A COMPARATIVE STUDY: EFFECTS OF FINENESS OF CEMENT ON CONSISTENCY AND COMPRESSIVE STRENGTH OF DIFFERENT BRANDED CEMENT IN PAKISTAN

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Received: 15.03.2023 / Accepted: 02.04.2023 / Revised: 05.04.2023 / Available online: 31.05.2023

DOI: 10.2478/jaes-2023-0002

KEYWORDS: Ordinary Portland cement, Physical Properties, Fineness, Consistency, Compressive Strength

ABSTRACT:

Cement is one of the key components of concrete, and the qualities of a particular type of cement will affect the attributes of concrete made with that cement. The influence of variations in cement brand attributes that are available in Pakistan is examined in this study. Poor cement choice may affect how long a concrete building project will last. Fineness, cement consistency, concrete compressive strength, and mortar cube strength all grow with cement fineness since they all have a positive relationship with each other. This study aimed to investigate a few particular mechanical and physical characteristics of eight cement brands used in Punjab, Pakistan. The brands of cement that were compared were Kohat, Askari, Bestway, Paidaar, DG, Pioneer, Flying, and Fauji cement. The testing was carried out in a lab and according to ASTM guidelines. In contrast, Kohat had 5.17%, Askari had 8.67%, Bestway had 3%, DG had 2.67, Flying had 9.67, and Fauji cement had 6.33%, with only Paidaar above the allowed limits. Kohat and Paidaar cement's typical consistency was 30%, DG cement was 26%, and Bestway cement was 26%; all of them fell within the range of (26%- 33%). The 28-day compressive strength test results for DG cement and Bestway cement were 7787.74 Psi and 7225.17 Psi, respectively. The strength of Pioneer and Flying cement was found to be lower than that of other cement brands. Except for DG and Bestway cement, all eight brands of cement are used for all structural elements. Bestway cement is much superior for high-rise structures and heavy structural members. Consequently, by comparing the trace element concentration of various brands of Portland cement in Pakistan, the study evaluates the impact of trace element content on cement quality and concrete strength.

1. INTRODUCTION

Cement will still be a common building material for civil engineering projects in the future. The most important component of concrete was it. Unfortunately, Tarun, 7.36 × 106 ki per ton of energy is needed to produce one ton of cement (Duggal, 2009). Cement comes in two different varieties: hydraulic and non-hydraulic. An example of a non-hydraulic kind that might increase its strength without the need for water was the plaster of Paris (POP). Hydraulic cement hardens and sets in water, resulting in a stable final product. The most common example of this is regular Portland cement (OPC). The qualities of the completed Portland cement products are governed by the chemical and morphological composition of the clinker, gypsum, and other additives added during the grinding process. Given that the quality of the clinker may have a major impact on the quality of the cement, it is essential to have a fundamental grasp of these elements before thinking about the features of the cement.

According to (N. U. & A. K. Amin, 2009; Ghosh, 2014) contains the following four main cement minerals: Tetra calcium, dicalcium silicate (C2S), tricalcium silicate (C3S), and tricalcium aluminate (C3A) Examples of calcium compounds (C4AF) include alamino ferrite, each of which serves a specific function in the hydration process that transforms dry cement into hard cement paste. (MUNIR & Atif, 2009).According to M. Adil et al., the compound composition of C3S, C2S, C3A, and C4AF was calculated using the cement's chemical analysis. The amounts of Al2 O3 and SO3 in Paidaar and Fauji cement were found to be higher than allowed. Sulphates in cement enlarge as there is additional SO3. Also, research of four essential components (C3S, C2S, C3A, and C4AF) showed that Paidaar, Lucky, and Fauji cement had less C3S and more C2S, which results in it having the lowest strength when compared to other cement brands. The chemical compositions of several brands were examined, and the Paidaar, Lucky, DG, Fauji, and Bestway cements all fell within the acceptable ranges (Muhammad Adil Sultan et al., 2023).

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Cementitious materials have been used in construction projects for as long as there has been humankind. Cement is essential and required in the construction of many constructions, including buildings, bridges, tunnels, etc. Failure of buildings and construction projects due to poor-quality cement can result in the loss of lives and property. Physical tests on three brands of Portland cement (Dangote cement, Elephant superset cement, and Elephant Lafarge cement) sold in Kwara state, Nigeria, showed that the fineness obtained for Dangote, Elephant superset, and Elephant Lafarge cement are within the standard specification of 10% maximum was up to the statutory value of 3.1 minimum in recent years, Nigeria has seen several instances of fallen structures. Only in the year 2006, around thirty persons were killed in four identical incidents that occurred in residential complexes in Ebute Metta, Lagos (Yahaya and Muibat D, 2009). Yahaya and Muibat claim that the usage of subpar materials is the main reason why buildings frequently collapse in Punjab. As cement is a key component of building construction, attention has been focused on the product's quality assurance evaluation.

In this work, it was analyzed how new sources of SCMs, such as calcined diatomite (CD), calcined bentonite (CB), and silica fume (SF), shear thicken sustainable cement paste (SCP) under the control of specific physical parameters. Considering the ratio (w/b) (PCE and PNS), it was found that high anhydrous particle concentrations, irregular or circular shapes, large grain sizes (a few tensmicrometerstres), and a deflocculated grain condition all contributed to the ease with which shear thickening occurred in suspensions (H. Kemer et al., 2021).

Cement is of interest to scientists, engineers, and other professionals because of the expanding need in the building sector. They are interested in its standards and quality. According to the construction sector, cement is an essential element of concrete construction (N. U. & A. K. Amin, 2009).

The superiority of the construction materials must be guaranteed to debate the sustainability issue with any concrete structure. Hence, understanding the mechanical and physical characteristics of cement is essential for the production of concrete in practical applications. Concrete is an essential component of a building, and its strength and longevity rely on several factors, including the caliber of the cement (Mohammed et al., n.d.). By substituting a portion of cement with various amounts of calcined clays, our work intends to characterize the physico-chemical properties as well as the structural (TGA-DSC) and microstructural (SEM) features. The physicochemical properties have been examined in an experimental investigation. The dose needed for superplasticizer tends to rise with the inclusion and replacement of clay for a portion of the cement (N. Mesboua et al., 2021).

Cementitious materials have been used in construction projects for as long as there has been humankind. Cement is essential and required in the construction of many constructions, including buildings, bridges, tunnels, etc. Failure of buildings and construction projects due to poor-quality cement can result in the loss of lives and property. Cement quality must be assessed to ensure that it meets the requisite acceptable standard (Karakaş, 2020). Cement used during assembly must have specific qualities, including fineness, setting time, and strength, among others, to properly improve building structure. The cement will function successfully and within the restrictions given by ASTM. To ensure the quality of cement, many tests are conducted by the criteria of the relevant standards (Asef et al., 2022).The several types of ordinary Portland cement (OPC) from the Punjab province offered in Pakistani markets have somewhat different physical and mechanical traits, impacting their physical characteristics.

For this comparative research, eight OP cement brands were chosen, including Kohat, Askari, Bestway, Paidaar, DG, Pioneer, Flying, and Fauji Cement. The physical and mechanical evaluations of commonly used regular Portland cement will be looked at in this study. The physical characteristics are fineness, typical paste consistency, and cement strength. In addition, the number of trace elements found in the various brands of Portland cement supplied in Pakistan will be analyzed, and their effects on the strength of concrete and cement quality will be assessed. The study's goal was to look at the mechanical and physical characteristics of brands of regular Portland cement sold in Punjab, Pakistan. So, one of the study's main goals is to establish criteria for the essential properties of regular Portland cement to create a categorization framework that would enable users and purchasers to choose among a variety of cement types.

1.1 Chemical Properties of Portland cement

Raw materials including iron oxides, silica, calcium, aluminum, and other components are heated at temperatures between 1200^0 and 1400^0 C to produce Portland cement Chemical reactions that occurred inside the partially molten bulk produced the four main cement components (table 1) (N. -Amin & Ali, 2010).

Compound	Abbreviation	Chemical formula	Typical concentration %
Tricalcium silicate	C_3S	$3CaO•SiO_2$	60 to 70
Dicalcium silicate	C_2S	$2CaO•SiO_2$	10 to 20
Tricalcium silicate	C_3A	$3CaO•Al2O_3$	5 to 10
Tetra calcium Alamino-ferrate	C_4AF	$4CaO•Al_2O_3$	3 to 8
		•Fe2O3	

Table 1. Portland cement's major mineral constituents

The two chemicals mainly responsible for the cement's strength are C3S and C3A. High C3S percentages (low C2S percentages) cause the concrete to produce an excessive amount of heat during the curing process. The opposing combination of higher C2S and lower C3S increases strength more gradually (took 52 days to complete versus 28 days) and generates less heat. By adding CaSO4 to the completed product, C3A's unwanted heat production and rapid reaction rate may be reduced. Fe2O3 can change C3A into the more desirable C4AF before heating, but it also prevents the formation of C3S. C4AF makes cement more resistant to seawater, which causes a delayed reaction that emits less heat.

Physical properties of Portland cement

1.2.1 Fineness: The fineness or crystalline size of Portland cement affects the rate of hydration, which affects the pace of strength development. Smaller particle size increases the surface area available for interactions between water and cement. For the first seven days, more fineness frequently influences strength.

1.2.2 Consistency of standard paste: When a visit plunger with a 10 mm diameter and 50 mm length can puncture the mold to a depth of 33-35 mm, the cement paste is said to be of standard consistency.

1.2.3 Compressive and tensile strength of cement: The most crucial characteristic of cement is strength. The grades specified on the deferent types of cement bags given below (Figure 1), for 53 grades OPC, really represent the cement's strength. In plain English, 53 Grade OPC Cement means that the up to 10,000 Psi (53 Mpa) 28-day compressive strength of cement-mortar cubes manufactured from that cement. Instead of utilizing a smooth cement paste, the strength of cement is evaluated using hardened cement-sand mortar cubes. Definitions of cement strength in terms of compression and tensile are given. Usually, compression tests are run. The amount of water in the cement, the amount of cement to sand, the kind and grade of the sand, the mixing technique, the size and shape of the specimen, the conditions for curing, the rate of load capacity, and the age of the sample may all affect the outcome.

Figure 1. Deferent Types of Cement Bags

1.3 The impact of cement fineness on the characteristics of concrete

(Celik, 2009) studied the relationship between cement strength development and surface area and particle size dispersion. Based on his observation that there is a correlation between variation in cement fineness and cement strength based on cement particle sizes, he concluded that fineness significantly affects two-day strength. The concentration of larger particles has a stronger influence on strength at later ages than does the concentration of smaller particles. Celik also looked at the effects of cement surface area, chemical composition, and particle size distribution on the development of cement strength. He established a relationship between the distribution of particle sizes, chemical composition, and surface area, and then used simulation modeling to optimize clinker grinding. Researchers studied how cement particle transport affected the functional properties of materials manufactured of Portland cement (Aginam et al., n.d.). While coarse grains practically set at a lower quantity of moisture, he indicated that they take longer to set. They will initially release heat more slowly and gain strength more gradually than finer cement. The authors also argued for the use of coarser cement in the production of high-performance concretes. (McCarter, 1989) examined numerous techniques for determining cement particle size distribution and contrasted the most important elements of each.

1.4 Variations in cement affect compressive strength

The degree of deformation of the concrete, the properties of the cement, the water-to-cement ratio, the curing procedure, and the phase of the concrete are all important factors in influencing the strength of hardened concrete. The concrete gets stronger over time. The grading type and mix proportions of the aggregate virtually have no impact on strength. These factors affect how much water is required to produce a certain degree of workability, which indirectly impacts strength. While the kind of aggregate and amount of cement used dictate the improvement in compressive strength for a given lightweight aggregate, an average 10% increase in cement content will only result in around a 5% improvement in strength (Clarck & John L., 1993).

1.5 Elements affecting the strength of the water-to-cement ratio

"Water cement ratio" refers to the ratio of cement volume to mixing water. The ratio of cement to water can be used to gauge the required strength of a concrete mixture. With a lower ratio, the combination becomes stronger. A rich mix of concrete has a higher strength since more cement is used in it, but this is also because less water and more cement might be used in the mixture.

2. RESEARCH METHODOLOGY

This project's goal was to examine the mechanical and physical characteristics of three different varieties of common Portland cement used in Punjab, Pakistan (Kohat, Askari, Bestway, Paidaar, DG, Pioneer, Flying, and Fauji cement).

Materials

2.1.1 Cement: Kohat, Askari, Bestway, Paidaar, DG, Pioneer, Flying, and Fauji Cement were the three cement brands that were selected. The cement brands chosen were widely available in the research area's market. In addition, they represent more than 70% of all cement brands used in Punjab, Pakistan's construction industry. A special effort was made to stop certain cement brands from being re-bagged outside of the mill.

2.1.2 Fine aggregates: The caliber of the sand used determines the quality of the concrete made using any brand of cement. Sand from Lawrencpur was utilized as the fine aggregate. Analysis of the Lawrencpur Sand Sieve (Table 2) displays observations of Lawrencpur sand along with computations (Table 2, Figure 2). For each sieve, data from the grain-size distribution and the ASTM standard's limiting values were shown on a semilogarithmic scale in Figure 2.

Weight of sample:1000 g							
Sieve No.	ASTM Limits for Fine Aggregate			Observations & Calculations			
	Passing Limits			Wt. of Agg. Retained	Wt. Retained % age	Cumulative Wt. Retained	Cum. % age Passing
	Sieve Size	Min. %	Max. %				
#4	4.75	95	100	0.15	0.015	0.015	99.985
#8	2.36	80	100	25.1	2.51	2.525	97.475
#16	1.18	50	85	69.9	6.99	9.515	90.485
#30	0.6	25	60	234.45	23.445	32.96	67.04
#50	0.3	10	30	427.7	42.77	75.73	24.27
#100	0.15	2	10	187.05	18.705	94.435	5.565
Pan	-	-	-	55.95	5.595	100.03	-0.03

Table 2. Calculation of Sieve Analysis of Lawrencpur Sand

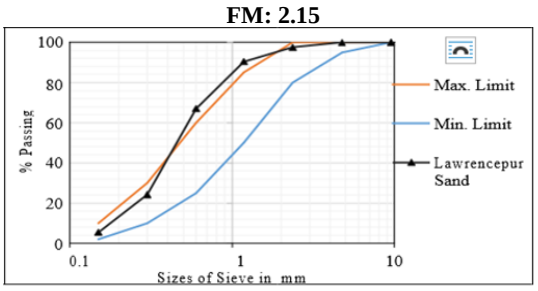

Figure 2. Sieve Test Result of Lawrencpur Sand

2.1.3 Water for curing: The lab's water faucet was utilized to provide the water for the test. It was employed in the creation and curing of concrete. The process of curing encourages the hydration reaction of cement paste and calls for the regulation of ambient temperature as well as the passage of moisture into and out of the concrete. After the concrete samples were placed, water started to evaporate from the concrete surface. This depends on the relative humidity and temperature of the air in the area. Jute bags were used to cure the research sample castings.

2.1.4 Tests: The following tests were run on each brand of selected cement. Data Collection Technique (Table 3). The following is how the tool will be used:

2.1.4.1 Experiment-1: Sieve B.S.200 (90 Micron Sieve), Three beam balance, Trowel, Sieve Brush, Spatula.

2.1.4.2 Experiment-2: Glass plate, weighing scale, measuring cylinder, Vicat equipment with Vicat plunger and Vicatmould, and rubber gloves.

2.1.4.3 Experiment-3: weighing scale, graduated cylinder, Trowel, non-porous plate, sieve set, trowel, testing device, vibrating table, and tamping rod.

Designation	Fineness no.	Consistency no.	Compression no.			Total tested samples
			3	7	28	
KOHAT	3	3	3	3	3	15
ASKARI	3	3	3	3	3	15
BESTWAY	3	3	3	3	3	15
PAIDAAR	3	3	3	3	3	15
DG	3	3	3	3	3	15
PIONEER	3	3	3	3	3	15
FLYING	3	3	3	3	3	15
FAUJI	3	3	3	3	3	15
						120

Table 3. Sample Collection Details

2.2 Specimen preparation and test setup

Schematic diagrams of sample preparation and test setup are provided. According to the established standards for cement fineness (ASTM C184), normal consistency (ASTM C187), compressive strength of cement mortar (ASTM C109), and ASTM C191 tests were conducted in this study (ASTM, 2019). Locally available fine and coarse materials that satisfy ASTM criteria were utilized to make cement mortar and concrete (Testing and Materials, 2004) and compressive strength (cylindrical). Cubes mortar samples were tested for compressive strength at ages 3, 7, and 28. The total number of samples analyzed for this inquiry was shown as a matrix in Table 3.

Figure 3. During the Casting of Cement Cube

3. RESULTS & DISCUSSIONS

According to the experimental results presented in Tables 4-6, different cement brands have different percentage contents of the various types of cement under study. According to the variance test, there were significant differences in the values of their physical composition when the chemical composition and physical features (dependent variables) were modified jointly (independent variable).

3.1 Fineness test

By the requirements of the ASTMC191 (2004), Table 4 shows that the average percentage of cement that has gone through a 200 No. (90microns) sieve is 97.0% for DG and Bestway cement, 95% for Kohat cement, and 91% for Askari cement. Only Paidaar did not meet the required passing percentage. The total cement surface area is a representation of the material that was available for hydration since hydration starts at the surface of the cement particle. Because of this, the fineness of the cement particles affects how rapidly they hydrate; hence, a high fineness was required for a rapid rise in strength. Nevertheless, grinding to a finer consistency has a high cost, and the finer the cement, the quicker it will deteriorate in the presence of oxygen.

As opposed to coarse cement, however, fine cement doesn't leak as much. The amount of gypsum needed for effective retardation grows with cement fineness because more C3A was accessible for early hydration in finer cement (Figure 4).

Branded Cement	Kohat	Askari	Bestway	Paidaar	DG	Pioneer	Flying	Fauji
Passing %	95	91	97	89	97	90	90	95

Table 4. Fineness Test Results in %

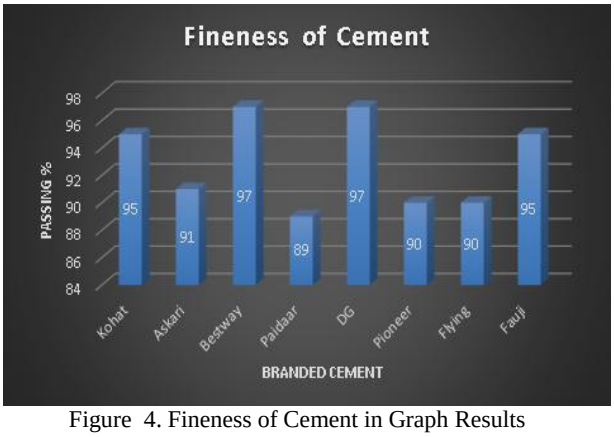

Figure 4. Fineness of Cement in Graph Results

3.3 Consistency of standard paste test

Table 5 reveals that for Kohat and Paidaar cement, 26% for DG cement, and 26% for Bestway cement, the average water-cement ratio of standard consistency was 30%, all of which fit within the range (26%-33%) defined by the ASTM C 187 (British standard-12) for ordinary Portland cement. Nonetheless, several samples of Askari, Paidaar, Pioneer, and Flying cement have water-cement ratios exceeding 33% (Figure 5). For the Le Chatelier soundness test, the initial and end-setting periods were to be calculated using tidy cement paste with a homogeneous consistency. It was crucial to take the significance of the consistency test into account when determining how much water was required to make a standard paste.

Branded Cement	Kohat	Askari	Bestway	Paidaar	DG	Pioneer	Flying	Fauji
Consistency Avg %	28	30	27	30	26	30	29	29

Table 5. Consistency Test Results w/c ratio in percentage

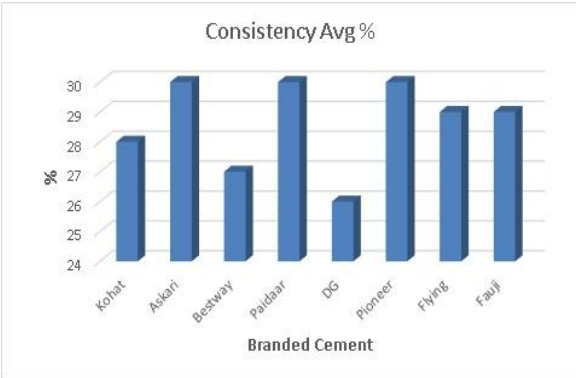

Figure 5. Avg % Consistency of Water Cement Ratio Graph

3.2 Impacts between fineness and consistency

The degree of density or stiffness is shown by the cement's consistency. It is the amount of water required to turn a certain amount of cement into cement paste with a defined consistency. At increasing fineness, cement's specific surface area rises. As a result, more surface area may be covered by the same amount of cement. More water will thus be required to produce cement paste with the required consistency.

3.4 The compression strength of cement

The results of compressive testing for the eight brands of cement are shown in Table 6. For the concrete test, the highest strength at 28 days was 7787.74 Psi for DG cement and 7225.17 Psi for Bestway cement. The findings demonstrate that concrete test strength rises as curing time increases, as would be predicted for a cube mortar. Also, it was found that, as anticipated, the compressive strength after 7 days after curing was between 65% and 70% of that at 28 days (Figure 6). This complies with ASTM C 109's requirements.

The hardened cement's mechanical strength was the property that was perhaps most obviously required for structural use. The cohesiveness of the cement paste, its adherence to the aggregate particles, and to a lesser extent the strength of the aggregate itself all go towards making mortar or concrete strong. Concrete samples, mortar samples, and cement paste samples can all be used to gauge the strength of cement. But which study employed the ASTM-recommended cement mortar method? The properties of the aggregate used affect how much concrete is utilized in the test. Although it was easier to create smooth cement paste when using cement paste for the test, cement sand was a better indication of cement strength.

Concrete also hardens and gets stronger as it hydrates. Hydration takes a very long time to complete. It starts rapidly and then gradually slows down. The entire strength of concrete couldn't be ascertained for some years. The specification-drafting authority concluded that all concrete should be tested after 28 days since doing so would not be practical. At this age, most of the hydration has already taken place. Every sample was made with a 5.08 x 5.08 x 5.08 cm cement cube.

Branded Cement	Kohat	Askari	Bestway	Paidaar	DG	Pioneer	Flying	Fauji
3 Days (Psi)	1665.18	1140.13	2173.74	925.41	2171.49	937.23	1088.18	1290.14
7 Days (Psi)	4186.4	3490.14	4733.21	2327.7	5292.21	2459.15	3002.96	3735.79
28 Days (Psi)	7000.15	5800.02	7225.17	4264.03	7787.74	4785.72	5575.37	6025.04

Table 6. Average Compressive Strength (pound per square inch). Test Results of deferent branded Cement

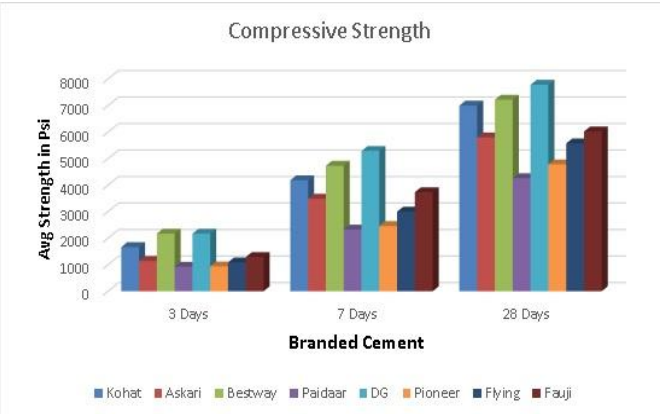

Figure 6. Average Compressive Strength (Psi) Test Results Graph

3.5 Fineness impact on compression strength of cement

As cement's fineness was enhanced, its compressive strength also rose. This can be explained by the rise in the minerals C3S (tricalcium silicate) and C2S's quick hydration kinetics (dicalcium silicate). The primary minerals that ensure the development of strength are these two stages. The increase in cement fineness had a noticeable impact on the concrete's compressive strength. This indicates the critical role that granulometry-mechanical activation or improved grinding-plays in the quick and complete hydration of cement. The increase in mechanical response varies based on the kind of cement and the fineness (mechanical activation). The kind and quantity of the mineral intake determine this. When cement paste's fineness improves, the time it takes for it to cure or harden decreases.

4. CONCLUSIONS

Based on the results of the tests carried out in this project, the following conclusions can be made:

1. That the eight brands of ordinary Portland cement used by Lafarge Kohat, Askari, Bestway, Paidaar, DG, Pioneer, Flying, and Fauji cement conform to the ASTM Standard [PS 232, 2008] standards for ordinary Portland cement in terms of their physical qualities.

2. Paidaar and Pioneer cement from them had residue of more than 10% as stipulated by the ASTM Standard C 184-2004, with Kohat having 5.17%, Askari 8.67%, Bestway 3%, DG 2.67%, Flying 9.67%, and Fauji cement 6.33%, and only Paidaar was not within limitations.

3. The ASTM standard C187 specifies a range of 26-33% for the water-cement ratio of standard consistency for Kohat, Bestway, and DG cement. The percentages for Kohat and Paidaar cement, DG cement, and Bestway cement all fall within the range of 26% to 33% specified by ASTM C 187 (British standard-12) for regular Portland cement. Yet, several samples of the cement Askari, Paidaar, Pioneer, and Flying had a consistency water cement ratio that was more than 33%.

4. Compressive testing for the eight cement brands revealed that Bestway cement had a maximum strength of 7225.17 Psi after 28 days, whereas DG cement had a maximum strength of 7787.74 Psi. The strength of Pioneer and Flying cement was found to be lower than that of other cement brands. The findings demonstrate that, in the concrete tests, strength improves during the course of curing, as is typical for cube mortar. Also, it was found that, as anticipated, the compressive strength after 7 days after curing was between 65% and 70% of that at 28 days. This complies with ASTM C 109's requirements.

5. For high-rise structures and hefty structural components, all cement brands used for structural members aside from DG and Bestway cement are far superior. Moreover, concrete blocks and pavement are made with Paidaar, Pioneer, and Flying cement.

5. RECOMMENDATION

It is advised that DG, Askari, and Bestway cement are the best in terms of strength and are good for concrete work. Pioneer, Paidaar, Flying, and Fauji cement is second and is also recommended; it is good for concrete work such as columns, beams, slabs, and bridges, among other things, and is stronger, more durable, and easier to work with than DG, Askari, and Bestway cement. For the chemical minerals of the aforementioned branded cement's mechanical and physical qualities, more research is necessary.

6. ACKNOWLEDGEMENTS

The technical personnel of the Concrete Laboratory of the Civil Engineering Department at the Punjab University of Technology Rasul (PUT) also contributed to the preparation, curing, and testing of the samples, which the authors warmly recognize. There is no financial support available to the authors.

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