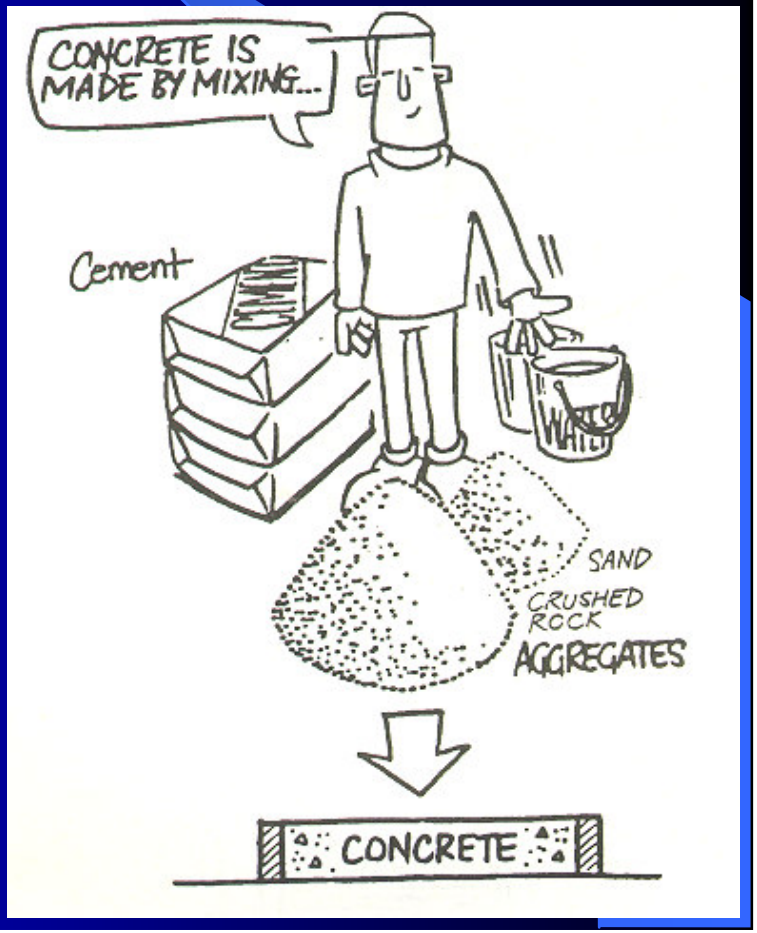
# Concrete Demystified

By: Joe Pietrosanto
TJM Operations Pty Ltd
Trading as: VIC MIX

# 1. Concrete Constituents

- Concrete's constituent materials are:
  - Cement;
  - Aggregate;
  - Water; and
  - Admixtures;



# 1.1.a Cement Constituents

- Cement means Portland or Blended cement
  - **Portland Cement** is a hydraulic cement manufactured as a homogeneous product by grinding together portland cement clinker and calcium sulfate. It may also contain up to 5% of mineral additions. Portland Cement shall comply with AS3972
  - **Blended Cement** is a hydraulic cement containing portland cement and a quantity comprised of one or both of the following:
    - Greater than 5% fly ash or granulated iron blast furnace slag
    - Up to 10% silica fume
  - **Fly Ash** shall comply with AS3582.1
  - **Ground slag** shall comply with AS3582.2
  - **Silica fume** shall comply with AS3582.3

# 1.1.b Cement Constituents

- Supplementary cementitious materials
  - has progressively increased over the last 20 years
  - can improve certain plastic properties of the concrete
  - can improve economy, since they are often industrial by-products which are cheaper than portland cement
  - can improve the environment by reducing demand on raw materials and reducing carbon dioxide emission due to reduced portland cement manufacture
  - can improve the long term strength of concrete
  - Good curing practice is essential to develop the strength potential of any concrete, and this is especially so when supplementary cementitious materials are used

# 1.1.c Aggregates

- Aggregates for concrete shall comply with AS2758.1
  - Besides the requirements of this standard, the type and quality of aggregates for concrete is dictated by:
    - the intended concrete application; and
    - the desired plastic properties of the concrete

Washed concrete sand
(fine aggregate)

Crushed stone for concrete
(coarse aggregate)

# 1.1.d Water

- Mixing water shall be deemed to be of acceptable quality if:
  - service records of concrete made with that water indicate that it is not injurious to the strength or durability of the concrete or the materials embedded in it; or
  - it has been suitably tested in a laboratory and the test results are within the limits given below
    - 7 and 28 day compressive test results 90% or greater than a control sample
    - Time of initial set from 60 minutes earlier to 90 minutes later than the control sample
    - Maximum concentration of impurities:
      - 100 ml/L for sugar
      - 50 ml/L for oil and grease
    - pH level greater than 5.0
  - it is assumed that water acceptable for drinking is also acceptable for concrete

# 1.1.e Admixtures

- Chemical Admixtures shall comply with AS1478
  - admixtures which are not compatible shall not be used in the same volume of mixed concrete

New admixtures require extensive testing

# 1.2 Concrete Properties

- Some fundamental concepts are:
  - Water/Cementitious ratio;
  - Voids content ;
  - Strength (paste, aggregate and bond); and
  - workability;

# 2.1.a Specification

AS1379
Specification &
Supply of Concrete

- AS1379 governs concrete which is:
  - site mixed;
  - factory mixed; and
  - truck mixed
- AS1379 specifies requirements for:
  - concrete materials;
  - plant / equipment; and
  - specification / ordering concrete

# The Big Picture

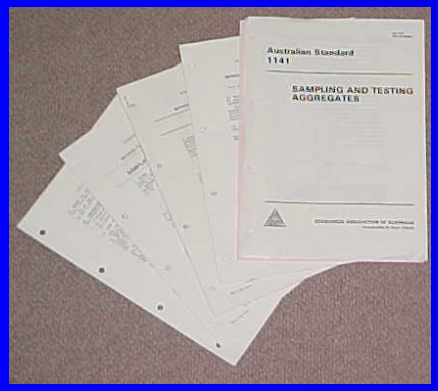
AS3600
Supplement 1

AS3600
Design of Concrete

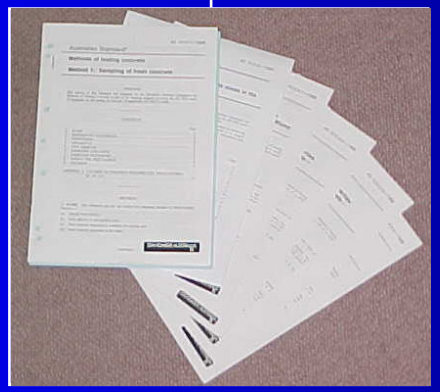
AS1379
Supply of Concrete

AS1379
Supplement 1

AS1141 Aggregate




AS1012 Concrete



AS3972 Cement

AS3582 Supplementary Cements

AS2758 Aggregates

AS1478 Admixtures

Sampling and Testing

Constituent Materials

# 2.1.b Specification of Concrete

- Normal Class
  - Concrete which is specified primarily by a standard compressive strength grade with other characteristics in accordance with Clause 1.6.3
  - Intended to cover the majority of concrete applications

- Normal Class requirements
  - Mass per unit volume between 2100 and 2800 kg/m3
  - Chloride content not more than 0.8 kg/m3
  - Sulfate content not more than 50g/kg of cement
  - Shrinkage strain not exceeding 1000 microstrain
  - A mean compressive strength at 7 days of approx. half the specified 28 day strength
  - A cement complying with AS3972 or AS3582
  - No lightweight aggregate

# 2.1.c Specification of Concrete

- Special Class
  - Concrete which is specified to have certain properties or characteristics different from, or additional to, those of Normal Class concrete

- Special Class requirements
  - Performance based
    - may specify a property which can be verified through testing - such as compressive strength of 60MPa @ 28 days
  - Prescription based
    - may specify the mix design by dictating the material types and proportions - such as 280 GP Cement
  - Performance and Prescription based

# 2.2.a Method of Ordering

- Normal Class Concrete - the customer must specify:
  - the quantity of concrete required ($m^3$) and delivery address
  - the standard compressive strength grade (N20, N25, N32, N40, N50)
  - the slump at point of acceptance (between 20 and 120mm at 10mm intervals)
  - the maximum nominal size of aggregate (10mm, 14mm or 20mm)
  - the intended method of placement (pump, spray, wheel barrow, etc.)
  - whether project assessment is required to be carried out
  - the level of air entrainment (up to a maximum of 5.0%)

# 2.2.b Method of Ordering

- Special Class Concrete - **performance** order
  - the quantity of concrete required ($m^3$) and delivery address
  - the standard strength grade (if applicable compression, flexural, indirect tensile)
  - the slump at point of acceptance (between 20 and 120mm at 10mm intervals)
  - the maximum nominal size of aggregate (as allowed by AS2758.1)
  - the intended method of placement (pump, spray, wheel barrow, etc.)
  - whether project assessment is required to be carried out
  - the level of air entrainment (if applicable)
  - any other performance requirements such as:
    - early age strength limitation
    - any shrinkage strain limitation
    - the use of fibres or colouring pigments
    - a requirement for colour control of the hardened concrete

# 2.2.c Method of Ordering

- Special Class Concrete - **prescription** order
  - the quantity of concrete required ($m^3$) and delivery address
  - the standard strength grade (if applicable compression, flexural, indirect tensile)
  - the particle density, maximum nominal size and grading of the coarse aggregate (ii accordance with AS2758.1) or alternatively, the source of aggregate supply
  - the particle density and grading of the fine aggregates within the ranges provided for AS2758.1, or alternatively, the source of aggregate supply
  - the type of portland or blended cement selected from AS3972
  - the limitation, if any, on the use of other cement products
  - the limitiation, if any, on the type and proportions of admixtures
  - the proportions of aggregates and cement by mass
  - the maximum water/cement ratio or the required slump at point of acceptance

Prescription orders require an indepth knowledge and understanding of the materials available to the suppliers in the region in which the concrete is to be supplied. Performance based ordering places this responsibility with the supplier.

# 2.3 Manufacture

**need to ensure compliance with the mix design**

- Material Storage
- Batching accuracy
  - Why batch accurately?
  - What are the tolerances?
  - Computers & records
  - Weighing Equipment;
  - Liquid Dispensing; Equipment; and
  - Mixing Equipment
  - Slump control

# 2.3.a Bulk storage of materials

- Cement shall be stored in a manner to ensure
  - material is kept dry and free from contaminants
  - clear identification and prevention of uncontrolled intermingling or mixing

# 2.3.b Bulk storage of materials

- Aggregates are stored in a manner to ensure
  - free drainage
  - clear identification and prevention of uncontrolled intermingling or mixing of different types and nominal sizes


CLEAR IDENTIFICATION

# 2.3.c Why batch accurately?

- Accurate batching is a prime concern for every concrete plant to ensure the closest possible compliance with the given mix design.
- AS1379 recognises that tolerance are a practical necessity and has set requirements for all concrete ingredients.
- Errors in batching can alter the concrete's expected properties. The following are examples of effects on placement and compaction

  - Under batched cement may result in loss of cohesiveness and segregation at high slump
  - Over batched coarse aggregate will reduce workability and pumpability
  - Under or over batched fine aggregate will alter shrinkage, flowability and ease of compaction. Underbatched fines may increase bleed.
  - Over or under dosed admixture will alter plastic duration, bleed, and mix mobility
  - Like admixtures, water content will alter plastic duration, bleed, mix mobility and has an enormous affect on Strength and Durability of the concrete.

# What are acceptable tolerances?

Table 5 of AS1379

| | Tolerance | | | |
|---|---|---|---|---|
| | Weight batching for batch size Q | | | Volume batching |
| | Q < 2 $m^3$ | 2$m^3$ <= Q <= 4$m^3$ | Q > 4$m^3$ | |
| Each cementitious ingredient | -5 + 30 kg | -10 + 30 kg | -20 + 40 kg | ±1% |
| Total cementitious materials | -5 + 30 kg | -10 + 30 kg | - 20 + 40 kg | ±1% |
| Fine aggregate | -75 +50 kg | ±75 kg | ±100 kg | ±2% |
| Coarse aggregate | -75 +50 kg | ±75 kg | ±100 kg | ±2% |
| Total aggregate | -75 +50 kg | ±75 kg | ±100 kg | ±2% |
| Chemical admixtures | ±5% * | ±5% * | ±5% * | ±5% * |

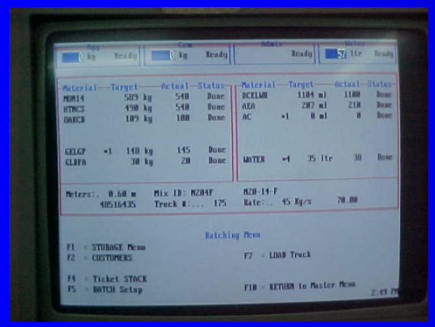
* or 20 mL, whichever is greater

# 2.3.d How tolerances are met

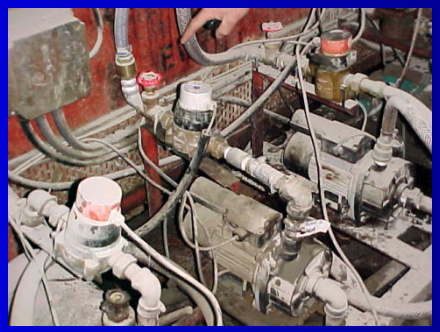
**to ensure compliance with the given mix design**

- Computers control batching and help to ensure tolerances are met;
- Regular maintenance and calibration of equipment reduces malfunctions; and
- Calibration records provide evidence of the work done.

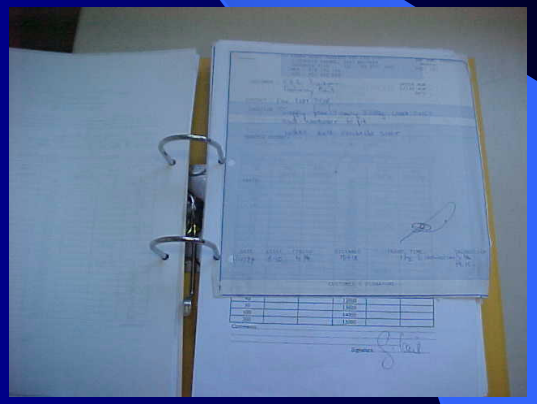
Computer systems



Equipment maintenance



Calibration Records



# 2.3.e Batching Records

**verify accuracy and provide traceability**

Records containing the source, type and target quantity of each ingredient used in the production of each batch are maintained for 12 months

Records are also kept of the date and time of any plant malfunctions

Example of batch record

| Docket No | Truck No | Mix Code | Slump | Load size |
|---|---|---|---|---|
| 48929442 | 758 | N254F | 70 | 3.60 |

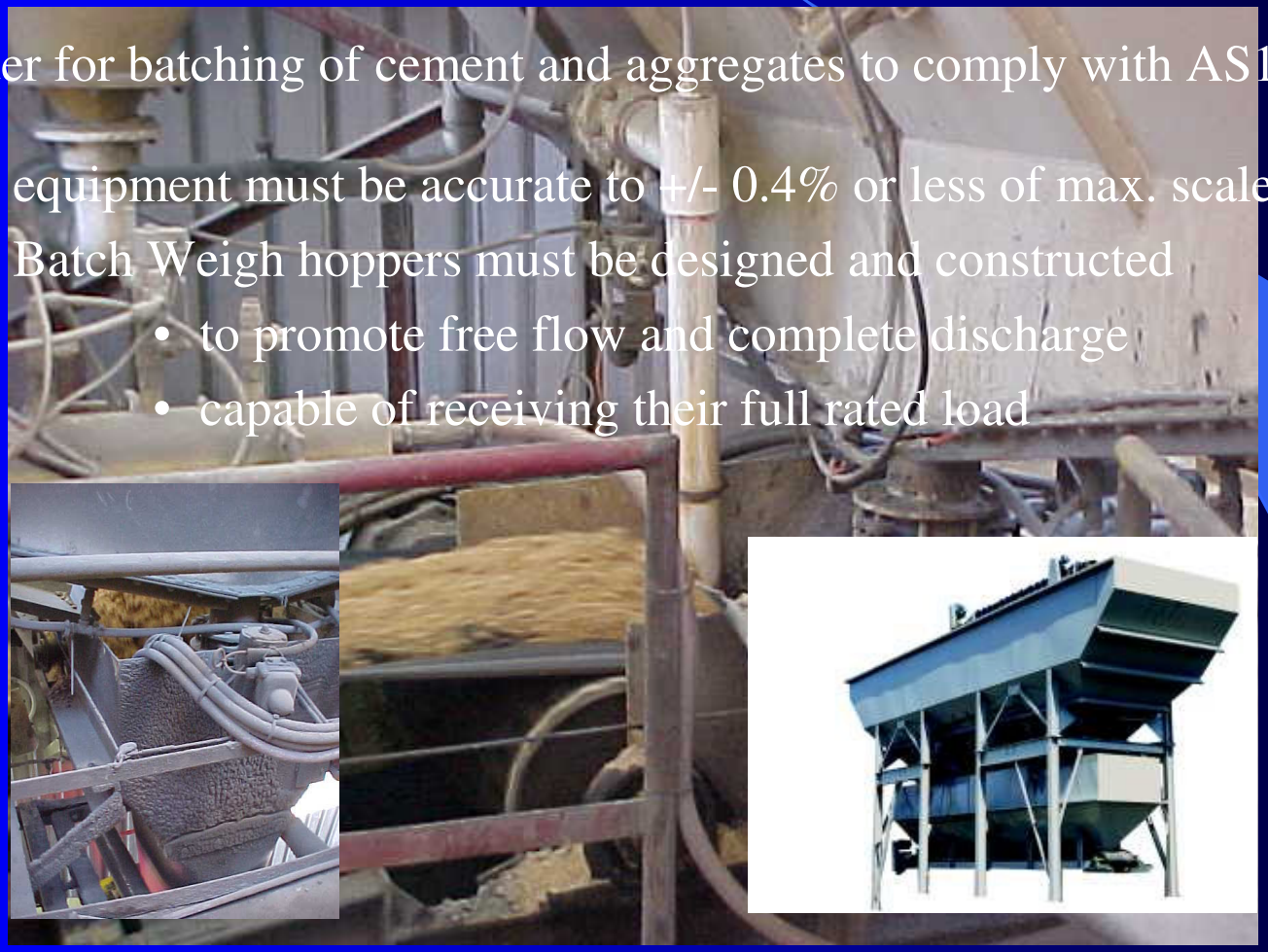
| Material Code | Target | Actual | Difference | % Difference |
|---|---|---|---|---|
| OAK14 | 003700 | 003700 | 0 | 0.00 |
| HTNCS | 002486 | 002500 | 14 | 0.56 |
| LYNCS | 000960 | 000960 | 0 | 0 |
| GOLGP | 000748 | 000750 | 2 | 0.27 |
| GLDFA | 000183 | 000180 | -3 | -1.64 |
| DCELWR | 006552 | 006450 | -102 | -1.56 |
| AEA | 001404 | 001420 | 16 | 1.14 |
| WATER | 000180 | 000182 | 2 | 1.11 |

# Weighing Equipment

**ensure compliance with the mix design**

In order for batching of cement and aggregates to comply with AS1379

- equipment must be accurate to +/- 0.4% or less of max. scale value
- Batch Weigh hoppers must be designed and constructed
  - to promote free flow and complete discharge
  - capable of receiving their full rated load



# Liquid Dispensing Equipment

**ensure compliance with the mix design**

In order for batching of water and admixtures to comply with AS1379

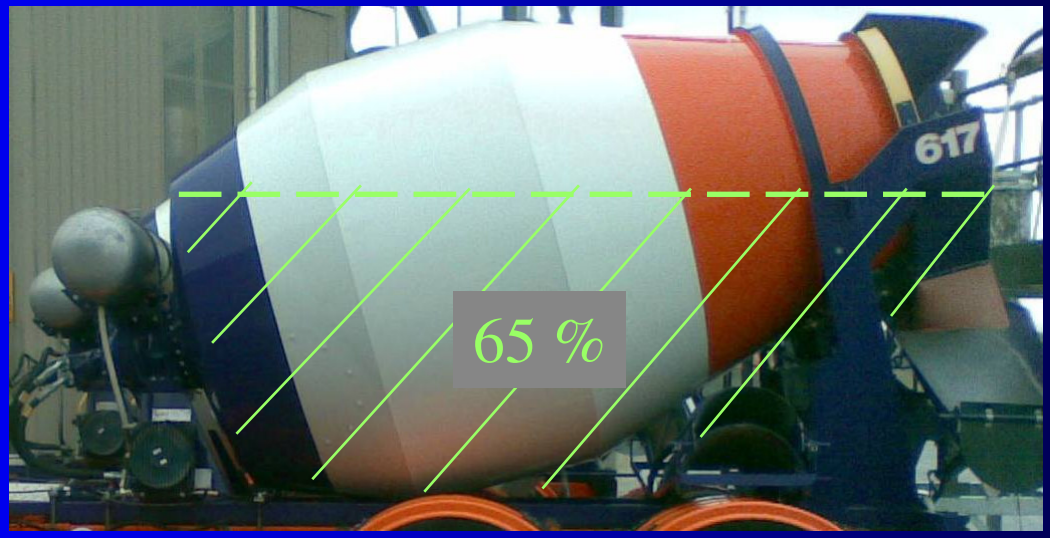
- equipment must be accurate to +/- 2.0% or less of the value shown on the indicating device for water
- equipment must be accurate to +/- 5.0% or less of the value shown on the indicating device for other liquids
- the frequency for calibration of dispensing equipment cannot exceed 6 monthly.


# Batch Mixing Equipment

**ensure uniformity of mixing and avoid segregation**

- Batch Mixers are designed to:
  - uniformly distribute ingredients throughout the volume of mixed concrete with the minimum mixing time or number of revolutions necessary.
  - have variable speed for mixing, discharging and agitating
  - have a rated mixing capacity not more than 65% of the gross internal volume of the mixing chamber unless proven otherwise

Common truck mounted mixing barrel



# Slump Control

**ensure desired level of consistence and workability is achieved**

- A sufficiently experienced operator will assess the consistency of a batch and estimate any further addition of water needed to produce the specified slump
- Water is added via a hose fitted with a measuring device
- Slump tests are conducted on site to confirm the consistency of concrete


Slump Stand at the Concrete Plant

Slump test

# Mix Design Considerations

**Two KEY aspects of the Mix Design relate to placement and compaction**

1. Avoid segregation

## Mix stability

- defined as the concrete's resistance to bleeding and segregation.

2. Aid compaction

## Mix compactability

- defined as the ease with which fresh concrete is consolidated and entrapped air is removed from the concrete.

## Mix mobility

- defined as the flowability of the concrete and described in terms of viscosity, cohesion and internal resistance to shear.

# Mix Stability

**with relation to Bleeding**

- Bleeding is the name given to the action of water rising to the top of concrete shortly after compaction. Mix design factors which affect bleeding are:
  - Consistency or slump (particularly high slumps 140mm +)
  - Volume of fines in the mix



- Bleeding is generally reduced by:
  - A reduction in the water content of the mix
  - An increase in the ultra fines content of the mix (this may increase shrinkage)
  - The use of specialist admixtures (ie Air Entrainers, fibres)

# Mix Stability

**with relation to Segregation**

- Segregation is defined as the separation of the components of fresh concrete such that they are no longer uniformly mixed. Mix design factors which may affect segregation are:
  - Cementitious content
  - Consistency or slump (wet mixes are generally more prone to segregation)
  - Grading of aggregates (particularly fine aggregates)

- Segregation is generally reduced by:
  - An increase in cement (increase in cohesiveness and resistance to segregation)
  - A reduction in the water content of the mix
  - An increase in the ultra fines content of the mix

# Mix Compactability

**the effect of consolidation**

- Consolidation is the name given to the action of packing the constituent particles as close together as possible. Mix design factors which affect consolidation are:
  - Aggregate grading and particle shape
  - Cement content & paste volume; and
  - Consistency or slump (consolidation improves with increases in slump)

- Consolidation is generally improved by:
  - Increasing lubrication of constituent particles in the mix such as:
    - increasing cement fines (consider secondary cementitious products)
    - increasing water or using admixtures (ie Super plasticisers)
    - using continuously graded aggregates to minimise void space

# Mix Compactability

**with relation to removal of entrapped air**

- Removal of entrapped air is the second stage of compaction and is necessary to achieve the greatest possible density of concrete.
- Mix design factors which affect entrapped air are:
  - Admixture useage; and
  - Cement content and type

**e generally needs the entrainment of air to**
**the plastic state.**
**Entrapped air, on the other hand, should be removed with appropriate compaction techniques in order to impove density and strength.**

# Mix Mobility

**the effect on the flow of concrete**

- Flowability of concrete is defined in terms of its viscosity, cohesion and internal resistance to shear. Mix design factors which affect these parameters are:
  - Admixture useage
  - Slump and water content
  - Cement content and type
  - Aggregate grading and particle shape

- Mix mobility is generally improved by:
  - Increasing admixture useage (superplasticisers, air entrainer, water reducers)
  - Increasing the water and cementitious content of the mix
  - Increase mix fines (sands, cementitious materials - flyash, slag, silica fume)
  - Avoid poorly shaped particles

Lets have a closer look at aggregate shape

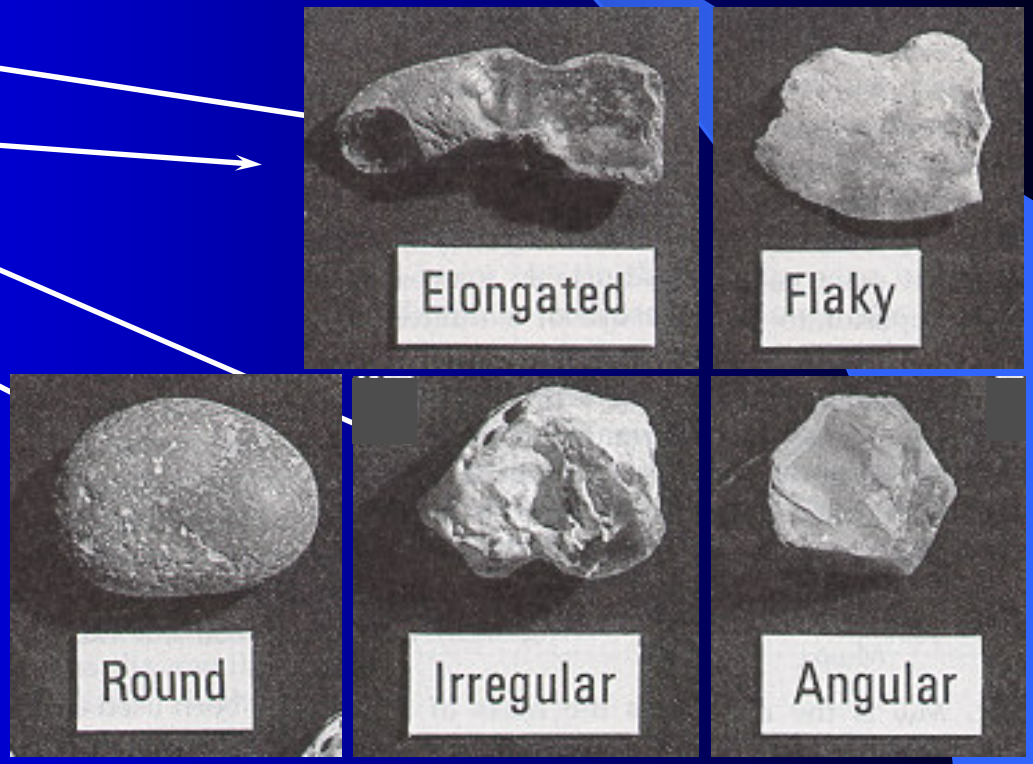
# Aggregate Shape

**the effect on mobility**

Shape of aggregate has an important influence upon the workability of fresh concrete.

AS2758.1 provides guidance on the classification of shape. They are as follows:

- **FLAKY**
- **ELONGATED**
- **ANGULAR**
- **IRREGULAR**
- **ROUND**




Round produces the best workability
Two key reasons:
1. Ball bearing effect
2. Smallest surface area. More paste available for flowability of the mix

# Placeability and Pumpability

Highrise Construction

Placability and pumpability is generally dictated by the following:

- Number of floors
- Consistency or slump
- Volume of fines
- Size, shape and texture of coarse aggregates

Placability and pumpability is generally improved by:

Increase in slump/consistency

Increase in paste volume

Increase in roundness
Decrease in size of aggregate

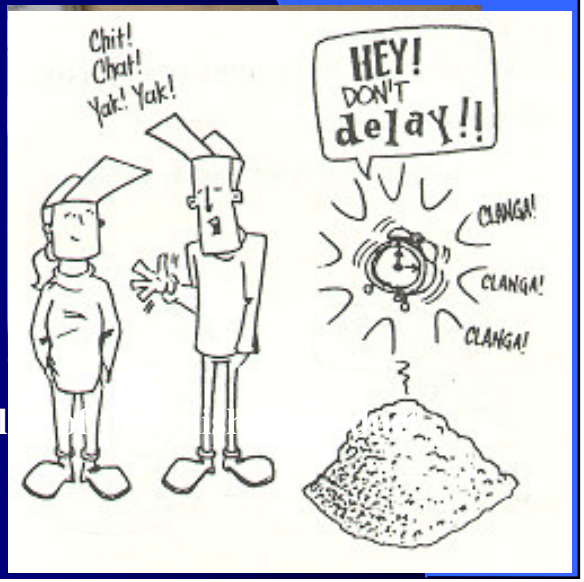
# Placement and Compactive Effort

- How to avoid segregation on site
  - avoid very wet or very dry concrete mixes (these are most susceptible)
  - avoid uncontrolled drops (use a drop chute or a pump hose)
  - always deposit concrete into the face of that already placed
  - always commence placing from the lowest point in a pour
- How to aid compaction on site
  - use a correctly tailored mix design for the job (pump, tremmie, etc)
  - place concrete in layers which are a suitable depth for the compaction equipment
  - use the correct compaction equipment for the job; and
  - ensure the compaction equipment is used correctly

# Temperature and Duration

**effect on placement and compaction**

- It is important to control delivery of plastic concrete so as to:
  - prevent segregation; and
  - avoid premature stiffening
- Be aware that
  - Elevated concrete temperature can result in
    - premature stiffening; and
    - rapid loss of workability
- And
  - This also applies once the concrete is discharged
    - Delays in completion of discharge can result in
      - loss of workability
      - cold joints




**Addition of water to restore the consistency will generally reduce the qual**

# Section 4 Sampling and Testing of Concrete

- The primary quality parameters for testing are:
  - Slump
  - Strength
  - Air content
  - Chloride and Sulfate Content
  - Drying Shrinkage
  - Other parameters

# Section 5 Sampling and Testing of Concrete

- Slump
  - Frequency of Testing
    - A slump is generally performed on each strength sample
  - Determination of Slump
    - shall be in accordance with AS1012.3
  - Compliance
    - shall be in accordance with Table 6 of AS1379
  - Repeat tests for slump
    - If the in… comply … immedi…
    - Compli… from the repe…

Table 6 of AS1379

PERMISSIBLE TOLERANCE ON SLUMP

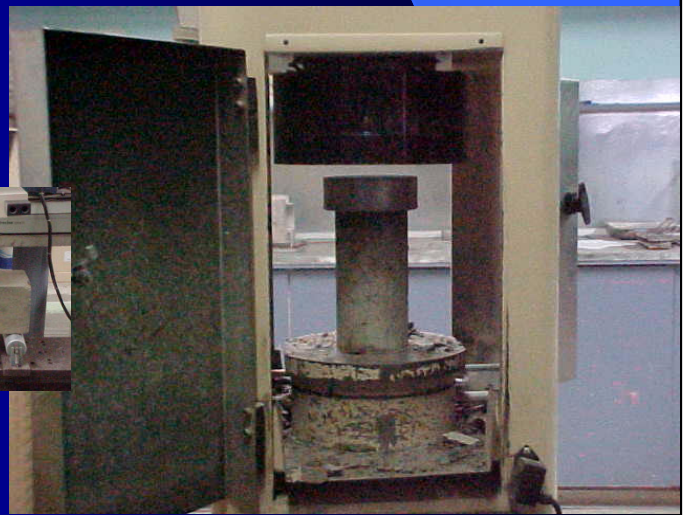
| Specified slump, mm | Tolerance, mm |
|---|---|
| < 60 | ±10 |
| ≥ 60 ≤ 80 | ±15 |
| > 80 ≤ 110 | ±20 |
| > 110 ≤ 150 | ±30 |
| > 150 | ±40 |

# Section 5 Sampling and Testing of Concrete

- Strength
  - 28-day characteristic strength
    - Sampling, testing and assessment of concrete for strength is carried out in accordance with the following
      - Compressive strength grade in accordance with Section 6
      - Flexural and Indirect tensile strength in accordance with Section 6 for an equivalent mean compressive strength, provided that
        - the equivalent mean compressive strength is first determined by establishing a relationship between compressive strength and flexural or indirect tensile strength
        - the relationship continues to be monitored

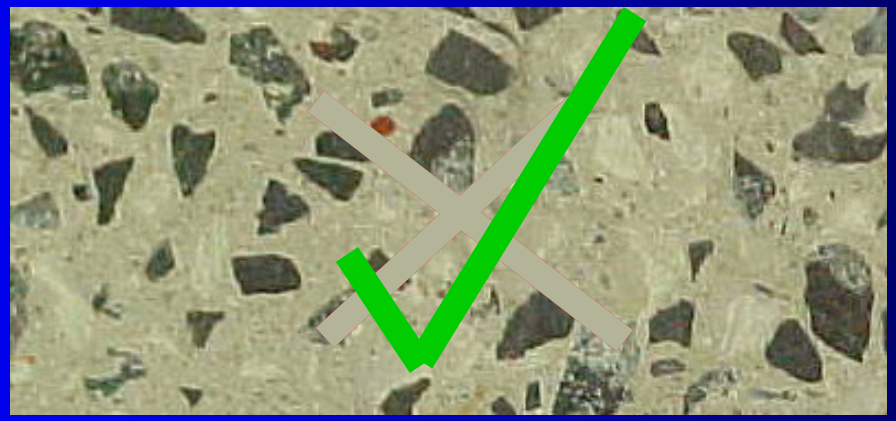
Indirect Tensile Testing
(Brazil or Splitting Test)

Flexural Testing
(Modulus of Rupture)



# Section 5 Sampling and Testing of Concrete

- Strength
  - Action on NonCompliance
    - Concrete that does not comply may be accepted as satisfactory for its intended purpose if:
      - the supplier has a third-party audited and registered quality control system which can provide evidence that demonstrates the low test results are within the limits of probable random variation
      - the supplier can demonstrate that the causes of the low results have been established and corrected; or
      - the supplier and customer mutually agree on another method to demonstrate the structure is fit for purpose



# Section 5 Sampling and Testing of Concrete

- Air Content
  - Frequency of sampling
    - If a percentage of air entrainment is specified, air content samples shall be taken with every alternate strength sample
  - Determination of air content
    - Air content shall be determined in accordance with AS1012.4
  - Compliance
    - The concrete shall comply if the measured air content is within 1.5% of the specified air content
  - Repeat test
    - If the initial result does not comply, one repeat test shall be made immediately. If the value obtained complies, the concrete shall be deemed to comply

# Section 5 Sampling and Testing of Concrete

- Chloride and Sulfate Content
  - Frequency of sampling
    - The most frequently supplied grade in a plant is sampled and tested every 6 months
  - Determination of content
    - Two standard cylinders shall be made from one sample and cured for 7 days in accordance with AS1012.8
    - The density of the specimens shall be determined in accordance with AS1012.12
    - Test specimens shall be prepared from the cylinder specimens and tested in accordance with AS1012.20. The results shall be used to calculate:
      - the chloride content (kg/m3)
      - the sulfate content (grams/kg of cement)
  - Compliance
    - The concrete shall comply if the:
      - chloride content does not exceed 0.8 kg/m3
      - sulfate content does not exceed 50g/kg of cement

# Section 5 Sampling and Testing of Concrete

- Drying Shrinkage of Normal Class Concrete
  - Frequency of sampling
    - The most frequently supplied grade in a plant is sampled and tested every 6 months
  - Determination of shrinkage
    - Sampling shall be in accordance with AS1012.1
    - Casting, curing, storage transport and demoulding in accordance with AS1012.13
    - Measurement of shrinkage shall be performed by a registered laboratory
  - Compliance
    - The concrete shall comply if the:
      - mean value of the shrinkage strain, rounded to the nearest 50 microstrain does not exceed 1000 microstrain

# Contractual Issues

Difficult Specifications

Demonstrating the correct volume

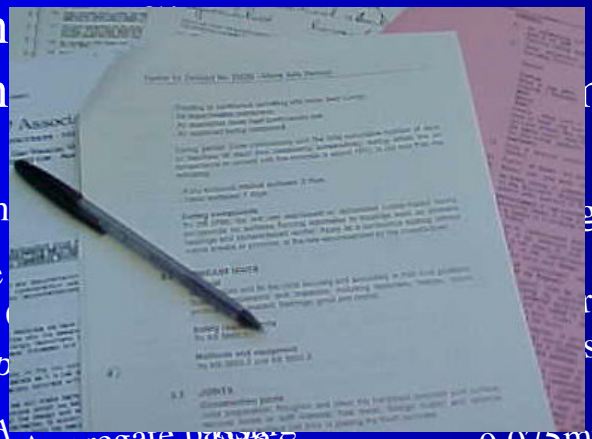
Demonstrating Strength Compliance

# Section 2 Difficult Specifications

Special Class concrete can contain prescriptive and performance based requirements with the aim of obtaining the best possible concrete

Problems arise when

- requiremen
- requiremen



nonly accepted

The concrete shall not exh

No admixtures shall be incorp

The number and rate of concrete slump tests shall be at the rate of one (1) test per truck.

Aggregates shall be delivered to the Concrete Plant at lea 24 hrs before batching

The concrete (a)

rger sieve

Aggregate passing 0.15mm to 0.075mm sieve

Target slump for hand placed concrete shall not exceed 20mm

g tolerances as required for workability.

| Tolerance for % passing sieve |
|---|
| +/- 4 |
| +/- 3 |
| +/- 2 |
| +/- 1 |

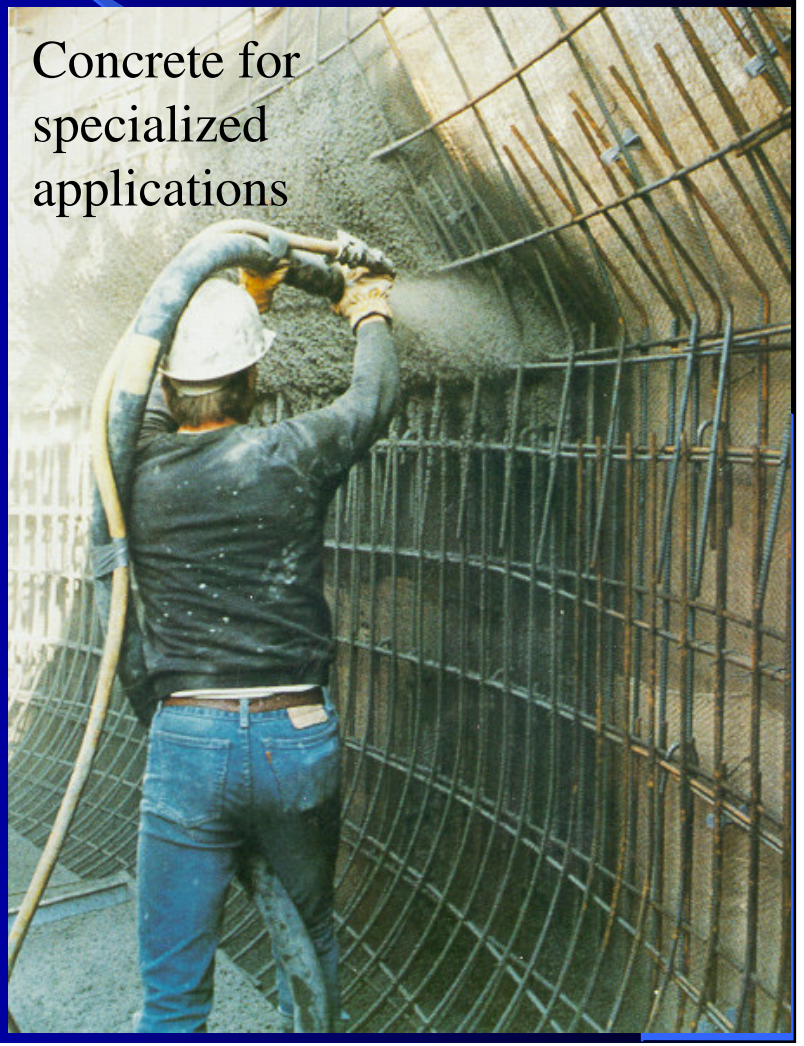
The use of Fly Ash is strictly prohibited

Aggregates shall at all times be dealt with in such a way that the exact weight of any one size of aggregate may be incorporated in a batch of concrete in accordance with the approved design of a batch to meet the strength and density requirements.

mix design shall match the attached combined particle size distribution

# Section 2 Assistance with Specifications

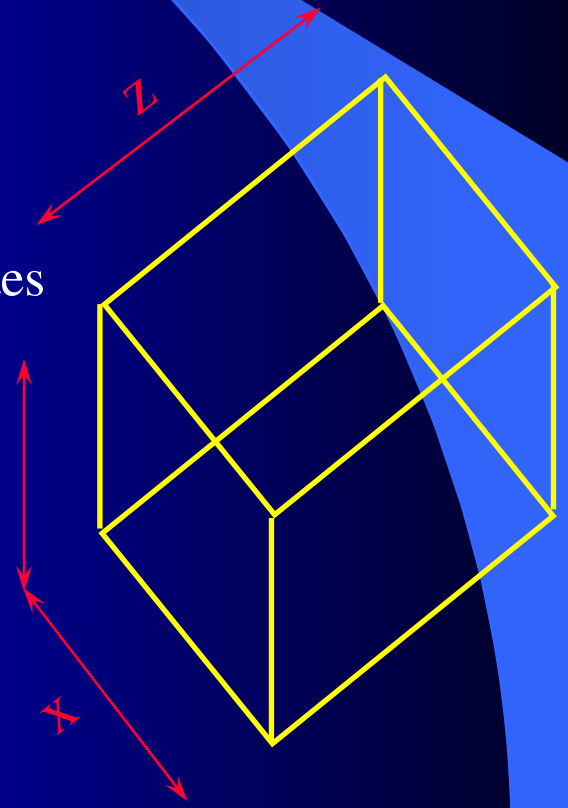
- Table B1 of AS1379
  - provides specifiers with a guide on various parameters
    - For Example
      - Shrinkage strain of 500 to 1000 microstrain
      - Chloride content of 0.4 to 0.8 kg/m3
      - refer to page 10 in your notes for full details
  - advises specifiers to consult with suppliers before specifying



# Section 3 Demonstrating the correct volume

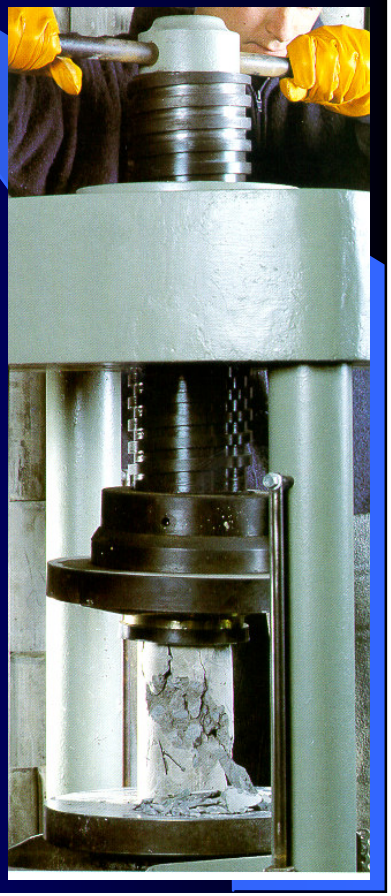
- Yield
  - The volume of concrete measured in accordance with AS1012.5
  - Cannot be less than 98 % of the Ordered volume

- Factors affecting the volume or yield
  - batching deviations from allowed tolerances
  - variation in the moisture content of aggregates
  - handling and compaction
  - the effects of hardening
  - slump variation
  - temperature changes
  - formwork deflection and spillage



# Section 6 Demonstrating Strength Compliance

- AS1379 presents statistical methods for determining the compliance of Concrete with specified requirements
- The strength grade assessment methods are:
  - Production Assessment
  - Project Assessment



# Section 6 Principles of statistical methods

- Why use statistics to analyse concrete testing?

## TO SAVE TIME AND MONEY

Instead of testing every batch of concrete produced, we randomly select samples at a specified frequency so as to provide adequate statistical confidence that they are representative of the project or production run.

Sampled and tested at random to represent all concrete supplied

# Section 6 Assessment for Compliance

- General requirements
  - concrete specified by compressive strength grade equal to or greater than 20MPa, shall be
    - sampled and tested
    - subject to production assessment by the supplier; or
    - subject to project assessment on request by the customer; or
    - subject to alternative means of production and project control which is mutually agreed between supplier and customer

## strength grade assessment required?

| yes | no |
| --- | --- |
| all mixes specified by strength<br>• normal class<br>• special class with specified strength | non- strength mixes such as:<br>• kerb & channel<br>• pattern pave<br>• stabilised sand<br>• blinding |

# Section 6 Assessment for Compliance

- Production Assessment
  - the supplier carries out testing on standard strength grades produced by a single plant
  - testing from concrete supplied to multiple projects is used to prove mix compliance supplied by the plant
  - a sample is needed for every 100 cubic meters of concrete produced

test results from the same grade irrespective of project

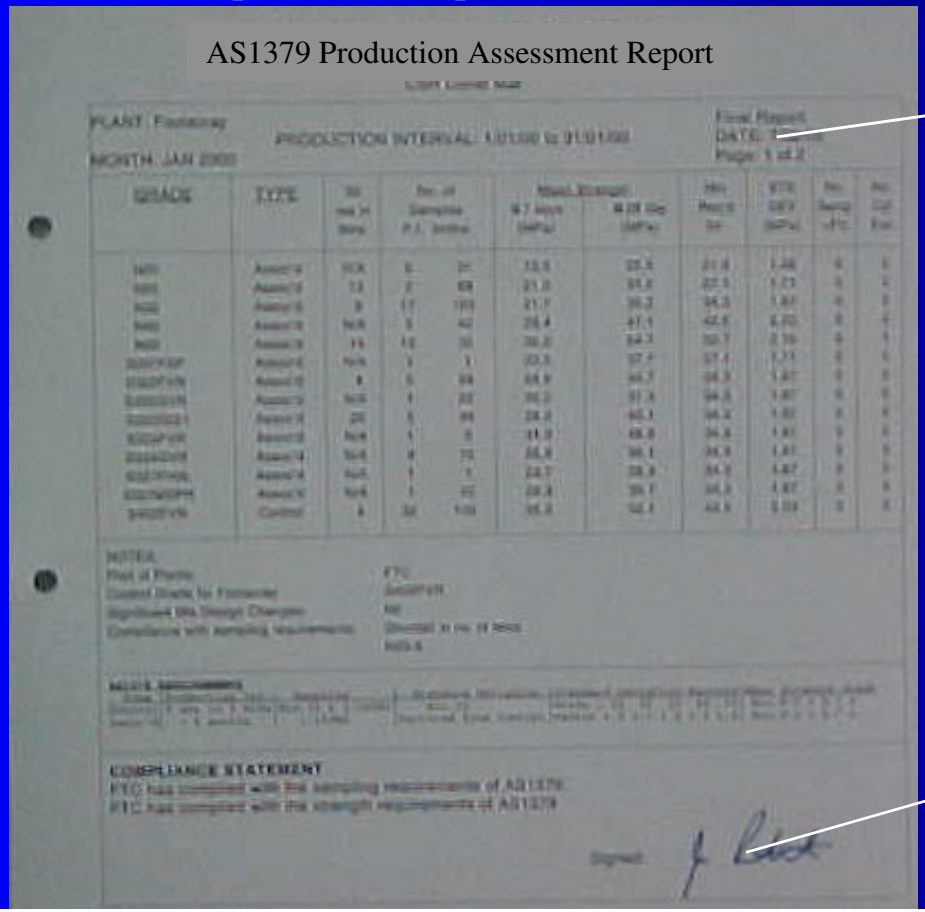
N20 supplied to Project A

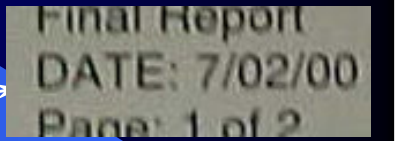
N20 supplied to Project B

N20 supplied to Project C

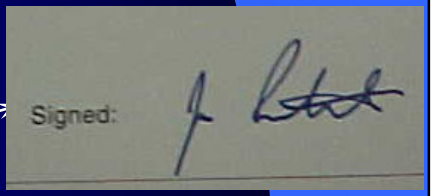
# Section 6 Assessment for Compliance

- Recording and dissemination of production assessment information
  - Records and reports
    - reports of test results are kept for at least 12 months
    - certified copies of the reports shall are made available for inspection




+ 12 months




certified copies

# Section 6 Assessment for Compliance

- Project assessment for plants subjected to production assessment
  - each grade of concrete used in the project shall be treated as follows:
    - the concrete shall be sampled at the project site prior to site handling
    - provide at least one sample from each 50m3 of concrete
    - the concrete represented by a group of samples shall be deemed not to comply if the moving average strength of three consecutive samples is less than f'c
    - where less than three samples are available, the concrete may be assessed on a single sample only. It shall be deemed not to comply if the sample strength is less than 0.85f'c

# Where to get more information

- Cement & Concrete Association of Australia
- Other Industry Associations
- Tertiary Education Libraries
- Pre-mix Concrete Suppliers
- Industry Magazines
- The Internet

# End of Unit 11