	280.00	3.96	**3.97**	**2.29**
	28 Days	279.00	3.95		

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	28 Days	283.00	4.00		
Mix C102020	28 Days	290.00	4.10	**4.11**	**5.93**
	28 Days	287.00	4.06		
	28 Days	295.00	4.17		
Mix C153030	28 Days	298.00	4.21	**4.25**	**9.46**
	28 Days	301.00	4.26		
	28 Days	302.00	4.27		
Mix C204040	28 Days	279.00	3.95	**4.02**	**3.50**
	28 Days	283.00	4.00		
	28 Days	290.00	4.10		

V. CONCLUSION

1. The concrete mix made using steel slag, bottom ash, and silica fume with coarse aggregate, fine aggregate, and, cement respectively, on the performance of HPC showed good physical properties of concrete mixes.

2. The workability of concrete increased with the addition of steel slag, bottom ash, and silica fume with coarse aggregate, fine aggregate, and, cement respectively, on the performance of HPC. Comparative analysis to nominal concrete with multi bended Mix concrete Mix designation of nominal concrete Mix designation Mix CC is Slump Value Vibrators not used 75 mm and Mix designation Mix C153030 is Slump Value Vibrators not used 81 mm.

3. Comparative analysis to nominal concrete with multi bended Mix concrete, Mix designation of nominal concrete Mix CC is Compressive Strength 28.99 N/mm2 with 0.00 % Increase in strength at 7 days Mix designation of nominal concrete Mix C153030 is Compressive Strength 32.22N/mm2 with 11.14% Increase in strength at 7 days.

4. Comparative analysis to nominal concrete with multi bended Mix concrete, Mix designation of nominal concrete Mix CC Compressive Strength is 38.70 N/mm2 with 0.00 % Increase in strength at 28 days Mix designation of nominal concrete Mix C153030 Compressive Strength is 42.26 N/mm2 with 9.19 % Increase in strength at 28 days.

5. Comparative analysis to nominal concrete with multi bended Mix concrete, mix designation of nominal concrete Mix CC Splitting Tensile Strength is 3.88 N/mm2 with 0.00 % Increase in strength at 28 days Mix designation of nominal concrete Mix C153030 Splitting Tensile Strength is 4.25 N/mm2 with 9.46 % Increase in strength at 28 days.

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