American Concrete Institute®
Advancing concrete knowledge

Total Water Control

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Controlling Total Water Content During Transit

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Outline

Sources of Water in Concrete

Water is added to concrete from multiple sources

	Percent of Total Water	Accurately Measured?
Residual water from prior load	0 – 10%	rarely
Aggregate free water	10 – 40%	sometimes
Batch water (metered)	60 – 90%	yes
Wash down ("slump rack") water	0 – 10%	rarely
Driver added water	0 – 20%	sometimes
TOTAL WATER	100%	???

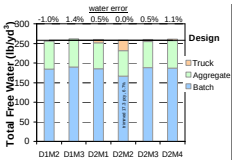
Metered batch water is measured most accurately. But, variability in other sources of water makes it difficult to determine how much batch water should be added.

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.**

Does controlling to a target slump affect variation in water content?

By controlling to constant slump, variation in total water was less than +/- 1.5% for 6 loads tested over 2 days



To ensure accuracy of the slump vs. water content relationship:

- Manage other likely causes of slump change, such as temperature
- Recalibrate the slump vs. water content relationship periodically
- Measure slump accurately

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

Adding Water After Batching

Adjusting to a target slump at the site by adding water increases variability. Scenario #2 requires more water.

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.

3-inch (75 mm) slump

3-inch (75 mm) slump?

Using Admixture to Achieve Target Slump

plant

- 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

jobsite

- Transport to the jobsite introduces new sources of slump variation, for example:
  - transit time
  - concrete temperature
  - mixing
- Adding superplasticizer instead of water at the jobsite ensures:
  - less water used
  - less variation in water content

Recommendations to Control Total Water Content

- ✓ **Manage all sources of water**
  - ✓ "Back out" drum before loading to remove residual wash water
  - ✓ Accurately measure aggregate moisture
  - ✓ Limit wash down water
  - ✓ Accurately measure water added on the truck
- ✓ **Accurately measure slump – don't rely on visual assessments**
- ✓ **Control to the right slump – don't allow unauthorized changes to the target slump at the site**
- ✓ **Limit the amount of water added on truck – don't exceed the maximum water-to-cementitious materials ratio**
- ✓ **Adjust slump with admixture once maximum water content is reached**

Automated Slump Control Technology

Verifi® Concrete Control System

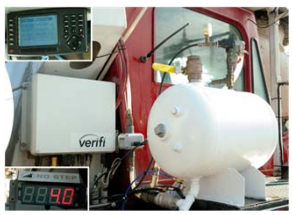
Measures slump and temperature of concrete in mixer, drum speed, and water added

Adds water and superplasticizer to slump target, automatically or manually

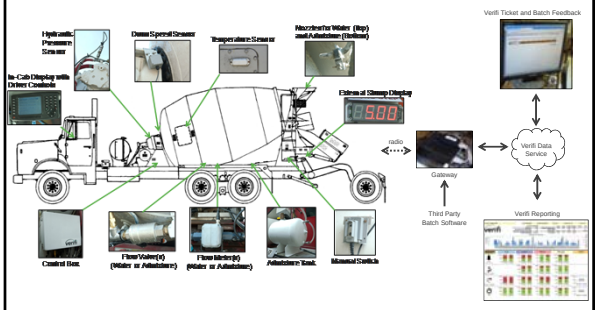
Prompts driver to ensure concrete is fully mixed

Documents delivery process

Enables change based on data

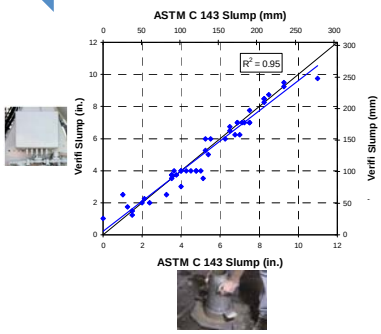


Verifi Concrete Control System - Components



Experimental Testing: Slump Measurement

Accurate slump measurement



Testing conducted on 3 trucks at 2 plants

Initial calibration of each truck conducted on limited set of mixtures

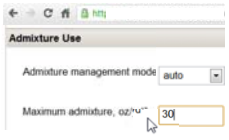
Slump measurement was accurate across much wider range of mixtures and test conditions

- Materials (cement, SCMs, aggregates, HRWR, VMA, AEA)
- Mixture Proportions
- Unit Weight (110 – 150 lb/ft³)
- Multiple Locations
- Load Size
- Transit vs. Stationary

Automated Admixture Addition on Truck

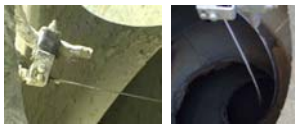
Admixture use pre-programmed centrally in web-application

User selects slump, system automatically determines correct dose



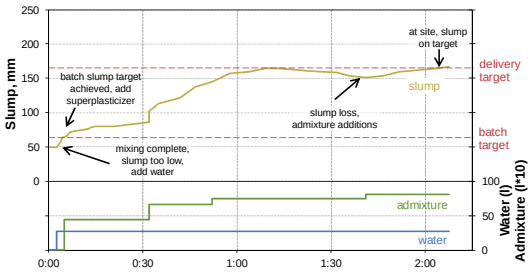
Limits applied to amount of admixture added

Admixture injected under pressure to reach concrete in drum



Typical Delivery: Water and Superplasticizer Adjustment

Successful adjustment of water and superplasticizer to target slumps

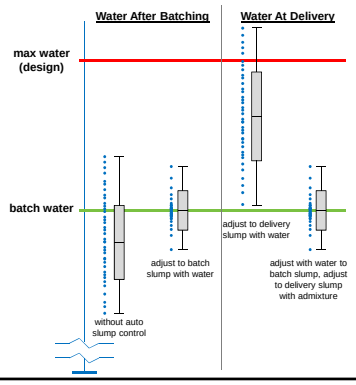


Managing Water with Automated Admixture Addition

Batch below maximum water content to allow for water addition in transit.

Automated admixture addition in transit can results in less total water use and less variation in total water.

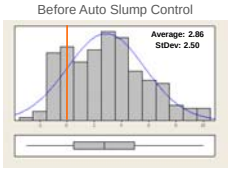
Opportunity to reduce cement content.



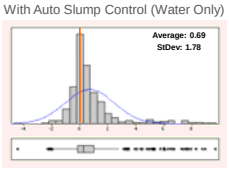
Reduction in Slump Variability with Auto Slump Control

Slump at Discharge vs. Target

Before Auto Slump Control



With Auto Slump Control (Water Only)



- 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.

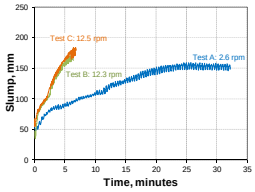
Post Delivery Adjustments

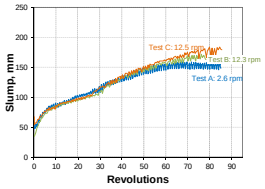
Operations and QC management receive reports on slumps and water and admixture added to every load. This can be used to ensure correct water content and redesign mixtures.

Mixing of Superplasticizer in Transit

Superplasticizer additions can be fully mixed at agitating speed

- **Polycarboxylate-based superplasticizer added at agitating speed (2.6 rpm) or mixing speed (12.5 rpm), dose of 0.06%solids/cement**
- **Stable slump reached at equal number of revolutions**

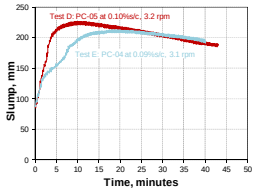


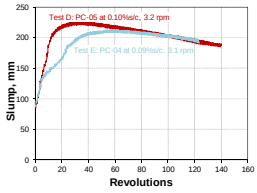


Mixing of Superplasticizer in Transit

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.