Edge Cracking in Hot Mix Asphalt Pavements

Final Report

Prepared for

Colorado Asphalt Pavement Association
Englewood, Colorado

by

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Knowledge to Go Places

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Introduction

A longitudinal crack occasionally occurs in hot mix asphalt pavements from 1.5 to 6 feet from the boundary of the gutter and pavement. These cracks occur within one to three weeks after paving and often before public traffic. The cracks are often discontinuous, occurring in various lengths and not symmetrical to the centerline of the paver or the pavement.

Edge cracking has been an asphalt pavement failure mechanism in Colorado for many years. When edge cracking began and how widespread the phenomenon is difficult to determine. This is because the problem seems to be limited to private construction projects in subdivisions and parking lots rather than public pavements constructed by the DOT. In most cases cracking is said to occur a few weeks after paving is completed and is not noticed by the owner until the pavement is cleaned of soils deposited from construction activities. This can be from weeks to months after paving. Therefore, the time required for the cracks to appear is difficult to measure and probably varies with each pavement. When edge cracking began is difficult to measure because many paving contractors repair the crack to satisfy the owner and do not embark on a research project to determine the cause. The time and cost involved is greater than the repair and in most cases the contractor is interested more in satisfying a customer than determining cause or blame for the cracking.

The purpose of this research is to determine the probable cause or causes of edge cracking in asphalt pavements in Colorado.

Survey Results

The CAPA Edge Cracking Work Group met on February 3, 2004 to discuss the problem and provide individual accounts of experiences related to the distress. A summary of this meeting is shown in the shaded area of Table 1. In addition to this group discussion, individual interviews were conducted between February and May, 2004. The results of these interviews are shown below the shaded area in Table 1. The apteryxes in Table 1 indicate a response by the individual interviewed that the feature shown in the table was related in some way with edge cracking. Asphalt pavement state association executives from around the country were interviewed, as well, to determine whether edge cracking was being observed in other areas of the country. These individuals included Richard Schreck, Virginia; James Huddleston, Oregon; Harold Mullen, Texas; Marvin Traylor, Illinois; and Richard Wolters, Minnesota. None of these individuals were aware that the type of edge cracking experienced in Colorado was occurring in their respective states.

A review of Table 1 indicates that four features appear to be common to the occurrence of edge cracking. These features may not be the only factors that contribute to this cracking but are offered as those that most observers agree are predominant.

1. Curb and gutter construction
2. Full-depth hot mix asphalt pavement
3. Swelling clay subgrade soil
4. Cracks originate at the top of the pavement

Other factors which may also be significant are shown below:

1. Harder asphalt binders
2. Lower asphalt content mixtures
3. Lack of backfill behind curb
4. Higher moisture behind curb and under cracks than at pavement centerline
5. Cut pavement sections

Based on this information the four features shown above were targeted during the field study portion of this project as the principal features common to edge cracking. The additional five features will be considered as contributors and will also be targeted.

Interviewee	Location	C & G		Full-Depth		Top-Down	Clay		Subgrade Stabil			Thickness	Swell		Sub	C & G	Binder	Section	
		Yes	No	Yes	No	Cracks	Yes	No	LTS	Flyash	CTS		High	Low	Excav	Settles		Cut	Fill
Herman Altergott, Agg Ind	Evans, CO	*	*	*	*		*	*				10"							
Sam Urton, PSI	Douglas, Co	*							*					*					
Lester Litton, Earth Engr			*	*	*	*			*	*									
	Loveland	*		*			CL					10"		2.70%					
	Meade	*		*								10.5"		1-2%					
	Winsor	*			*		CL					3.5-7"		1-2%					
	Meridien	*		*			CL-CH	*				8-10"	8%	0.10%					
Jim Noll, Kumar and Assoc.	Arapahoe Co.	*		*	*	*	CL		*			8"		2-4%	*	*	64-22		*
Tom Gee, Asphalt Specialties	DIA		*		*				*			17"	*		*				
	Meridien			*			*		*										
Darin Duran, J. A. Cesare	E470		*	*							*							*	
Davce Potter, Denver	Denver																		
Bob Bisgard, Asphalt Paving																			
Erich Purcell, Connell Resources																		*	
Damon Thomas, CTL	Chatfield Green			*								6.5"	4-6%		10'				
Dan Kehn, Kehn Construction	N. Colorado	*	*	*														*	
Bonner Gilmore, Pulte		*		*		*	*									*		*	
Dick Leopoldis, Oakwood	All	*		*			*									*		*	
Jarrett Welch, Brannan S & G		*		*	*	*	*										64-22		
Eric West, WesTest	All	*	*	*		*	*						*						
Rodney Schneider, PPI	Various	*		*		*	*					5.5-6"					58-22		
Tom Hastings, Wassenaar	Aurora	*		*		*	*							*			64-22		
John Johnson, Aurora	Aurora	*		*		*	*					6-8"		*				*	*
J. P. Mangone, Connell Resources	Various	*		*		*	*					6-8"		*			58-22	*	*

Table 1 – Summary of Interviews Regarding Experience with Edge Cracking

The field investigation is designed to determine whether cracks initiate at the top of the pavement. If so, this is significant to the state of stress in the pavement and is one key to identifying the failure mechanism.

There are reports (1) indicating that moisture content of the soil under the cracks to be substantially higher than the soil at the center of the pavement. This is reported even though moisture during construction was at or near optimum with no reported rain occurring between the time of construction and cracking. The source of this moisture is unclear, although condensation has been suggested by some (5). Since higher moisture content of the clay soils at or near the gutter could reduce bearing capacity this could lead to settlement of the curb and gutter or bearing capacity failure due to loading. Movement of the curb and gutter would either create a separation from the hot mix asphalt pavement or a crack in the hot mix asphalt pavement if the bond between concrete and hot mix asphalt pavement was higher than the internal strength of the hot mix asphalt pavement itself. Therefore, thermal condensation and other factors will be explored to determine the cause for the higher moisture content under the hot mix asphalt pavement at the crack and under the curb and gutter.

If cracking initiates at the top of the pavement then a bending moment must be developing in the area of the crack which creates a strain exceeding the failure strain of the hot mix asphalt pavement. This bending moment can occur by the mechanisms shown in Figure 2. One, the curb, gutter and hot mix asphalt pavement between the gutter and crack can move downward caused by a downward acting force such as gravity or external loads or, two, the pavement can move upward by a force acting in the vicinity of the crack such as soil swell pressure. Or, three, a combination of these forces.

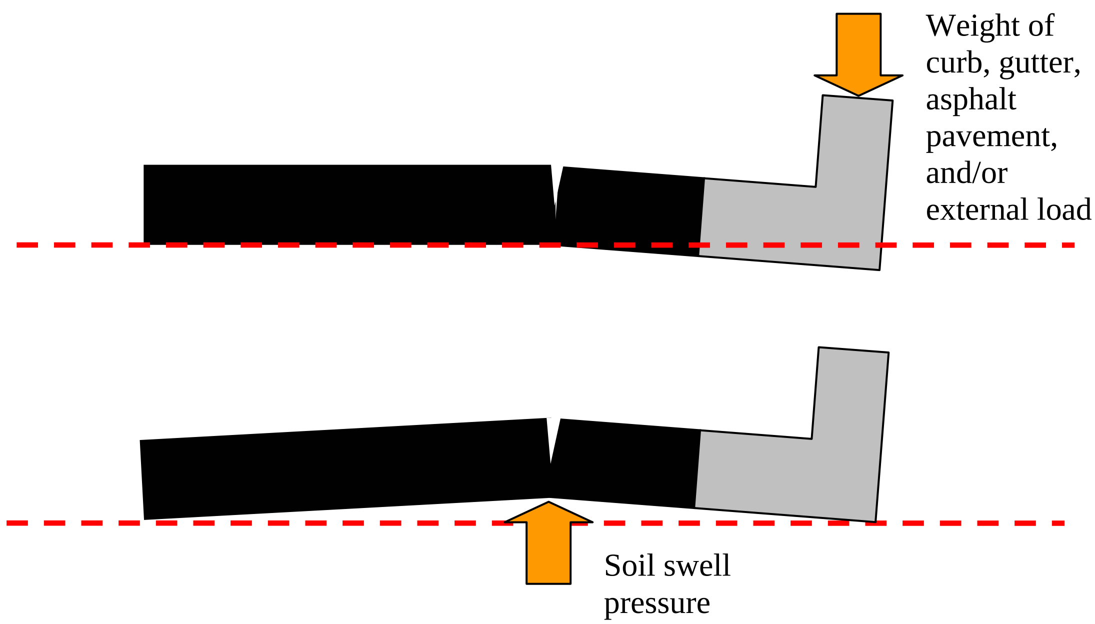

Figure 2 – Possible Forces Causing Edge Cracking

Three reports (2, 3, 4) indicate that swelling clay subgrades create enough upward pressure to produce the surface cracks. The swelling may be caused by soils under the hot mix asphalt pavement taking on moisture from beneath due to the heat of the hot mix asphalt. These soils swell very little when moisture contents are at or above the optimum moisture content of the soil. Therefore, for this mechanism to cause the cracking, moisture content of the soil would need to be lower than optimum prior to paving. This situation might occur if the soil were allowed to dry prior to paving. This is possible if high moisture contents in the soil lead to low bearing capacity preventing paving.

The above scenario may describe possible mechanisms for edge cracking in full-depth asphalt, but it may not explain the mechanism for asphalt pavements constructed over lime treated subgrade. Some of those interviewed indicated edge cracking occurs on pavement sections of this type, as well, and since the purpose of lime treatment is to mitigate swelling, this may mean that either the failure mechanism is different for lime treated sections, or the lime treatment in the sections demonstrating edge cracking is not effective for reducing swell.

Some of those interviewed indicated that edge cracking has been eliminated in curb and gutter sections when a crushed stone base course is placed beneath the hot mix asphalt pavement. In fact, some local agencies such as Douglas County currently require crushed stone base under hot mix asphalt pavements as insurance against this type of failure. An analysis of the possible reasons why crushed stone bases may reduce the occurrence of edge cracking has not been done; however, some suggest that an element of lateral support may be present in the crushed stone base that is lacking in a clay subgrade under a full-depth hot mix asphalt section.

An evaluation of the differences between the two types of construction may provide some clues regarding the reason for this performance difference.

Full-Depth Hot Mix Asphalt Approximate Construction Sequence

1. Over lot grading and compaction
    a. This may not be done by the paving contractor
    b. Compaction may not be to same standards under curb and gutter as pavement subgrade

2. Curb and gutter placed with vibrating slip-form machine
3. Asphalt contractor cuts a trench between the gutters to form the foundation for the hot mix asphalt pavement.
    a. Asphalt contractor reworks the subgrade soil typically to 12 inches below the bottom of the hot mix asphalt pavement, recompacts to specification tolerances, typically 98 percent of ASTM D698 (Standard Proctor) optimum moisture and density and grades to create a crown of a minimum 2 percent cross-slope.
4. Hot mix asphalt pavement is placed on top of prepared subgrade.

Hot Mix Asphalt Pavement on Crushed Aggregate Base ("Composite") Approximate Construction Sequence

1. Over lot grading and compaction
    a. This may not be done by the paving contractor
    b. Compaction may not be to same standards under curb and gutter as pavement subgrade
2. Curb and gutter placed with vibrating slip-form machine
3. Asphalt paving contractor cuts a trench between the gutters to form the foundation for the aggregate base and hot mix asphalt pavement.
    a. Asphalt paving contractor reworks the subgrade soil typically to 12 inches below the bottom of the aggregate base course, recompacts to specification tolerances, typically 98 percent of ASTM D698 (Standard Proctor) optimum moisture and density and grades to create a crown of a minimum 2 percent cross-slope.
    b. Aggregate base course is placed on prepared subgrade and compacted.
    c. Hot mix asphalt pavement is placed on top of prepared aggregate base course.

Figures 3 and 4 are graphical depictions of these two processes.

One Possibility

It is possible that moisture in the clay subgrade is drawn toward the surface by mechanical means, such as the vibration generated by the slip-form paver when constructing the curb and gutter, or the vibration produced by the vibratory rollers and heat generated in the soil by the hot mix asphalt. It is also possible the moisture and density of the subgrade under the curb and gutter are not at or near the optimum values desired. They may be higher than optimum moisture and lower than optimum density. This might particularly be true for cut sections where insitu density would be expected to be lower than that produced by mechanical compaction. If the soil is not compacted to greater than 95% of D698 under the curb and gutter, movement of water through the soil would be facilitated. It is also possible moisture could move up in the soil, even with adequate compaction. This is something that should be evaluated in the field. Assuming that moisture is pulled to the surface of the soil under the curb and gutter, the moisture content would be higher near the surface than testing would have indicated if done prior to curb placement. Also, it is possible that the density of the soil is lower than desired. If so, this may be the first step to explaining the pavement cracks.

In the full-depth section, the situation is represented in Figure 5. Cracking is probably not caused by the weight of the concrete curb and gutter and hot mix asphalt pavement, alone. However, if an external load provided by construction traffic were placed at or near the edge of the hot mix asphalt pavement, the lower bearing capacity may not support the load, and a tensile crack could be initiated at the surface as shown in Figure 6. The swelling pressure from below then heaves the pavement slightly at this location due to the localized weakness. As the crack propagates through the hot mix asphalt pavement moisture flows to the surface of the clay subgrade. Although this surface moisture probably cannot penetrate the clay significantly, it may be enough to cause some localized swelling. As the moisture content increases to equilibrium, swelling ceases and cracking stops.

Figure 7 depicts how this mechanism would be hindered by the composite pavement section. The aggregate base course strength is not as susceptible to bearing capacity failure as the clay subgrade soils for an equal increase in moisture content. Therefore, construction traffic is less likely to create a surface crack in the hot mix asphalt pavement even though moisture content under the curb and gutter is higher than desired. Since the drier subgrade surface is beneath the aggregate base course (ABC) in this section, any swelling of the clay occurs beneath the ABC. And since the ABC is not a rigid body, it can absorb much of this strain without affecting the hot mix asphalt pavement 8 inches or more above.

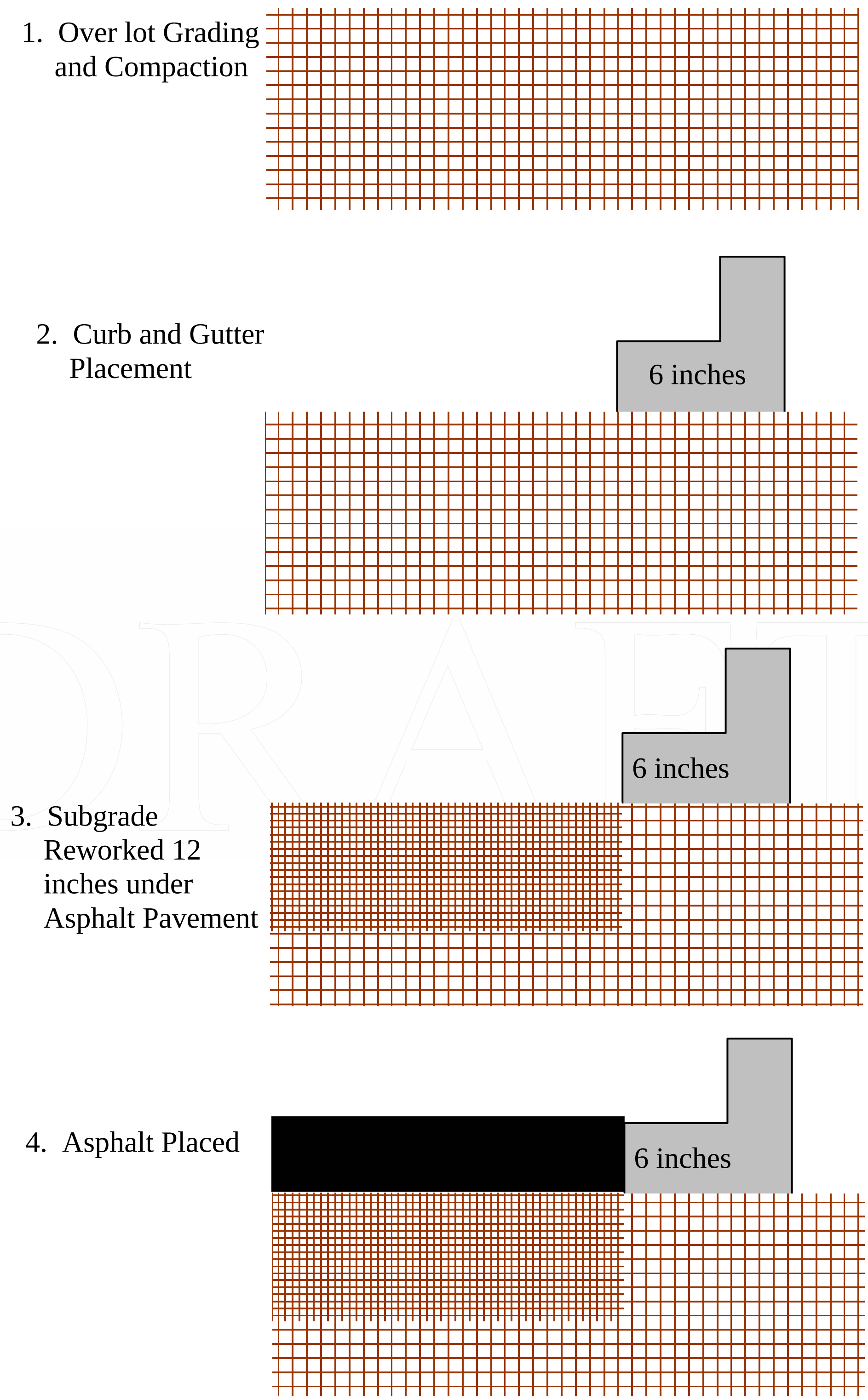

Figure 3 – Full-Depth Hot Mix Asphalt Pavement Construction Sequence

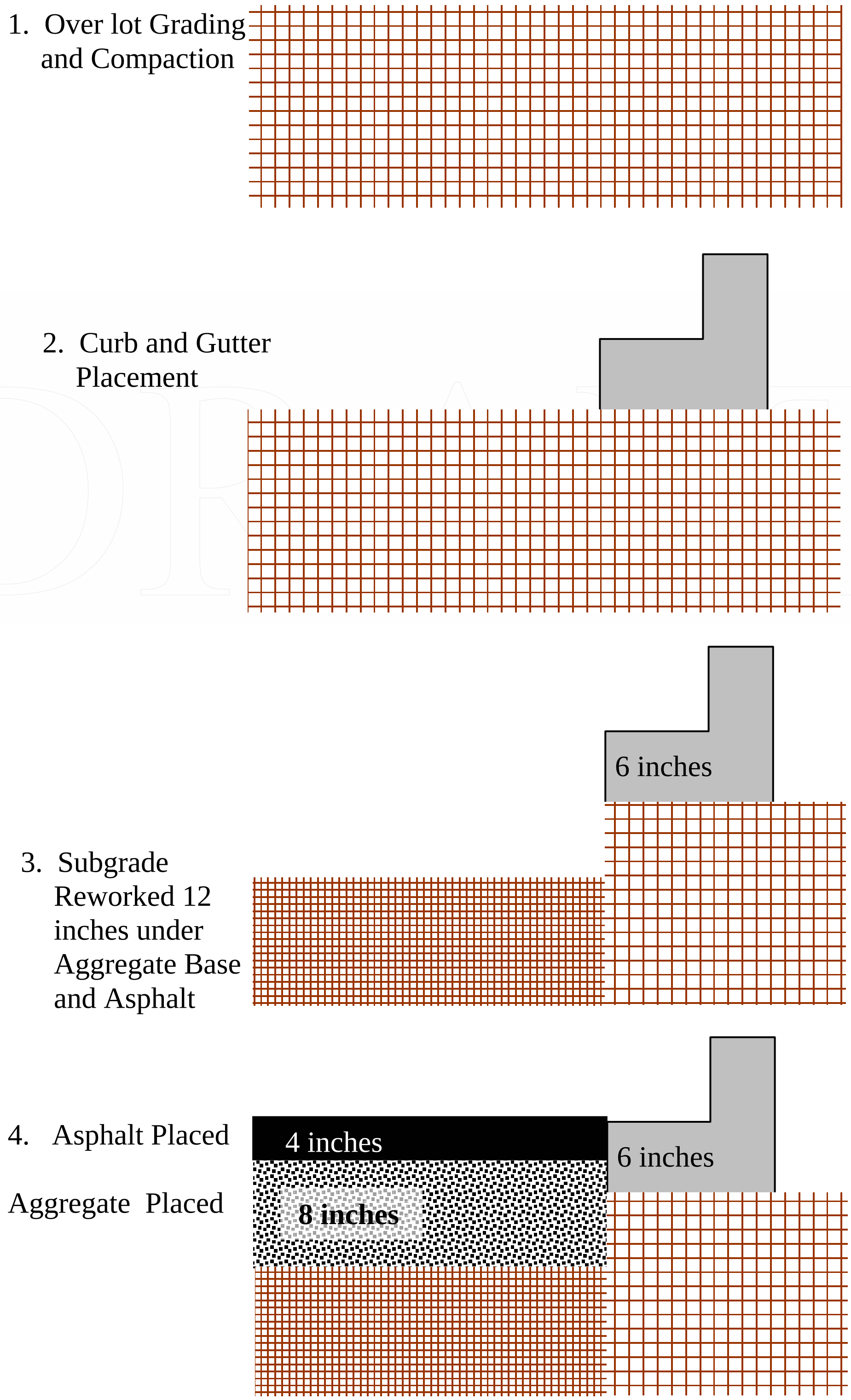

Figure 4 – "Composite" Pavement Construction Sequence

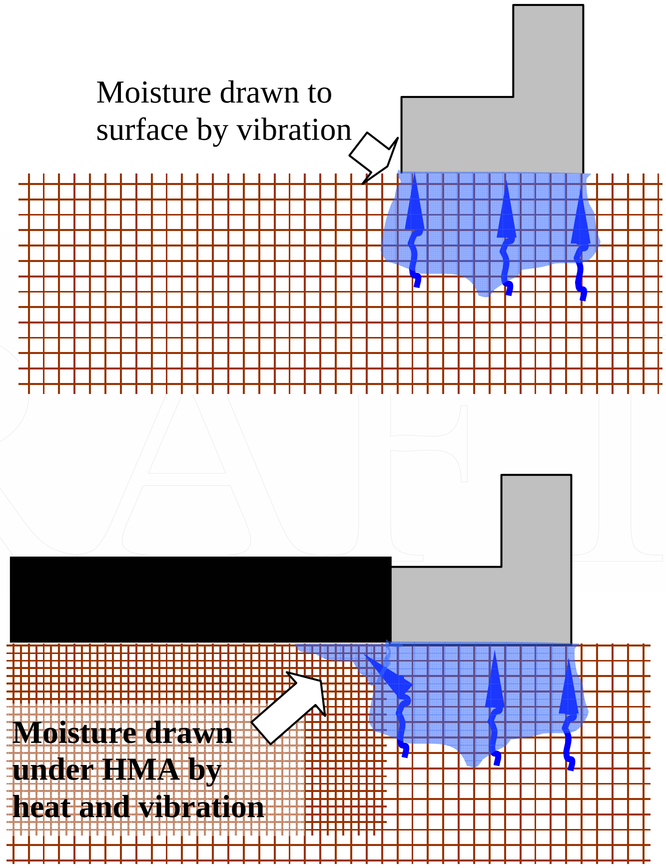

Figure 5 – Possible Moisture Movement to Surface after Slip-Form Vibration and Paving

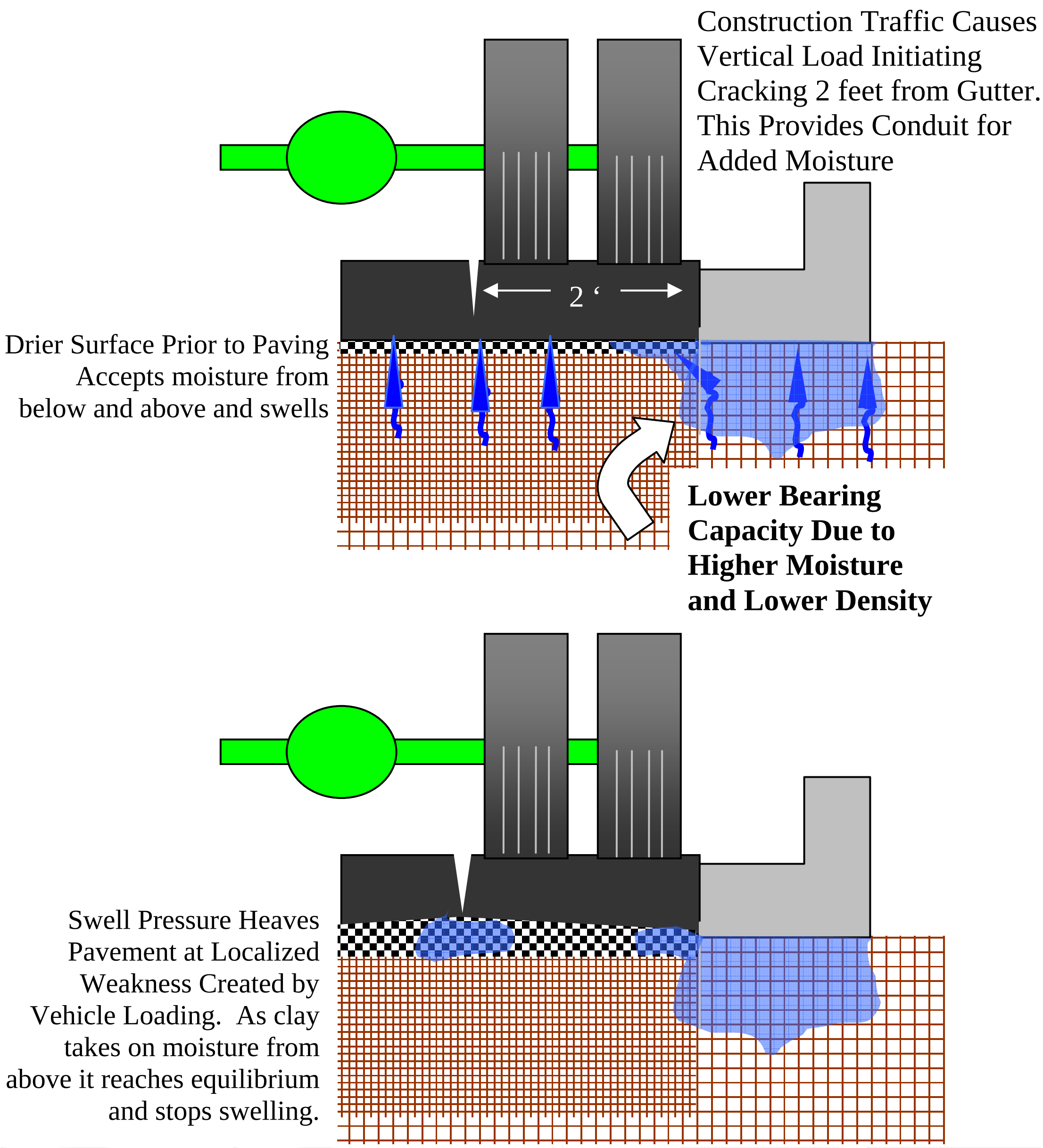

Figure 6 – One Possible Mechanism for Edge Cracking in Full-Depth Sections

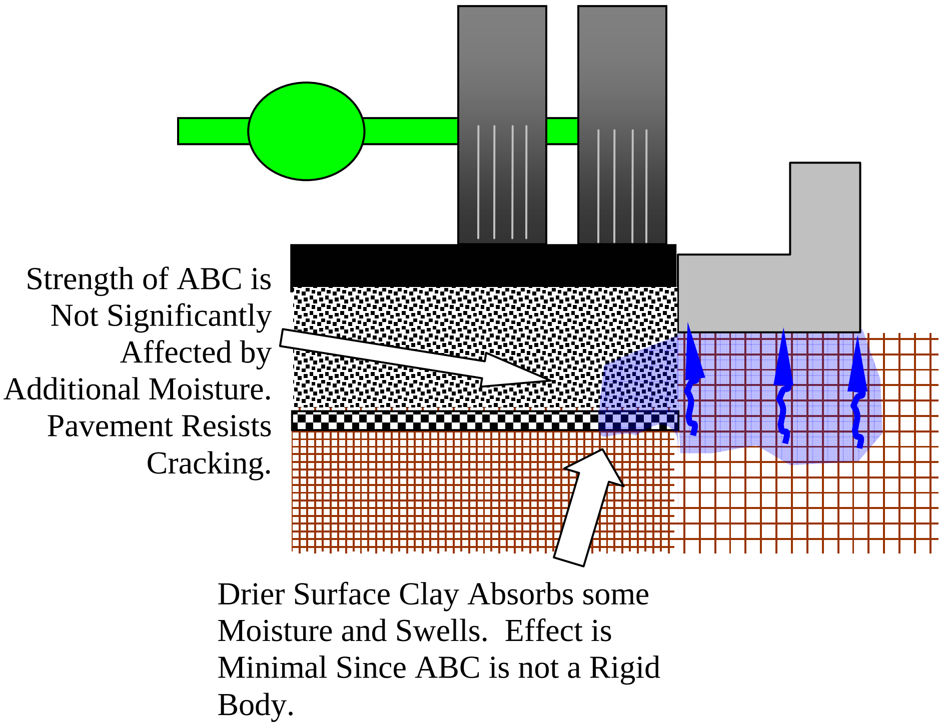

Figure 7 – Possible Explanation for Lack of Edge Cracking in Composite Sections

Another possibility is that during the subgrade preparation between the curb and gutter, the subgrade is not reworked immediately adjacent the concrete gutter. This may be for at least two reasons: 1) the equipment being used to prepare the subgrade is not physically capable of working immediately adjacent the gutter, or 2) the contractor preparing the subgrade is reluctant to work too close to the freshly placed concrete for fear of damaging the new gutter. In this case, the reworked subgrade might look more like that shown in Figure 8 where the subgrade prepared for paving is perhaps 6 inches away from the gutter. The mechanism for failure is the same as described previously, except the potential for moisture movement in the soil adjacent the gutter is higher due to the lower density prior to paving.

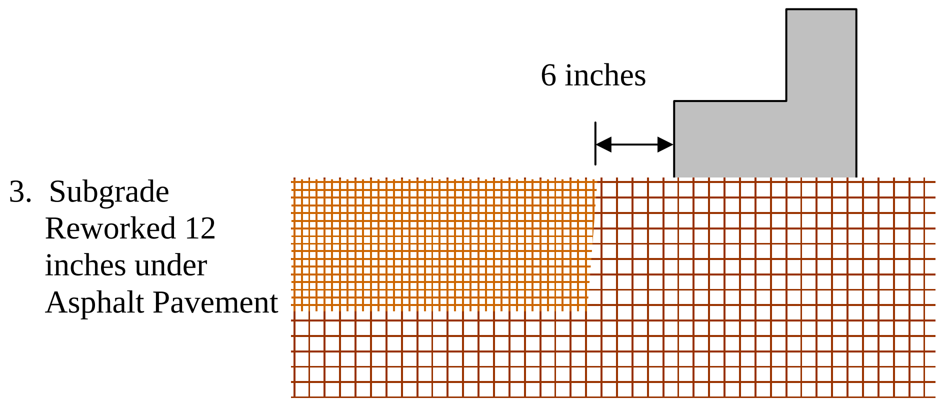

Figure 8 – Alternative Full-Depth Hot Mix Asphalt Pavement Subgrade Preparation

Field Sites

The premise of this task was to obtain pavement and soils data from multiple sites as soon after cracking was observed as possible. As indicated above, "as soon after cracking was observed" is problematic. Therefore, it is not assumed that each site was sampled at the same time after cracking. However, every attempt was made to obtain samples not longer than two months after construction. It would have been desirable to obtain samples within days of the appearance of the cracks, but because of reasons previously cited, this was impractical. Sites were rejected for study if construction had occurred longer than several months before notification of cracking. Sites were also selected only when the reason for edge cracking was not obvious. For example, if the curb and gutter had clearly settled, causing a crack, or if poor compaction over utilities resulted in settlement and cracking, the site was not sampled.

Sampling

Eight locations in three sites were sampled in Task B. A fourth site was identified and soil samples were collected before construction in an attempt to obtain pre-cracking soils data. It is unknown whether cracking will occur at this site, therefore this site and data from it should be considered for future study.

The three sites evaluated are located in the two geographic locations shown in Figure 9. Two sites are located within the Vista Ridge development in the town of Erie, Colorado and the third site is in the Tollgate Crossing development in Aurora, Colorado.

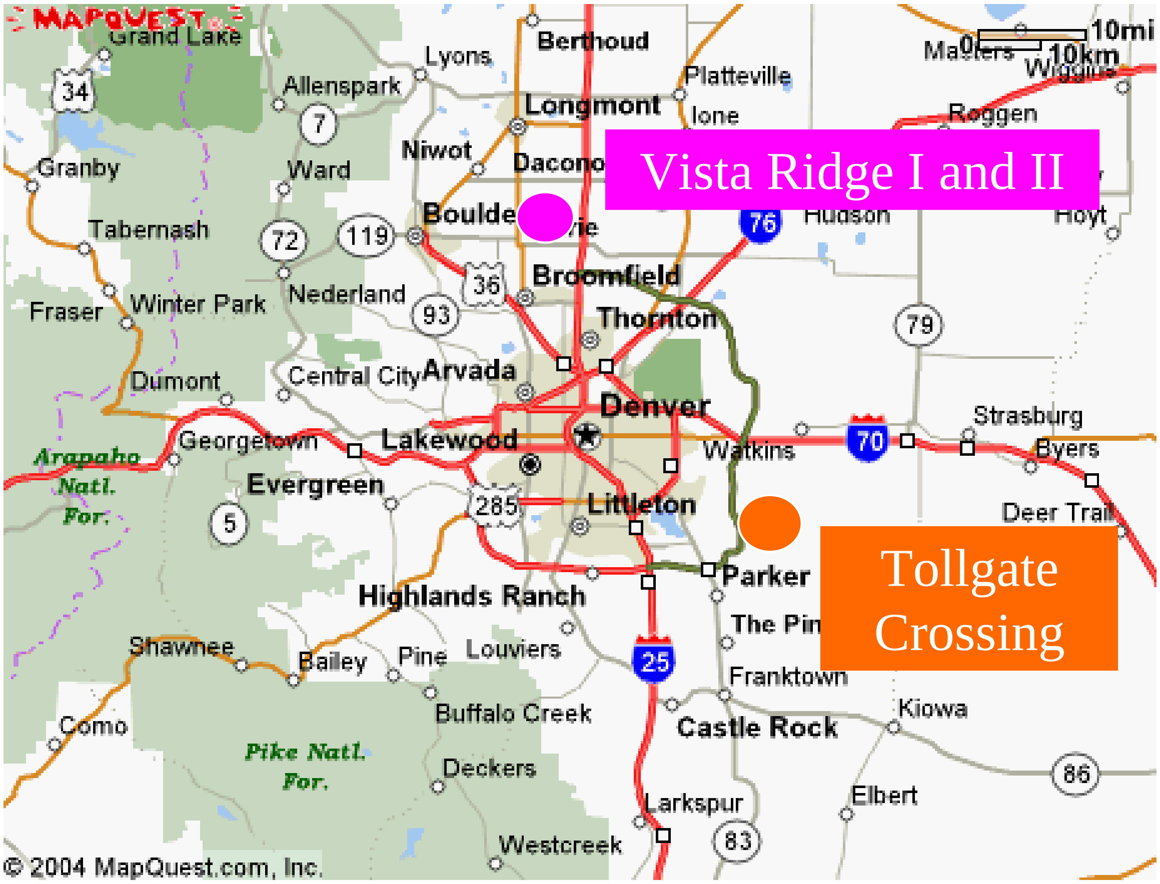

Figure 9 – Test Sites

The primary objectives studied at the sites are:

1. Whether cracks originate at the top of the pavements
2. Whether the pavement nearest the gutter has the same slope as the adjacent pavement across the crack
3. The difference between subgrade density and moisture content under the pavement and behind the curb and gutter
4. The difference between insitu density and moisture and optimum determined by ASTM D698
5. The type of pavement structural section and soil type
6. The swell potential of subgrade soils

Vista Ridge I

The first site evaluated was located in the Vista Ridge development in the Town of Erie, Colorado on the northbound lane of Sunset Way. Vista Ridge was sampled in two locations, Vista Ridge I and II. Figure 10 describes the locations of samples designated Vista Ridge I.

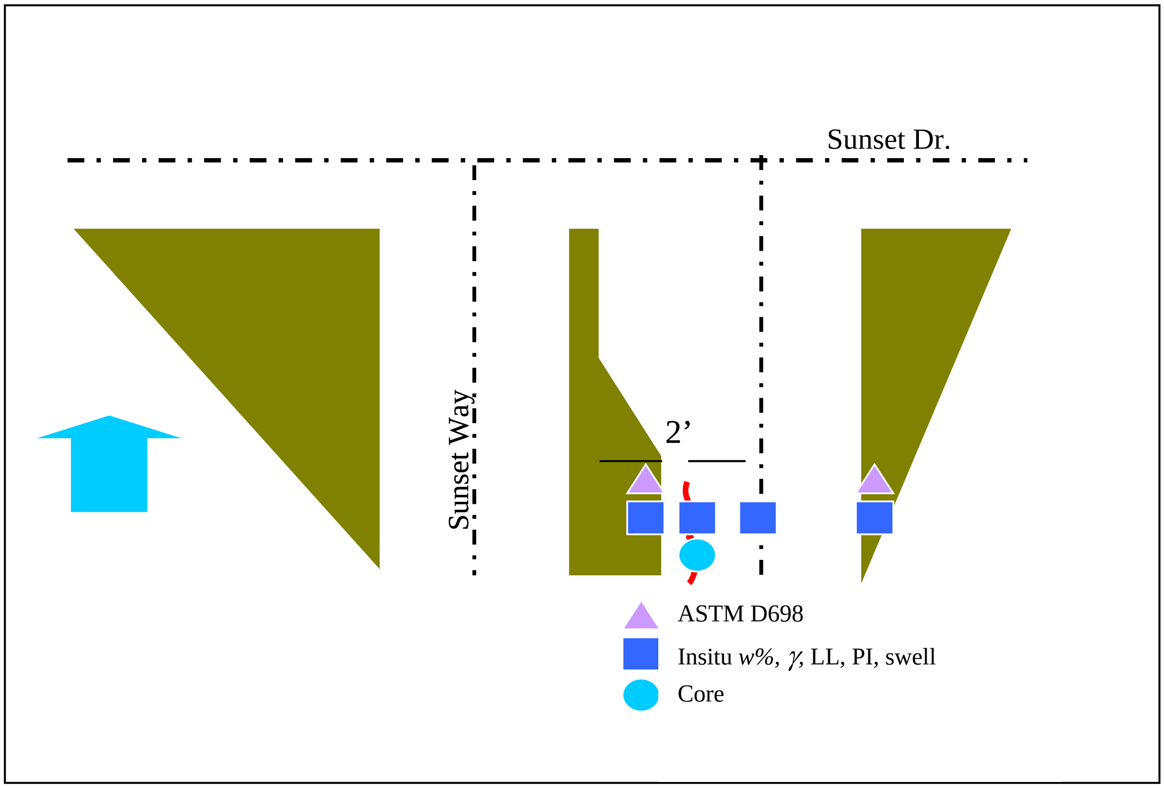

Figure 10– Sampling and Testing Plan at Vista Ridge I

Tollgate Crossing

The second site evaluated is located in the Tollgate Crossing development in Aurora, Colorado. Four locations were evaluated at Tollgate Crossing as shown in Figure 11. These locations were included because two exhibited edge cracking and two did not. The two locations with cracking were both cul-de-sacs and full-depth asphalt sections. One location that did not indicate cracking was a composite section and one was a full-depth section. Each of these locations was sampled for tests as shown on Figure 12. Two samples were taken at each of the locations shown on Figure 12 and evaluated by separate testing laboratories. Duplicate samples were taken to determine variability in insitu moisture and density test results.

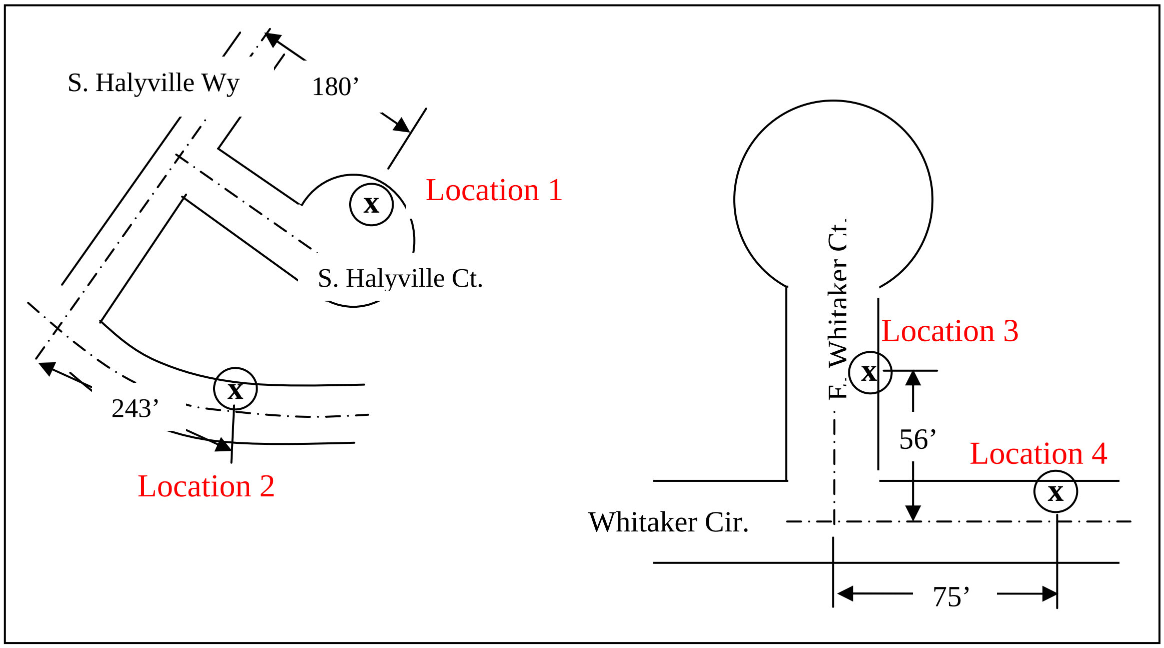

Figure 11 – Sample Locations at Tollgate Crossing

Vista Ridge II

The third site evaluated is also located in the Vista Ridge development in the Town of Erie, Colorado as previously noted. Three locations were evaluated at this site as shown in Figure 13. Each of these locations was sampled for tests as shown on Figure 14.

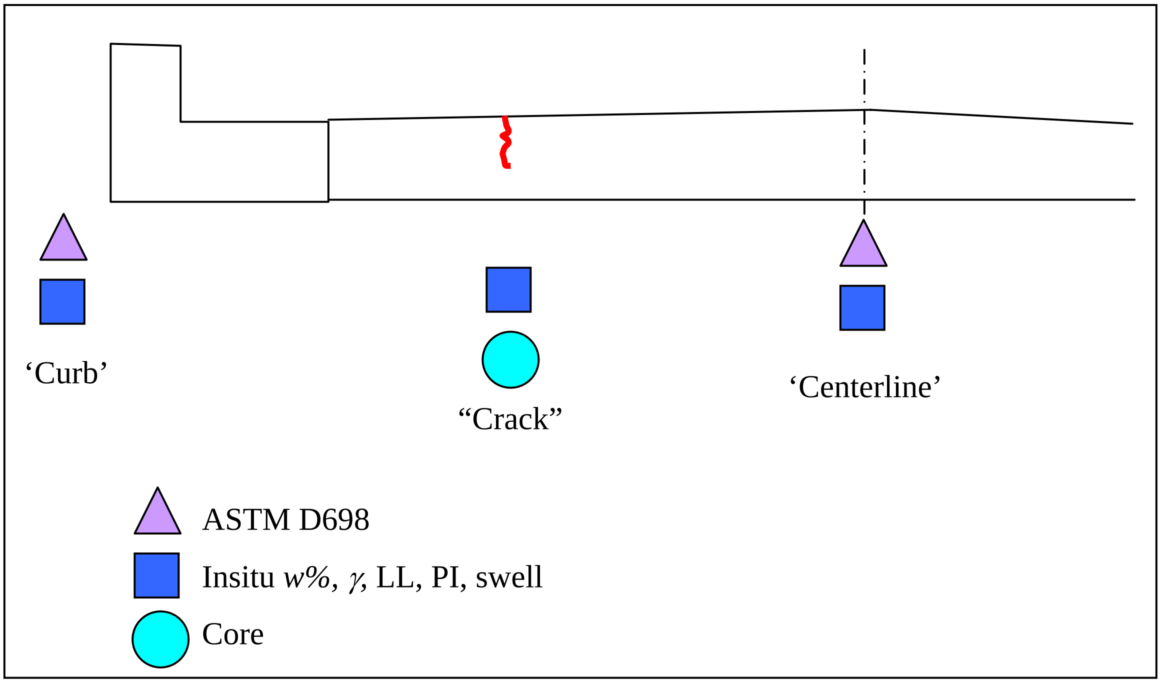

Figure 12 – Sampling Plan and Tests at Tollgate Crossing Locations

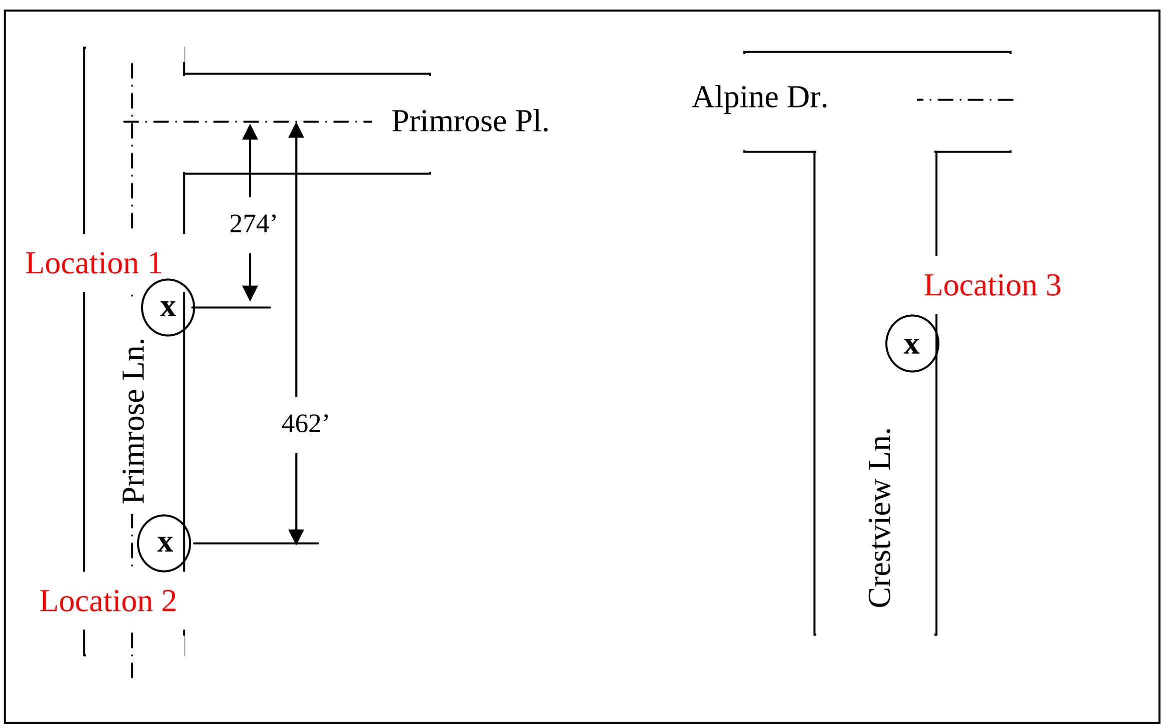

Figure 13 – Sample Locations at Vista Ridge II

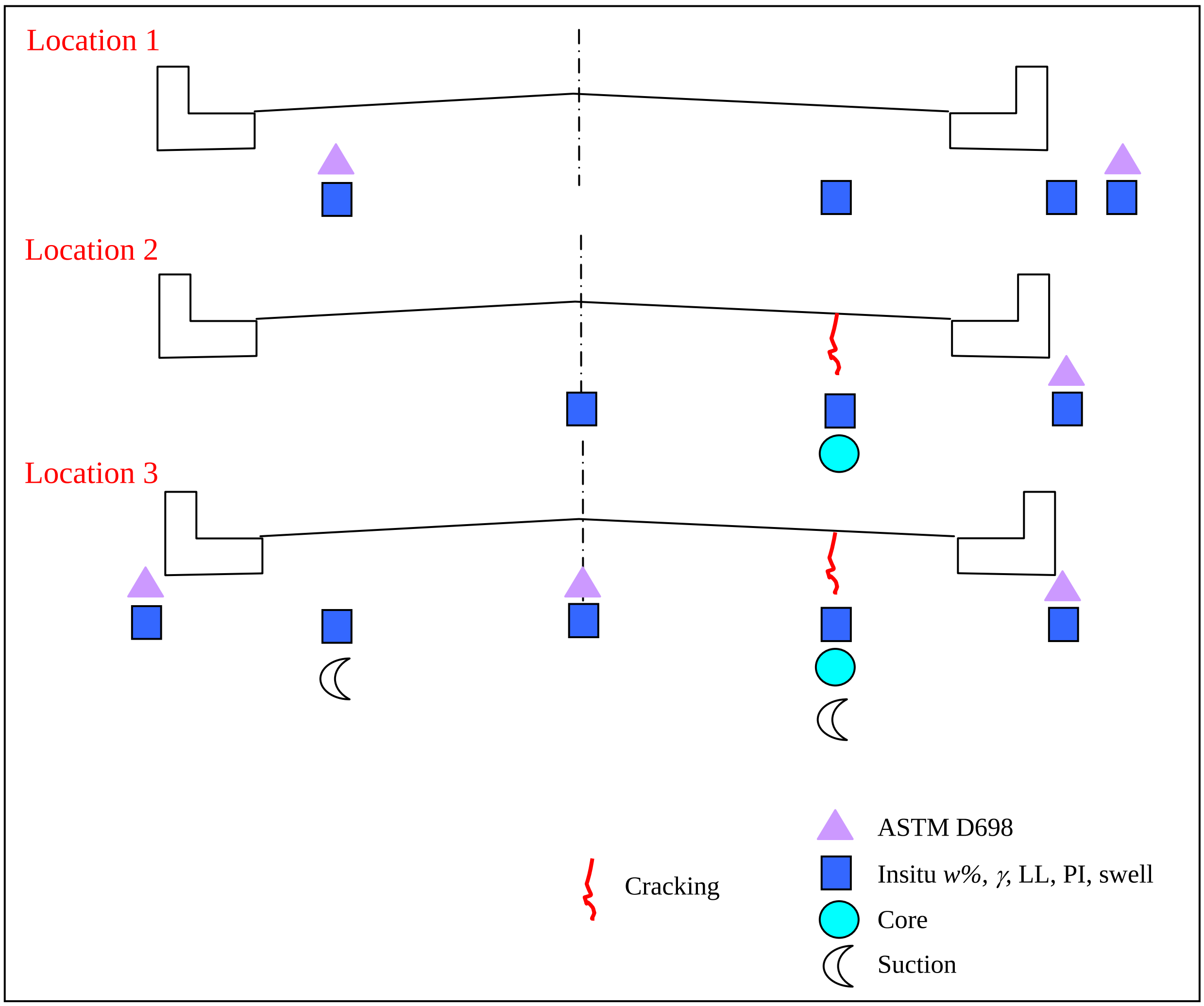

Figure 14 – Sample Plan at Vista Ridge II

Results

Testing consisted of optimum moisture-density, insitu moisture and density, swell potential for the soils and the pressure required to return the swelled samples to the original 100 psf surcharge position, liquid limit and plasticity index, coring to determine the location of the cracks and an evaluation to determine if the slope of the pavement was different on one side of the crack compared with the other side. In addition, two laboratories were used to evaluate the insitu moisture and density of the soils from Tollgate Crossing. This was done to evaluate the potential variability of the soils.

These results are shown in Tables 2 through 5.

Table 2 – Test Results from Vista Ridge I

Section	Sample Location	Density, pcf D698	Moisture, % D698	Density, pcf Insitu	Moisture, % Insitu	Swell, %	Pressure, psf	P200, %	LL, %	PI	Crack Location	Slope
9 in Full Depth	Curb-L	100	20		23	1.1	750	84	46	29		
	Crack-L			105	20	1.8	1100	87	52	35	Top	None
	Centerline			119	14	7.2	8500	80	48	35		
	Curb-R	101	19		24	0.5	700	82	47	31		

Table 3 – Test Results from Tollgate Crossing Laboratory 1

Tollgate Crossing-Lab 1	Section	Sample Location	Density, pcf D698	Moisture, % D698	Density, pcf Insitu	Moisture, % Insitu	Swell, %	Unc-Compr, psf	Crack Location	Slope
1-Cracked	5-1/2 in Full Depth	Curb	95	24						
		"Crack"			89	27			Top	None
		Centerline	92	27						
2-No Cracks-Composite	3-1/2 in HMA 7-1/2 in ABC	Curb	95	24		24		2269		
		"Crack"			110	13	0.3		na	na
		Centerline	95	26	106	21				
3-Cracked	5-1/2 in Full Depth	Curb	96	25	91	29		3904		
		"Crack"			94	26	1.2		Top	"Tent"
		Centerline	97	23	97	23				
4-No Cracks-Full	5-1/2 in Full Depth	Curb	96	25	88	29				
		"Crack"			97	24		3105	na	na
		Centerline	98	22	87	29				

Table 4 – Test Results from Tollgate Crossing Laboratory 2

Tollgate Crossing-Lab 2	Section	Sample Location	Density, pcf Insitu	Moisture, % Insitu
1-Cracked	5-1/2 in Full	Curb	91	30
	Depth	"Crack"	90	29
		Centerline	100	22
2-No Cracks-Composite	3-1/2 in HMA	Curb	94	25
	7-1/2 in ABC	"Crack"	101	23
		Centerline		9
3-Cracked	5-1/2 in Full	Curb	88	27
	Depth	"Crack"	95	27
		Centerline	97	26
4-No Cracks-Full	5-1/2 in Full	Curb	89	28
	Depth	"Crack"	98	24
		Centerline		24

Table 5 – Test Results from Vista Ridge II

Vista Ridge II	Sample Location	Density, pcf D698	Moisture, % D698	Density, pcf Insitu	Moisture, % Insitu	Swell, %	Pressure, psf	P200, %	PI	Suction, pF	Crack Location	Slope
1 - No Cracks	Curb-L											
	"Crack"-L	110	16	114	17	4	2000	81	28			
	Centerline	107	19						28			
	"Crack"-R			111	18	3.9	3000	87	27		na	na
	Curb-R	107	19	86	28	7.1	4000	90	32			
	Curb-R3'	107	19	116	16	4.3	4000	90	32			
2 - Cracked R	Curb-L											
	"Crack"-L											
	Centerline			114	16	6.6	6000	89	32			
	"Crack"-R			103	24	7.5	7000	92	39		Top	none
	Curb-R	107	19	112	17	3.8	2000	95	29			
3 - Cracked R	Curb-L	110	16	116	16	2.9	1500	63	28			
	"Crack"-L			120	14	7.3	6000		28	4.0		
	Centerline	110	16	109	21	3	2000	86	30			
	"Crack"-R			120	16	2.8	2000		28	3.8	Top	none
	Curb-R	110	16	121	15	5.6	5000	67	26			

Analysis

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 ASTM D698, "Moisture Density Relationships for Soils." Results of these comparisons are shown in Figures 15 through 18 for the density results and Figures 19 through 22 for the moisture results.

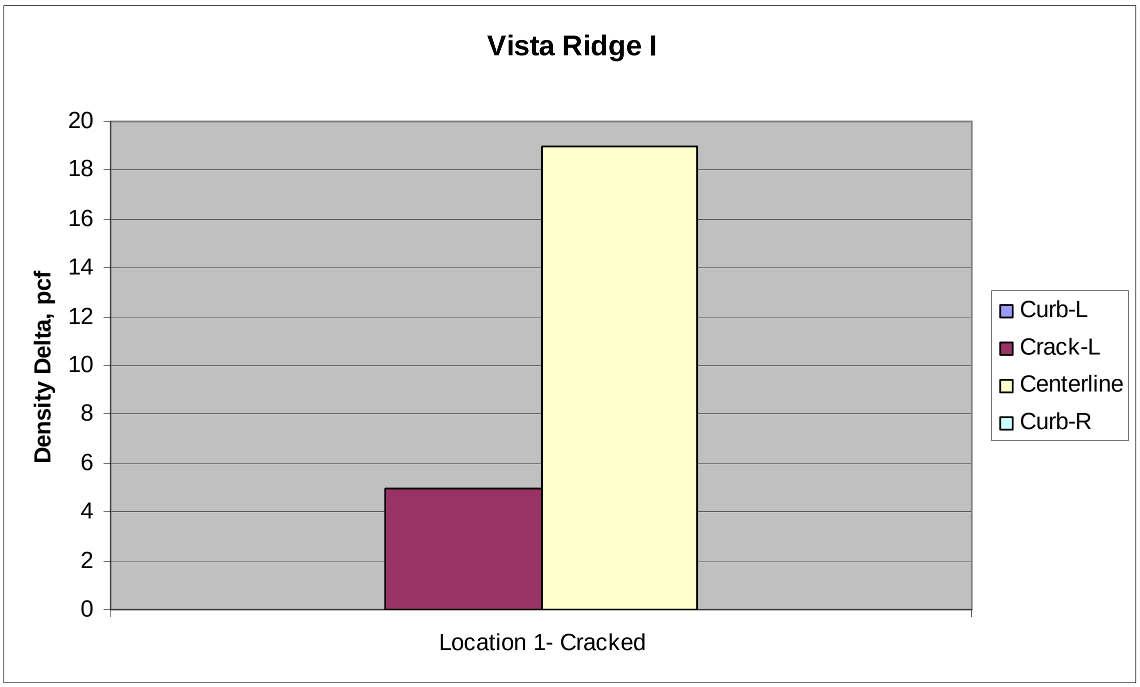

Figure 15 – Difference in Density between Insitu and Optimum for Vista Ridge I

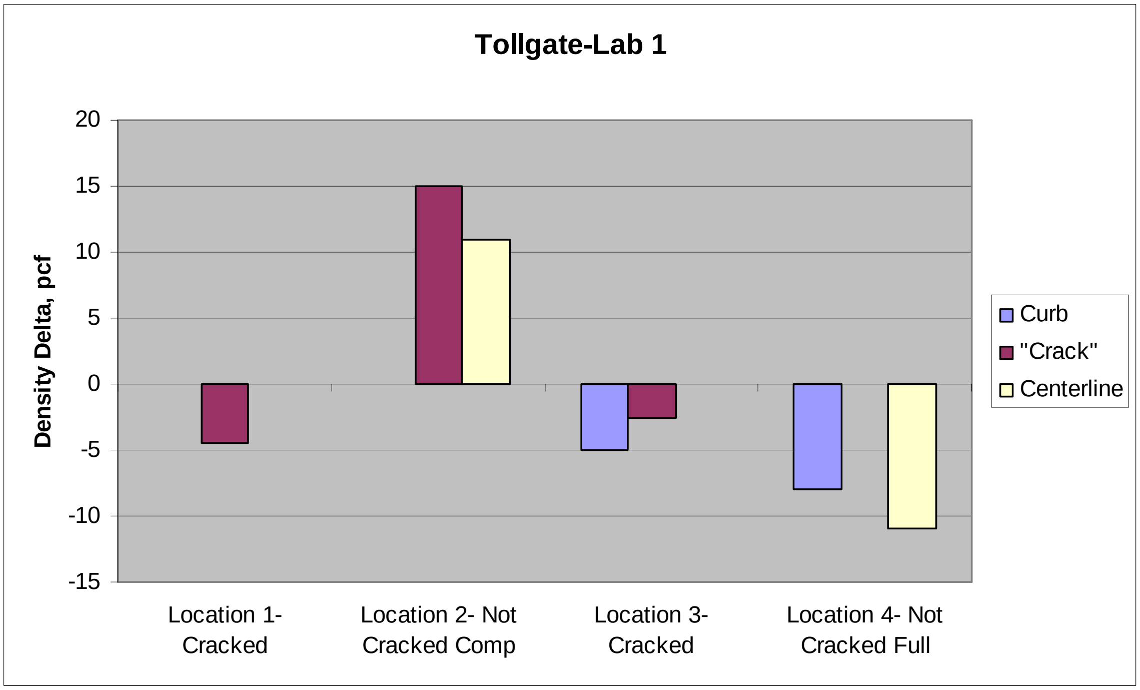

Figure 16 – Difference in Density between Insitu and Optimum for Tollgate Lab 1

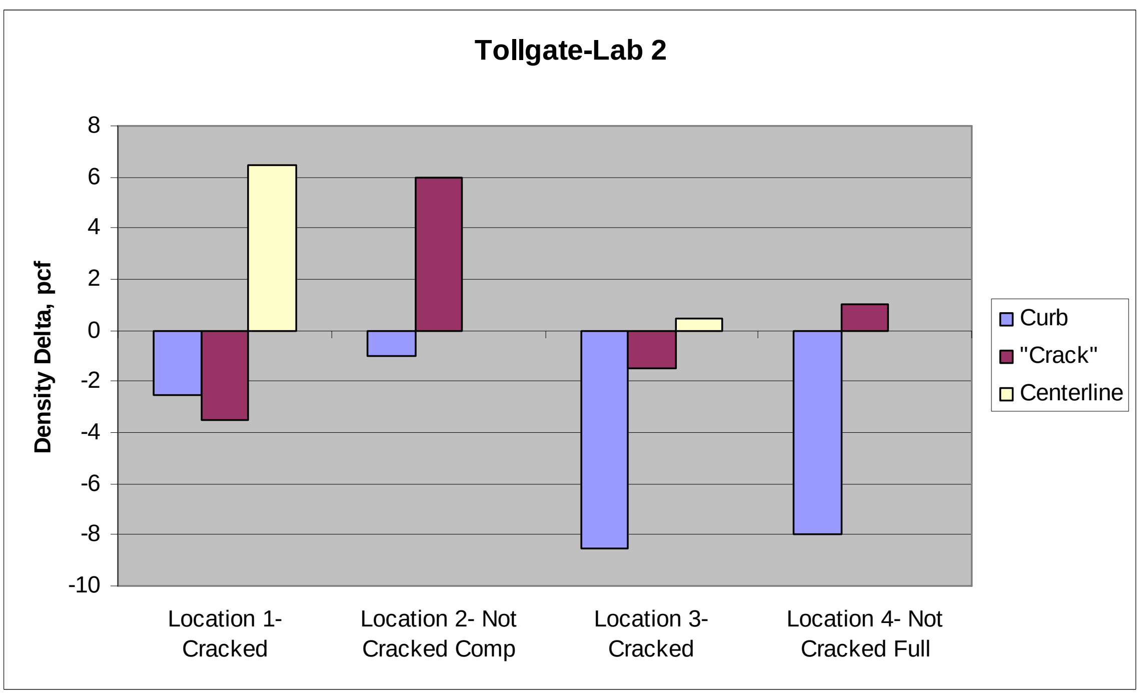

Figure 17 – Difference in Density between Insitu and Optimum for Tollgate Lab 2

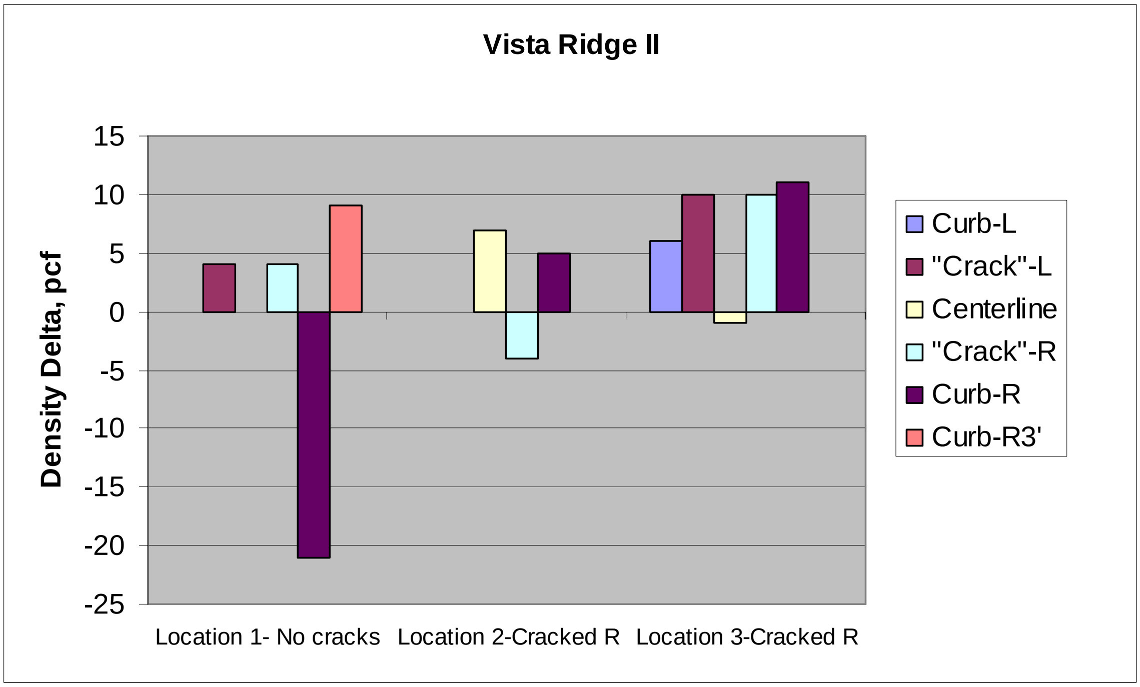

Figure 18 – Difference in Density between Insitu and Optimum for Vista Ridge II

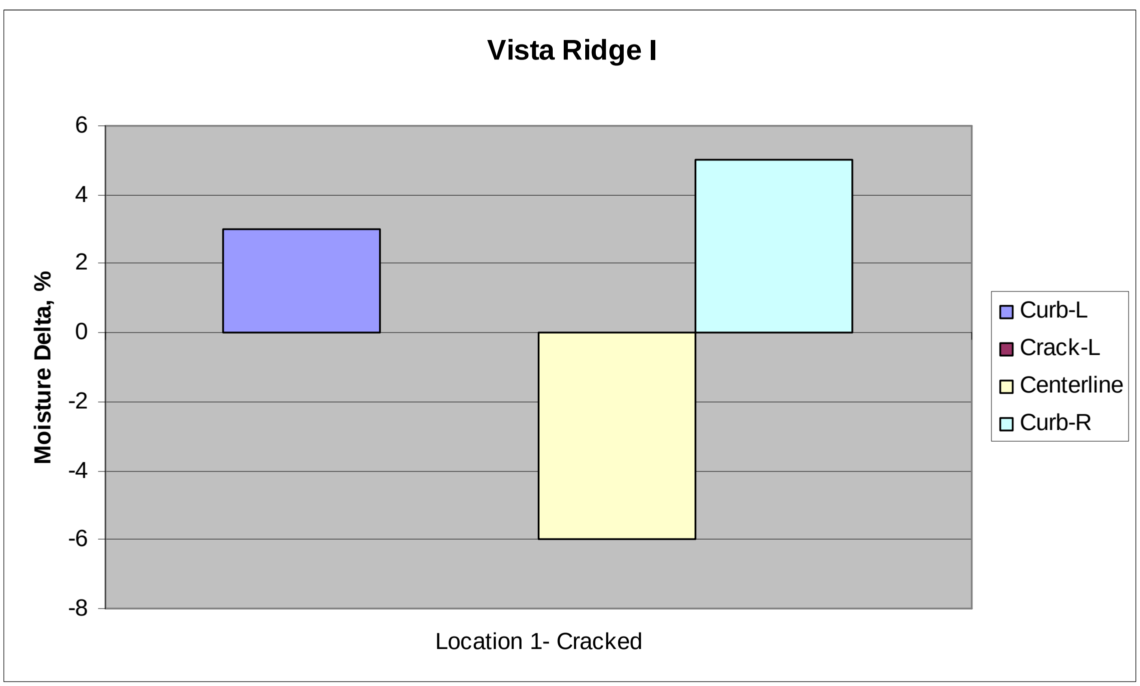

Figure 19 – Difference in Moisture between Insitu and Optimum for Vista Ridge I

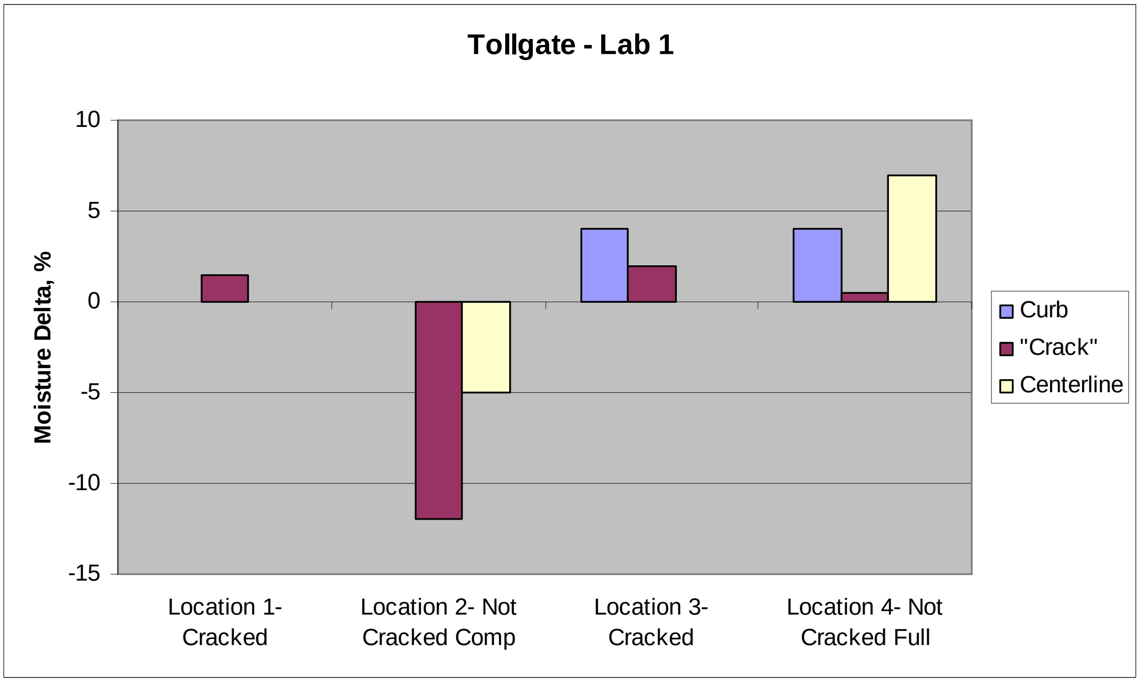

Figure 20 – Difference in Moisture between Insitu and Optimum for Tollgate Lab 1

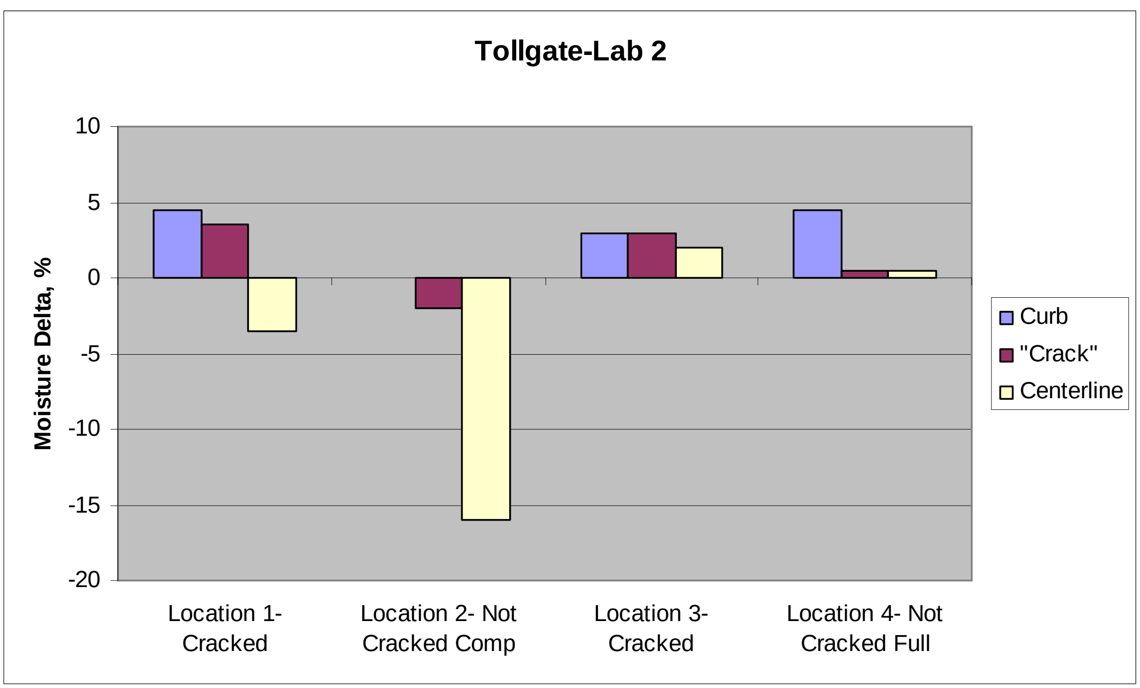

Figure 21 – Difference in Moisture between Insitu and Optimum for Tollgate Lab 2

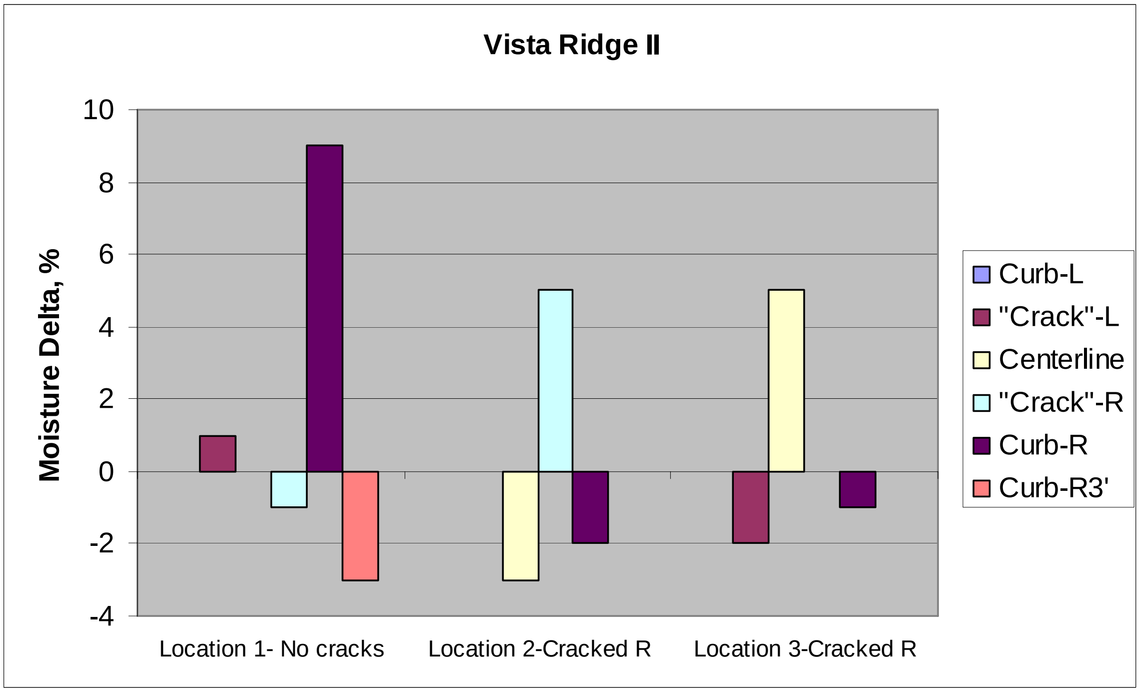

Figure 22 – Difference in Moisture between Insitu and Optimum for Vista Ridge II

Table 6 – Density Gradient Curb to "Crack"

Density Insitu, %												
	Vista Ridge I	Tollgate 1-1	Tollgate 1-2	Tollgate 1-3	Tollgate 1-4 "No"	Tollgate 2-1	Tollgate 2-2 'No'	Tollgate 2-3	Tollgate 2-4 'No'	Vista II-1 'No'	Vista II-2	Vista II-3
Curb-L				91	88	91	94	88	89			
"Crack"-L				94	97	90	101	95	98			
Centerline												
"Crack" R										111	103	120
Curb-R										86	112	121
Curb R+3'												

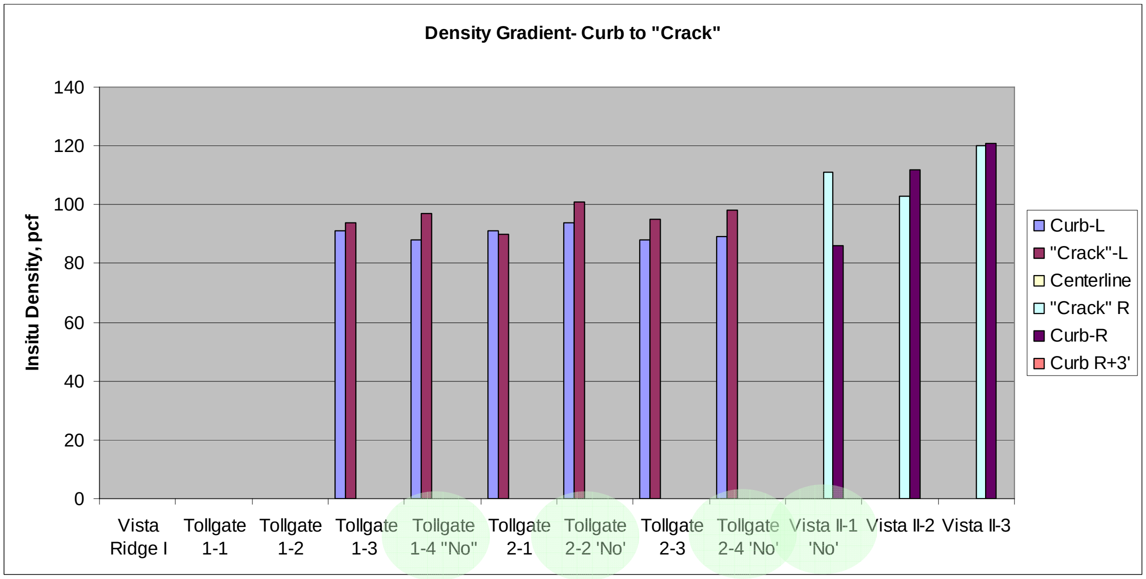

Figure 23 – Density Gradient Curb to "Crack"

Table 7 – Moisture Gradient Curb to "Crack"

	Moisture Insitu, %										
	Vista I	Tollgate 1-2 "No"	Tollgate 1-3	Tollgate 1-4 "No"	Tollgate 1-2	Tollgate 2-2 "No"	Tollgate 2-3	Tollgate 2-4 "No"	Vista II-1 "No"	Vista II-2	Vista II-3
Curb-L	23	24	29	29	30	25	27	28			16
"Crack"-L	20	13	26	24	29	23	27	24			14
"Crack" R									18	24	16
Curb-R									28	17	15

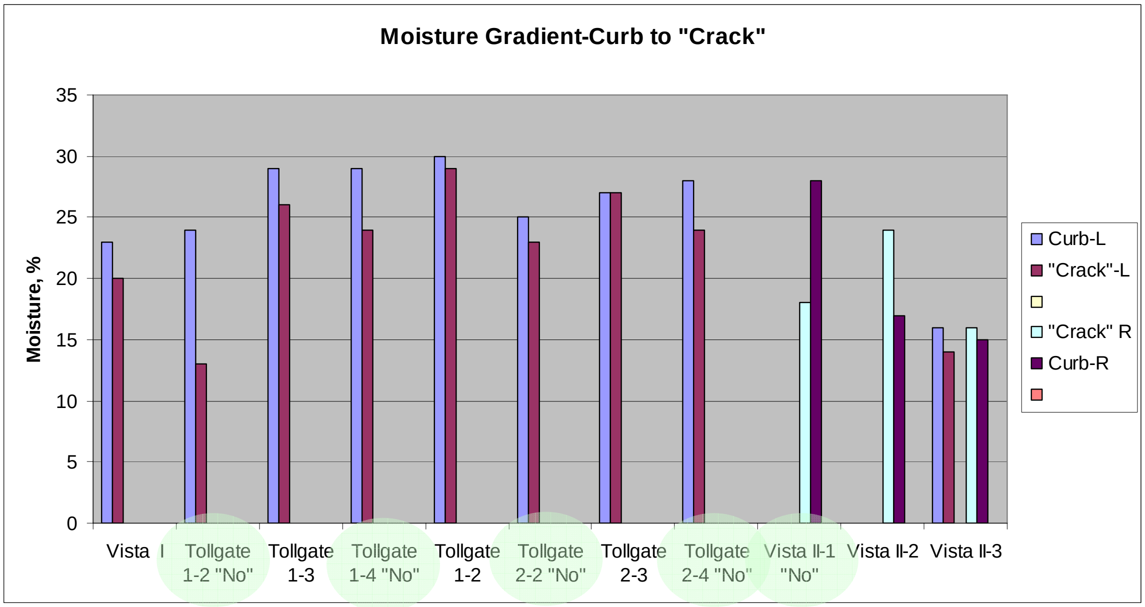

Figure 24 – Moisture Gradient Curb to "Crack"

The swell potential of the subgrade soils was evaluated at 100 pounds per square foot surcharge. The actual surcharge varied with each site depending on the actual pavement thickness. The actual surcharge in the case of Tollgate Crossing with 5-1/2 inches of full-depth asphalt pavement is approximately 69 psf, and approximately 100 psf in the composite section. Vista Ridge has approximately 113 psf. However, the difference between these values should not be considered significant with respect to swell behavior and the consistent 100 psf surcharge used allows better comparison between sites.

The results of this evaluation are shown in Figures 25 and 26 for swell percentage and Figures 27 and 28 for swell pressure.

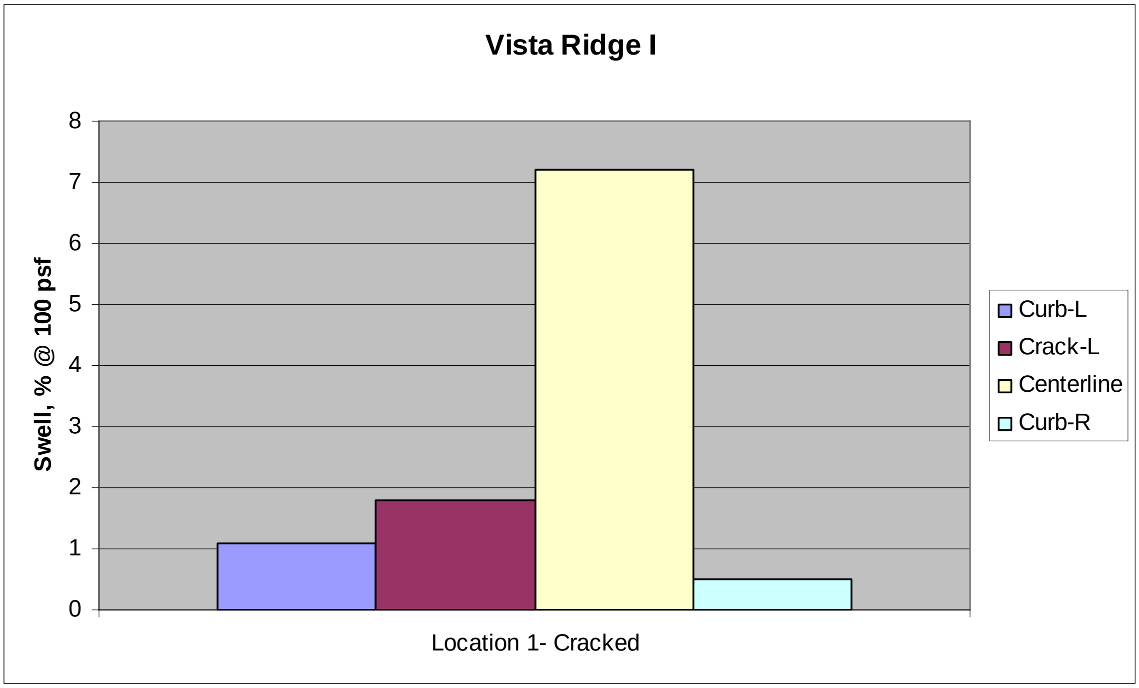

Figure 25 – Swell Potential for Vista Ridge I

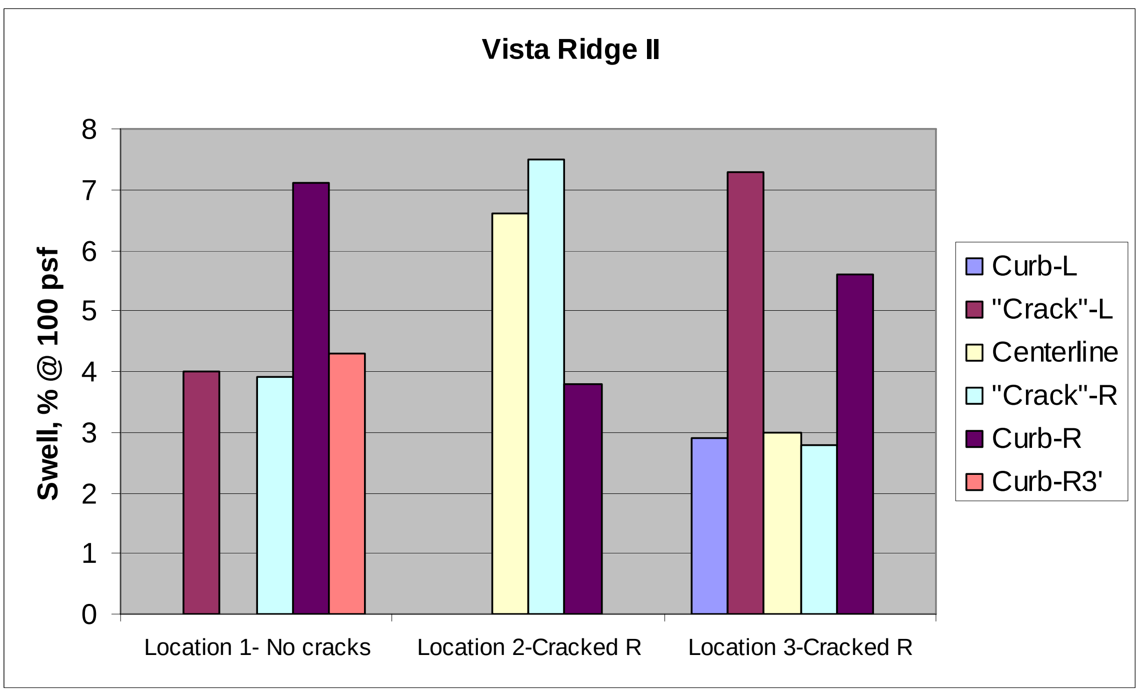

Figure 26– Swell Potential for Vista Ridge II

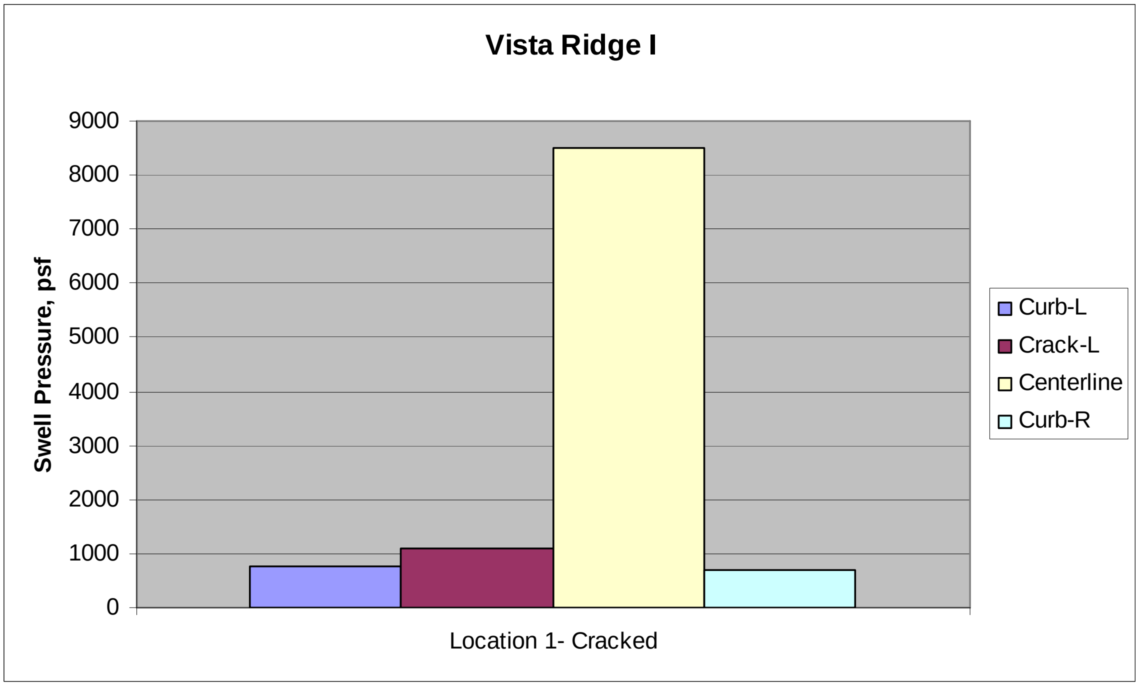

Figure 27 – Swell Pressure for Vista Ridge I

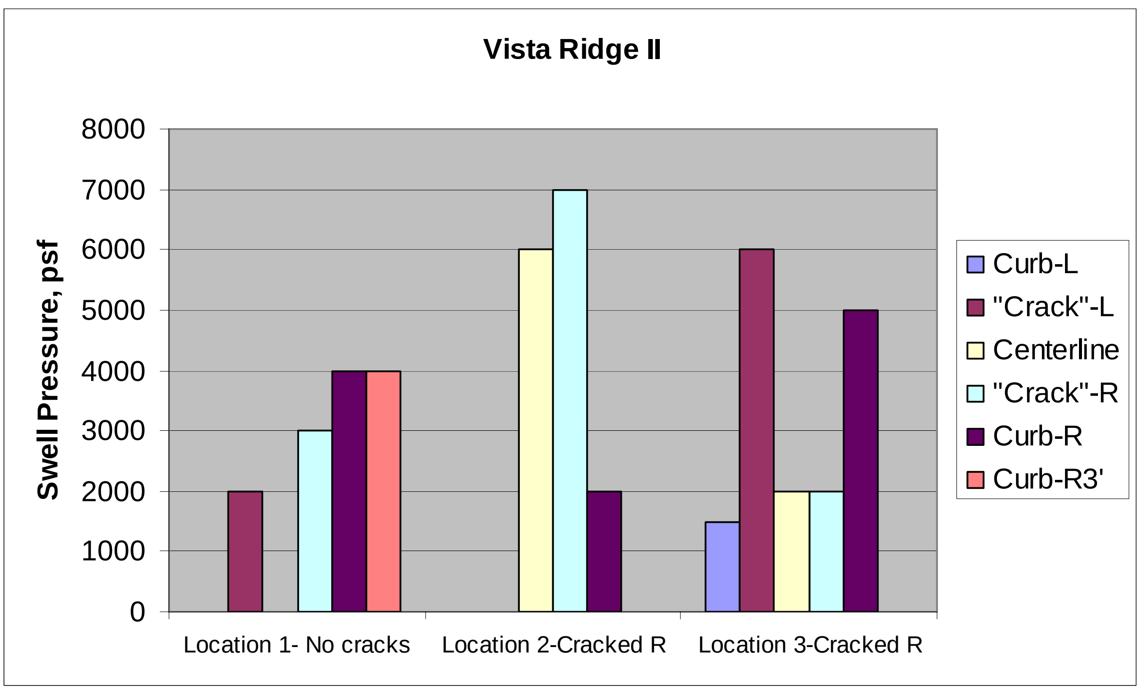

Figure 28 – Swell Pressures for Vista Ridge II

Probable Cause

There have been several reasons proposed as the cause of edge cracking in asphalt pavements. While there remains no definitive evidence that explains the cause or causes of edge cracking, to date, this study has helped to eliminate some of the potential causes, leaving fewer probable causes.

Swelling Soils

Figure 29 compares the swell potential for the cracked and uncracked pavements. Three of four cracked pavements had lower swell than the uncracked pavements. However, testing was conducted at insitu moisture contents, which may have been near or above optimum moisture. At these moisture contents significant swelling would not be expected. Therefore, since the swelling mechanism could create a crack originating at the surface of the pavement, swelling should remain a potential candidate for contributing to edge cracking.

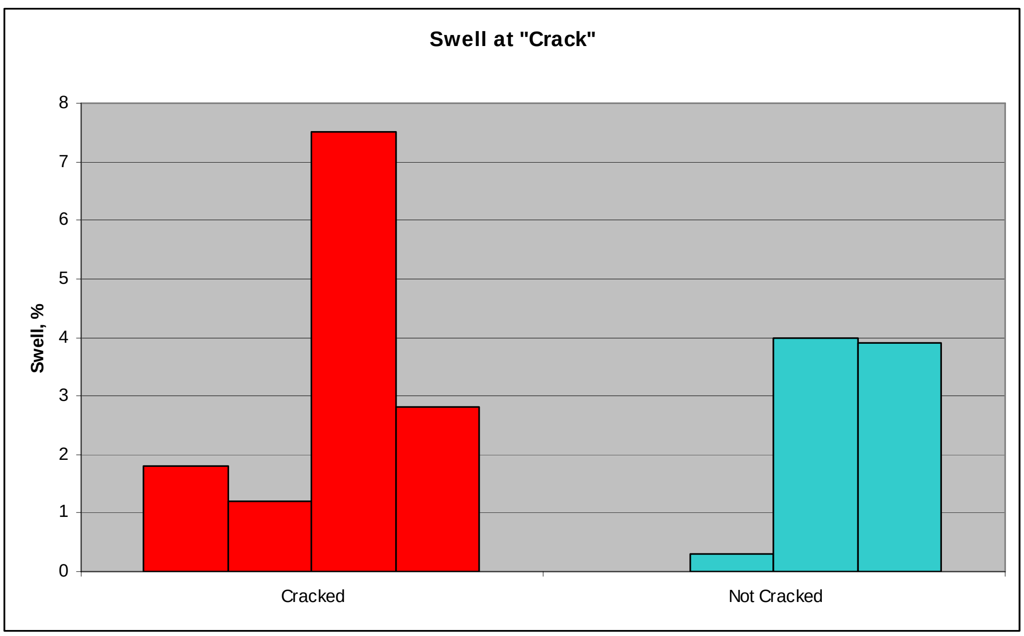

Figure 29 – Swell under Crack or Potential Crack Location

Asphalt Mixture

It has been suggested the Superpave mix design process may be contributing to edge cracking. Since Superpave has been implemented the gyratory compaction process has lead to lower optimum asphalt contents in some mixtures. In addition, somewhat harder asphalts are occasionally used. These two factors could contribute to an increase in stiffness of the asphalt mixture and potentially a lower strain tolerance. Although measuring the physical properties of the mixtures was not part of the scope of work Table 8 is a summary of some of the mixture characteristics used at each site:

Table 8 – Asphalt Mixture Characteristics at Each Site

Site	Paving Contractor	Asphalt Grade	Asphalt Refinery	Asphalt, %	Mix Grading	Dust: Asphalt
Vista Ridge I	1	PG 64-22	W	5.1	S	1.27
Tollgate Crossing	2	PG 64-22	W	5.0	S	1.36
Vista Ridge II	3	PG 64-22	C	5.5/4.6	S/SG	1.26

It appears that the PG64-22 binder and the S gradation are common to each site. Differences include the refineries producing the binders, asphalt content of the mixtures, dust to asphalt content, aggregate source, and paving contractor. Therefore, while there is some commonality between sites, there are more differences with respect to the paving mixtures and methods of construction. In addition, it is unreasonable to expect any asphalt mixture, even with a softer grade binder, to withstand the level of strain which has caused the edge cracking at the sites studied. Therefore, the likelihood that the asphalt mixture is contributing to edge cracking has low probability.

Subgrade Density beneath Crack or Potential Crack Location

Figure 30 compares the difference between subgrade insitu density and the maximum density determined by ASTM D698 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.

Subgrade Moisture beneath Crack or Potential Crack Location

Figure 31 compares the difference between subgrade insitu moisture content and the optimum moisture content determined by ASTM D698 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.

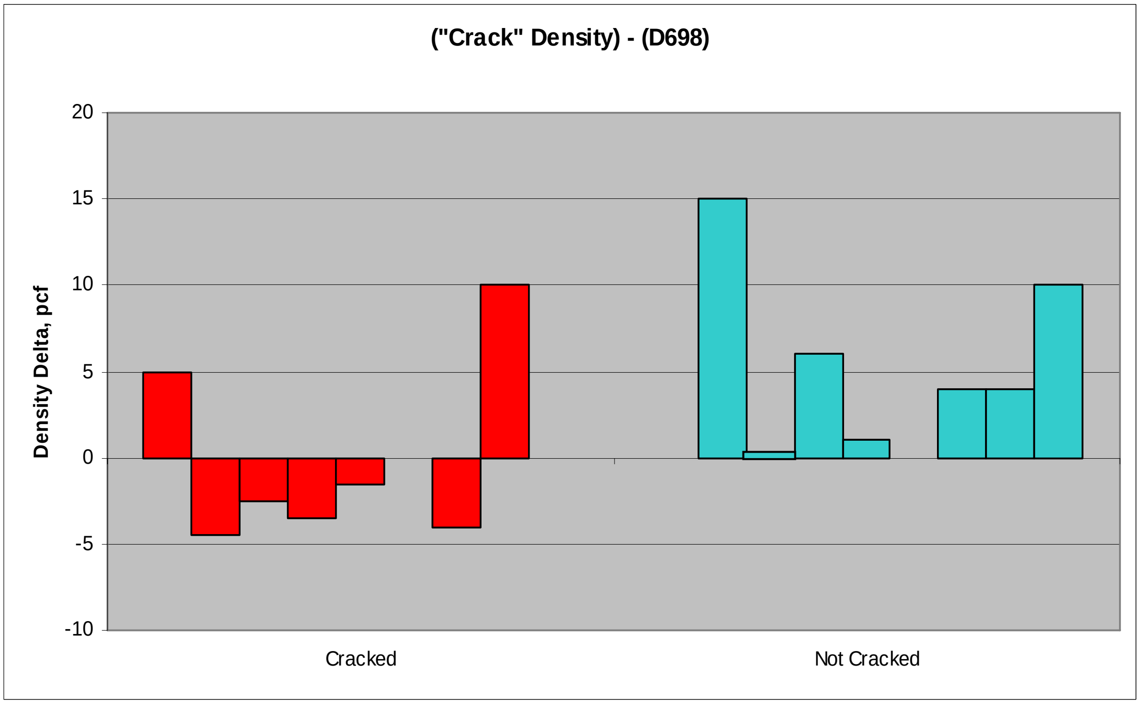

Figure 30 – Difference between Density Insitu and Maximum Density (ASTM D698)

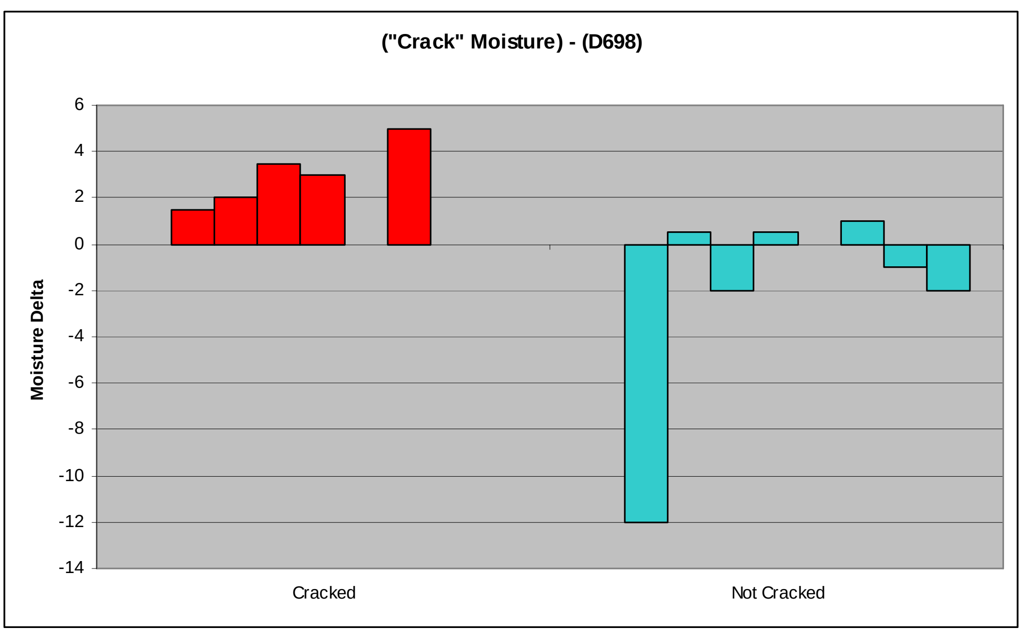

Figure 31 – Difference between Moisture Insitu and Maximum Density (ASTM D698)

Subgrade Density and Moisture Difference - Behind Curb to Crack or Potential Crack Location

It has been suggested that edge cracking is 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 or potential crack location. Figures 32 and 33 are the results of this comparison.

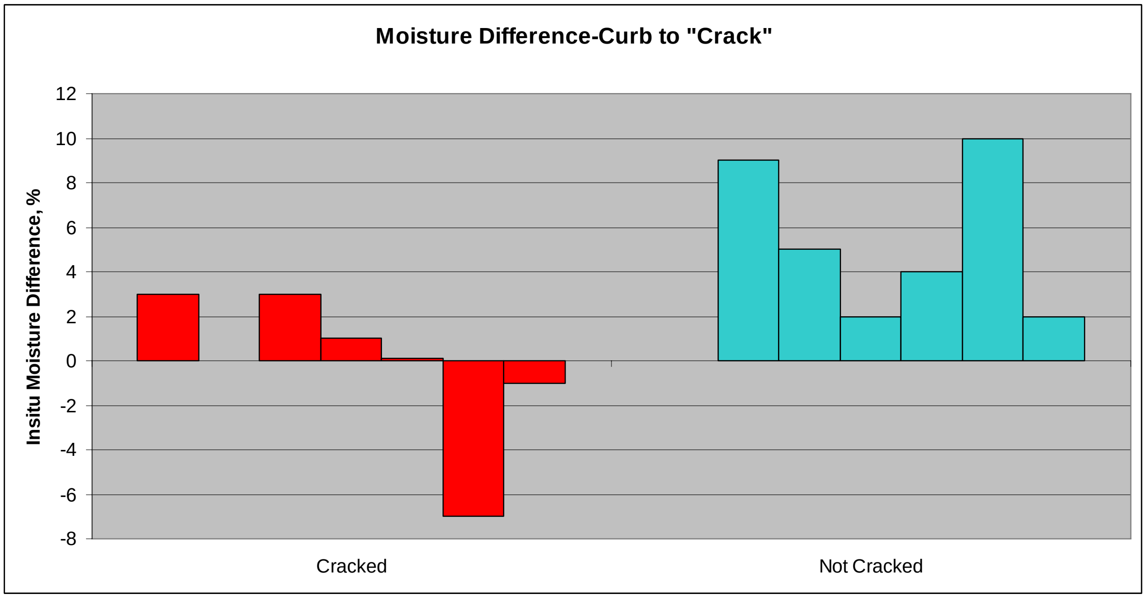

Figure 32 – Moisture Difference From Behind Curb to Crack or Potential Crack Location

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 or potential 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.

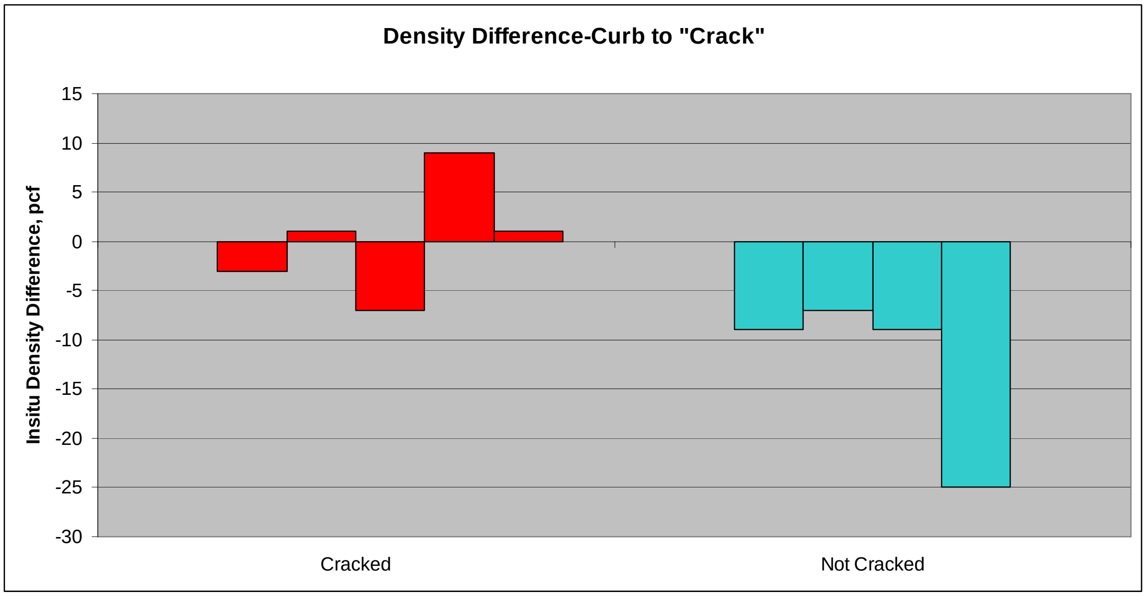

Figure 33 – Density Difference From Behind Curb to Crack or Potential Crack Location

Summary of Findings

1. Cracking at all eight sites began at the top of the cores.
2. The slope of the pavement across all cracks appeared to be constant except at Tollgate, Site 3 where ‘tenting’ was observed, i. e., the crack appeared elevated relative to the pavement on either side.
3. No cracking was observed in the composite pavement sections located in the same development as the full-depth sections. However, there were areas in the full-depth sections where cracking was also not observed. Therefore, it is not clear from this preliminary study whether cracking is confined to full-depth pavements, only. More work is needed to determine the differences between the two pavement types with respect to edge cracking.
4. Pavements with cracks had higher density and lower moisture behind the curb than under the crack.
5. There does not appear to be a correlation between cracking and swell potential or pressure. Although swell and pressure was high in one cracked location (Vista Ridge II, Location 2) both were lower in another cracked location (Vista Ridge II, Location 3). This is the location where ‘tenting’ was observed at the crack when a straightedge was placed on the crack. However, testing was conducted at insitu moisture content which may have been high enough to preclude swelling.
6. The swell percentage and pressure of the uncracked location at Vista Ridge II tended to be lower than the cracked locations. However, the swell of the soils under the cracked locations generally tended to be lower than the swell under similar locations at uncracked sites.
7. The density of the soil in the composite section of Tollgate Crossing was higher than optimum and the moisture content of these soils were lower than optimum. The moisture of the soils in all full-depth sections were higher than optimum and the densities were lower than optimum. Both laboratories provided the same result, although absolute values were different.

8. Moisture content is at least 1% lower than optimum under the uncracked pavements and approximately 2% over optimum or higher under the cracked pavements in the area of the crack or potential crack. There appears to be a trend to densities higher than optimum under the uncracked pavements and lower than optimum under the cracked pavements. It is possible densities are lower over the cracked pavements because compaction was attempted on soils with low bearing capacity caused by high moisture content.

9. Asphalt mixtures at each site were designed by Superpave using an S gradation and PG 64-22 binders. However, mixes had different asphalt contents, from different producers, aggregates were from at least three different sources, paved by three different contractors and the character of the gradations was different for each. Therefore, without significant laboratory materials characterization to prove otherwise, it seems unlikely the mixtures have the same physical properties. In addition, it is unreasonable to expect any asphalt mixture, even with a softer grade binder, to withstand the level of strain which has caused the edge cracking at the sites studied. Therefore, the likelihood that the asphalt mixture is contributing to edge cracking has low probability.

10. The soils obtained from each site varied somewhat between samples. This variability can be seen in the differences in moisture and density data between Laboratories 1 and 2 from Tollgate Crossing. In addition, there were significant differences in moisture content within the same samples for Tollgate Crossing as reported by both laboratories even though samples were taken from at least 12 inches below the ground surface in all cases. For this reason, analysis of results for moisture and density was done using the test results from the bottom portion of the 12 inch core. Nevertheless, differences in test results could also be due to no homogeneity in the soils themselves.

Conclusions

1. The edge cracking observed at all eight locations in this study began at the top of the pavement. This means that upward movement from below and/or bending is causing excessive tensile strain at the surface of the pavement. The result is edge cracking.

2. Lower density and higher moisture than optimum of the subgrade beneath the edge cracks appears to be related to the cracking.

3. The soils at all three locations were plastic clays with potential for high volume change. It seems likely that swelling of these soils contributed to the edge cracking, however, no strong correlation was found.

4. Edge cracking is probably not related to the asphalt mixture.

Recommendations

1. The cause of edge cracking in asphalt pavements remains unclear. This result was not unexpected since this study was intended as exploratory research to focus future work (see CSU Proposal "Edge Cracking in Asphalt Pavements: Phase 1-Probable Cause"). However, there appear to be apparent differences in the material properties of the subgrade soils for the composite asphalt pavement and corresponding full-depth pavements in the same development. Observations of composite versus full-depth pavements were not planned in the original proposal, but should be examined further to determine if the differences observed are trends. If so, these differences may be important clues to why the one type of pavement cracks.

2. Observations should be made of the pavements that displayed no cracking in this study to determine if cracking has occurred since these observations were made.

3. Three pavements should be constructed in developments where edge cracking has been observed. Construction should mimic that for other pavements which manifested edge cracking. One pavement should be a full-depth section and one should be a composite section. The subgrade soils should be thoroughly characterized before, during and after construction so that changes occurring in the soil properties can be recorded prior to crack initiation. Moisture content of the subgrades 12 inches below the pavements should be placed under, at, and above optimum and compacted to achieve 95 percent of maximum dry density, if possible.
4. One laboratory should be utilized to conduct all testing in any future study. This will minimize variability associated with testing differences between laboratories and personnel.

References

1. CTL Thompson Report dated July 19, 1999 to U. S. Homes Corporation for Job No. CS-9234
2. EEC Report dated October 10, 2001 to LAJ 2000, Project No. 1004077
3. EEC Report dated December 19, 2001 to Schmidt Earth Builders, Project No. 1994101
4. EEC Report dated January 29, 2002 to Asphalt Specialties, Project No. 1022001
5. Unpublished account by CTL Thompson to MGPEC.

Acknowledgements

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