CHEMICAL ANALYSIS OF ORDINARY PORTLAND CEMENT OF BANGLADESH

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Abstract: This study compares the quality of different brands of Ordinary Portland Cement (OPC) available in Bangladesh. The amounts of chemical constituents like SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, insoluble residue (IR), free lime and loss on ignition (LOI) were determined in accordance with British Standard (BS) Specifications. All the results are presented to provide both quantitative and qualitative notion of several locally produced ordinary Compositions of most of this constituents as determined experimentally were within the range of the standard values. The possible reasons for variation in chemical compositions and their consequences have been discussed.

Keywords: *Ordinary Portland Cement, Chemical Composition, Quality Verification.*

INTRODUCTION

Every year a huge amount of OPC is produced and used for the construction of building, roads and highways and other local purposes. In Bangladesh, 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 to be used in construction must have certain qualities in order to play its part effectively in structure. When these properties lie within a certain specified range of standard values, the engineer is confident that in most of the cases the cement performance will be satisfactory. In addition, 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 conforms to the requirement of the relevant standards [1, 2].

There are several brands of OPC available in market but their chemical compositions are same. Variations in physical properties occur due to the variation in the amount of chemical constituents. The study was aimed to conduct chemical analysis of OPC. Chemical constituents like silica, Al_2O_3, Fe_2O_3, lime content, magnesium oxide, SO_3, IR, free lime and LOI were determined Five widely used brands namely Holcim, Shah, Crown, King brand, and Anwar cement were chosen for the comparative analysis.

BASIC CHEMISTRY OF PORTLAND CEMENT

During calcination the volume contracts, and during hydration it swells. Two possible reactions take place.

Calcination: $CaCO_3(s) = CaO(s) + CO_2\ (g)$
Hydration: $CaO(s) + H_2O\ (l) = Ca\ (OH)_2(s)$

The raw materials used in the manufacture of Portland cement consist mainly of lime, silica, alumina and iron oxide. These compounds interact with one another in the kiln to form a series of more complex products, and apart from a small residue of uncombined lime, which has not had sufficient time to react; a state of chemical equilibrium is reached.

Chemical components in Portland cement are combined to from different potential compounds. The amounts of these potential compounds are responsible for various physical properties of Portland 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 behaviour of the cement significantly [3, 4].

EXPERIMENTAL

The testing procedures based on British Standards (BS12: 1992) have been followed for chemical analysis of Portland cement. Amount of total SiO_2, Al_2O_3, Fe_2O_3, lime content, MgO, SO_3, IR, free lime and LOI were determined [2,5,6].

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RESULTS AND DISCUSSION

Different calculated data have been taken for different parameters during the laboratory work. Table 1 is a summarized form of various test results. For better comparison these are presented graphically.

Table 1: Amount of chemical constituents in Portland cement

% Elements	BS for OPC	OPC Samples				
		Holcim	Shah	Crown	King	Anwar
SiO_2	21.0	21.45	21.52	22.13	21.62	22.33
Al_2O_3	6.00	4.3	4.58	5.32	4.95	3.89
Fe_2O_3	3.50	3.28	3.38	3.34	3.44	3.45
CaO	65.0	64.32	66.02	63.73	63.76	65.56
MgO	0.70	1.18	1.26	1.89	1.8	1.42
Free lime	2.00	1.274	1.205	1.092	1.165	1.106
SO_3	1.50	3.56	2.76	2.42	1.87	0.95
IR	1.50	0.35	0.45	0.5	0.55	0.65
LOI	4.00	2.055	1.235	1.5	1.87	1.375

British standards specify amounts of SiO_2 in Portland cement within the range 21% to 22%. It has been observed that Holcim, Shah and King Brand cements are within specified limit. But Crown, and Anwar cements slightly deviate from the specification. Figure 1 shows the amount of SiO_2 in different brands of cement.

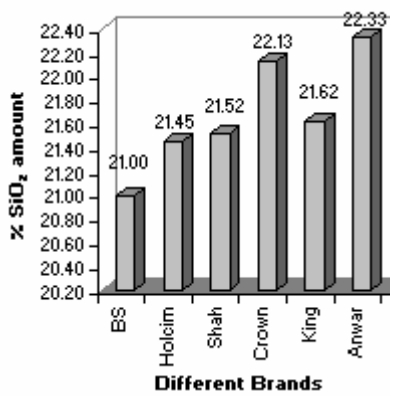

Figure 1: Variation of SiO_2

Amount of CaO as specified by the British standards should be within the range 63% to 67%. All five brands of cement contain CaO within the specified limit that can be observed from Figure 2.

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 [3,7]. High lime content is associated with early strength whereas, slightly lower content of lime favours ultimate strength which develops gradually over a long period of time [7, 8]. 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 [3, 7].

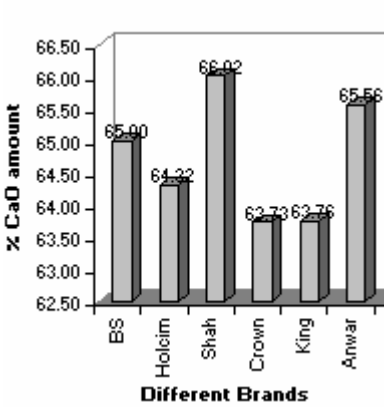

Figure 2: Variation of CaO

British standards specify amounts of MgO in OPC not more than 2.0%. It was found that all the cement samples were within the specified limit.

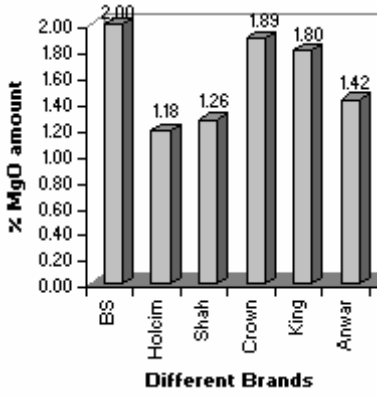

Figure 3: Variation of MgO

The magnesia content is limited by the standard specifications not to exceed 2% because higher magnesia contents may be detrimental to the soundness of the cement, especially at late ages. Beyond that limit 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 [1, 3, 7].

There is no advantage in adding extra lime unless it is brought into combination with other constituents. If appreciable lime is left uncombined, it may cause expansion and cracking of the mortar or concrete [3, 7]. Amount of free lime were found to vary in between 1.092 to 1.274% among the different brands of cements that is shown in Figure 4.

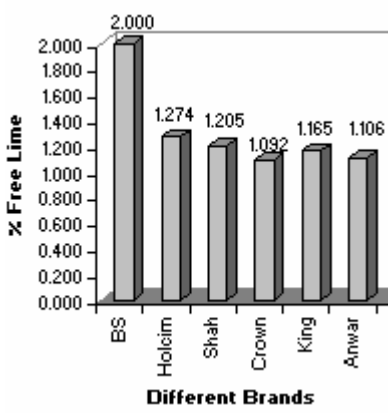

Figure 4: Variation of Free Lime

It was found that amount of Al_2O_3 in Crown cement was within the specified limit. But Holcim, Shah, Anwar and King cement were slightly below the specified limit. On the other hand, amount of Fe_2O_3 was found within the specified range. Variations of Al_2O_3 and Fe_2O_3 are shown in Figure 5 and 6 respectively.

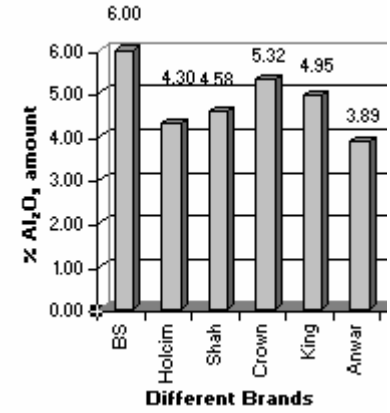

Figure 5: Variation of Al_2O_3

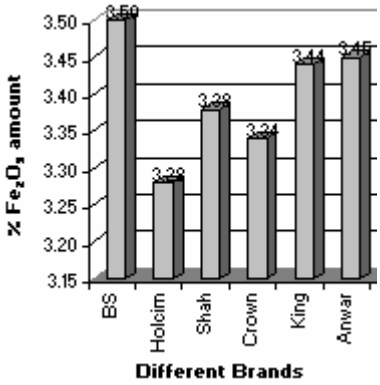

Figure 6: Variation of Fe_2O_3

If the lime content is fixed, and the silica becomes too high, which may be accompanied by a decrease in alumina and ferric oxide, the temperature of burning will be raised 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 [3, 7].

British standards specify maximum amounts of SO_3 in Portland cement be 1.5%. Holcim, Shah and Crown cements were found to contain excess amount of SO_3 whereas King brand cement slightly deviated from the specification.

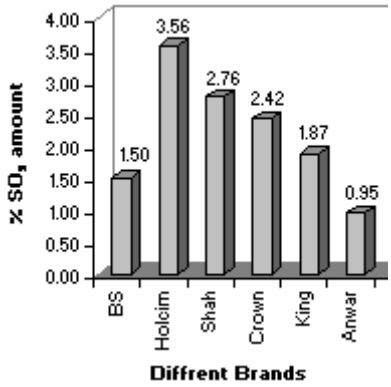

Figure 7: Variation of SO_3

To control setting time effectively, cement needs a minimum amount of calcium sulfate, mostly in the form of gypsum added to the clinker.

On the other hand, the maximum allowable SO_3-content in the cement to prevent sulfate expansion, is established according to the various cement standards, between 1.5 and 2.5 % SO_3. At the lowest limit imposed by cement standard specification, it could be possible that there is no sufficient scope left for an extensive sulfatizing of the alkalies [1, 3, 7].

Insoluble residue is a non-cementing material, which eventually exists in Portland cement. This residue material affects the properties of cement, especially its compressive strength. To control the non-cementing material in Portland cement, British standard allows the IR content to a maximum limit of 1.5%. Figure 8 shows that all the cement samples were within this limit.

Addition of the IR in Portland cement affect the compressive strength of cement mortar during the early age, but it is reduced as the cement mortar getting older.

A high LOI indicates pre-hydration and carbonation, which may be caused by improper and prolonged storage or adulteration of OPC during transport or transfer. All the cement samples were found to be competent with regard to maximum LOI limit of 4.0% as specified by the British Standard.

The possible reasons of variations are specification of raw mix, non-uniformity of mixture, and impurities from various stages of

processing, and intentional alteration.

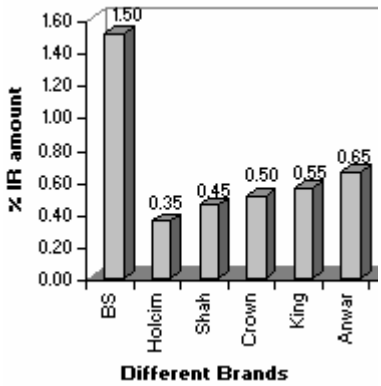

Figure 8: Variation of Insoluble Residue (IR)

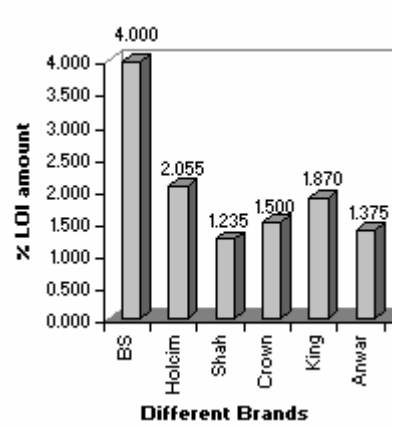

Figure 9: Variation of Loss of Ignition (LOI)

Variations in chemical constituents affect the cement properties like, hardening/hydration, setting time, corrosion resistance, color, etc [3, 4, 8].

Possible and potential sources of error in testing might be grade of chemicals, and preparation of reagents, and accuracy of titrametric method (Classical analytical method) which depends on the technical experience of the investigator. Maximum temperature range of the furnace was 800°C. But sometimes it was necessary to raise temperature upto 1000°C.

CONCLUSION

The ideal composition range 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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