Concrete Ingredient
CE 231 Construction Materials
June 28th, 2011

Withit PANSUK
Department of Civil Engineering
Faculty of Engineering
Chulalongkorn University

Outline
• Review
• Cement Properties
• Water
• Aggregate

Review
• Concrete Ingredients
  – Cement
  – Aggregate
  – Water
  – Admixture (If any)

Main compounds in Portland Cement

Schematic representation of the formation and hydration of Portland Cement
Cement Properties

- Cements differ from plant to plant due to changes in raw material properties, kiln temperatures, and fineness upon grinding.
- When different cements are used in concrete, these changes can significantly affect concrete properties e.g. setting time, strength, durability etc.

Cement Properties

- Cement properties
  - Particle Size and Fineness
  - Setting time
  - Strength
  - Soundness
  - Consistency
  - Loss on Ignition; LOI
  - Insoluble Residue

Particle Size and Fineness

- Cements have the angular shape
- In the same lot, cements have the different sizes of each particle (95% smaller than 45 µm)

Particle Size and Fineness

- The rate of hydration depends mainly on the particle size and fineness of cement particles
- For rapid development of strength a high fineness is always necessary

Particle Size and Fineness

- The size distribution of cement particles can be done by
  - Sieve Analysis using sieve No 325 (ASTM C 430)
  - Electronic (X-Ray or Laser) Particle Size Analyzer

Particle Size and Fineness

- Sieve Analysis using sieve No. 325 (ASTM C 430)
Particle Size and Fineness

Laser Size Analyzer can be used for particles in the range of 0.02 micron to 2000 micron.

However, these methods for analyzing the particle size are not widely used in practice.

“Specific Surface (m²/kg)” is usually used to determine the fineness property of cement.

Example of particle size distribution and cumulative surface area contributed by particles up to any size for 1 gram of cement.

To determine the fineness of cement, we can use sedimentation or elutriation techniques which are based on Stoke’s law (Wagner turbidimeter; ASTM C 115) but this method is not mostly used.

Standard Testing for fineness of cement particles (Mostly used):

- BS Standard
  - by Air Permeability (Lea and Nurse) method
- ASTM Standard
  - Blaine air permeability method
Particle Size and Fineness

• Notice that the each method cannot give the absolute value but we can have the comparative value to compare the fineness properties between 2 or more cements samples.

Setting time

• Setting is mainly caused by a selective hydration of C₃A and C₃S and is accompanied by temperature rises in the cement paste.
• Initial set corresponds to the rapid rise and final set correspond to the peak temperature.

• Initial set & final set should be distinguished from "false set" with sometimes occurs.
• False set is the rapid development of rigidity in a cement paste, mortar, or concrete without the generation of much heat this rigidity can be dispelled and plasticity regained by further mixing without addition of water.

To determine the setting time we used the Vicat Needle (ASTM C 191) or Gillmore Needle(ASTM C 266).
Strength

- Strength test are not made on neat cement paste because of difficulties in obtaining good specimens and in testing with a consequent large variability of test results.

- ASTM C109 prescribes a cement-sand mix with proportions of 1:2.75 and a water/cement ration of 0.485 using ottawa sand or standard grading sand for making 2 inch cubes.

Soundness

- It is essential that the cement paste does not undergo a large change in volume (expansion).

- Expansion may occur due to reactions of free lime, magnesia and calcium sulphate, and cements exhibiting this type of expansion are classified as unsound.

- The tensile and flexural strengths test are also possible by briquet and prism specimens with standard mix proportion according to ASTM C190 and C348 respectively.

- Table 1.4: BS 12: 1978 and ASTM C 195-84 requirements for strength of cement.

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Ordinary Portland</th>
<th>Rapid-hardening</th>
<th>Ordinary Portland</th>
<th>Rapid-hardening</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23</td>
<td>2000</td>
<td>29</td>
<td>1200</td>
<td>13</td>
<td>1900</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>2000</td>
<td>31</td>
<td>1200</td>
<td>13</td>
<td>1900</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>2000</td>
<td>31</td>
<td>1200</td>
<td>13</td>
<td>1900</td>
</tr>
<tr>
<td>28</td>
<td>41</td>
<td>5000</td>
<td>46</td>
<td>4700</td>
<td>29</td>
<td>4200</td>
</tr>
</tbody>
</table>

* Not normally specified.
Soundness

**Free lime**
- present in inter-crystallized with other compound, it hydrates very slowly and occupying a larger volume than CaO
- Free lime cannot be determined by chemical analysis of cement because it is not possible to distinguish between unreacted CaO and Ca(OH)₂ produced by hydration

**Magnesia**
- reacts with water in the same manner as Free lime

**Calcium Sulphate**
- cause expansion through the formation of ettringite from excess gypsum

Soundness

- In practice, unsoundness due to free lime is very rare.
- The autoclave test (ASTM C 151) is sensitive to both expansions due to free magnesia and free lime
- There is no test available for the detection of unsoundness due to excess of calcium sulphate

Soundness

**Consistency**
- The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the ASTM C 187
- Standard consistency of cement is the consistency at which the Vicat plunger penetrates to a point 5-7mm from the bottom of Vicat mould.
**Loss on Ignition; LOI**

- a test used in inorganic analytical chemistry, particularly in the analysis of Cement
- It consists of strongly heating a sample of the cement at a specified temperature (900 – 1000 °C), allowing volatile substances to escape, until its mass ceases to change

**Loss on Ignition; LOI**

- The loss on ignition is reported as part of an elemental or oxide analysis of a mineral
- The volatile materials lost usually consist of combined water and carbon dioxide from carbonates
- In cement manufacture, the loss on ignition of the raw material is roughly equivalent to the loss in mass that it will undergo in a kiln.

**Loss on Ignition; LOI**

LOI Testing Equipment

Cement properties

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Increasing C3S (Decreasing C2S)</th>
<th>Increasing C3A (Decreasing C4AF)</th>
<th>Increasing alkalies</th>
<th>Increasing sulfate</th>
<th>Increasing minor components</th>
<th>Increasing fineness</th>
<th>Increasing steepness of particle size distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air content</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Setting time</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Strength</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Workability</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
<td>Increases</td>
</tr>
</tbody>
</table>

* Assuming only a change in one given component. This is unlikely to happen in reality because of the complexity of the Portland cement system. For example, a change in clinker sulfate is almost always accompanied by a change in alkali content. A change in gypsum content may be associated with a change in fineness as the plant operator seeks to control setting times and early strengths.

**Water**

- In general, we are talking about water in concrete in term of “quantity” rather than “quality” because the vital influence of the quantity of water in concrete mix on the strength but the quality of water is also important

**Water**

- The impurities in water may interfere with the
  - Setting time
  - The strength of the concrete
  - Staining on the surface
  - Corrosion of the reinforcement
- Clear distinction must be made between the effects of mixing water, curing water and the attack on hardened concrete
Mixing Water

- Many specifications, saying that "water for mixing should be fit for drinking (or potable water)" but this idea is not absolute if the water has a high concentration of sodium or potassium
- There is a danger of alkali-aggregate reaction and sometimes will effect to the setting time and the strength of concrete

Mixing Water

- The water should be free from injurious amounts of deleterious materials
- Seawater water is generally inadvisable unless good protection system (e.g. FRP) to the reinforcement has been installed
- The water used for wash out the mixer is considered satisfactory because the solids in it are proper concrete ingredients

Curing Water

- In general, the water which is satisfactory for mixing concrete can also be used for curing it but should not produce any objectionable stain or unsightly deposit on the surface

Curing Water

- Iron and organic matter in the water are chiefly responsible for staining or discoloration especially when concrete is subjected to prolong wetting
- Tannic acid or iron compounds in the curing water is objectionable

Aggregate

- Aggregate was originally viewed as an inert and inexpensive material
- In fact, aggregate is not truly inert because its physical, thermal and sometimes chemical properties influence the performance of concrete

Aggregate

- The acceptance of an aggregate for use in concrete on a particular job should be based upon specific information obtained from tests used to measure the aggregate quality, or upon its service record, or both
Aggregate

- Classification of aggregate
- Mechanical Properties
- Physical Properties

Classification of aggregates

- Unit weight
- Source and method of preparation
- Shape and texture
- Petrographic

Unit weight Classification

We can classify the aggregates into 3 groups
- **Light Weight Aggregate**
  Unit weight: 300 – 1,100 kg/m³
- **Normal Weight Aggregate**
  Unit weight: 2,400 – 3,000 kg/m³
- **Heavy Weight Aggregate**
  Unit weight: more than 4,000 kg/m³

Source and method of preparation Classification

- Aggregates may be broadly classified as natural or artificial
- Screening and washing in the process may be used to make an aggregate suitable for concrete

Source and method of preparation Classification

- Natural Aggregates
  - Natural sands and gravels are the product of weathering and the action of wind or water, while stone sands and crushed stone are produced by crushing natural stone
  - Aggregates may be produced from igneous, sedimentary, or metamorphic rocks
  - Products of processes developed to manufacture aggregates with special properties, such as expanded clay, shale or slate that are used for lightweight aggregates
  - Some lightweight aggregates such as pumice or scoria also occur naturally.
Shape and texture classification

Table 3.2: Particle shape classification of aggregates according to BS 88: Part 1: 1975, with examples

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rounded</td>
<td>Fully water-worn or essentially shaped by attrition</td>
<td>River or seaside gravel; desert, seaweshore and wind blown sand</td>
</tr>
<tr>
<td>Irregular</td>
<td>Naturally irregular, or partly shaped by attrition and having rounded edges</td>
<td>Other gravels, blind or dug fills</td>
</tr>
<tr>
<td>Flaky</td>
<td>Material of which the thickness is small relative to the other two dimensions</td>
<td>Laminated rock</td>
</tr>
<tr>
<td>Angular</td>
<td>Possessing well-defined edges formed at the intersection of roughly planar faces</td>
<td>Crushed pieces of all sizes; broken-down slag</td>
</tr>
<tr>
<td>Irregular and elongated</td>
<td>Material having the length considerably larger than the width, and the width considerably larger than the thickness</td>
<td>-</td>
</tr>
</tbody>
</table>

Shape and texture classification

- Effect of the shape and surface texture of aggregate:
  - More water is required when there is a greater void content of the loosely-packed aggregate
  - Flakiness and shape of the coarse aggregate have an appreciable effect on the workability of concrete
  - The workability decreases with an increase in the angularity number

Petrographic classification (Cont)
Mechanical Properties

- It is not possible to relate the potential strength development of concrete to the properties of the aggregate, and indeed it is not possible to translate the aggregate properties into its concrete making properties.

Bond

- The bond between the surface of the aggregate particles and cement matrix is a decisive factor for the strength of concrete.
- Both the shape and surface texture of aggregate influence considerably the bond and therefore the strength of concrete.

Bond

- A rougher texture results in a greater adhesion or bond between the particles and the cement matrix.
- The larger surface area of a more angular aggregate provides a greater bond but reduce workability.

Bond

- Softer, porous and mineralogical heterogeneous particles, allowing penetration by the paste, possess a better bond than those textures which do not permit the paste penetration.

Strength

- The compressive strength of concrete cannot significantly exceed that of the major part of the aggregate contained therein, although it is not easy to determine the crushing strength of aggregate itself.
Strength

- The aggregate crushing value (ACV) test is prescribed by BS 812: Part 110 - 1990 is a useful guide when dealing with aggregates of unknown performance.
- There are no explicit relations between ACV and its compressive strength but, in general, ACV is greater for a lower compressive strength.

Strength

- For crushing value over 25 – 30, the test is rather insensitive, the ten percent fine value (TFV) test as also prescribed by BS 812 Part 111 – 1990 should be implemented.

Toughness

- Toughness can be defined as the resistance of aggregate to failure by impact.
- To determine the toughness of aggregate we use aggregate impact value (AIV) test as described by BS 812 Part 112 – 1990.
- The impact is provided by a standard hammer falling 15 times upon the aggregate in a cylindrical container.

Toughness

- Following are the recommended AIVs:
  - 25% when the aggregate is to be used in heavy duty concrete floor finishes.
  - 30% when the aggregate is to be used in concrete pavement wearing surfaces.
  - 45% when to be used in other concrete.

Hardness

- Hardness, or resistance to wear, is an important property of concrete used in road and in floor surface subjected to heavy load.
- The aggregate abrasion value of the bulk aggregate is assessed using BS 812 Part 113, while the Los Angeles test is prescribed by ASTM C131.
Hardness

The Los Angeles machine
ASTM C131

Physical Properties

• Specific gravity
• Bulk density
• Porosity, absorption and moisture content
• Bulking of sand
• Unsoundness due to volume changes
• Thermal properties
• Deleterious substances
• Sieve analysis, grading curve and fineness modulus

Specific gravity

• The bulk specific gravity (bulk particle density) refers to the volume of the solid material including all pores
• The absolute specific gravity or the absolute particle density refers to the volume of the solid material excluding all pores

Specific gravity

• The apparent specific gravity (the apparent particle density) refers to the volume of solid material including the impermeable pores, but not the capillary pores
• The test methods for specific gravity are prescribed by BS 812 Part 107 and ASTM C 127 for coarse particles and C 128 for fine particles

Bulk density

• The density refers to the volume of individual particles only
• Aggregate is not possible to pack these particles so that no void between them
• When aggregate is to be batched by volume it is necessary to know the bulk density

Bulk density

• Bulk density is depended on the degree of compaction, The test methods for bulk density are described by BS 812 Part 2 and ASTM C 29
Porosity, absorption and moisture content

Schematic representation of moisture in aggregate

Bulking of sand

- In case of sand, there is effect of the present of moisture so called **bulking**, which is increase in the volume of a certain mass of sand caused by films of water pushing the sand particles apart
- The bulking does not affect the proportioning of materials by mass

Bulking of sand

Dry Moisture content 3 – 5 % Saturated

Unsoundness due to volume changes

- The physical causes of large or permanent volume change of aggregate are freezing and thawing, thermal changes at temperature above freezing, and alternating wetting and drying

Unsoundness due to volume changes

- If the aggregate is unsound, such change in physical condition result in deterioration of concrete so called pop-outs and even extensive surface cracking
- The testing of unsoundness is prescribed by ASTM C88 in which aggregate is subjected alternately to immersion in sulphate solution and to drying

Unsoundness due to volume changes

- The process causes disruption of particles due to the pressure generated by the formation of salt crystals
- The degree of unsoundness is expressed by the reduction in particle size after a specific number of cycles (5 cycles is usually used)
Thermal properties

- There are 3 thermal properties that may be significant in the performance of concrete
  - coefficient of thermal expansion,
  - specific heat
  - Conductivity
- The last two are of interest in mass concrete, but usually not in ordinary structural works.

Deleterious substances

- There are 3 broad categories of deleterious substances that may be found in aggregate for concrete
- Impurities which interfere the processes of cement hydration such as organic impurities

### Table 1.12: Linear coefficient of thermal expansion of different rock types

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Thermal coefficient of linear expansion (10^-5 per °C)</th>
<th>Thermal coefficient of linear expansion (10^-5 per °F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite</td>
<td>1.0 to 11.9</td>
<td>1.8 to 6.6</td>
</tr>
<tr>
<td>Diorite, andesite</td>
<td>4.1 to 10.3</td>
<td>2.3 to 5.7</td>
</tr>
<tr>
<td>Graphite, talc, diabase</td>
<td>3.6 to 9.2</td>
<td>2.9 to 5.4</td>
</tr>
<tr>
<td>Sandstone</td>
<td>4.3 to 13.9</td>
<td>2.4 to 7.7</td>
</tr>
<tr>
<td>Dolomite</td>
<td>6.7 to 8.8</td>
<td>3.7 to 6.8</td>
</tr>
<tr>
<td>Limestone</td>
<td>6.9 to 12.2</td>
<td>0.5 to 6.8</td>
</tr>
<tr>
<td>Chert</td>
<td>7.4 to 13.1</td>
<td>4.3 to 7.3</td>
</tr>
<tr>
<td>Marble</td>
<td>1.1 to 10.9</td>
<td>0.4 to 3.9</td>
</tr>
</tbody>
</table>

Deleterious substances

- Coating preventing the development of good bond between aggregate and cement paste such as clay, silt and other fine materials
- The certain particles which are weak or unsound

Deleterious substances

- The test method for organic impurities for fine aggregate is prescribed by ASTM C 40
- The test methods for clay, silt and fine dust contents for fine aggregate are prescribed by BS 812 Part 103 and ASTM C 33
Physical Properties

Sieve analysis, grading curve and fineness modulus

- The test methods are prescribed by BS 812 Part 1 and ASTM C 136

<table>
<thead>
<tr>
<th>Table: Sieve analysis and grading curve</th>
<th>Fineness modulus</th>
<th>Table: Test sieve sizes prescribed by BS 812 Part 1 and ASTM C 136</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS Aperture (mm)</td>
<td>Previous Designation</td>
<td>ASTM Aperture (mm)</td>
</tr>
<tr>
<td>5.0 mm</td>
<td>1/ in.</td>
<td>4.75 mm</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>8</td>
<td>2.50 mm</td>
</tr>
<tr>
<td>1.70 mm</td>
<td>6</td>
<td>1.83 mm</td>
</tr>
<tr>
<td>600 µm</td>
<td>0.0234</td>
<td>0.0234</td>
</tr>
<tr>
<td>300 µm</td>
<td>0.0117</td>
<td>0.0117</td>
</tr>
<tr>
<td>150 µm</td>
<td>0.0059</td>
<td>0.0059</td>
</tr>
</tbody>
</table>

Sieve analysis, grading curve and fineness modulus

- Table: Example of sieve analysis

<table>
<thead>
<tr>
<th>BS Aperture (mm)</th>
<th>Previous Designation</th>
<th>ASTM Aperture (mm)</th>
<th>Previous Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0 mm</td>
<td>1/ in.</td>
<td>6.00 mm</td>
<td>No. 1</td>
</tr>
<tr>
<td>5.00 mm</td>
<td>8</td>
<td>4.50 mm</td>
<td>No. 2</td>
</tr>
<tr>
<td>2.50 mm</td>
<td>6</td>
<td>4.00 mm</td>
<td>No. 3</td>
</tr>
<tr>
<td>1.25 mm</td>
<td>6</td>
<td>3.7 mm</td>
<td>No. 4</td>
</tr>
<tr>
<td>600 µm</td>
<td>0.025</td>
<td>0.025</td>
<td>No. 5</td>
</tr>
<tr>
<td>300 µm</td>
<td>0.005</td>
<td>0.005</td>
<td>No. 6</td>
</tr>
<tr>
<td>150 µm</td>
<td>0.0025</td>
<td>0.0025</td>
<td>No. 7</td>
</tr>
</tbody>
</table>

Sieve analysis, grading curve and fineness modulus

- Table: Sieve size range for coarse aggregate according to ASTM C 148-56

<table>
<thead>
<tr>
<th>BS Aperture (mm)</th>
<th>Previous Designation</th>
<th>ASTM Aperture (mm)</th>
<th>Previous Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0 mm</td>
<td>1/ in.</td>
<td>4.75 mm</td>
<td>No. 4</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>8</td>
<td>2.50 mm</td>
<td>No. 5</td>
</tr>
<tr>
<td>1.70 mm</td>
<td>6</td>
<td>1.83 mm</td>
<td>No. 6</td>
</tr>
<tr>
<td>600 µm</td>
<td>0.0234</td>
<td>0.0234</td>
<td>No. 35</td>
</tr>
<tr>
<td>300 µm</td>
<td>0.0117</td>
<td>0.0117</td>
<td>No. 30</td>
</tr>
<tr>
<td>150 µm</td>
<td>0.0059</td>
<td>0.0059</td>
<td>No. 100</td>
</tr>
</tbody>
</table>
Sieve analysis, grading curve and fineness modulus

Table 1.1a: Grading requirements for fine aggregate according to BS 882:1983 (amended in 1998).

<table>
<thead>
<tr>
<th>Percentage by mass passing size of nominal size</th>
<th>% passing size</th>
<th>Percentage by mass passing size of nominal size</th>
<th>% passing size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve No.</td>
<td>Size</td>
<td>40 mm (0.16 in)</td>
<td>20 mm (0.08 in)</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>0.50</td>
<td>-</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>0.95</td>
<td>55</td>
</tr>
<tr>
<td>30</td>
<td>2</td>
<td>0.95</td>
<td>55</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.5</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1.25</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>630</td>
<td>2</td>
<td>25–50</td>
<td>50–70</td>
</tr>
<tr>
<td>370</td>
<td>2</td>
<td>75–100</td>
<td>75–100</td>
</tr>
<tr>
<td>260</td>
<td>2</td>
<td>100–150</td>
<td>100–150</td>
</tr>
<tr>
<td>110</td>
<td>2</td>
<td>200–250</td>
<td>200–250</td>
</tr>
<tr>
<td>80</td>
<td>2</td>
<td>250–300</td>
<td>250–300</td>
</tr>
<tr>
<td>60</td>
<td>2</td>
<td>300–350</td>
<td>300–350</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>350–400</td>
<td>350–400</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>400–450</td>
<td>400–450</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>550–600</td>
<td>550–600</td>
</tr>
</tbody>
</table>

References

• ACI Committee 221, “Guide for Use of Normal Weight Aggregates for Concrete (ACI 221R-86),” American Concrete Institute, Farmington Hills, Mich., 1998, 29 pp.
• C 29, “Test for Density (unit weight) of Aggregate.”
• C 33, “Specifications for Concrete Aggregates.”
• C 40, “Test for Organic Impurities in Sands for Concrete.”
• C 131, “Test for Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine.”
• C 142, “Test for Clay Lumps and Friable Particles in Aggregates.”
• C 535, “Test for Resistance to Abrasion of Large Size Coarse Aggregates by Use of the Los Angeles Machine.”

Sieve analysis, grading curve and fineness modulus

Figure 1.9: Typical aggregate grading.

References

• Boonchai Stitmannaithum, “Advance Concrete Technology (Lecture Note)” Chulalongkorn University 2005 : Chapter I Materials for Concrete
• CPAC Concrete Academy: The Concrete Product and Aggregate co., ltd. http://www.cpacademy.com
• Portland Cement Association (PCA). Cement & Concrete Technology; http://www.cement.org/

Assignment

A mixing water should be a “potable water” so could you explain the meaning of this word – potable water.
Next... Standard test for Concrete Ingredient
CE 231 Construction Materials
July 6th, 2011

Withit PANSUK
Withit.P@chula.ac.th