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A comparative Analysis of Compressive Strength of Different Cement Brands Locally Available in Pakistan

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Abstract: **Concrete is a compressible substance that is used to bear compressive loads in construction works. It is composed fine and coasrse aggregates, cement, and water. Its workability and strength is mostly dependent on the properties cement. This paper suumarizes the findings of an experimental inquiry to understand the qualities of five brands of cement existing in Pakistan. The chemical composition of the used brands and suggested values were in accordance with PS-232/2008 and ASTM C150. Concrete samples made with each brand of cement were evaluated for compressive strength using an ASTM C-39, Universal Testing Machine at curing ages of 7, 14, 21, and 28 days. Concrete, cement sand mortar, and cement sample compression tests were conducted. Concrete cylinders with specific strengths were produced and tested in compression. In addition, compression tests were performed on cement sand mortar cubes. The experimental results along with the suggested values given by the standards, were used to compare the properties of different cement brands. Only two cement brands (Best Way and Maple Leaf) reached the acceptable compressive strength at the 28-day age limit. The mechanical test findings for mortar and concrete were supported by the compound composition and cement fineness used in the process.**

Keywords: **Concrete, Compressive Strength, Cement Brands, Paksitan, Construction Industry**

I. INTRODUCTION

Throughout the world, concrete is a widely utilized building material for both structure and non-structural usage. Bert-Okonkwor **[1]** has defined concrete as a mixture of Portland cement, water, air and aggregate. Sharma **[2]** continues by noting that the ingredients of concrete include cement, water, fine and coarse aggregates, and additives (if necessary) in a heterogeneous mixture. ASTM C 150 **[3]** has defined OPC as "hydraulic cement (cement that not only hardens by reacting with water but also forms a water-resistant product) produced by pulverizing clinkers consisting primarily of hydraulic calcium silicates, usually containing one or more forms of calcium sulphate as an intern ground addition." In a broad sense, cements are substances that are cohesive and sticky that can combine solid matter particles to form a long-lasting mass with enough strength **[4, 5, 6]**. The major anticipated qualities of cement in building, according to Duggal **[7]** are the permanence of construction, load bearing capacity, and rate of setting according to the demands of the work. Cement is an important component of the concrete matrix; when combined with water, it works as a binding agent. Lime silicates and aluminates make up the majority of cement. The quality of the cement has a big impact on the properties of concrete. Concrete resists fire and has a high compressive strength **[8, 9]**But since tensile strength only

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makes up 10% of compressive strength, current research attempting to improve concrete's overall strengths has focused on this property **[10]**. A number of researches **[11, 9]** have highlighted the usage of poor ingredients, particularly concrete, as the basic reason for builfing failure in Nigeria. Gollu et al. **[12]** said that inappropriate, unreliable, sensitive, and polluted aggregates are among the causes of concrete failure in structures.

Ajagbe and Tijani **[13]** mentioned that assessing concrete aggregate is critical for overcoming the issue of structure failure in a certain climate. Compressive strength is the most important mechanical property of concrete. It is obtained by the measurement of a 28-day-cured concrete specimen. The strength of concrete is affected by a number of variables, including water content, cement strength, aggregate quality, and the ratio of cement to water **[14]**. Joseph and Raymond **[15]** considers that concrete gains 26% of its 28-day strength on average in a single day and 85% in 21 days, it may be concluded that concrete gains strength more quickly when it is young rather than as it ages. Shetty **[16]** according to reports, aggregates and paste are the two most important components influencing concrete strength. Abdullah, **[17]** said that the kind of coarse aggregate and the integrity of the cement paste are the main factors influencing the strength of the concrete in the interfacial zone. Portland cement paste's binding property comes from a chemical interaction between cement and water **[18]**.

Yahaya, et, al., **[19]** have investigated the compressive strengths of four cement brands: Ibeto cement, Eagle cement, Unicem, and Ordinary Dangote. Eagle cement was found to have the maximum compressive strength after 28 days. An other study by Bhamere, S. **[20]** focuses on five cement brands: Dangote 3X, Ibeto, Purechem, Unichem, and Elephant (superset). Cement quality varies between producers owing to differences in raw material qualities or production processes. These modifications can drastically impact the qualities of mortar or concrete when employing various cements. The main qualities of cement that are expected in construction are strength, durability of the structure, and setting rate that is suitable for the task at hand **[21]** **[4]**. Cement is widely utilized in construction and building projects. However, when choosing which brand of cement to use in their projects, most construction firms base their decision on availability, cost, and experience. As a result, quality control is now a big deal and essential part of making cement **[22]**.

Pakistan's building sector is not structured scientifically **[23]**, consequently, quality difficulties are frequently encountered during building. The use of building materials with questionable properties is one of the main problems with Pakistan's lack of a techno-legal framework. This can lead to poor construction since it does not meet the design standards. Because various sections of country are in earthquake prone zones, poor building is a serious worry in terms of life safety. The Pakistani people will never forget the devastation caused by the 2005 Kashmir earthquake. Approximately 73 000 persons died and at least 69 000 were injured as structures fell during this earthquake. Furthermore, the loss of 450 000 buildings resulted in the homelessness of about 2.8×106 persons **[24]**. While building designs in Pakistan are based on (ACI 318R-02, 2002) **[25]** because of many factors including inaccurate test findings, inconsistent material quality, and so forth, designers often have little effective control over the materials used during construction. Consequently, it is uncertain if these structures can endure the forces envisioned in the design.

The study will employ aggregate of the same size, cement of the same strength, water content, and water/cement ratio to determine how cement quality impacts concrete strength. The study's conclusions would help prevent the use of subpar aggregates as source materials, which might lead to structural collapse, and provide information on the concrete strength of various combinations of coarse and fine aggregates. This research study presents the results of an experimental investigation on the characteristics of several cement brands that are sold in Pakistan. Physical testing were done using the applicable standards. The latter comprised concrete and cement-sand mortar strength tests. Based on the test findings, potential influencing variables for variances in the strength-related characteristics of the cements used have been discovered.

Kolver K. and Roussel N, **[26]** described the properties of fresh concrete with interest in the workability and rheological properties, Time effect: Thixotropy, that is, structuration of concrete at rest and de-structuration upon initiation of flow during mixing and placing in the formwork, Slump loss, setting time and Hydration Stability of fresh concrete, bleeding and segregation. They also described hardened concrete properties as primarily compressive strength and durability while other secondary properties include: tensile strength, shrinkage, creep, crack resistance and thermal properties. Anejo J. A et. al., **[27]**, conducted a comparative study of selected cement brands in Nigeria at the time and related five different brands in terms of their fineness, consistency, soundness and compressive strengths. In their observation all the brands achieved the standards for the class 32.5 cement. Win M. T., et al., **[28]**, In Myitkyina City, we compared the physical qualities of three different cement brands. They focused on specific gravity, fineness, soundness, setting times and compressive strengths. Their observation was that while all brands attained values within possible limits, one brand was superior to others in all parameters tested.

Bamigboye G. O. et al., **[29]**, during the study, the compressive strength of concrete produced by five different cement brands in Nigeria was evaluated. They investigated the concrete ingredients and tested concretes in terms of setting times and compressive strengths for two different mix ratios concurrently. Their observation was that while all but one brand of cement attained the minimum cube strength, Compressive strength increased gradually from early to late age cure. Tarek U. M. et al., **[30]**, investigated several cements used in Bangladesh in terms of normal consistency, bleeding, beginning and final setting periods, and compressive strengths.

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They observed a linear correlation between 28th day compressive strengths and final setting times where the former can be predicted with knowledge of the early strengths from quick laboratory test. Moreover, Bamigboye et al. **[29]** has used different brands of Portland cement to make concrete in 1:2:4 and 1:3:6 mix ratios, with curing times of 3, 7, 14, 21, and 28 days, respectively. No additives were employed in the mixture. The experiments comprised a vicat test to determine the setting time for various cement brands, a compressive strength test for hardened concrete, and a slump test for new concrete.

Mohammed **[31]** conducted study on the various cement brands typically utilized in Bangladesh. Investigating the common causes of concrete structure deterioration in Bangladesh, common problems at construction sites that cause early deterioration in Bangladesh, the mechanical properties of concrete made with different aggregates available in Bangladesh, a review of the different cement brands sold in Bangladesh, and the recycling of demolished concrete as coarse aggregate for new construction projects were the objectives of the research. Sam et al. al., **[32]** have studied the chemical qualities of cement brands in Ghana, including Dangote cement. According to the findings, two of the assessed cement brands satisfied worldwide standards. According to Adewoke, et al **[33]** The amount and quality of cement play a significant part in determining concrete's compressive strength. The main component of concrete's strength is cement, which joins the fine and coarse aggregate to form a stiff, weight-bearing mass. Bert-Okonkwor **[34]** suggests that the variables that could affect the concrete's strength include the water-to-cement ratio, the type of aggregate used, the aggregates' surface texture, the type and brand of cement used, the composition of the actual compound included, the age of the concrete, the fineness of the cement, and the degree of hydration. Sulymon et al. **[35]** pointed that it has been discovered that the sources of gravel significantly affect the split-tensile, flexural, and compressive strengths of concrete.

E. Sutandar et. al., **[36]** has investigated the effects of several cement brands on the mechanical and physical characteristics of reactive powder concrete (RPC) and discovered that PCC Conch is the best (optimal) brand of cement with regard to these characteristics. It is feasible to conclude that one of the PCC cement brands has better mechanical and physical qualities than the PPC cement brand based on the cement brands that are offered on the Indonesian market, which contain both PPC and PCC cement kinds. Every brand of PCC-type cement produces compressive strengths more than 52 MPa. Therefore, it is suggested that a PCC cement brand be used for making RPC concrete. Sahu, A., **[37]** After analyzing the compressive strength of various brands of cement available in Chhattisgarh, they concluded that strength development in Ultratech 43 grade Ordinary Portland cement and Ultratech 53 grade Ordinary Portland cement is maximum after 28 days compared to the rest of the 43 and 53 grade cement available in the market. Almabrok, Magdi & Khashin, Naser. **[38]** evaluated the performance of several cement brands regularly used in Libya and determined that, based on compressive strength data, all cements might be appropriate for routine building works where strength is crucial. Al Borge Egypt cement could be preferred.

Anejo, J. A., **[39]** has compared the physical characteristics of a few chosen cement brands in Nigeria. This study set out to look at some of the physical characteristics of certain Nigerian-made cement brands. Ashaka, Sokoto, Dangote, Rhino, and Elephant are the selected brands. With a minimum compressive strength of 33.5N/mm2, every product put through testing fits within the grade 32.5 categorization. However, after 28 days, elephant cement was able to reach a strength of 23.5N/mm^2, suggesting that it is not appropriate for structural concrete operations. Shahnaz et al, **[40]** has conducted a quick investigation to find out whether certain Pakistani common Portland cements meet ASTM composition requirements. The majority of cement's chemical composition, as determined by established processes, was found to be within acceptable limits. However, the discrepancies in cement ingredients between brands are attributable to changes in quality control setups at different cement factories. Arimanwa, et al **[41]** investigated the impact of regular Portland cement's chemical composition on the compressive strength of the concrete. The concrete produced with Cement Sample IBETO has the highest 28-day compressive strength, measuring 27.96 N/mm2. According to the study, concrete with similar compressive strength ratings is produced by cement with the same chemical characteristics. When it comes to resistance to compression and the rate at which strength develops, it recommended Cement Sample B as the best choice out of all the options evaluated. Rafi, M. M., **[23]** investigated, via experiments, the chemical and physical characteristics of cements made in Pakistan. Every one of the seven cement brands met PS and ASTM specifications and shared the same chemical makeup. Cement Brand B has a greater content of silicate (C3S and C2S) than the other cement brands. Because power cement contains more silicate, it has a stronger 28-day strength. This was the only brand of cement that met the necessary strength requirements. Different types of cement produced concrete with lower compressive strengths than required in all three strength categories.

II. MATERIALS AND METHODS

Five cement brands were chosen for analysis: Lucky Cement, DG Khan Cement, Best Way Cement, Maple Leaf Cement, and Pak Land Cement. The cement brands were chosen because they are widely available in the market at the research site. These are the most often utilize brands in Pakistan's building sector. They were obtained on the open market in Islamabad. An effort was taken to guarantee that the brands of cement purchased were not re-bagged outside the mill. Okoli et al**.** [42] requires that the physical characteristics of Portland cement samples be assessed for soundness, fineness, compressive strength, and setting time. Every one of these elements affects how well cement performs in concrete. The cement's fineness affects how quickly it hydrates. Similar to

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the amount of cement used in concrete, it similarly affects the placeability, workability, and water content of a concrete mix. All of these cements were similar varieties of regular Portland cement, ASTM C150 [43].

Cement samples were tested in the laboratory for normal consistency (ASTM C187) [44], initial and final setting time (ASTM C191) [45], compressive strength (ASTM C109) [46], fineness of cement (ASTM C184) [47], bleeding (ASTM C 143) [48], and bulk unit weight (ASTM C 128) [49] as soon as the cement bags were picked up from the market. The compressive strength was measured using locally accessible Lawrence Pur standard-graded sand.

The quality of the sand used determines the grade of concrete that may be made with any brand of cement. The Lawrencepur/Harrow sand, which originates in the Lawrencepur District of Attock, Punjab, Pakistan, was utilized as the fine aggregate. The Indus River produces sand that is of exceptional quality and strength, which is why it is often utilized in the Punjab region. It had no silt or harmful elements, and the particles were no larger than 5 mm. The sieving technique was used to determine the particle size distribution of Lawrencepur/Harrow sand (ASTM C 136, 2001) [44]. The 20mm size is the most popular variety of coarse aggregate used in construction projects. For the coarse aggregate, crushed, angular, graded granite with a maximum size of 20 mm was utilized. There was no dust or other impurity in the supply. Both aggregate types underwent sieve examination in accordance with ASTM C33-03 [45]. Abruckle, [46], specifies that water used to mix concrete must be suitable for drinking or come from a source that has been approved. The water used in the experiment was taken straight from the lab tap. It was employed in the production as well as the curing of concrete.

III. RESULTS & DISCUSSIONS

The outcomes of the finess test by taking 50g of each brand of cement for three times has given that the Maple Leaf Cement and DG Khan have a heighest finess ratio with a residue of 5.83%. While Bestway Cement has a residue (6.66%), Lucky Cement (6.83%) and Pak Land Cement has a heighest value of (7%) which is comparitiveely less fine than others.

By combining 400g of cement sample with an exact amount of water and properly mixing the mixture to make a consistent cement paste, the consistency of the cement was evaluated. The gauging period lasted three to five minutes. Using a trowel, the cement paste was correctly leveled inside the Vicat mold. The Vicat device's plunger was gradually lowered until it made contact with the cement paste's surface. After that, the plunger was let go, enabling it to fall into the paste. After the plunger was released into the paste, the gauge's reading was recorded. Until the gauge read between 5 and 7 mm, the above process was repeated with new cement samples and varying water volumes.To the first decimal point, the water content was given as a percentage of the dry cement weight.

Lucky Cement gives a satisfactory result of Depth of Penetration (5mm) at weight (400g), weight of water (115ml), W/C Ratio (28.75%). While with same input parameters the other brands DG Khan Cement, Best Way Cement, Maple Leaf Cement and Pak Land cement havePenetration values 6mm, 5mm, 5mm, 6mm respectively. Even after reducing each specimen's water content by five milliliters at a time, it was discovered that no cement brand could provide the required outcomes with water amounts of 125 and 120 milliliters. Nonetheless, with a standard consistency of 28.75% per sample, all samples reached the required depth of penetration at the 115ml water volume. In summary, the plunger penetration depths of all tested cement brands fell between 5 and 7 mm, as specified by the relevant British Standard, indicating that the cement brands were normal.

According to the tests done on the cement samples, each sample's unique expansion fell between 3 and 5 mm. The two cements with the highest rate of expansion, maple leaf and best manner, are 5 mm apart. Conversely, tests revealed that Pak Land cement had the lowest cement expansion rate, measuring at 3 mm, while DG Khan and Lucky cement had respective expansion rates of 4 mm. The examined cement samples all meet the necessary requirements, which state that each cement sample's individual expansion cannot exceed 10 mm. As seen in Table 1, Pak Land cement, on the other hand, has the least rate of expansion and may thus regulate how quickly concrete cracks.

TABLE I. RESULT FOR SOUNDNESS TEST

Cement Type	Weight of Cement (g)	Weight of Water (ml)	Distance b/w Pointers before Heating(mm)	Distance b/w Pointers after Heating(mm)	Expansion $l_2 - l_1$(mm)
Lucky Cement	400	115	12	16	4
DG Khan	400	115	11	15	4
Best Way Cement	400	115	13	18	5
Maple Leaf Cement	400	115	12	17	5
Pak Land Cement	400	115	10	13	3

The test block was put under the rod holding the needle, and it was gently lowered to make contact with the cement paste's surface before being swiftly released to allow the needle to pierce the block, providing the initial and final setting times for the cement samples. This process was continued until the needle was unable to penetrate the test block at a distance of 5.0 (±.05) mm measured from the mold's bottom. This was accomplished after 45 minutes, which was noted as the first setting time. The results are displayed in Table 2.

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TABLE II. INITIAL AND FINAL SETTING TIME

Cement Type	Weight of Cement (g)	Weight of Water (ml)	Depth of Penetration (mm)	W/C Ratio(%)	Initial Setting Time	Final Setting time
Lucky Cement	400	115	5	28.75	1h:20 mins	8h:28 mins
DG Khan Cement	400	115	6	28.75	1h:23 mins	9h:00 mins
Best Way Cement	400	115	5	28.75	1h:14 mins	8h:20 mins
Maple Leaf Cement	400	115	5	28.75	1h:13 mins	8h:15 mins
Pak Land Cement	400	115	6	28.75	1h:30 mins	9h:15 mins

The findings of the initial and final paste setting periods for each cement sample indicate that it was found that, in comparison to other samples like Best Way and Maple Leaf cement, which had final set times that were noted to be less than nine hours, DG Khan and Pak Land cement took longer to set completely. However, when compared to the acceptable standards as stated by BS 12, 1991, It stipulates that all cement brands tested sufficiently satisfy the standard standards, with the first setting time of two standard concrete pastes not to be less than 45 minutes and the ultimate setting time not to exceed 10 hours.

We followed the guidelines outlined in ASTM C 143 for conducting the slump test. The height difference between the concrete and the mold is measured using a scale, generally to the closest 5 mm (1/4 in).

For Compressive strength measurement 9 concrete cylinders of 6x12 inch of each cement were casted for each brand of cement. The target concrete strength was kept 28.3 MPa. The cylinder was tested for their compressive strength at 7 days, 14 days, 21 days & 28 days after casting. Two cylinders were tested for first 3 testing and 3 cylinders were tested on 28 days' test. And the average values for each testing were taken. 7 cubes of 4x4 inch were casted od each cement and the was tested as 2 cubes on 7 days test , 2 cubes on 14 days test , 1 cube on 21 days test and 2 cubes on 28 days test. The compressive strength were measured is taken average values of the cubes. For every cement brand, cube-shaped samples of cement-sand mortar were created. The specimens had a cube shape of 50 mm. For the purpose of making mortar, a ratio of 1:2.75 for cement to sand and 0.485 for water to cement was utilized. ASTM C109/C109M was followed in the completion of this study. Using the usual ASTM standard, nine cubes were cast for every cement brand.

Figure 1. Test Cylinders

Figure 2. Test Cubes

Using a universal testing machine, compression tests were performed on mortar cubes and concrete cylinders (UTM). The apparatus is a hydraulic type machine with a stiff loading head manufactured by Shimadzu. In contrast to concrete cylinders, which were tested at 7, 14, 21, and 28 days, mortar cubes were evaluated at 7, 14, 21, and 28 days. Saturated surface dry (SSD) testing was conducted on the cubes and cylinders. A universal testing machine is used to determine compressive strength. The load is applied up until the test specimen is crushed. The applied load's output is measured in KN. Next, these values are translated from KN to MPa using the empirical calculations that follow (1).

Figure 3. Curing of Test Samples

Figure 4: Compressive Strength Tesing

Figure 1,2,3 and 4 sows thw different experimental stages carried out in the current study.

$$\text{Compressive strength in MPa} = \frac{\textbf{\textit{Total load in N}}}{\textbf{\textit{X − sectional area of the sample}}} \quad \text{……(1)}$$

Figure 4: Compressive Strength Tesing

The following figures give the outcomes for the compressive strengths of samples. Figure 5 presents compressive strength data for different types of cement specimens (2" mortar cubes, 4" concrete cubes, and 6"x12" cylinders) of D.G. Khan Cement at various curing times (7, 14, 21, and 28 days). The compressive strength values, measured in megapascals (MPa), demonstrate how the cement's strength develops over time. For

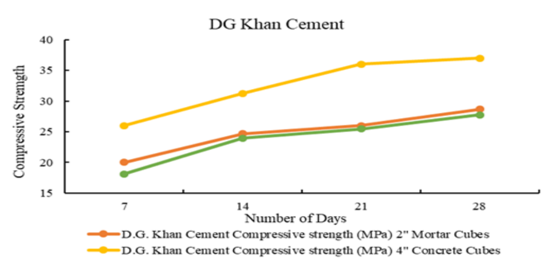

Figure 5. Compressive Strenth DG Khan Cement

instance, at 7 days, the compressive strength ranges from 20 MPa (2" mortar cubes) to 26 MPa (4" concrete cubes) to 18.117 MPa (6"x12" cylinders). Compressive strength usually improves with increasing curing time; significant improvements are shown at 28 days for all specimen types.

The figure 6 illustrates compressive strength measurements for various types of Maple Leaf Cement specimens (2" mortar cubes, 4" concrete cubes, and 6"x12" cylinders) at different curing durations (7, 14, 21, and 28 days), with compressive strength values reported in megapascals (MPa). At 7 days, the compressive strength values range from 26 MPa (2" mortar cubes) to 27 MPa (4" concrete cubes) to 15.994 MPa (6"x12" cylinders). Over the subsequent curing periods of 14, 21, and 28 days, the compressive strength generally increases across all specimen types, indicating the cement's progressive development in strength over time.

For instance, at 28 days, the compressive strength reaches 44 MPa for 2" mortar cubes, 42.75 MPa for 4" concrete cubes, and 28.403 MPa for 6"x12" cylinders, highlighting the cement's enhanced strength characteristics with longer curing durations.

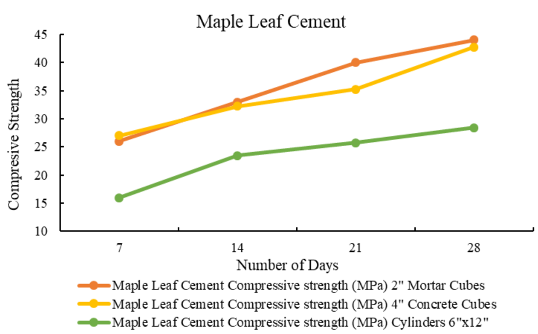

Figure 6. Compressive Strenth Maple Leaf Cement

With compressive strength values given in megapascals (MPa), Figure 7 displays the compressive strength data for Lucky Cement specimens (2" mortar cubes, 4" concrete cubes, and 6"x12" cylinders) at various curing times (7, 14, 21, and 28 days). Seven days later, the compressive strength varies from 17.41 MPa (6"x12" cylinders) to 25.75 MPa (4" concrete cubes) and 22 MPa (2" mortar cubes). All specimen types typically exhibit a steady rise in compressive strength throughout the course of the next 14–21, and 28-day curing periods, showing a gradual growth of strength over time. For instance, at 28 days, the compressive strength reaches 36 MPa for 2" mortar cubes, 31.25 MPa for 4" concrete cubes, and 25.383 MPa for 6"x12" cylinders, reflecting the cement's improved strength characteristics with longer curing durations.

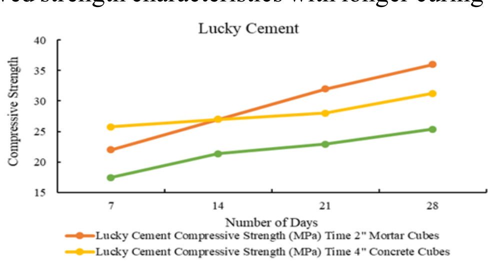

Figure 7. Compressive Strenth Lucky Cement

Figure 8 shows the compressive strength measurements for specimens made by Pak Land Cement at several curing intervals (7, 14, 21, and 28 days). The compressive strength values are given in megapascals (MPa) and include 2" mortar cubes, 4" concrete cubes, and 6"x12" cylinders. At seven days, the compressive strength varies from 15.853 MPa (6"x12" cylinders) to 23.75 MPa (4" concrete cubes) and 23 MPa (2" mortar cubes). All specimen types exhibit a constant rise in compressive strength as the curing period increases to 14, 21, and 28 days. By 28 days, the compressive strength reaches 39.333 MPa for 2" mortar cubes, 30.75 MPa for 4" concrete cubes, and 26.138 MPa for 6"x12" cylinders.

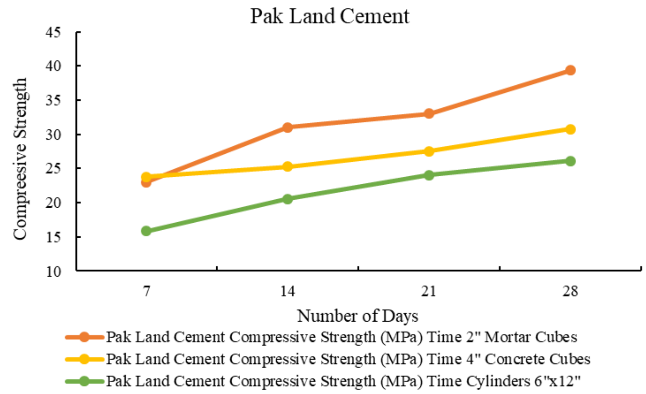

Figure 8. Compressive Strenth Pak Land Cement

With compressive strength values given in megapascals (MPa), Figure 9 shows the compressive strength data for Bestway Cement specimens, comprising 2" mortar cubes, 4" concrete cubes, and 6"x12" cylinders, at various curing times (7, 14, 21, and 28 days). Within a span of seven days, the compressive strength varies between 28 MPa (2" mortar cubes), 30.25 MPa (4" concrete cubes), and 21.09 MPa (6"x12" pistons). Over subsequent curing periods of 14, 21, and 28 days, there is a consistent increase in compressive strength across all specimen types, indicating progressive strength development over time. By 28 days, the compressive strength reaches 48.667 MPa for 2" mortar cubes, 48 MPa for 4" concrete cubes, and 30.573 MPa for 6"x12" cylinders.

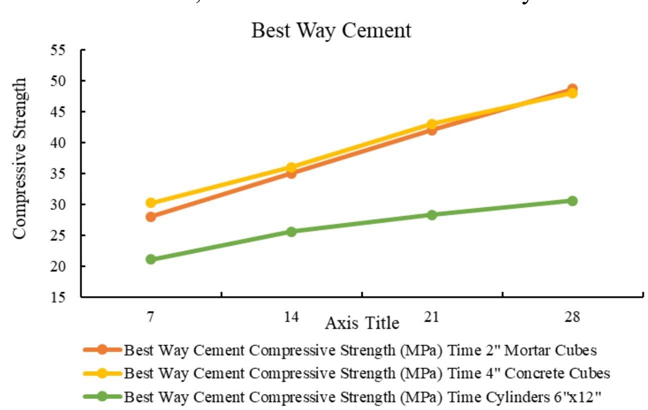

Figure 9. Compressive Strenth of Best Way Cement

Figure 10 presents a comparison of the compressive strength development of 2" mortar cubes across four different curing periods (7, 14, 21, and 28 days) for five different cement brands: D.G. Khan Cement, Maple Leaf Cement, Lucky Cement, Pak Land Cement, and Bestway Cement. Bestway Cement first has the highest compressive strength at 7 days, measuring 28 MPa. Maple Leaf Cement, Pak Land Cement, Lucky Cement, and D.G. Khan Cement follow with 26 and 23 MPa, respectively. As the curing duration increases, all cement brands show an increase in compressive strength. By 28 days, Bestway Cement exhibits the highest strength of 48.667 MPa, followed by Maple Leaf Cement at 44 MPa, Pak Land Cement at 39.333 MPa, Lucky Cement at 36 MPa, and D.G. Khan Cement at 28.667 MPa. This comparison highlights the varying strength performance of different cement brands over time, with Bestway Cement consistently demonstrating the highest compressive strength across all curing durations,

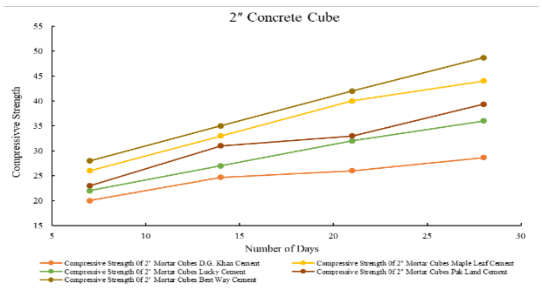

Figure 10. Comparison of all 5 types of cement strength for 2″ mortar cube

followed by Maple Leaf Cement and Pak Land Cement.

With compressive strength values given in megapascals (MPa), figure 11 compares the development of 4" concrete cubes' compressive strength over four different curing periods (7, 14, 21, and 28 days) for five different cement brands: D.G. Khan Cement, Maple Leaf Cement, Lucky Cement, Pak Land Cement, and Bestway Cement. Bestway Cement first has the greatest compressive strength at 7 days, measuring 30.25 MPa. Maple Leaf Cement, Lucky Cement, D.G. Khan Cement, and Pak Land Cement follow with 27 and 25.75 MPa, respectively. Every cement brand exhibits an

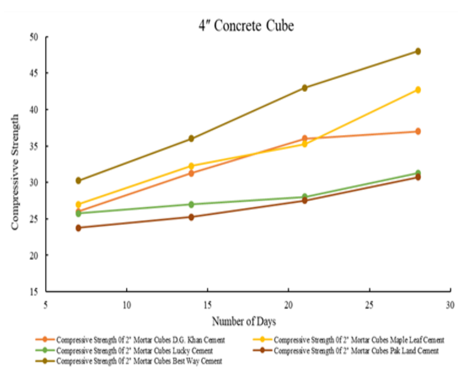

Figure 11. Comparison of all 5 types of cement strength for 4″ Concrete cube

increase in compressive strength as the curing period goes on. By 28 days, Bestway Cement shows the highest strength of 48 MPa, followed by Maple Leaf Cement at 42.75 MPa, Lucky Cement at 31.25 MPa, Pak Land Cement at 30.75 MPa, and D.G. Khan Cement at 37 MPa. This comparison highlights the variation in strength performance among different cement brands over time, with Bestway Cement consistently exhibiting the highest compressive strength across all curing durations, followed by Maple Leaf Cement and Lucky Cement.

With compressive strength values given in megapascals (MPa), Figure 12 compares the development of compressive strength in 6" x 12" concrete cylinders for five different cement brands: D.G. Khan Cement, Maple Leaf Cement, Lucky Cement, Pak Land Cement, and Bestway Cement. The comparison is done over four different curing periods (7, 14, 21, and 28 days). With a compressive strength of 21.09 MPa after 7 days, Bestway Cement has the highest value, followed by Lucky Cement (17.41 MPa), D.G. Khan Cement (18.117 MPa), Maple Leaf Cement (15.994 MPa), and Pak Land Cement (15.853 MPa). As the curing duration progresses, all cement brands exhibit an increase in compressive strength. By 28 days, Bestway Cement shows the highest strength of 30.573 MPa, followed by Maple Leaf Cement at 28.403 MPa, Lucky Cement at 25.383 MPa, Pak Land Cement at 26.138 MPa, and D.G. Khan Cement at 27.742 MPa.

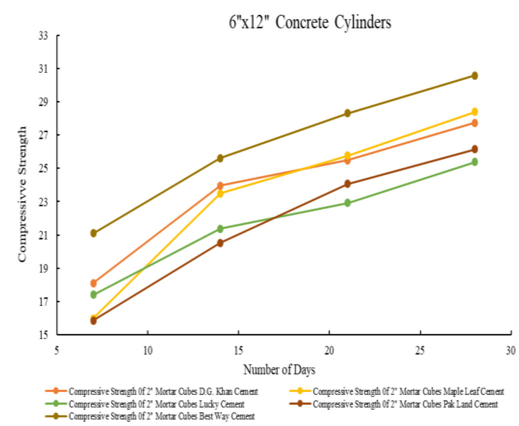

Figure 12. Comparison of all 5 types of cement strength for 6"x12" Concrete Cylinders

IV. RELATIVE STRENGTH DEFICIENCY OF ALL CEMENT BRANDS IN %AGE WITH MAXIMUM ACHIEVABLE STRENGTH AT 28 DAYS

TABLE III. HEIGHEST COMPRESSIVE STRENGTH

Cement Brands	Heighest Compressive Strength (Mpa)		
	2" Cubes	4"Cubes	Cylinder 6"X12"
Best way Cement	48.667	48	30.573
Maple Leaf	44	42.75	28.403
Cement	28.667	37	27.742
DG Khan	39.333	30.75	26.138
Cement	36	31.25	25.383
PaPak Land Cement	48.667	48	30.573

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With compressive strength values given in megapascals (MPa), table 3 compares the development of compressive strength in 6" x 12" concrete cylinders for five different cement brands: D.G. Khan Cement, Maple Leaf Cement, Lucky Cement, Pak Land Cement, and Bestway Cement. The comparison is done over four different curing periods (7, 14, 21, and 28 days). Initially, at 7 days, Bestway Cement demonstrates the highest compressive strength of 21.09 MPa, followed by Lucky Cement at 17.41 MPa, D.G. Khan Cement at 18.117 MPa, Maple Leaf Cement at 15.994 MPa, and Pak Land Cement at 15.853 MPa. As the curing duration progresses, all cement brands exhibit an increase in compressive strength. By 28 days, Bestway Cement shows the highest strength of 30.573 MPa, followed by Maple Leaf Cement at 28.403 MPa, Lucky Cement at 25.383 MPa, Pak Land Cement at 26.138 MPa, and D.G. Khan Cement at 27.742 MPa. This comparison underscores the variation in strength performance among different cement brands over time, with Bestway Cement consistently displaying the highest compressive strength across all curing durations for 6"x12" concrete cylinders.

TABLE IV. %AGE OF COMPRESSIVE STRENGTH

Cement Brands	**%Age of Compressive Strength (Mpa) w.r.t Highest Achieved Compressive Strength In Our Project**		
	2" Cubes	4"Cubes	Cylinder 6"X12"
Best way Cement	100	100	100
Maple Leaf	90.410	89.063	92.902
Cement	58.904	77.083	90.740
DG Khan	80.821	64.063	85.494
Cement	73.972	65.104	83.024
Pak Land Cement	100	100	100

The table 4 compares the compressive strength performance of different cement brands relative to the highest achieved compressive strength in a project, measured using 2" cubes, 4" cubes, and 6"x12" cylinders. Bestway Cement and Pak Land Cement achieved 100% of the highest compressive strength across all specimen types, indicating consistent and reliable performance. Maple Leaf Cement achieved approximately 90-93% of the highest strength values, demonstrating strong performance across all specimen sizes. DG Khan Cement showed varying percentages, achieving around 81-85% of the highest strength, with slightly lower performance in 4" cubes compared to other brands. This comparative analysis provides insights into each cement brand's strength relative to the project's benchmark, helping to assess and select the most suitable cement for specific construction applications based on compressive strength requirements.

TABLE V. %AGE DEFICIENCY OF COMPRESSIVE STRENGTH

Cement Brands	**%Age of Compressive Strength (Mpa) w.r.t Highest Achieved Compressive Strength In Our Project**		
	2" Cubes	4"Cubes	Cylinder 6"X12"
Best way Cement	0.000	0.000	0.000
Maple Leaf	9.590	10.938	7.098
Cement	41.096	22.917	9.260
DG Khan	19.179	35.938	14.506
Cement	26.028	34.896	16.976
Pak Land Cement	0.000	0.000	0.000

This table 5 presents the percentage of compressive strength achieved by different cement brands relative to the highest achieved compressive strength in your project, measured using 2" cubes, 4" cubes, and 6"x12" cylinders. The values represent the percentage of the highest achieved compressive strength for each cement brand and specimen type. "Bestway Cement" and "Pak Land Cement" both show 0% relative strength across all specimen types, indicating that they did not achieve the highest compressive strength in your project for any of the tested sizes. "Maple Leaf Cement" achieved approximately 9.590-10.938% of the highest compressive strength, with the lowest percentage seen for 6"x12" cylinders at 7.098%. "DG Khan Cement" demonstrated variable performance, achieving around 19.179-35.938% of the highest strength across different specimen types, with the highest percentage observed for 4" cubes. This analysis provides insights into the relative compressive strength performance of different cement brands for specific specimen sizes in your project.

V. CONCLUSION

In conclusion, the discussed tables and figures provide a comprehensive comparison of the compressive strength performance of various cement brands across different specimen types (2" cubes, 4" cubes, and 6"x12" cylinders) and curing durations (7, 14, 21, and 28 days). Bestway Cement consistently demonstrated the highest compressive strength across all specimen types and curing periods, followed closely by Maple Leaf Cement and Pak Land Cement in certain scenarios. DG Khan Cement showed competitive performance but with variability across different specimen types and curing durations. These findings underscore the importance of selecting the right cement brand based on specific project requirements, considering factors such as compressive strength development over time and suitability for different applications. The percentage-based comparison relative to the highest achieved compressive strength provides valuable insights into the performance differences among these cement brands, aiding in informed decision-making for construction projects.

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