Lecture 4: CEMENT

CEMENT:

- History
- Manufacture
- Chemistry
- Types
- Uses
- Properties
- Tests and Specifications

History:

- Egyptians, Romans, Indians
- Pyramid mortar 81.5% $CaSO_4$ and 9.5% carbonate
- Indians used powdered brick named as surki in mortar
- Romans used blood, milk and lard to achieve workability
- John Smeaton in 1756 concluded that limestone with clayey matter yields hydraulic cement
- L.J. Vicat and James Frost (1911) also led the knowledge of cement
- Joseph Aspdin Leeds builder patented PC in Oct, 1824
- Germans specified PC in 1877, British in 1904, ASTM in 1904
- PC was first manufactured in India in 1913

Manufacture:

- Collection of raw materials
- Crushing, grinding and mixing of raw materials
- Burning
- Grinding of clinker
- Addition of gypsum

Cement Chemistry:

Raw materials of cement – lime, silica, alumina and iron oxide interact with one another in the kiln and a chemical equilibrium is reached by making complex four major compounds. The relative proportions of these compounds are responsible for influencing various properties of cement in addition to rate of cooling and fineness of grinding. Following are the compounds.

	Compound	Oxide Comp.	Abb.	%	Function
1.	Tricalcium Silicate	$3CaOSiO_2$	C_3S	54.1	Strength
2.	Dicalcium Silicate	$2CaOSiO_2$	C_2S	16.6	Strength
3.	Tricalcium Aluminate	$3CaOAl_2O_3$	C_3A	10.8	helps reaction
4.	Tetracalcium Aluminoferrite	$4CaOAl_2O_3Fe2O_3$	C_4AF	9.1	Acc. Hydr

Functions of various ingredients/oxides of cement:

1. Lime – CaO -- it forms about 63 percent of cement, controls strength and soundness, its deficiency reduces strength and setting time
2.. Silica – SiO_2-- it forms about 20 percent, imparts strength, excess causes slow setting

3. Alumina – Al2 O_3 – around 6 percent, imparts quick setting, excess lowers strength

4. Iron Oxide – Fe_2O_3 – around 3 percent, imparts color, helps in fusion and imparts hardness and strength to cememt forming tricalcium aluminoferrite

5. Magnesia – MgO - around 1.5 percent and should not be more than 2 percent, imparts color and hardness, excess causes cracks and unsoundness

6. Sulphur Trioxide – SO_3 - around 2 percent, makes cement sound, excess makes unsound

7. Sodium, Potasium Oxide – K_2O, Na_2O – around 1 percent, excess makes unsound

Hydration of Cement:

When water is added to cement, anhydrous(dry) constituent compounds of cement start reacting and forming hydration products C-S-H (tobermorite gel), with reactions as follows

$2C_3S + 6H_2O \rightarrow C_3S_2H_2O + 3\,Ca(OH)_2$,

$2C_2S + 4H_2O \rightarrow C_3S_2H_2O + Ca(OH)_2$

$C_3A + 6H_2O \rightarrow C_3AH_2O$ this is rapid and retarded by adding gypsum

Heat of Hydration and Strength:

Hydration of cement compound is exothermic and the quantity of heat per gram of unhydrated cement, evolved upon complete hydration at a given temperature, is defined as heat of hydration. Methods to find is ASTM C186-82. C_3S, C_2S, C_3A and C_4AF produces 502, 260, 867, 419 joules per gm respectively. So, by reducing proportions of C_3A and C_3S, heat of hydration can be reduced. [see also supplied sheet]

Types of cement:

- Ordinary Portland Cement (BS), Type- I (ASTM), most common, high C_3S
- Modified Cement (BS), Type- II (ASTM), low heat gen., for mod. sul. action
- Rapid –hardening Portland cement (BS), Type-III (ASTM), rapid st. dev. due to high C_3S content, high fineness, for emergency works
- Low heat Portland cement (BS), Type-4 (ASTM), for large gravity dams, low amount of C_3S and high C_2S, slow rate of development of strength
- Sulphate resisting PC (BS), Type-5 (ASTM), good for resisting sulfate attack
- Portland blast-furnace cement (BS), Type-IS (STM), for mass concrete
- Portland – pozzolan cement (BS), Type IP, P and I(PM) –ASTM, for mass concrete

Other types of Cement:

- Special rapid hardening/ Ultra-high early strength cement
- Super sulfate cement
- White and Coloured cement
- Expansive cement
- High-alumina cement
- Hydrophobic cement
- Oil-well cement
- Readyset cement
- Masonry cement
- Pozzolana cement
- Natural cement

Testing of Cement: Laboratory tests

- Fineness
- Setting time
- Strength
- Soundness
- Heat of hyrdration
- Chemical composition

: Field tests

- Colour, uniformly greenish grey
- Physical, no lumps
- Cool feeling inside bag
- When pressed between fingers, smooth feeling
- When thrown on water, the particles should float for sometime
- A thick paste on a glass when kept under water for 24 hrs, should set and not crack.

Additional Tests – (not common)

Composition tests:

Magnesium Oxide (MgO) :
causes delayed expansion when present in large amounts. ASTM limits all cements to 6.0%.

Sulphuric anhydride (SO3):
is an indirect measure of the amount of gypsum or calcium sulphate(C_aSO_4) in the cement. Gypsum is added to cement for the purpose of regulating setting time. Too much gypsum can cause expansion and, therefore, SO_3 is generally limited to 3.5% in Type I cement with a C_3A content greater than 8% and limited to 3.0% in Type II cement with a C3A content less than 8%. Gypsum predominantly affects concrete set times by delaying the hydration of C3A which typically "flash sets" on contact with water.

Ignition loss (LOI):
represents the % weight loss suffered by a sample of cement after heating to 1832 F. Any water bonded to hydrated cement particles is expelled above this temperature. The higher the LOI, the less strength the cement will develop. ASTM limits the LOI to 3.0%.

Insoluble Residue: represents that a fraction of cement which is insoluble in hydrochloric acid. Almost all of the clay compounds present in the raw mix of cement are insoluble in acids. After After reactions with lime, these compounds are soluble making this test an indication of the efficiency of the burning process. (I.E. Determines the amount of unburnt raw materials and contamination from gypsum or storage.) ASTM limit is 0.75%
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Alkalies: - The alkali content of cement (mostly chloride) is reflected in the amounts of potassium oxide (K_2O) and sodiumoxide (Na_2O). Large amounts can cause certain difficulties in regulating set times of cement. Low alkali cements, when used with calcium chloride in concrete can cause discoloration in trowelled flatwork surfaces. ASTM has an optional limit in total alkalies of 0.60%, calculated by the equation $Na_2O + 0.658\ K_2O$.

False set: - Is a test to determine if the cement has abnormal early stiffening. This is an optional requirement of ASTM-150. False set is not a problem with transit mixing, where the concrete is continuously agitated before placing or where the concrete is remixed prior to placement, as with pumping. ASTM minimum is 50 percent.

Autoclave Expansion: - This provides an index of potential delayed expansion caused by the hydration of CaO or MgO or both. It is impossible to tell exactly how much CaO fails to combine into clinker minerals during the burning process. CaO that does not combine is called free lime, too much of which can cause delayed expansion. Because of the difficulty in determining the exact amount of free lime ASTM-150 requires a soundness test which measures the volume stability of cement. An autoclave expansion test where bars of cement paste are subjected to pressure of about 295 psi and temperatures of about 420 F. The change in length is limited to 0.80% for all cements.

Air Content: - All cements when mixed with water and sand have a tendency to entrain air. The air content of concrete is influenced by many factors, including the potential for air entrainment from cement. ASTM limit is 12%.

Specification: - as per sheet and test results given

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

Mobile: 01819 557 964; PABX: 966 5650-80 Ext. 7226; www.buet.ac.bd/ce/

CONCRETE LABORATORY

BRTC Bureau of Research, Testing & Consultation

BRTC No. : **1100-16957/11-12/CE; 24/8/2011**

Sent by : Quality Assurance & Environment Manager, Heidelberg Cement Bangladesh Ltd., SYMPHONY, Gulshan, Dhaka

Ref. No. : Letter; 24/8/2011

Project : -

Sample : **Cement** [Brand name: LOOSE/RUBY; ID: P- August,' 11] Our ID: MS-129

Date of Casting : 27/8/2011

Test Results of Portland Composite Cement (PCC)

ASTM C109	Age	3 days	7 days	28 days
	Date	30-Aug-11	3-Sep-11	24-Sep-11
Compressive strength, psi (MPa)	In figure	**2270 psi**	**3400 psi**	**5310 psi**
		(15.7 MPa)	(23.4 MPa)	(36.6 MPa)
	In words	**Two thousand two hundred seventy**	**Three thousand four hundred**	**Five thousand three hundred ten**
Standard Requirements for PCC Type-IP/IS ASTM C595		1890 psi 13.0 MPa	2900 psi 20.0 MPa	3620 psi 25.0 MPa
Mixing water temperature		22 °C	Curing water temperature	20.5 - 25°C

Water for Normal Consistency ASTM C187	Initial setting time (minutes) ASTM C191		Final setting time (minutes) ASTM C191	
	Standard requirement, ASTM C595	Test result	Standard requirement, ASTM C595	Test result
24%	Not less than 45 min.	**139**	Not more than 420 min.	**423**

Fineness (specific surface), m^2/kg ASTM C204 (air permeability method)	
Standard requirement, ASTM C595	Test result
****	****

Wt. of Cement Bag = ****

Note: Sample was received in unsealed condition.

Countersigned *by*: Test performed *by*:

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended at all test reports are collected by duly authorized person, and not by the Contractor/Supplier.