STATE OF FLORIDA

PERFORMANCE EVALUATION OF CRACK-AND-SEAT REHABILITATION STRATEGY: A 10-YEAR PERSPECTIVE

Research Report
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EXECUTIVE SUMMARY

In the early 1990's, the Florida Department of Transportation (FDOT) initiated the rehabilitation of seven deteriorating Portland cement concrete (PCC) pavement sections with an asphalt overlay using the crack-and-seat technique. These projects included 14 two-lane roadway sections located along the I-10 corridor crossing five counties in the northern part of Florida. All east and westbound traffic lanes on these projects were rehabilitated. An Asphalt-Rubber Membrane Interlayer (ARMI) layer was also introduced as a supplementary strategy to further reduce reflective cracking. The sections were periodically tested and monitored with the primary objective of obtaining long-term field performance data. The latter was then used to assess the effectiveness of using the crack-and-seat technique with an Asphalt-Rubber Membrane Interlayer (ARMI) in reducing reflective cracking in asphalt overlay over deteriorated PCC pavements.

The performance data collected over a ten-year period indicates that the crack-and-seat technique when used in conjunction with an ARMI layer can be an effective rehabilitation strategy for deteriorated PCC pavements.

INTRODUCTION

Background

One of the major challenges that highway agencies face today is how to evaluate, maintain, and rehabilitate their existing highway network to meet today's trends toward heavier traffic loadings, greater traffic volumes, and higher tire pressures. In fact, most reported road-related expenditures are for maintenance, repair, and rehabilitation purposes.

A pavement system is a highly complex structure from a stress analysis standpoint. It is constantly subjected to traffic loads as well as environmental stresses caused by changes in temperature and moisture conditions. Its surface layers are supported by soil whose physical properties vary greatly from one location to another. In addition, material properties change with age, affecting the characteristics and response of the pavement. Over time, factors such as traffic loading, environment, and age tend to decrease the initial high serviceability to a level where it becomes unacceptable. At this stage, the pavement must be rehabilitated or reconstructed.

Over the years, transportation agencies have used various restoration treatments and strategies in an effort to extend the service life of deteriorating pavements. Depending on the volume of traffic, the most prevalent treatment currently is the use of overlays. Although different types of overlay may be possible, this report focuses only on hot-mix asphalt (HMA) overlays on Portland cement concrete (PCC) pavements using a technique referred to as the crack-and-seat procedure.

A major concern associated with HMA overlays on PCC pavements is reflection cracking. Reflection cracking is a premature failure mechanism that is detrimental to the ride quality and structural integrity of a pavement system. It is defined as the crack pattern in the overlay surface that originates, or reflects off existing cracks and/or joints in the underlying layer. It is believed that this reflection is primarily induced by both the horizontal and the differential vertical movements occurring at the joints and cracks in the underlying pavement. The differential vertical movement is due to traffic loading while the horizontal movement is the result of temperature and moisture changes *(1)*. Horizontal movements in a bonded HMA overlay create excessive tensile stresses along the cracks and joints at the PCC/HMA interface. These horizontal movements are generally believed to be more critical in the formation of reflection cracking. The vertical movements which occur when traffic crosses over a crack only accelerate the crack propagation process *(1, 2)*. Thus, it is likely that early reflection cracking will appear within a year or two in an HMA overlay over a PCC pavement if proper design and construction techniques are not properly followed *(3)*.

Methods to Minimize Reflection Cracking

Several methods may be used to potentially minimize reflection cracking in HMA overlays on PCC pavements. The choice of the method to use is dictated by several factors such as the type of PCC, the condition of the PCC and of the embankment, the available budget, and the experience using the proposed technique. One method is to incorporate stress relieving membranes to reduce the stresses that build at the overlay/PCC interface, which tend to propagate through the overlaying HMA. When a membrane includes asphalt rubber as a binder, it is generally referred to as an asphalt-rubber membrane interlayer (ARMI). The ARMI retards reflection cracking because it has a low modulus of elasticity. The effectiveness of an ARMI in preventing cracking appears to be varied. However, most reports indicate that open graded or gap graded mixes perform best, while higher density mixes may not provide much benefit *(4, 5)*.

Another technique is to strengthen the overlay by increasing the thickness or modify the HMA through additives to increase crack resistance *(2)*. Other processes include reducing PCC slab movements due to thermal gradients by fracturing and/or destructing the continuity in the slab body structure. Crack-and-seat is another process intended for Jointed Plain Concrete Pavements (JPCP). This technique involves cracking the existing pavement into small sections with a gravity or pneumatic type breaker. The purpose is to reduce the concrete slabs into sections small enough to minimize movement but large enough to maintain some structural integrity through aggregate interlock. The cracked sections are typically 4 to 6 ft in size. The cracked sections are then seated with heavy rollers, and overlaid with an asphalt mixture. A similar process used for Jointed Reinforced Concrete Pavements (JRCP) is known as break-and-seat. The bond between the concrete and steel reinforcement must be broken to reduce horizontal movement. The energy required to disrupt the bond is greater than that required for crack-and-seat, and the structural capacity of the slab is further reduced. When the integrity and structural capacity of pavement slabs are jeopardized, rubblization could be considered. Rubblization reduces existing slabs to small pieces and transforms it into a granular base *(6)*.

Many variables must be accounted for in order to obtain optimal performance from crack-and-seat projects. First, the PCC slab cracking pattern must be small enough to reduce or eliminate thermally related movement of the slab, and the slab must be cracked from top to bottom. Care must be taken to not damage the underlying pavement layers while cracking and later seating the PCC segments. Also, loss in slab strength must be accounted for after slab cracking *(7)*.

OBJECTIVE

Nationally, there have been a number of studies performed on the construction and field performance of HMA overlays on cracked-and-seated sections *(3, 7, 8, 9, 10, 11)*. However, the findings from these studies have not all been in agreement. Therefore, it was felt that there was still a need for long-term field data to define performance that would allow for appropriate decision making in developing improved rehabilitation and reconstruction strategies. Thus, the present study was initiated with the primary objective of collecting long-term field performance data on the effectiveness of the crack-and-seat technique to minimize reflection cracking in HMA overlays for Florida conditions. The results of a ten-year performance evaluation are documented in this report.

PROJECT DESCRIPTION

In 1993 and 1994, the Florida DOT initiated the implementation and monitoring of seven crack-and-seat rehabilitation projects across five counties in northern Florida, namely Jefferson, Leon, Gadsden, Jackson, and Walton Counties. These projects consisted of 14 two-lane sections in the eastbound and westbound travel lanes of I-10 corridor. The original pavement on this high volume facility was a 9-inch plain jointed PCC pavement, with a 20-foot joint spacing on a 12-inch cement stabilized base. A 4,000 lb. gravity-type breaker was used to crack the original pavement into 36 in. maximum size pieces. The cracked slabs were seated using a pneumatic tired-roller, followed by the placement of a 0.5 inch ARMI layer, 4 inches of typical Florida structural asphalt mixtures, and a 0.5 inch open-graded friction course. All the asphalt mixtures used in these projects, with the exception of the Gadsden County project, contained recycled asphalt pavement (RAP) material. In addition, all the crack-and-seat sections were retrofitted with edge-drains. A summary of the key information related to each project and the details regarding traffic data are presented in Tables 1 and 2 respectively. Figure 1 shows the typical pavement cross sections before and after rehabilitation.

Table 1 Projects Information Summary

Project Number	Completion Date	Location				Contractor
		BMP	EMP	Length, mile	County	
54001-3429	Mar-94	4.920	10.007	5.087	Jefferson	Anderson Columbia
55320-3435	Jan-95	4.573	8.576	4.003	Leon	Peavy
55320-3436	Aug-93	15.630	19.755	4.125	Leon	Anderson Columbia
50001-3437	Mar-94	20.437	31.538	11.101	Gadsden	C. W. Roberts
53002-3428	Jan-94	8.680	10.351	1.671	Jackson	White
53002-3439	Nov-94	10.351	13.609	3.258	Jackson	Anderson Columbia
60002-3418	Nov-93	18.100	24.061	5.961	Walton	Okaloosa Asphalt

Table 2 Traffic Data Summary

Survey Year	Jefferson County Project No. 54001-3429		Leon County Project No. 55320-3435		Leon County Project No. 55320-3436		Gadsden County Project No. 50001-3437		Jackson County Project No. 53002-3428		Jackson County Project No. 53002-3439		Walton County Project No. 60002-3418	
	AADT	Percent Truck	AADT	Percent Truck	AADT	Percent Truck	AADT	Percent Truck	AADT	Percent Truck	AADT	Percent Truck	AADT	Percent Truck
1994	18,888	20	NA	NA	NA	NA	NA	NA	14,400	18	14,400	18	14,544	18
1995	19,207	20	42,510	11	19,207	20	20,885	26	16,463	18	16,463	18	14,424	17
1996	19,873	20	44,045	11	19,873	20	21,619	24	17,296	18	17,296	18	14,638	18
1997	20,905	21	45,776	10	20,905	21	23,116	18	18,044	14	18,044	14	15,573	22
1998	21,782	21	48,530	11	21,782	21	24,378	17	18,723	23	18,723	23	16,315	24
1999	22,803	20	52,245	12	22,803	20	26,960	18	19,968	17	19,968	17	17,456	21
2000	26,500	25	44,500	17	29,000	21	22,500	28	19,500	32	19,500	32	16,752	26
2001	23,500	25	44,000	17	29,500	21	19,100	28	22,000	32	22,000	32	17,952	26
2002	22,500	27	37,500	20	30,500	19	23,000	20	18,400	33	18,400	33	18,637	25
2003	24,500	27	40,000	20	34,000	19	22,000	20	20,300	33	20,300	33	19,334	25

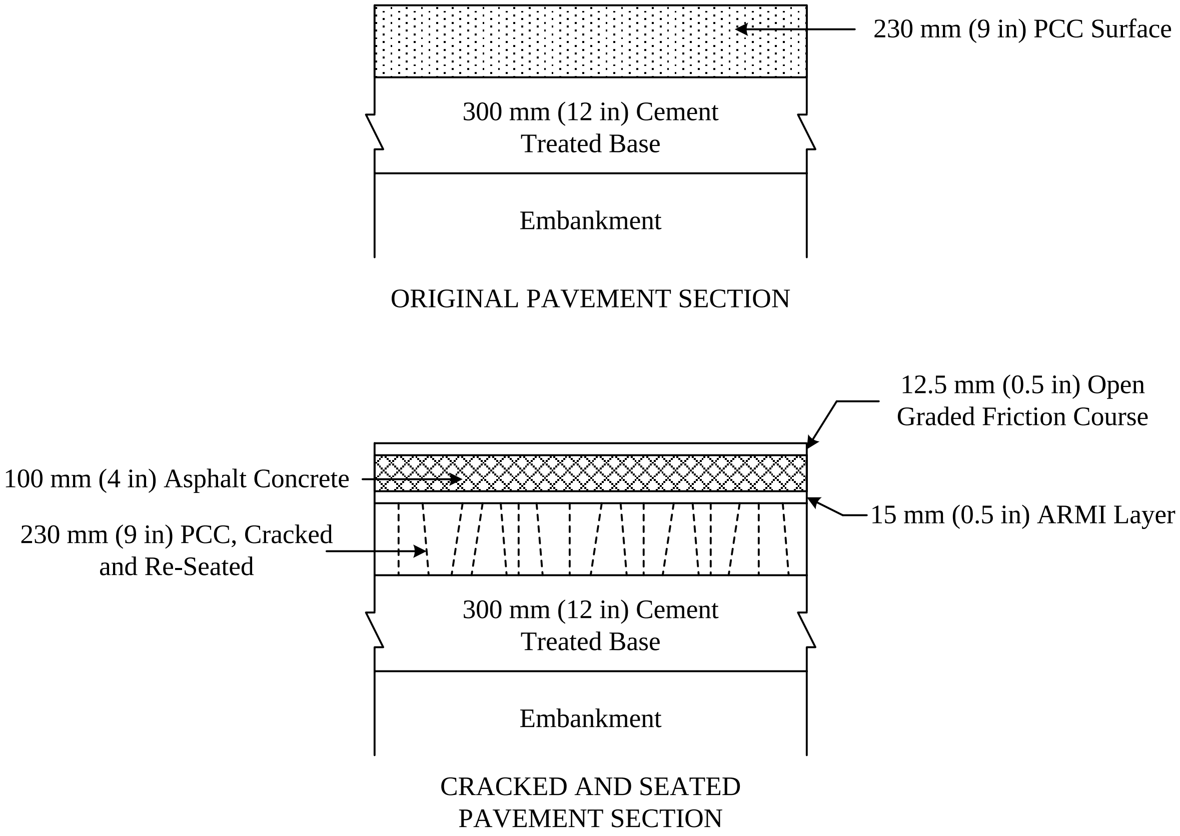


Figure 1 Typical pavement cross sections.

DATA ANALYSIS

The objective of this work was to evaluate the effectiveness of the crack-and-seat technique when used in combination with an ARMI layer in minimizing reflection cracking in HMA overlays. The performance of the sections was first evaluated at the time of construction, and annually thereafter for a period of 10-years. This evaluation was performed in terms of three specific distress parameters, namely: (1) rideability, (2) rutting, and (3) cracking and patching.

Rideability

A high-speed inertial profiler was used to measure the longitudinal profile from which the rideability is determined. The rideability was expressed in terms of Ride Number (RN), which is rated on a scale of 0 (maximum possible roughness) to 5 (perfectly smooth). Ride Number is an index resulting from non-linear transform of roadway profiles which represents the roughness of a pavement. The ride number data was plotted against the Average Daily Truck Traffic (ADTT) for each of the seven projects and has been summarized in Figure 2. In Figure 2, the ADTT is plotted on the primary y-axis, and the ride number data for both the eastbound and westbound directions has been plotted on the secondary y-axis. It should be noted that the ADTT plotted in this and subsequent figures is for both east and westbound directions combined. The ride number data has also been summarized in Figures 3 and 4 to illustrate the comparative ride performance for all the projects. The ride number data indicates that most of the projects have performed well in terms of ride quality and have been rated better than 4.0 for most of the ten years of service.

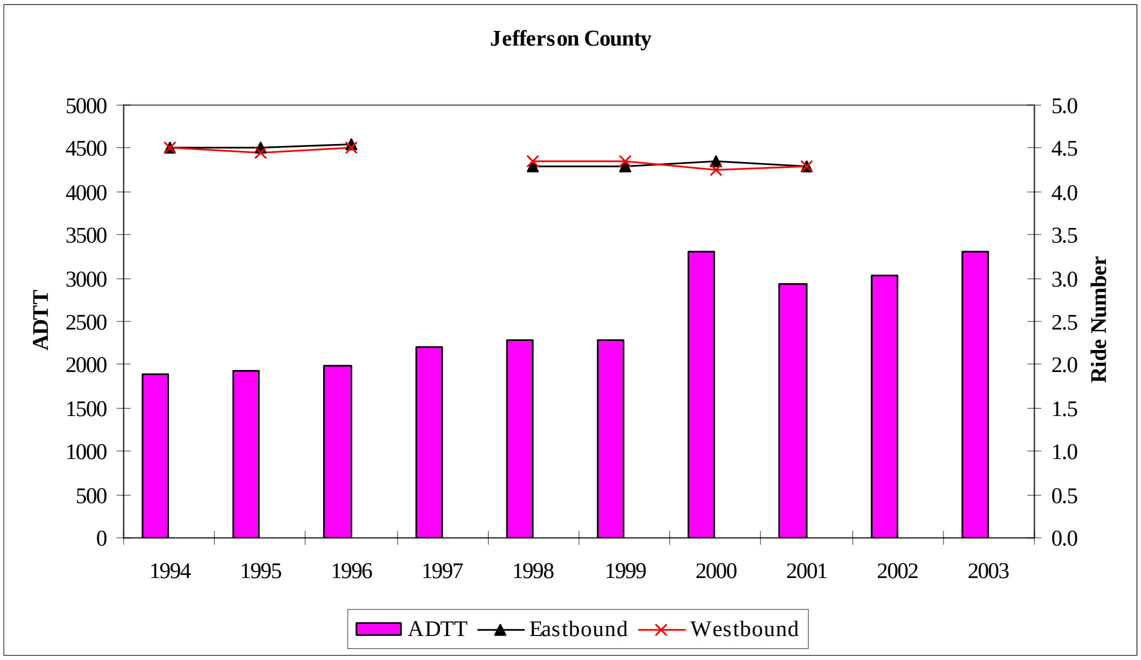


Fig 2 (a)

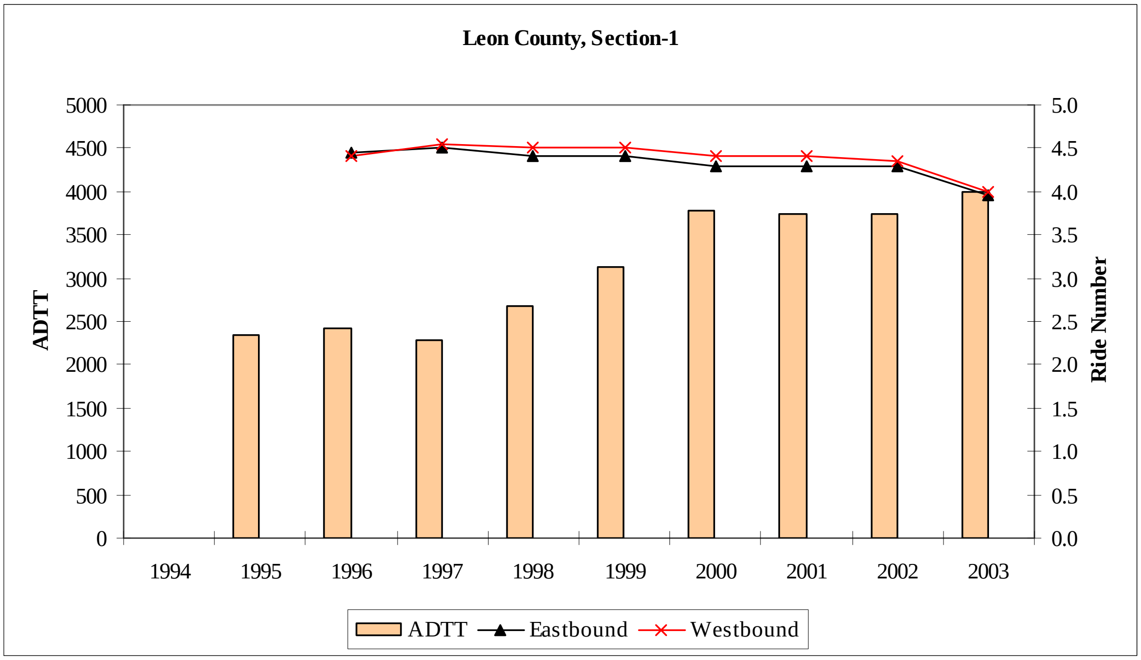


Fig 2 (b)

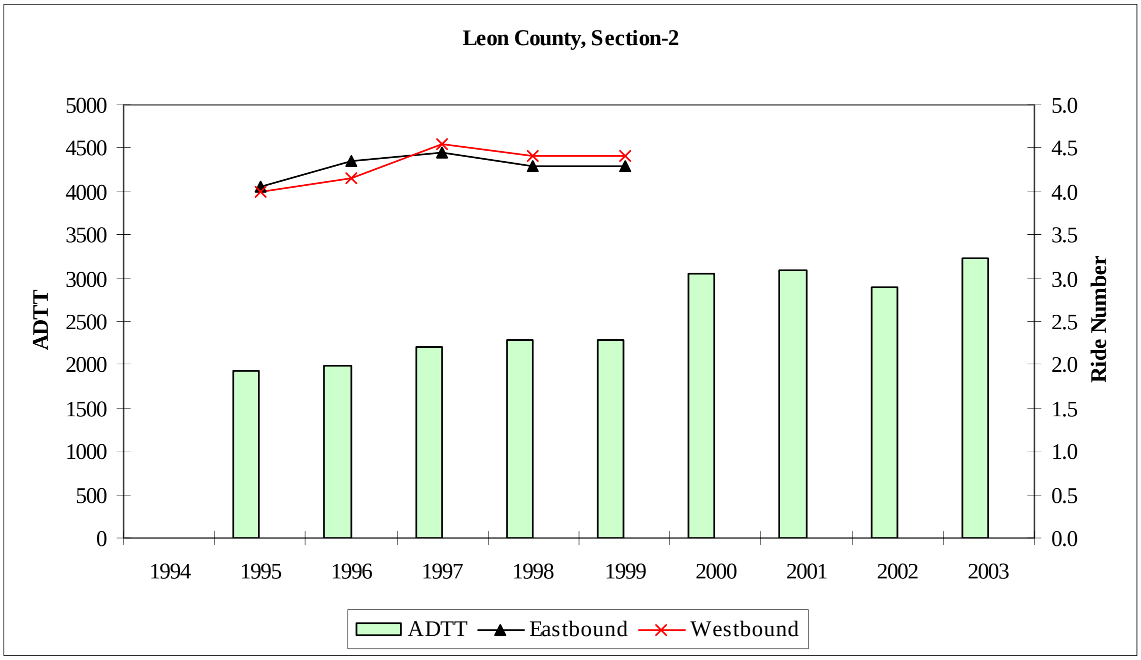

Leon County, Section-2
ADTT
Ride Number
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 2 (c)

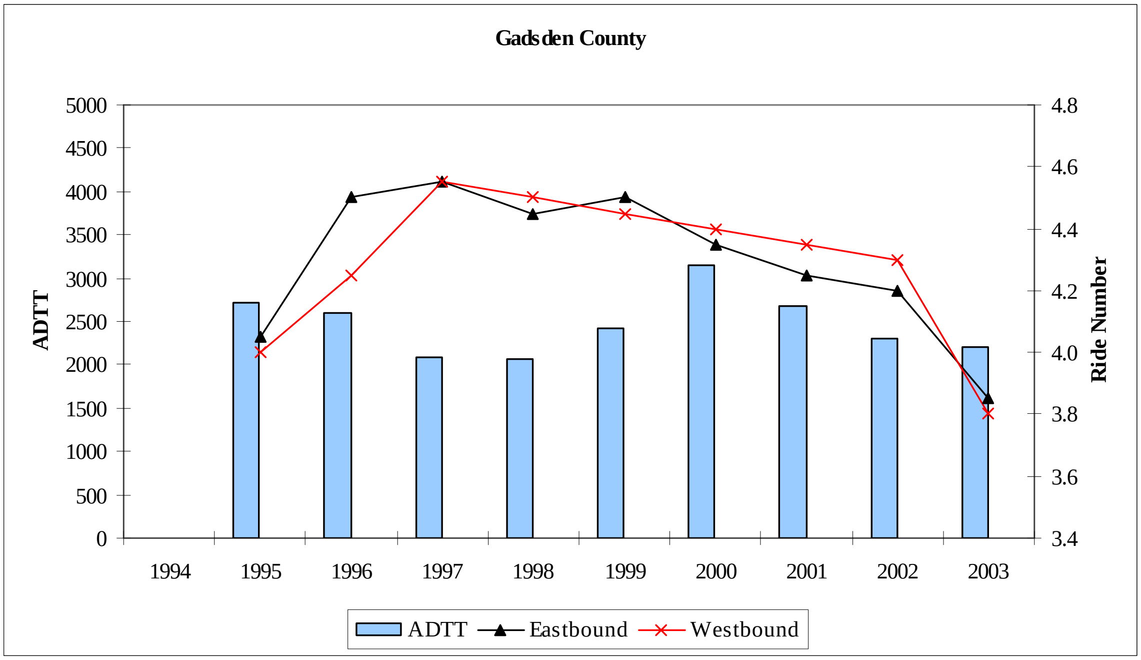

Gadsden County
ADTT
Ride Number
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 2 (d)

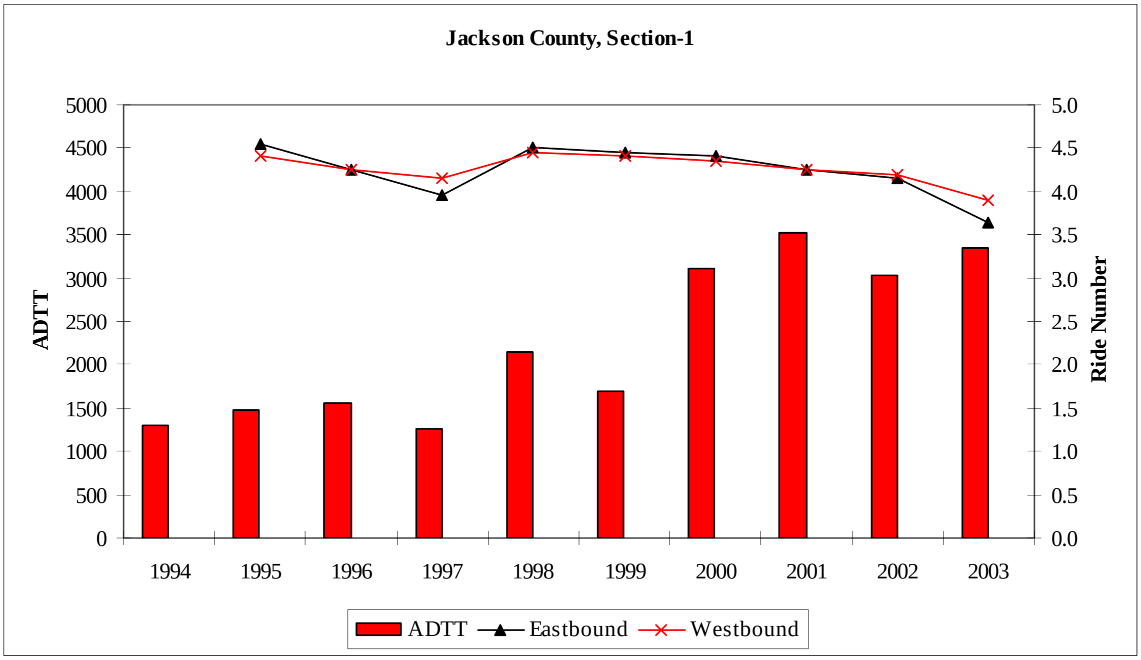

Jackson County, Section-1
ADTT
Ride Number
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 2 (e)

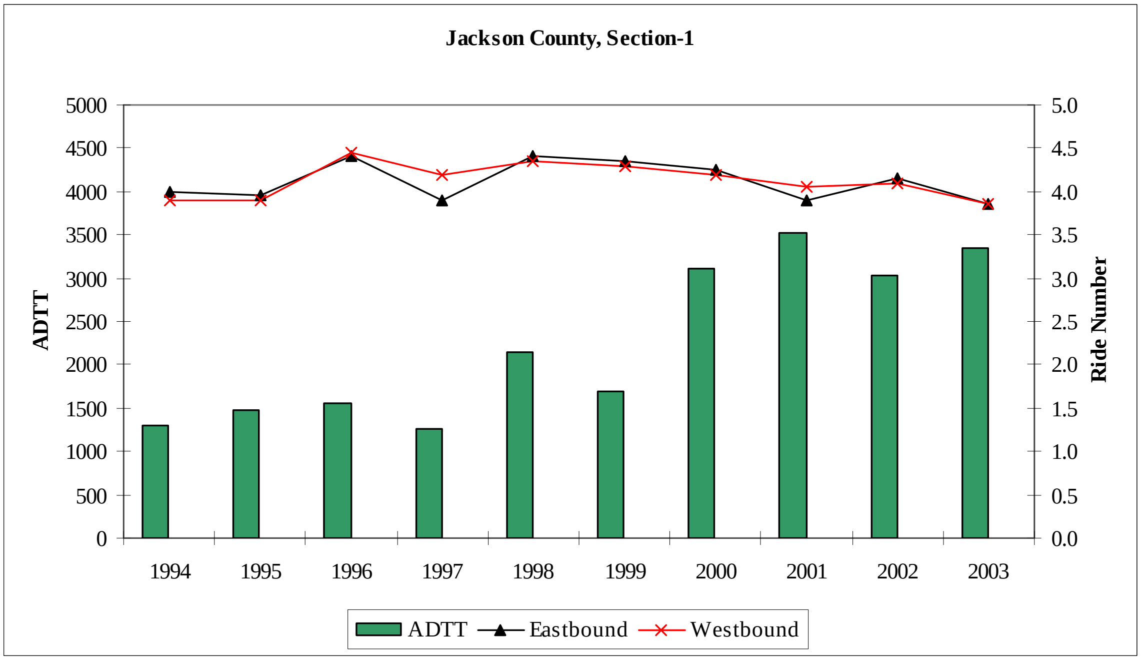

Jackson County, Section-1
ADTT
Ride Number
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 2 (f)

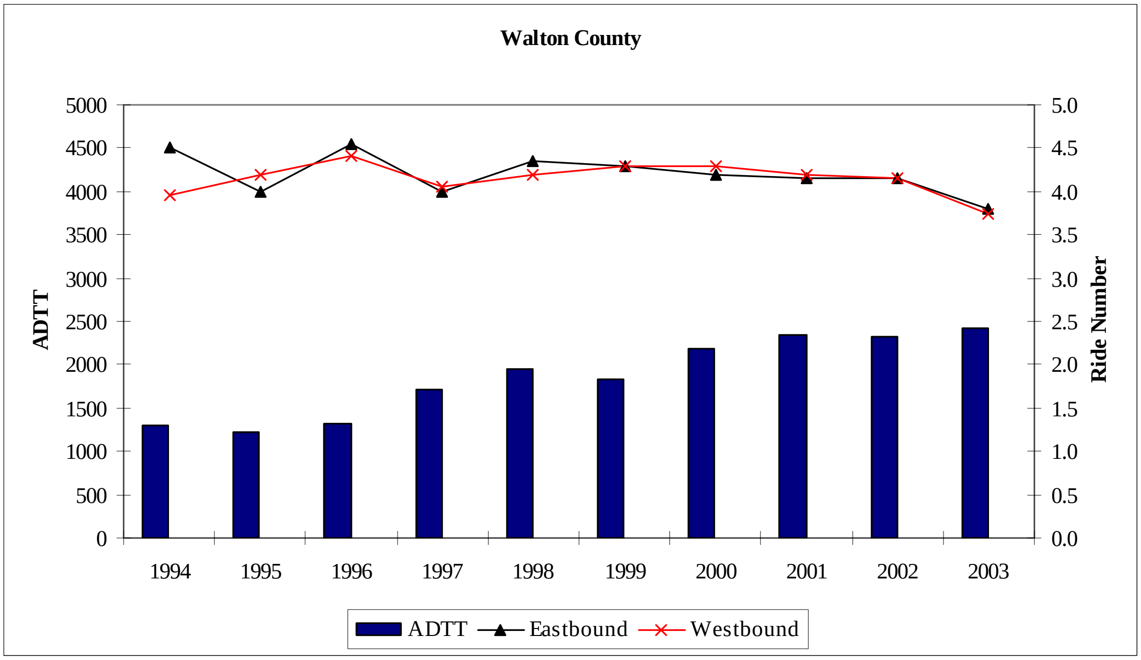


Fig 2 (g)

Note: ADTT is plotted on the primary y-axis and Ride Number is plotted on the secondary y-axis.

Figure 2 Ride Quality Measurements and ADTT.

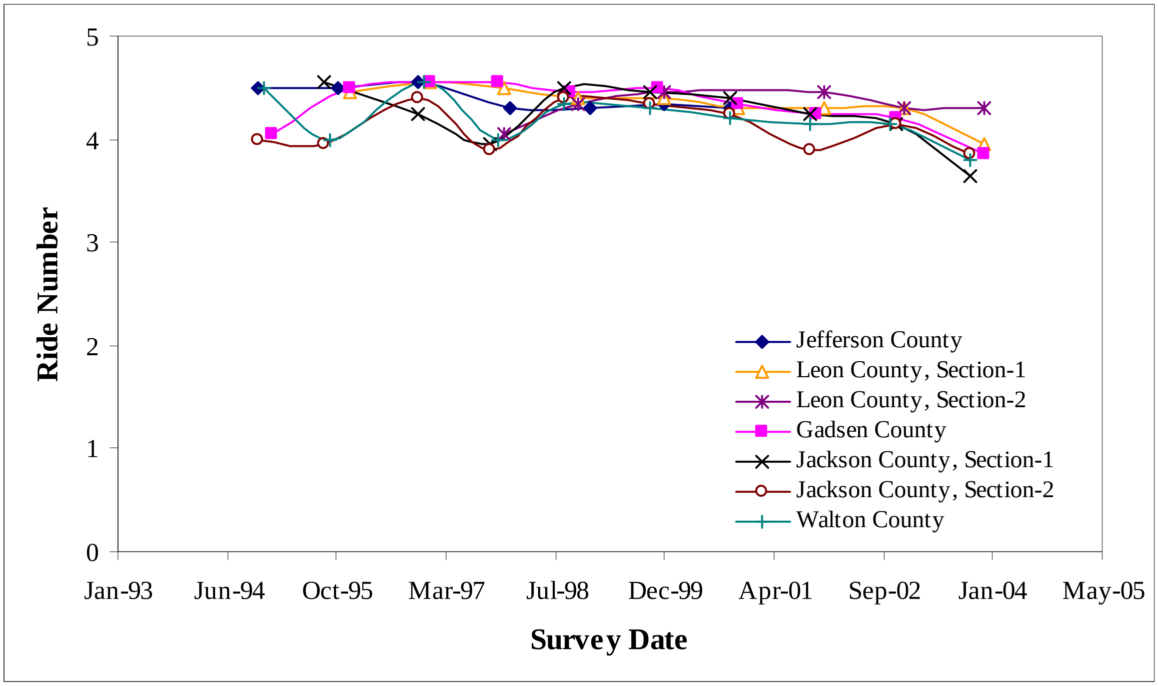


Figure 3 Ride quality measurements in the east bound direction.

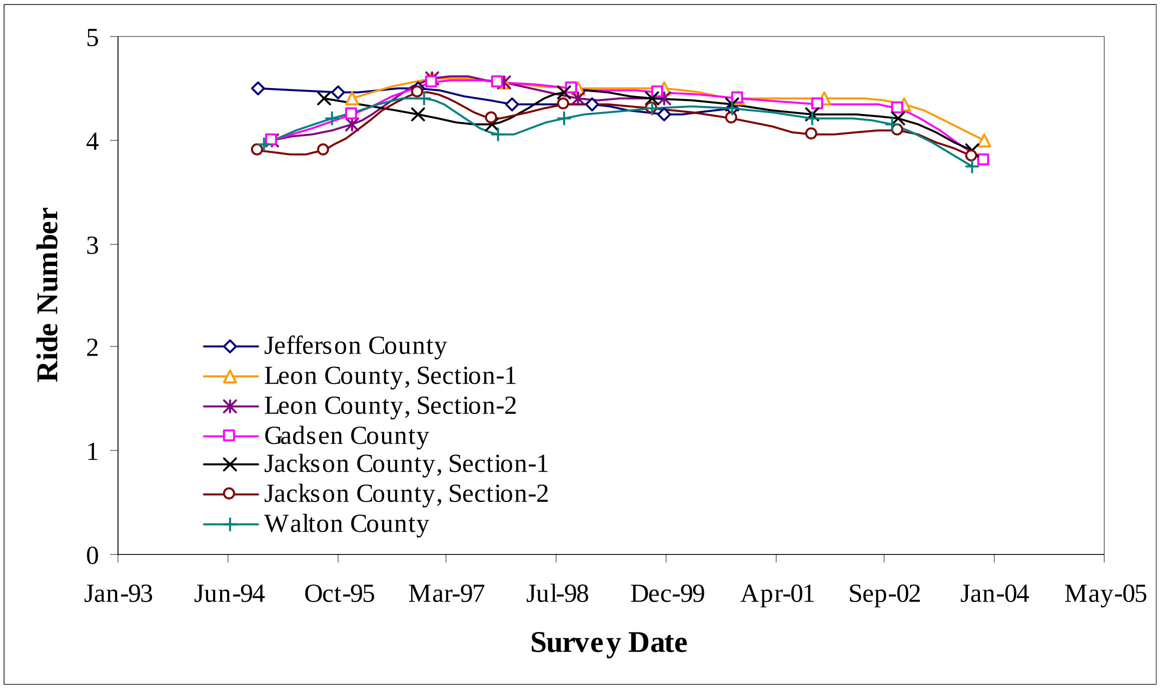
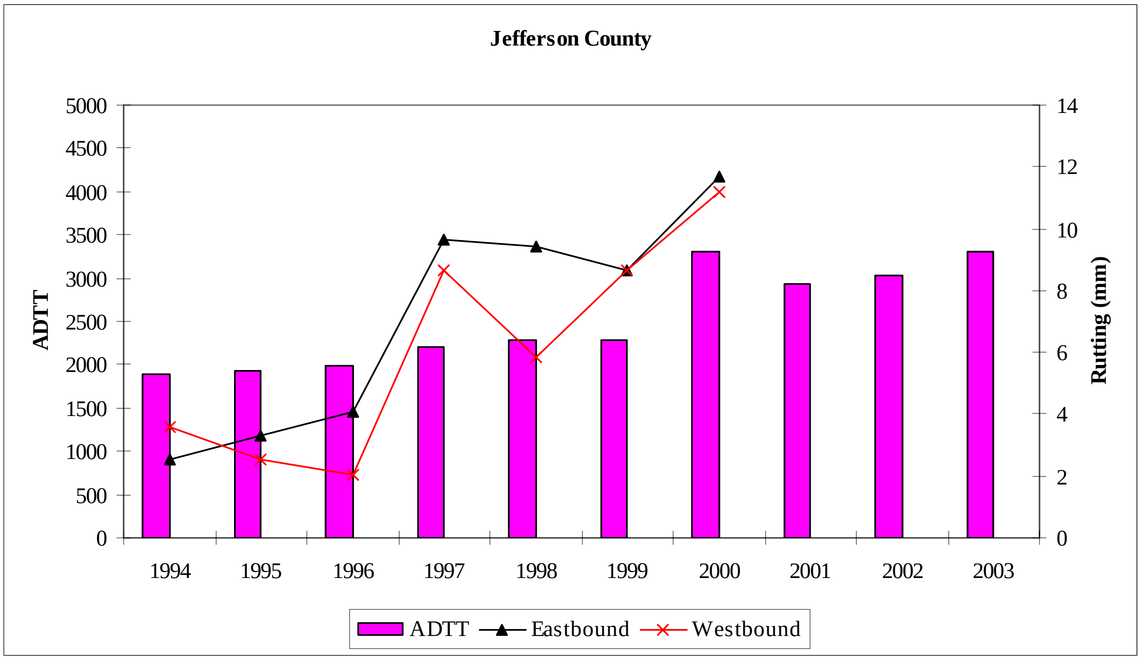


Figure 4 Ride quality measurements in the west bound direction.

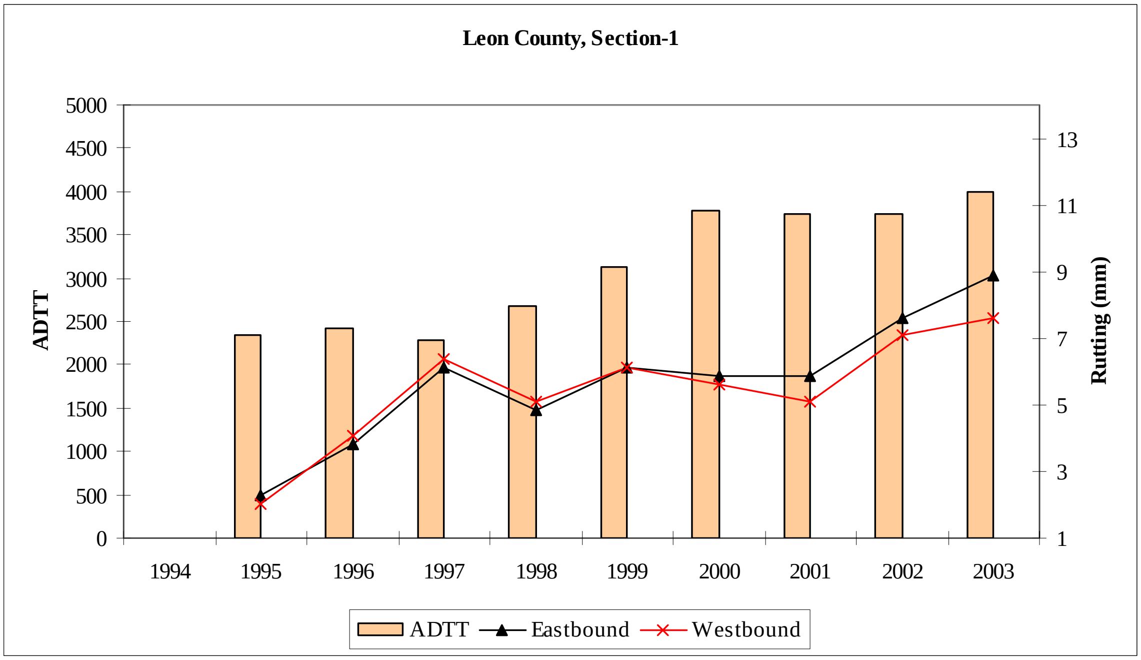
Rut Depth

Rutting in HMA overlays of concrete pavements occur entirely in the overlay. The long term rutting tends to develop slowly, following the initial rutting due to compaction of the mix. The rutting measurements used in this study were acquired with an ASTM 950 class 1 high-speed laser profiler using a three laser system, and represents the average rut value of both wheelpaths. These measurements are illustrated in Figures 5 through 7, which show a maximum rut depth of approximately 0.35 inch on the majority of the test sections. The two projects that exhibited the highest levels of deformation are those in Jefferson and Leon (second project) Counties, where rut depths averaging 0.4 inch were recorded between December of 1999 and April of 2001. It is likely that this rutting is due to problems with the asphalt mixture since a number of issues were encountered during production, and the same mixture was placed on both projects. Critical low in-place air voids (ranging from 0.2 to 1.9 percent) were measured on the Leon County project *(13)*, which resulted in the removal and replacement of a substantial amount of pavement on this project before its completion in August of 1993. It is also probable that the fine-graded, 50-blow Marshall designed mixes were inadequate to withstand the actual loading conditions. Over the past 10 to 15 years, and before the implementation of Superpave, a significant number of asphalt pavements on interstate projects in North Florida have experienced premature failures, primarily due to rutting *(14)*. The Jefferson County project was resurfaced in 2001 and the Leon County (second project) was resurfaced in 2000. The survey measurements which were taken after the resurfacing of these projects are not included in this evaluation.



Jefferson County
ADTT
Rutting (mm)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
14
12
10
8
6
4
2
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 5 (a)



Leon County, Section-1
ADTT
Rutting (mm)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
13
11
9
7
5
3
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 5 (b)

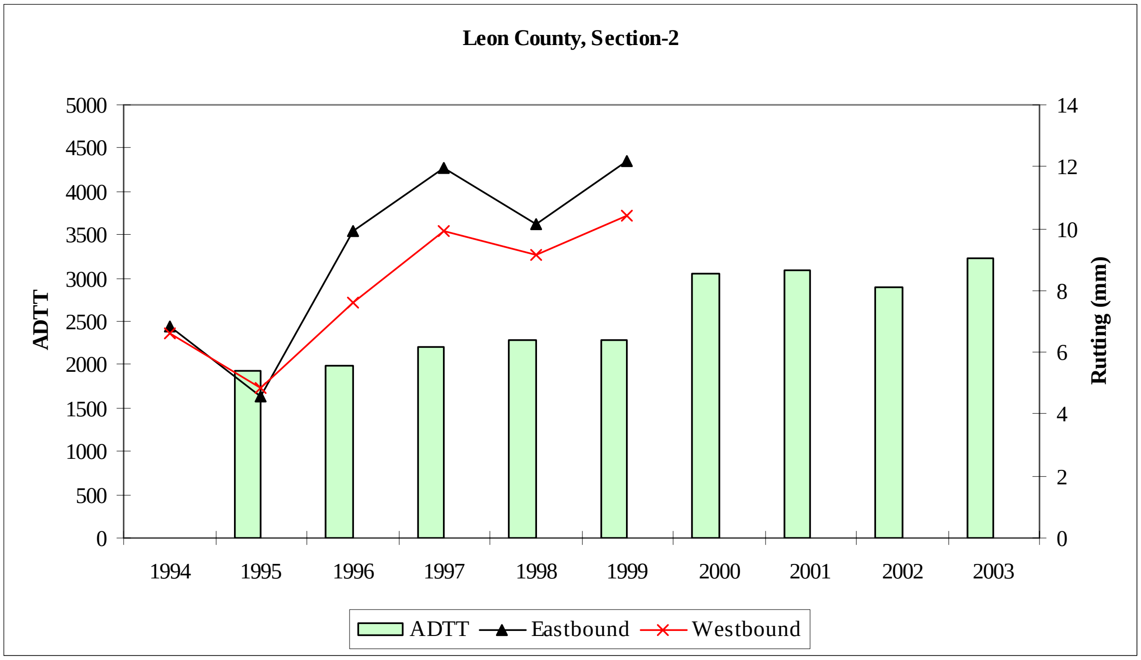

Leon County, Section-2
ADTT
Rutting (mm)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
14
12
10
8
6
4
2
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 5 (c)

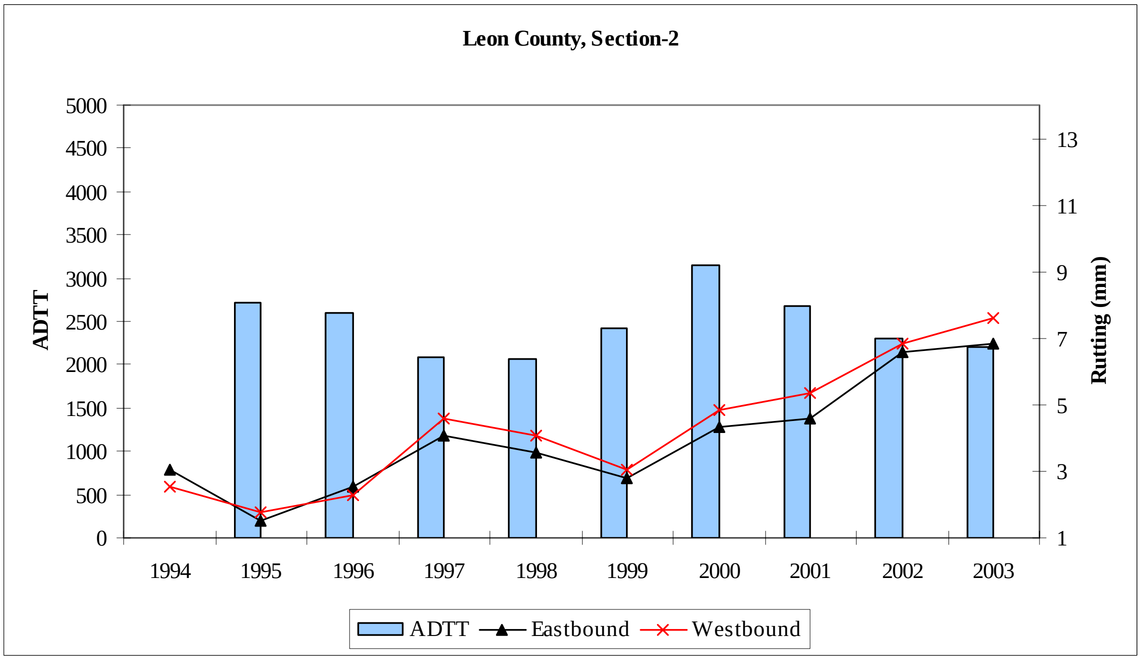

Leon County, Section-2
ADTT
Rutting (mm)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
13
11
9
7
5
3
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 5 (d)

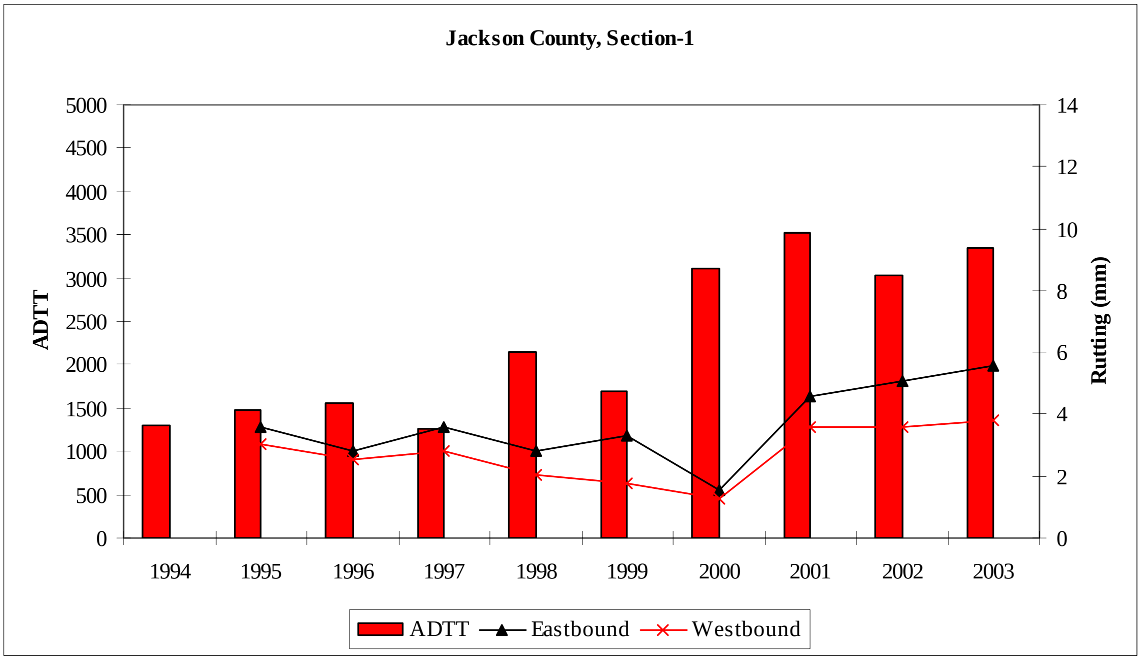

Jackson County, Section-1
ADTT
Rutting (mm)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
14
12
10
8
6
4
2
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 5 (e)

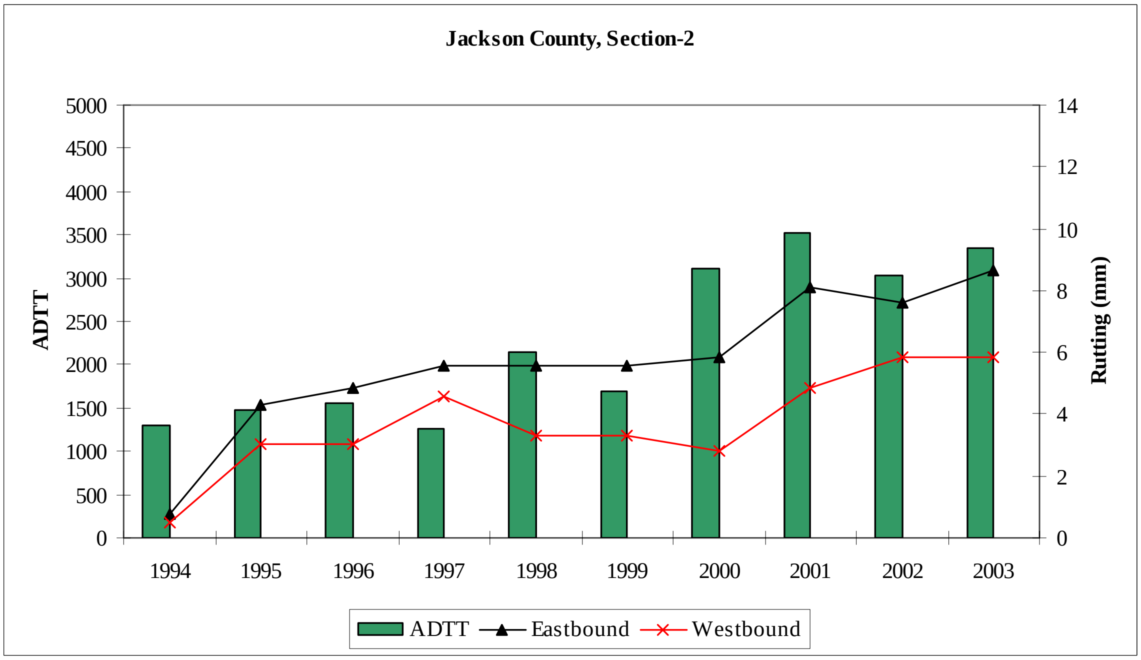

Jackson County, Section-2
ADTT
Rutting (mm)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
14
12
10
8
6
4
2
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 5 (f)

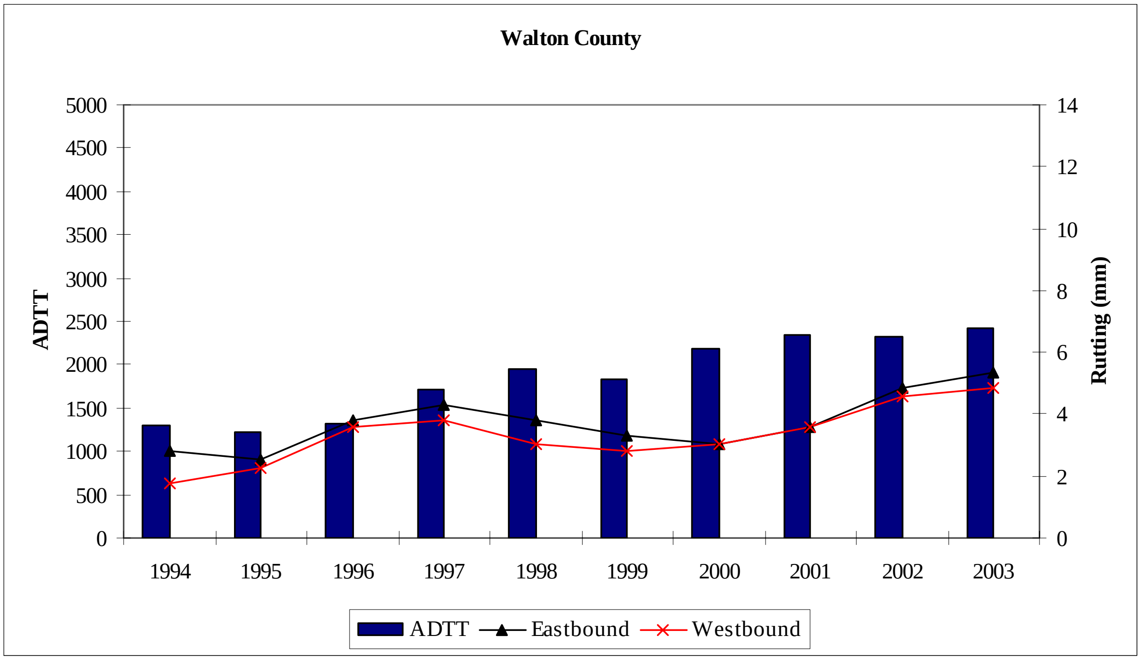


Fig 5 (g)

NOTE: ADTT is plotted on the Primary y-axis and Ride Number is plotted on the secondary y-axis.

Figure 5 Rutting measurements and ADTT.

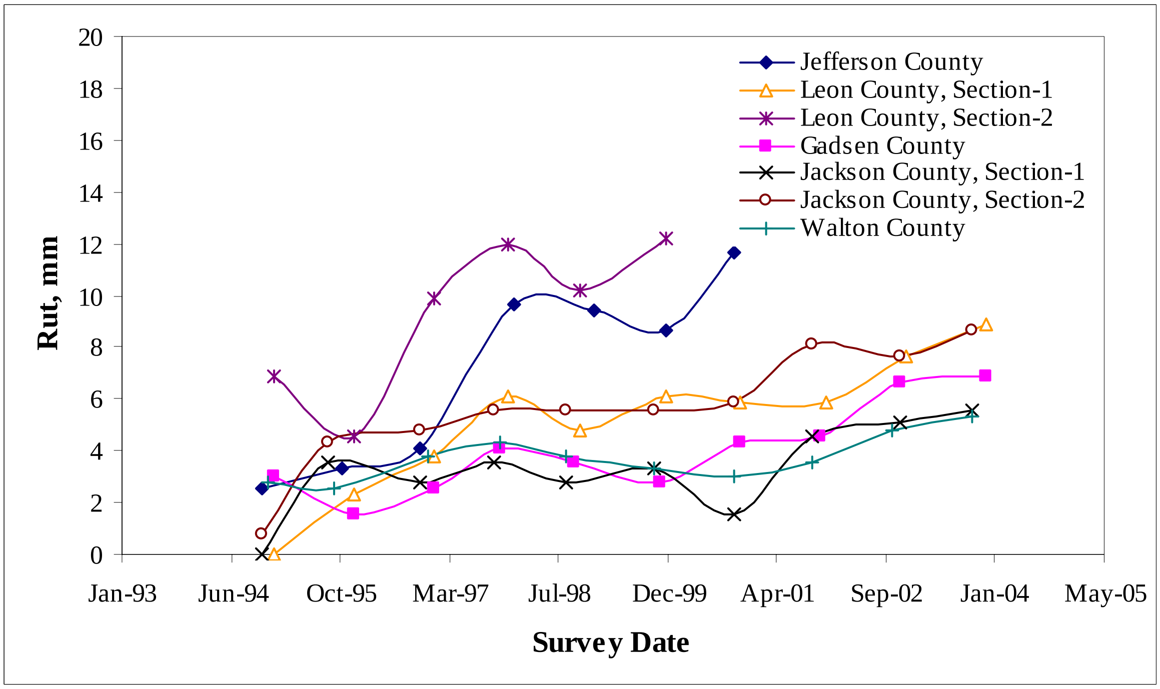


Figure 6 Rutting measurements in the eastbound direction.

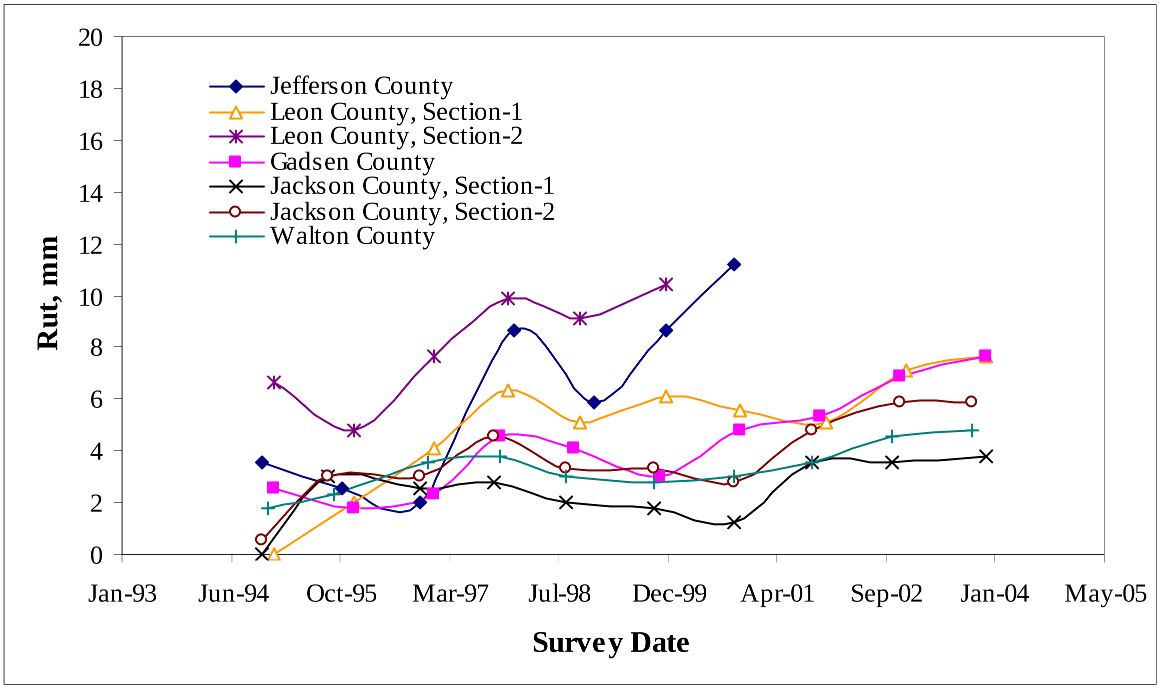


Figure 7 Rutting measurements in the westbound direction.

Crack Rating

The major distress associated with the HMA overlays of PCC pavements is reflective cracking. Therefore, a more appropriate measure of crack-and-seat field performance should be in terms of cracking. Standard FDOT crack evaluation methodology was used to determine the crack rating for the sections. The rating is on a 0 to 10 scale, with 10 representing a relatively new pavement free of cracks and patches. A section rating is determined by deducting a number of points from 10, depending on the extent, severity, and location of the cracks (in the wheelpath or outside wheelpath). According to the 'Flexible Pavement Condition Survey Handbook', the crack rating is given by *(15)*:

$$Cracking\ Defect\ Rating = 10 - (CW + CO) \text{ ....(1)}$$

Where:

CW is the numerical deduction for cracking confined to the wheel paths
CO is the numerical deduction for cracking outside of the wheel paths.

The results from earlier investigative studies performed by others indicated that the cracking-and-seating method reduced reflection cracking during the first few years after construction, but then increased after 4 to 5 years of service *(7, 9)*. Performance of the Florida crack-and-seat projects appear to show somewhat better performance as illustrated in Figures 8, 9 and 10. The first project to experience cracking was Gadsden County five years after rehabilitation; this was followed by Leon County (section 1) after six years. The other counties all experienced cracking in the seventh year. Visual surveys indicate that the amount of cracking is greatest in both directions of the second project in Jackson County, and to a lesser extent the westbound direction of the Gadsden County project.

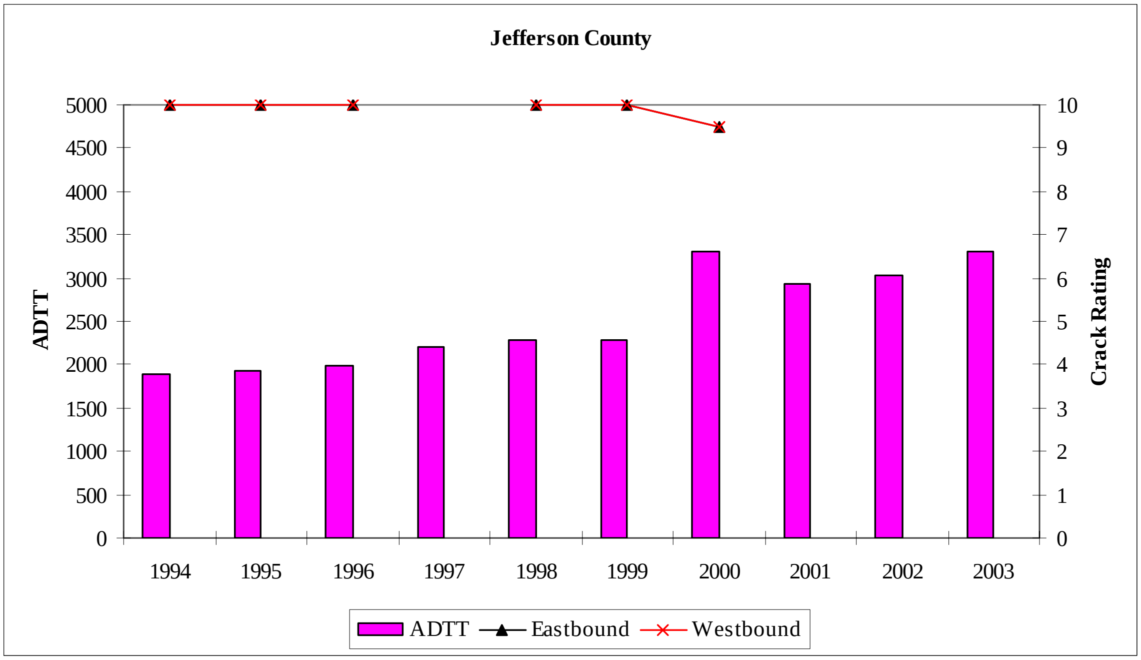


Fig 8 (a)

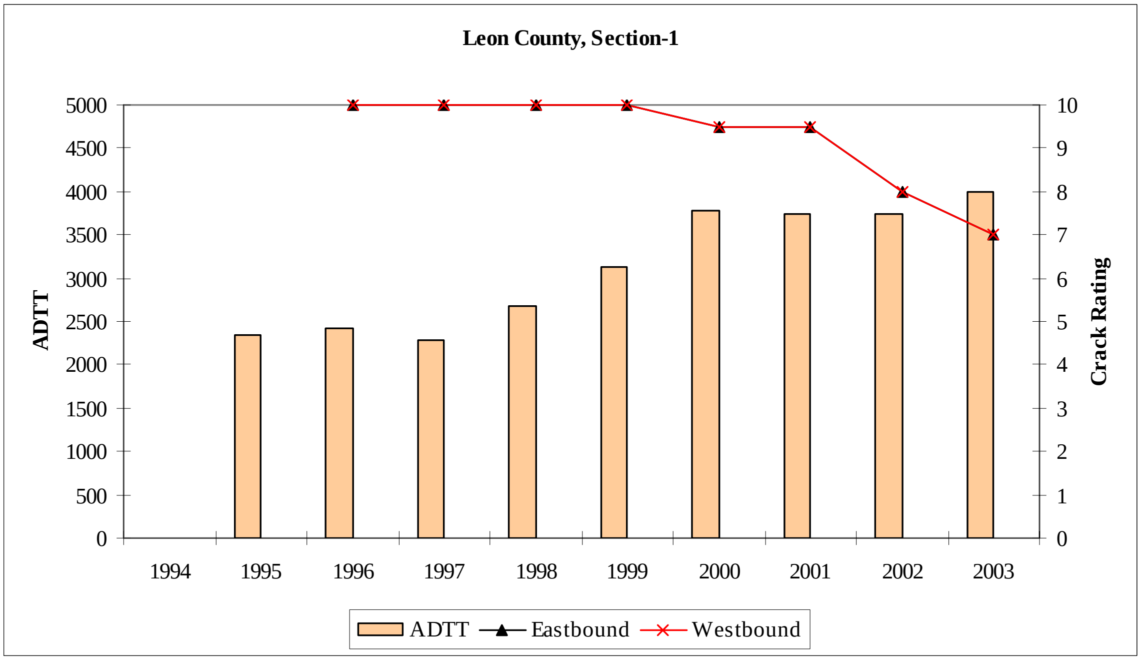


Fig 8 (b)

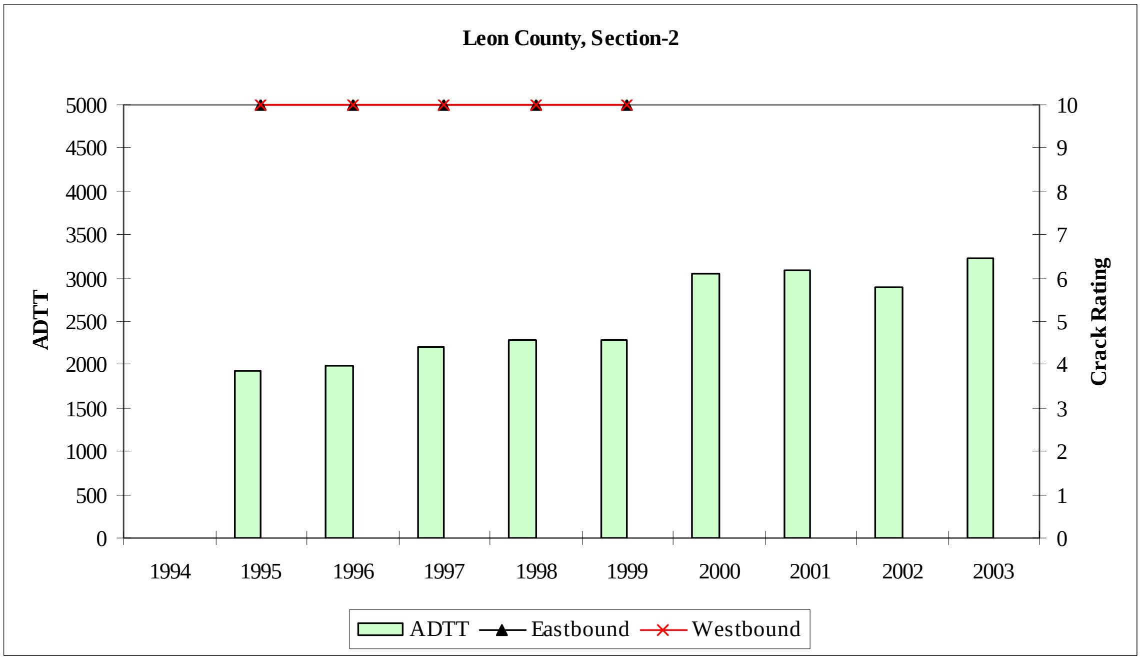

Leon County, Section-2
ADTT
Crack Rating
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10
9
8
7
6
5
4
3
2
1
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 8 (c)

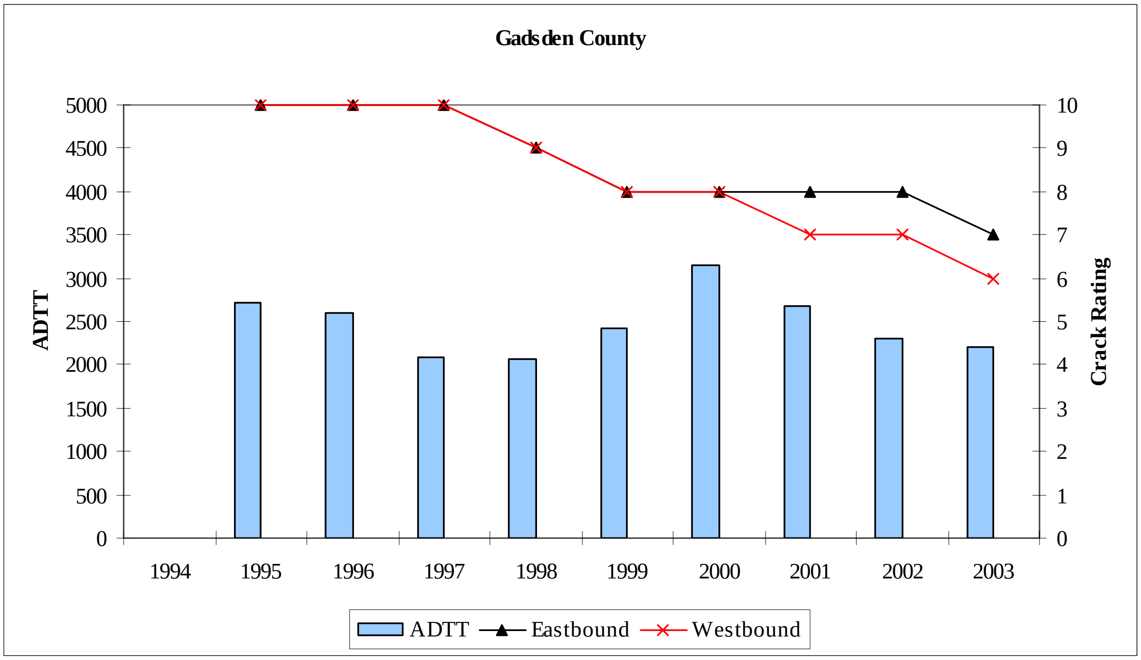

Gadsden County
ADTT
Crack Rating
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10
9
8
7
6
5
4
3
2
1
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 8 (d)

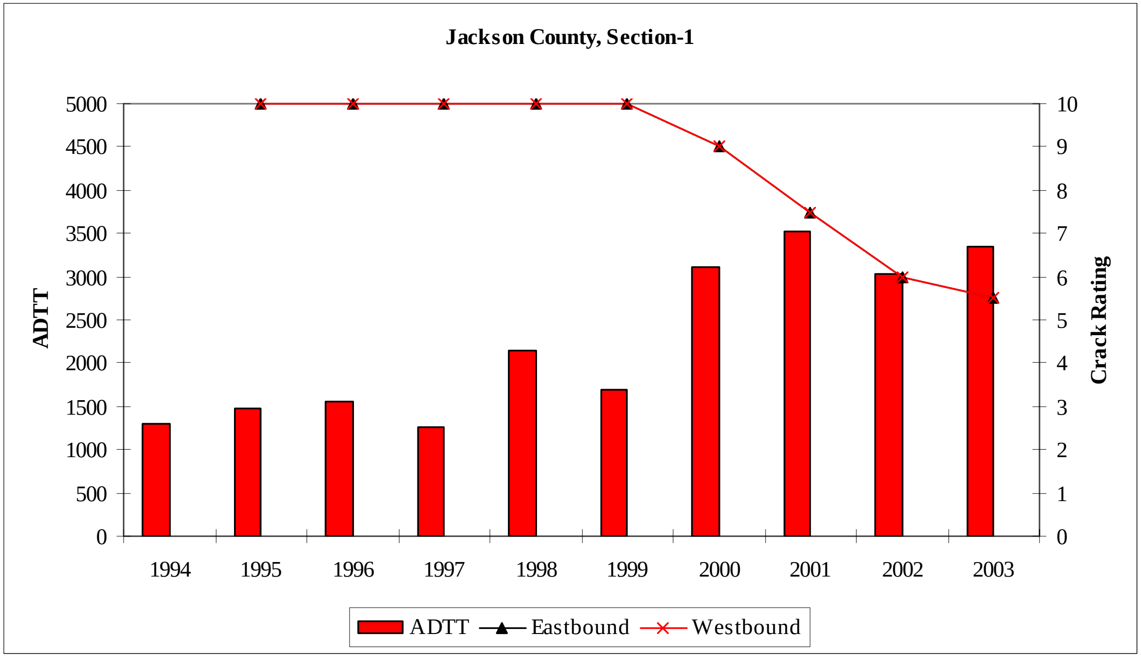

Jackson County, Section-1
ADTT
Crack Rating
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10
9
8
7
6
5
4
3
2
1
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 8 (e)

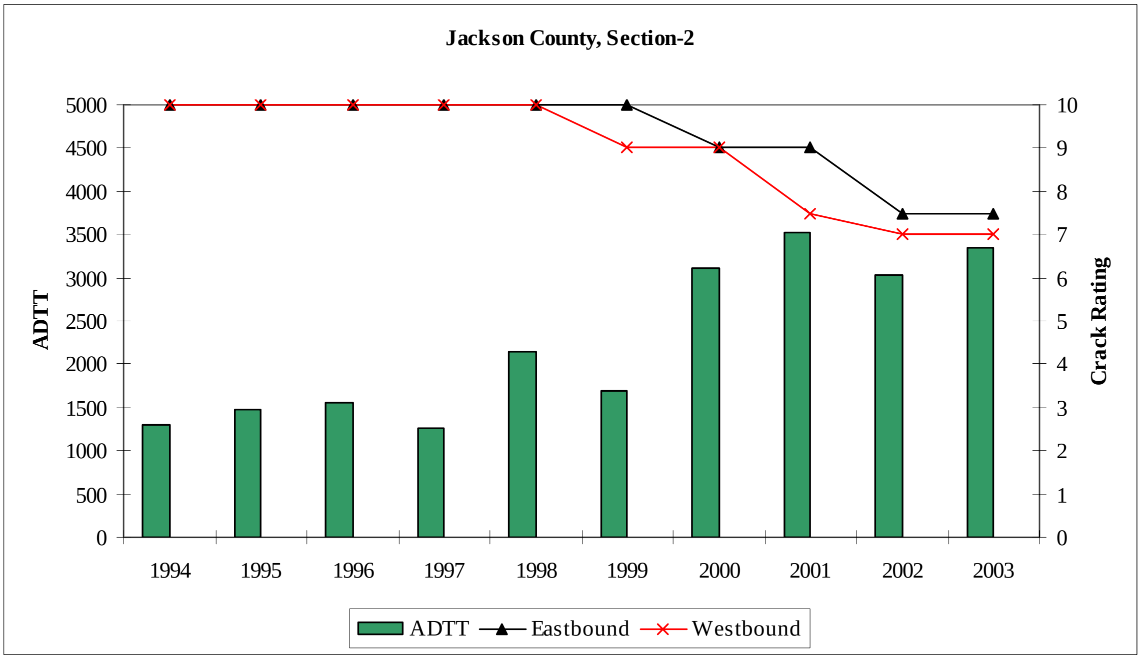

Jackson County, Section-2
ADTT
Crack Rating
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10
9
8
7
6
5
4
3
2
1
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
ADTT
Eastbound
Westbound

Fig 8 (f)

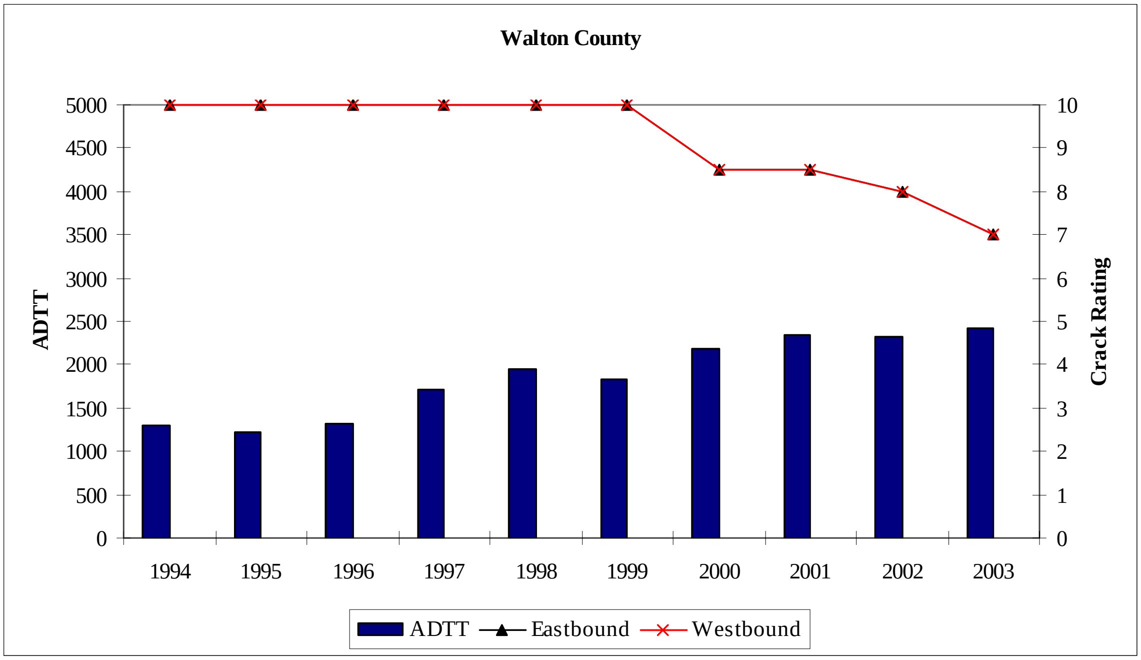


Fig 8 (g)

NOTE: ADTT is plotted on the Primary y-axis and Ride Number is plotted on the secondary y-axis.

Figure 8 Crack rating and ADTT

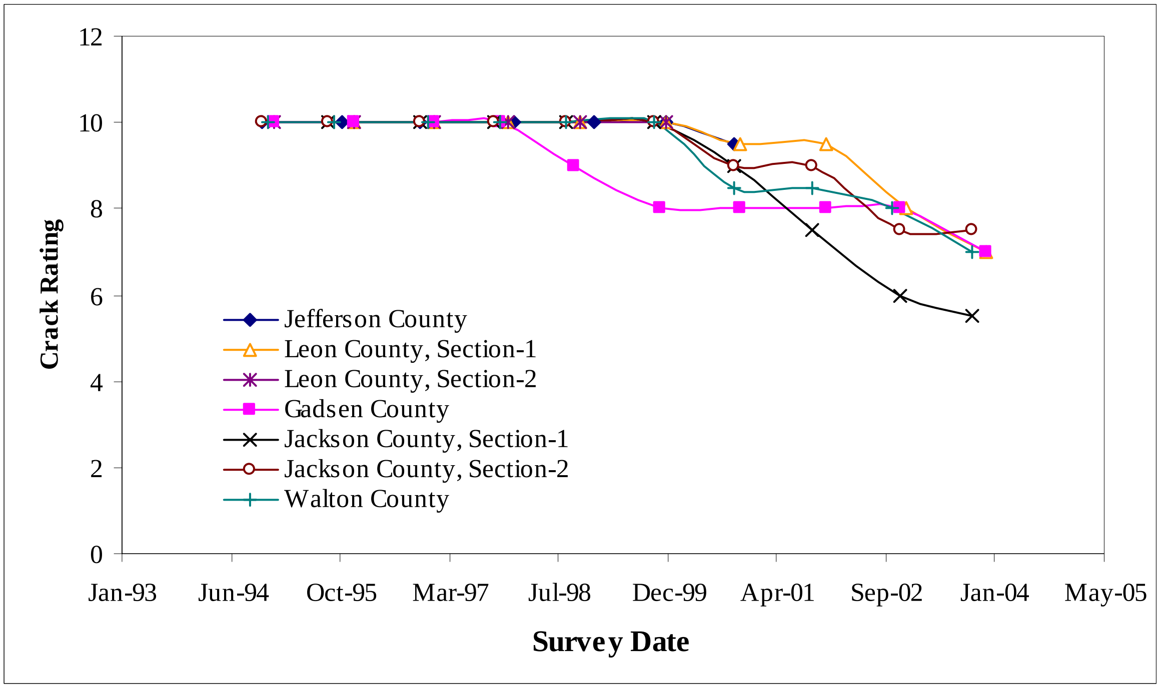


Figure 9 Crack rating in the eastbound direction.

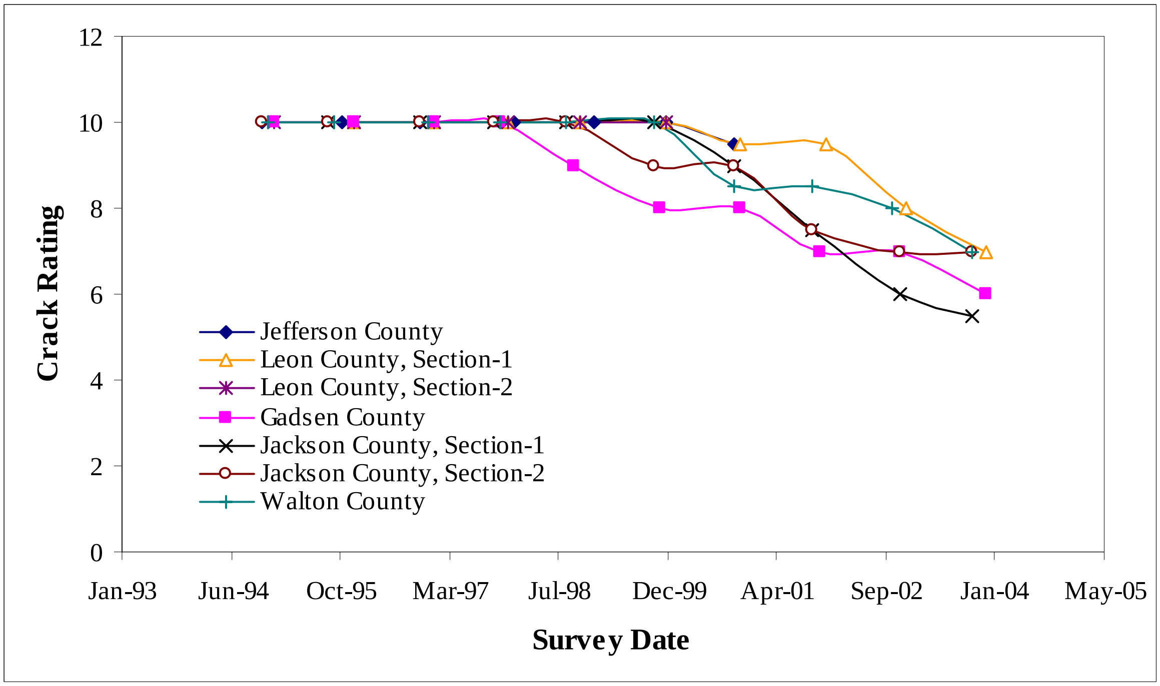


Figure 10 Crack rating in the westbound direction.

CONCLUSIONS

The primary objective of this effort was to collect long-term field performance data of the crack-and-seat rehabilitation technique and evaluate its effectiveness when used in conjunction with an ARMI layer in minimizing reflection cracking in HMA overlays. In all, seven projects totaling 14 two-lane sections, all located on the I-10 corridor in North Florida, were monitored for performance, from the construction and periodically thereafter. Analysis of the performance data on these sections after approximately ten years of service indicates the following:

- All seven projects (14 sections) have performed well in terms of ride quality in both the eastbound and westbound directions.
- Five out of seven projects exhibited an average rutting of approximately 0.35 inch after ten years of service. Two projects, located in Jefferson and Leon (second project) Counties, showed higher levels of deformation, averaging approximately 0.5 inch, and appear to be asphalt mix related. These two sections were resurfaced in 2001 and 2000 respectively.
- No cracking was observed for the first four years for all sections. However, cracking was evident on all sections by the seventh year, indicating that all sections performed as good as if not better than what literature suggested. Visual surveys indicate that the amount of cracking is greatest in both directions of the second project in Jackson County and to a lesser extent the westbound direction of the Gadsden County project.

In conclusion, the performance data indicates that the crack-and-seat technique, when used in conjunction with a stress relief membrane such as an ARMI layer, could be an effective rehabilitation strategy of PCC pavements.

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REFERENCES

1. L T Huang, Y. H. *Pavement Analysis and Design*. Prentice-Hall, Inc., New Jersey, 1993.
2. Sherman, G. *NCHRP Synthesis of Highway Practice 92: Minimizing Reflection Cracking of Pavement Overlays.* TRB, National Research Council, Washington, D.C., 1982.
3. Rajagopal A., I. Minkaraha, K. Kandula, and A. Gosain. *Performance Evaluation of Asphalt Overlays on Broken and Seated Concrete Pavements.* In Transportation Research Record 1543, TRB, National Research Council, Washington, D.C., 1996.
4. Fager, G. *Use of Rubber in Asphalt Pavements: Kansas Experience.* In Transportation Research Record 1436, TRB, National Research Council, Washington, D.C., 1994.
5. Choubane, B., Sholar. G.A., Musselman, J.A., and G.C. Page. *Long Term Performance Evaluation of Asphalt-Rubber Surface Mixes*. Technical Report 98-431, Florida Department of Transportation, State Materials Office, Gainesville, FL, November 1988.
6. Galal, K.A., B.J. Coree, J.E. Haddock, and T.D. White. *Structural Adequacy of Rubblized PCC Pavement.* In Transportation Research Record 1684, TRB, National Research Council, Washington, D.C., 1999.
7. Thompson, M. R. *NCHRP Synthesis of Highway Practice 144: Breaking/Cracking and Seating Concrete Pavements*. TRB, National Research Council, Washington, D.C., 1989.
8. Wells, G. K., J. B. Hannon, and N. H. Predoehl. California Experience with Cracking and Seating of Concrete Pavements. In *Transportation Research Record 1307*, TRB, National Research Council, Washington, D.C., 1991.
9. *Crack-and-Seat Performance*. Review Report, Demonstration Projects Division and Pavement Division, Federal highway administration, Washington, D.C., 1987.
10. Hall, T.H., Correa C.E., and A. Simpson. *Performance of Rigid Pavement Treatments in the LTPP SPS-6 Experiment.* In Transportation Research Record 1823, TRB, National Research Council, Washington, D.C., 2003.
11. Gulen S., and Noureldin A.S. *Evaluation of Concrete Pavement Rehabilitation Techniques on I-65.* In Transportation Research Record 1730, TRB, National Research Council, Washington, D.C., 2000.
12. *2004 Flexible Pavement Condition Survey Facts and Figures*. Technical Report 04-470, Florida Department of Transportation, State Materials Office, Gainesville, FL, May 2004.
13. J. A. Musselman, G. C. Page, D. C. Romano, and R. C. West. *Pavement Distress Investigation I-10, Leon County.* Technical Report 94-3, Florida Department of Transportation, State Materials Office, Gainesville, FL, December 1994.
14. J. A. Musselman, B. Choubane, G. C. Page, and P. B. Upshaw. Superpave Field Implementation: Florida’s Early Experience. In *Transportation Research Record 1609*, TRB, National Research Council, Washington, D.C., 1998.
15. Rigid Pavement Condition Survey Handbook, Florida Department of Transportation, State Materials Office, April 2003.