STUDY OF THE PHYSICAL PARAMETERS OF ORDINARY PORTLAND CEMENT OF KHYBER PAKHTOON KHWA, PAKISTAN AND THEIR COMPARISON WITH PAKISTAN STANDARD SPECIFICATIONS

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Abstract: This study discusses different physical parameters of ordinary Portland cement (OPC) produced and available in Khyber Pakhtoon Khwa, Pakistan, and their comparison with Pakistan standards specification, which includes Blaine, compressive strength at different ages, consistency, setting time and Le-chatelier Expansion. All the results are presented to provide both quantitative and qualitative notion of several locally produced ordinary Portland cement of most of this constituents as determined experimentally were within the range of the standard values. The possible reasons for variation in physical parameters and their consequences have been discussed. It has been found that cherat cement is on the top in all the samples studied with reference to their physical parameters.

Keywords: *Ordinary Portland cement, physical parameters, quality verification*

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1. Introduction

In this rapidly developing world, cement plays an important role in the construction industry. Therefore, the use of cement is increasing day by day. New cement factories are being installed with a very rapid pace. There are twenty-seven cement plants in Pakistan, out of which six are in the Khyber Pakhtoon Khwa namely Cherat Cement Company Limited Nowshera, Lucky Cement Limited, Kohat Cement Company Limited, Askary Cement Limited Nizampur (Army welfare trust), Bestway Cement Company Limited and Mustehkam Cement [1]. The annual production of cement in Khyber Pakhtoon Khwa is about 4629000 tons. All these cement plants produce Ordinary Portland cement (OPC).

The use of poor quality cement in structural and constructional works may cause loss of lives and properties. So, quality assurance of OPC has become an important and critical factor. The cement, which is used in construction work, must have certain qualities in order to play its part effectively otherwise it will create a number of problems. When these properties lie within a certain specified range of standards, the engineer is confident that the cement performance will be quite satisfactory. Moreover based on these properties it is possible to compare the quality of cement from different sources. A number of tests are performed in the laboratories of cement industries to ensure that the cement is of the desired quality and it meets the requirement of the relevant standards [2, 3]. There are several brands of OPC available in the local market of Khyber Pakhtoon Khwa, whose chemical ingredients are the same, but variations in their physical parameters occur due to the variation in the amount of chemical constituents. The study was aimed to conduct study of the physical parameters of the OPC in order to make a comparison with Pakistan standard specifications.

2. Basic Chemistry of Portland Cement

Cement is made from a mixture of calcium carbonate (generally in the form of limestone), silica, iron oxide and alumina [4–7]. Calcium oxide CaO is the principal oxide of cement, which makes up approximately 75-80% of the raw materials mix used in cement clinker. This primary calcareous raw material may contain significant amounts of the other oxides as impurities. The secondary raw material is clay (Argil) or shale [2, 3]. A high-temperature kiln, often fueled by coal, heats the raw materials to a partial melt at 1450°C, transforming them chemically and physically into a substance known as clinker. This grey pebble-like material is comprised of special compounds that give cement its binding properties. Clinker is mixed with gypsum and ground to a fine powder to make cement.

Four major compounds in Portland cement are C_2S, C_3S, C_3A, and C_4AF. The silicates, C_3S and C_2S, are the most important compounds, which are responsible for the strength of hydrated cement paste. The presence of C_3A in cement is undesirable. C_4AF is also present in cement in small quantities, and, compared with the other three it does not affect the behavior of the cement significantly [8].

3. Experimental

Cement samples were collected from local market of the six cement plants namely Cherat Cement, Army Welfare Trust, Bestway Cement, Kohat Cement, Lucky Cement and Mustehkam Cement, and stored in the polyethylene bags and carried to the laboratory for study. For each brand of cement

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three samples were collected from different stores on different dates and each sample was about one kilogram. The testing procedures based on Pakistan Standards were followed.

3.1. Determination of compressive strength

For studying the effect of compressive strength of the blended mortar, mixes were prepared by adopting a cementitious to sand ratio of 1:3. The blends were sufficiently mixed in dry and wet condition for four minutes, and were cast in to mould of 40mm × 40mm × 40 mm using a vibrating machine with normal speed 1200 r/minute for 120 seconds in order to get compact cubes. The temperature of the mixing room was kept at 20±2°C and relative humidity of 65%. The molded samples were placed in the moist curing chamber for 24 hours at a temperature of 20±1°C and relative humidity of 90%. After 24 hours the specimens were stripped from their moulds and were placed in water curing tank having a temperature of 20±1°C until testing. A Toni tecknik compressive strength machine with a load cell of 0-300 kN and a loading rate of 24 kN/sec was used for the compressive strength. The compressive strength of the specimens was measured according to Pakistan standard specification PS 232-1983 (R), after 3, 7 and 28 day from the mixing date. For each age three specimens of every mixture were tested and the mean value of these measurements is reported.

3.2. Determination of standard consistence and setting time

The standard consistence of cement was determined by vicat apparatus. 400 g cement and a measured quantity of water were mixed vigorously on non-porous surface by means of two trawls for 240 seconds. The mould was filled immediately with the cement paste and the surface of cement was smoothed in the mould. The plunger was lowered to touch the surface the cement paste and allowed to sink in the surface.

The same procedure was performed with different paste containing different amounts of water and the amount of water was noted for which the plunger remained about 5 mm above from the bottom of the mould.

The cement paste, which was already used for standard consistence, was used for the study of setting time. The setting time was determined at 20°C and 65% relative humidity.

3.3. Determination of Le-chatlier expansion (soundness)

100 g of the cement was mixed with sufficient quantity of water to give a standard consistence. The mould was placed on a glass plate and filled with cement paste, keeping the split closed. The second glass plate was placed on the mould and a small weight was placed on it. The whole apparatus was immersed in water at a temperature of 20°C and left for 24 hours. The mould was removed from the water and measured the distance separating (expansion) the indicator points.

4. Results and Discussion

Compressive strength at 3 days, 7 days and 28 days of hydration time of all the studied samples is shown in Figure 1. It is obvious from the figure that minimum compressive strength after three days of hydration is that of Mustahkam cement (13.73 N/mm^2) while maximum is that of cherat cement (28.03 N/mm^2), while the minimum limit is 15 N/mm^2 according to Pakistan standard specifications. The minimum compressive strength after seven days was observed in mustahkam cement (19.82 N/mm^2) while maximum in cherat cement (35.33 N/mm^2) while the lower limit of compressive strength at seven days 24 N/mm^2 according to Pakistan standard specification. Similarly the lowest value of compressive strength at twenty eight days was found to be 35.79 N/mm^2 for kohat cement and that of highest as 46.99 N/mm^2 for cherat cement, which should not go below 34.5 N/mm^2 according to Pakistan standard specification. These results show that all the studied samples have compressive strengths at all the ages with in the limits.

The proper lime content is limited due to the lower early strength produced when lime content of OPC is too low, and unsoundness when it is too high [9, 10]. High lime content is associated with early strength where as, slightly lower content of lime favors ultimate strength which develops gradually over a long period of time. In order to increase the strength it is necessary to raise the lime content, or grind finer, or both. But higher temperatures are required to burn the high lime mixtures.

Figure 2 shows consistency of all the studied cement samples. It is obvious from the figure that Mustahkam cement has a normal consistency of 26.00% while Cherat cement

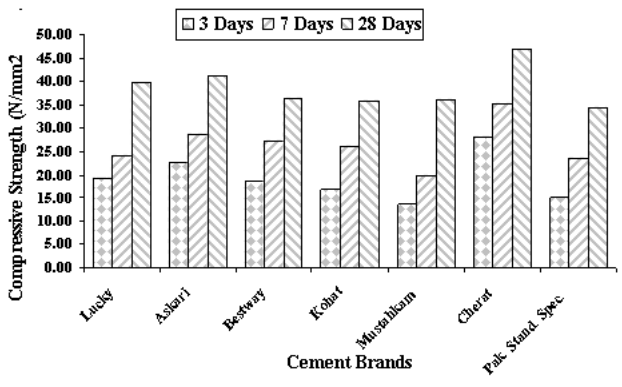

Figure 1: Compressive strength of different brands of cements

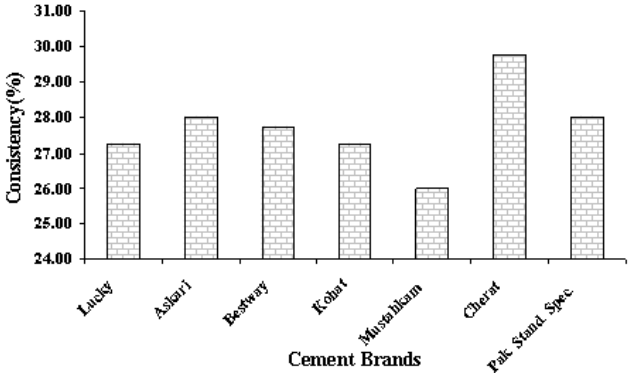

Figure 2: Consistency of different brands of cements

showed 29.75% and the minimum limit according to Pakistan standard specification is 28.00%. From the present investigation it is clear that only Askari and cherat cement have consistency with in the permissible range while all other cements have lower values of normal consistency.

Sitting time of all the studied cement samples and their comparison with Pakistan standard specification is shown in Table 1. Comparing all the values in Table 1, one can observe that Askari cement has lowest, 130 min, 225 min, and Best way cement has the highest 175 min, 280 min initial and final setting time respectively, while according to Pakistan standard specification the lower limit of initial setting time is 45 and upper limit is 600 min.

Table 1: Setting time and Le-Chatelier expansion of different brands of cements

Physical tests		Lucky	Askari	Bestway	Kohat	Mustahkam	Cherat	Pakistan standard
Setting time (min)	Initial	150	130	175	150	160	145	45
	Final	245	225	280	235	245	230	600
Le-Chatelier Expansion (mm)		1.68	1.75	1.55	1.89	1.78	1.5	10

Setting time of the cement apart from other parameters may also be closely related with lime content in clinker and cement. If the lime content is kept fixed, and the silica too high, which may be accompanied by a decrease in alumina and ferric oxide, the temperature of burning will be raised automatically and the special influence of the high lime will be lost. If the lime content is too low, which means an increase in the alumina and ferric oxide; the cement may become quick-setting and contain a larger amount of alumina compounds, which appear to be of little value for their cementing qualities. Rapid setting is undesirable, and is not permitted by the standard specifications, because the cement sets up so rapidly that it cannot properly be worked in the forms before stiffening occurs [8].

Another factor for low and high setting time of the cement is amount of sulphuric anhydride. High content of SO_3 increases the setting time [9]. It is clear from Table 1, that all the cement produced in the Khyber Pakhtoon Khwa have the setting times with in the limits of standard specification.

Table 1 also shows soundness (Le-chatelier expansion) observed for all cement samples. The maximum expansion was observed in kohat cement i.e. 1.89 mm and minimum in cherat cement 1.5 mm, while the upper limit of Le-chatelier expansion according to Pakistan standard specification is 10 mm. it is concluded that all the cement samples have the expansion in permissible limits.

The expansion of cement apart from other factors is closely related with magnesia contents especially at later ages [8, 11]. If magnesia goes above 2%, it appears in the clinker as free MgO (periclase). Periclase reacts with water to form $Mg(OH)_2$, and this is the slowest reaction among all other hardening reactions. Since $Mg(OH)_2$ occupies a larger volume than the MgO and is formed on the same spot where the periclase particle is located, it can split apart the binding of the hardened cement paste, resulting in expansion cracks commonly known as magnesia expansion [12, 13]. Apart from periclase free lime may cause expansion and cracking of the mortar or concrete.

Figure 3 shows the fineness or Blaine of all the studied cement samples. The observed Blaine was 3008, 3224, 3102, 3179, 2651and 3011 cm^2/g for lucky cement, Askari cement, Bestway cement, kohat cement, Mustahkam cement and cherat cement respectively, while it should not be less than 2250 cm^2/g according to Pakistan standard specification. It is not difficult to deduce from the figure that cement samples have fineness in accordance to Pakistan standard specification.

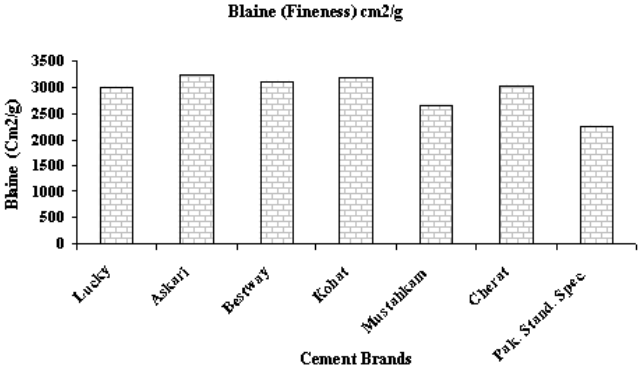

Figure 3: Blaine (fineness) of different brands of cements

The possible reasons of variations in physical parameters may be different which includes the variation in chemical composition of the raw mix, non homogeneity of the material, poor burning of kiln feed in the kiln, variation in retention time in the kiln, grain size of the cement etc.

5. Conclusion

The physical parameters of almost all the cement samples were found in accordance to the permissible range of Pakistan standard specifications. However some minor deviations were found in some of the samples which may be due to different reasons, as the samples were collected from market. The ideal range of physical parameters of Portland cement is the problem of the research chemist. But out of the experience of observant operatives and the formulation of experimentally demonstrated principles by engineers and chemists, there have been established certain rather definite limitations in the feasible composition of a cement. Within those limits experience has shown that the mixture behaves satisfactorily in the kilns and produces good cement; outside of those limits experience has shown that trouble in burning may result or that the cement may be of inferior quality.

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