



American Concrete Institute

# Analysis of Measured Parking Lot Data

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**AMERICAN SOCIETY OF CONCRETE CONTRACTORS**

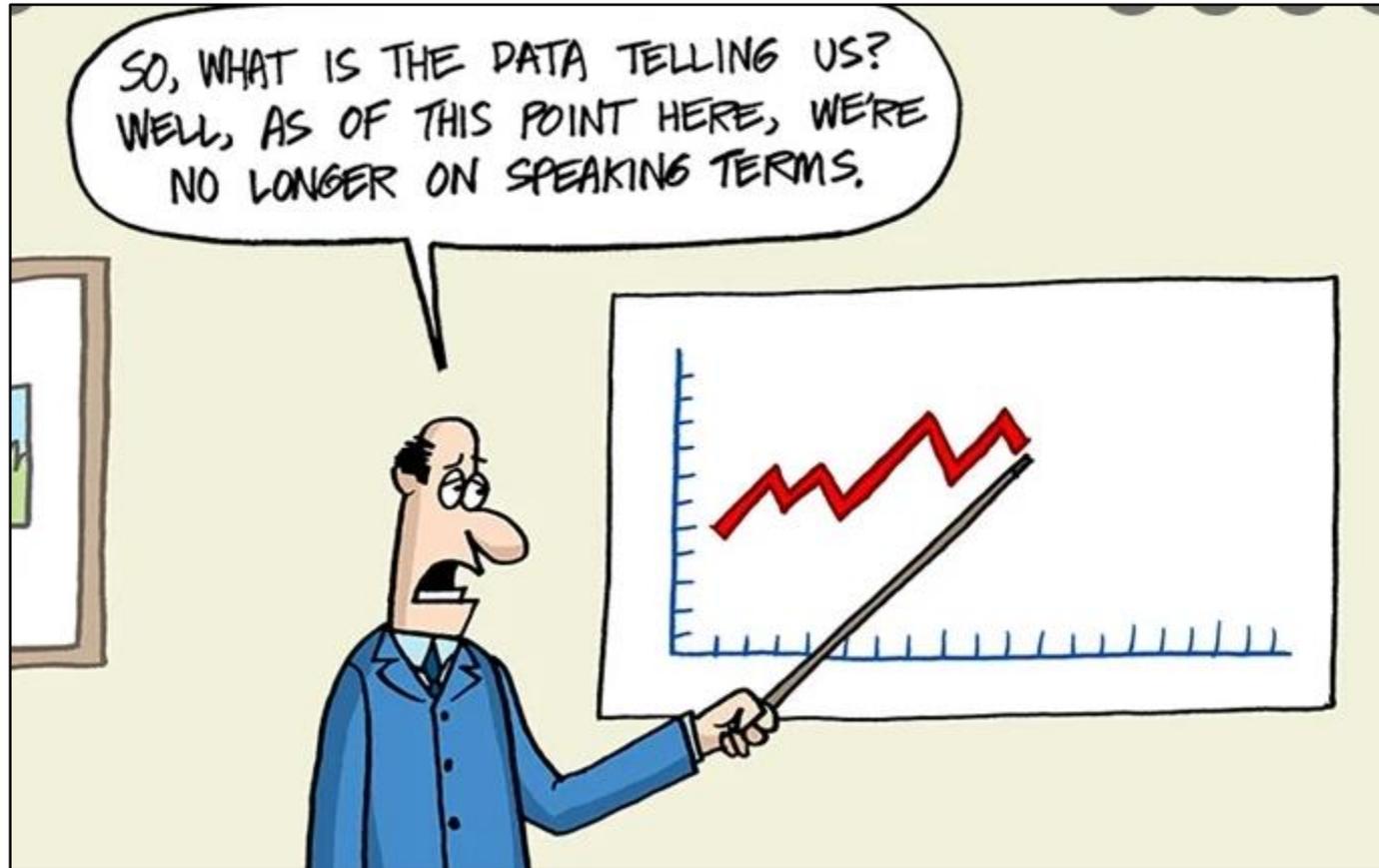
Enhancing the Capabilities of Those Who Build with Concrete





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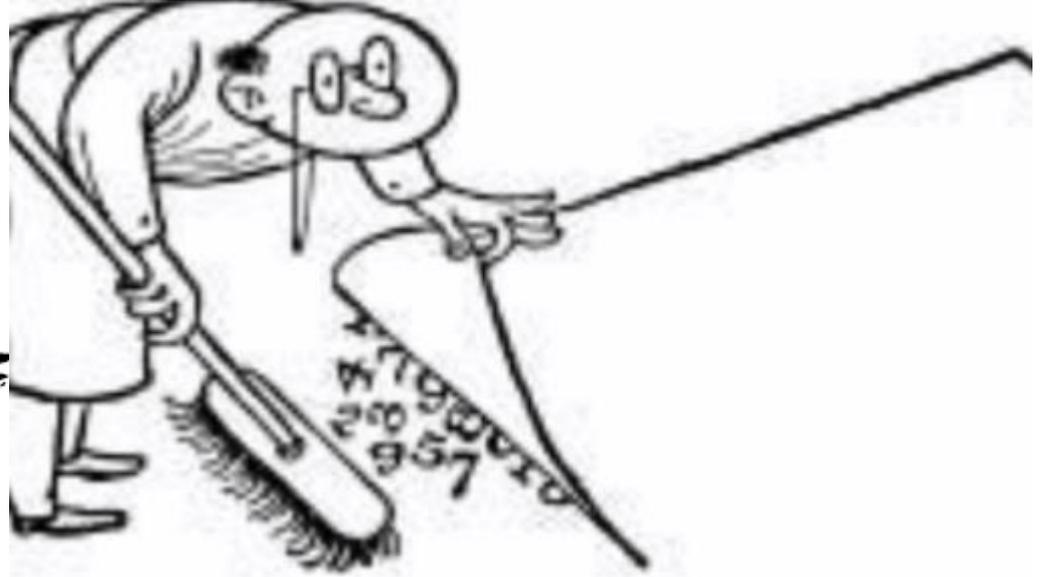
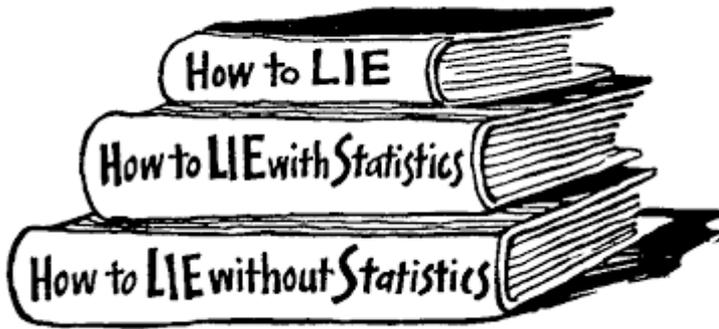
# Data Analysis





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# Is My Mouth Moving?

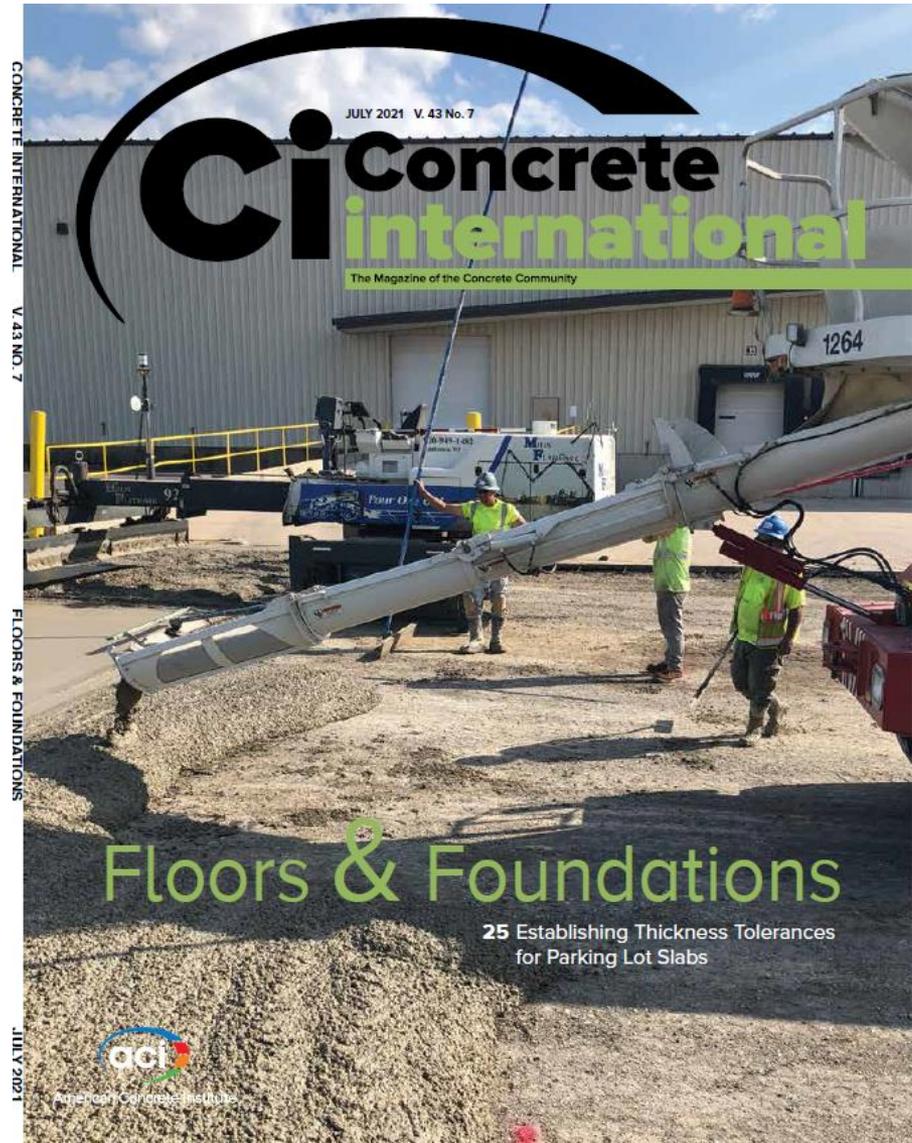




# Lie in Public

## Lie with Friends

**“Establishing Thickness Tolerances for Parking Lot Slabs,”**  
Eldon Tipping, Tim Manherz, Paul J. Beagley, Peter J. Ruttura, and Bruce A. Suprenant, *ACI Concrete International*, July 2021.





# It's Not Lying if You Show it All



- Level hard-troweled slab-on-ground data (Table 5)
- Sloped broomed slab-on-ground data (Table 6)
- Warped broomed slab-on-ground (Table 7)



# Level Troweled (Interior)

**Table 5:**  
Level hard-troweled slab-on-ground data collected by ACI Committee 330

Placement size, ft <sup>2</sup>	Number of samples	<i>t</i> , in.	Bottom surface (subbase), in.		Top surface (concrete), in.		Measured thickness, in.		Construction method	
			<i>MD</i>	<i>SD</i>	<i>MD</i>	<i>SD</i>	<i>MD</i>	<i>SD</i>	Subbase	Top surface
23,000	39	6	-0.56	0.41	+0.15	0.13	0.71	0.43	Laser grader	Laser strike-off
23,000	38	6	-0.60	0.39	-0.14	0.12	0.47	0.35	Laser grader	Laser strike-off
21,000	40	8	-0.54	0.30	-0.21	0.11	0.33	0.28	Laser grader	Laser strike-off
22,000	50	7	+0.13	0.26	+0.07	0.15	-0.06	0.28	Laser grader	Laser strike-off
41,000	39	8	0.31	0.28	-0.01	0.11	-0.32	0.32	Laser grader	Laser strike-off
1380	20	5	0.08	0.43	0.19	0.10	0.11	0.42	Box blade	Laser strike-off
3600	25	10	-0.17	0.38	-0.06	0.16	0.11	0.36	Laser grader	Laser strike-off
40,830	38	8	0.31	0.28	-0.01	0.11	-0.32	0.32	Laser grader	Laser strike-off
21,400	26	6	0.63	0.36	0.65	0.18	0.01	0.38	Laser grader	Laser strike-off
3000	30	7	0.18	0.40	-0.29	0.26	-0.47	0.32	Box blade	Laser strike-off
3500	30	6	0.04	0.33	+0.44	0.20	0.40	0.33	Box blade	Laser strike-off
6400	30	7	-0.39	0.36	-0.07	0.16	0.32	0.36	Dozer	Laser strike-off

Note: *t* = specified thickness; *MD* = mean deviation from specified; *SD* = standard deviation



# Sloped Broomed (Exterior)

**Table 6:**

Sloped broomed slab-on-ground data collected by ACI Committee 330

Placement size, ft <sup>2</sup>	Number of samples	t, in.	Bottom surface (subbase), in.		Top surface (concrete), in.		Measured thickness, in.		Construction method	
			MD	SD	MD	SD	MD	SD	Bottom surface	Top surface
15,000	40	6	*	*	*	*	0.24	0.38	Box blade	Manual strike-off
21,000	40	7	*	*	*	*	0.52	0.46	Motor grader	Manual strike-off
15,500	40	12	*	*	*	*	0.05	0.56	Motor grader	Manual strike-off
11,000	44	12	*	*	*	*	0.33	0.41	Motor grader	Manual strike-off
7200	36	12	*	*	*	*	0.03	0.46	Motor grader	Manual strike-off
4000	31	12	*	*	*	*	0.17	0.45	Motorgrader	Manual strike-off
11,000	44	12	*	*	*	*	0.37	0.54	Motor grader	Manual strike-off
9500	33	12	*	*	*	*	0.15	0.43	Motor grader	Manual strike-off
5500	32	12	*	*	*	*	-0.31	0.41	Motor grader	Manual strike-off
5500	37	12	*	*	*	*	0.01	0.53	Motor grader	Manual strike-off
1760	25	6	*	*	*	*	0.49	0.54	Dozer	Manual strike-off
2700	20	7	*	*	*	*	0.19	0.62	Box blade	Manual strike-off
27,200	40	7	*	*	*	*	0.30	0.60	Box blade	Manual strike-off
25,800	30	8	0.19	0.87	-0.22	0.29	-0.42	0.94	Dozer	Laser strike-off
25,800	30	8	-0.19	0.20	0.34	0.45	0.52	0.52	Robotic grader	Laser strike-off

Note: t = specified thickness; MD = mean deviation from specified; SD = standard deviation

\*Contractor did not provide data from survey points



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# Warped Broomed (Exterior)

**Table 7:**  
Warped broomed slab-on-ground data<sup>1</sup> collected by ACI Committee 330

Placement size, ft <sup>2</sup>	Number of samples	t, in.	Bottom surface (subbase), in.		Top surface (concrete), in.		Measured thickness, in.		Construction method	
			MD	SD	MD	SD	MD	SD	Bottom surface	Top surface
21,000	30	6	0.77	0.86	1.13	0.36	0.36	0.59	Motor grader	Laser strike-off
17,600	30	6	0.07	1.10	0.75	0.59	0.68	0.70	Motor grader	Laser strike-off
26,500	30	7	-2.22	1.36	-2.58	0.91	-0.36	0.88	Motor grader	Laser strike-off
16,500	30	7	-1.31	0.67	-1.62	1.11	-0.31	0.95	Motor grader	Laser strike-off
16,500	31	7	2.35	0.67	2.39	0.44	0.03	0.63	Motor grader	Laser strike-off

Note: t = specified thickness; MD = mean deviation from [No Title] SD = standard deviation

<sup>1</sup>Contractor described project as “gnarly, multi-level, multi-sloping parking lot with connecting roads”



**Table 4:**  
Summary of slab-on-ground data collected by ACI Committee 330

Description	Level hard-troweled	Sloped broomed	Warped broomed
Total number of projects	12	15	5
Total area, ft <sup>2</sup>	210,110	178,960	98,100
Number of measurements	405	522	151
Specified thickness, in.	5, 6, 7, 8, 10	6, 7, 8, 12	6
Weighted average mean deviation from specified, in.	+0.11	+0.16	+0.09
Weighted average standard deviation, in.	0.34	0.52	0.75
Subbase elevation-control	Laser grader: 8 Box blade: 2 Dozer: 1	Motor grader: 9 Robotic grader: 1 Box blade: 3 Dozer: 2	Motor grader: 5
Top surface strike-off	Laser: 12	Manual: 13 Laser: 2	Laser: 5



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# Compare to Other Data

## Suprenant and Malisch, ASCC 2008

**Table 8:**  
Weighted average measured thickness values

Slab type and surface finish	Number of placements	Number of samples	<i>MD</i> , in.	<i>SD</i> , in.
Level hard-troweled	12	405	0.11	0.35
Sloped broomed	15	522	0.18	0.52
Warped broomed	5	151	0.09	0.75

Note: *MD* = mean deviation from specified; *SD* = standard deviation

**Table 9:**  
Level hard-troweled slab-on-ground data summarized by Suprenant and Malisch (ASCC data set)<sup>16</sup>

Project	Slab area, ft <sup>2</sup>	Number of measurements	<i>t</i> , in.	<i>MD</i> , in.	<i>SD</i> , in.
1	240,000	862	4	-0.1	0.60
2	200,000	75	6	-0.5	0.47
3	100,000	186	6	-0.55	0.70
4	100,000	427	6	-0.28	0.60
5	100,000	153	6	-0.38	0.57
6	90,000	79	4	-0.36	0.90
7	100,000	111	4	-0.32	0.77
8	Unknown	60	5	-0.34	0.73

Note: *t* = specified thickness; *MD* = mean deviation from specified; *SD* = standard deviation



# Compare to Other Data

Jim Cornell at ACI-ASCC 117, 3/30/21

**Table 8:**  
Weighted average measured thickness values

Slab type and surface finish	Number of placements	Number of samples	<i>MD</i> , in.	<i>SD</i> , in.
Level hard-troweled	12	405	0.11	0.35
Sloped broomed	15	522	0.18	0.52
Warped broomed	5	151	0.09	0.75

Note: *MD* = mean deviation from specified; *SD* = standard deviation

Jim Cornell Data presented 3/30/21 to 117: Sloped Paving 473 GPR points  
6-in. AVG = 5.8 in SD = 0.44 in.

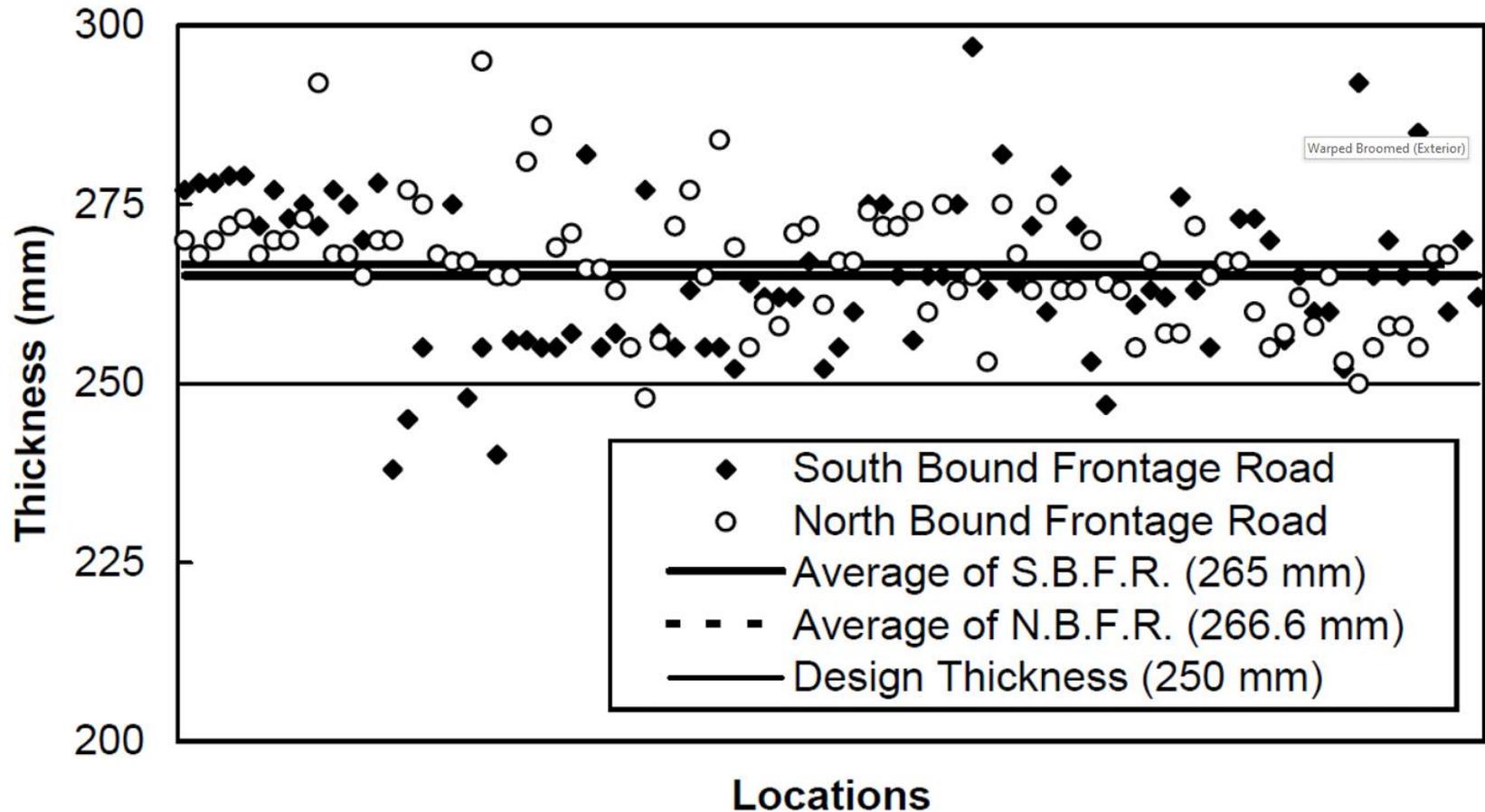
Jim Cornell Data presented 3/30/21 to 117: Warped Paving 1175 GPR points  
6-in. AVG = 5.8 in SD = 0.93 in.



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# Highway Data

Texas Department of Transportation, 2002  
Seong-Min Kim and B. Frank McCullough



# Highway Department Experience

- Minnesota— HWY #1: 0.45 in. and 0.43 in.
- Texas— 0.44 in., 0.34 in., 0.44 in., 0.52 in., 0.47 in., 0.63 in.
- Average Standard Deviation = 0.48 in.
  
- Same Thickness Variability as SOG
  
- Main Difference—Average Thickness is Greater Than Design Thickness



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# Learned What We Knew

Base elevations more difficult to control than concrete elevations

**Table 11:**

Weighted average measured bottom surface (subbase) and top surface (concrete) elevation values

Slab type and surface finish	Number of placements	Number of samples	Bottom surface (subbase), in.		Top surface (concrete), in.	
			<i>MD</i>	<i>SD</i>	<i>MD</i>	<i>SD</i>
Level hard-troweled	12	405	-0.07	0.34	0.04	0.15
Sloped broomed	2	60	NA	NA	NA	NA
Warped broomed	5	151	-0.07	0.93	0.14	0.68

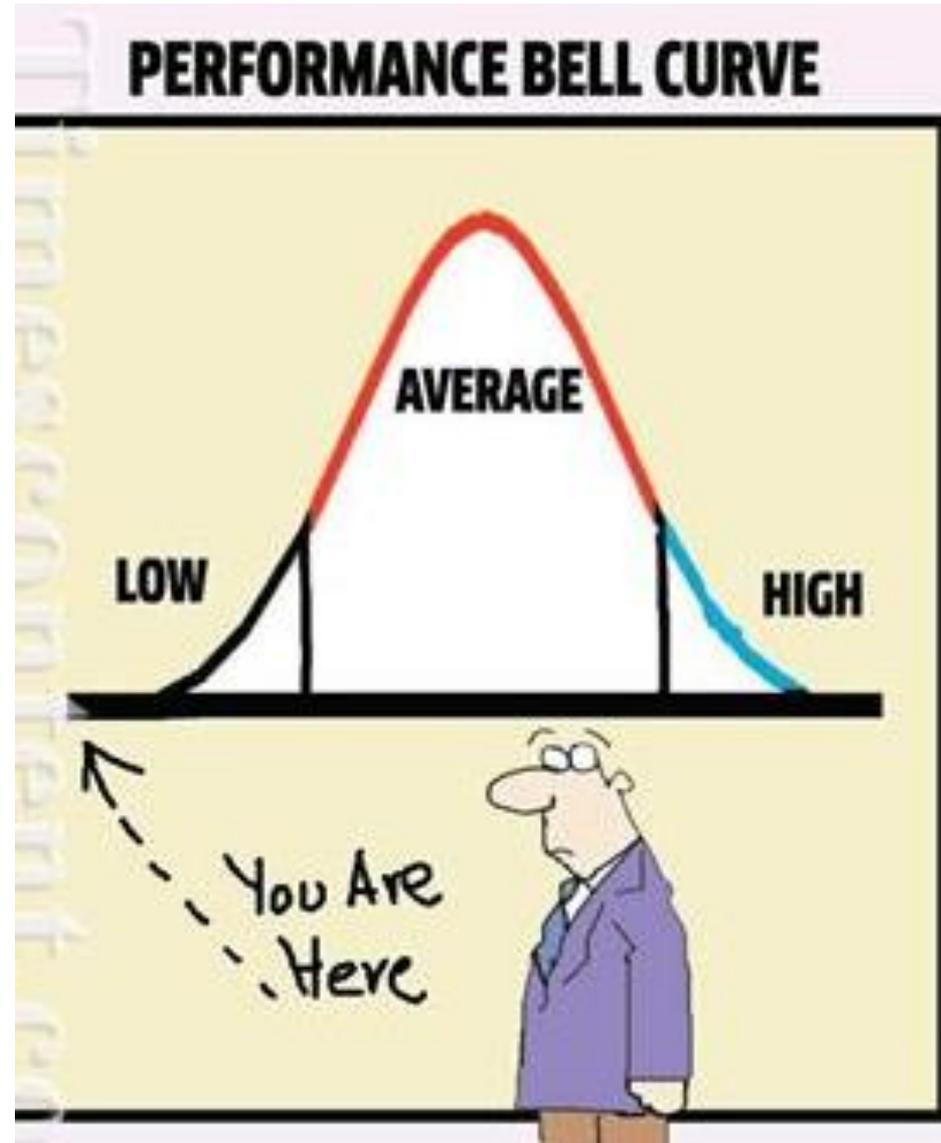
Note: *MD* = mean deviation from specified; *SD* = standard deviation



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- Completely randomized points
- Entirely unbiased – eliminates human error and favoritism of picking a spot that looks best
- **All true**

## Is the Data Random?



# Sampling

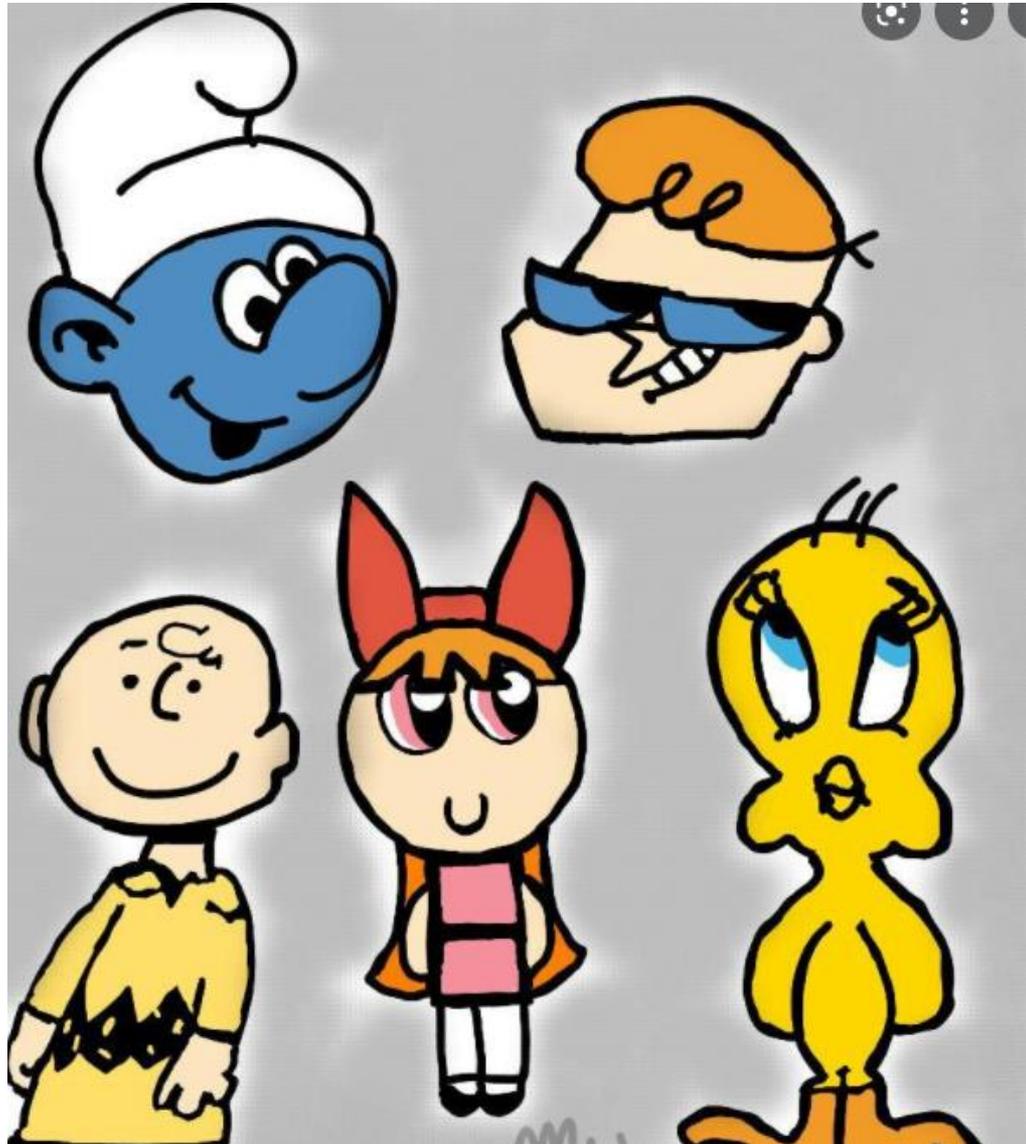
- Volunteer sampling
- Convenience sampling
- Random sampling



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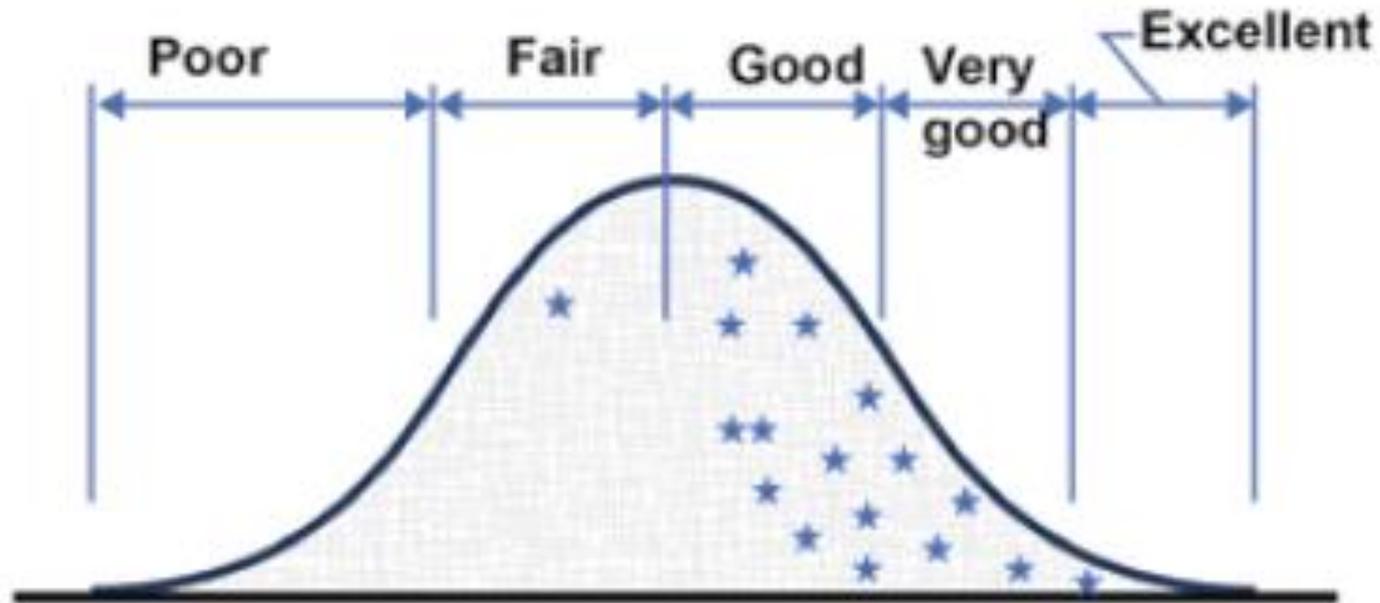


## Random Participants?





# What Bias????



**Fig. 4: Expectation of where the ACI Committee 330 data set falls within the target population**



# ACI 214 Approach

**Table 15:**  
Levels of thickness control for slabs-on-ground

Slab type and surface finish	SD for different levels of thickness control, in.				
	Excellent	Very good	Good	Fair	Poor
Level hard-troweled	Below 0.30	0.30 to 0.37	0.38 to 0.45	0.46 to 0.53	Above 0.53
Sloped broomed	Below 0.45	0.45 to 0.52	0.53 to 0.60	0.61 to 0.68	Above 0.68
Warped broomed	Below 0.70	0.70 to 0.80	0.81 to 0.90	0.91 to 1.00	Above 1.00

Note: SD = standard deviation



# Recommendations

**Table 16:**  
Tolerance recommendations for slabs-on ground

Slab type and surface finish	Elevation tolerance, in.	<i>X</i> value to be used in computing average thickness, in.	Thickness tolerances below specified thickness, in.	
	Fine grade of soil immediately below	Individual sample thickness = minimum of sample thickness or ( <i>X</i> + the specified thickness)	Average of all samples	Individual sample
Level hard-troweled	±1	1	-3/8	-1
Sloped broomed	±1-1/4	1-1/4	-3/8	-1-1/4
Warped broomed	±1-1/2	1-1/2	-3/8	- 1-1/2



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# ACI-ASCC 117 and ACI 330

**ACI 117-10**  
(Reapproved 2015)

**Specification for Tolerances for  
Concrete Construction and Materials  
(ACI 117-10) and  
Commentary (ACI 117R-10)**

An ACI Standard

Reported by ACI Committee 117



American Concrete Institute®

An ACI Standard

Specification for  
Unreinforced Concrete  
Parking Lots and Site Paving

Reported by ACI Committee 330

ACI 330.1-14

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