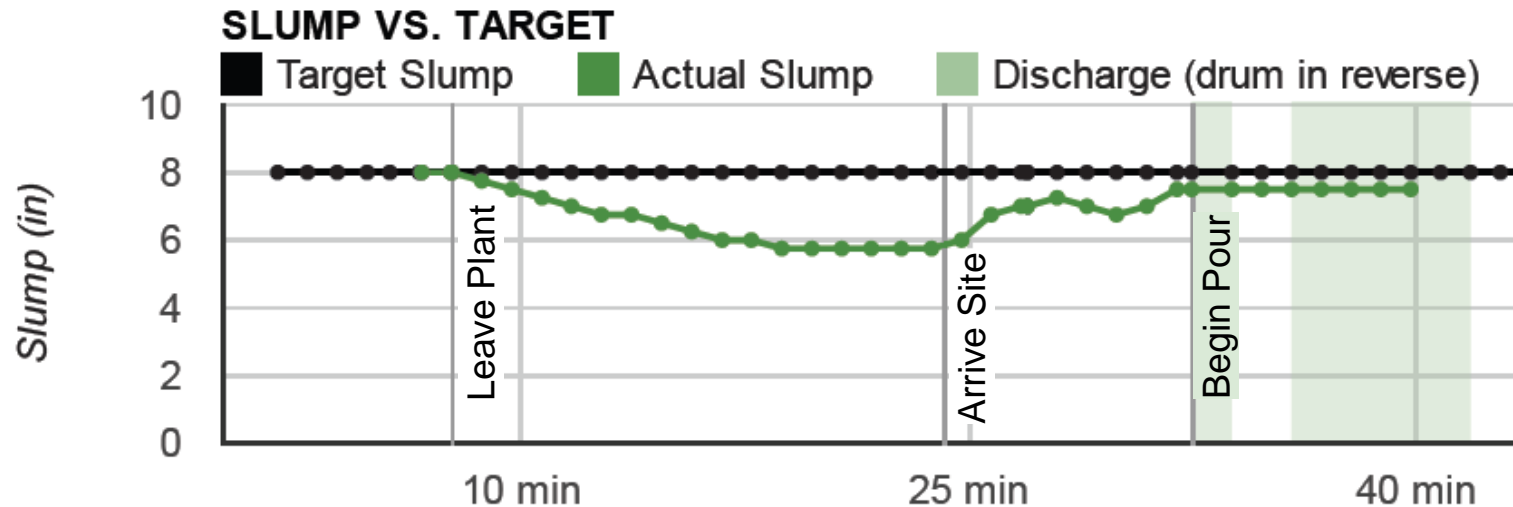




# Rethinking Concrete Delivery for Increased Quality

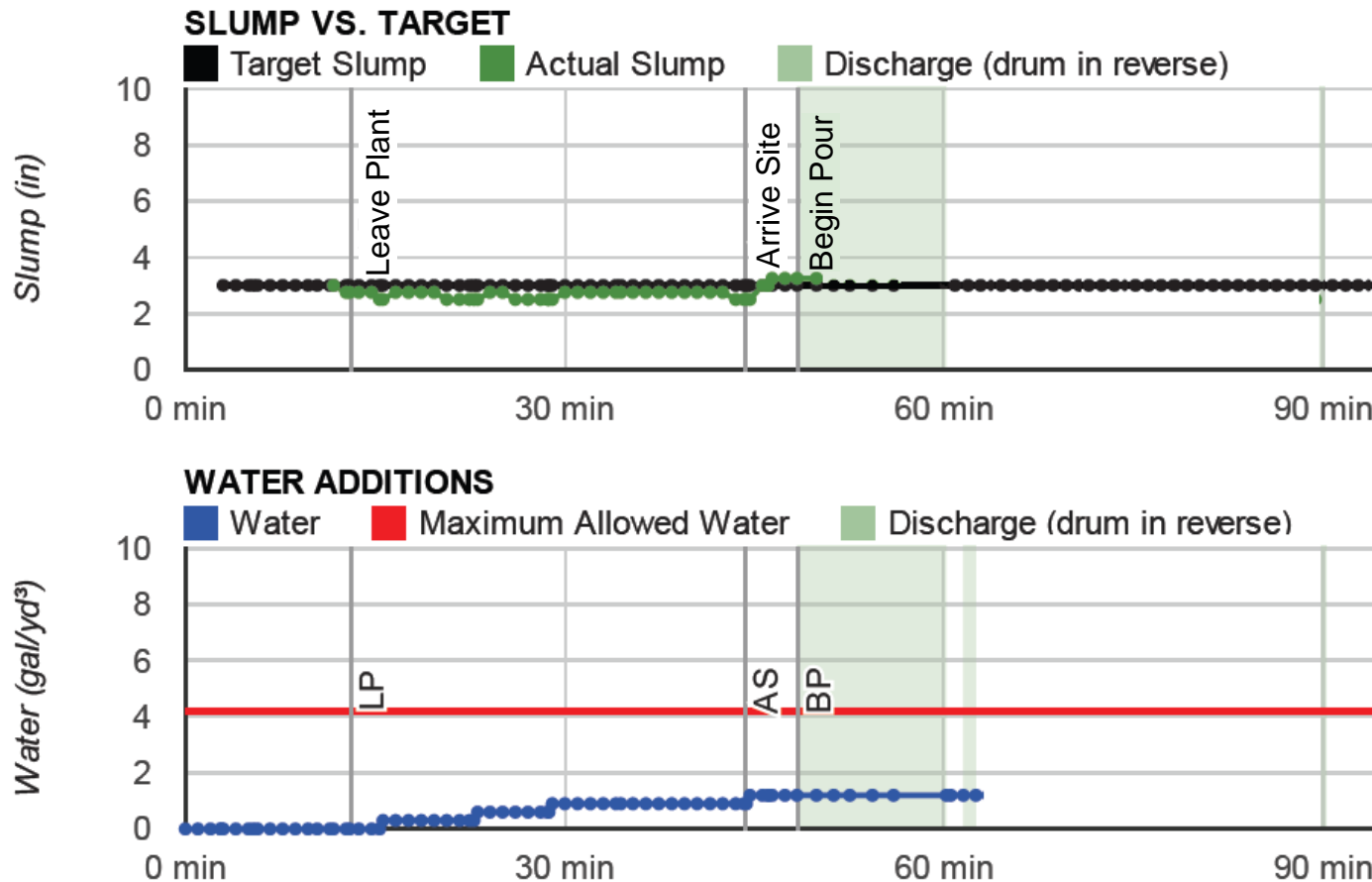
Eric P. Koehler, Ph.D.  
[eric.koehler@verificoncrete.com](mailto:eric.koehler@verificoncrete.com)

# Typical Concrete Delivery – Manual Control



- 1) Inspector cannot test every truck.
- 2) Addition is manual and subjective.
- 3) Delays in construction → added costs

# Automated Water Control



- 1) All water additions measured, on every truck.
- 2) Data available to inspector.
- 3) Automated: no driver involvement.
- 4) Maximum water not exceeded.

# Automated Slump & Water Control Systems

Truck-mounted equipment to measure, manage, and record:

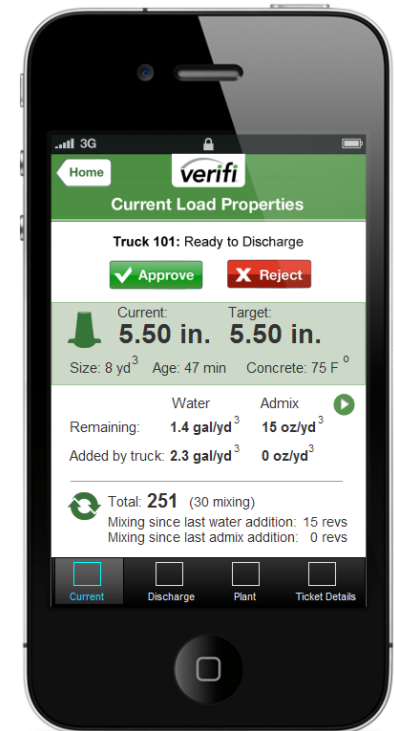
Slump	Water
Temperature	Admixture
Drum Speed	Age
Revolutions	Load Size

Commercially available from multiple vendors.  
Features may vary.

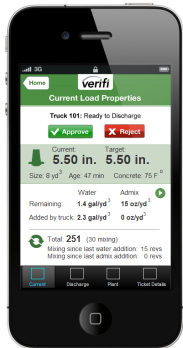
Purchased by the ready mix concrete supplier.

Data can be made available to inspector and engineer to ensure concrete meets specification.

Specification changes sometimes required.



# Measure, Manage, Record



Real Time  
Concrete Quality

Slump  
Temperature  
Load Size  
Revolutions

Drum Speed  
Water  
Admixture  
Age

cellular

Driver Interface



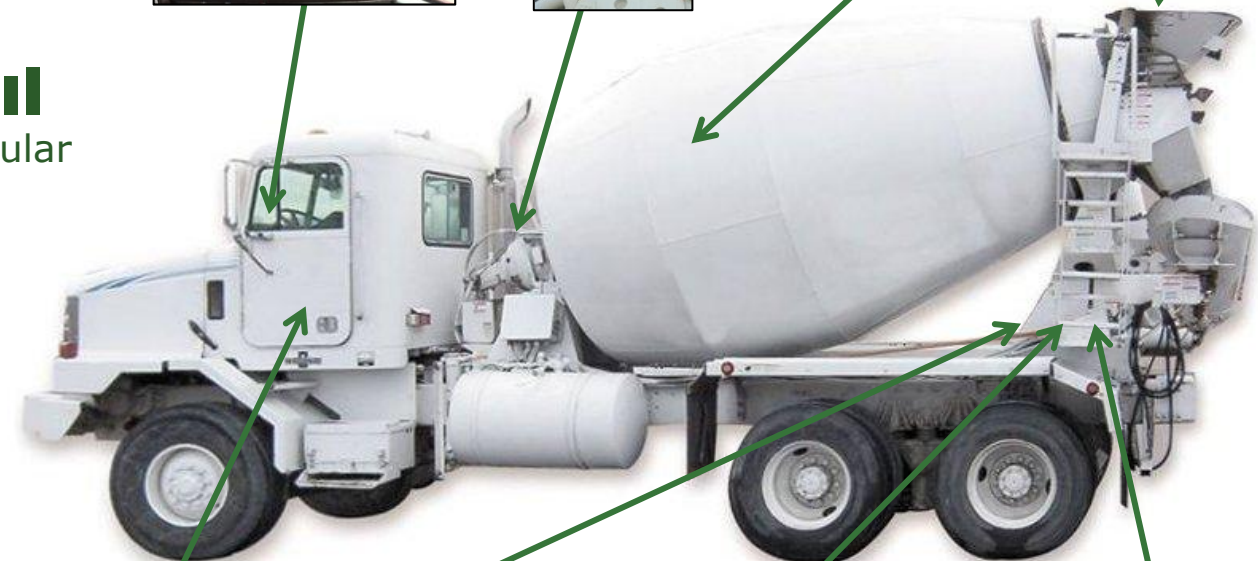
Hydraulic  
Pressure Sensors



Temperature  
and Drum  
Speed Sensor



Water (Top) and  
Admixture  
(Bottom) Nozzles



Processor, GPS, and  
Cellular Modem



Admixture Tank



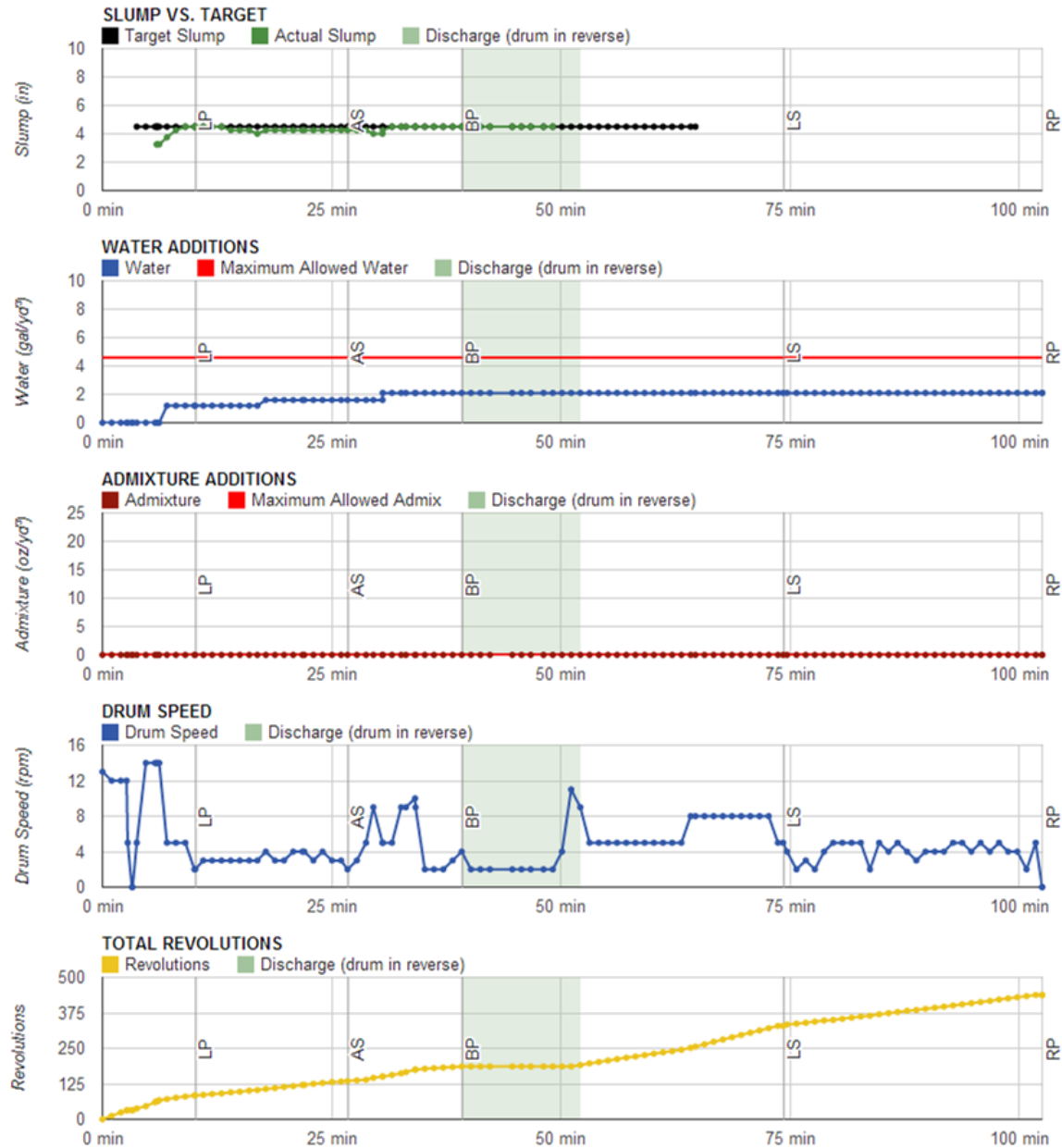
Flow Valves and  
Meters



Slump  
Display



# Measure, Manage, Record



# Inspector and Engineer Access

Contact the concrete supplier for access.

## At The Site

Water added is shown on the driver interface and can be provided to the inspector.

### Ready for Discharge

+

-

**Add Water**

**Change target slump**

**Remaining revs until mixed: 0** Air is Off

INCH		RPM		TOTAL	GAL	F
CURRENT	TARGET	CURRENT	TARGET		REMAINING	LOAD
6.00	6.00	4	2-6	127	2	75




## After the Pour

Concrete producers can provide a report showing properties on every load.

verifi PORTAL

HOME STATUS REPORTS

Compliance Reports Load Reports



### Load List > Detailed Load Report

Load:

Date	Mix ID	Verifi Instructions	Initial	Target Slump
09/30/2013	1590	Default Instruct..	5.00	5.00

Properties at Arrival:

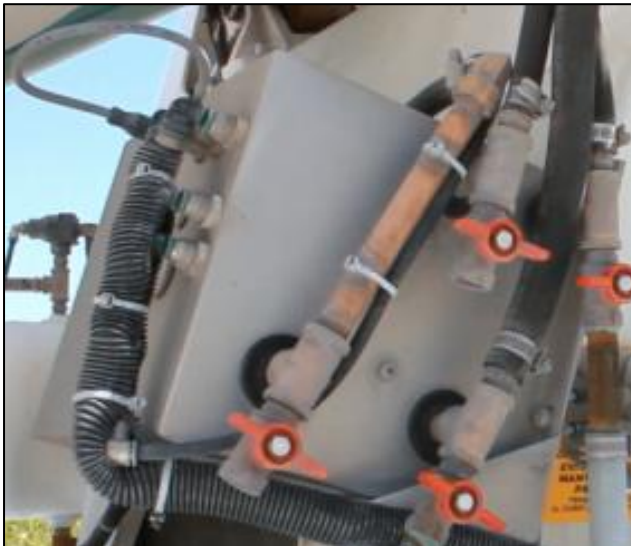
Slump (in)	Temp (°F)	Total Metered Water (gal/bcf)	Total Admix (oz/bcf)
6.00	55.0	127.0	0.00

# All Water Additions Are Recorded



**All water in line to drum flows through Verifi flow meters**

**Water must be added through the in-cab interface**



**Ready for Discharge** +

**Add Water** -

**Change target slump**

**Remaining revs until mixed: 0** Air is Off

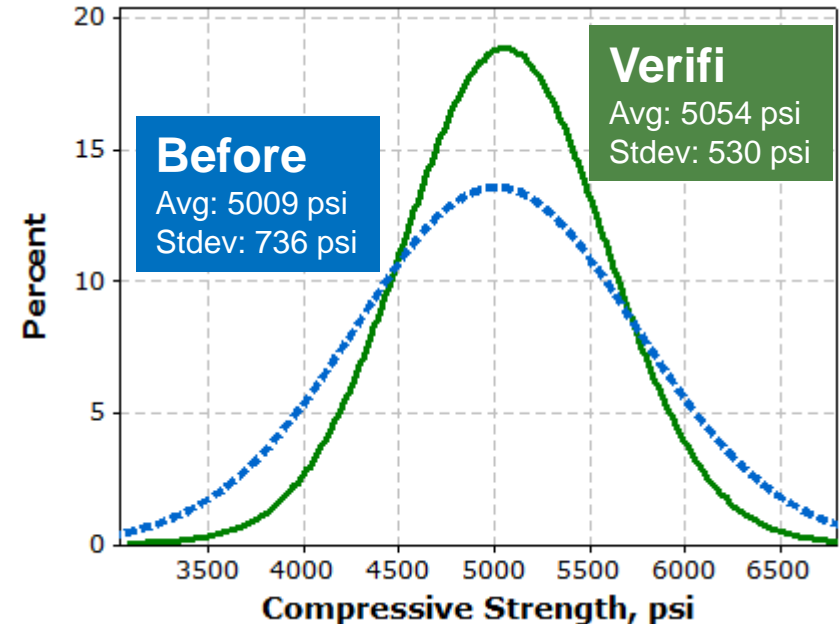
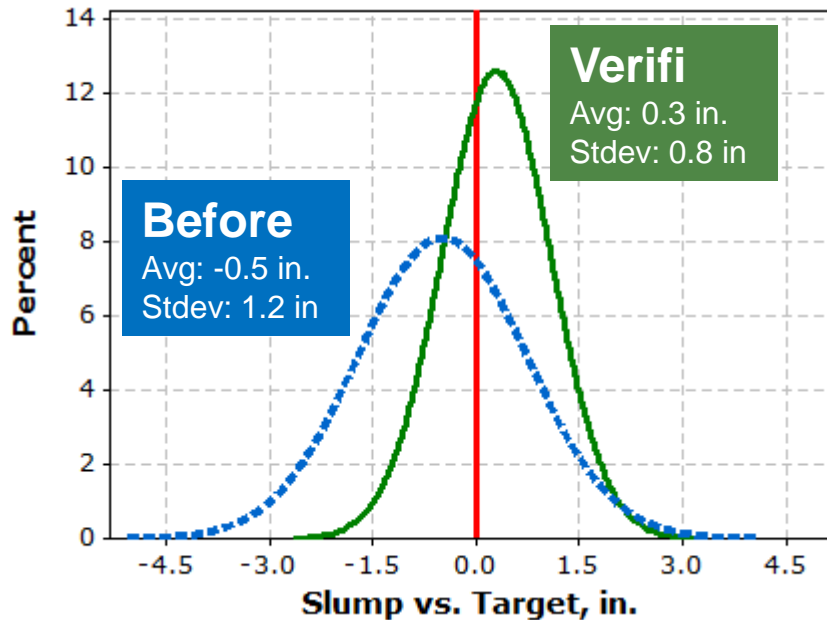
	INCH		RPM			
CURRENT	TARGET	CURRENT	TARGET	TOTAL	REMAINING	LOAD
6.00	6.00	4	2-6	127	2	75



# Consistent Quality Concrete with Verifi

Consistent **Slump** at Discharge

Consistent **Strength** at 28 Days



And consistent:  
+ durability  
+ air content  
+ finishability  
+ setting time  
+ pumpability

# MoDOT Research

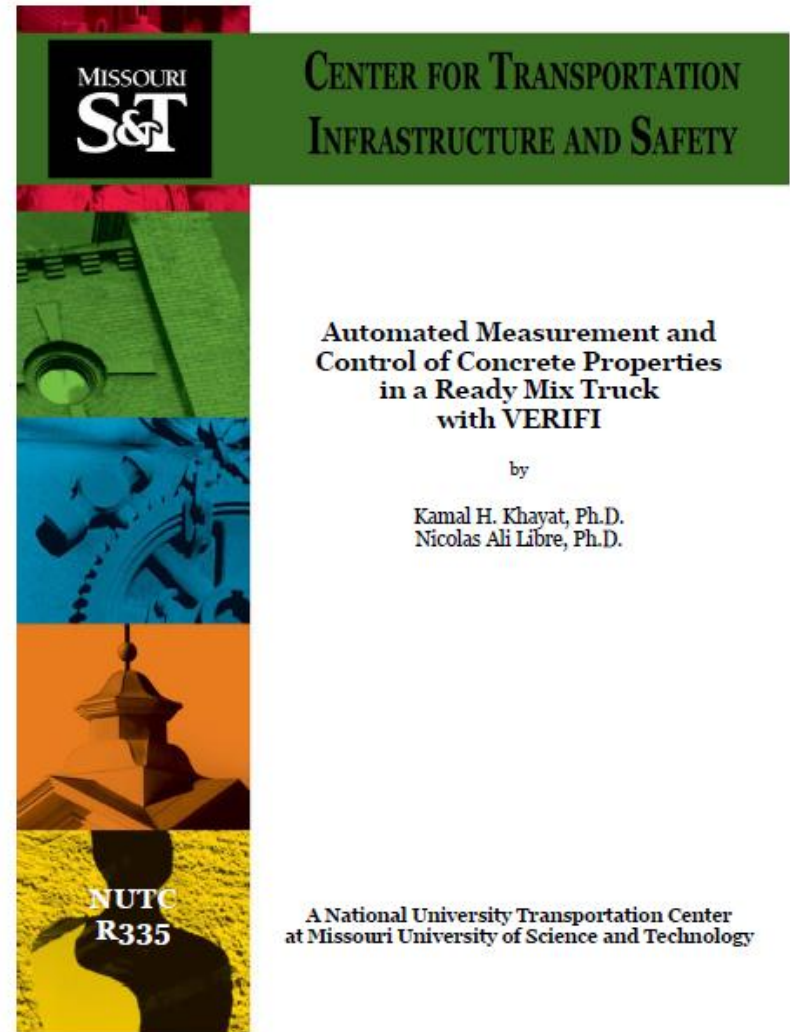


Research project conducted in Summer 2013 by Kamal Khayat and Nicolas Libre at Missouri S&T.

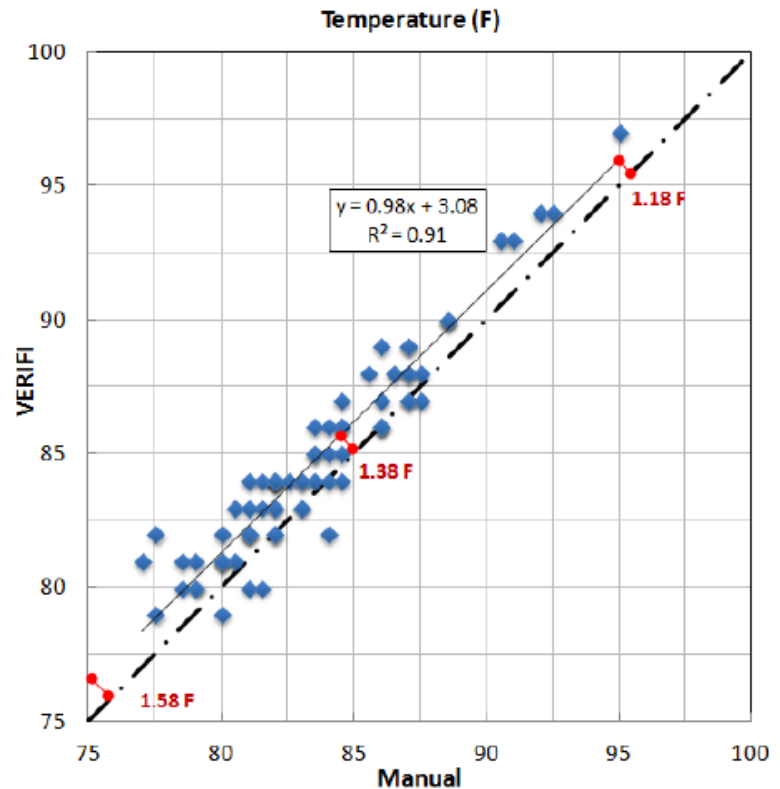
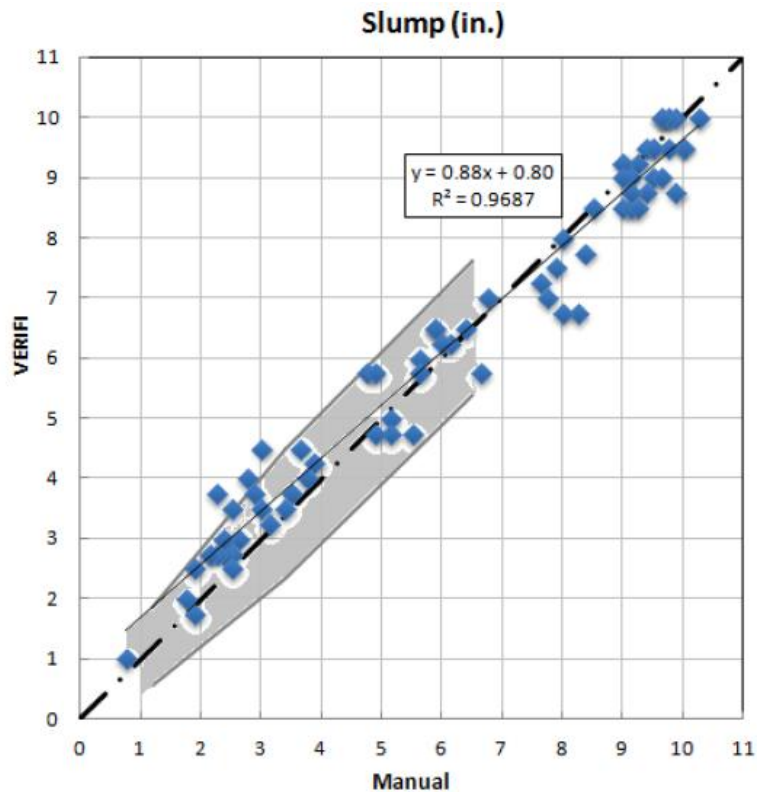
Funded by MoDOT

Researchers sought to answer:

- 1) Can Verifi accurately measure slump and temperature?
- 2) Can Verifi adjust slump with water and admixture?
- 3) What are the effects on concrete properties?



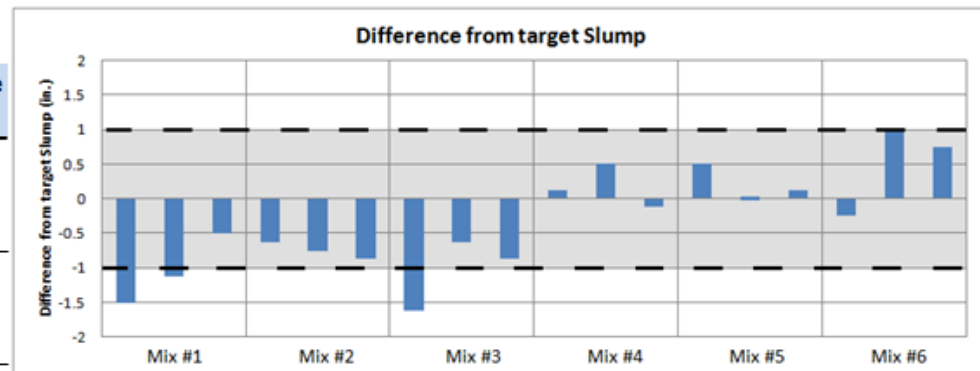
Question 1: Can Verifi accurately measure slump and temperature?



## Question 2: Can Verifi adjust slump with water and admixture?

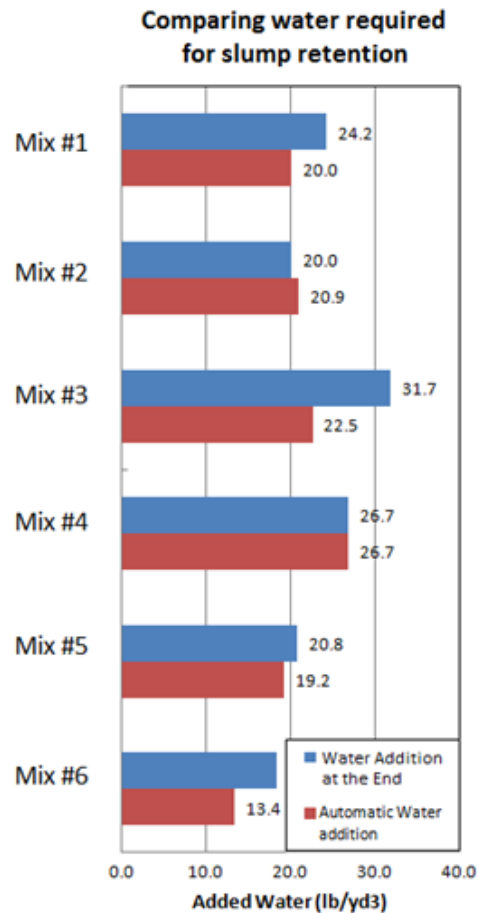
Mix #	Test #	Time	Target slump	VERIFI Slump	Difference (V-T)	Measured Slump	Difference (M-T)
1	11R	30	4	3.5	-0.5	2.5	-1.5
		60	4	3.75	-0.25	2.875	-1.125
		90	4	3.75	-0.25	3.5	-0.5
2	12	30	3	3	0	2.375	-0.625
		60	3	2.75	-0.25	2.25	-0.75
		90	3	2.75	-0.25	2.125	-0.875
3	13	30	6.5	5.75	-0.75	4.875	-1.625
		60	6.5	6.5	0	5.875	-0.625
		90	6.5	6	-0.5	5.625	-0.875
4	14	30	5	4.75	-0.25	5.125	0.125
		60	5	4.75	-0.25	5.5	0.5
		90	5	4.75	-0.25	4.875	-0.125
5	15R	30	9	9.5	+0.5	9.5	0.5
		60	9	9	0	9	0
		90	9	8.75	-0.25	9.125	0.125
6	16	30	7	7	0	6.75	-0.25
		60	7	6.75	-0.25	8	1
		90	7	7	0	7.75	0.75

*Difference between Measured slump and Target slump*

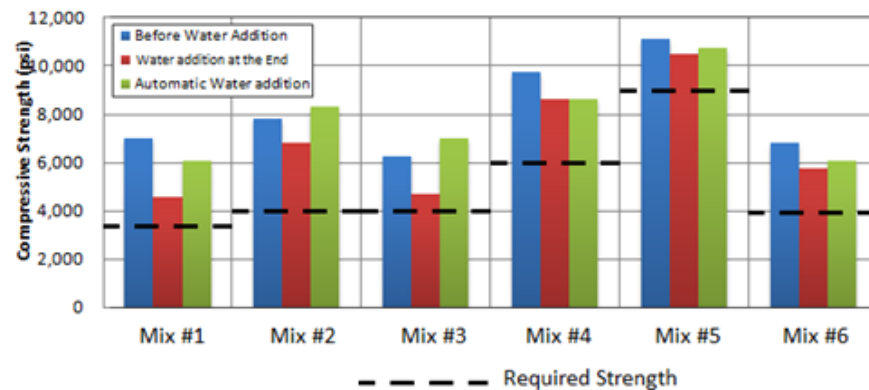


Slump Difference*	During Transportation
Max (Abs)	1.62 in.
Ave (Abs)	0.66 in.
Standard Deviation (Abs)	0.46 in.

## Question 3: What are the effects on concrete properties?



Mix #	Test #	Slump retention Method	compressive strength (3 days)			compressive strength (28 days)			Required Compressive Strength (psi)
			Before Water Addition	After Water Addition	reduction after retention	Before Water Addition	After Water Addition	reduction after retention	
1	2	Water Addition at the End	4760	3050	-36%	6970	4590	-34%	3500
	11R	Automatic Water addition	4760	4130	-13%	6970	6070	-13%	
2	7	Water Addition at the End	5870	4670	-20%	7,840	6,800	-13%	4000
	12	Automatic Water addition	5870	6180	+5%	7,840	8,330	+6%	
3	8	Water Addition at the End	4,250	3,070	-28%	6,260	4,670	-25%	4000
	13	Automatic Water addition	4,250	4,550	+7%	6,260	7,030	+12%	
4	9	Water Addition at the End	5830	4880	-16%	9,760	8,640	-11%	6000
	14	Automatic Water addition	5830	5150	-12%	9,760	8,600	-12%	
5	4	Water Addition at the End	7800	7250	-7%	11,140	10,520	-6%	8750
	15R	Automatic Water addition	7800	6690	-14%	11,140	10,770	-3%	
6	10	Water Addition at the End	5380	3820	-29%	6820	5780	-15%	4000
	16	Automatic Water addition	5380	4650	-14%	6820	6060	-11%	



## Question 3: What are the effects on concrete properties?

Mix #	Test #	Comments	Air content (%)				Required Air Content (%)
			30	60	90	Variation	
1	2	without slump retention	7.1%	5.5%	4.5%	2.6%	5-8%
	11	Automatic Water addition	6.5%	6.4%	5.9%	0.6%	
2	7	without slump retention	6.3%	6.3%	5.1%	1.2%	5-8%
	12	Automatic Water addition	3.4%	4.0%	3.7%	0.6%	
3	8	without slump retention	6.3%	5.1%	5.0%	1.3%	4.5-7.5%
	13	Automatic Water addition	6.5%	7.3%	7.6%	1.1%	
	18	Automatic Admixture Addition	5.5%	5.1%	4.5%	1.0%	
4	9	without slump retention	1.5%	1.3%	1.6%	0.3%	0-3%
	14	Automatic Water addition	1.8%	1.6%	1.4%	0.4%	
5	4	without slump retention	1.2%	1.2%	1.4%	0.2%	0-3%
	15R	Automatic Water addition	1.0%	1.0%	1.0%	0.0%	
	20	Automatic Admixture Addition	1.0%	0.8%	0.9%	0.2%	
6	10	without slump retention	5.6%	4.5%	4.1%	1.5%	5-8%
	16	Automatic Water addition	5.0%	4.1%	4.0%	1.0%	

- We are looking at the change in air over time, not the absolute value of air content
- Variation of Air content in Automatic slump retention method is equal or lower than corresponding mixture without slump retention



## Research Conclusions

The results of this research indicate that

- 1) VERIFI is able to accurately measure concrete slump and temperature in the truck,
- 2) VERIFI is able to adjust slump automatically to target by adding water and admixture, and
- 3) Adding water in transit instead of at the jobsite or plant does not negatively affect concrete performance.

Compared to current industry practices, VERIFI provides more accurate and complete documentation of concrete properties, including all additions of water, so that engineers and inspectors can confirm whether concrete meets specification. Therefore, VERIFI can be allowed to add water during transit and data from VERIFI can be used for acceptance purposes.



Link to the report at: [verificoncrete.com/modot](https://verificoncrete.com/modot)

# ASTM Update: In-Transit Water Additions



## What Changed?

ASTM C94 now allows water additions in transit on trucks equipped with automated slump and water management systems. The maximum w/cm cannot be exceeded.

## Why Did This Change?

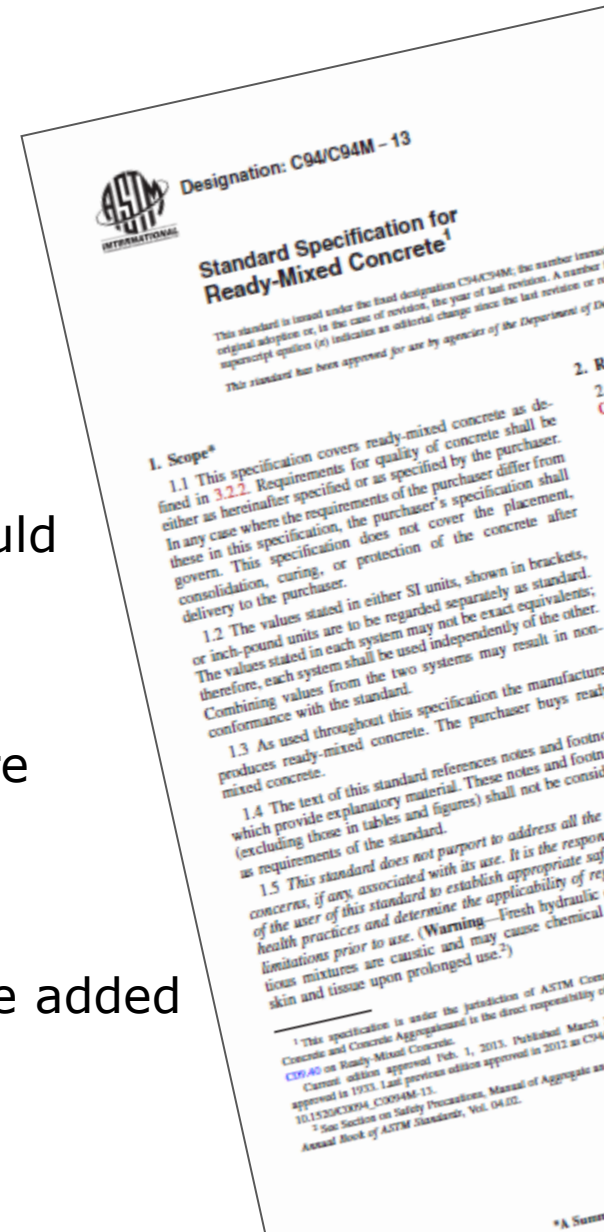
Previously, any water added on the truck needed to be added at the jobsite so that an inspector could be present.

## What Are The Benefits?

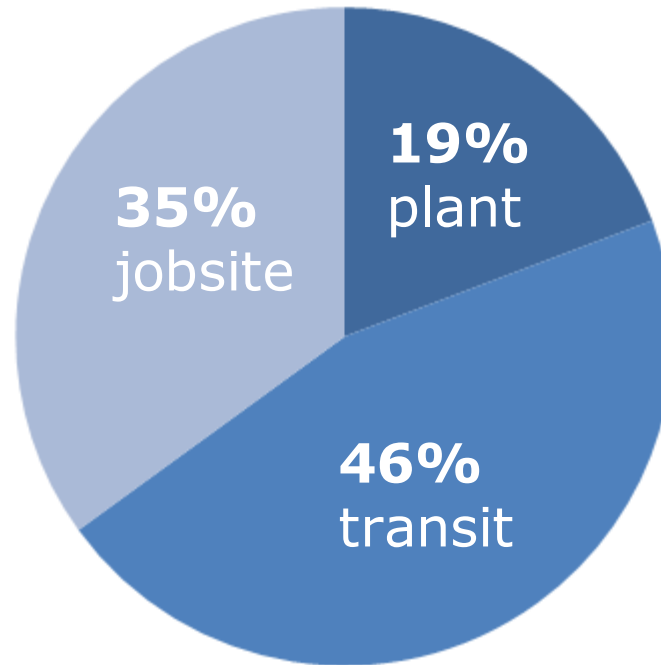
Concrete arrives ready to pour. Water additions are automated and documented, on every load.

## What Can I do?

Ensure specifications indicate that: "Water shall be added in accordance with ASTM C94."



## Verifi water added, by location in 2013



# DOT Projects



## Conclusions

Equipment is available to measure, manage, and record concrete properties in the truck

All water additions are recorded for every load, every truck

Greater level of control to purchaser of concrete

May require specification changes

Results in higher quality concrete and faster construction

# Questions?