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Research Article

Comparative Analysis of Different Types of Ordinary Portland Cement Brands and Evaluating Their Strength Characteristics

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Abstract – This study presents a comparative analysis of various brands of Ordinary Portland Cement (OPC) available and mostly used for the Civil Engineering construction works. The research evaluates the strength characteristics of concrete samples prepared using different cement brands by conducting tests such as fineness, consistency, setting time, and compressive strength. Laboratory experiments were performed following ASTM standards, and the results provide insights into the performance of different OPC brands in construction applications. The findings of this research will help engineers and construction professionals in selecting suitable cement for various structural applications.

Keywords – Cement Type, Soundness, Setting Time, Mortar Strength.

I. INTRODUCTION

1.1 Overview of Ordinary Portland Cement

Ordinary Portland Cement (OPC) is the most widely used type of cement in the construction industry worldwide. It is a hydraulic cement that is primarily composed of calcium silicates, along with smaller amounts of calcium aluminates and calcium ferrites. OPC is known for its excellent binding properties and ability to form durable concrete structures. Understanding the history and characteristics of OPC is essential for comprehending its role in the construction industry.

1.1.1 History of Ordinary Portland Cement

The development of OPC can be traced back to the early 19th century. In 1824, Joseph Aspdin, an English bricklayer, invented a new cement by burning a mixture of limestone and clay to form a clinker, which was then ground into a fine powder. Aspdin named this cement "Portland cement" due to its resemblance to the high-quality building stones found in Portland, England. This invention marked the birth of OPC and laid the foundation for modern cement production (Taylor et al., 1997).

1.1.2 Composition and Manufacturing Process of OPC

OPC is primarily composed of four main mineral phases: tricalcium silicate (C3S), dicalcium silicate (C2S), tricalcium aluminate (C3A), and tetra calcium aluminoferrite (C4AF) (Mehta and Monteiro, 2014). The proportions of these phases may vary depending on the specific formulation and manufacturing process.

The manufacturing process of OPC involves the following steps:

1. Raw Material Preparation: Limestone and clay are carefully selected and proportioned to achieve the desired chemical composition.
2. Clinker Production: The raw materials are heated in a rotary kiln at high temperatures (approximately 1450°C), resulting in the formation of clinker nodules.
3. Clinker Grinding: The clinker nodules are ground into a fine powder, known as cement, along with a small amount of gypsum to regulate setting time (Neville et al., 2011).

1.1.3 Strength Development and Hydration of OPC

Upon mixing OPC with water, a series of chemical reactions occur, collectively known as hydration. These reactions lead to the formation of hydrated cementitious compounds, such as calcium silicate hydrates (C-S-H) and calcium hydroxide (CH), which contribute to the strength development of concrete.

The strength development of OPC-based concrete is time-dependent and follows a characteristic curve. Initially, there is a rapid increase in strength, known as the initial setting period, followed by a slower but continuous strength gain, referred to as the final setting period (Mehta and Monteiro, 2014).

Several studies have investigated this topic, including the work of Li et al. (2019)(1) was compared the compressive strength and hydration characteristics of concrete made with cement from four different companies.

Similarly, Siddique and Khan (2011)(2) evaluated the influence of cement properties on the workability and strength of concrete and found that the properties of the cement, including fineness and chemical composition, had a significant impact on the performance of the concrete. Overall, it is crucial to select the appropriate cement type for concrete construction based on its intended application and the desired physical properties.

1.1.4 Standard Specifications for OPC

Various international and national standards govern the manufacturing, testing, and use of OPC. The most widely adopted standards include the American Society for Testing and Materials (ASTM) standards, the British Standards Institution (BSI) standards, and the Pakistan Standards and Quality Control Authority (PSQCA) standards (ASTM C150, BSI EN 197, PSQCA).

1.1.5 Advantages and Limitations of OPC

OPC offers several advantages, including high strength development, availability, cost-effectiveness, and compatibility with various admixtures and supplementary cementitious materials. However, OPC also has limitations, such as its high carbon footprint due to the energy-intensive manufacturing process and the potential for alkali-silica reaction and sulfate attack under certain conditions.

1.2 Factors affecting Cement Performance:

The performance of cement, particularly in concrete applications, is influenced by several key factors. These factors can impact various properties and characteristics of cement, including setting time, strength development, durability, workability, and overall performance. Understanding these factors is crucial for optimizing cement performance in construction. Here are some of the main factors that affect the performance of cement:

1.2.1. Chemical Composition: The chemical composition of cement significantly influences its performance. The main components of cement are clinker, gypsum, and minor additives. The type and proportions of these components determine the cement's characteristics, such as setting time and strength development. Different types of cement, such as Ordinary Portland Cement (OPC) or blended cements, have varying chemical compositions, affecting their performance properties.

1.2.2. Fineness: The fineness of cement particles affects its reactivity and hydration characteristics. Finer particles provide a larger surface area for chemical reactions, leading to faster hydration and potentially higher early strength. (Neville et al., 2011). The fineness of cement is typically measured by the specific surface area, often reported as the Blaine fineness.

1.2.3. Water-Cement Ratio: The water-cement ratio (w/c) is the ratio of water to cementitious materials in a concrete mix. It directly affects the workability, strength, and durability of concrete. Higher water-cement ratios generally result in higher workability but lower strength and durability. Optimal water-cement ratio control is essential to achieve the desired performance characteristics of concrete.

1.2.4. Curing Conditions: The curing conditions, including temperature, humidity, and duration, significantly impact the hydration process and strength development of cement. Proper curing is crucial for achieving optimal strength, durability, and overall performance. Inadequate or improper curing can lead to reduced strength, increased permeability, and potential durability issues.

1.2.5. Aggregate Properties: Aggregates, such as sand and crushed stone, constitute a significant portion of concrete volume. The properties of aggregates, including grading, shape, size, and surface texture, affect the workability, strength, and durability of concrete. Well-graded aggregates with appropriate particle shapes and sizes enhance the overall performance of concrete.

1.2.6. Admixtures: Admixtures are chemical additives added to concrete to modify its properties. They can enhance workability, reduce water demand, improve strength development, control setting time, or provide special characteristics such as air entrainment or water repellency. Admixtures, such as water reducers, superplasticizers, air-entraining agents, and mineral admixtures, can significantly impact the performance of cement and concrete.

1.2.7. Environmental Conditions: Environmental factors, such as temperature, humidity, exposure to aggressive chemicals, and freeze-thaw cycles, can affect the performance and durability of cement and concrete. High temperatures can accelerate the hydration process, while low temperatures can slow it down. Aggressive chemical environments can cause chemical reactions that deteriorate the cement paste and compromise the concrete's durability.

1.2.8. Manufacturing Process: The manufacturing process of cement, including the selection and processing of raw materials, grinding, and clinker production, can affect its performance. Factors such as kiln temperature, residence time, and cooling rate can influence the mineralogical composition and reactivity of clinker, impacting the cement's properties.

In conclusion, the performance of cement in concrete applications is influenced by several factors, including chemical composition, fineness, water-cement ratio, curing conditions, aggregate properties, admixtures, environmental conditions, and the manufacturing process. Understanding and controlling these factors is essential for achieving desired concrete properties, such as strength, durability, workability, and overall performance.

II. MATERIALS AND METHOD

The methodology adopted in this research consists of laboratory testing of different OPC brands. The cement brands analyzed in this study include:

- **DG Cement**
- **Kohat Cement**
- **Pioneer Cement**
- **Maple Leaf Cement**
- **Bestway Cement**

The tests were performed as per ASTM standards, as outlined in Table 1.

Table 1: ASTM Standards Used for Testing

Description	ASTM Standard
Sieve Analysis of Cement	ASTM C430
Consistency Test	ASTM C187/C187M
Setting Time	ASTM C191
Compressive Strength	ASTM C109/C109M
Slump Test	ASTM C143/C143M
Flexural Strength Test	ASTM C78

III. RESULTS AND DISCUSSION

1. Fineness Test

Fineness influences the rate of hydration and strength development in cement. The results of fineness tests for different cement brands are shown in Table 2 and Figure 1.

Table 2: Fineness of Cement Samples

Cement Brand	Fineness (%)
Bestway Cement	98.0
Maple Leaf Cement	93.2
DG Cement	96.0
Kohat Cement	95.6
Pioneer Cement	97.0

2. Consistency Test

The standard consistency of cement determines the water required to achieve a workable paste. The results are summarized in Table 3 and Figure 2.

Table 3: Consistency of Cement Brands

Cement Brand	Consistency (%)
Bestway Cement	29
Pioneer Cement	29
Maple Leaf Cement	29
Kohat Cement	29
DG Cement	29

3 Setting Time Test

The setting time of cement affects its workability and strength gain. Table 4 presents the initial and final setting times for different cement brands.

Table 4: Setting Time of Cement Samples

Cement Brand	Initial Setting Time (min)	Final Setting Time (min)
Bestway Cement	45	250
Maple Leaf Cement	38	230
DG Cement	43	210
Kohat Cement	39	240
Pioneer Cement	48	220

4 Compressive Strength Test

The compressive strength test is crucial for determining the load-bearing capacity of concrete. Table 5 provides compressive strength results at 7, 14, and 28 days.

Table 5: Compressive Strength of Concrete Samples (MPa)

Cement Brand	7 Days	14 Days	28 Days
Bestway Cement	22.5 MPa	28.2 MPa	35.4 MPa
Maple Leaf Cement	20.4 MPa	26.8 MPa	34.1 MPa
DG Cement	21.8 MPa	27.5 MPa	33.9 MPa
Kohat Cement	23.1 MPa	28.9 MPa	36.2 MPa
Pioneer Cement	21.0 MPa	26.5 MPa	33.2 MPa

IV. DISCUSSION

This study evaluated the performance of different OPC brands available in Pakistan based on laboratory tests. The results indicate variations in fineness, consistency, setting time, and compressive strength among the cement brands.

Key findings:

- Bestway and Pioneer Cement exhibited higher fineness values, which contribute to better early-age strength development.
- All cement brands met the ASTM consistency standard, ensuring good workability.
- Kohat Cement demonstrated the highest compressive strength at 28 days, making it suitable for high-strength applications.
- Maple Leaf Cement had the lowest fineness, potentially affecting its strength development rate.

Based on these findings, construction professionals can select suitable cement brands depending on specific project requirements. Future research should focus on evaluating the durability aspects of these cement brands over an extended period.

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