EXPERIMENTAL STUDY ON ASSESSMENT OF DIFFERENT QUALITY PARAMETERS FOR DIFFERENT BRANDS OF CEMENT AVAILABLE IN LOCAL MARKET

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***ABSTRACT**: Cement is the most important binder used in the structure of all kinds that makes cement a necessity in construction. So it's an important job to find out which brand of OPC is right for the desired job. The purpose of this research is to measure the quality parameters of different brands of Portland cement available in Sargodha while keeping the physical conditions constant. There are many types of cement available in the market from which only Portland cement falls under the scope of this document. In the market of Sargodha, a lot of brands are dealing in Portland cement out of which only 5 brands (Bestway, Maple Leaf, DG, Flying Pakistan, and Pioneer) were used to assess the quality parameters of Portland cement. The selection of brands for Portland cement was done on the basses of ease of availability in the local market. The adopted method to assess the quality parameters of Portland cement was 5 tests of cement (compressive strength test, consistency test, fineness test, soundness test, setting time test), while 2 tests of cement (heat of hydration and chemical composition test) are recommended for future work by students. DG gained the highest compressive strength (20.79 MPa) after 28 days and it also turned out to be the most consistent cement (for 10 mm penetration in 30 sec). Bestway is the finest of all the brands (98% fineness) with an initial setting time of 100 minutes. To give recommendations, the results of the test performed and the study may provide useful insight and guidelines about the best brand of Portland cement.*

Keywords: Bestway; Maple Leaf; DG Cement; Compressive strength; soundness test; fineness test; brands of cement

1. INTRODUCTION

Cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. It is used to bind sand and gravel (aggregate) together. It is used for float coatings and cement slurry etc. It is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete [1].

Cement, in general, adhesive substances of all kinds, but, in a narrower sense, the binding materials used in building and civil engineering construction[2]. The cement of this kind is finely ground powders that, when mixed with water, set to a hard mass. Setting and hardening result from hydration, which is a chemical combination of the cement compounds with water that yields submicroscopic crystals or a gel-like material with a high surface area[3]. Because of their hydrating properties, constructional cement, which will even set and harden underwater, are often called hydraulic types of cement [4].

The scope of this work is limited to OPC hence only the types of OPC are discussed. The ASTM has designated five types of Portland cement, designated Types I-V. Physically and chemically, these cement types differ primarily in their content of C3A and in their fineness[5]. In terms of performance, they differ primarily in the rate of early hydration and in their ability to resist sulfate attack[6]. The general characteristics of these types are listed in Table 1

2. EXPERIMENTAL PROGRAM

2.1. Lab Testing

In order to assess the quality parameters for the selected brands of OPC easily available in the local market five different tests were performed according to the accessibility in the lab of the department which is as under[7]:

1- Compressive Strength of Hydraulic Cement (OPC) Mortars (Using 2-in. or (50-mm) Cube Specimens)(ASTM C109)

2- Normal Consistency of the Hydraulic Cement (OPC)(ASTM C 187-04) 3.Fineness of cement test (ASTM C 184 – 94)

3- Soundness of cement (ASTM C189)

4- Standard test method for the Determination of the Initial and Final Setting Time of the Hydraulic Cement (OPC) By VICAT Needle Apparatus (ASTM C191-04b)

5- Fitness Test for cement (ASTM C 184 – 94)

Table. 1: Description of Cement Types

Type	Classification	Characteristics	Applications
Type 1	General Purpose	Fairly high C3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc.)
Type II	Moderate sulfate resistance	Low C3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C3S (<50%) and C3A	Massive structures such as dams
Type V	High sulfate resistance	Very low C3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White color	No C4AF, low MgO	Decorative (otherwise has properties similar to Type I)

2.1.11. Compressive Strength of Hydraulic Cement (OPC) Mortars (Using 2-in. or (50-mm) Cube Specimens)(ASTM C109)

This test method covers the determination of the compressive strength of hydraulic cement mortars, using 2-in. or (50 -mm) cube specimens. The AUTOMAX compact Line Automatic Compression (EN 12390-4) machine was used for testing[8]. The machine having a capacity of 2000KN with a maximum working pressure of 650bar as shown in Fig 1.

Fig.1: Compression Testing Machine

Procedure

Firstly, molds were oiled to achieve the proper finishing of the cube specimen.

Mortar cubes in a moist closet, protected from dripping water, for between 20 and 24 hours, after which the cubes stripped from the molds as shown in Fig 3.

166.67 grams of cement and 458.33gm of sand were taken in the mixing tray. The cement and sand were mixed in the dry state.

80.8 grams of water was added in the cement and sand mixture which was further stirred for 1 more minute.

The mixing of mortar was finished at medium speed in 60 seconds in mixing tray as shown in Fig 2.

Immediately upon completion of mixing, the specimens were molded by placing the mortar in three layers in all of the three cube compartments.

The mortar cubes were inserted in a water bath until they were ready for testing.

All specimens were tested within a specified time period and readings were recorded as shown in tables 2-6.

Fig.2: Mixing Tray

Fig.3: 2-inch Cube Mold

Observations and Calculations (Days = 28)

Table 2 (Bestway Cement)

Sample	Load (kN)	Strength (MPa)
Best way Cement	37.18	14.41

Table 3 (Maple Leaf Cement)

Sample	Load (kN)	Strength (MPa)
Maple Leaf Cement	44.98	17.43

Table 4 (DG Cement)

Sample	Load (kN)	Strength (MPa)
DG Cement	53.65	20.79

Table 5 (Flying Pakistan Cement)

Sample	Load (kN)	Strength (MPa)
Flying Pakistan Cement	34.88	13.52

Table 6 (Pioneer Cement)

Sample	Load (kN)	Strength (MPa)
Pioneer Cement	18.02	7

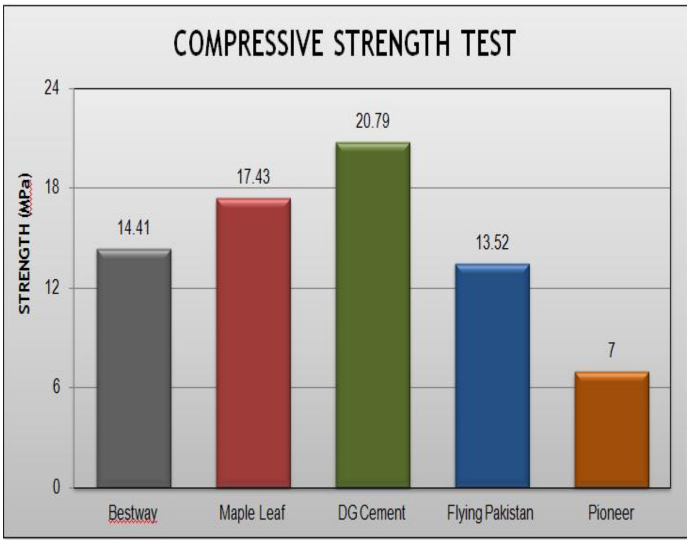

Fig. 4: 28 Days Strength Test Graph

Comments

Pioneer cement showed the least strength in comparison to other brands while the difference in strength from the peak was 13.9 MPa. All brands except Pioneer almost attained the same strength after 28 days. DG Cement gained the highest strength after 28 days[9].

2.1.2 NORMAL CONSISTENCY OF THE

HYDRAULIC CEMENT (OPC) (ASTM C187-04)

It is used to find out the percentage of water at which the standard consistency is achieved. In this test, the Vicat apparatus was used.

Fig.5: Vicat Apparatus

Procedure

A 650gm sample of cement was taken in a mixing pan.

Initially, water was added, let say on the hit and trial bases i.e. 30% of the weight of the sample.

The above-mentioned quantity of water was mixed with the cement thoroughly, then placed in the Vicat ring and, the top surface was leveled.

The mixing of cement and placing of that cement in the Vicat ring was done within 4 minutes.

Once the sample was leveled in the Vicat ring. Plunger was released and after 30 seconds the penetration of the plunger was noted[10].

Fig.6: Mixing Tray and Vicat Needle

Fig.7: Plunger Penetration

Observations and Calculations

Table 7 (Normal Consistency for Bestway cement)

Observations	Measurements
Weight of water added (gm)	175.5
Penetration of plunger (mm)	10
% water by weight = (quantity of water for 10 mm penetration/W2 × 100)	27

Table 8 (Normal Consistency for Maple Leaf cement)

Observations	Measurements
Weight of water added (gm)	182
Penetration of plunger (mm)	10
% water by weight = (quantity of water for 10 mm penetration/W2 × 100)	28

Table 9 (Normal Consistency for DG cement)

Observations	Measurements
Weight of water added (gm)	185.25
Penetration of plunger (mm)	10
% water by weight = (quantity of water for 10 mm penetration/W2 × 100)	28.5

Table 10 (Normal Consistency for Flying Pakistan cement)

Observations	Measurements
Weight of water added (gm)	182
Penetration of plunger (mm)	10
% water by weight = (quantity of water for 10 mm penetration/W2 × 100)	28

Table 11 (Normal Consistency for Pioneer cement)

Observations	Measurements
Weight of water added (gm)	169
Penetration of plunger (mm)	10
% water by weight = (quantity of water for 10 mm penetration/W2 × 100)	26

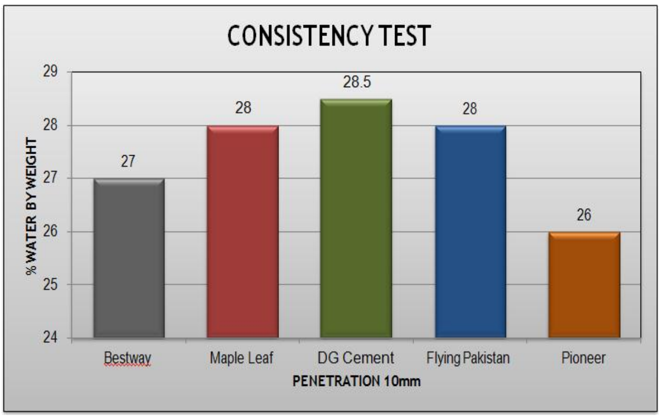

Fig. 8: Graph for Consistency Test

Comments

DG Cement showed the best consistency result as it used the highest percentage of water by weight for 10 mm penetration. DG Cement in comparison to other brands is the most consistent of them all because it requires water 185.25 grams i.e. 16.25 grams more than what Pioneer consumed. Other than DG cement all other brands almost achieved the same consistency.

2.1.3 FINENESS OF CEMENT TEST (ASTM C 184 – 94)

This experiment is carried out to check the proper grinding of cement by U.S. sieve no.100.

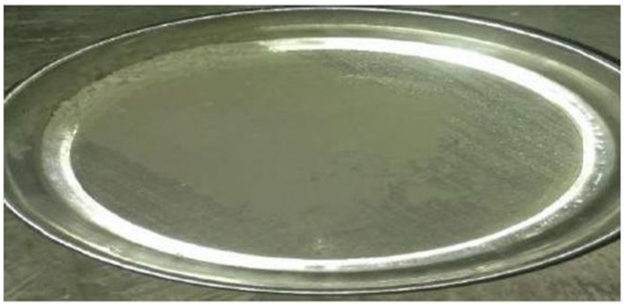

Fig. 9: Sieve No. 100

Procedure

Cement was weighed using the pan and electronic balance.
Cement was carefully put into the U.S. sieve no.100and sieve was closed tightly.
Sieve was shaken horizontally for 10 to 15 minutes.
After that shaking, the residue (cement left on sieve) was weighted again and the reading was noted as RS.
The following formula was used to calculate the fineness of the cement.
W= Total weight of cement, RS= Weight of cement left on sieve
Formula: Percentage of fineness= 100 – [(Rs/W) x 100]

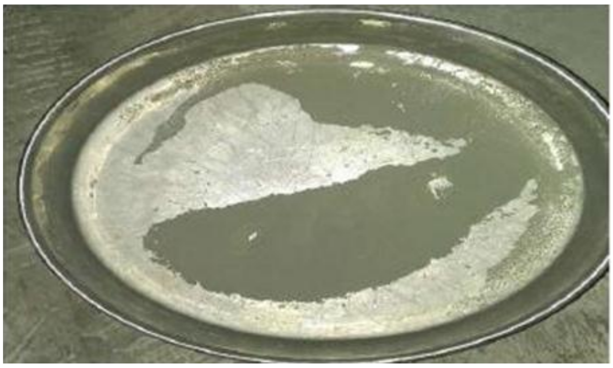

Fig. 10: Residue on Sieve No. 100

Observations and Calculations

Table 12. The fineness of Bestway Cement

Observations	Measurements
Total weight of cement = W(gm)	50
Weight Retained on #100 sieve = Rs	1
Percentage of fineness = 100 – [(Rs/W) x 100]	98

Table 13. Fineness of Meaple leaf Cement

Observations	Measurements
Total weight of cement = W(gm)	50
Weight Retained on #100 sieve = Rs	3.4
Percentage of fineness = 100 – [(Rs/W) x 100]	93.2

Table 14. Fineness of DG Cement

Observations	Measurements
Total weight of cement = W(gm)	50
Weight Retained on #100 sieve = Rs	2
Percentage of fineness = 100 – [(Rs/W) x 100]	96

Table 15. Fineness of Flying Pakistan Cement

Observations	Measurements
Total weight of cement = W(gm)	50
Weight Retained on #100 sieve = Rs	2.2
Percentage of fineness = 100 – [(Rs/W) x 100]	95.6

Table 16. Fineness of Poineer Cement

Observations	Measurements
Total weight of cement = W(gm)	50
Weight Retained on #100 sieve = Rs	1.5
Percentage of fineness = 100 – [(Rs/W) x 100]	97

2.1.4 SOUNDNESS TEST OF CEMENT

In the soundness test, a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is speeded up and can be detected. Soundness means the ability to resist volume expansion. The water bath for Le - Chatelier mold EN 196-3 (Model no. 62- L0025/F) was used as shown in figure 11.

Fig. 11 : Le-chatelier Bath

PROCEDURE

To achieve standard consistency the paste was made by adding 0.78 times the required amount of water.
Le-chatelier mold and a glass sheet were subjected to a few drops of oil, then the mold was placed on the glass sheet as shown in figure 12.

Fig. 12: Le-chatelier Mold

The process of filling the mold with the cement paste prepared earlier went smoothly.
Another glass sheet covered in few drops of oil was then used as lid of paste filled mold as shown in figure 13.

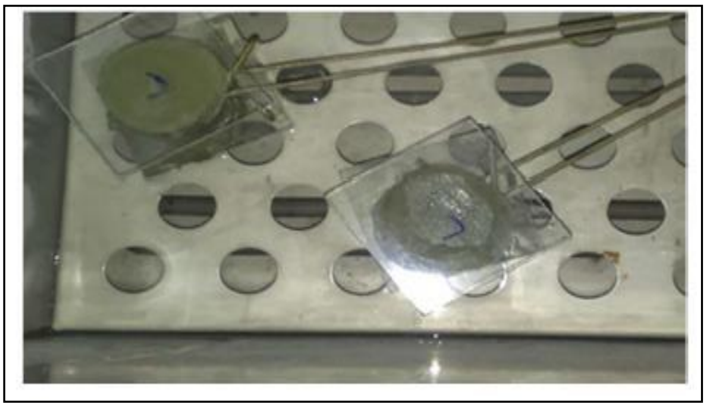

Fig. 13 : Samples in Le-chatelier Bath

The whole assembly was submerged in the water at a temperature of 27 ± 20 C and kept there for 24 hours.
The whole assembly was removed from the water bath and the distance separating the indicator points to the nearest 0.5 mm (L1) was measured as shown in figure 14.

Fig. 14: Measurement of Expansion from Le-chatelier Mold

The assembly was given another water bath but only this time the temperature of the water was raised to boiling point in 30 minutes and maintained for 3 hours.
After the duration of 3 hours, the temperature of the water was left to lower at room temperature on its own and once room temperature was achieved, the assembly was removed from the water bath.
The distance between the two indicator points to the nearest 0.5 mm (L2) was measured.

Observations and Calculations

Table 17. Soundness Test of Bestway Cement

Observations	Measurements
The measurements after 24 hours of immersion in water at a temp. of 27 ± 2°C = L1 (mm)	5.35
The measurements after 3 hours of immersion in water at boiling temperature = L2 (mm)	2.76
Soundness/expansion of cement = L1 - L2 (mm)	2.59

Table 18. Soundness Test of Maple leaf Cement

Observations	Measurements
The measurements after 24 hours of immersion in water at a temp. of 27 ± 2°C = L1 (mm)	5.55
The measurements after 3 hours of immersion in water at boiling temperature = L2 (mm)	3.15
Soundness/expansion of cement = L1 - L2 (mm)	2.40

Table 19. Soundness Test of DG Cement

Observations	Measurements
The measurements after 24 hours of immersion in water at a temp. of 27 ± 2°C = L1 (mm)	4.80
Measurements after 3 hours of immersion in water at boiling temperature = L2 (mm)	2.80
Soundness/expansion of cement = L1 - L2 (mm)	2.00

Table 20. Soundness Test of Flying Pakistan Cement

Observations	Measurements
Measurements after 24 hours of immersion in water at a temp. of 27 ± 2°C = L1 (mm)	4.83
Measurements after 3 hours of immersion in water at boiling temperature = L2 (mm)	2.00
Soundness/expansion of cement = L1 - L2 (mm)	2.83

Table 21. Soundness Test of Pioneer Cement

Observations	Measurements
Measurements after 24 hours of immersion in water at a temp. of 27 ± 2°C = L1 (mm)	3.77
Measurementsafter 3 hours of immersion in water at boiling temperature = L2 (mm)	1.56
Soundness/expansion of cement = L1 - L2 (mm)	2.21

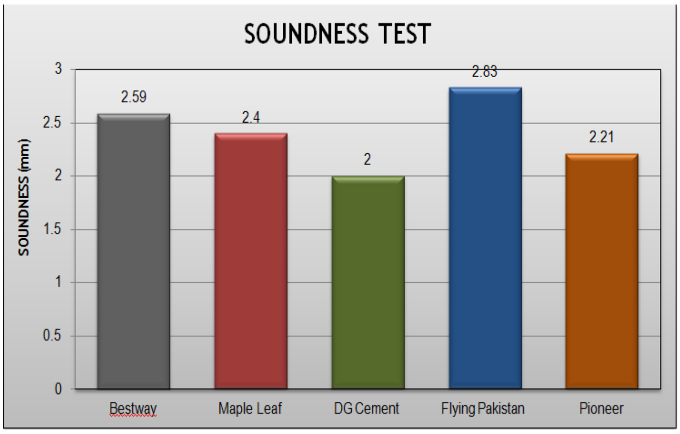

Fig. 15: Soundness Test Graph

COMMENTS

DG Cement showed the least expansion i.e.2.00mm hence according to soundness test it is the most suited OPC cement. Flying Pakistan Cement expanded most hence it's the worst choice as far as soundness is a concern. All brands expanded as much as Flying Pakistan but DG Cement showed the best result.

2.1.5 Standard test method for the determination of the initial and final setting time of the hydraulic cement (OPC) by Vicat needle apparatus (ASTM c191-04b)

This test method is used to determine the time of setting of the hydraulic cement by the Vicat needle apparatus. In this test Vicat apparatus (Model no.63-L0028/1) was used as shown in figure 16.

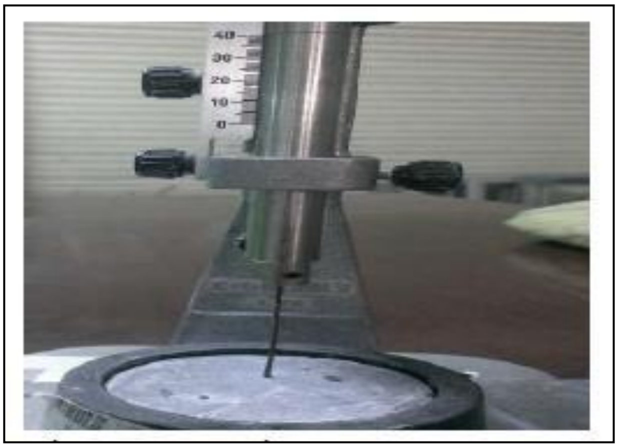

Fig. 16: Vicat Apparatus

PROCEDURE

A 650gm sample of cement was taken in a mixing pan.

Initially, water was added, let say on the hit and trial bases i.e. 30% of the weight of the sample.

The above-mentioned quantity of water was mixed with the cement thoroughly, then placed in a Vicat ring and, the top surface was leveled as shown in figure 17.

Everything was done within 4 minutes.

Once the sample was leveled in the Vicat ring, the rod attached with the 1mm-needle was released and after 30 seconds the penetration of the 1-mm needle was noted.

When penetration of 10mm was obtained then the time was noted as initial setting time.

The penetration of the needle after an interval of 30 minutes, until there was no considerable penetration shown by the needle, was noted as final setting time

Fig. 17: Pouring Mortar in Vicat Ring

Observations and Calculations

Table 22. Initial and final setting time of Bestway Cement

Observations	Measurements
Initial setting time (min)	100
Final setting time (min)	270

Table 23. Initial and final setting time of Maple leaf Cement

Observations	Measurements
Initial setting time (min)	80
Final setting time (min)	230

Table 24. Initial and final setting time of DG Cement

Observations	Measurements
Initial setting time (min)	85
Final setting time (min)	260

Table 25. Initial and final setting time of Flying Pakistan Cement

Observations	Measurements
Initial setting time (min)	80
Final setting time (min)	280

Table 26. Initial and final setting time of Pioneer Cement

Observations	Measurements
Initial setting time (min)	90
Final setting time (min)	320

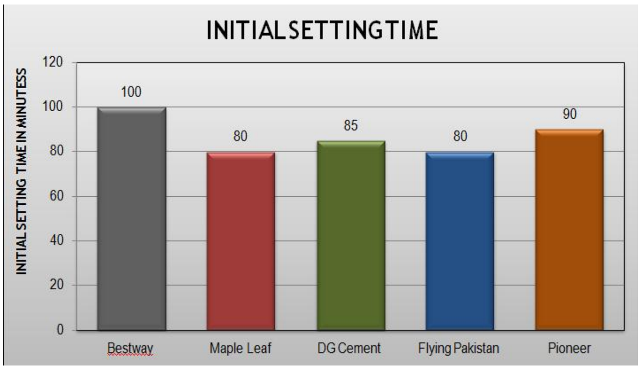

Fig. 18: Graph for Initial setting time

For all brands, initial setting time falls within the limit i.e. 45 minutes<initial setting time<375 minutes as shown in figure 18.

The final setting should be within the limiting value i.e. (90 + 1.2 × (initial setting time)) minutes <final setting time < 600minutes or 10hrs.The values of the final setting for all the brands are within the limits as shown in figure 19.

COMMENTS

According to the results obtained Maple Leaf Cement is the best choice when it comes to setting time. As Pioneer has higher setting time so as far as setting time is concerned Pioneer cement falls at bottom of the priority list due to higher setting time.

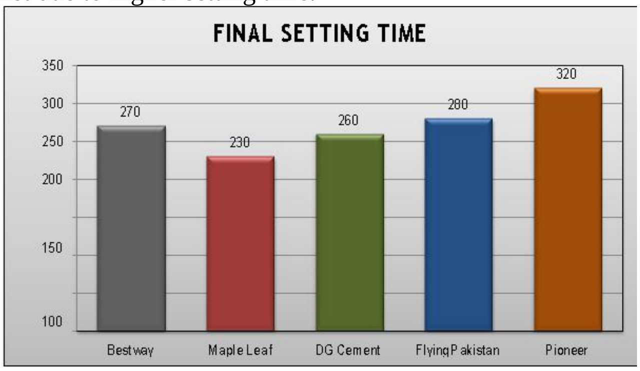

Fig. 19: Graph for Final setting time

3. CONCLUSIONS

- Higher the value of strength higher will be the quality of cement.
- When a megastructure is to be build or the structure that has to withstand very high loads then the strength parameter becomes the governing factor for determining the quality of cement.
- DG gained the highest compressive strength (20.79 MPa) after 28 days.
- The plunger should penetrate 10 mm in 30 sec. Consistency is directly proportional to workability. In the megastructure, it will be preferred. More the percentage of water by weight (quantity of water for 10 mm penetration/W2 × 100) more will be the consistency.W2 is the weight of cement.
- When pilling is involved and high workability is required then the consistency parameter becomes a governing factor for the quality of Cement.
- If a high rising building is to be built then high workability becomes necessity, strength, and consistency becomes a governing factor.
- If workability is high then self -compacting concrete will set on its own without the use of vibrator. Voids will be filled easily.
- DG cement turned out to be the most consistent cement (for 10 mm penetration in 30 sec.)
- Fineness less than 90% means the bad quality of cement. With an increase in the fineness of cement, both consistency of cement and workability of concrete increase. An increase in inconsistency means an increase in water demand to get cement paste of standard consistency while the increase in workability means an increase in flowability at the same water/cement ratio.
- Increasing the fineness of cement reduces the amount of bleeding in concrete.
- Increasing the fineness of cement from 2700 to about 4000 g/cm2 reduces the water requirement of concrete.
- Where early strength is required e.g. structures submerged in water, bridges, etc. The fineness test becomes a governing factor for the quality of Cement.
- Fineness is directly proportional to the workability of cement.
- Bestway winds up as finest of them all (98% weight of residue overweight of cement ratio).
- After the final setting time if there is lesser expansion it means higher will be the soundness of cement.
- Earthquake affected area and where earthquakes are the norm of life soundness test becomes the governing factor for the quality of cement.
- The more sound the cement the more durable will be the structure. More soundness means less volume expansion in the Cement.
- DG cement produces the soundest cement (18 mm expansion in volume after final setting time).
- Higher initial time preferred to ensure the transportation, pouring, and compaction of concrete. On the other hand, lesser final setting time will be preferred to remove the formwork as early as possible and to gain the early strength. The limitation of the final setting time is a maximum of 10 hours and not less than 90+1.2(initial setting time).
- The circumstances in which cement has to be transported from long distances then the governing factor for the quality of cement will be setting time of Cement.
- The initial setting time (highest value) will be preferred.
- With the initial setting time of 100 minutes, Bestway cement has the highest workability.

4. RECOMMENDATIONS

This thesis will serve as a foundation for further work on cement quality parameters by students. In future chemical composition tests and heat of hydration, the test should be performed in addition to five tests that are already performed to get more accurate inside on quality parameters of cement. Contractors will be able to find useful information regarding construction material (OPC). The construction industry will have a guideline to improve the quality and overcome the weak parameters of their respective brand.

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