Controlling Total Water Content During Transit

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Sources of Water in Concrete

<table>
<thead>
<tr>
<th>Percent of Total Water</th>
<th>Accurately Measured?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual water from prior load</td>
<td>0 – 10%</td>
</tr>
<tr>
<td>Aggregate free water</td>
<td>10 – 40%</td>
</tr>
<tr>
<td>Batch water (metered)</td>
<td>60 – 90%</td>
</tr>
<tr>
<td>Wash down (“slump rack”) water</td>
<td>0 – 10%</td>
</tr>
<tr>
<td>Driver added water</td>
<td>0 – 20%</td>
</tr>
<tr>
<td>TOTAL WATER</td>
<td>100%</td>
</tr>
</tbody>
</table>

Water is added to concrete from multiple sources. Melted batch water is measured most accurately. But, variability in other sources of water makes it difficult to determine how much batch water should be added.

Use of Slump to Control Water Content

- Deviations in slump may indicate a deviation in water content
  - Water has a significant effect on slump.
  - Water is typically the largest variation during batching.

- Therefore, it is common to add water to reach a target slump during or immediately after batching.
  - Wet batch (central mix): adjust to mixer power (amp meter)
  - Dry batch (truck mix): manual adjustment by driver to reach target slump

- Once the truck leaves the plant, additional sources of variation are introduced.

Outline

01 Sources of Water in Concrete
02 Adding Water to Adjust Slump
03 Adding Admixture to Adjust Slump
04 Automated Slump Control Equipment
05 Mixing of Water and Admixture During Transit
06 Conclusions

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The Challenge of Ready Mix Batching and Delivery

Concrete must be batched in one condition to meet acceptance criteria later at the construction site.

- **Batching**
  - raw material variation
  - aggregate moisture variation
  - residual material in drum

- **Transit**
  - transit time variation
  - weather

- **Site**
  - jobsite delays
  - mixing variation
  - jobsite-added water (if allowed)
  - sampling and testing variation
  - limited measurement and data

Concrete must be batched in one condition to meet acceptance criteria later at the construction site.

Adding Water After Batching

Adjusting to a target slump at the site by adding water increases variability.

**Scenario #1**
- mix design A
- 10 minute haul
- 50°F and cloudy
- 6 in. slump

**Scenario #2**
- mix design A
- 60 minute haul
- 90°F and sunny
- 8 in. slump

Adding Water After Batching

When adjusting to a target slump on the jobsite by adding water, further variability is introduced due to the lack of accurate slump measurement:

- Adjustments to water are often made based only on a visual estimate of slump.
- Contractors and other site personnel may request an increase in slump beyond what is ordered.
- This introduces variability in water content, even if water is below the maximum w/cm in both cases.

Using Admixture to Achieve Target Slump

- At the plant, water content is typically the largest source of variation in slump.
- Adjusting batch slump with water is effective for reducing variation in water content, provided other sources of variation in slump are properly managed.
- Initial admixtures, including optionally superplasticizer, still added at plant.
Verifi Concrete Control System - Components

Automated Admixture Addition on Truck

Admixture use pre-programmed centrally in web-application
User selects slump, system automatically determines correct dose

Limits applied to amount of admixture added

Admixture injected under pressure to reach concrete in drum

Managing Water with Automated Admixture Addition

Batch below maximum water content to allow for water addition in transit.
Automated admixture addition in transit can result in less total water use and less variation in total water.
Opportunity to reduce cement content.

Experimental Testing: Slump Measurement

Testing conducted on 3 trucks at 2 plants
Initial calibration of each truck conducted on limited set of mixtures
Slump measurement was accurate across much wider range of mixtures and test conditions
- Materials (cement, SCMs, aggregates, HRWR, VMA, AEA)
- Mixture Proportions
- Unit Weight (110 – 150 lb/ft³)
- Multiple Locations
- Load Size
- Transit vs. Stationary

Reduction in Slump Variability with Auto Slump Control

- Less variability in slump at discharge
- Lower slump at discharge = less water added
- Improved customer satisfaction due to a more consistent concrete: finishability, air content, setting time, strength development
Data Available to Control Total Water

Real Time Feedback
Batch operator sees slump after batching and water added to reach target slump. This can be used to adjust subsequent batches. Drivers see accurate slump reading and an estimate of water need to reach target slump. They can add a precise amount of water through in-cab interface.

Post Delivery Adjustments
Operations and QC management receive reports on slumps and water and admixture added to every load. This can be used to ensure correct water content and redesign mixtures.

Mixing of Superplasticizer in Transit

Mixing requirements primarily a function of admixture and revolutions
- Two different polycarboxylate based superplasticizers added at agitating speed
- To reach stable slump, PC-05 required 30 revolutions and PC-04 required 60 revolutions

Adding Admixture at Jobsite

Benefits of Adding Admixture at the Jobsite
- Compensate for variations in haul time, weather, and other factors
- Consistent final slump and other concrete properties
- Less amount and variation in total water – possible reduction in cement
- Transport large loads – use low slump in transit to avoid spillage, then higher slump at jobsite
- For long hauls, ability to wait to bring slump to target at jobsite

Automated addition can ensure:
- Correct dose is added
- Concrete is fully mixed prior to discharge
- Slump is correct prior to discharge
- No manual dosing required

Conclusions
- Water is added to concrete from numerous sources, leading to variations in total water content
- New technology is available to measure and control concrete in the truck
  - Accurate slump measurement
  - Accurate and automated water addition and measurement
- Automated admixture addition enables improved concrete quality
  - Provide desired slump and avoid exceeding maximum w/cm
  - Reduce total amount of and variation in amount of water added
- Superplasticizer can be successfully mixed in transit, even at agitating speed

Thank You.