Cement : Physical Properties and Types of Cement

Physical Properties

- Portland cements are commonly characterized by their physical properties for quality control purposes. Their physical properties can be used to classify and compare Portland cements. The challenge in physical property characterization is to develop physical tests that can satisfactorily characterize key parameters.

The physical properties of cement

- Setting Time
- Soundness
- Fineness
- Strength

Setting Time

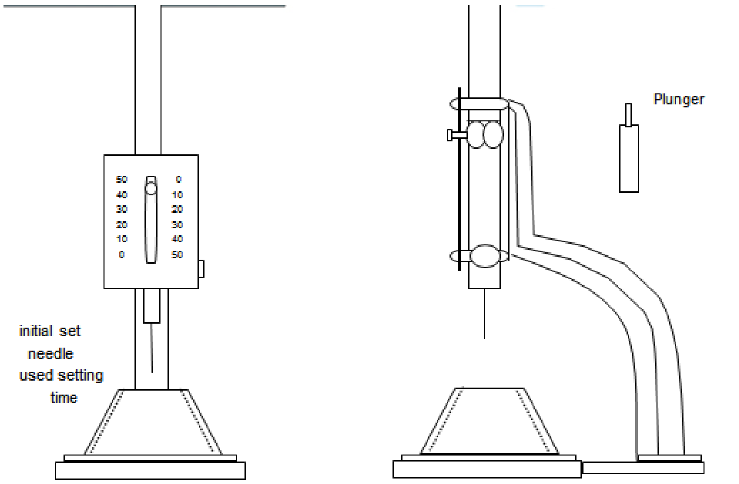
- Cement paste setting time is affected by a number of items including: cement fineness, water-cement ratio, chemical content (especially gypsum content) and admixtures. Setting tests are used to characterize how a particular cement paste sets.
- For construction purposes, the initial set must not be too soon and the final set must not be too late. Normally, two setting times are defined:
- Initial set. Occurs when the paste begins to stiffen considerably.
- Final set. Occurs when the cement has hardened to the point at which it can sustain some load.
- Setting is mainly caused by C_3A and C_3S and results in temperature rise in the cement paste.
- False set :No heat is evolved in a false set and the concrete can be re-mixed without adding water
- Occures due to the conversion of unhydreous/semihydrous gypsum to hydrous gypsum($CaSO_4.2H_2O$)
- Flash Set: is due to absence of Gypsum. Specifically used for under water repair.

Tests:

Consistency

- The consistency is measured by the Vicat apparatus using a 10mm diameter plunger.
- A trial paste of cement and water is mixed and placed in the mold having an inside diameter of 70mm at the base and 60mm at the top, and a height of 40mm.
- The plunger is then brought into contact with the top surface of the paste and released. Under the action of its weight the plunger will penetrate the paste. The depth depending on the consistency.
- When the plunger penetrates the paste to a point 5 to 7mm from the bottom of the mold. The paste is considered to be at “normal consistency”.

- The water content of the paste is expressed as a percentage by weight of dry cement. The usual range of values being between 26% and 33%.



- Vicat Apparatus: front and side views

Setting time

- The setting time test is conducted by using the sameVicat apparatus, except that a 1mm diameter needle is used for penetration.
- The test is started about 15 minutes after placing the cement paste (which has normal consistency) into the mold. Trials for penetration of the needle are made.
- The final setting time is defined as the length of time between the penetration of the paste and the time when the needle(with annular ring) no longer sinks visibly into the paste.
- The initial setting time is defined as the length of time between the penetration of the paste and the time when the needle penetrates 25mm into the cement paste.

Soundness

- When referring to Portland cement, "soundness" refers to the ability of a hardened cement paste to retain its volume after setting without delayed expansion. This expansion is caused by excessive amounts of free lime (CaO) or magnesia (MgO). Most Portland cement specifications limit magnesia content and expansion.
- The cement paste should not undergo large changes in volume after it has set. However, when excessive amounts of free CaO or MgO are present in the cement, these oxides can slowly hydrate and cause expansion of the hardened cement paste.
- Soundness is defined as the volume stability of the cement paste.

Test For Soundness

- IS prescribe a Soundness Test conducted by using the Le Chatelier apparatus. The apparatus consists of a small brass cylinder split along its generatrix. Two indicators with pointed ends are attached to the cylinder on either side of the split.

- The cylinder (which is open on both ends) is placed on a glass plate filled with cement paste of normal consistency, and covered with another glass plate.
- The whole assembly is then immersed in water at 20 ± 1°C for 24 hours. At the end of that period the distance between the indicator points is measured. The mold is then immersed in water again and brought to a boil. After boiling for one hour the mold is removed from the water, after cooling, the distance between the indicator points is measured again. This increase represents the expansion of the cement paste for Portland cements, expansion is limited to 10mm.

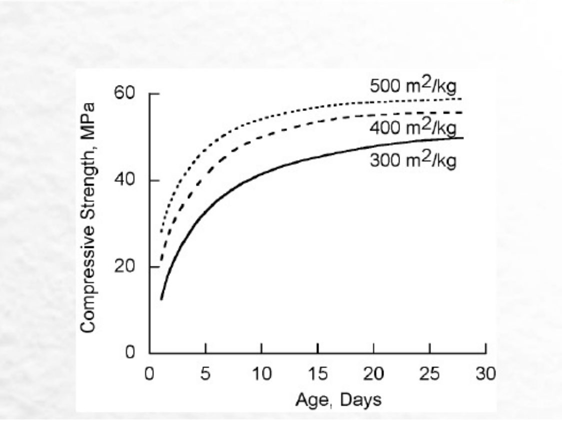
Fineness

- Fineness, or particle size of Portland cement affects Hydration rate and thus the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, and thus, the more area available for water-cement interaction per unit volume. The effects of greater fineness on strength are generally seen during the first seven days.
- When the cement particles are coarser, hydration starts on the surface of the particles. So the coarser particles may not be completely hydrated.This causes low strength and low durability.
- For a rapid development of strength a high fineness is necessary.

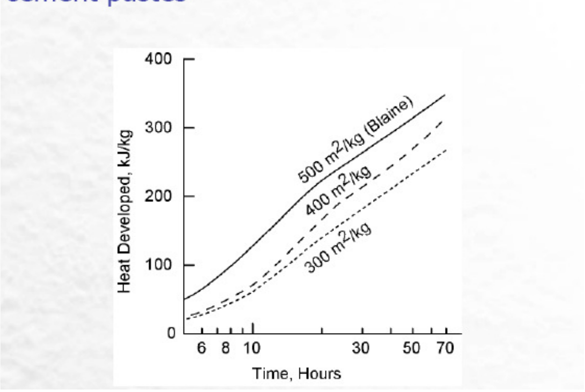
Test for Fineness

- There are various methods for determining the fineness of cement particles. The Blaine air-permeability method is the most commonly used method.
- In the Blaine air-permeability method, given volume of air is passed through a prepared sample of definite density. The number and size of the pores in a sample of given density is a function of the particles and their size distribution and determines the rate of air flow through the sample. Calculations are made and the fineness is expressed in terms of cm^2/g or m^2/kg

Influence of cement fineness on strength



Influence of fineness on heat development in cement pastes



Strength

- Cement paste strength is typically defined in three ways: compressive, tensile and flexural. These strengths can be affected by a number of items including: water-cement ratio, cement-fine aggregate ratio, type and grading of fine aggregate, curing conditions, size and shape of specimen, loading conditions and age.

Duration of Testing

Typically, Durations of testing are:

- 1 day (for high early strength cement)
- 3 days, 7 days, 28 days and 90 days (for monitoring strength progress)
- 28 days strength is recognised as a basis for control in most codes.
- When considering cement paste strength tests, there are two items to consider:
- Cement mortar strength is not directly related to concrete strength. Strength tests are done on cement mortars (cement + water + sand) and not on cement pastes.

Compressive Strength

- Compressive strength of Portland cement is determined by the BIS method.
- The cement paste (consisting of 1 part cement+3 parts standard sand+ water, by weight) is placed in 7cm molds. And the specimens are water cured for various ages for testing.
- The mortar specimens taken out of the molds are subjected to compression to determine the strength.
- The compressive strength test is conducted on mortar cubes.. After finding the breaking load in compression, P_{max} , Compressive Strength is calculated by the relation $\sigma_c = P_{max}/A$, where $A=50cm^2$.
- The average of the results found by testing six specimen is the compressive strength of the mortar cubes.

Table 2.9. Brief Summary of Cement Testing Procedure and grades of Cement in various contries.

Country	Grade	TESTING PROCEDURE: Material	Size of Cube mm.	Compaction	W/C ratio	COMPRESSIVE STRENGTH MPa: 1 day	3 days	7 days	28 days
India	33	1:3 Mortar	70.6 (50 cm²)	Vibration 12000/min For 2 min	0.39 to 0.45	-	16	22	33
	43	-	-	-	-	-	23	33	43
	53	-	-	-	-	-	12	37	53
Germany	30	Mortar	Prism 40 40 160 (25 cm²) **	Vibration	0.5	-	12	-	30
	35		-	-	-	-	15	-	35
	40		-	-	-	-	20	-	40
	45		-	-	-	-	25	-	45
	50		-	-	-	25	-	-	50
	55		-	-	-	25	-	-	55
China	275	1:2.5 Mortar	-	-	0.44	-	-	16	28
	325	-	-	-	-	-	12	19	33
	425	-	-	-	-	-	16	25	43
	525	-	-	-	-	-	21	32	53
	625	-	-	-	-	-	27	41	63
	725	-	-	-	-	-	36	-	73
U.S.S.R.	400	1:3 Mortar	Prism 40 40 160 **	-	0.4	-	-	-	40
	500	-	-	-	-	-	-	-	50
	550	-	-	-	-	-	-	-	55
	600	-	-	-	-	-	-	-	60
U.K.	OPC	Mortar 1:3	70.6	Vibration 12000 ± 400 for 2 min	0.4	-	23	-	42
	-	Concrete 1:2.5:3.5	101.6	Tamping	0.6	-	13	-	30
U.S.A.	OPC Type 1	Mortar 1:2.75	50	Tamping	0.485	-	13	20	29

* P/4 + 3%, where P is standard consistency.

** After bending test, one half of the prism is stressed along the longer edges with loading area restricted to 25cm².

Types of Cement

- **Types of Portland Cement**
    - The rapid increase in sophistication of design and construction techniques and the greater attention to variations in regional and job conditions have created demand for modifications of certain properties of concrete. This has resulted in the development of several "types" of Portland cement and a greater use of concrete admixtures.

    - The production of a different type of Portland cement involves certain adjustments in the manufacturing process;
      mainly the selection of raw materials,
      chemical proportions,
      special additives, and
      degree of grinding.

IS 456-2000 recognises several types of cement for RCC construction.

Table 2.5. Physical Characteristics of Various Types of Cement.

Sl.No.	Type of Cement	Fineness (m^2/kg) Min.	Soundness By: Le chatelier (mm) Max.	Soundness By: Autoclave (%) Max.	Setting Time: Initial (mts) min.	Setting Time: Final (mts) max.	Compressive Strength: 1 Day min. MPa	Compressive Strength: 3 Days min. MPa	Compressive Strength: 7 Days min. MPa	Compressive Strength: 28 Days min. MPa
1.	33 Grade OPC (IS 269-1989)	225	10	0.8	30	600	N S	16	22	33
2.	43 Grade OPC (IS 8112-1989)	225	10	0.8	30	600	N S	23	33	43
3.	53 Grade OPC (IS 12269-1987)	225	10	0.8	30	600	N S	27	37	53
4.	SRC (IS 12330-1988)	225	10	0.8	30	600	N S	10	16	33
5.	PPC (IS 1489-1991) Part I	300	10	0.8	30	600	N S	16	22	33
6.	Rapid Hardening (IS 8041-1990)	325	10	0.8	30	600	16	27	N S	N S
7.	Slag Cement (IS 445-1989)	225	10	0.8	30	600	N S	16	22	33
8.	High Alumina Cement (IS 6452-1989)	225	5	N S	30	600	30	35	N S	N S
9.	Super Sulphated Cement (IS 6909-1990)	400	5	N S	30	600	N S	15	22	30
10.	Low Heat Cement (IS 12600-1989)	320	10	0.8	60	600	N S	10	16	35
11.	Masonry Cement (IS 3466-1988)	*	10	1	90	1440	N S	N S	2.5	5
12.	IRS-T-40	370	5	0.8	60	600	N S	N S	37.5	N S

*N S – Not specified

Type	C_3S	C_2S	C_3A	C_4AF	Fineness (m^2/kg)	Remarks
OPC	40	35	12	10	225	Normal Stg. @ 28d
RHPC	60	15	12	10	325	Same @ 7d
LHPC	30	45	05	13	320	As for OPC normally
PPC	(up to 35% of fly ash to OPC)				300	As for OPC normally
PSC	(25 – 60% of slag to OPC)				225	As for OPC normally

Summary

- Physical characteristics are important to control the quality of different cements produced by different manufacturers at site.
- It is important to follow the standard test procedure prescribed and understand its limitations while interpreting the results.
- In general, different types of cement are the results of modifications of portland cement in their physical and chemical composition and few additives in few cases.

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3. "Concrete Technolgy – Theory and Practice", M.S. Shetty, S. Chand and Company Ltd.,, 2005.