

Effect of Performance Improver Additives on the Properties of 53 Grade Ordinary Portland Cement

Pramod Kumar Singh^{1*}, Dharmendra Kumar Shukla² and Shubham Goswami³

¹Dean (Academics & Research), Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India. Email: pk.singh@juet.ac.in

²Assistant Professor, Department of Civil Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India. Email: dharmendra.shukla@juet.ac.in

³Research Scholar, Department of Civil Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India. Email: samgoswami1995@gmail.com

*Corresponding Author

Abstract: It is an established fact that additives when used in certain proportions, improve the desired properties of cement. Indian Standard (IS-269) for 33, 43 and 53 grades Ordinary Portland Cement has made a provision to add ten different kind of performance improvers and addition of these is limited to maximum 5%. Consequently, different manufactures use various materials as performance improvers depending upon suitability and cost effectiveness with sustainability. Another advantage is from environment point of view as substantial quantity of wastes (by products of various other industries) are converted to value added product. In the current study various types of mineral additives such as limestone, granulated blast furnace slag, lignite fly ash, kiln return dust, marine gypsum are used to improve the performance of 53 Grade Ordinary Portland cement (OPC). The results show that using these additives increase the performance of cement besides the saving in natural resources and thermal energy.

Keywords: Improver additives, Insoluble residue, 53 Grade ordinary portland cement.

I. INTRODUCTION

The cement industry is facing number of challenges, including raw material scarcity, increasing demand for cements and concretes, rising environmental issues related to climate change. Improved OPC performance and formulations that minimize or eliminate CO₂ emissions from the cement manufacturing process are considered high on priority. Regarding this, available minerals and recycled material (industrial, agricultural, and domestic) wastes may be suitable for blending with OPC as substitute or replacement in the study [1].

Limestone, granulated blast furnace slag, lignite fly ash, kiln return dust and marine gypsum can be used for this purpose. Limestone is a low-cost, readily available material that is easier to grind than clinker, resulting in better particle packing and hydration. In comparison to [2] OPC, it increases workability and prevents 'bleeding' in cement [1] [3]. Lignite fly ash is a waste material generated from the thermal power plants, using lignite as an energy source. Fly ash is often used to substitute approximately 30% of the mass of Portland cement due to its pozzolanic properties, such as to minimize permeability and initial heat evolution [1] [4]. Granulated blast furnace slag is a by-product of the steel industry. It has hydraulic properties and consists of calcium and magnesium alumino-silicates [1] [2].

The present study covers a wide range of alternatives materials such as limestone, granulated blast furnace slag, lignite fly ash, kiln return dust and marine gypsum for increasing the performance of OPC 53 Grade cement as performance improvers.

II. MATERIALS AND METHODS

With above points in mind a study was carried out using 53-grade Ordinary Portland Cement (OPC) as reference. A laboratory ball mill is used to grind clinker (OPC), meeting IS 53 Grade specification requirements and was taken as control sample. This was prepared using 98.75% clinker and 1.25% marine gypsum. To this, various performance improvers were added during ball milling to get the desired fineness. Table I enumerates various combinations of available additives such as limestone, granulated blast furnace slag, lignite fly ash, kiln return dust, marine gypsum which were added during ball mill grinding.

TABLE I: PROPORTIONING IN PERCENTAGE BY WEIGHT (S = SAMPLE)

Materials	S-1	S-2	S-3	S-4	S-5	S-6
Clinker	98.75	94.75	93.75	94.75	83.75	96.75
Gypsum	1.25	1.25	1.25	1.25	1.25	1.25
Limestone	-	4.0	-	-	4.0	-
Granulated blast furnace slag	-	-	5.0	-	5.0	-
Lignite fly ash	-	-	-	4.0	4.0	-
Kiln return dust	-	-	-	-	2.0	2.0

The resultant cements were tested for various physical properties and key chemical parameters with an aim to establish the best combination that shows maximum improvements in vital cement properties like chemical composition [5], insoluble residue [5], normal consistency [6], specific surface area (m^2/kg) [7], loss on ignition [5], compressive strength [8].

III. RESULTS AND DISCUSSION

This section describes the test results of all prepared combinations.

A. Chemical Composition

The chemical composition of the clinker, limestone, granulated blast furnace slag, lignite fly ash, kiln return dust and marine gypsum is summarized in Table II.

B. Insoluble Residue (IR)

The part of materials insoluble in acid as well as in base is called IR. IR in materials is determined as per Indian Standard [5] and results shown in Table III.

TABLE II: CHEMICAL COMPOSITIONS OF ALL MATERIALS

Parameter Tested (%)	Clinker	Limestone	Granulated Blast Furnace Slag	Lignite Fly Ash	Kiln Return Dust	Marine Gypsum
SiO ₂	20.5	3.8	31.8	28.4	10.8	-
Al ₂ O ₃	5.4	1.65	23.0	29.8	3.30	-
Fe ₂ O ₃	4.3	1.4	2.26	16.4	2.70	-
CaO	64.2	49.1	34.1	13.0	43.2	-
MgO	3.1	2.5	7.5	2.9	2.4	-
SO ₃	1.8	0.2	0.2	6.9	0.24	39.50
Cl	0.035	0.08	-	0.11	0.09	1.20
Na ₂ O	0.035	Traces	-	0.09	0.09	-
K ₂ O	0.20	Traces	-	0.5	0.20	-
Purity	-	-	-	-	-	85.0
LOI	0.2	41.3	-	1.9	36.3	-
Lime Reactivity (MPa)	-	-	-	8.0	-	-

TABLE III: INSOLUBLE RESIDUE IN MATERIALS

Combinations	Insoluble Residue
S-1	0.60
S-2	1.14
S-3	1.60
S-4	2.70
S-5	2.91
S-6	1.10

C. Normal Consistency, Specific Surface and Loss on Ignition (LOI)

The normal consistency, specific surface and loss on ignition are important parameters, which are mentioned in Indian Standard specifications and the values of these parameters are mentioned in Table IV.

TABLE IV: PROPERTIES OF VARIOUS COMBINATIONS

Combinations	Normal Consistency (%)	Specific Surface (m ² /kg)	Loss on Ignition (%)
S-1	23.5	297	0.90
S-2	24.8	308	2.62
S-3	24.3	295	1.80
S-4	23.5	309	2.10
S-5	25.0	358	3.25
S-6	24.3	317	1.62

D. Compressive Strength

Fig. 1 show the compressive strength results of all the compositions. All the compositions achieve 60 MPa compressive strength at 28 days but S-5 combination gives similar strength at maximum replacement when compared with all the combinations.

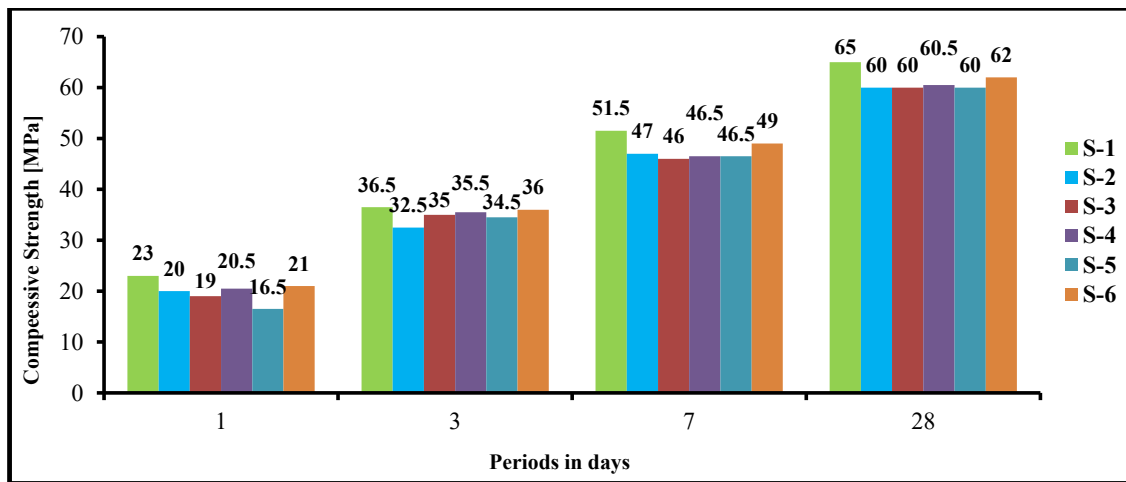


Fig. 1: Compressive Strength of All Combinations in MPa

IV. CONCLUSION

The above results indicated that:

- Cements produced in all the combinations meet all the requirements of 53 Grade-OPC.
- Slight increase in the specific surface in case of cement produced by using slag as performance improver makes vast improvement in compressive strength at all ages, even as compared to control samples.
- In case of S-5 sample, in spite of addition of 15% performance improvers (apart from gypsum), the compressive strengths are comparable at 3, 7 and 28 days with those of other combinations.
- The above study indicates that 43 & 53 Grade- OPC varieties can be comfortably produced while using appropriate performance improvers even as high as 15% while still meeting the requirements of relevant IS specifications.

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