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NOTATION SUMMARY

d_i	Line height number
L_3	Mean intercept length
MSE	Mean squared error
N_L	Number of aggregate intercepts per unit length
P_a	Percentage of aggregate by point count.
s	Standard deviation
V_a	Percentage of aggregate by volume.
y_i	Test line count
l	Mean free distance between aggregate
s	Mean traverse length

Table 1: Mixture proportions per cubic yard and per cubic meter.

Mixture	K Mix L	K Mix U	S Mix
Designation	K-75L K-50L K-Mix67L	K-75U K-50U K-Mix67U	S-75 S-50
	Per Cubic Yard		
Material	Weight (lbs)	Weight (lbs)	Weight (lbs)
Coarse Agg.	1397	1537	1490
Fine Agg.	1183	1117	1374
Cement	715	675	590
Fly Ash	155	146	150
Slag	78	73	75
Water	360	340	310
Total	*3888*	*3888*	*3988*
HRWR	55 fl. oz.	55 fl. oz.	64 fl. oz.
VMA	15 – 30 fl. oz.	15 – 30 fl. oz.	15 fl. oz.
	Per Cubic Meter		
Material	Mass (kg)	Mass (kg)	Mass (kg)
Coarse Agg.	829	912	884
Fine Agg.	702	663	815
Cement	424	400	350
Fly Ash	92	87	89
Slag	46	43	44
Water	214	202	184
Total	*2307*	*2307*	*2366*
HRWR	2100 ml	2100 ml	2500 ml
VMA	600 – 1200 ml	600 – 1200 ml	1200 ml

Table 2: Slump Flow Results.

Mixture	Slump Flow Diameter (inches/cm)	Degree of Segregation (visual)
K-75L	24.75/63	None
K-75U	24/61	Very minor
S-75	23.75/60	None
K-50L	25.5/65	None
K-50U	25/64	None
S-50	26/66	Minor
K-Mix67L	--	--
K-Mix67U	--	--

Table 3: Horizontal flow box results.

Mixture	% Filling Capacity
K-75L	72.3
K-75U	69.8
S-75	62.0

Table 4: Passing Ability Results.

	¾" nom. max. size agg.			½" nom. max. size agg.			Mixed #67 agg.	
Mixture Designation	K-75L	K-75U	S-75	K-50L	K-50U	S-50	K-Mix67L	K-Mix67U
Aggregate Content	Low	High	Low	Low	High	Low	Low	High
Spacing	Test Result							
1.5 in. (38 mm)	Passed	Passed	Passed	--	--	--	--	Passed
1.25 in. (32 mm)	Passed	Passed	Passed	--	--	--	Passed	Failed
1 in. (25 mm)	Failed	Failed	Failed	Passed	Passed	Passed	Failed	Failed
0.83 in. (21 mm)	--	--	--	Failed	Failed	Failed	--	--
0.67 in. (17 mm)	--	--	--	Failed	--	--	--	--

Table 5: Stereology Results, Average of 6 Samples Each Mixture.

	¾" nom. max. size agg.			½" nom. max. size agg.		Mixed #67 agg.	
Mixture Designation	K-75L	K-75U	S-75	K-50L	K-50U	K-Mix67L	K-Mix67U
Aggregate Content	low	high	low	low	high	low	high
P_a	0.324	0.348	0.321	0.295	0.317	0.301	0.343
N_L	1.130	1.193	1.119	1.248	1.301	1.176	1.402
λ	0.599	0.549	0.610	0.567	0.528	0.595	0.469
L_3	0.287	0.293	0.288	0.237	0.243	0.256	0.245
σ	0.887	0.841	0.898	0.804	0.772	0.852	0.714

Note: all values are in inches
1 inch = 25.4 mm

Table 6: Comparison of stereology spacing and spherical packing model spacing.

Spacing Method	Center-to-center Spacing	K-75L	K-75U	S-75	K-50L	K-50U	K-Mix67L	K-Mix67U
Stereology	σ	0.887	0.841	0.898	0.804	0.772	0.852	0.714
BCC	Upper	*1.023*	*0.990*	*1.005*	0.682	0.660	0.740	*0.716*
	Lower	*0.682*	*0.660*	*0.670*	0.512	0.495	0.483	*0.467*
FCC	Upper	**1.124**	**1.087**	**1.104**	0.749	0.725	0.812	**0.786**
	Lower	**0.749**	**0.725**	**0.736**	0.562	0.543	0.530	**0.513**

Note: all values are in inches
1 inch = 25.4 mm
italic entries = stereology results bounded by BCC model
bold entries = stereology results bounded by FCC model

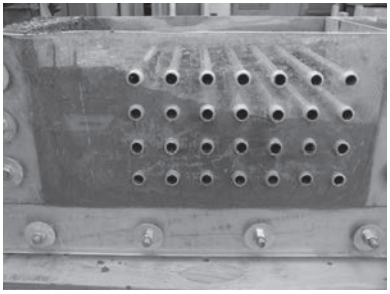

Figure 1: Horizontal flow box apparatus.

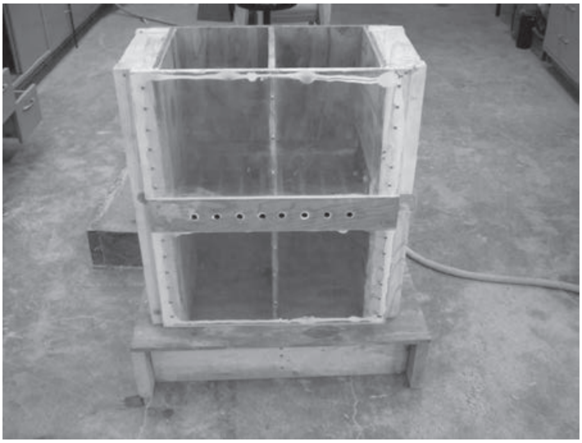

Figure 2: Passing ability test apparatus.

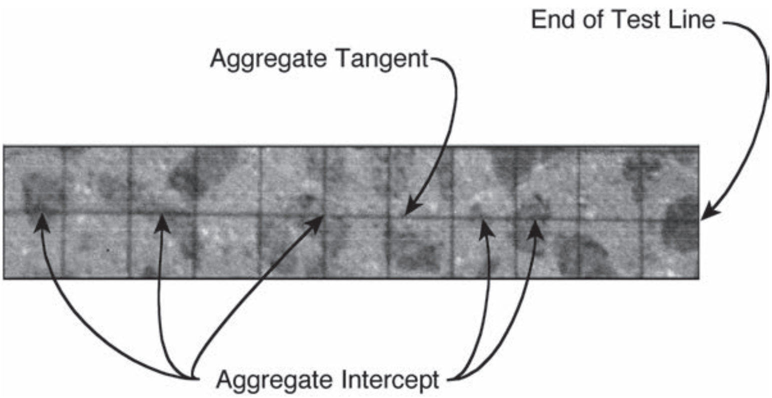

Figure 3: Example of Line Count, NL = 6/L (5 intercepts + 2 x 1/2 counts).

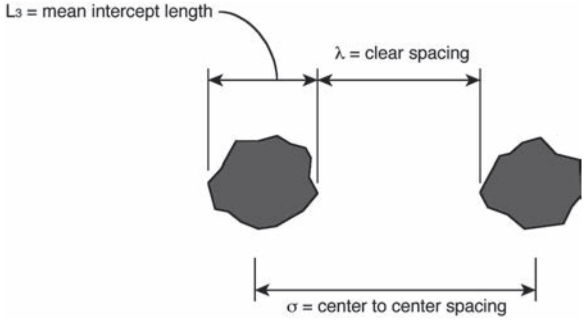

Figure 4: Streology parameters.

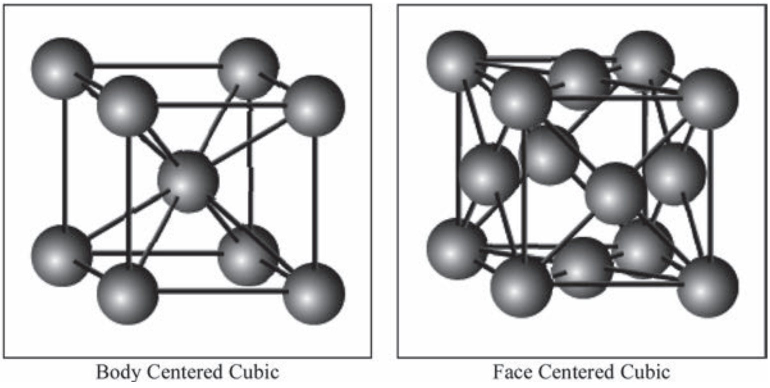

Figure 5: Spherical Packing Models.

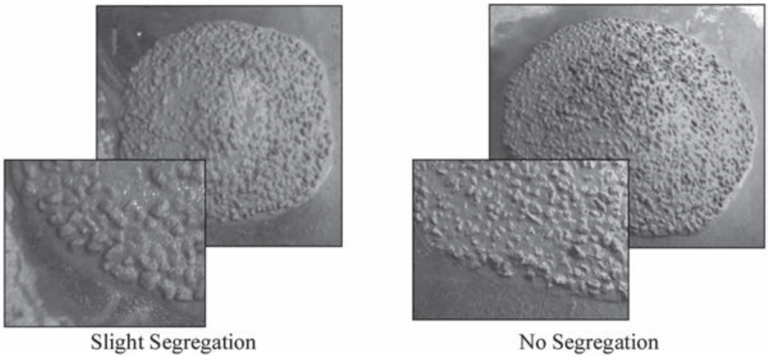

Figure 6: Typical slump flow results.

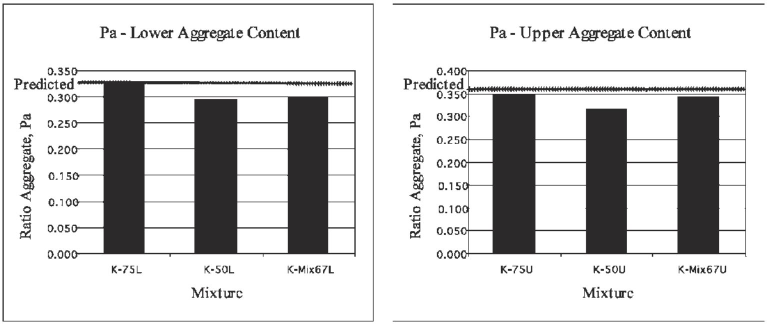

Figure 7: Comparison of actual aggregate content and Pa from stereology.

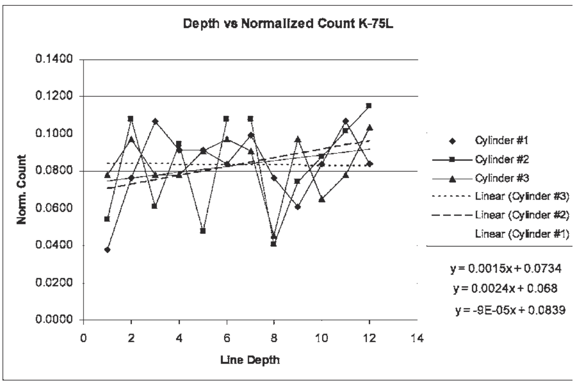

Figure 8: Normalized line counts vs. depth, typical.

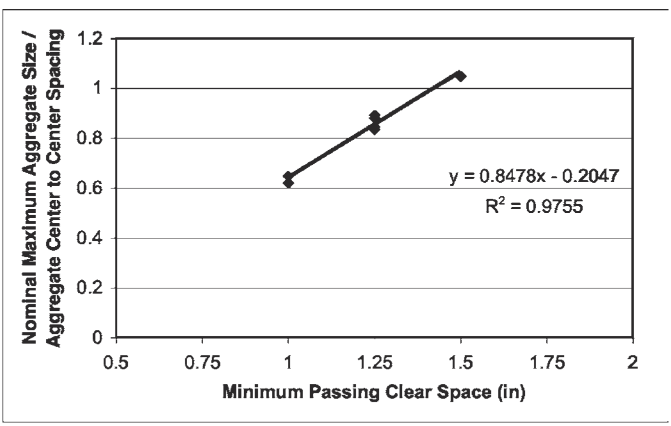

Figure 9: Maximum aggregate size / Aggregate center to center spacing ratio vs. Minimum passing clear space between bars.

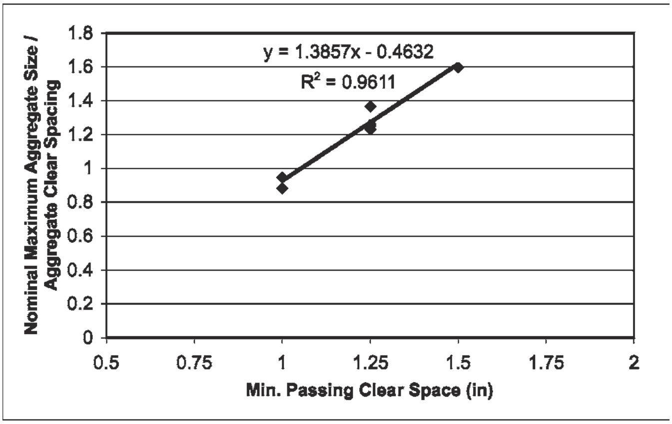

Figure 10: Maxmimum aggregate size / Aggregate clear spacing ratio vs. Minimum passing clear space between bars.

A New, Portable Rheometer for Fresh Self-Consolidating Concrete

by E.P. Koehler, D.W. Fowler, C.F. Ferraris, and S. Amziane

Synopsis: The accurate determination of fresh concrete rheology is key to ensuring the successful production of self-consolidating concrete (SCC). Rheometers, however, are used infrequently in the field. Empirical test methods are most commonly used to determine SCC workability despite measuring quantities that are related to rheological parameters only in an indirect way, if at all. Instead of using multiple empirical test methods to measure the workability of SCC, it is desirable to use a rheometer in both the laboratory and field to determine the flow properties of SCC quickly. Existing rheometers are generally unsuitable for routine field use due to their large size, high cost, or both. This paper describes the use of the International Center for Aggregates Research (ICAR) rheometer, a low-cost, fully portable device that can measure concrete mixtures ranging in workability from approximately 50 mm in slump to SCC. Laboratory test results of SCC mixtures and field testing experience are presented to demonstrate the validity and practicality of the ICAR rheometer.

Keywords: field testing; mixture proportioning; rheology; self-consolidating concrete (SCC); slump flow; stability; workability

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INTRODUCTION

Since the introduction of self-consolidating concrete (SCC) in the 1980s, a profusion of test methods has been proposed for measuring SCC workability (1, 2). Most of these new tests are empirical; that is, they generally are used to simulate a field condition and to measure a quantity related to an aspect of workability, such as the ability of concrete to fill formwork, pass through reinforcing bars, or resist segregation. In contrast, rheology—or the scientific study of the flow and deformation of matter—has been applied on a limited basis to concrete in order to measure fundamental flow parameters. Although the application of rheology has proven promising, important challenges must be addressed to apply rheology to concrete on a wider basis in the field. This paper describes a new, low-cost, portable rheometer for fresh concrete, presents rheometer test results for SCC mixtures, and discusses how the rheometer can be used on a routine basis in the field.

RESEARCH SIGNIFICANCE

The characterization and control of fresh concrete properties are often more critical for SCC than for conventional concrete. The flow properties of SCC can be strongly influenced by construction conditions and changes in material properties and mixture proportions. Rheology represents a direct, scientific approach to monitoring and controlling SCC properties. The use of a low-cost, portable rheometer to develop mixture proportions and to monitor and control SCC in the field can improve SCC quality control and enhance the efficiency of SCC production.