DRAFT - SUBJECT TO REVISION.

VARIABLES AFFECTING COHESION TEST ACCURACY AND REPRODUCTIBILITY-NOTES

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INTRODUCTION

Since the introduction in 1983 of the manual modified cohesion tester for classifying slurry systems by their rate of cohesive strength development, more than 170 of these instruments have come into use worldwide. Occasionally we hear complaints of erratic results or lower than expected results even when the "wrist calibrations" are in agreement with the sand and paper calibrations. A few clients have even purchased new torquemeters or have returned them to the manufacturer for recalibration only to discover that sample preparation was the primary cause of the variations experienced, not the equipment.

In an effort to overcome variations perceived as due to the human factor in the manual test, 4 U.S. and 3 overseas researchers have used the motorized cohesion tester only to discover, again, that sample preparation was the most critical cause of variation.

1.) An example of variation in sample preparation from our 1990 records (mix formula-water content) follows:

FORMULA (01129-2)			COHESION, kg/cm		
FLR	H_2O	AE	30′	60′	
.5pc	10	12	10.2	16.2	slow set
.5pc	8	12	14.0	16.8	quick set
.5pc	6	12	19.2	21.8	quick set
.5pc	4	12	21.5	22.4	quick traffic

Figure 1.

In this system, it is clear that as little as 1 or 2% change in mix water content can cause very different results. This plot of single point tests shows a change from a slow set, slow traffic system to a quick-set, quick-traffic system simply by getting the water content correct. This system is also an example of one type of "water sensitive" system.

One frequently questions if his results are correct when "twisting" only one sample. We have felt in the past that the test gave a true torque value within a tolerance of ± 1.0 kg-cm.

PURPOSE

The purpose of this report then is to examine a few of the causes of variations of cohesion test results and to roughly establish accuracy and confidence levels of test results.

METHOD

A single emulsion (10104-1) and a single aggregate (Latham #298, Dolomite 0/#4) at constant filler and emulsion contents of .5% pc (Portland Cement) and 12% AE was used. 100-gram cup mixes were made, cast and finished at 30 to 45 seconds into 3, 6mm specimens. The cohesion test was performed on all three specimens at 60 minutes. Examples 1 through 12 are for "wet" cohesions. Cured cohesions are only summarized.

2) EFFECT OF WATER CONTENT

FORMULA	Cohesion @ 60′ (1)	(2)	(3)	Average	Spread	Tolerance ±	Standard Deviation
.5pc-3-12	13.2	14.3	12.9	13.5	1.40	.70	0.60
.5pc-6-12	17.8	17.2	18.9	18.0	1.70	.85	0.70
.5pc-8-12	15.2	15.1	15.9	15.4	.80	.40	0.36

3) TWO CONSECUTIVE MIXES

FORMULA	(1)	(2)	(3)	Average	Spread	Tolerance	Standard Deviation
.5pc-6-12	17.8	17.2	18.9	18.0	1.70	±.85	0.70
.5pc-6-12	17.2	17.1	17.9	17.4	0.80	±.40	0.36

4) EFFECT OF MIXING TIME

FORMULA	(1)	(2)	(3)	Average	Spread	Tolerance	Standard Deviation
.5pc-6-12 30"mix	17.2	17.1	17.9	17.4	0.80	±.40	0.36
.5pc-6-12 180"mix	14.2	13.3	13.1	13.5	1.10	±.55	0.59

5) EFFECT OF VARIABLE UNEVEN SURFACE FLATNESS (4-5mm)

FORMULA	(1)	(2)	(3)	Average	Spread	Tolerance	Standard Deviation
.5pc-6-12	13.3	12.5	12.7	12.8	0.60	±0.3	0.34

6) EFFECT OF MOLD THICKNESS (10mm)

FORMULA					Average	Spread	Tolerance	Standard Deviation
.5pc-6-12	16.1	16.2	16.8	15.3	16.1	1.50	±0.75	.053

7) EFFECT OF COARSE AGG. 0/8mm in 6mm Mold

FORMULA	(1)	(2)	(3)	Average	Spread	Tolerance	Standard Deviation
.5pc-6-12	18.2	17.3	16.3	17.3	1.90	±0.95	0.78

8) EFFECT OF FINES CONTENT (Fines Segregation)

FORMULA	(1)	(2)	(3)	Average	Spread	Tolerance	Standard Deviation
.5pc-6-12 (5% 0/#200)	18.9	18.2	18.3	18.5	0.70	±.35	0.31
.5pc-10-12 (5% 0/#200)	*7.5	15.2	16.0	16.2	2.30	±1.15	0.95
.5pc-6-12 (15% 0/#200)	16.7	17.0	17.3	17.0	0.60	±0.3	0.24
.5pc-10-12	15.5	16.1	16.7	16.1	1.20	±.6	.049

9) EFFECT OF PACKING INTO MOLD

FORMULA	(1)	(2)	(3)	Average	Spread	Tolerance	Standard Deviation
.5pc-4-12(loose)	19.1	18.9	21.8	19.9	2.90	±1.5	1.32
.5pc-4-12(packed)	13.2	12.5	12.8	12.8	0.70	±0.35	0.29

10) EFFECT OF AGGREGATE MOISTURE CONTENT (Same Total Water)

Additional Cement

FORMULA	(1)	(2)	(3)	Average	Spread	Tolerance	Standard Deviation
.75pc-3-12	20.8	19.7	18.8				
4% Agg. H_2O	19.2Ns	19.3S	20.2	19.7	1.60	±0.8	0.67
.75pc-7-12	22.3	22.0	19.9				
0% Agg. H_2O	21.3	21.3	21.2	21.3	2.40	±1.2	0.76

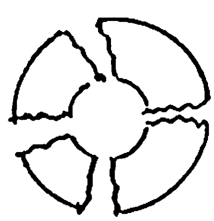
Figure 11.

11. EFFECT OF AGGREGATE SOURCE WITH SAME EMULSION (01212-1)

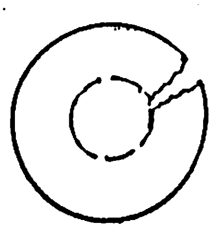
% Chemical Filler	Slag 30′	Slag 60′	Granite 30′	Granite 60′	Dolomite 30′	Dolomite 60′
			Cohesion kg-cm			
0	7.0	7.0	BUST	-	-	-
.25	6.0	5.8	BUST	-	15.2	18.1
.50	5.9	6.9	13.3	17.2	17.0	23.0
.75	6.8	6.9	13.1	14.5	17.4	23.0
1.00	-	-	11.8	13.2	16.5	20.0
1.50	7.0	15.0	10.2	11.9	17.2	20.1
	Filler Accelerates		Filler Retards		Typical QS-QT	

Figure 12.

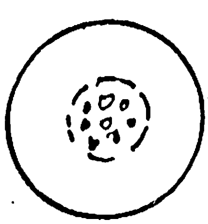
12. MODE OF RUPTURE. On occasion, the unconfined cohesion test specimen may break apart or rupture in an abnormal manner or remain solid or barely touched by the tester foot ("hydroplaning"). It is useful to note the mode of rupture on the record and to sometimes assign a cohesion value for graphing purposes as follows:



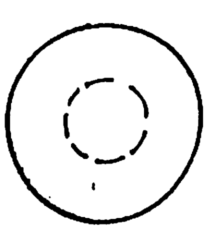
"N" = Normal. Multiple radial cracks are noted. Below 12 kg-cm there is no cracking but more of a "splash".



"NS" = Near Spin. Only one radial crack appears. (Equivalent cohesion value is ca. 20 kg-cm).



"S" = Spin. No cracks appear but aggregate is dislodged directly beneath the foot and "rolls" under the foot. (Equivalent cohesion value is ca. 23 kg-cm).



"SS" = Solid Spin. No cracks appear. No aggregate is dislodged, no tearing. The foot skids or slides over the surface. Some bitumen film may be removed. (Equivalent cohesion value is ca. 26 kg-cm).

CONCLUSIONS

SUMMARY OF WET COHESION RESULTS

With a single technician preparing and testing 18 sets of samples, results ranged from 12.8 to 21.8 kg-cm depending upon the particular variable investigated. Within sets we calculate a 95% confidence level at ±1.2 kg-cm and a 83% confidence level of ±1.0 kg-cm with a single, inexperienced technician performing both specimen preparation and testing. The overall average spread was 1.372 with an average tolerance of ±.68.

A SUMMARY OF 60° CURED COHESION RESULTS

24 sets of 3 60C cured cohesion tests were randomly selected from our 1990 log. These were performed by an inexperienced technician. The average spread of results was 2.754 kg-cm or a tolerance of ±1.38. The best 2 of 3 tests in the set average spread was .875 or a tolerance of ± .44 at a 95% confidence level.

15 additional sets done by an experienced technician gave a 2.480 spread of ± 1.24 tolerance for the complete sets. The best 2 of 3 in the set yielded an average spread of .860 or a tolerance level of ± .43.

We note that while experience helped somewhat, there was no really significant difference between experienced and inexperienced technicians.

We also note considerably greater margin of error in the 60C cured cohesion test which we believe is due mostly to sample preparation.

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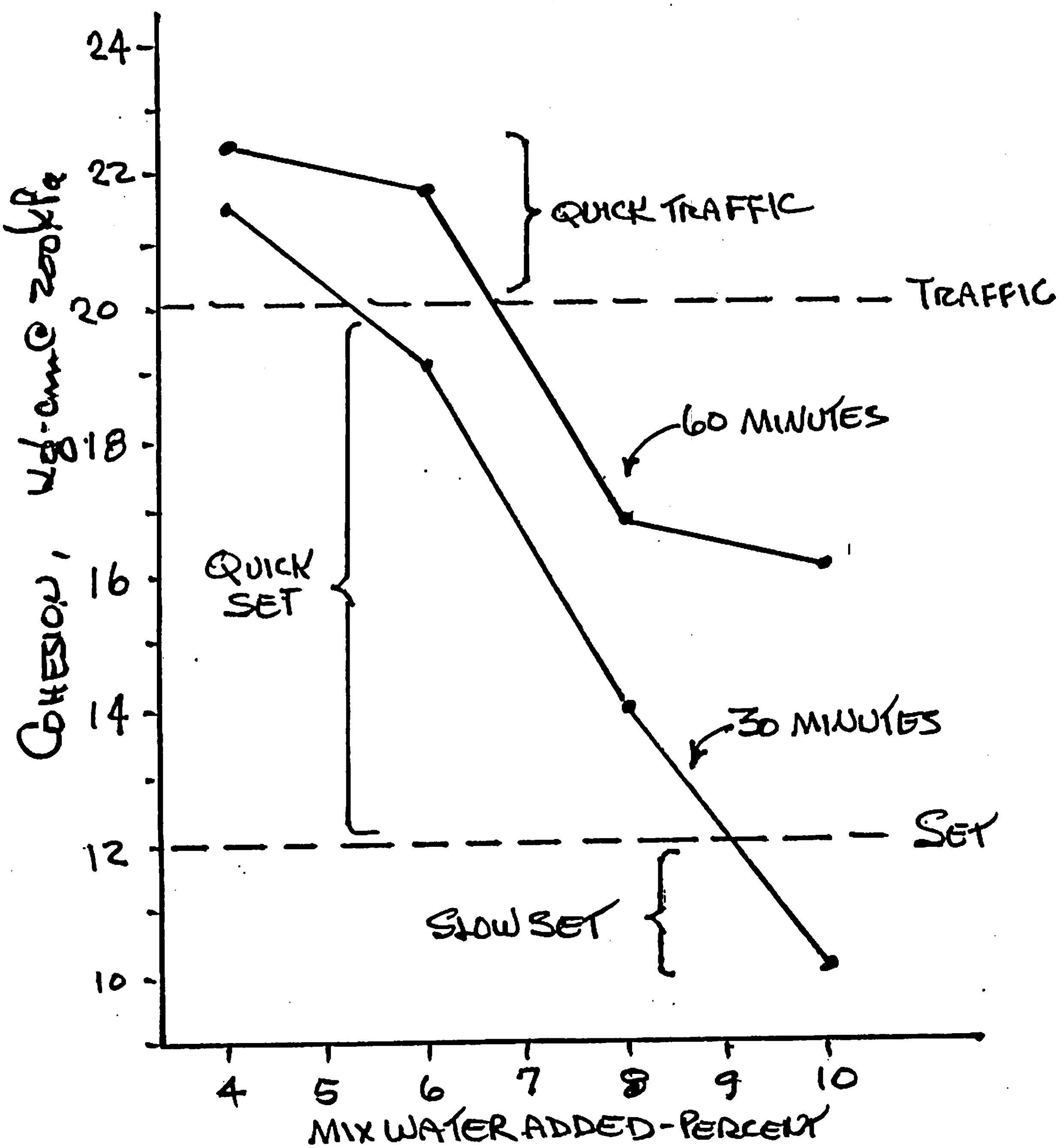

FIGURE 1. EFFECT OF MIX WATER ADDED ON 30 & 60' WET COHESION – A WATER SENSITIVE SYSTEM (AE#01129-2)

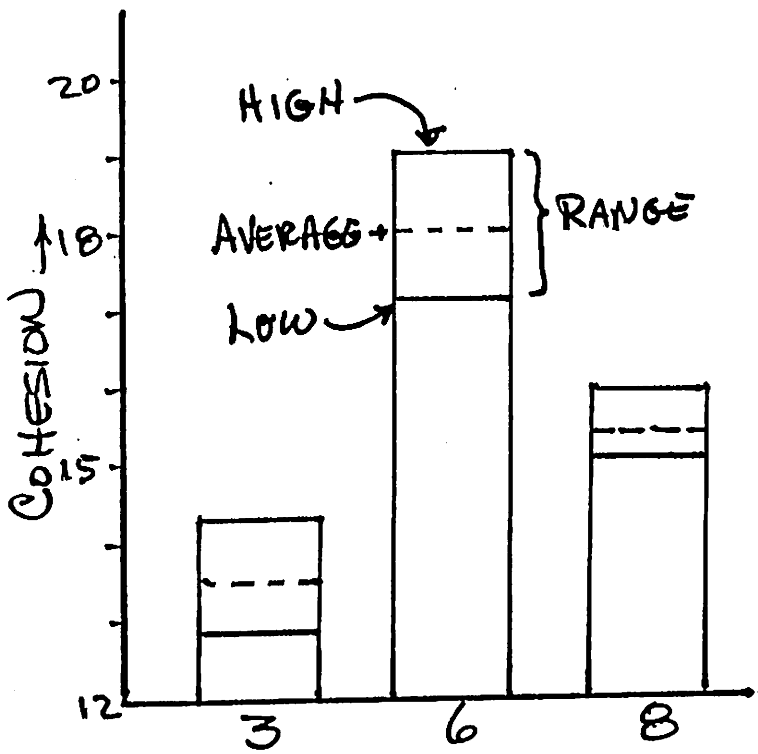

FIG 2. PERCENT MIX WATER

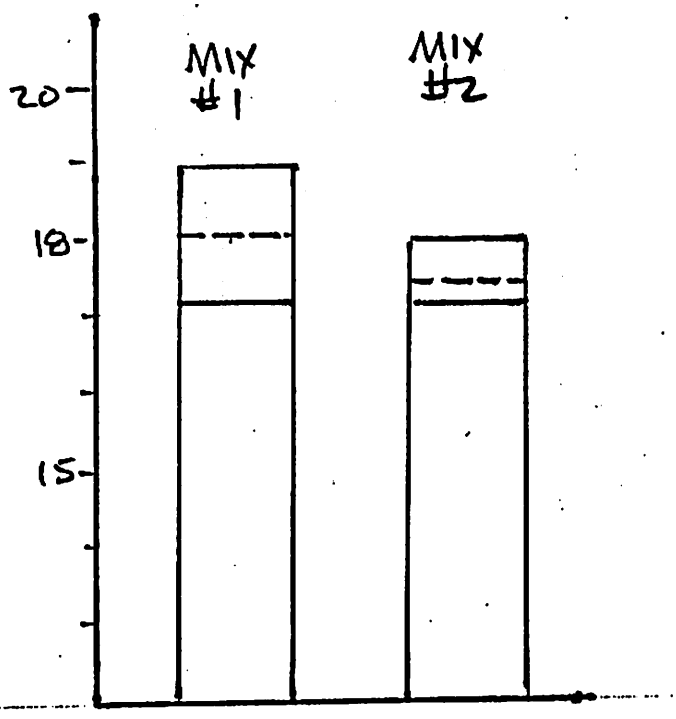

FIG 3. 2 CONSECUTIVE MIXES

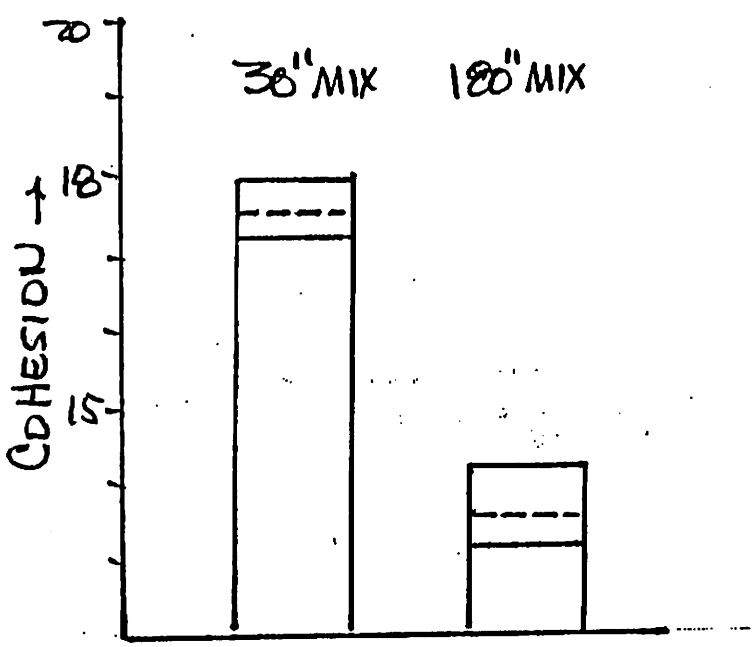

FIG 4. EFFECT OF MIXING TIME

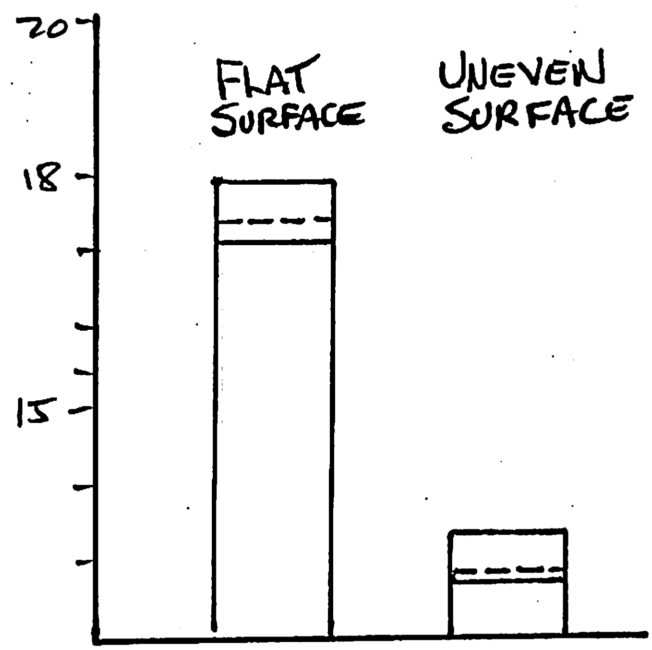

FIG 5. EFFECT OF IRREGULAR SURFACE

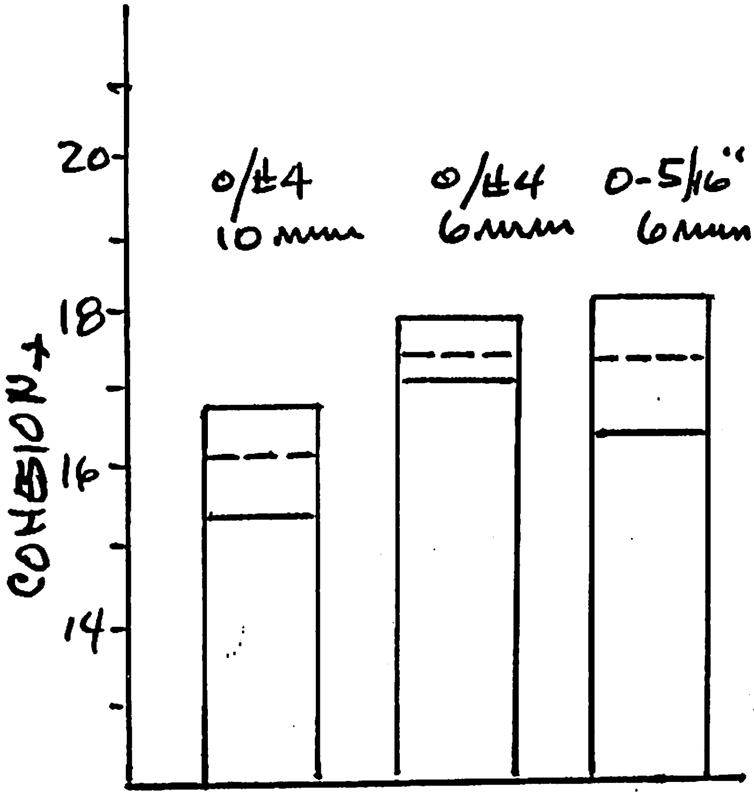

FIG 6-7 EFFECT OF MOLD THICKNESS & GRADATION

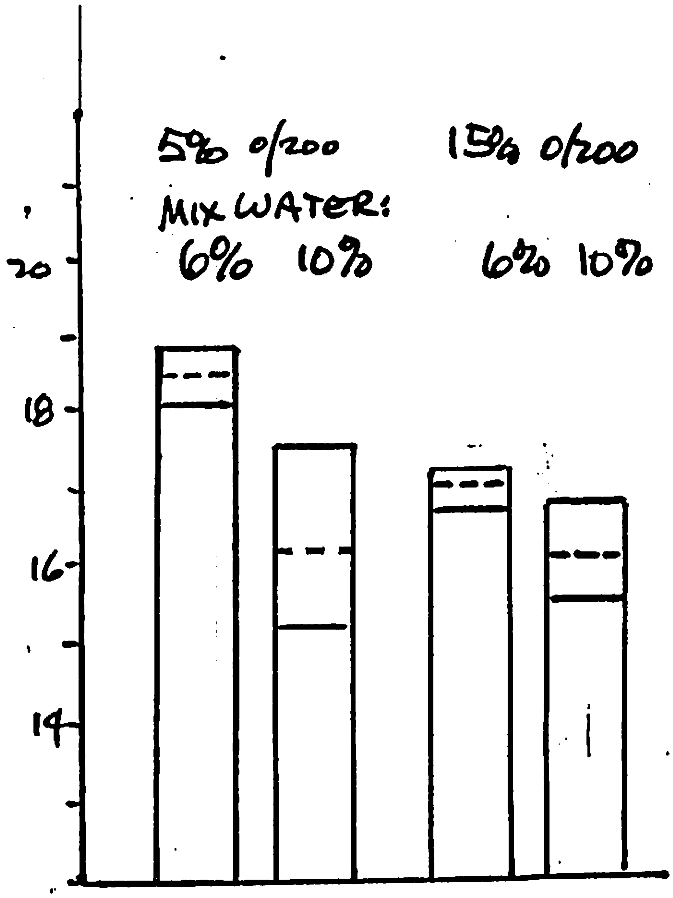

FIG.8 EFFECT OF FINES %

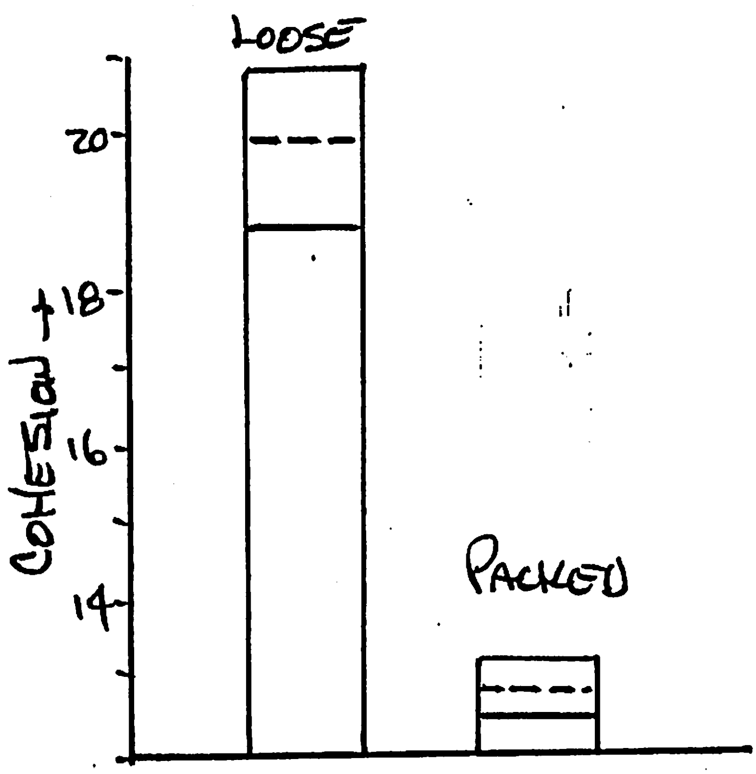

FIG 9. EFFECT OF PACKING INTO MOLD

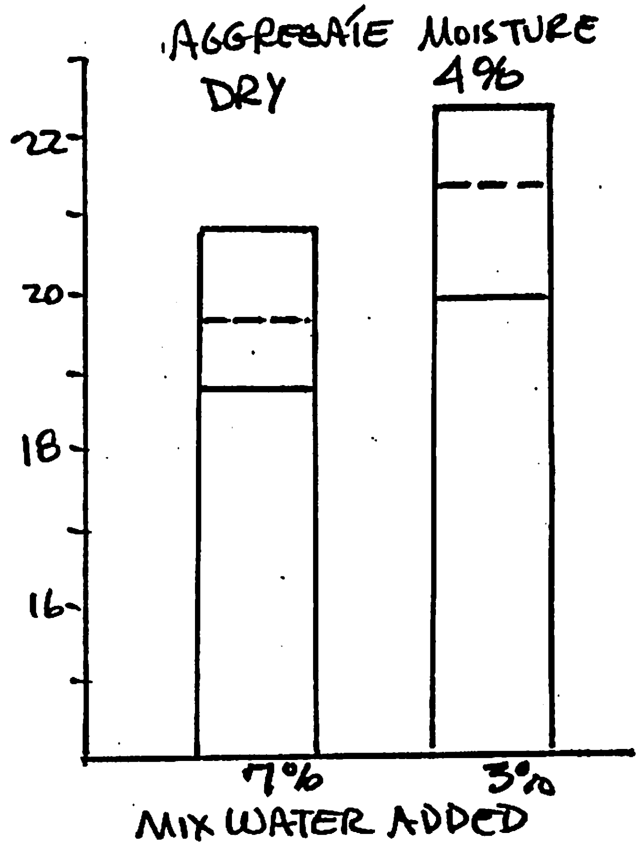

FIG.10 EFFECT OF AGGREGATE MOISTURE CONTENT

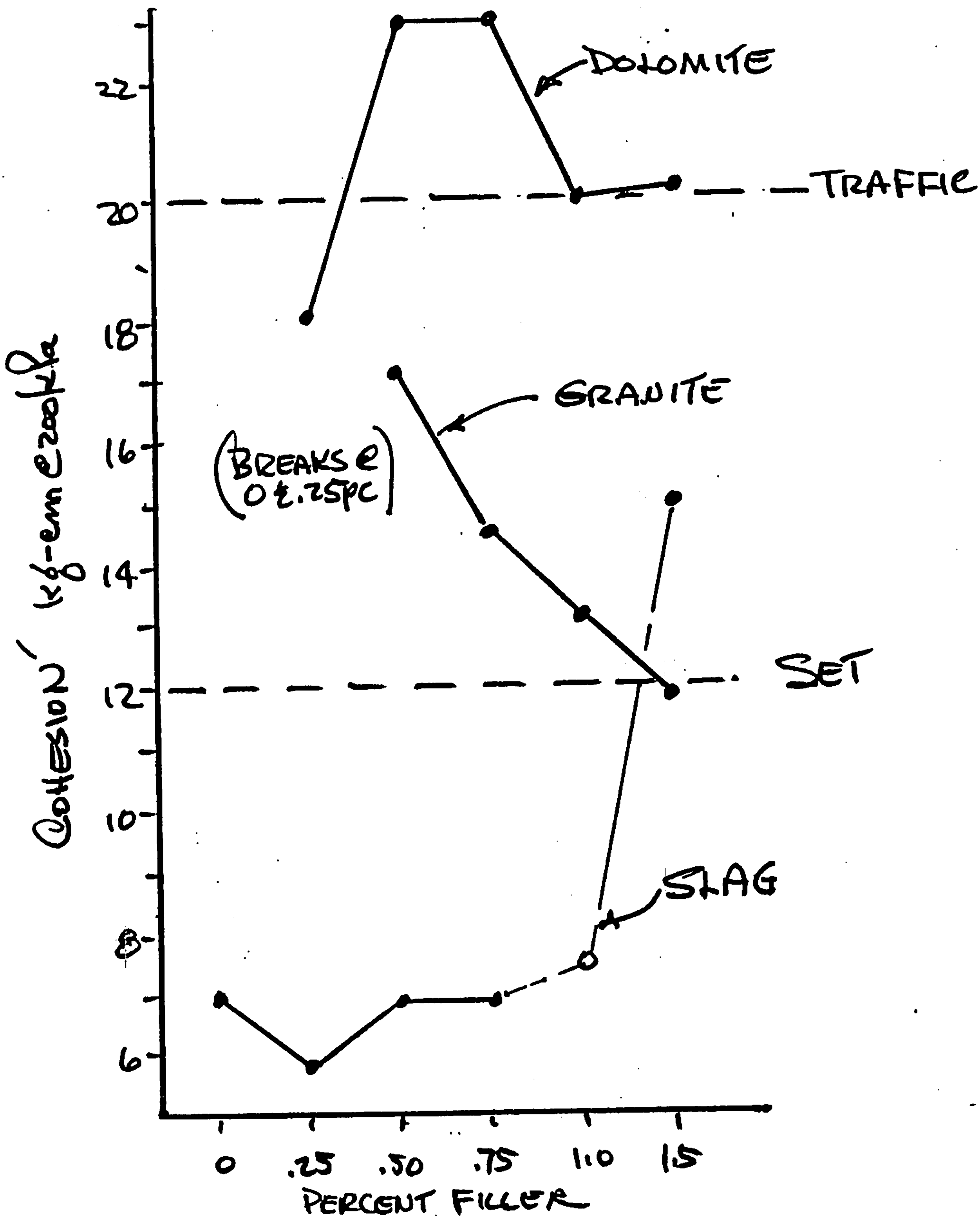

FIG. 11. 3 AGGREGATE TYPES
SAME EMULSION (01212-1)
60' WET COHESION