Pak. J. Chem. 3(4): 163-169, 2013 Full Paper
ISSN (Print): 2220-2625
ISSN (Online): 2222-307X DOI: 10.15228/2013.v03.i04.p04

A Short Study to Test the Compliance of Various Pakistani Ordinary Portland Cements with ASTM Composition Standards

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ABSTRACT
Cement is widely used everywhere for construction purposes and quality comparison of different ordinary Portland cements is very important. Five different brands of cement were tested for their chemical constituents such as silica, alumina, iron, calcium, magnesium, sulfates, insoluble residue, free lime and loss on ignition with American standards for testing and materials (ASTM). Results for five locally produced Portland cements revealed that the chemical compositions of most cement as determined by standard methods lie within standard limits. But the difference in constituents of various brands of cements is due to quality control setup differences of different cement plants.

Keywords: Ordinary Portland Cement (OPC), Chemical constituents, Quality

1. INTRODUCTION
A gigantic quantity of Ordinary Portland Cement created at different cement plants in Pakistan and used for the erection of edifice, bridges, highway and additional domestic purposes. This is especially important for Pakistan where earthquakes are common and therefore all buildings need to be able to withstand severe shocks. Moreover the severe climate of Pakistan with hot summers and cold winters with heavy rains during the monsoon months of July August again highlight the requirement and importance of quality and tailor- made construction materials.

Cement, used during assembly must include assured qualities like strength and setting time etc. consecutively to improve building structure effectively. The cement performance will be satisfactory if the above mentioned properties lounge within specified limits. To ensure the quality of cement a number of tests performed that conform the requirement of the relevant standards [1].

Several ordinary Portland cements (OPC) are available in Pakistani markets and their chemical constituents vary to some extent which leads to variations in their physical properties. This study was undertaken to perform chemical analysis of commonly available ordinary Portland cements. Five brands of OP cements namely Askari, DG, Bestway, Pioneer and Flying cement were chosen for this comparative study. For these cements chemical constituents such as Silica (SiO_2), Alumina (Al_2O_3), Iron Oxide (Fe_2O_3), Calcium Oxide (CaO), Magnesium Oxide (MgO), Sulfuric Anhydride (SO_3), Insoluble Residue (IR), free lime (F.CaO) and Loss on Ignition (LOI) were determined using standard methods[2].

2. BASIC CHEMISTRY OF PORTLAND CEMENT
Portland cement is a type of hydraulic binder developed by grinding cement clinker with one or more form of calcium sulphate. Portland cement clinker itself is a mixture of compounds of various silicates, aluminates and ferrites of calcium, with some minor contaminating compounds of lesser importance.

Silicates of lime are primary constituents of Portland cement, so any material, providing silica and calcium in favorable composition and proportion is appropriate for cement manufacturing. Chemically speaking, the raw materials required primarily are the basic calcium carbonate and acidic oxides of silica, alumina and iron. Seldom a single material in which all the required component s are present is available to provide the required type of Portland cement so a combination of limestone, clay and laterite or bauxite are used to produce the cement. The composition of raw material as well as those of clinkers and cements is expressed in term of oxides of various elements present however the composition of clinker and cement is characterized by compound composition rather than oxides composition.

Chemical components in Portland cement are responsible for various physical properties of Portland cement. Major compounds in Portland cement are tricalcium silicate (C_3S), dicalciumsilicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferite (C_4AF). The silicates are responsible for strengthening the hydrated cement paste. C_3A in cement is suspectable to sulphate attack. C_4AF also present in small amount does not affect the behaviour of the cement significantly [3, 4].

*Corresponding Author Received 12th November 2013, Accepted 25th December 2013

3. MATERIALS AND METHODS

American Standard ASTM C-114 followed for chemical investigation of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, IR, free lime (CaO) and LOI in mentioned brands of cements by using chemicals of analytical grade.

4. RESULTS AND DISCUSSION

All the results obtained are summarized in Table-1 with ASTM specifications. For better comparison these are presented graphically.

Table.1: Chemical composition of various Portland cement brands

%age Elements	ASTM for OPC	OPC Samples				
		Askari	DG	Bestway	Pioneer	Flying
SiO_2	20.00 min	20.25	20.40	20.01	19.85	19.85
Al2O3	6.00	5.12	5.01	5.13	5.14	5.45
Fe2O3	6.00		3.21	3.15	3.01	3.24
CaO	-	63.21	62.54	63.12	64.00	64.45
MgO	6.00	1.56	1.54	2.01	2.12	2.21
Free lime	2.00	1.20	1.25	1.51	1.01	1.64
SO3	3.00	2.45	2.35	2.41	2.65	3.10
IR	0.75	0.55	0.70	0.65	0.53	0.45
LOI	3.00	1.75	2.21	2.25	2.45	2.95

American standard (ASTM) identify the amount of SiO2 within the range not less than 20%. This minimum amount of SiO_2 is essential for silicate mineral of cement. Askari, DG and Bestway B cements show specified amount of silica. But pioneer and flying cements results faintly diverge from specification as shown in Fig.1.

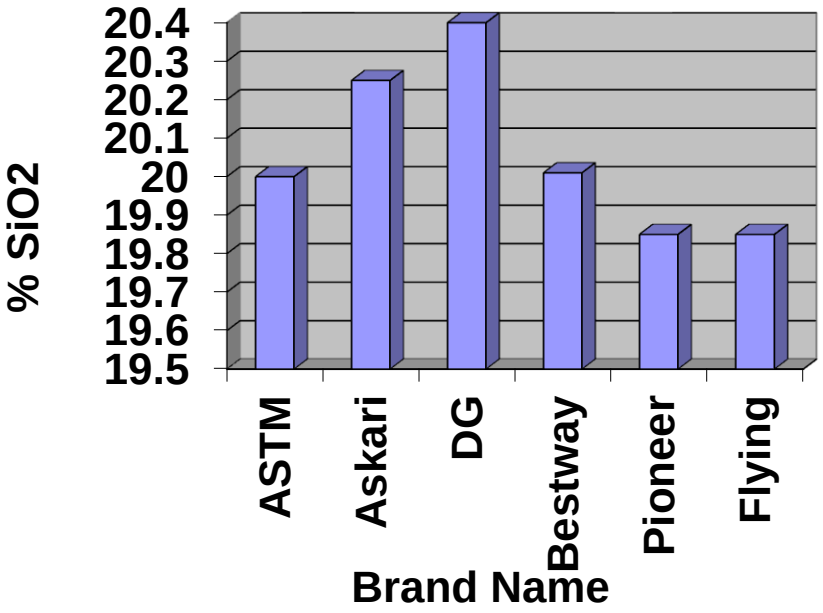

Fig.1: Silica (SiO_2) Content in various cement brands

Amount of calcium oxide (CaO) is not précised by the American standard (ASTM) but normally it range from 62% to 65%. Above mentioned five brands of cement contain CaO within the normal range and can be observed from Fig.2.

The lime content strengthens the cement. Under low lime content the main strength forming mineral tricalcium silicate (C_3S) will not formed in sufficient amount which lead to low strength cement and when it is too high the free lime increases which on hydration creates unsoundness. Lime content is linked with premature strength while vaguely lesser content of lime favors eventual potency which develops steadily above elongated period of time [5]. In order to boost the potency, it is compulsory to elevate the lime content but privileged temperatures are required to blaze up high lime mixtures [6].

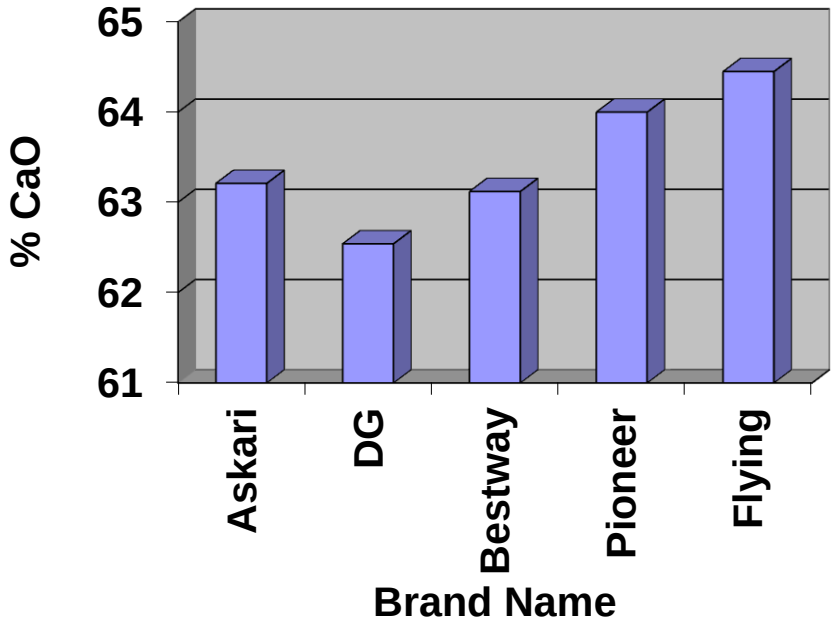

Fig.2: Calcium Oxide (CaO) content in various cement brands

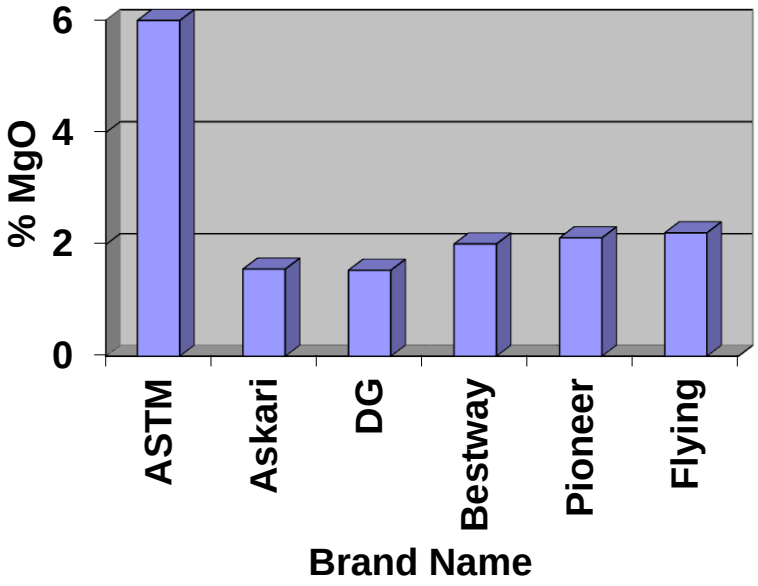

Fig.3: Magnesium Oxide (MgO) content in various cement brands

ASTM specifies that the amount of Magnesium oxide (MgO) in ordinary Portland cement (OPC) is less than 6.0%. Magnesium oxide content lies within the specified limit as shown in Fig.3

The magnesia content does not go beyond 6% as higher magnesium oxide content may cause soundness of cement. Beyond that limit it appears in the clinker as free MgO known as Pericles which reacts with water to form Mg

$(OH)_2$, in view of the fact that $Mg(OH)_2$ occupies a huge volume than MgO resulting in expansion cracks and destroys the hardened structure.

If noticeable lime left uncombined, it might cause expansion and cracking of the mortar or concrete [7]. Free lime content present from 1.2 to 1.51 % among the different brands of cements as shown in Fig.4.

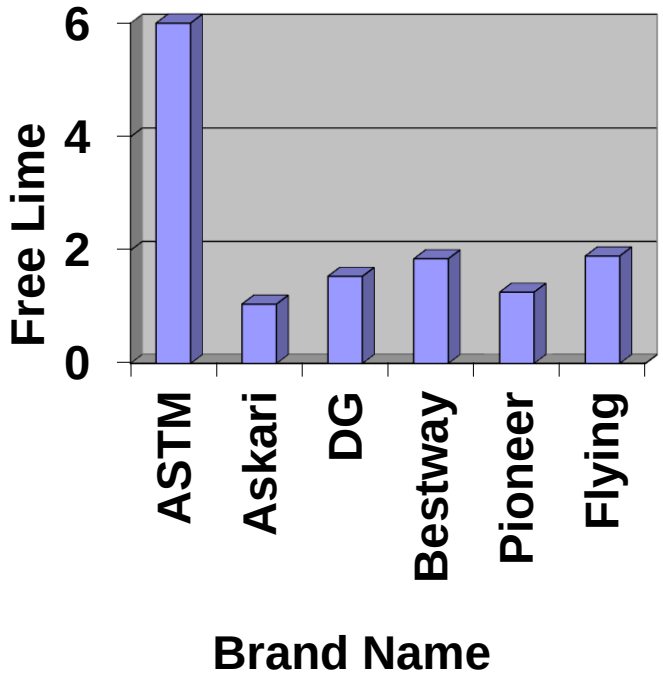

Fig.4: Free lime (F.CaO) content in various cement brands

Amount of Al_2O_3 and Fe_2O_3 was found to be within particular range. Al_2O_3 and Fe_2O_3 in different brands are exposed in Figure 5 and 6 respectively.

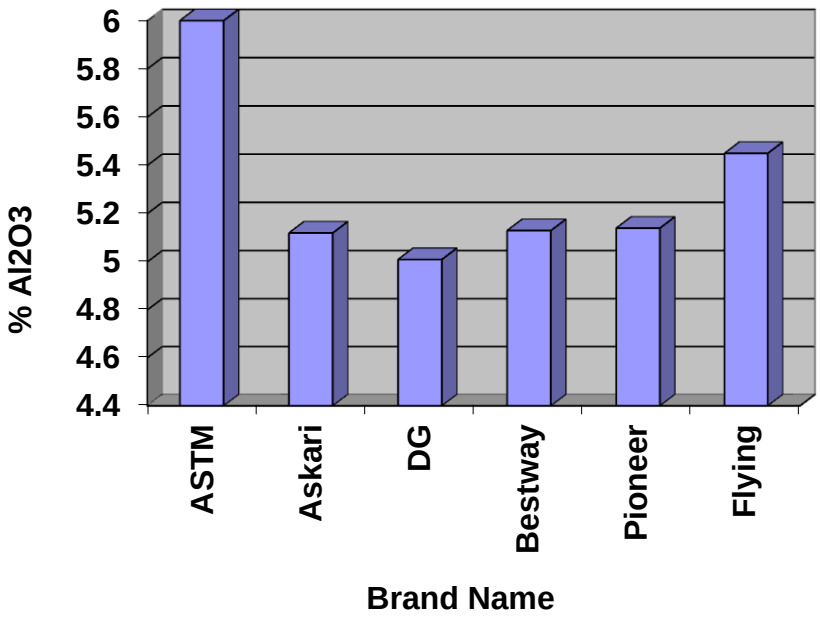

Fig.5: Alumina (Al_2O_3) content in various cement brands

If the lime content is predetermined and the silica is decreasing, which may decrease alumina and ferric oxide and temperature of burning will be raised. Alumina and ferric oxide both act as flux so these must be in controlled limit. The high alumina lead to formation of greater C_3S and cement will set quickly which decrease the workability of cement.

Greater quantity of alumina compounds (C_3S) which come into sight of diminutive worth for cementing behavior but are suspected to sulphate attack. Swift setting is unwanted and is not allowed by standard specifications since cement sets up so quickly that it cannot appropriately worked prior to stiffening occurs [3, 7]

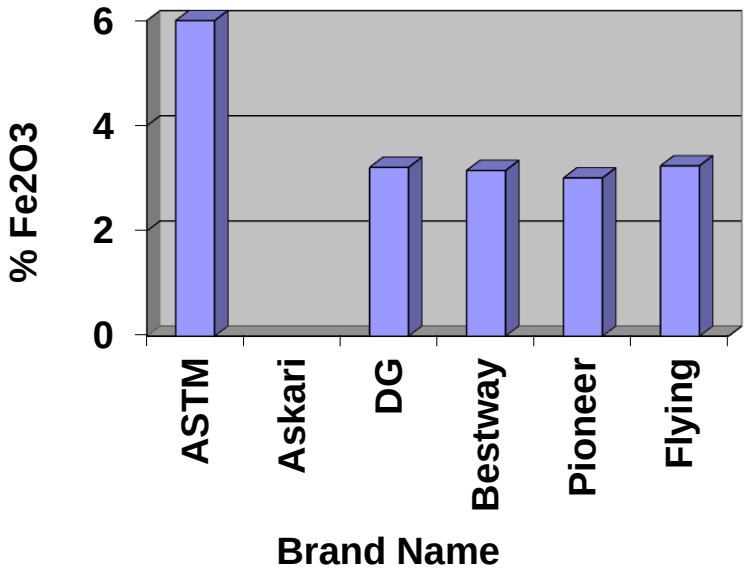

Fig.6: Iron Oxide (Fe2O3) in various cement brands

American Standard for Testing and Materials (ASTM) C-150 specifies maximum amounts of SO_3 in Portland cement 3.00 %. Askari, DG, Bestway and Pioneer cements were found to contain SO_3 within normal range whereas Flying cement slightly deviated from the specification.

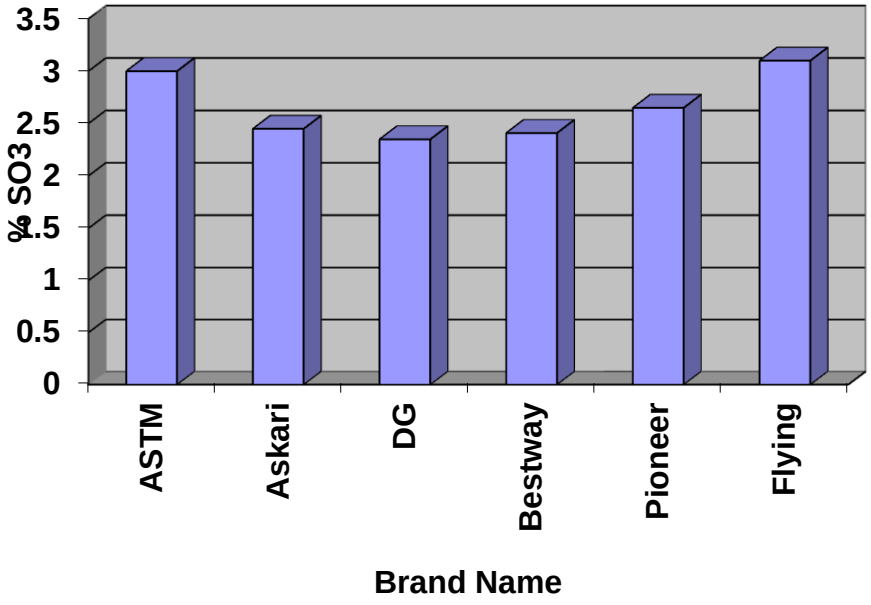

Fig.7: Sulfuric Anhydride (SO3) content in various cement brands

Small amount of calcium sulfate (gypsum) is added to clinker to control setting time of cement efficiently. Maximum acceptable sulfuric anhydride content (SO_3) prevents sulfate expansion lies between 1.5 to 2.5 %. The lowest limit imposed by cement standard specification, prevent extensive sulfatizing of the alkalies [1, 3, 7].

Insoluble residue comes from raw materials such as clay and particularly affects compressive strength of cement. According to American standard, maximum IR content limit is 0.75 %. IR content in Portland cement influence the compressive strength of cement mortar during hydration as it hinders the formation of channel type structure of cement. Fig.8 exposes IR content in given cement samples.

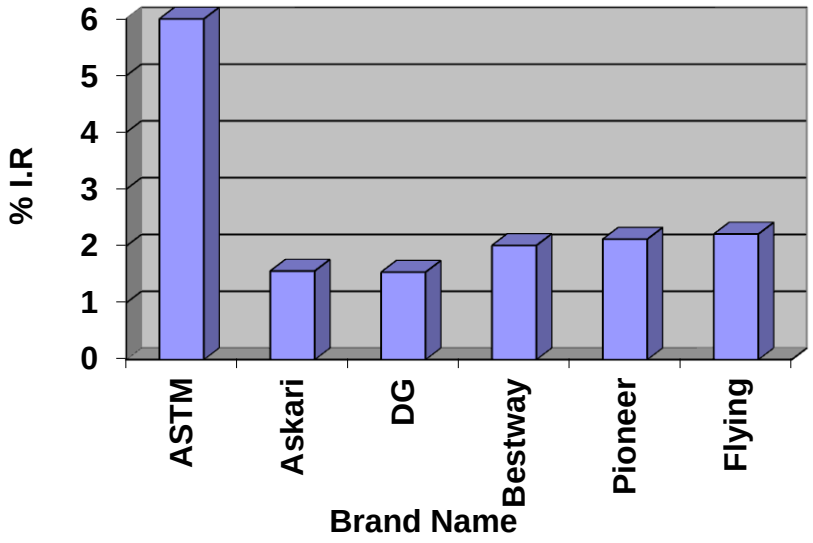

Fig.8: Insoluble Residue (IR) in various cement brands

Loss on ignition is very important parameter of cement quality. A high LOI indicates mixing of some unburned material in cement due to pre-hydration and carbonation caused by improper and prolonged storage of ordinary Portland cement (OPC). LOI of under investigation brands is shown in fig.9.

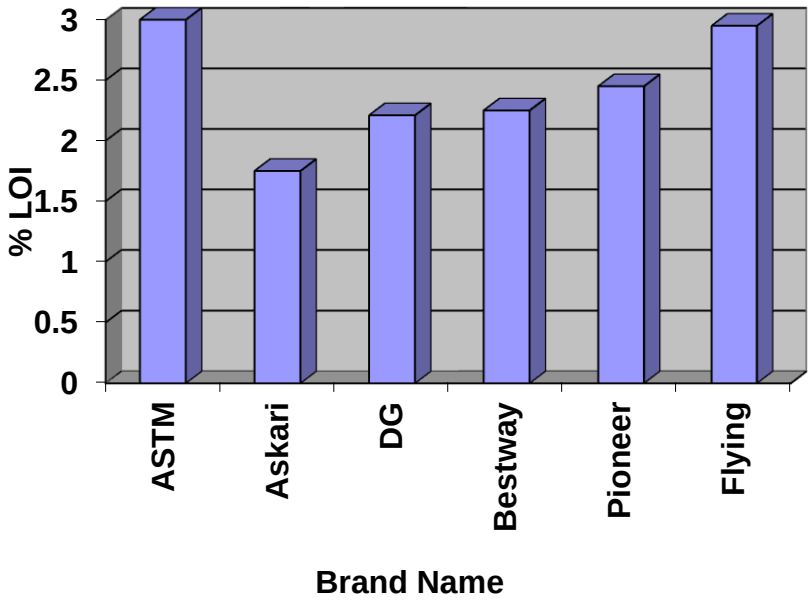

Fig.9: Loss on ignition (LOI) in various cement brands

5. CONCLUSION

Ordinary Portland cement is an artificial mineral which is manufactured from natural minerals the possible reasons of variations in different brands are raw material sources, raw mix design parameter such as Lime Saturation Factor (LSF), Silica modulus, alumina modulus, improper blending and impurities during processing of raw materials.

Chemical constituents influence the quality of cement akin to hardening behaviour, setting time, compressive strength, corrosion resistance, soundness, expansion etc [8, 9].

The perfect composition array of Portland cement is predicament for a chemist. But experience of vigilant operatives, experimentally demonstrated formulation by engineers and chemists certain specific boundaries has been established in the viable sonata of cement[10].If the constituents of cement are present within standard limits, mixture behaves satisfactorily in the kilns and produce good quality cement and Outside of those limits experience trouble in burning and inferior quality of cement.

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