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Parametric Experimental Studies on Sustainable Concrete Containing Waste under Different Curing Conditions

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Abstract*: *The Civil Industry finding out the sustainable solution in every area focusing on environment prevention concept. As per the research data of past few decades, there is a big challenge to reduce CO2 emissions in the environment when construction field is developing rapidly. In this situation, the waste disposal and CO2 emission is the biggest challenge for the entire civil industry. Entire civil industry is facing the problem of CO2 emission because of cement and steel production. To give the best solution for environment and construction field to produce sustainable concrete, the use of industrial waste in concrete is introduced nowadays. In this research work, the use of steel industry waste in concrete with optimum replacement was done. For this study, different percentages of replacement were done with the waste powder of steel industry in place of cement. After the numbers of replacement, optimum replacement percentage has been done to achieve the desired grade of concrete. For the better understanding of sustainability of the produced concrete from waste were investigated for different fresh and mechanical properties under different test as per the specifications. After finding out the properties of concrete, the same properties were investigated under acidic and alkaline curing conditions till 180 days at 28 days interval to understand the strength and other micro and macro level properties. From this entire investigation, the results were found satisfactory which shown that the concrete with optimum waste replacement under different curing conditions giving best results even after 180 days so it can be used as in structures which are continuously in contact with severe exposure conditions. This investigation gives the better sustainable solution with tremendous results and also found economic in cost. So as an outcome of this research, this feasible concrete is used in construction industry at different places after this research.

***Index Terms*: Concrete; Curing; Environment; Sustainability; Waste**

I. INTRODUCTION

The construction sector is one of the fastest growing industries in the world due to rapid urbanization, population growth and infrastructure development [12]. In this fastest growth of concrete industry, it is facing the challenge to produce concrete having adequate strength and durability, which is environment friendly, economical and thus sustainable [18].

After the construction industry the main focus on steel industries as Iron is the most demanding metals used in construction worldwide. Limestone, Iron ore, coal, and recycled steel are the main raw materials used in Iron production. There were 270-320 Mt iron slag was produced in 2012, and it is increases every year because of high demand of steel [17]. These type of requirements and civil and steel industries are also responsible for pollution in environment. Therefore the recycling of the by-product waste, improvement in energy recovery, and recycling in the process of iron making will have positive global implications, both environmentally and economically [22] and there is extreme need arise to find out alternatives of cement use. In the iron industries, the steel making process produces significant amounts of waste materials, such as slag [11] and dust. This type of waste in landfill is restricted for other environmental considerations, recycling of these byproducts is now became major problem for the steel producing industry [4]. The natural resources preservations and energy conservation is main aim for such industries to give suitable material properties and characteristics [13] where it can be used.The slag produced from the different steel-industries is used as per the requirements based on its physical and chemical properties [2], use of these different slag is contributed in saving natural resources and prevent the environment [15]. For the CO2 emission-mitigation strategies, its pain point for civil industry to find out solution for CO2 emission, global-warming and GHG emission which are the key factor for rapid growth of global-warming [3]. Most of the researchers reported the works considering only energy and CO2 emission reduction strategies. The one group of researchers have been extended to include economics and profitability as a key decision-making criteria in this field [21].The solution of the problem related to global warming, CO2 emission in environment and the pollution due to inappropriate methods of waste disposal can be solved out by finding alternatives for it. The utilization of such waste in concrete to minimizes the use of cement and also give the best solution for waste disposal. On the other hand in High Performance Concrete (HPC) slag use in introduced by the researchers in certain extent. Ground granulated blast furnace slag (GGBFS) utilized as a partial replacement of cement, has been proven to overcome excessive shrinkage and improved the durability of concrete.

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The GGBFS containing High performance concrete is more compact and impermeable than control concrete [16]. Hannant et al. [6] & Nasser and Neville [14] reveals the truth for long-term mechanical behavior of high performance concrete under temperature considering structure serviceability, tension losses in strength, excessive deflections, and cracking. The experimental investigation includes the concrete-mixture proportion, exposure to acidic solutions and comparison of mechanical properties of HPC with control concrete.

II. MATERIALS AND METHODS

A. Material

In hydraulic cement concrete, the binder is composed of a mixture of hydraulic cement and water. As per the Indian-Standard 12269:2013 [8], the Portland cement having grade of 53 grade was used for the entire work. To get exact properties of cement, it was tested in each phase during the work in end and beginning of work. The sample of the cement selected as above was thoroughly mixed before testing. In this experimental program, as per specifications of IS 383:1970 [9], river sand as fine aggregate and crushed stones as coarse aggregate available locally in Surat has been used. There are so many steel making industries in nearby area, but for this particular research work locally available slag (industry-waste) was collected from Surat. The material collected from the industry was in granular form which can be used as fine-aggregate and it was grinded in ball mill to use as a cementitious material. As per the BS 6699:1992 [1], properties of that waste powder was tested chemically which found similar like cement. The slag was used as cement replacement for preparation of mortar mixes ranging from 10 % to 90 % with the interval of 10 %. Compressive strength of mortar mixes was found which are shown in Figure 1. From the test it was found that for 50 % of cement replacement by slag gives maximum increased strength. The mixed designs for Conventional Concrete and HPC with 50 % cement replacement by industrial waste were done.

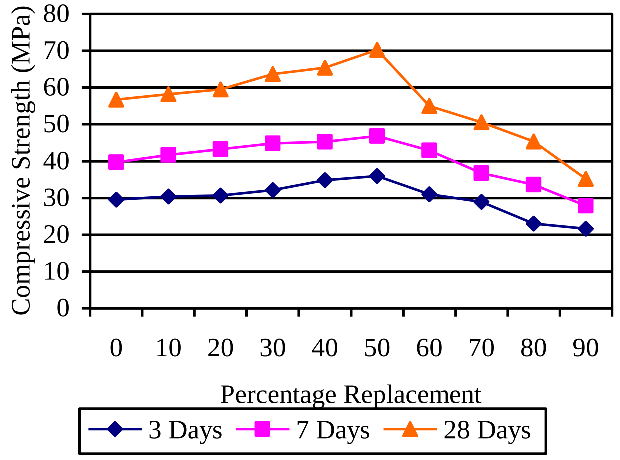

Fig. 1.Compressive strength of cement replacement with waste for different percentage

As per ASTM C989, the average strength of compressive-strength of cement-slag (50%-50%) mortar-cubes to the compressive force to the average compressive-strength of control cement-mortar cubes is identified as slag-activity-index. The different percentages of waste for cement mortar containing waste are given in the Table-1.

$$Slag\ Activity\ Index = \frac{SP}{P} \times 100$$

SP = average compressive-strength of slag-cement-mortar cubes in MPa, and

P = average compressive-strength of cement-mortar cubes in MPa.

Table 1. Slag Activity Index for Percentage variation of Waste in Waste-Cement Mortar

Slag Activity Index	Percentage of waste in Waste-Cement mortar								
	10	20	30	40	50	60	70	80	90
7 Days	105	109	113	114	118	108	93	85	70
28 Days	103	105	112	115	124	97	89	80	62

The slag activity index for 50 % replacement of cement by waste is 118 for 7 days and 124 for 28 days which indicates the grade of waste material is Grade 120.

B. Concrete Ingredient and Exposure Conditions

When To achieve the desired grade of HPC concrete with adequate properties, numbers of trial have been taken for the concrete containing 50% waste powder replacement. Table 2 indicates the comparison compositions for HPC containing 50% waste with Control concrete. The specimens were casted and cured in tap water for 28 days. Specimens were exposed in acidic solution with 5 % concentration of HCl acid and 5 % concentration of $MgSO_4$ solution to determine the effect of aggressive exposure.

Table 2. Mix-Proportions for CM & HPC

Material	Control Mix (CM)	HPC with Waste as 50% cement replacement
Cement	465	235
Waste Powder	-	235
Water	186	169
Sand	531	680
Coarse-aggregate (10 mm)	423	428
Coarse-aggregate (20 mm)	728	740
Admixture	-	3.10
Water cement Ratio	0.40	0.36
Slump		
Initial	135	160
30 min	95	140
60 min	-	120
90 min	-	100

C. Testing

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The compression test was performed on cube specimen with the edge of 150 mm as per IS 516:1959 [10]. The specimens were prepared as per the dimensions suggested in specifications for the compressive-strength (Cubic specimens with 150 mm edge length), tensile-strength (Cylindrical specimens with the diameter of 150 mm and the height of 300 mm) and Impact-Strength (diameter of 150 mm and the height of 50 mm). After the casting of specimen, the specimens were cured in tap water at a 20°C temperature in the room condition prior to test days. As per the IS 516:1959 standard, Compressive test was done, split tensile test was carried out in accordance to the IS 5816:1999 standard, impact strength tests were done as per ACI Committee 544.

III. RESULT OUTCOMES AND CRITICAL OBSERVATIONS

A. Effect of waste-powder on Workability

From the achieved results, it is concluded that the High-performance-Concrete containing waste with 50% replacement having improved workability compare to control concrete. The comparison is given in the Table 2.This result was due to the surface properties of the waste, which created smooth slip planes in the paste reported by Wood [19]. Wu and Roy [20] found that pastes containing GGBF slags exhibited different rheological properties compared to paste of Portland cements alone. Their results indicate a better particle dispersion and higher fluidity of the pastes and mortars with and without admixtures.

B. Effect of waste-powder on Workability

The setting time of concrete containing waste is more than that of Portland cement. The setting time is affected is dependent on the initial temperature of the concrete, the proportion of the blend used, the water-binder ratio, and the properties of the Portland cement [5].

C. Effect of waste on strength

The compressive strength of conventional concrete and HPC with steel industry waste at different age as per IS 516:1959 for different exposure conditions is shown in Figure 2.The observed outcomes reveals the truth behind compressive strength that the w/b ratio of 0.36 with 50% replacement of cement at 28days and after long time also giving increased strength compare to reference concrete. When compared to Portland cement concrete, use of Grade 120 slag typically results increased strength at later ages [7]. The increase in 28 days strength of HPC mixes is because of the effectiveness of the mineral admixture. The pozzolanic action of steel industry waste reacts with OPC, which yields early strength at lower *w*/*b* ratios. The compressive strength for HPC at the age of 180 days has been increased by 3 % in normal condition where as it has been decreased by 4 % and 6 % for HCl and MgSO4with comparisons of control concrete to its 28 days strength respectively. For conventional concrete the loss of strengths in HCl and MgSO4was found to be 9.74 % and 11.85 % respectively.

Figure 3 indicates the split tensile strength of conventional concrete and HPC for different exposure conditions and at different age of concrete. It indicates the gain in strength of HPC with age in normal conditions whereas the effect of HCl and $MgSO_4$ decrease the strength of both HPC and conventional concrete. The split tensile strength has been decreased by 10 % for both HPC and conventional concrete in HCl and $MgSO_4$ exposures.

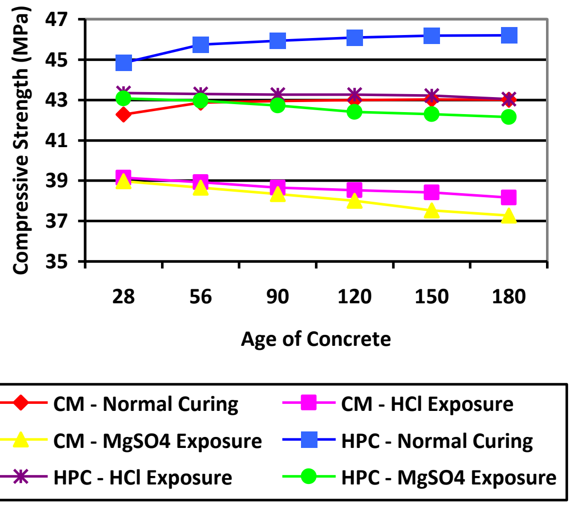

Fig. 2.Comparison of Compressive strength with the age of concrete

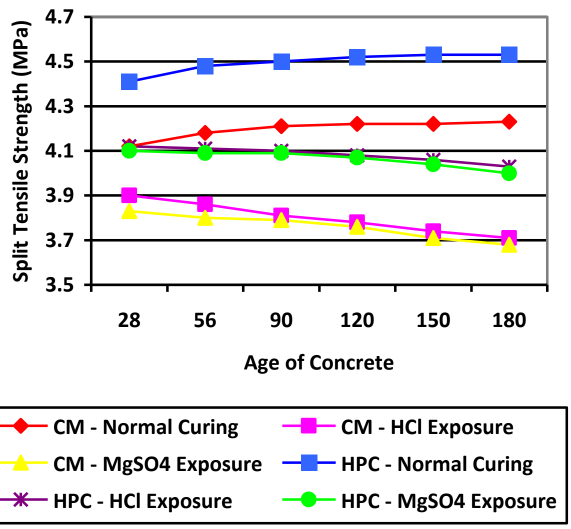

Fig. 3.Comparison of Split Tensile strength with the age of concrete

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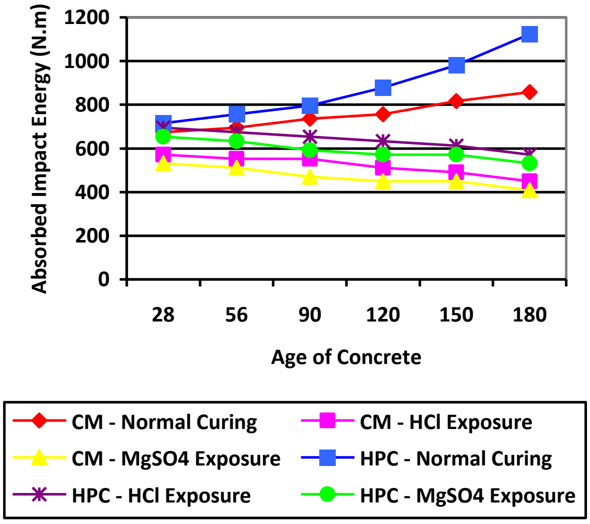

Fig. 4.Comparison of Impact strength with the age of concrete

The impact test is an important parameter in terms of effect of waste in concrete. Figure 4 indicated that the absorbed impact energy increases with the age of concrete for HPC. This increment is due to the closed particle packing of the hardened concrete which is the outcome of fine particle size of waste. The absorbed impact energy for HPC at the age of 180 days is increased by 57.14 % compare to that of 28 days. The absorbed impact energy for HPC and conventional concrete were decreased by 20 % and 33.33 % in HCl exposure and 25 % and 39.4 % in MgSO4 exposure respectively.

IV. Conclusion

It is clearly investigated that steel making waste powder, Grade 120 as per SAI, giving desired compressive strength for 50% replacement in place of cement in concrete. So it is suggested to use this HPC having industrial waste in place of conventional concrete to increase the strength of concrete structure but not in places where high early strength is required. The use of steel-industry waste as a cementitious-material improves the workability of concrete and helpful to decrease w/b ratio due to increased paste volume because of lower density of the used waste. It is directly benefited as economical point of view to use industrial waste as cement replacement. The HPC has better performance on aggressive exposure which makes it durable.

Particular advantages in the use of waste as a separate cementitious material in ready-mixed concrete are: increased strength, reduced cost of cementitious material, increased flexibility, improved workability and reduced strength loss in concrete subject to aggressive exposures.

The impact energy is high for HPC which makes it to be used in important structures like assembly, army bases etc. where blast/attacks are likely to be occur.

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