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EXTENT OF TOP-DOWN CRACKING IN COLORADO

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DEPARTMENT OF TRANSPORTATION RESEARCH

July 2003

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

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16. Abstract

In 2000, a forensic evaluation was conducted on a project that was exhibiting early longitudinal cracking near the wheel paths. A team of national asphalt experts conducted this forensic evaluation. The forensic team concluded that the cracking on the project was surface initiated cracking and was caused by a number of contributing factors. One of the contributing factors to the early distress that was identified by the experts were the pockets of segregation that were observed at the bottom of the surface lift but were not apparent on the surface.

The object of this study was to determine the extent of "top-down cracking" in Colorado, what causes it, how can it be prevented, if it occurs how is the distress treated, and how quickly does the distress need to be treated.

Out of the twenty-five sites that were cored 72% contained top-down related cracking. Of these 18 sites 67 had visual evidence of segregation.

Implementation

In 2003, a new mix design change was incorporated. The mix design change allows for an increase in the asphalt cement content which will ultimately reduce the potential for segregation to occur.

The Colorado Department of Transportation, in cooperation with industry, has established a segregation task force to develop a specification for segregation. This task force will be developing the specification to identify sub-surface segregation.

Paving equipment manufacturers have also identified areas within the paver that promote segregation. The manufacturers have taken the initiative to develop an anti-segregation kit.

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Executive Summary

In 2000, a forensic evaluation was conducted on a project that was exhibiting early longitudinal cracking near the wheel paths. A team of national asphalt experts conducted this forensic evaluation. The forensic team concluded that the cracking on the project was surface initiated cracking and was caused by a number of contributing factors. One of the contributing factors to the early distress that was identified by the experts were the pockets of segregation that were observed at the bottom of the surface lift but were not apparent on the surface.

The object of this study was to determine the extent of "top-down cracking" in Colorado, what causes it, how can it be prevented, if it occurs how is the distress treated, and how quickly does the distress need to be treated.

Twenty-five sites were cored to determine the type of distress in terms of top-down versus reflective cracking. The longitudinal crack in 72% (18 of 25) of the sites that were cored was top-down related cracking. Of these 18 sites 67% had visual evidence of segregation.

In addition the manufacturer and model of the pavers used on the projects were identified. Identifying the manufacturer and model of the paver that was used on specific projects helped to determine the relationship between the edges of the slat conveyors and the location of the longitudinal cracks found in the pavement. On the projects that were identified to have top-down cracking, the location of the longitudinal cracking typically corresponded to the outside edges of the slat conveyors or to the center point of the paving equipment.

The Colorado Department of Transportation (CDOT) and the asphalt paving industry have begun to take steps to help reduce the potential for paver segregation.

With the mix design changes that were incorporated during 2003, the potential for top-down cracking should be reduced. The change allows for an increase in the asphalt cement content in the mix, which will ultimately reduce the potential for segregation to occur.

CDOT, in cooperation with industry, has established a segregation task force. This task force will be developing a specification that will help to identify sub-surface segregation during construction.

Paving equipment manufacturers have also identified areas within the paver that promote segregation. The manufacturers have taken the initiative to develop an anti-segregation kit that can be retrofitted onto existing pavers.

Since approximately 67% of the top-down cracking cores had visual signs of segregation, the report recommends that the cracks be sealed as soon as possible. If moisture is allowed into the pavement through the cracks the segregated areas will be prone to rapid deterioration. Sealing the crack will prevent moisture from penetrating the pavement and deteriorating the pavement further.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 BACKGROUND

In July 1997, a section of I-25 between Colorado State Highway 7 and 120th Avenue in Denver, Colorado was rehabilitated. Construction on the project consisted of milling up to 3 inches of the existing pavement and replacing with 3 inches of hot bituminous pavement. A total of 62,000 tons of a ¾" Superpave asphalt mixture was placed. The ¾" mixture was designed using the Superpave gyratory compactor (109 design gyrations) with a performance graded 76-28 asphalt binder. The project received bonuses for material quality and smoothness, as well as passed all the torture tests (Hamburg and French Wheel Rutter) in Colorado Department of Transportation's Euro Laboratory.

Within a year of completion longitudinal cracks appeared in the surface. The cracking appeared in the outside lanes of both the north and southbound direction. The severity of the cracking ranged from low to medium and in some locations high severity. The occurrence of this premature cracking prompted a series of investigations.

The first investigation included obtaining three cores over the top of the existing longitudinal cracks. In two of the three cores it was apparent that the cracks were reflecting through from the underlying pavement. It was determined from this investigation that the reflective cracking was created by the presence of moisture and traffic. Although the mix and thickness design for this project met state-of-the-art procedures the appearance of the longitudinal cracking in the wheel path initiated the study, which produced the report titled "Guidelines for Selection of Rehabilitation Strategies for Asphalt Pavement". [1]

By May 2000, the pavement was beginning to deteriorate quite rapidly. The cracking was now throughout the entire length of the project. There were three longitudinal cracks in lane number one (Figure 1): two on either side of the left wheel path and one on the left side of the right wheel path. Region 6 requested a forensic evaluation of the project. A team of three national asphalt material and construction experts (Michael Anderson, Asphalt Institute, John D'Angelo, FHWA, Gerry Huber, Heritage Research) was established to perform a forensic evaluation.

Figure 1. Longitudinal cracking was found on this project as shown in this photograph. This cracking pattern was consistent throughout the entire length of the project.

The forensic team met with members of the CDOT project team, which included the project engineers and technicians. They reviewed the project construction data and the condition videotapes of the project prior to rehabilitation; they also developed a study plan. The plan included a forensic investigation on a distressed and non-distressed area in the project. Cores were taken for determining the volumetric properties, mixture composition, recovered asphalt binder properties, and mixture mechanical properties. A full depth slab was also cut across the width of the number one lane. Figure 2 shows the location of the cracks with respect to the other longitudinal cracking.

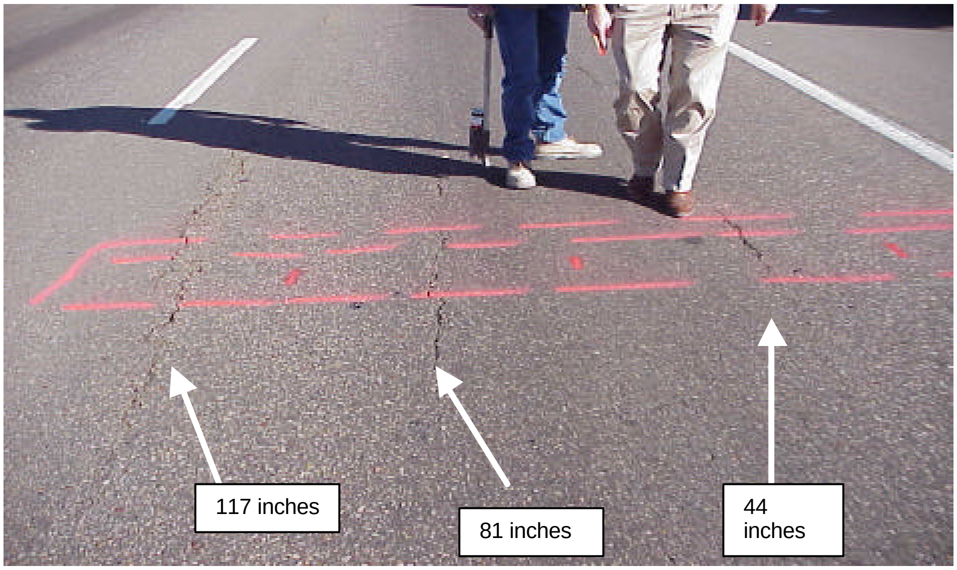


Figure 2. **This photograph shows the location of each crack with respect to the other cracks. The distance is measured from the outside shoulder stripe.**

Although this forensic study was limited to sampling in only a small section of the roadway, the section sampled was representative of the entire project. The forensic team concluded that the cracking on the project was surface initiated cracking and was caused by a number of contributing factors. One of the factors was the pockets of segregation that were observed at the bottom of the lift in the slab that was taken across the pavement (Figure 3). There is not a concentration of the rocks near the surface so no segregation was visible from the surface. Other contributing factors include percentage of air voids in the pavement, volume of effective asphalt binder and physical properties of the asphalt binders. Details of this forensic study are documented in the CDOT report titled “Forensic Investigation of Early Cracking on I-25 In Denver, Colorado”.[2]

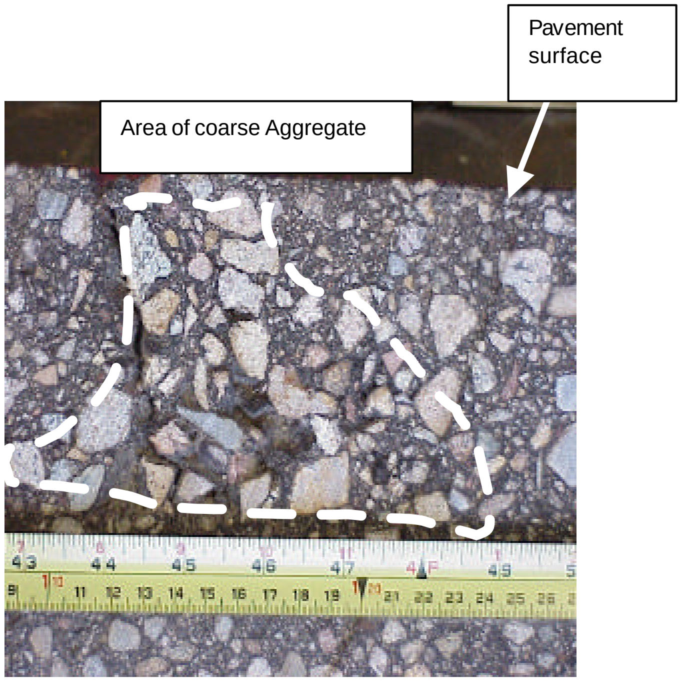


Figure 3. There was segregation present within the mat at each of the cracks. The segregation was particularly severe at the 44-inch crack.

CDOT has addressed all the contributing factors that were identified by the forensic team. This report documents the quick study that was developed to determine the extent of surface initiated cracking (top-down cracking) in Colorado.

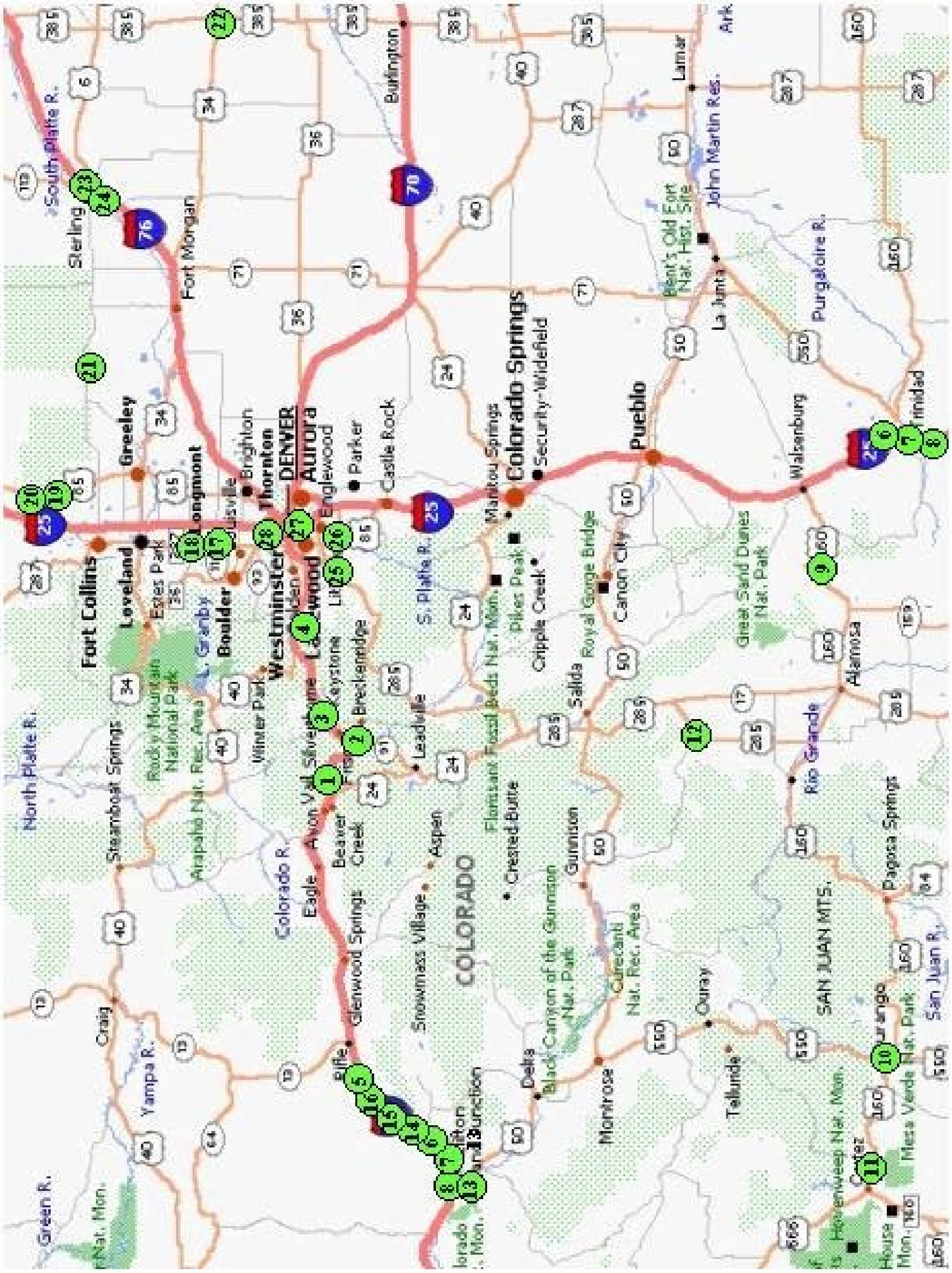
The objective of this study was to determine the extent of "top-down cracking" in Colorado, what causes it, how can it be prevented, if it occurs how is the distress treated, and how quickly does the distress need to be treated.

2.0 PROJECT SELECTION

The Region Materials Engineers (RME) and the Area Engineer of the Project Development Branch provided the projects selected for evaluation. The RME's were asked to provide the location of projects, which were experiencing longitudinal cracking in the wheel path. The Project Development Branch also provided a number of the projects for evaluation.

There were a total of 28 sites selected for evaluation but only 25 sites were actually evaluated. It was not possible to obtain cores from three of the sites as they had either been overlaid or traffic control was not possible to schedule. Figure 4 shows the location of the projects that were evaluated.

Figure 4. Project locations



3.0 EVALUATION CRITERIA

The project study panel met to discuss what the process would be for the collection of data. The plan for collection of data included:

- Visual survey of the project.
- Obtaining a 6” core over the longitudinal crack.
- Visual observation of the core to determine if the cracking had initiated at the surface and cracked downward or if the crack was reflective and had propagated to the surface from the underlying layer.
- If the crack appeared to be reflective, no addition cores were taken.
- If the crack appeared to have initiated at the surface (top-down), two additional 10” cores were obtained.
- An additional 10” core centered over the crack, and one 10” core 18” to the side of the core transversely in an uncracked area.

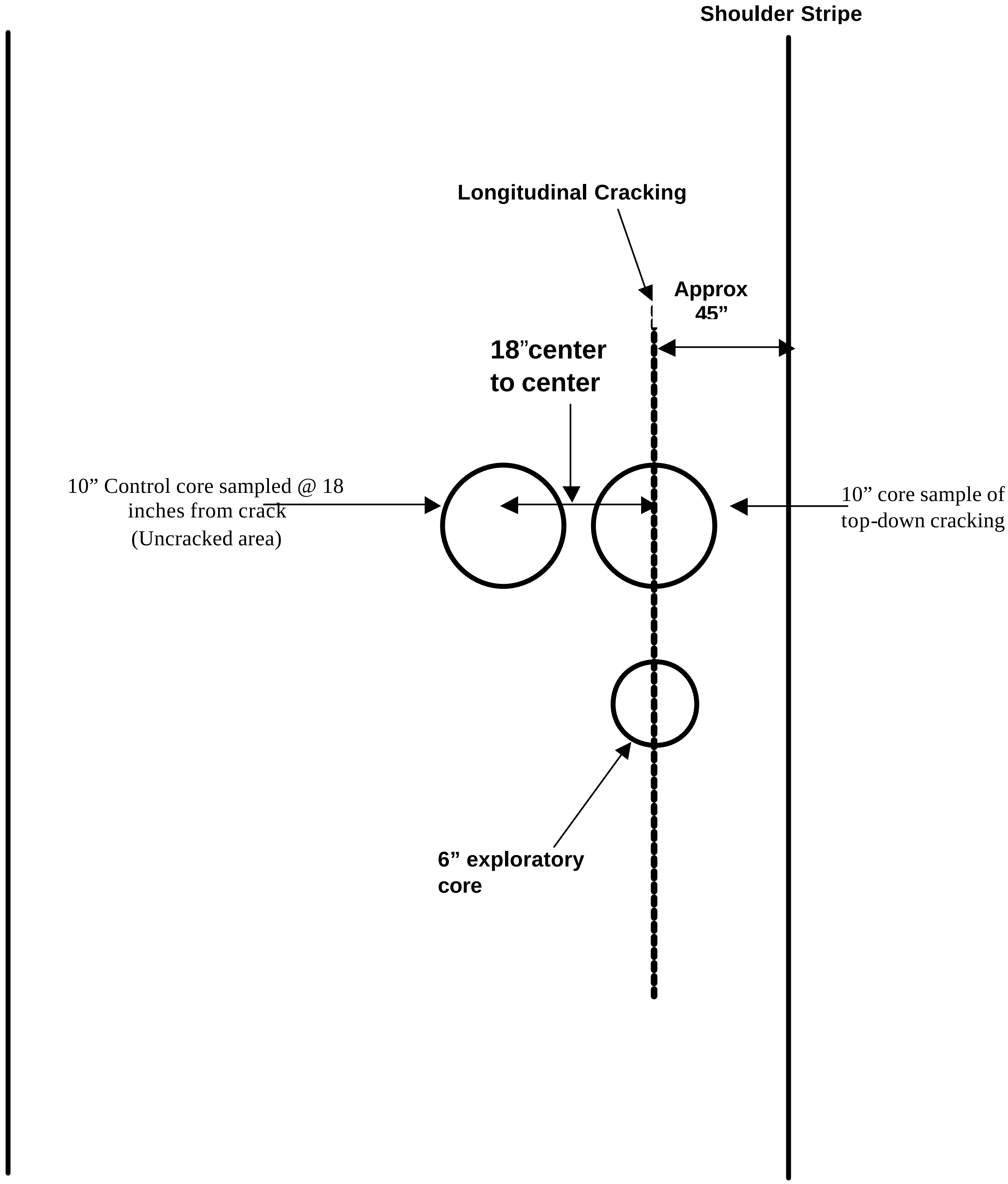
In addition, the longitudinal cracks in relationship to the longitudinal construction joints were measured to determine if there was any correlation between specific locations on the paver and the location of the longitudinal crack.

Figure 5 is a typical diagram of the core configuration taken during each project evaluation.

The cores from the top-down cracking sites were sent to the laboratory for further investigation. In the laboratory, the cores taken over the cracked area and the uncracked area were visually inspected for possible segregation. A gradation for each of the cores was obtained with the ignition oven. The gradation of the cracked core was compared to the uncracked core to determine if it was possible to detect the segregation through a difference in gradation.

Appendix A contains photographs taken during each evaluation.

Figure 5. **Diagram of typical coring configuration for top-down cracking sites**



4.0 RESEARCH FINDINGS

4.1 Identifying Distress

Twenty-five sites were cored to determine the type of distress in terms of top-down versus reflective cracking.

Table A lists the location of the projects that were selected for evaluation. This table also indicates if the cracking as determined from the cores was reflective (light gray shading) or top-down (dark gray shading). Figure 6 is a core from a project that was determined to be reflective. Figure 7 is a core that clearly shows the crack initiated at the surface and is cracking down (top-down).

Only the top-down cracking sites are summarized in Table B. This table also shows whether the cores taken over the crack exhibit any visual signs of segregation (gray shading). In addition, results from the gradation (% passing the #4 and #8 sieves) of the cracked and uncracked cores are shown in Table B.

Figure 6. This crack is reflective, as it goes through the entire thickness of the pavement

Figure 7. This crack is top-down as you can see it is only visible in the top lift

Table A. Evaluation site information

Site Number	Region	Location (Hwy, Direction, Lane, Milepost)	Crack Type
1	1	I-70 EB Driving Lane, M.P. 185.7	Top-down
2	1	I-70 EB Driving Lane, M.P. 193.8	Top-down
3	1	I-70 EB Driving Lane, M.P. 194.3	Top-down
4	1	I-70 EB Driving Lane, M.P. 232.0	Unable to core
5	2	I-70 EB Driving Lane, M.P. 75.3	Reflective
6	2	I-25 Driving Lane, M.P. 17.6	Top-down
7	2	I-25 Driving Lane, M.P. 11.7	Reflective
8	2	I-25 Driving Lane, M.P. 9.2	Reflective
9	2	US 160, M.P. 282-283	Unable to core
10	5	US 160, Jct 550, M.P. 87.7	Reflective
11	5	US 160, E. of Cortez to Mesa Verde	Unable to core
12	5	US 285, SB, M.P. 96.5 (Saquache)	Top-down
13	3	US 50, NB Driving Lane, MP 41.2 (Red Mountain)	Top-down
14	3	I-70, EB M.P. 38.2 (Clifton)	Top-down
15	3	I-70, EB M.P. 64.0, Driving lane (DeBeque)	Top-down
16	3	I70, EB M.P. 74.1, Passing Lane (Parachute)	Top-down
17	4	SH 119, SB Driving Lane; M.P. 51.7 (Longmont)	Top-down
18	4	US 287, NB Driving Lane, (north of 9th Street)	Top-down
19	4	US 85, MP 280.2, NB, Driving Lane (North of Ault)	Top-down
20	4	US 85, M.P. 292.2, SB (Nunn)	Top-down
21	4	SH 114, M.P. 198.8, EB (Buckingham)	Reflective
22	4	US 385, M.P. 253.3, SB (North of Wray)	Reflective
23	4	I-76, M.P. 127.3, WB, Passing Lane (Sterling Rubblization)	Top-down
24	4	US 6, WB, M.P. 409.2, (Sterling)	Reflective
25	6	US 285, NB. M.P. 251.3, Driving Lane	Top-down
26	6	C-470, WB, M.P. 11.3, Passing Lane	Top-down
27	6	I-76, M.P. 1.2 – 1.3	Top-down
28	6	I-25, M.P. 218.6	Top-down

Table B. Sites that contained top-down cracking

Site Number	Location	Visible Segregation	Core	Percent on No. 4	Percent on No. 8
1	I-70 EB Driving Lane, M.P. 185.7 (Region 1)	Yes	Cracked	61	43
			Uncracked	70	52
2	I-70 EB Driving Lane, M.P. 193.8	Yes	Cracked	45	34
			Uncracked	50	38
3	I-70 EB Driving Lane, M.P. 194.3	Yes	Cracked	48	36
			Uncracked	50	37
6	I-25 Driving Lane, M.P. 17.6	No	Cracked	57	41
			Uncracked	58	42
12	US 285, SB, M.P. 96.5 (Saquache)	No	Cracked	52	36
			Uncracked	53	36
13	US 50, NB Driving Lane, MP 41.2 (Red Mountain)	No	Cracked	42	29
			Uncracked	46	31
14	I-70, EB M.P. 38.2 (Clifton)	Yes	Cracked	56	42
			Uncracked	60	44
15	I-70, EB M.P. 64.0, Driving lane (DeBeque)	Yes	Cracked	58	45
			Uncracked	61	48
16	I70, EB M.P. 74.1, Passing Lane (Parachute)	Yes	Cracked	57	45
			Uncracked	61	48
17	SH 119, SB Driving Lane; M.P. 51.7 (Longmont)	Yes	Cracked	53	41
			Uncracked	64	49
18	US 287, NB Driving Lane, (north of 9th Street)	No	Cracked	58	47
			Uncracked	59	48
19	US 85, MP 280.2, NB, Driving Lane (North of Ault)	Yes	Cracked	53	38
			Uncracked	65	47
20	US 85, M.P. 292.2, SB (Nunn)	Yes	Cracked	57	40
			Uncracked	74	56
23	I-76, M.P. 127.3, WB, P L (Sterling Rubblization)	No	Cracked	55	40
			Uncracked	63	46
25	US 285, NB. M.P. 251.3, D L	Yes	Not enough material to test		
26	C-470, WB, M.P. 11.3, P L	Yes	Not enough material to test		
27	I-76, M.P. 1.2 – 1.3	No	Cracked	65	52
			Uncracked	67	53
28	I-25, M.P. 218.6	Yes	Not enough material to test		

The longitudinal crack in 72% (18 of 25) of the sites that were cored was top-down related cracking. Of these 18 sites, 67% had visual evidence of segregation.

Table C. Percent of specific distress in evaluation site

Distress	Percent of distress found in the 25 evaluated sites
Reflective Cracking	28%
Top-Down Cracking (Segregation)	48%
Top-Down Cracking (No Segregation)	24%

The ignition oven was used to determine gradation of the cracked and uncracked cores. The segregation that was visible within these cores was very minimal and typically could only be seen on one side of the core. The segregation was not visible throughout the entire depth or width of the core. Although there was clear evidence that segregation was apparent, it was so limited that it is possible that the overall gradation would not be significantly affected. The diameter and height of the core created a large enough sample that the small pocket of segregated aggregates could have been diluted.

Gradations were determined using the ignition oven for cores that had visual segregation. The difference in the percent passing on the #4 sieve for the cracked and uncracked cores ranged from 2 to 17, with a mean or 7.4 and a standard deviation of 5.1. For the # 8 sieve the range was 1 to 16, with a mean of 6.1 and a standard deviation of 4.8. Based on the results from the ignition oven, CDOT's current specification for determining segregation (Appendix B) is inconclusive.

4.2 Paver Configuration and Location of Longitudinal Crack

Further investigation was done to determine the manufacturer and model of the pavers used on the projects that exhibited top-down cracking. In addition the location of the longitudinal cracking on the project with respect to the longitudinal construction joint was determined.

The slat conveyors, which are located at the bottom of the paver hopper, are used to carry the asphalt mix from the hopper to the augers and eventually to the screed. Figure 8 shows the geometry of the slat conveyors relative to the subsequent cracking that occurred on the pavement. This same relationship can also be seen in Figure 9. Superimposing a schematic of the configuration of the slat conveyors for the equipment used on a specific project over a drawing of the longitudinal cracks also helped to determine if specific points on the paver could be identified as areas where segregation and cracking were appearing within the mat. There are three locations where cracking has been observed, on the outside edges of the two slat conveyors and one under the gearbox between the two slat conveyors.

Table D contains specific information on each project. The information contained in this table includes the paver manufacturer, paver model and the location of each longitudinal crack in relation to the longitudinal construction joint. The top-down cracking appeared in pavements that were constructed by three different paving manufacturers. The manufacturers are shown in the table as Manufacturer 1, 2, and 3. The different models are shown in the table as Model A, B, C, D, and E.

In 1993 the Illinois Department of Transportation conducted a study that detailed the history and investigation of longitudinal cracking in asphalt surfaces.[3] Results from the Illinois study indicated that there is a high degree of correlation between the outside edges of the conveyors on the paver and the longitudinal cracking in the pavement. This study identified two pavers that demonstrated the correlation between the longitudinal cracking in the pavement and the outside edges of the conveyor slats.

Figure 8. Top view of paver and mat

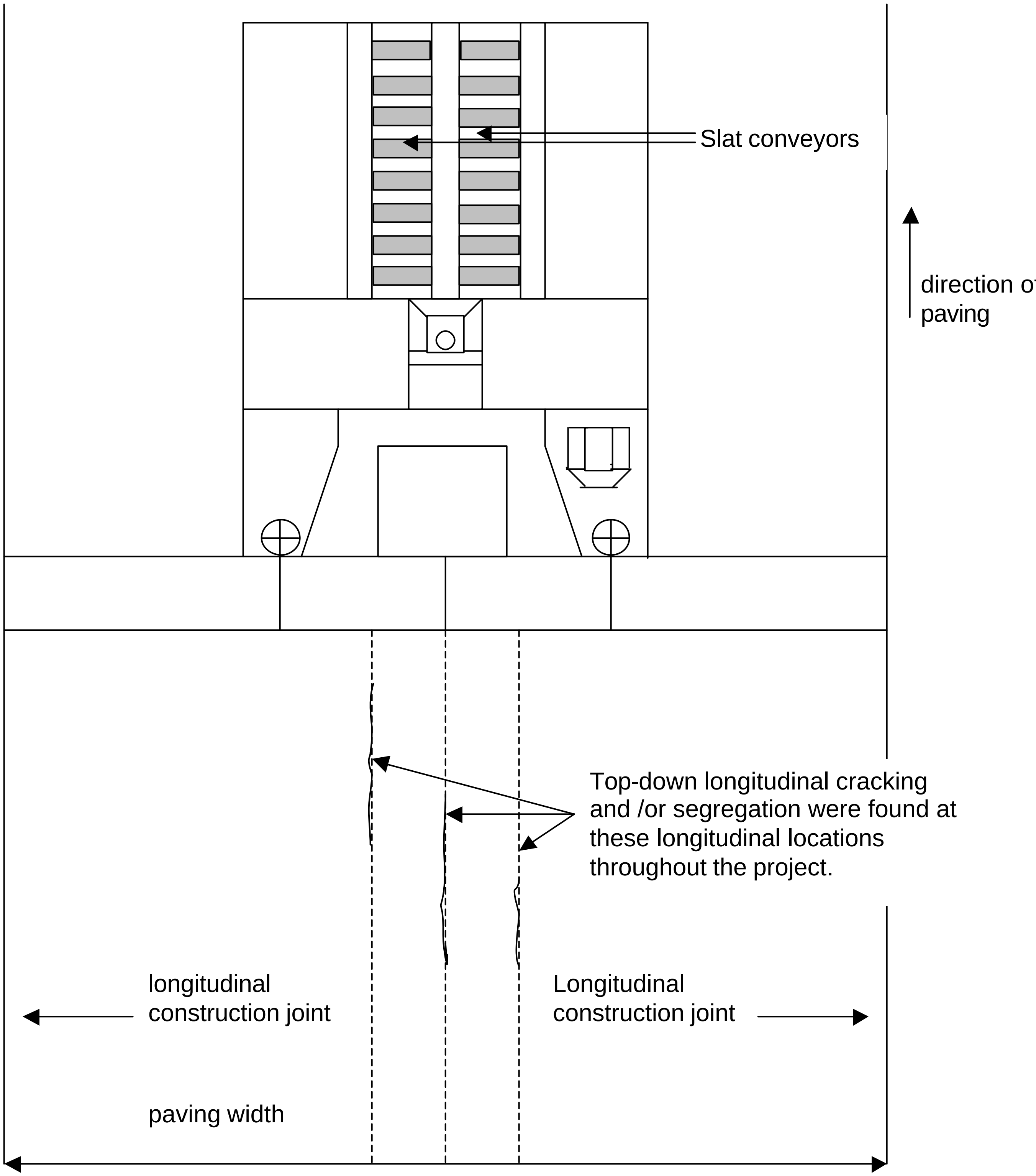


Table D. Paver manufacturer/model and location of longitudinal cracking

Site No.	Paver Manufacturer/Model	Distance from longitudinal construction joint: First longitudinal crack	Second longitudinal crack	Third longitudinal crack
1	1/A	No crack	No crack	139”
2	1/A	40”	72”	No crack
3	1/A	38”	73”	No crack
6	1/B	18”	No crack	102”
12	1/A	This section has been chip sealed		
13	2/E	37”	No crack	97”
14	1/A	57”	No crack	133”
15	1/*	No crack	72”	No crack
16	1/*	53”	No crack	133”
17	1/C	46”	No crack	109”
18	1/*	38”	No crack	No
19	1/D	69”	No crack	128”
20	3/*	58”	87”	No crack
23	2/*	41”	70”	99”
25	*	No crack	No crack	104”
26	*	This section has been overlaid		
27	*	18”	No crack	No Crack
28	*	No Crack	73”	104”

***** Unable to obtain information

Depending on the manufacturer and model the distance between the outside edges of the slat conveyor varies. The distances between the outside edges of the slat conveyors on three of the pavers (two different manufacturers, three models) that were identified as ones used on the projects were 57-1/4", 57-1/2", and 71-1/4". As can be seen in Table D, the distances between the first crack and the third crack are very similar to the distance between the outside edges of the slat conveyor, indicating that the cracking that is appearing in the surface of these projects is related to specific points on the paving equipment. Also the distances between the first and second crack and the second and third crack are approximately half of the distance between the first and third crack. This indicates that if the first and third crack are located at the outside of the slat conveyors the second crack, since it is halfway in between, must align with the centerline of the paver.

4.3 Visual Inspection of Pavement Surface and Core

One of the projects that exhibited top-down cracking was a location that was part of another on-going research study. This project was overlaid in 1999. Following construction the surface texture of the pavement appeared to be very tight and uniform. Figure 10 shows the surface texture of the pavement within months after construction. During the evaluation conducted in 2003 it was noted that this same pavement surface was showing signs of top-down cracking in addition to what appears to be segregation on the surface. Figures 11 and 12 show the surface texture as it appears today.

Figure 13 shows a photograph of a core taken from another project that has exhibited top-down cracking. This core was taken centered over the top-down crack. As you can see in the photograph, it is apparent that around the cracked area there are less fines than in the non-cracked area of the core.

Figure 10. This photograph shows the project shortly after construction. Segregation on the surface was not apparent.

Figure 11. This photograph was taken 4 years after construction. There are two areas where segregation has began to appear.

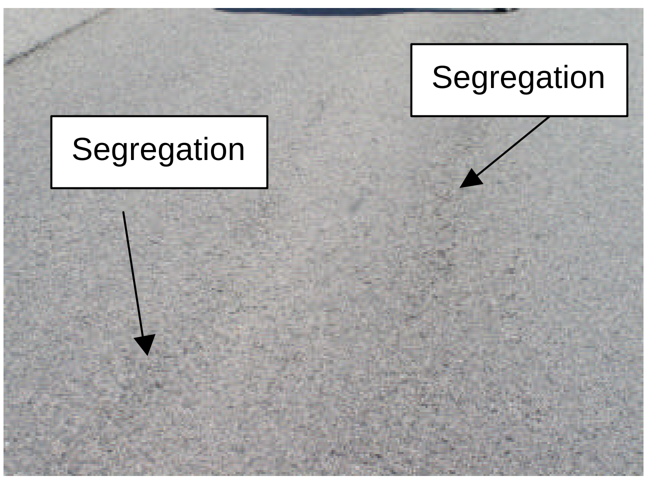
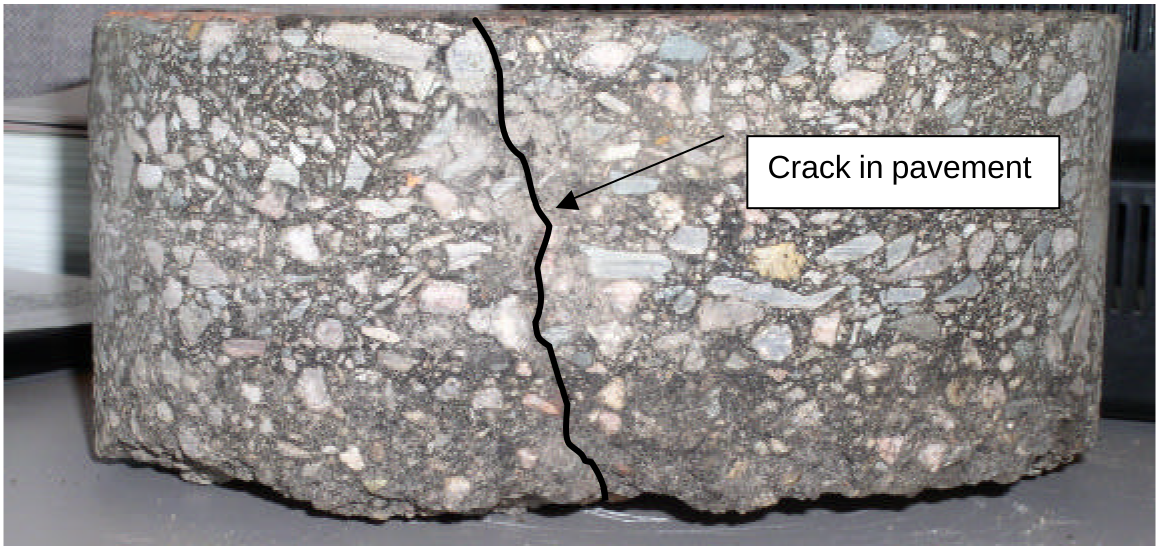


Figure 12. This is a close-up of the segregated area in Figure 11.

Figure 13. Photograph of core taken over a top-down crack. This crack was only found in the top mat; it was not apparent in the lower mat. Although it is not well defined it does appear that the material around the crack is coarser than the material on either side of the crack.



5.0 OBSERVATIONS AND CONCLUSIONS

5.1 Determine the Type of Longitudinal Cracking

A visual observation of the longitudinal cracks will not determine whether the longitudinal crack is reflective or top-down. During this study it was noted that typical top-down cracking appeared to be straight and parallel with the roadway and with lower severity than typical reflective cracking. However, this was not always the case. As can be seen in Figures 14 and 15, the crack must be cored to determine the exact cause of the cracking.

Figure 14. This distress was a reflective crack. Note the linear straightness and low severity of the crack.

Figure 15. This crack was top-down. Although the crack is straight, the severity was enough to warrant crack sealing.

5.2 New Mix Design Changes

With the mix design changes that were incorporated during 2003, the potential for top-down cracking should be reduced. The change allows for an increase in the asphalt cement content in the mix, which will ultimately reduce the potential for segregation to occur.

5.3 Potential Extent of Top-Down Cracking

Realizing that the distress of top-down cracking was real and prevalent based upon this research study, it was decided to review the distresses on CDOT's highways to determine how extensive top-down cracking could be. By using the inventory of the system and pavement distress data collected through the Pavement Management Unit, it was possible to determine the potential extent of top-down cracking on a statewide basis.

CDOT has 22,660 lane miles of highway, or 9,058 centerline miles. Distresses are gathered for approximately half of the system each year, a total of 11,035 data collection miles. The distresses are analyzed and the remaining service life of each project length of pavement is calculated. Good pavements have an RSL of 11 years or greater, fair have equal to 6 but less than 11 years RSL, and poor pavements have less than 6 years RSL. For the pavement condition reported in 2002, there were 39% in good condition, 19% in fair condition, and 42% in poor condition.

CDOT has 8458 centerline miles of hot mix asphalt pavement (HMAP) and 600 miles of portland cement concrete pavement (PCCP). HMAP comprises 93% of the system and PCCP comprises 7% of the system. The hot mix asphalt pavements have 42% poor condition, which equates to 3552 centerline miles. Table E shows the breakdown of distresses that are causing the HMAP to be in poor condition.

Table E. Distresses on hot mix asphalt pavements

Hot Mix Asphalt Pavements		
Type of Distress Causing "Poor" Rating	Of Those in Poor Condition (%)	Of Those Statewide (%)
Cracking (longitudinal, fatigue, or block)	81	34
Cracking (transverse)	12	5
Rutting	4	2
Ride	3	1
Total	100	42

Based on the data from the Pavement Management Unit, the primary distress that is responsible for the poor condition of HMAP is cracking. The phenomena of top-down cracking is certainly a portion, if not a large portion, of this distress.

5.4 Treatment of Top-Down Cracking

Since approximately 67% of the top-down cracking cores had visual signs of segregation, it is recommended that the cracks be sealed as soon as possible. If moisture is allowed into the pavement through the cracks the segregated areas will be prone to rapid deterioration. Sealing the crack will prevent moisture from penetrating the pavement and deteriorating the pavement further.

6.0 FUTURE RESEARCH

The Colorado Department of Transportation, in cooperation with industry, has established a segregation task force. This task group has developed a segregation specification (Appendix B), which will be incorporated into projects during 2003. However this specification is limited to identifying surface segregation during construction and larger areas of segregation than what was found through the visual observations of the top-down cores. The segregation that was found in top-down cracking is isolated to a small longitudinal area and will not always be identified through the comparison of gradation nor will it necessarily be visible during construction. Further development of the specification to identify sub-surface segregation needs to be addressed. This could possibly be accomplished by incorporating a density profile into the specification.

Paving equipment manufacturers have also identified areas within the paver that promote segregation. The manufacturers have taken the initiative to develop an anti-segregation kit.

The anti-segregation system, which can be retrofitted onto the paver, consists of two parts. To keep the material moving forward into the auger the system incorporates a series of chains. These chains help keep the material from breaking and running forward. The second part of the system includes deflectors that keep the material flowing from the chains to the auger. The chains and deflectors prevent the material from dropping under the auger, separating and not being processed adequately. This modification will help reduce the potential for sub-surface segregation.

REFERENCES

1. Bud A Brakey, "Guidelines for Selection of Rehabilitation Strategies for Asphalt Pavement." Colorado Department of Transportation, CDOT-DTD-R-2000-8, August 2000.

2. Mike Anderson, John D' Angelo, Gerry Huber, " Forensic Investigation of Early Cracking on I-25 in Denver Colorado." Colorado Department of Transportation, CDOT-DTD-R-2001-10, August 2001.

3. "A Review of Cracking on Full Depth Bituminous Pavement (Longitudinal Cracking)." Illinois Department of Transportation, August 1993.

Appendix A
“Photographs of Projects Evaluated”

TOP-DOWN CRACKING IN COLORADO

Region 1

Site 1 (I-70, MP 185.7, Vail Pass)

Top-Down Cracking

Top-Down Cracking

Site 2 (I-70, MP 193.8 – W. of Copper Mtn)

Top-Down Cracking

Top-Down Cracking

Site 3 (I-70, MP 194.3 W. of Copper Mtn)

Top-Down Cracking

Site 4 (I-70, MP 232, Jct US40)

Unable to Core

Region 2

Site 5 (I-25, MP 75.3, Colorado City)

Reflective Cracking

Site 6 (I-25, MP 17.6, N. of Trinidad)

Top-Down Cracking

Top-Down Cracking

Site 7 (I-25, MP 11.7, S. of Trinidad)

Reflective Cracking

Reflective Cracking

Site 8 (I-25, MP 9.2 Raton Pass)

Reflective Cracking

Reflective Cracking

Region 3

Site 12 (US 285, MP 96.5 – Saquache)

Top-Down Cracking

Top-Down Cracking

Top-Down Cracking

Site 13 (US 50, MP 41.2 – Red Mountain)

Top-Down Cracking

Site 14 (I-70, MP 38.2- Clifton)

Top-Down Cracking

Site 15 (I-70, MP 64.0 – DeBeque)

Top-Down Cracking

Site 16 (I-70, MP 74.1 – Parachute)

Top-Down Cracking

Region 4

Site 17 (SH 119, MP51.7 – Longmont)

Top-Down Cracking

Top-Down Cracking

Top-Down Cracking

Site 18 (US287, N. of 9^{th} Street, Longmont)

Top-Down Cracking

Site 19 (US 85, MP 280.2 – Ault)

Top-Down Cracking

Site 20 (US 85, MP 290.2 – Nunn)

Top-Down Cracking

Top-Down Cracking

Site 21 (SH114, MP 198.8 – E. of Buckingham)

Reflective Cracking

Reflective Cracking

Reflective Cracking

Site 22 (US 385, MP 253.3 – N of Wray)

Reflective Cracking

Reflective Cracking

Site 23 (I-76, MP 127.3 – Sterling Rubblization Site)

Top-Down Cracking

Site 24 (US6, WB, MP 409.2, (Sterling)

Reflective Cracking

Region 5

Site 9 (US 160, MP282-283)
Unable to Core
No Photograph

Site 10 (US160, MP87.7, Jct US550 in Durango)

Reflective Cracking

Reflective Cracking

Site 11 (US160, E of Cortez)

Unable to Core

Region 6

Site 25 (US 285, NB MP 251.3)

Top-Down Cracking

Site 26 (C470, WB, MP 11.3)
No Photograph

Site 27 (I-76, WB Passing Lane; MP 1.3)

Top-Down Cracking

Site 28 (I-25, SB Driving Lane; MP 218.6)

Top-Down Cracking

Appendix B
“Standard Special Provisions (Segregation)”

December 20, 2002

REVISION OF SECTION 401
PLANT MIX PAVEMENTS - GENERAL

This is a standard special provision that revises or modifies CDOT's *Standard Specifications for Road and Bridge Construction*. It has gone through a formal review and approval process and has been issued by CDOT's Project Development Branch with formal instructions regarding its use on CDOT construction projects. It is to be used as written without change. Do not use modified versions of this special provision on CDOT construction projects, and do not use this special provision on CDOT projects in a manner other than that specified in the instructions unless such use is first approved by the Standards and Specifications Unit of the Project Development Branch. The instructions for use on CDOT construction projects appear below.

Other agencies that use the *Standard Specifications for Road and Bridge Construction* to administer construction projects may use this special provision as appropriate and at their own risk.

INSTRUCTIONS FOR USE ON CDOT CONSTRUCTION PROJECTS:

Use this standard special provision on projects with any grading of hot bituminous pavement.

REVISION OF SECTION 401
PLANT MIX PAVEMENTS – GENERAL

Section 401 of the Standard Specifications is hereby revised for this project as follows:

In subsection 401.02(b), delete the eighth, ninth, and tenth paragraphs (last three paragraphs) and replace with the following:

If one or more samples fail to meet the requirements of Table 401-2, material from the area represented by the failing sample will be evaluated as follows:

If the area represented by the failing sample contains 2000 tons of the new pavement or less, then the result for the failing sample shall be considered a lot of one and will be evaluated according to the formulas and procedures in subsection 105.03.

If the area represented by the failing sample contains more than 2000 tons of the new pavement, then the material from the area represented by the failing sample will be sampled and tested according to the following method:

Pavement samples for possible moisture susceptibility testing will be taken at a minimum frequency of every 2000 tons throughout the project. The Engineer will observe the sampling, take possession of the samples, and retain these samples for possible testing. Sample size shall be a minimum of 9 kg (20 pounds). If a 10,000 ton sample fails then the four 2000 ton samples from the area represented by that failing 10,000 ton sample will be tested for moisture susceptibility. The 10,000 ton result and the four 2,000 ton result will be considered a lot of five and will be evaluated according to the formulas and procedures in subsection 105.03. If less than four retained samples are on hand because the 10,000 ton sample represents less than 8000 tons of hot bituminous pavement, the price adjustment will be based on the test results from the retained samples on hand plus the test result from the 10,000 ton sample.

For the above evaluation the “F” factor used in calculating P factors shall be 2.5. The P value shall be applied to price of the HBP item. If asphalt cement is not paid for separately the price reduction shall be multiplied by 0.60. Lottman P values will not be combined with Pay Factors for other elements determined in accordance with QC/QA specifications.

In subsection 401.16, delete the last paragraph and replace with the following:

If at any time, the Engineer observes segregated areas of pavement, he will notify the Contractor immediately.

After rolling, segregated areas will be delineated by the Engineer and evaluated as follows:

(1) The Engineer will delineate the areas to be evaluated and inform the Contractor of the location and extent of these areas within two calendar days, excluding weekends and holidays, of placement.

(2) In each area or group of areas to be evaluated, the Contractor shall take five 10” cores at random locations designated by the Engineer. The coring shall be in the presence of the Engineer and the Engineer will take immediate possession of the cores. The Contractor may take additional cores at the Contractors expense.

(3) Gradation of the aggregate of the cores will be determined by CDOT in accordance with Colorado Procedure 46.

(4) The core aggregate gradation will be compared to either the applicable Form 43 target gradation or the running average of five. The running average five is defined as the average of the five gradations as follows: The aggregate gradation for the mix produced on the day the segregated pavement was placed, plus the two production gradations immediately before and the two production gradations immediately after. If there are adequate gradations available to determine the running average of five, and all these gradations conform to the specification, then the running average of five will be used as the required gradation for comparison. Otherwise, the applicable Form 43 gradation will be used as the required gradation.

(5) Two key sieves of the core gradations will be compared to the corresponding required gradations to determine the difference. If differences for both key sieves exceed the allowable difference specified in the table below, the area is segregated.

Table for Segregation Determination

Mix Grading	Key Sieves	Allowable Difference, %
SX	#8, #4	9
S	#8, #4	9

(6) Segregated areas in the top lift shall be removed and replaced, full lane width, at the Contractor's expense. The Engineer may approve a method equivalent to remove and replace that results in a non-segregated top lift. Segregated areas in lifts below the top lift, that are smaller than 50 square feet per 100 linear feet of lane width, will be corrected by the Contractor at the Contractor's expense in a manner acceptable to the Engineer. Segregated areas larger than 50 square feet per 100 linear feet of lane width in any lift shall be removed and replaced, full lane width, by the Contractor at the Contractor's expense.

(7) If the area is determined to be segregated, the coring will be at the expense of the Contractor. If the area is not determined to be segregated, the Engineer shall reimburse the Contractor $1,000 for obtaining the five cores.

Subsection 401.17 shall include the following:

The longitudinal joints shall be compacted to a target density of 92 percent of the maximum specific gravity. The tolerance shall be ± 4 percent. Maximum specific gravity will be that shown on the Form 43 for the asphalt mix used in construction of the joint. If two Form 43's apply to the joint material, the average of the maximum specific gravities shown on the Form 43's will be used. Density (percent relative compaction) will be determined in accordance with Colorado Procedure 44.

The Contractor shall obtain one 6-inch diameter core at a random location within each longitudinal joint sampling section for determination of the joint density. The Contractor shall drill the cores at the location directed by the Engineer and in the presence of the Engineer. The Engineer will take possession of the cores for testing. The Contractor may take additional cores at the expense of the Contractor. Coring locations shall be centered on the line where the joint between the two adjacent lifts abut at the surface. Core holes shall be repaired by the Contractor using materials and methods approved by the Engineer.

Payment will apply to the hot bituminous pavement on each side of the joint that forms the joint. If a lift of pavement has a joint constructed on both sides, payment for each of those joints will apply to one half of the pavement between the joints.

Subsection 401.22 shall include the following:

Coring for longitudinal joint density testing, core hole repair and associated expenses will not be paid for separately but shall be included in the work. Traffic control for this work will be paid for in accordance with the contract.

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