Placement and Compaction

- a Pre-mix Suppliers Perspective -

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Introduction

Areas covered:

1. Mix design and material properties;
2. Batch Plant;
3. On site; and
4. Defects.
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)
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

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 usage; and
- Cement content and type

IMPORTANT
Concrete generally needs the entrainment of air to improve mix stability and mobility whilst in the plastic state. Entrapped air can generally be easily removed with appropriate compaction techniques.

Entrapped air is generally reduced by:
- Not using air entraining admixtures, but suffering a loss in workability
- Increasing the cementitious content of the mix
- Using supplementary cementitious materials such as flyash, slag or silica fume if they are significantly finer than cement
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 usage
- Slump and water content
- Cement content and type
- Aggregate grading and particle shape

Mix mobility is generally improved by:

- Increasing admixture usage (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

Let's have a closer look at 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.
Batch Plant

Batching accuracy

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

need to ensure compliance with the mix design
**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

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>Weight batching for batch size Q</th>
<th>Volume batching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q &lt; 2 m³</td>
<td>2m³ &lt;= Q &lt;= 4m³</td>
</tr>
<tr>
<td>Each cementitious ingredient</td>
<td>-5 + 30 kg</td>
<td>-10 + 30 kg</td>
</tr>
<tr>
<td>Total cementitious materials</td>
<td>-5 + 30 kg</td>
<td>-10 + 30 kg</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>-75 +50 kg</td>
<td>±75 kg</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>-75 +50 kg</td>
<td>±75 kg</td>
</tr>
<tr>
<td>Total aggregate</td>
<td>-75 +50 kg</td>
<td>±75 kg</td>
</tr>
<tr>
<td>Chemical admixtures</td>
<td>±5% *</td>
<td>±5% *</td>
</tr>
</tbody>
</table>

* or 20 mL, whichever is greater
How tolerances are met

- 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.
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

<table>
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<tr>
<th>Material Code</th>
<th>Target</th>
<th>Actual</th>
<th>Difference</th>
<th>% Difference</th>
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</thead>
<tbody>
<tr>
<td>OAK14</td>
<td>003700</td>
<td>003700</td>
<td>0</td>
<td>0.00</td>
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<tr>
<td>HTNCS</td>
<td>002486</td>
<td>002500</td>
<td>14</td>
<td>0.56</td>
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<tr>
<td>LYNCS</td>
<td>000960</td>
<td>000960</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GOLGP</td>
<td>000748</td>
<td>000750</td>
<td>2</td>
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<tr>
<td>GLDFA</td>
<td>000183</td>
<td>000180</td>
<td>-3</td>
<td>-1.64</td>
</tr>
<tr>
<td>DCELWR</td>
<td>006552</td>
<td>006450</td>
<td>-102</td>
<td>-1.56</td>
</tr>
<tr>
<td>AEA</td>
<td>001404</td>
<td>001420</td>
<td>16</td>
<td>1.14</td>
</tr>
<tr>
<td>WATER</td>
<td>000180</td>
<td>000182</td>
<td>2</td>
<td>1.11</td>
</tr>
</tbody>
</table>
In order for batching of cement and aggregates to comply with AS1379:

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

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
Correctly designed and manufactured mixers will have identification plates detailing:

- gross internal volume of the mixer (m³)
- rated mixing capacity (m³)
- recommended minimum mixing time or revolutions required to achieve uniformity
Slump Control

- 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.
On site

Placement and Compaction of concrete on site should consider the following:

- Temperature and Duration
- Placement method and compactive effort
Temperature and Duration

- It is important to control delivery of plastic concrete so as to:
  - prevent segregation; and
  - avoid premature stiffening

  - Be aware that
    1. Elevated concrete temperature can result in
       - premature stiffening; and
       - rapid loss of workability

  - And
    1. Delays in completion of discharge can result in
       - loss of workability
       - cold joints (discussed later)

Addition of water to restore the consistency will generally reduce the quality of the finished product.
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
Concrete Defects due to poor placement and compaction

Defects can be caused by many factors including:

- **Design & Construction**
  - improper placement due to design and detailing of structural member
  - improper design/selection of concrete mix to suit placement conditions
  - improper placement practices; and
  - improper vibration and consolidation practices.

- **Equipment**
  - improper selection of equipment for application; and
  - equipment failure or interruption of service.

- **Materials**
  - material batching errors
  - improper use of admixtures; and
  - improper use and selection of release agents.

- **Environment**
  - extreme weather conditions.

Let's take a closer look at some common defects.
Concrete Defects due to poor placement and compaction

**Honeycombing**
Stony surface with air voids. Appears lacking in fines

**Caused by:**
- congested reinforcement and difficult construction conditions
- insufficient paste in the concrete mix (or over batch in coarse aggregate)
- improper placing techniques (segregation and/or lack of vibration); and
- premature stiffening of concrete (accelerating admixtures and/or high temperatures)
Concrete Defects 

due to poor placement and compaction

**Bugholes**

Appears as voids in the surface of off-form finished concrete. Vary in size up to 25mm.

**Caused by:**

- Air bubbles trapped between the concrete mass and the form, especially in sticky or stiff concrete mixtures of low workability which may have an excessive sand and/or entrapped air content;
- lack of complete vibration or proper insertion of the vibrator head may increase bughole formation.
Concrete Defects due to poor placement and compaction

**Layer lines**

Appear as dark lines on formed surfaces which indicate the boundary between concrete placements.

**Caused by:**

stiffening or insufficient consolidation of the lower level due to lack of penetration of the vibrator into the lower level
Cold Joints

Appears as a discontinuity between concrete placements. Similar to Layer lines.

Caused by:

- Stiffening of the concrete before further concrete can be placed against it, creating a discontinuity which generally results in a weak plane within the finished structure.
- Cold Joints can be avoided by contingency planning, backup equipment, and working to vibrate into lower lifts (if possible).
Concrete Defects due to poor placement and compaction

Settlement or Subsidence Cracking

Cracks that occur due to settlement whilst the concrete is still plastic.

Caused by:
These cracks occur as a result of settlement of concrete, after or near initial set, that is restrained by a local obstruction, or by a dramatic change in section depth. They typically occur over reinforcing bars with shallow cover. However, can also occur in columns where the upper concrete bridges between the forms while the lower concrete settles.
Thank you for your attention.