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EXPLORING CONCRETE QUALITY: ANALYZING PHYSICAL AND CHEMICAL ATTRIBUTES FOR MATERIAL SELECTION AND CONTROL SPECIMEN PRODUCTION

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ABSTRACT:

Concrete, crucial in construction, relies heavily on the physical and chemical attributes of its components for optimal performance and longevity. This study endeavors to delve into the intricate nuances of these properties, shedding light on their indispensable role in concrete formulation. The aim is to systematically assess the quality of standard materials—water, Ordinary Portland Cement (OPC), coarse aggregates, and fine aggregates—integral to concrete production. Laboratory evaluations of their physical and chemical properties, aligned with the Indian Standard Code, are conducted to ascertain their viability for concrete production as control specimens. These materials are intended for comparison with other test materials using a replacement methodology. Employing a laboratory-centered approach, an extensive investigation is conducted on the specified materials. This examination entails a meticulous assessment of these material's physical and chemical properties, intending to evaluate their suitability for concrete production and potential utilization as control specimens. The results obtained from meticulous experimentation highlight that the materials meet the stipulated requirements outlined in the Indian Standard (IS) Code. This reaffirms their appropriateness for concrete production and indicates their potential effectiveness as control specimens in experimental settings. Confirming the physical and chemical properties of these materials validates their notable impact on concrete performance. Additionally, their incorporation as control materials creates opportunities to investigate alternatives, like recycled waste materials. This endeavor advances our comprehension of concrete formation principles and enhances structural resilience in construction projects.

Keywords: ***Concrete quality, Physical and chemical attributes, Material selection, Control specimen production, Laboratory evaluation***

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 Journal Volume 11, Iss 12, 2022

INTRODUCTION AND BACKGROUND:

Concrete is widely recognized as the most commonly used synthetic material worldwide, trailing only water in terms of quantity consumed. It serves as a fundamental building block of modern society, with almost every aspect of our daily routines dependent, either directly or indirectly, on its existence. Its importance becomes evident when we think about commonplace features such as streets, bridges, structures, dams, and other infrastructure elements. Remarkably, about half of all manufactured materials and goods can be traced back to concrete [1]. Despite its omnipresence, its significance is sometimes overlooked due to its sheer prevalence.

Concrete production has evolved over centuries, from ancient Greek and Roman mortars to modern variants. Portland cement, a key component, is manufactured through a meticulous process involving limestone and clay or shale in high kiln temperatures. Supplementary materials like fly ash and blast furnace slag are commonly used, along with chemical admixtures for property enhancement. Despite its complexity, modern concrete remains incompletely understood. Recent research emphasizes sustainability, motivating advancements in smarter production methods and increased durability [2].

Concrete, prized for its affordability, versatility, and ready availability of raw materials, has long been a cornerstone of construction [3 – 4]. As engineering standards progress, there is an increasing demand for concrete to demonstrate improved mechanical properties, durability, and environmental sustainability [5]. The composition of concrete and the nature, physical, and chemical properties of its constituent materials can significantly influence these aspects.

Concrete deterioration can arise from exposure to various physical and chemical factors like acids, sulfates, alkalis, and freeze-thaw cycles [6 – 7]. Among the most severe issues in reinforced concrete is reinforcement corrosion, which reduces cross-sectional area and leads to concrete spalling. Corrosion starts after de-passivation caused by carbonation, chloride ion penetration, or both [8]. Transport phenomena through concrete pores, including gas and ion diffusion and water flow, are also involved in all degradation processes. Understanding pore structure, distribution, and constituent concentration evolution is crucial for managing these phenomena and concrete deterioration.

Additionally, in sulfate-rich environments, the erosion of concrete durability due to sulfate attack is a notable concern resulting from a blend of physical and chemical factors, alongside various other factors. This process can result in the creation of expansive substances and the disintegration of cement hydration products [9 – 11]. The corrosion of reinforcement induced by chloride is also a durability concern [12 – 13].

Assessing properties like fineness, soundness, specific gravity, compressive strength, heat of hydration, and setting time of Ordinary Portland Cement (OPC) is essential for ensuring concrete quality and durability. Proper regulation of these parameters helps prevent cracking, structural defects, and excessive heat generation during hydration. Adherence to standards

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 Journal Volume 11, Iss 12, 2022

and meticulous testing enables engineers to optimize mix designs and guarantee the long-term performance of concrete structures in various construction applications [14].

Testing fine aggregate (sand) for specific gravity, water absorption, bulking, and bulk density is essential for ensuring its suitability and performance in concrete applications. By conducting these tests, construction professionals can optimize concrete mix designs, ensuring the durability, workability, and uniformity of concrete structures in diverse construction environments [15].

The Indian Standard Codes offer comprehensive guidelines for assessing the physical and chemical characteristics of water, coarse aggregates, fine aggregates, and ordinary portland cement (Grade 43). Emphasizing the importance of these attributes concerning concrete durability is crucial for the selection of suitable materials, the refinement of mix designs, and the assurance of the enduring performance, dependability, and sustainability of concrete structures across varied construction contexts and environmental circumstances [16 – 18].

Given the significant focus on this topic, evaluating the physical and chemical properties of concrete's fundamental components—Ordinary Portland Cement (OPC), water, fine and coarse aggregates—is crucial for ensuring quality, performance, durability, optimized mix designs, compatibility, sustainability, and environmental impact of concrete structures. Consequently, conducting further relevant studies is essential. This facilitates the utilization of these materials to create control specimens for analyzing the replacement of standard components with recycled waste materials, thereby advancing sustainable and eco-friendly concrete production.

METHOD:

A systematic approach to evaluate the physical and chemical properties of fundamental materials for concrete production and their utilization as control specimens in experimental settings was employed, steps indicated below:

a. **Literature Review:** A thorough literature review was undertaken to elucidate the importance of testing both physical and chemical properties in enhancing concrete performance.

b. **Material Selection:** The necessary materials for making concrete, including Grade 43 Ordinary Portland Cement, coarse aggregates of both 10mm and 20mm sizes, and fine aggregate with particles larger than 4.75mm, were acquired from a nearby supplier. Since water is readily available in the laboratory, it was utilized as the primary source.

c. **Material Quantity:** 5 kilograms of both coarse aggregates (20mm and 10mm) were taken, along with an equal amount of fine aggregate. Additionally, 5 bags, each weighing 5 kilograms, of Ordinary Portland Cement (OPC) were used.

d. **Laboratory Setup:** Balaji Scientific Laboratories (BSL), Faridabad, Haryana, equipped with state-of-the-art facilities, was chosen as the ideal setting for performing physical

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11, Iss 12, 2022

and chemical analyses.

e. **Experimental Design and Testing Techniques:** A comprehensive assessment of physical and chemical properties was conducted in November 2023. Testing methods were adjusted to conform with the procedures outlined in the IS Codes as follows:

- ***Water Property Testing*:** To ensure the desired performance and durability of the concrete, water intended for concrete production underwent testing using techniques outlined in IS:3025-2022 [19 – 25] to meet quality standards. The results were then compared with permissible values specified in IS:456-2000 [26].

- ***OPC, Coarse Aggregate, and Fine Aggregates Property Testing:*** A comprehensive analysis was conducted, utilizing testing techniques specified in IS:4031 and IS:4032 [27 – 34] for Ordinary Portland Cement (OPC) and IS:2386 [35 – 38] for coarse and fine aggregate. This included assessing various physical and chemical characteristics of the materials to ensure compliance with Indian Standard Codes. The results were subsequently compared with permissible values specified in IS 269:2015 [39] for Ordinary Portland Cement (OPC) and IS 383-2016 [40] for coarse and fine aggregate.

- ***Sieve Analysis*:** Sieve analysis was conducted as per IS:2386 [41] to determine the particle size distribution of aggregates to ensure that the aggregates are well-graded and meet the specified requirements for workability, strength, and durability. The test outcomes were compared with the requirements outlined in IS 383-2016 [40].

f. **Compliance Assessment:** The obtained results were then compared with the specifications outlined in the Indian Standard Code to determine compliance.

g. **Interpretation:** The results were interpreted to determine the suitability of standard materials for concrete production and their potential as control specimens.

h. **Reporting:** A thorough report (#20231102001 to 20231102005) was assembled, meticulously outlining the outcomes derived from the conducted experiments. Within this report, particular emphasis was placed on contrasting the attained results with the specified criteria, alongside referencing the experimental methodology employed.

MATERIALS, TESTING EQUIPMENT, TESTING AGENTS AND ACCESSORIES:

Test Materials

Testing utilized Ordinary Portland Cement (OPC) of Grade 43, 10mm and 20mm coarse aggregate, and fine aggregate with particle sizes greater than 4.75mm. Figure 1 depicts the materials employed for testing purposes.

ISSN PRINT 2319 1775 Online 2320 7876

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Ordinary Portland Cement (OPC) | Fine Aggregate (Sand) | Coarse aggregate

Figure 1: Materials used for Testing Physical and Chemical Properties (Author's Property)

Testing Agents and Accessories

A range of sieve sizes (150 microns to 40 mm) was employed to determine the average particle size across the entire aggregate material. Various chemicals were used to test the quality of water and the physical and chemical properties of the materials. Graduated cylinders were chosen for measuring the quantity of water and other liquid agents. Figure 2 represents illustrations of these accessories and agents.

Sieves | Testing Chemical | Measuring Cylinders

Figure 2: Testing Accessories and Agents (Author's Property)

RESULTS

a. *Water Properties*

The analysis of water properties yielded insightful results crucial for ensuring concrete quality and performance. Table 1 presents the test parameters, along with references to the employed test methods, actual results obtained, and permissible values for comparison.

S No.	Parameter (SI unit)	Test Methods	Results	Permissible Value (IS 456-2000), RA-2021
1	pH at 25°C	IS:3025(P-11)-2022	6.89	Not less than 6.0
2	Chlorides as Cl (mg/L)	IS:3025(P-32)-1988	67.99	500/2000 Max. R.C.C./C.C

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11, Iss 12, 2022

3	Sulphate as SO_3,mg/L	IS:3025(P-24-Sec-1)-2022	36	400 Maximum
4	Acidity	IS:3025(P-22)-1986	1.2	Not more than 5ml of neutralizing agent
5	Alkalinity	IS:3025(P-23)-2023	24.6	Not more than 25ml of neutralizing agent
6	Organic Solid (mg/L)	IS:3025(P-18)-2022	98	200 Maximum
7	Inorganic Solid (mg/L)	IS:3025(P-18)-2022	243	3000 Maximum
8	Suspended Matter (mg/L)	IS:3025(P-17)-2022	12	2000 Maximum

Table 1: Results of Water Property Testing (Author's property, C/O Balaji Scientific Laboratories (BSL))

b. Coarse Aggregate (10mm and 20mm) Properties

The evaluation of coarse aggregate properties (Tables 2 and 3) provided valuable insights into its quality and suitability for concrete applications.

S No.	Parameter (SI unit)	Test Method	Results	Permissible Value (IS: 383-2016)
1	Impact valve (%)		17.9	30/45 max. for wearing/non-wearing surface
2	Crushing value (%)	IS:2386 (P-4)-1963	21.6	30/30 max for wearing/non-wearing surface
3	Abrasion value (%)		23.2	30/50 max. for wearing/non-wearing surface
4	Specific gravity		2.61	N.A
5	Water absorption (%)	IS:2386 (P-3)-1963	0.53	N.A
6	Bulk Density (Kg/ltr)		1.60	N.A
7	Soundness (%)	IS:2386 (P-5)-1963	4.3	12 Max (using Na_2So_4)
8	Alkali Reactivity, (millimoles/ltr.)	IS:2386 (P-7)-1963	Innocuous Aggregate	Innocuous Aggregate/Deleterious Aggregate
8.1	Dissolve Silica (millimoles/ltr.)		18.24	N.A

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11, Iss 12, 2022

8.2	Reduction in Alkalinity, (millimoles/ltr.)		75	N.A
9	Color	Visual Inspection	Dark Grey	N.A

Table 2: Properties of 10 mm Coarse Aggregate (Author's property, C/O Balaji Scientific Laboratories (BSL

S No.	Parameter (SI unit)	Test Method	Results	Permissible Value (IS: 383-2016)
1	Impact valve (%)	IS:2386 (P-4)-1963	18.7	30/45 max. for wearing/non-wearing surface
2	Crushing value (%)		20.3	30/30 max for wearing/non-wearing surface
3	Abrasion value (%)		23.0	30/50 max. for wearing/non-wearing surface
4	Specific gravity	IS:2386 (P-3)-1963	2.63	N.A
5	Water absorption (%)		0.67	N.A
6	Bulk Density (Kg/ltr)		1.61	N.A
7	Soundness (%)	IS:2386 (P-5)-1963	4.9	12 Max (using Na_2So_4)
8	Alkali Reactivity, (millimoles/ltr.)	IS:2386 (P-7)-1963	Innocuous Aggregate	Innocuous Aggregate/Deleterious Aggregate
8.1	Dissolve Silica (millimoles/ltr.)		18.32	N.A
8.2	Reduction in Alkalinity, (millimoles/ltr.)		70	N.A
9	Color	Visual Inspection	Dark Grey	N.A

Table 3: Properties of 20 mm Coarse Aggregate (Author's property, C/O Balaji Scientific Laboratories (BSL))

c. *Ordinary Portland Cement (OPC), Grade 43 Properties*

The analysis of Ordinary Portland Cement (OPC) test results (Table 4) also offers critical insights into its physical and chemical properties, essential for assessing its suitability and performance in concrete production.

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11, Iss 12, 2022

S No.	Parameter (SI unit)	Results	Permissible Value (IS 269 : 2015)	Test Methods
Chemical Properties				
1	Ratio of %age of Lime to %age of SiO_2, Al_2O_3 and Fe_2O_3	0.86	0.66-1.02	IS 4032 - 1985
2	Ratio of %age of alumina to iron oxide (Al_2O_3/ Fe_2O_3)	1.10	0.66 Min.	
3	Insoluble Residue, (%age by Mass)	2.20	5.0 Max.	
4	Magnesia as MgO (% by mass)	1.87	6.0 Max.	
5	Total Sulphur Content as SO_2, (% by mass)	1.79	3.5 Max.	
6	Loss of Ignition, (% by mass)	2.35	5.0 Max.	
7	Total Chloride (% by mass)	0.021	0.1 Max.; 0.05 (For Prestressed Structure)	IS 4032 - 1985 ;Amnd.02
Physical Properties				
8	Fineness blaine air permeability (m^2/kg)	298	225 Min.	IS 4031 (P-2)-1999
9	Soundness - Le Chatelier (mm) - Autoclave (%)	0.5 0.08	10 Max. 0.8 max.	IS 4031 (P-3)-1988
10	Setting time (min.) - Initial - Final	- 145 - 245	- 30 Min. - 600 Max.	IS 4031 (P-5)-1988
11	Consistency, %	29.0	NA	IS 4031 (P-4)-1988
12	Specific Gravity	3.15	3.11 - 3.14	IS 4031 (P-11)-1988
13	Compressive Strength, MPa a) 72 ± 1 Hr. b) 168 ±2 Hr. c) 672 ± 4 Hr.	28.0 38.0 46.5	23 Min. 33 Min. 43-58	IS 4031 (P-6)-1988
14	Color	Grey	NA	Visual Inspection

Table 4: Properties Results of OPC (Author's property, C/O Balaji Scientific Laboratories (BSL))

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11, Iss 12, 2022

d. *Fine Aggregate (Sand) Properties*

Table 5, highlights the examination of fine aggregate properties and furnishes essential information regarding its quality and characteristics, pivotal for determining its efficacy in concrete formulations.

S No.	Parameter (SI unit)	Test Method	Results	Permissible Value (IS:383-2016/ (ZONE-II)
Physical Properties				
1	Specific gravity	IS:2386(P-3)-1963	2.60	N.A
2	Water absorption (%)		1.12	N.A
3	Bulking of Sand (%)		4.7	N.A
4	Bulk Density (kg/ltr.)		1.72	N.A
5	Soundness (%), 5 Cycle	IS:2386(P-5)-1963	3.8	10 Max. (using Na_2SO_4)
Chemical Properties				
6	Alkali Reactivity, millimoles/ltr.	IS:2386(P-7)-1963	Innocuous Aggregate	Innocuous Aggregate/Deleterious Aggregate
6.1	Dissolved Silica, millimoles/ltr.		18.53	N.A
6.2	Reduction of Alkalinity, millimoles/ltr.		105	N.A
7	Color	Visual Inspection	Light Grey	N.A

Table 5: Properties Results of Sand (Author's property, C/O Balaji Scientific Laboratories (BSL))

e. *Sieve* Analysis

The below gradation curves (Figures 3, 4, and 5) indicate the distribution of particle sizes to characterize its engineering properties, such as permeability, compaction, and stability.

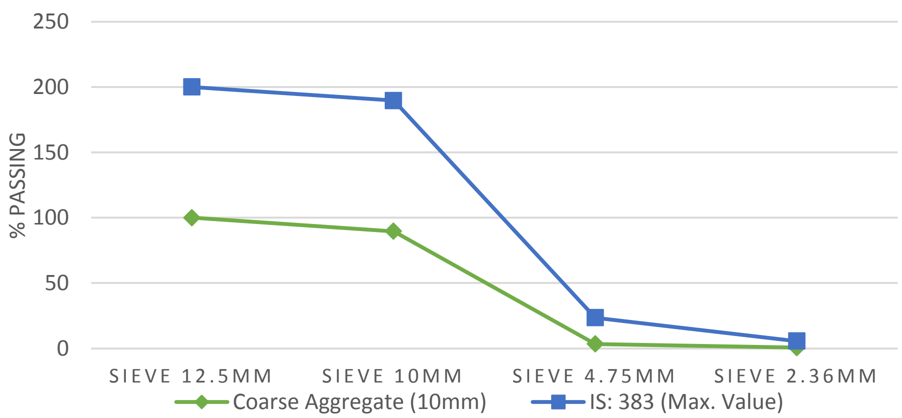

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Figure 3: Gradation Curve of Coarse Aggregate 10mm (Author's property, C/O Balaji Scientific Laboratories (BSL))

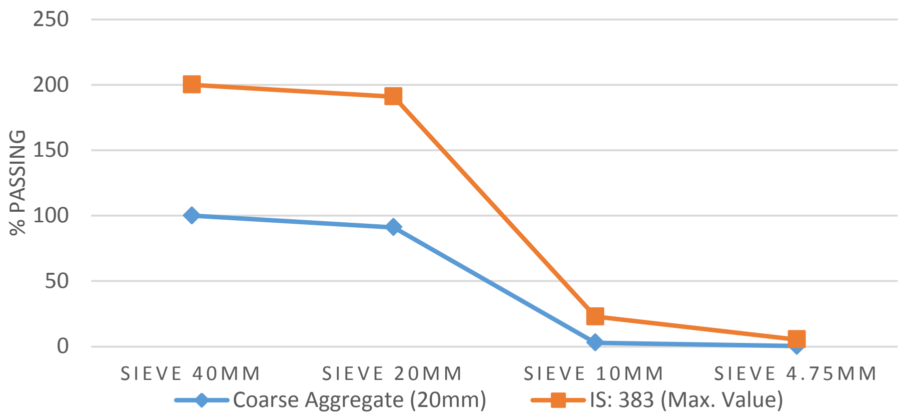

Figure 4: Gradation Curve of Coarse Aggregate 20mm (Author's property, C/O Balaji Scientific Laboratories (BSL))

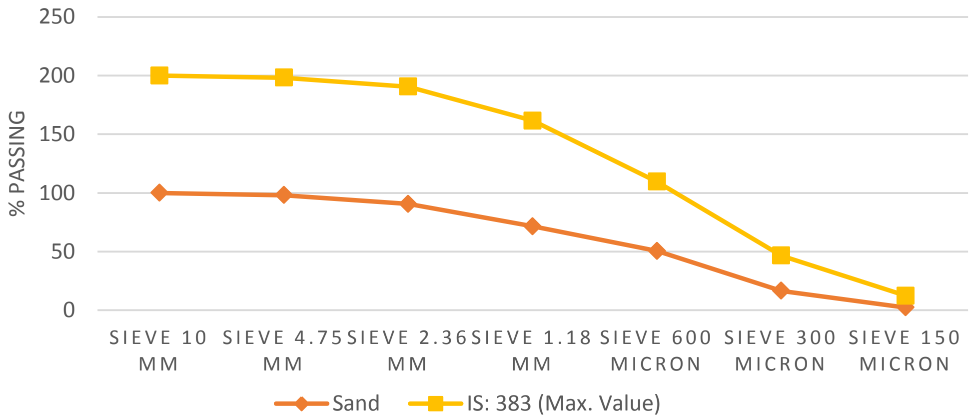

Figure 5: Gradation Curve of Fine Aggregate (Sand) (Author's property, C/O Balaji Scientific Laboratories (BSL))

CONCLUSIONS

The comprehensive investigation conducted in this study has highlighted the crucial role of physical and chemical properties in the formulation of concrete. The meticulous assessment of water, Ordinary Portland Cement (OPC), coarse aggregates, and fine aggregates, aligned with Indian Standard Code specifications, confirms their suitability for concrete production as control specimens. The results demonstrate that these materials meet the stipulated requirements, reaffirming their appropriateness for concrete production and potential effectiveness as control specimens in experimental settings.

This validation underscores the significant impact of these materials on concrete performance, paving the way for further exploration of alternative materials, such as recycled waste materials as alternatives to conventional components. By advancing our understanding of concrete formation principles and enhancing structural resilience in construction projects, this study contributes to the ongoing efforts to improve concrete quality and sustainability.

ABBREVIATIONS

– BSL: Balaji Scientific Laboratories
– OPC: Ordinary Portland Cement
– IS: Indian Standard

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ISSN PRINT 2319 1775 Online 2320 7876

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DECLARATIONS

The authors declare that the laboratory results are obtained from Balaji Scientific Laboratories (BSL), Faridabad, and are transcribed for this manuscript. The original laboratory report can be requested from the corresponding author via email at jaiduttciv201@osgu.ac.in.