RESIDUAL MOISTURE IN HOT MIX ASPHALT CONCRETE

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Residual moisture in hot mix asphalt concrete is thought to adversely affect pavement performance. Speculation is that residual moisture prevents full development of asphalt aggregate bonds thereby reducing mix and, thus, pavement strength.

The significance of the problem created by residual moisture is debatable. Table 1 is a listing of residual moisture criteria from 33 state specifications. Fifteen have quantitative criteria but 14 have no criteria.

The level at which residual moisture begins to be detrimental to pavement performance is also debatable. In Table 1 the quantifiable criteria for maximum allowable moisture content ranges from 0.5 to 2%. Table 2 lists a chronology of the evolution of ALDOT criteria and also illustrates uncertainty as to a definite upper limit for residual moisture.

The information in Tables 1 and 2 indicate some perceived differences between batch and drum plants. Six states (New York, New Mexico, Montana, North Carolina, North Dakota and Wyoming) have different criteria for batch and drum plants. ALDOT also had differences in 1976 and 1981 specifications. There is no apparent reason, based on the effects of residual moisture on pavement performance, why criteria should be different for batch and drum plants.

Residual moisture problems in Alabama appear to be restricted to mixes containing porous (absorption > 2%) gravels. These gravels, referred to as cherty gravels, can have absorptions up to about 5%. The pores in the cherty materials are very fine making complete water removal virtually impossible in the short drum retention times required for "normal" production rates. Figures 1 and 2 (Ref. 1) show that surface moisture is quickly removed. However, Figure 3 (Ref.1) shows that internal moisture continues to vaporize and escape after coating with asphalt cement. The numbers in parentheses in Figure 3 are average dry and wet stockpile aggregate moisture contents (see Figures 1 and 2).

Speculation is that escaping steam disrupts and prevents proper coating and weakens asphalt-aggregate bond. The weakened bonds are susceptible to the detrimental influence of water and thus stripping. This theory is somewhat substantiated by laboratory retained tensile strength testing of mix that is known susceptible to stripping. Table 3 is a compilation of retained tensile strength data from earlier studies (Refs. 2 and 3) and shows that, when aggregate is well dried (no residual mix moisture) for preparation of laboratory samples, retained tensile strength ratios are higher than expected for mix with high stripping potential. In addition, TSR results from samples prepared from laboratory mix with controlled residual moisture and field mix, reference 3, suggest a decrease in TSR as residual moisture content increases. Figures 4 and 5 show, respectively, relationships for laboratory and combined laboratory/field mix for three chert and one quartz gravel mixes. The relationships for the four gravel sources, individually and combined as shown in Figures 4 and 5, were consistent though statistically weak.

To minimize the stripping problem with chert gravel mixes, ALDOT proposed lowering maximum allowable mix moisture from 0.5 to 0.2%. The rationale for this change was that it would have no influence on the production of mixes with other types of aggregates (except possibly blast furnace slag), but would require special procedures for drying chert gravel. There was resistance to this change because this would mean that ALDOT requirements would then be much more stringent than other states, see Table 1.

To determine if 0.2% mix moisture was reasonable and could be routinely achieved, a number of mix moisture content measurements were made during fall of 1995 and the spring and summer of 1996. These measurements are compiled in Table 4 along with measurements from references 1 and 3. These measurements indicate that residual moisture contents less than 0.2% are achievable, except for mixes containing chert gravel coarse aggregate, with normal production procedures. This seems to be true for both batch and drum plants irrespective of stockpile moisture contents. Today's plants, operated at reasonable production rates, appear capable of removing surface moisture but apparently drum retention times are not sufficient for removing internal moisture.

REFERENCES

1. Powell, R.L. and L. Lockett, "A Study of Moisture Absorption Characteristics of Chert River Gravel Aggregate in Hot Mix Asphalt," Alabama Department of Transportation, Bureau of Research and Development, December, 1994.

2. Parker, F., "Stripping of Asphalt Concrete - Physical Testing," Final Report, Alabama Department of Transportation, Research Project 930-111, January, 1987.

3. Parker, F., "A Field Study of Stripping Potential of Asphalt Concrete Mixtures," Final Report, Alabama Department of Transportation, Research Project ST 2019-6, August, 1989.

Table 1 Limited State HMA Moisture Content Specification

STATE	YEAR	SPECIFICATIONS
Alabama	1995	0.5% Moisture Content Limit at Mixer
Alaska	1988	No Maximum Limit Defined for Moisture Content
Arkansas	1993	0.75% Moisture Content Limit at Paver
Arizona	1990	1% Moisture Content Limit at Paver
California	1992	1% Moisture Content Limit at Paver
Connecticut	1988	1% Moisture Content Limit at Truck
Florida	1991	No Maximum Limit Defined for Moisture Content
Georgia	1993	Limit of maximum allowable absorbed moisture defined by the point that objectionable segregation of asphalt from aggregate occurs.
Illinois	1988	No Maximum Limit Defined for Moisture Content
Indiana	1988	No Maximum Limit Defined for Moisture Content
Iowa	1992	No Maximum Limit Defined for Moisture Content
Kentucky	1991	Dryer shall be capable of drying and heating aggregate to the moisture content and temperature requirements set forth in the specifications.
Michigan	1990	Moisture in aggregates shall not cause foaming or a soggy mix. Mix shall not contain moisture detrimental to the mix.
Minnesota	1988	No Maximum Limit Defined for Moisture Content
Mississippi	1991	0.5% for surface mixes, 0.75% for base, leveling, & binder mixes
Missouri	1993	0.5% Moisture Content Limit at Mixer
Montana	1987	Aggregate must be thoroughly surface-dry. Allowable moisture content may be lowered if mixture contains evidence of excessive moisture (for batch plants)
New Jersey	1989	No Maximum Limit Defined for Moisture Content
New Mexico	1984	0.5% Moisture Content Limit for Drum Plants, Non Batch Plants
New York	1990	0.5% moisture content in aggregate at time of mixing in batch plant; 0.5% moisture content of mix upon discharge into the haul unit.
No. Carolina	1990	90 T/hr @ 300°F with removal of 5% moisture (drum plants)
North Dakota	1992	1.0% Moisture Content Limit for Drum Plants, 0.5% for Batch Plants
Ohio	1991	No Maximum Limit Defined for Moisture Content
Oklahoma	1988	0.75% Moisture Content Limit at Mixer
Pennsylvania	1988	No Maximum Limit Defined for Moisture Content
So. Carolina	1986	No Maximum Limit Defined for Moisture Content
South Dakota	1990	No Maximum Limit Defined for Moisture Content
Tennessee	1981	No Maximum Limit Defined for Moisture Content
Texas	1993	1.0% Moisture Content Limit at Mixer
Vermont	1990	No Maximum Limit Defined for Moisture Content
Washington	1991	2% Moisture Content Limit at Mixer
Wisconsin	1989	No Maximum Limit Defined for Moisture Content
Wyoming	1987	0.5% Moisture Content Limit at Drum

Table 2 Chronology of ALDOT HMA Moisture Content Criteria Development

SPECIFICATION YEAR	BATCH PLANTS % IN AGGREGATES	DRUM PLANTS % IN MIX
1933	None	None
1964	0.5	None
1975	0.5	None
1976	0.5	3% at Mix Discharge 1.25% at Spreader
1981	0.5	3% at Mix Discharge 1.25% at Spreader
1985	0.5	0.5% at mix Discharge
1989	0.5	0.5% at mix Discharge
1992	0.5	0.5% at mix Discharge
1995	0.5	0.5% at mix Discharge

TABLE 3 Retained Tensile Strength Ratios For HMA with Chert Gravel

MIX DESIGNATION	TSR, %
1 - Surface	80
1 - Base/Binder	59
2 - Surface	107
2 - Base/Binder	83
3 - Base/Binder	70
4 - Surface	56
5 - Surface	63
6 - Surface	88
7 - Surface	82
8 - Surface	67

Tested according to AASHTO T 283

Table 4 HMA Residual Moisture Content Measurements

COARSE AGG. TYPE	MIX TYPE	STOCKPILE CONDITIONS	PLANT TYPE	SAMPLING LOCATION	MOISTURE CONTENT
Chert Gravel	Binder	Wet	Batch	Truck	0.46% (3)
	Binder	Wet	Batch	Truck	0.38% (3)
	Binder	Wet	Batch	Truck	0.42% (2)
	Surface	Dry	Batch	Truck	0.20% (1)
	Base	Wet	Batch	Truck	0.39% (1)
	Surface	Wet	Batch	Truck	0.28% (2)
	Binder	Dry	Drum	Drum	0.67% (2)
	Binder	Dry	Drum	Truck	0.32% (2)
	Binder	Dry	Drum	Paver	0.27% (2)
	Binder	Wet	Drum	Drum	0.80% (2)
	Binder	Wet	Drum	Truck	0.35% (2)
	Binder	Wet	Drum	Paver	0.24% (2)
	Surface	Dry	Drum	Drum	0.28% (1)
	Surface	Dry	Drum	Truck	0.14% (1)
	Surface	Dry	Drum	Paver	0.08% (1)
	Surface	Wet	Drum	Drum	0.45% (1)
	Surface	Wet	Drum	Truck	0.38% (1)
	Surface	Wet	Drum	Paver	0.29% (1)
	Binder	Dry	Drum	Drum	0.34% (2)
	Binder	Dry	Drum	Truck	0.18% (2)
	Binder	Dry	Drum	Paver	0.22% (2)
	Binder	Wet	Drum	Drum	0.59% (1)
	Binder	Wet	Drum	Truck	0.27% (2)
	Binder	Wet	Drum	Paver	0.23% (2)
	Surface	Dry	Drum	Drum	0.23% (1)
	Surface	Dry	Drum	Truck	0.16% (1)
	Surface	Dry	Drum	Paver	0.13% (1)
	Surface	Wet	Drum	Drum	0.23% (1)
	Surface	Wet	Drum	Truck	0.21% (1)
	Surface	Wet	Drum	Paver	0.19% (1)
	Binder	Dry	Drum	*Truck	0.11% (3)
Quartz Gravel	Base	Dry	Batch	Truck	0.04% (2)
	Base	Dry	Drum	Drum	0.05% (2)
	Surface	Dry	Drum	Drum	0.02% (2)
	Surface	Dry	Drum	Drum	0.03% (3)
	Surface	Dry	Drum	Truck	0.04% (3)
Limestone	Binder	Dry	Drum	Drum	0.05% (2)
	Binder	Dry	Batch	Truck	0.08% (1)
	Base	Dry	Drum	Drum	0.04% (4)
	Base	Dry	Batch	Truck	0.04% (4)
	Binder	Wet	Drum	Drum	0.03% (4)
	Base	Wet	Drum	Drum	0.12% (4)
	Base	Dry	Drum	Drum	0.07% (3)
	Base	Dry	Drum	Drum	0.11% (4)
	Surface	Wet	Drum	Drum	0.04% (3)
	Binder	Wet	Drum	Drum	0.04% (3)
	Binder	Wet	Drum	Truck	0.04% (3)
Granite	Surface	Dry	Drum	Drum	0.06% (2)
Q-bop Slag	Surface	Dry	Drum	Drum	**0.11% (2)
	Surface	Dry	Drum	*Truck	**0.10% (4)

*Mix stored in silo for several hours prior to sampling.

**Samples dried in conventional oven. All others dried in microwave oven.

Notes: 1. Groups of measurements with similar shading are the same mixes. The measurements were part of an ALDOT study of moisture contents in chert gravel mixes where stockpile moisture was controlled (Reference 1).

2. Numbers in parentheses indicate the number of tests run.

FIGURE 1 Average Moisture Content for Binder Mix

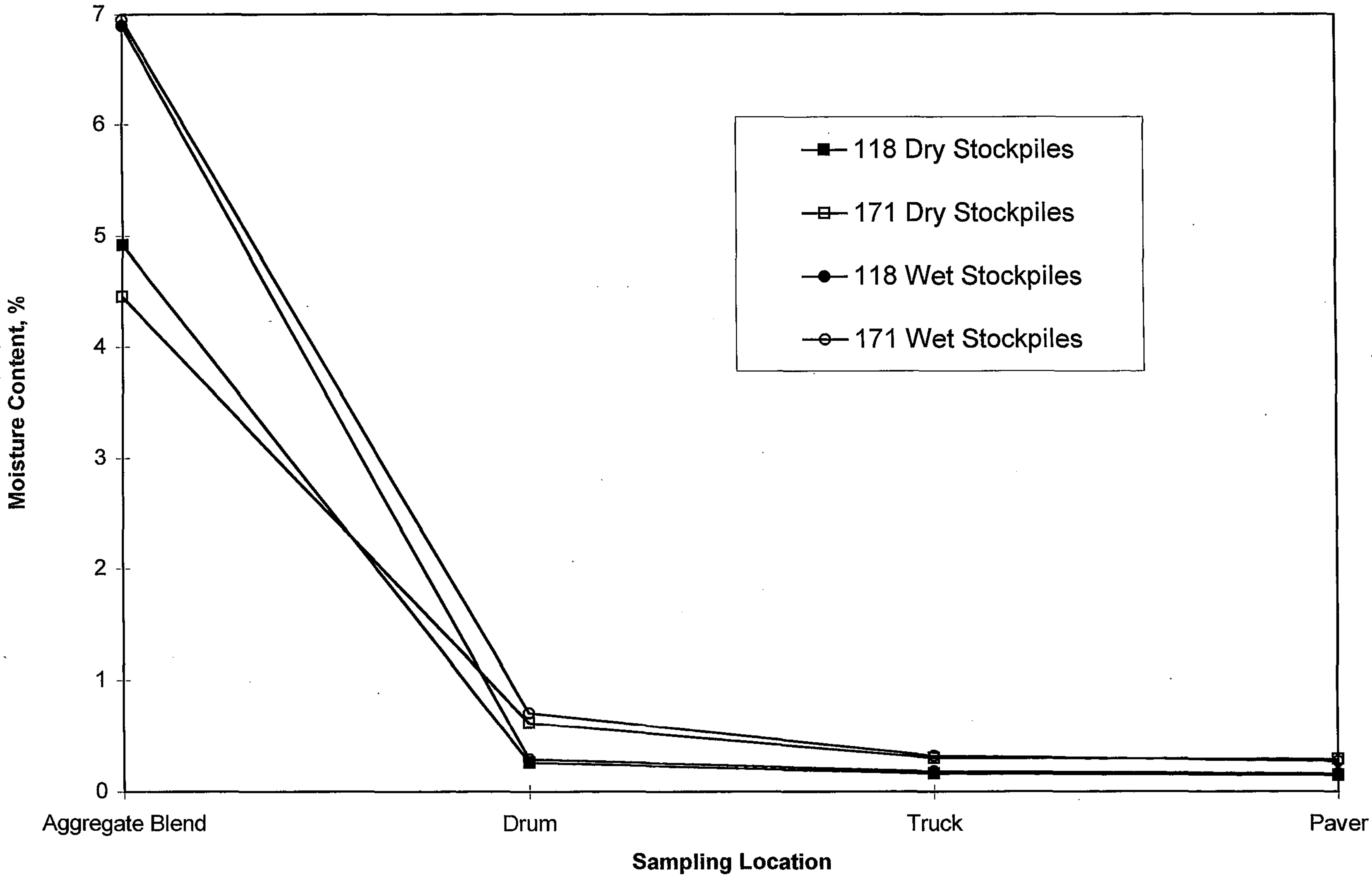

Figure 2 Average Moisture Content for Surface Mix

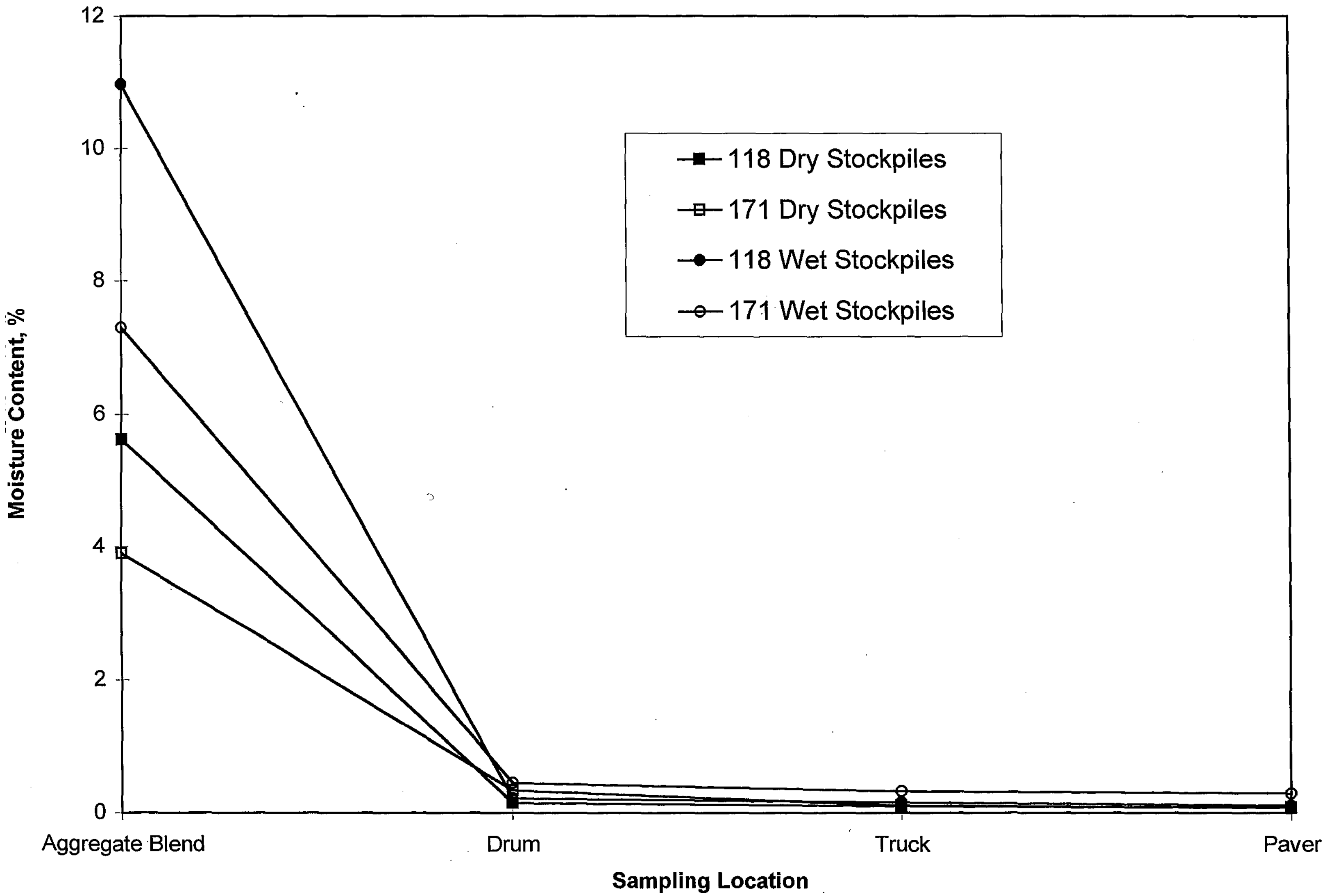

FIGURE 3 Average Mix Moisture Loss

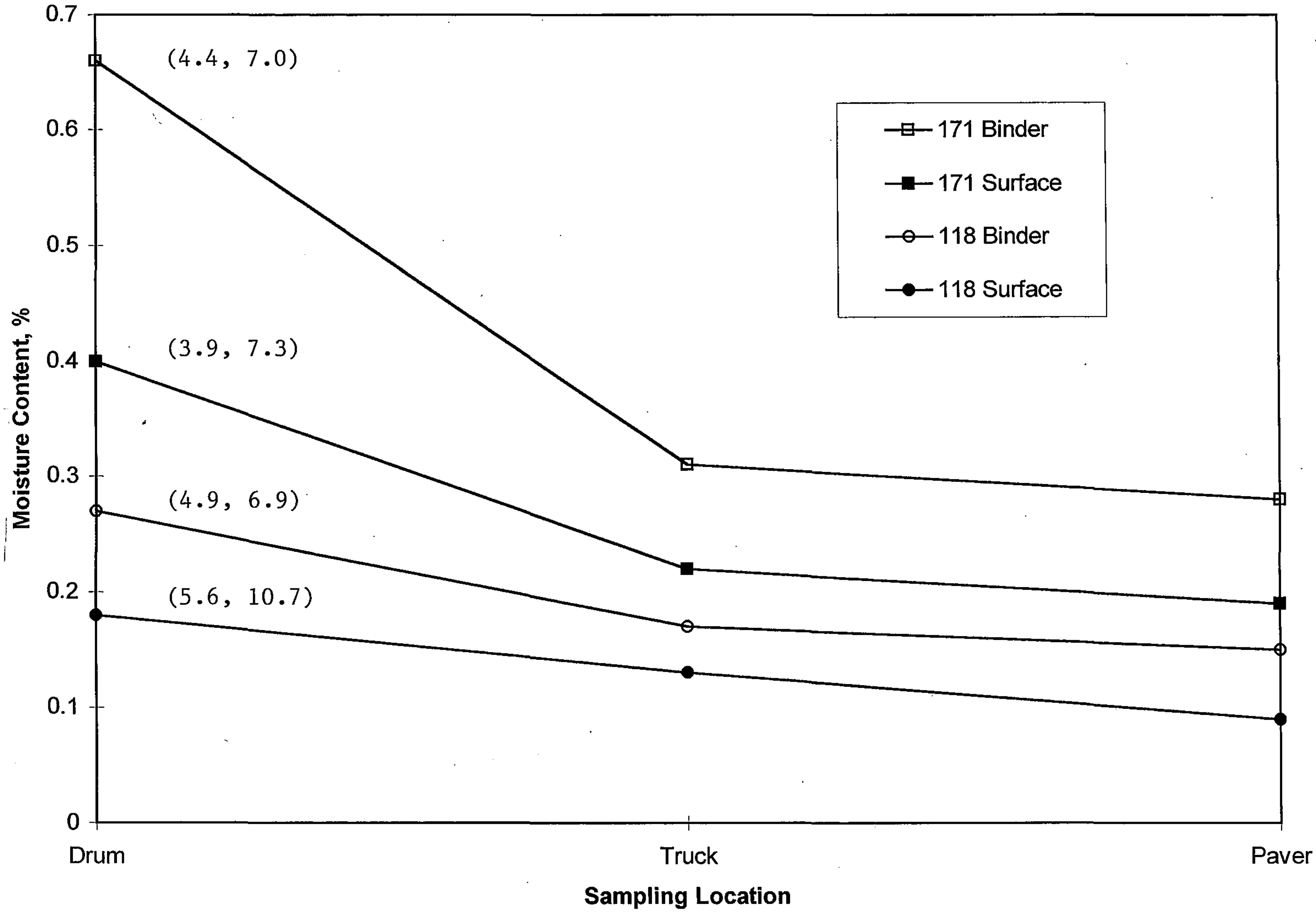

Figure 4 Effects of Residual Moisture on TSR, Laboratory Mix

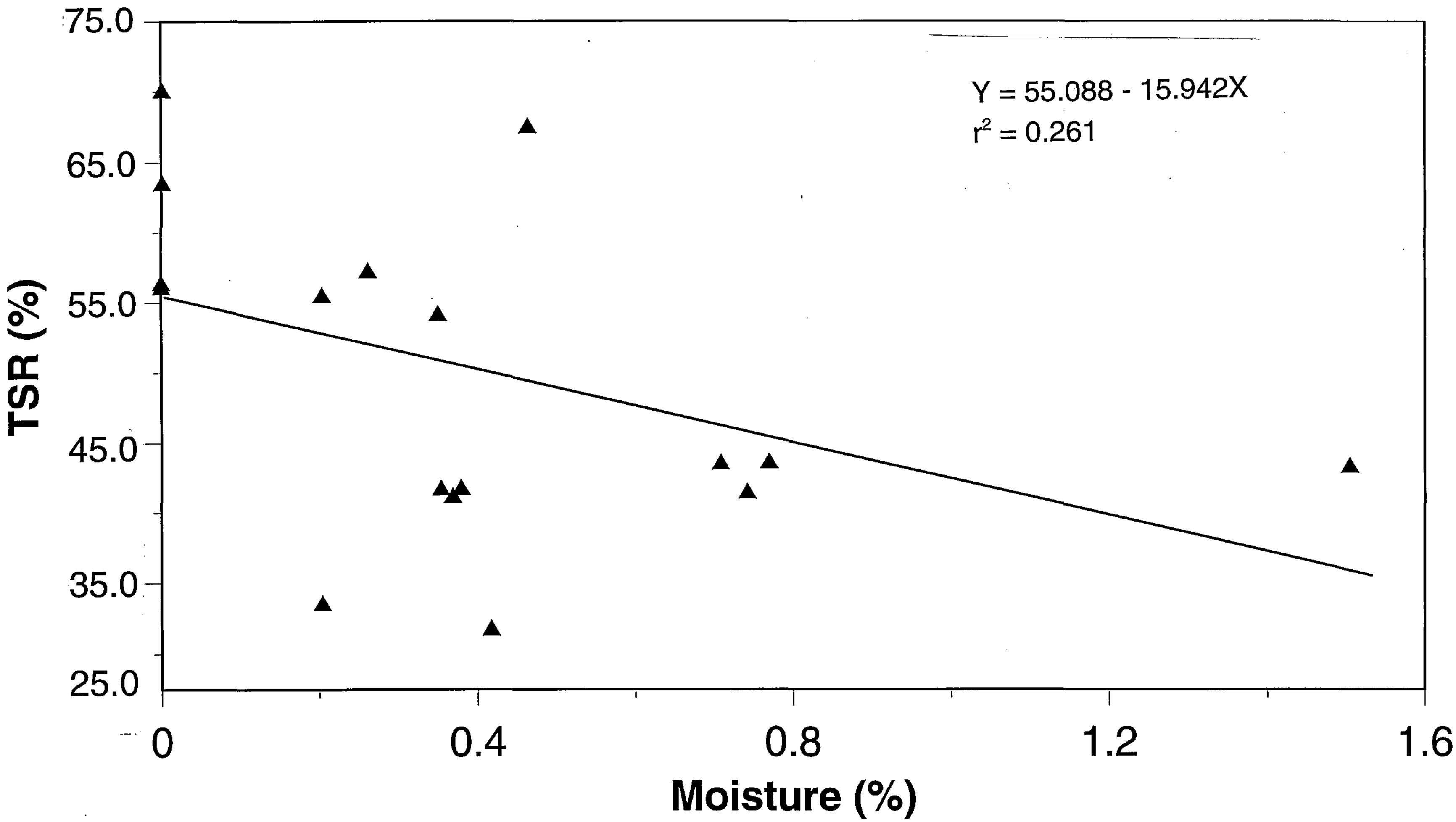

Figure 5 Effects of Residual Mositure on TSR, Laboratory and Field Mix