International Conference on Case Histories in Geotechnical Engineering

(2008) - Sixth International Conference on Case Histories in Geotechnical Engineering

15 Aug 2008, 1:30 pm - 3:00 pm

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Recommended Citation

Shuler, Scott, "Implications of Swelling Clays on Asphalt Pavement Performance in Colorado" (2008). *International Conference on Case Histories in Geotechnical Engineering*. 6.
https://scholarsmine.mst.edu/icchge/6icchge/session11b/6

6th International Conference on
Case Histories in Geotechnical Engineering, Arlington, VA, August 11-16, 2008

IMPLICATIONS OF SWELLING CLAYS ON ASPHALT PAVEMENT PERFORMANCE IN COLORADO

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ABSTRACT

Asphalt pavements constructed directly over high plasticity clays appear to be more susceptible to premature cracking parallel to the gutter on curb and gutter pavement cross sections than pavements with crushed stone bases.

This paper describes five factors common to two sites studied that may be contributors to this early distress. These factors are: cracking is top-down; moisture content of the subgrade soils beneath the cracks is higher than optimum; density of the subgrade soils beneath the cracks is lower than optimum; subgrade soils are highly plastic; full-depth construction; and all pavements had curb and gutter typical sections. In addition, similar pavements constructed on crushed stone bases in the vicinity of the full-depth pavements with the same construction and materials characteristics do not display this cracking. Results of this work warrant study of construction techniques with regard to optimum moisture and density requirements when paving full-depth asphalt over plastic clays.

BACKGROUND

Previous researchers have reported (Litton, 2001) that moisture content of the soil under cracks similar to those reported here may be higher than optimum measured by AASHTO T99. This higher moisture content could be due to various sources including precipitation or man-made sources. However, in one report no rain occurred and therefore, a hypothesis that condensation could be the culprit has been proposed by one investigator (Sounart, 2002). This higher moisture content near the concrete curb and gutter might lead to reduced bearing capacity. This loss of support could lead to settlement of the curb and gutter or result in a bearing capacity failure if loaded by construction equipment such as transit mix trucks or transports hauling drywall or other heavy building supplies. Some have suggested that a crack could initiate in the asphalt near the gutter due to this loading.

Swelling clays could produce vertical forces sufficient to cause pavement cracking (Litton, 2002). However, swelling is not likely when the moisture content of the soil is near optimum or above. So, for this theory to be convincing, these soils would have to contain lower than optimum moisture prior to paving. Often, this occurs when paving on plastic clays. Clays of this type have limited bearing capacity above optimum moisture. Therefore, some contractors allow the surface to dry before attempting paving operations. If the soils come in contact with sufficient moisture after paving, swelling can occur resulting in pavement cracking.

Full-depth asphalt placed over plastic clays could be related to the cracking. One local agency and a developer who build in areas with highly plastic clays have indicated that since crushed stone bases have been used under asphalt pavements in their jurisdiction, top-down, parallel-to-curb cracking has ceased to be a problem (Koch, 2004; Leopoldis, 2004). The reason crushed stone base under asphalt reduces the potential for cracking on plastic clay subgrades is unclear but may be related to increased lateral support and drainage lacking in clay subgrades (Shuler, et al, 2007).

APPROACH

Three paving projects were evaluated in this study in an attempt to explain the cause for premature cracking in full-depth asphalt pavements placed over plastic subgrades. Multiple locations were sampled among the three sites to obtain soil and asphalt test specimens. Soils behind the curb and gutter for all locations were graded flat to match the grade of the pavement. However, cracking was observed at all three sites before this finish grading was completed. Prior to finish grading the rough grades sloped away from the curbs. There was one exception to this where the soil behind the curb and gutter sloped toward the curb.

LABORATORY TESTING

Asphalt Cores

Asphalt cores were taken at each location directly over the cracks to determine if the cracks originated at the top or bottom of the pavement. The proper-ties of these asphalt cores are shown in Table 1.

Table 1. Asphalt Core Sample Properties

Project	Asphalt Grade, PG	Asphalt, %	Grading	Air Voids, %	VMA, %	Dust: Asphalt	Contractor	Refinery
A	64-22	5.1	S-19mm	4.5	14.3	1.27	1	X
B	64-22	5.5	S-19mm	4.2	14.5	1.26	2	Y
C	64-22	5.0	S-19mm	4.7	14.8	1.36	3	X

Subgrade

Subgrade soil samples were taken from four locations at each site. These were at the centerline of the pavements, under the cracks, on the opposite side of the pavement if no crack was present and behind the curb on the side of the pavement with the crack. Figure 5 is a schematic showing these locations.

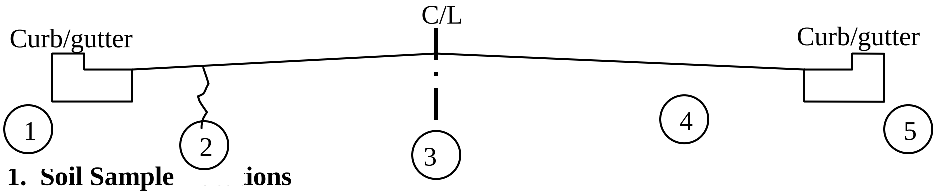

Figure 1. Soil Sample ions

In addition, samples were tested from locations at Sites B and C where no cracking was present in order that a comparison could be made to samples taken from areas with cracking. Laboratory tests conducted on the soil samples included AASHTO T99, insitu moisture content, density, and Atterberg limits.

Results of this testing are shown in Table 2.

Table 2. Soil Test Results

Site	Typical Section	Sample Location	T99 Density, pcf	T99 Moisture, %	Density Insitu, pcf	Moisture Insitu, pcf	% T99 Insitu	Insitu - T99 Moisture, %	P200, %	LL, %	PI
A	9 in full depth (cracked)	1	100	20	103	23	103	3	84	46	29
		2	100	20	105	20	105	0	87	52	35
		3	100	20	119	14	119	-6	80	48	35
		5	101	19		24			82	47	31
						avg >>	109	-1			
						s >>	9	5			
B	6 in full depth (not cracked)	1	110	16	114	17	104	1	80	42	29
		2	110	16	114	17	104	1	81	44	28
		3	107	19					85	45	28
		4	107	19	111	18	104	-1	87	47	27
		5	107	19	116	16	108	-3	90	45	32
						avg >>	105	-1			
						s >>	2	2			
	6 in full depth (cracked)	3	107	19	114	16	107	-3	89	49	32
		4	107	19	103	24	96	5	92	45	39
		5	107	19	112	17	105	-2	95	50	29
						avg >>	102	0			
						s >>	5	4			
	6 in full-depth (cracked)	1	110	16	116	16	105	0	83	41	28
		2	110	16	120	14	109	-2	86	40	28
		3	110	16	109	21	99	5	86	38	30
		4	110	16	120	16	109	0	88	44	28
		5	110	16	121	15	110	-1	67	36	26
						avg >>	107	0			
						s >>	5	3			
C	5.5 in full-depth (cracked)	1	95	24	91	30	96	6			
		2	92	27	90	28	98	1	90	48	34
		3	92	27	100	22	109	-5			
						avg >>	101	1			
						s >>	7	6			
	3.5 in HMA/7.5 in ABC (no cracks)	1	95	24	94	25	99	1	91	47	33
		2	95	25	108	18	114	-7	88	43	30
		3	95	26	106	21	112	-5	86	41	29
						avg >>	108	-4			
						s >>	8	4			
	5.5 in full-depth (cracked)	1	96	25	89	28	93	3	82	40	30
		2	96	24	95	27	99	3	87	43	32
		3	97	23	97	25	100	2	89	43	31
						avg >>	97	3			
						s >>	4	1			
	5.5 in full-depth (no cracks)	1	96	25	88	29	92	4	89	45	33
		2	97	23	97	24	100	1	85	43	30
		3	98	22	87	29	89	7	83	41	27
						avg >>	93	4			
						s >>	6	3			

RESULTS

Although the results of core density tests were limited to those shown in Table 1, they indicate that compaction of the pavement was well within acceptable limits ranging from a low of 95.3 to 95.8 percent of the maximum theoretical density. This is also an indication that adequate subgrade support was present during compaction of the asphalt as is indicated by the AASHTO T99 density test results shown in Table 2.

The moisture contents and density of the insitu soils beneath the pavements and behind the curbs were compared to the optimum moisture and density determined using AASHTO T99, “Moisture Density Relationships for Soils.” Results of these comparisons are shown in Figures 2 through 4 for the density results and Figures 5 through 7 for the moisture results.

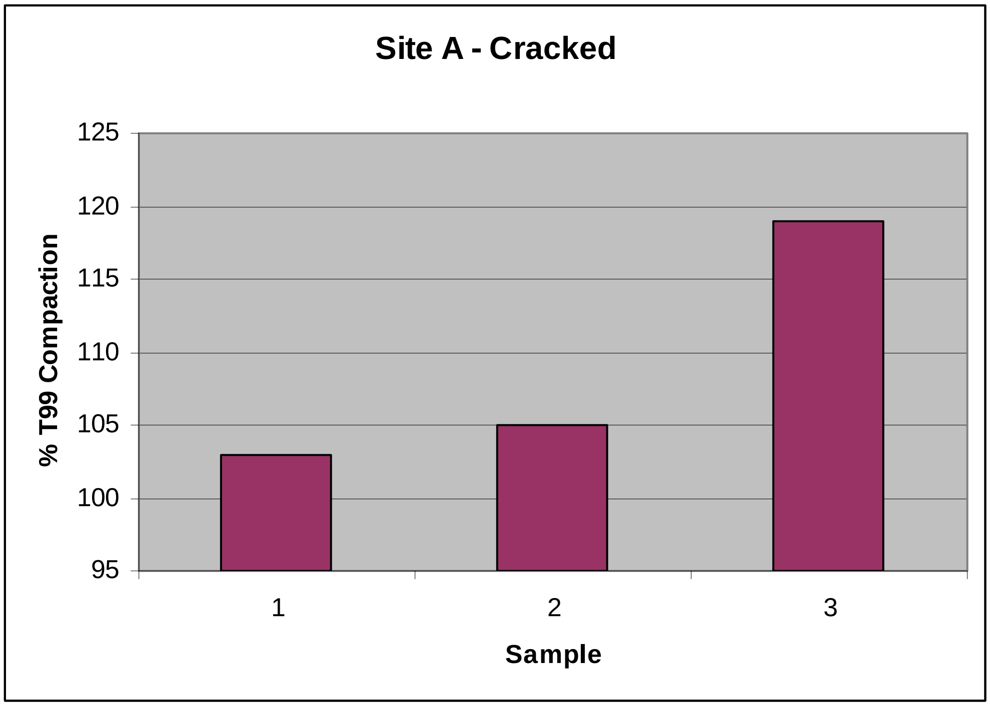

Figure 2 –Percent of AASHTO T99 for Site A

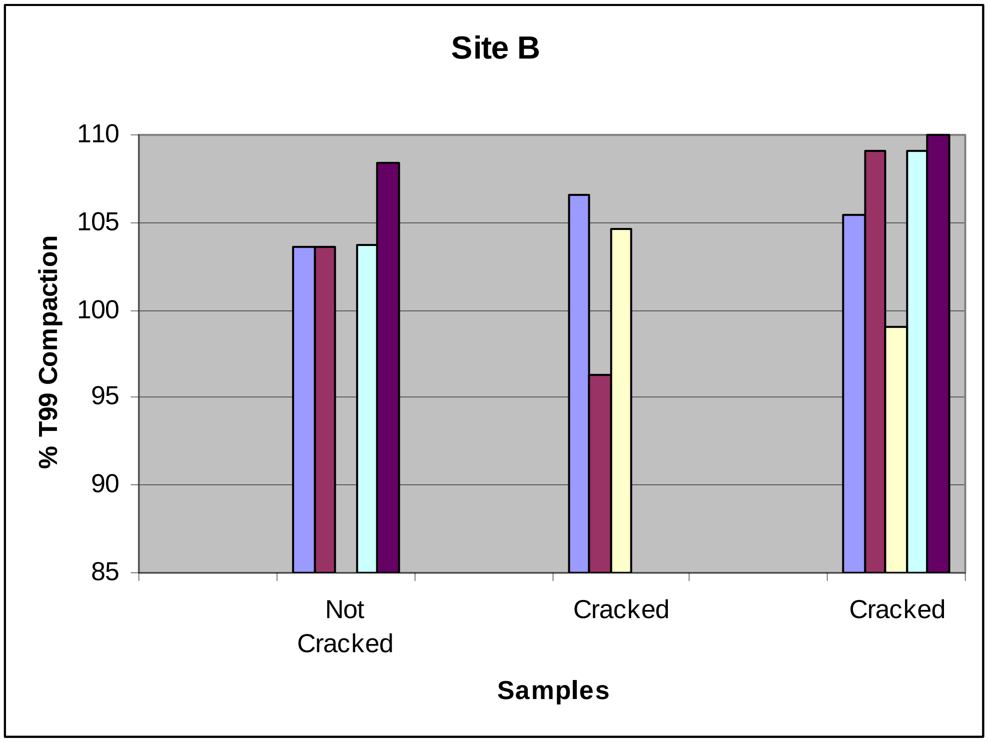

Figure 3 – Percent of AASHTO T99 for Site B

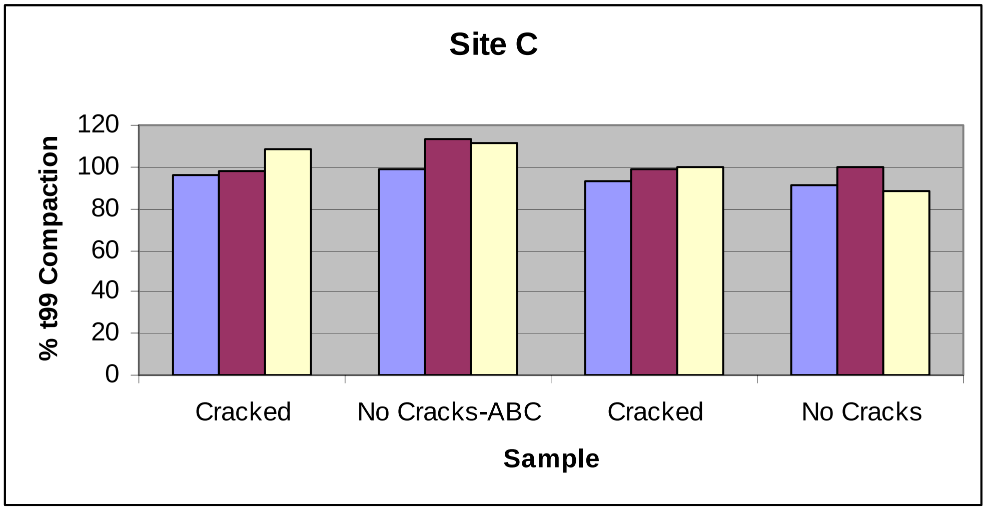

Figure 4 – Percent of AASHTO T99 for Site C

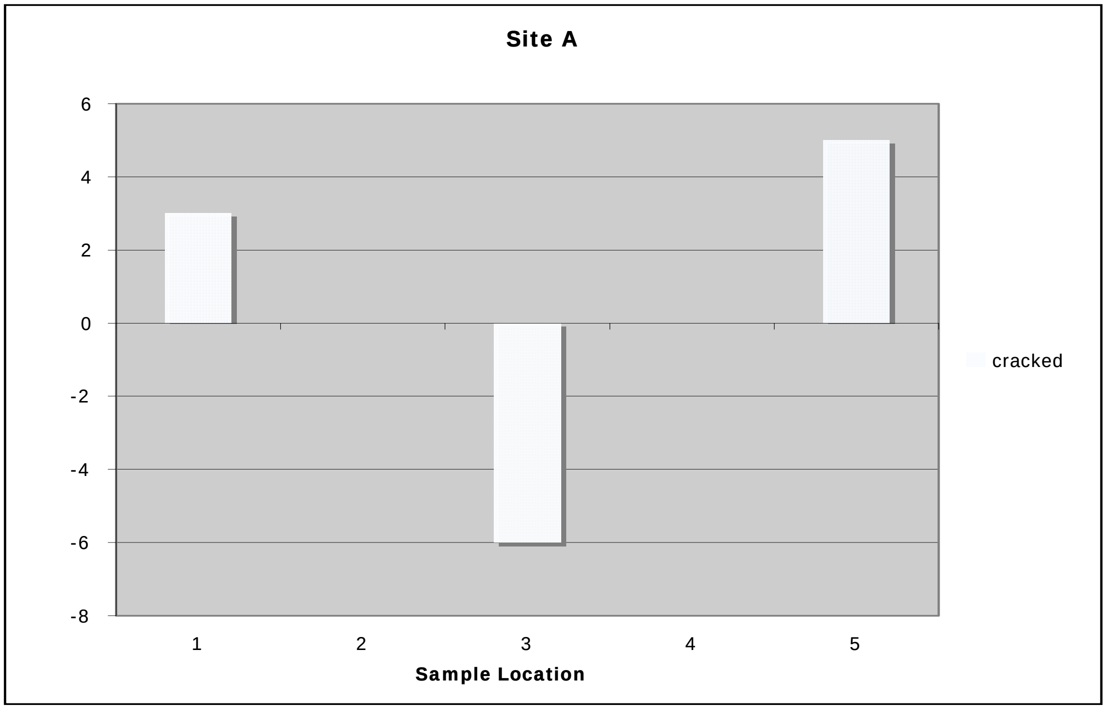

Figure 5 – Difference in Subgrade Moisture Between Insitu and T99 for Site A

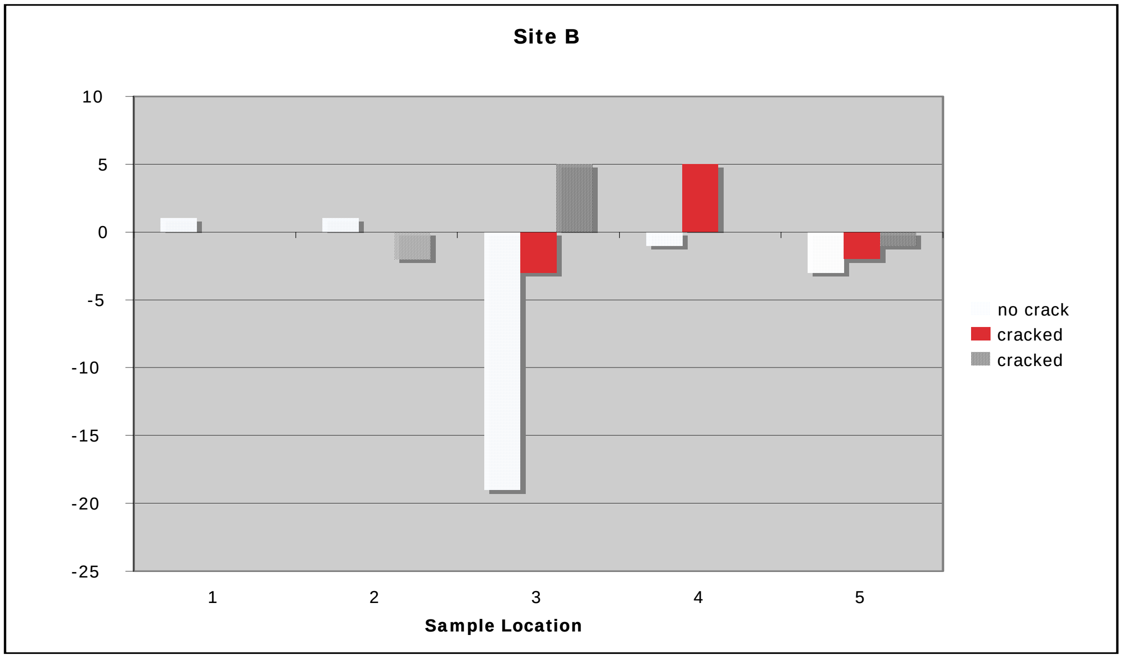

Figure 6 – Difference in Subgrade Moisture Between Insitu and T99 for Site B

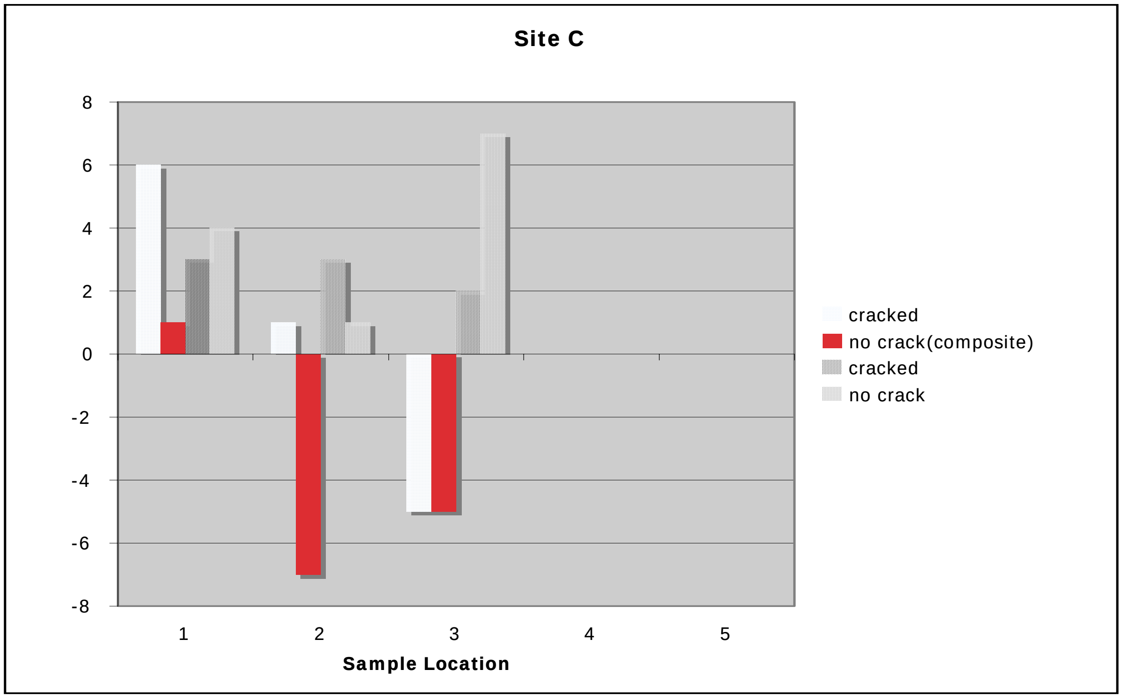

Figure 7 – Difference in Subgrade Moisture between Insitu and T99 for Site C

ANALYSIS

Subgrade Density Beneath Crack

Figure 8 compares the difference between subgrade insitu density and the maximum density determined by AASHTO T99 for the cracked and uncracked pavements. There appears to be a trend to densities lower than optimum under the crack. Compaction of the subgrade under the pavement is directly related to the load carrying capacity of the pavement. This factor could have much to do with edge cracking.

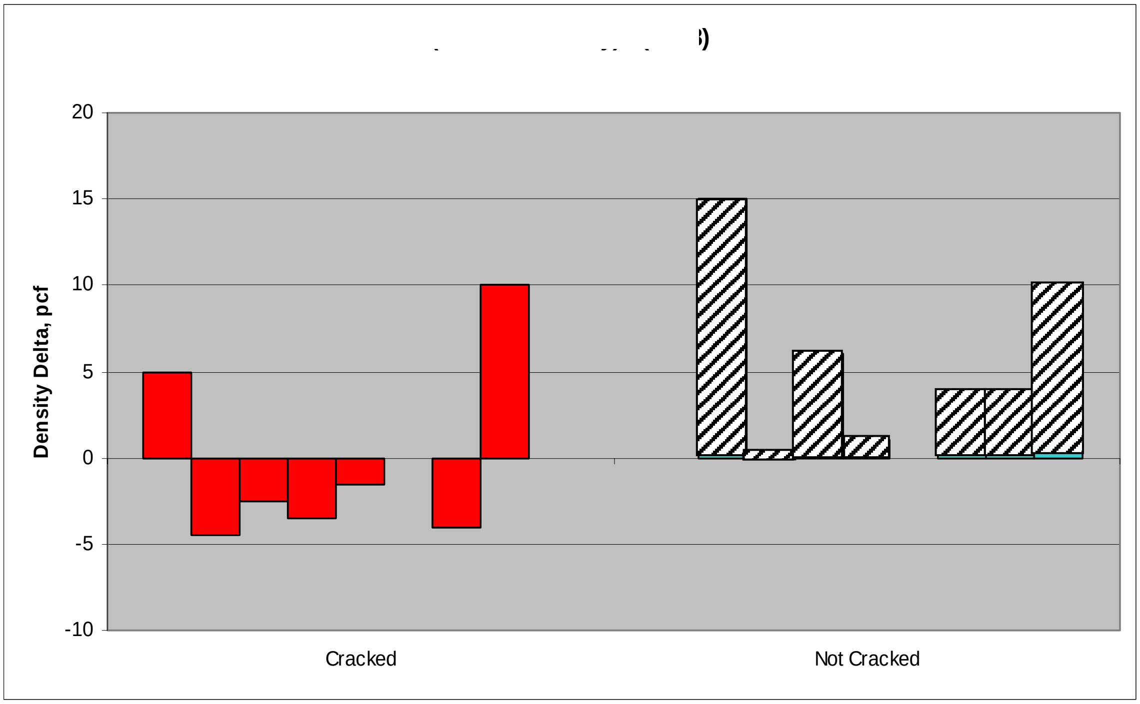

Figure 8 – Difference between Density Insitu and Maximum Density (AASHTO T99)

Subgrade Moisture Beneath Crack

Figure 9 compares the difference between subgrade insitu moisture content and the optimum moisture content determined by AASHTO T99 for the cracked and uncracked pavements. Moisture content appears to be at least 1% lower than optimum under the uncracked pavements and approximately 2% or greater above optimum under the cracked pavements. The moisture content of the subgrade under the pavement is directly related to the load carrying capacity of the pavement. This factor could have much to do with edge cracking and could be the reason compaction was lower than desired.

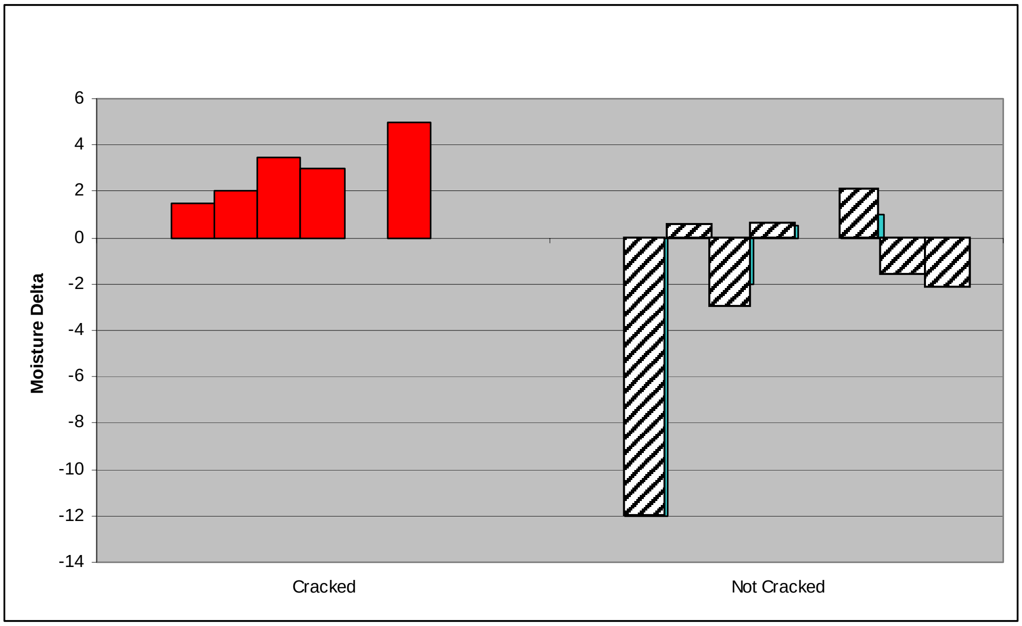

Figure 9 – Difference between Moisture Insitu and Optimum Moisture (AASHTO T99)

Subgrade Density and Moisture Difference - Behind Curb to Crack Location

This type of cracking could be caused by loss of subgrade support at the edge of the pavement. Therefore, the density and moisture contents of the subgrade behind the curb and gutter were compared with the density and moisture content beneath the crack. Figures 10 and 11 are the results of this comparison.

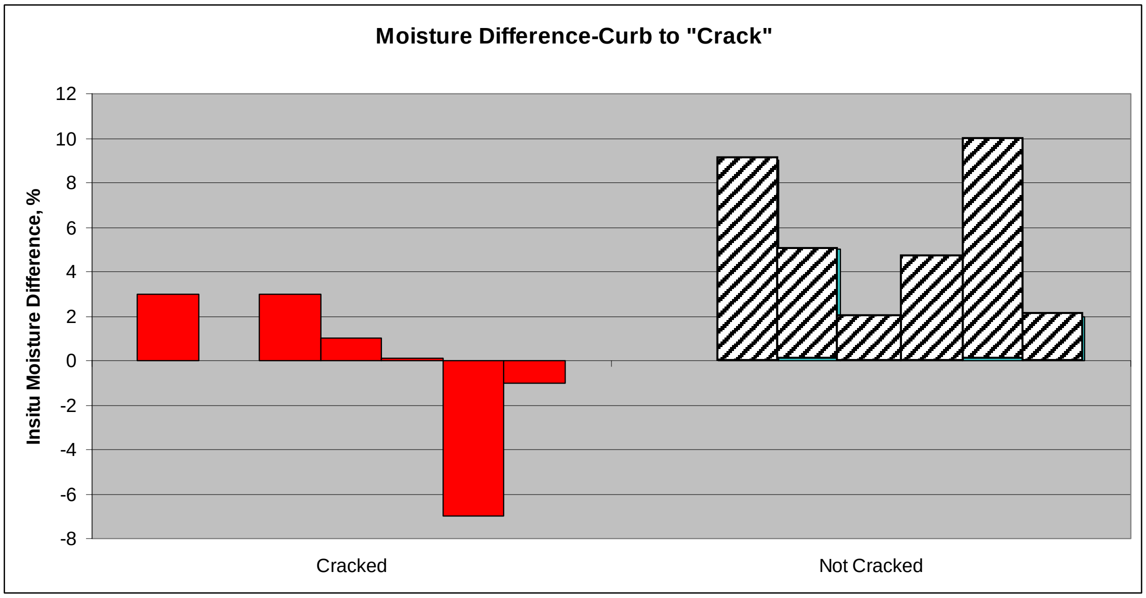

Figure 10 – Moisture Difference From Behind Curb to Crack Location

These data indicate that edge cracking occurs more frequently when the moisture content of the subgrade behind the curb is equal to or lower than moisture under the crack location.

In addition, it appears that edge cracking occurs more frequently when the density of the subgrade behind the curb is higher than density under the crack or potential crack location. Therefore, it appears a lack of support under the curb and gutter due to high moisture or low density is not the cause of edge cracking for the sites studied.

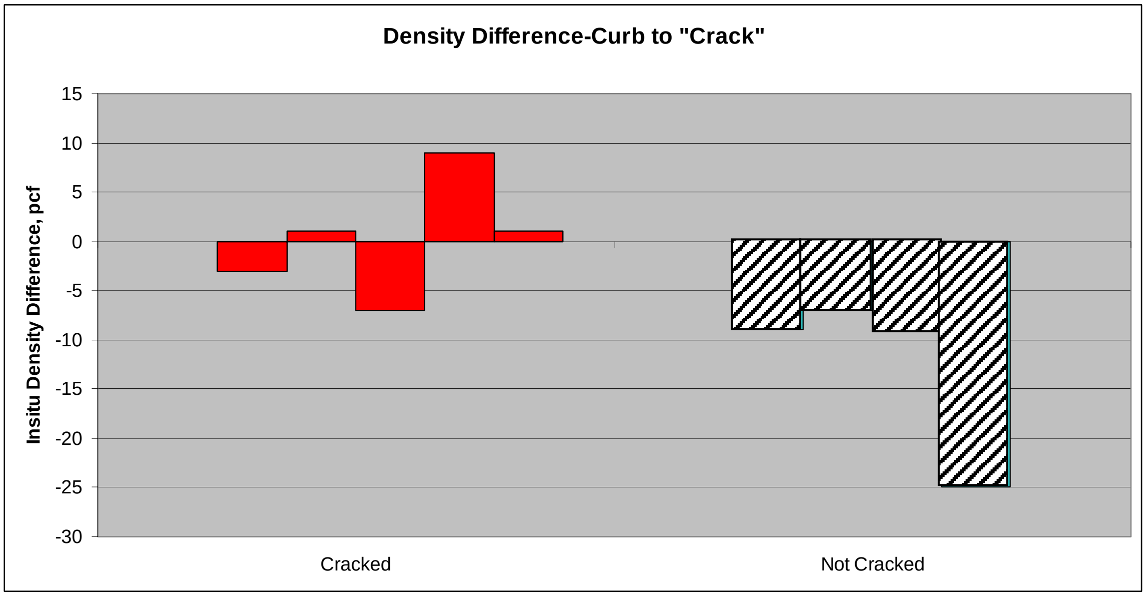

Figure 11 – Density Difference From Behind Curb to Crack Location

CONCLUSIONS

1. Soils at all three locations were classified as AASHTO A7 clays. These soils are known to be susceptible to high volume change along the Front Range of the Rocky Mountains where the research was conducted.

2. Pavement cracks began at the top of the pavement and propagated downward. Therefore, it seems reasonable that upward movement of the subgrade below the pavement is causing the stresses that are creating the cracks.

3. Compaction of the asphalt pavement appears to have been adequate based on limited core tests and is consistent with high relative compaction of the subgrade indicating adequate support for rollers. This is an indication that moisture content of the subgrade may have been lower than optimum during construction. If so, this is additional evidence that soil volume change may be related to the pavement cracks.

4. The subgrade beneath the cracks had lower density and higher moisture than the optimum properties measured with AASHTO T99. However, density elsewhere was higher than optimum.

5. Cracking did not appear to be related to maximum dry density as both cracked and uncracked pavements had subgrades with higher than T99 optimum density. However, seventeen of the twenty five samples had insitu density values greater than 100 percent of T99 optimum and only five samples were below 95 percent. This indicates the T99 optimum density was relatively easy to achieve and perhaps the T180 optimum density should be considered in the future on similar projects.

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