Structural Performance Evaluation of Recycled Pavements by Using Dynamic Deflection Measurements

SUDIPTA S. BANDYOPADHYAY

A comparative study is presented that concerns the structural performance of recycled pavements, which is based on the Dynaflect deflection measurements on five test sections of Kansas highway KS-96 that were monitored at regular intervals. Central-plant hot-recycling processes and in-place cold-recycling processes (with and without rejuvenating agent) were used to construct the four recycled test sections; the fifth one was a typical overlay section generally used in Kansas. In addition to the five deflection parameters that are associated with the Dynaflect measurements and are thought to be indicative of the structural characteristics of the measured pavement structure, criteria used for the comparative evaluation include the relative variation, with time, of required overlay thickness, pavement life, average pavement modulus, and subgrade modulus. The study reveals that the average values of layer coefficients for recycled materials generally found in the literature do not properly reflect the structural performance of the recycled sections. The study also reveals that the cold-recycled section (without rejuvenating agent) is perhaps superior in structural performance as compared with other sections. However, the typical overlay section and the cold-recycled section (with 2 percent rejuvenating agent) have a structural performance comparable to the previous one. Total pavement thickness is certainly a contributing factor. Gradual development of creep-actuated stiffening properties of the bituminous materials is found to vary widely, depending on the type of material.

The tremendous increase in recent years in the cost of asphalt cement and asphalt paving and an awareness of the need to conserve finite deposits of nonrenewable natural resources have prompted significant interest and investment in pavement recycling. In addition to the conservation of asphalt and aggregate, advantages of pavement recycling include conservation of energy, environmental preservation (reduced mining for new aggregate), and selective rehabilitation (elimination of the need for full-width overlays on multilaned highways).

Although pavement recycling as such is by no means a new concept, the methodology process, as it exists today, is still relatively new and undergoing changes. Thanks to the vigorous interest and participation of government, contractors, and researchers, pavement recycling is becoming a realization.

In general, pavement-recycling approaches can be classified under the following categories: surface recycling, in-place recycling, and central-plant recycling. Each of these three categories can be subdivided further into hot and cold processes.

Surface recycling is the reworking of the top 1 in of the pavement surface and can be achieved by techniques such as heater planing, heater scarifying, cold planing, and cold milling. Although surface recycling is effective in reducing distresses like rutting, shoving, corrugation, and reflection cracking, it produces limited structural improvement. In-place surface and/or base recycling consist of in-place pulverization followed by reshaping and compaction with or without the addition of a stabilizer. The advantages of in-place recycling include significant structural improvement and the ability to treat almost all types of pavement distress in asphalt-surfaced roadways. The problem of quality control is the major disadvantage of in-place recycling. In central-plant recycling, the pavement material is first scarified and removed from the roadway, mixed in a plant, and then laid and compacted to the desired grade. Advantages include improvements in structural capacity and the ability to correct all types of distress. Higher cost (compared with the other two), quality control, and potential air pollution problems are the disadvantages.

Although numerous publications have appeared in the specialized literature on design, construction, and cost analysis of different categories of pavement recycling, including reports of a symposium (1) and a seminar (2) at the national level, very little information, if any, is available concerning the relative performance of recycled pavements. The objective of this paper is to present a comparative structural evaluation of recycled pavements (in-place and central-plant) and analyze the performance of recycled pavements compared with typical pavement overlays. The analysis and evaluation are based on the dynamic deflection measurements obtained by a Dynaflect on different test sections of a reconstructed highway in Kansas.

PROJECT HISTORY

A test section about a mile long was selected on highway KS-96, which is east of Scott City in western Kansas. The original pavement was built in 1954 and was 7 in thick; it was a cold mix composed of sand-gravel with little or no crushed material and put down by blade laying. Conventional seals were added several times subsequently up to the current thickness of 8 in.

A 1952 soil survey report on the project described the soils as colby silt loam. The surface soil was a silt with a small proportion of very fine sand that extended to a depth of about 12-18 in. Underlying the surface soil was found a zone of dark brown weathered material that varied in thickness from 4 to 8 in and was classified as a silty clay. During the original construction, the top 12 in of the subgrade was compacted to a density equal to or greater than 95 percent of the Standard Proctor density.

The predominant type of distress that developed over the years was mainly transverse and some longitudinal cracking. The transverse cracks, which developed in the mat, eventually progressed from a single crack to a series of closely spaced multiple cracks. The mix beneath and adjacent to the cracks then deteriorated to the point where it lost its stability and load-carrying capacity substantially. The deterioration continued despite an extensive crack-sealing maintenance program.

PAVEMENT RECYCLING

The arrangement of the recycled test sections is shown in Figure 1. The decision to keep about 4 in of the existing mat was prompted by the requirement that traffic be allowed during the construction period. Construction was carried out during the last week of August 1979.

Central-Plant Hot Recycling

A CMI-750 Roto Mill, which is capable of cutting a section 12.5 ft wide, was used to mill about 3.5 in off the existing pavement in one pass. For the in-plant hot-recycling process (section A), the milled material was loaded into trucks, hauled, and

Figure 1. Arrangement of test sections.

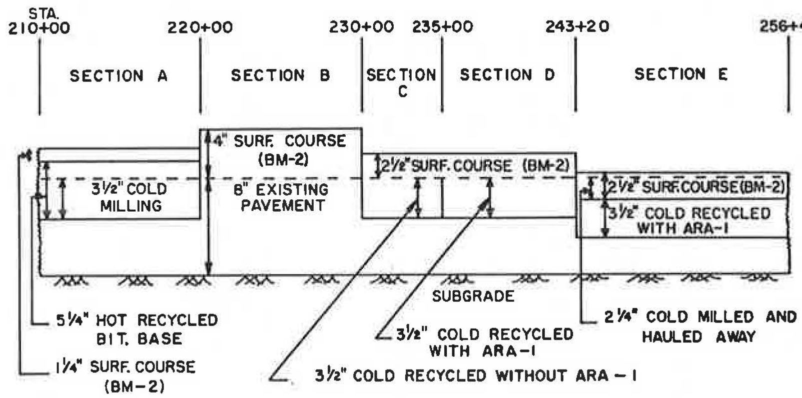
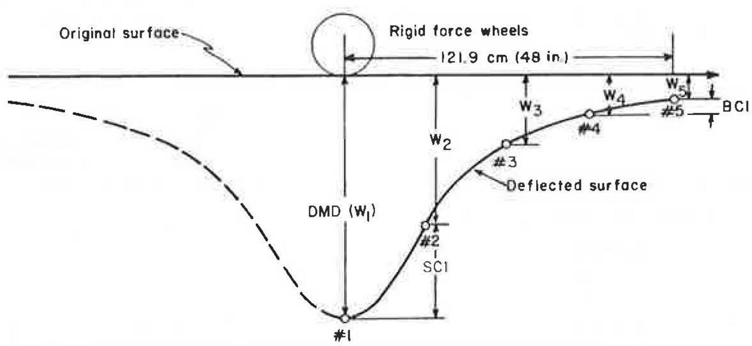


Figure 2. Deflection basin parameters associated with Dynaflect measurements.



W_{max} = Dynaflect maximum deflection (numerical value of sensor #1

SCI = Surface curvature index (numerical difference of sensor #1 and #2)

BCI = Base curvature index (numerical difference of sensor #4 and #5)

$$SP\% = \frac{W_1 + W_2 + W_3 + W_4 + W_5}{5\ W_1} \times 100$$

W_5 = Numerical value of sensor #5

stockpiled at the plant site. The reclaimed material was mixed with virgin material on a 50:50 proportion. About 2.5 percent new 120 to 150 penetration-grade asphalt was added. A split feed drum mixer was used, and the virgin aggregate was introduced at the flame end of the drum and superheated to 300°-500°F. The reclaimed material was introduced at about the midpoint of the drum and heated by hot gasses as well as by heat transferred from the superheated virgin aggregate. The combined material was then laid back in two lifts totaling 5.25 in thick on a 30-ft width. It was then topped with a 1.5-in wearing course.

In-Place Cold Recycling

The in-place cold recycling was done with and without a rejuvenating agent. A CMI-750 milled the old roadway 3.5 in deep and 12 ft wide. While milling, except in the no-additive section (section C), a distributor was attached by hose to the front of the PR-750. The rejuvenating agent (ARA-1) was pumped through the PR-750 water spray bar. The milled material formed a windrow about 3 ft high behind the PR-750. A blade followed and cut the turf shoulder down to the depth of the 3.5-in cut. A CMI Clarco Windrow loader, which was pushed by the paver, picked up the windrow and loaded it into the paver. The paver relaid the recycled material 15-ft wide. The recycled mix was then compacted and traffic was allowed on the rolled material. A wearing course was then applied the following day. A detailed account of the cold-recycled section is given elsewhere (3).

DEFLECTION MEASUREMENTS

The deflection basin parameters associated with Dynaflect measurements are shown in Figure 2. The Dynaflect maximum deflection (DMD) is a measure of the structural characteristics of the pavement and support conditions. The surface curvature index (SCI) is predominantly an indicator of the structural integrity of the surface layer. The base curvature index (BCI) measures the base support conditions. The spreadability (SP) measures the load-carrying capacity and stiffness ratio of the pavement structure, and the fifth sensor reading (W_5) has been shown to be an indirect measure of the subgrade modulus. These five parameters, considered either individually or jointly, can provide an estimate of the structural condition of the pavement structure being surveyed. Further information regarding evaluation and application of Dynaflect deflections is given elsewhere (3-12).

Dynaflect deflection measurements were obtained on all sections before and after construction. The results are presented in Table 1. All the parameter values are the average values normalized with respect to a base temperature of 70°F (5,10).

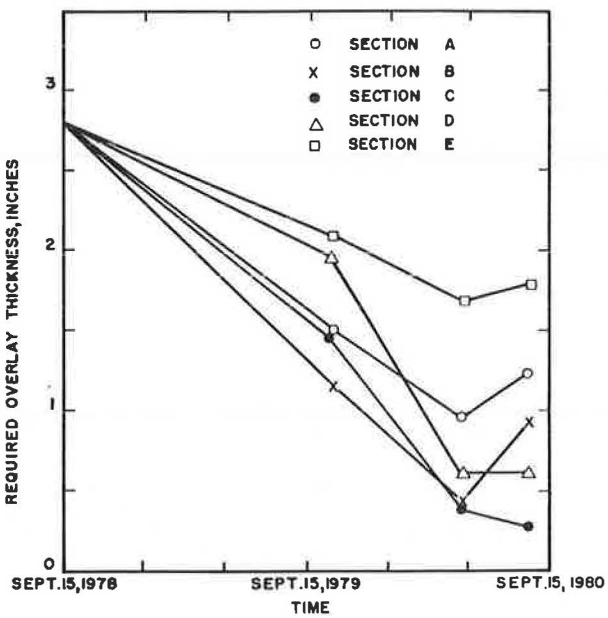
STRUCTURAL PERFORMANCE EVALUATION

Different thicknesses of the structural layers in the test section preclude a direct comparison between them. Therefore, the sections will be evaluated in terms of their structural number (SN). The SN is defined as an index number derived from an analysis of traffic, roadbed soil conditions, and a regional factor that may be converted to thickness

Table 1. Average Dynaflect parameter values.

Section	Date	DMD (mils)	SCI (mils)	BCI (mils)	SP (%)	W_5 (mils)
A	Sept. 15, 1978	1.58	0.49	0.11	50	0.30
	Oct. 23, 1979	1.53	0.21	0.13	61	0.35
	May 7, 1980	1.26	0.29	0.12	58	0.31
	Aug. 20, 1980	1.38	0.33	0.13	57	0.33
B	Sept. 15, 1978	1.58	0.49	0.11	50	0.30
	Oct. 23, 1979	1.31	0.14	0.11	67	0.41
	May 7, 1980	1.05	0.19	0.13	64	0.35
	Aug. 20, 1980	1.13	0.23	0.12	62	0.36
C	Sept. 15, 1978	1.58	0.49	0.11	50	0.30
	Oct. 23, 1979	1.42	0.25	0.12	59	0.33
	May 7, 1980	1.09	0.25	0.12	58	0.25
	Aug. 20, 1980	1.09	0.26	0.12	58	0.28
D	Sept. 15, 1978	1.58	0.49	0.11	50	0.30
	Oct. 23, 1979	1.64	0.30	0.13	59	0.38
	May 7, 1980	1.20	0.32	0.10	57	0.30
	Aug. 20, 1980	1.22	0.36	0.11	56	0.32
E	Sept. 15, 1978	1.58	0.49	0.11	50	0.30
	Oct. 23, 1979	1.58	0.49	0.13	54	0.42
	May 7, 1980	1.50	0.41	0.13	57	0.35
	Aug. 20, 1980	1.49	0.46	0.13	55	0.39

Figure 3. Required overlay thickness before and after reconstruction.



of various flexible-pavement layers through the use of suitable layer coefficients related to the type of material being used in each layer of the pavement structure. The layer coefficient (designated by a_1, a_2, and a_3 for surface, base, and subbase, respectively) is the empirical relation between SN for a pavement structure and layer thickness, which expresses the relative ability of material to function as a structural component of the pavement (13).

Analytically, the SN is given by the following equation:

$$SN = a_1 D_1 + a_2 D_2 + a_3 D_3 \quad (1)$$

where the D_i values are the respective layer thicknesses. A layer coefficient value of 0.44 is generally used for surface course in Kansas. Because layer coefficients for recycled materials have not yet been formulated in Kansas, the following coefficients are selected based on the recommendations by Epps (14):

1. Hot-recycled bituminous base = 0.40,
2. Cold-recycled bituminous base (with ARA-1) = 0.38, and
3. Cold-recycled bituminous base (without ARA-1) = 0.30.

A layer coefficient of 0.15 was selected for the existing mat. The SNs of different sections are then given by the following: section A = 3.33, section B = 2.96, section C = 2.83, section D = 3.11, and section E = 2.73. According to this criteria, section A is supposed to be structurally superior to the other sections and section E represents the weakest section, provided that the values of layer coefficients used are realistic. As will be seen in the following sections, pavements that might be categorized structurally superior according to SN criteria are not necessarily superior in their structural performance.

Overlay Thickness and Pavement Life Criteria

The recorded DMDs on each section were used to determine a representative DMD for the section. At the 95 percent confidence level, the representative DMD equals the following:

$$\text{Representative DMD} = (\overline{DMD} + 1.645\ s) \cdot f \cdot c \quad (2)$$

where

$\overline{DMD}$ = arithmetic mean of the individual values,
s = standard deviation,
f = temperature adjustment factor, and
c = critical period adjustment factor.

The representative DMD was used to compute the overlay thickness and the pavement life according to the Asphalt Institute method (15). An evaluation of f and c factors has been discussed elsewhere (5,10). It should be emphasized that too many extraneous forces affect the condition of the pavement for any method of estimating the overlay thickness and pavement service life accurately. This paper is primarily concerned with the comparative study of solutions and, therefore, comparative values rather than absolute values are mainly significant.

Required overlay thickness and pavement life for each section before and after reconstruction are plotted in Figures 3 and 4, respectively. It is evident from Figures 3 and 4 that, based on overlay thickness and pavement life criteria, section C (SN = 2.83) is superior to the other sections and section E (SN = 2.73) is the weakest section. It should also be noted that the performances of section B (SN = 2.96) and section D (SN = 3.11) are comparable with that of section C. For all sections, the percentage reduction in the required overlay thickness and the percentage increase in the pavement life after reconstruction are given in Table 2.

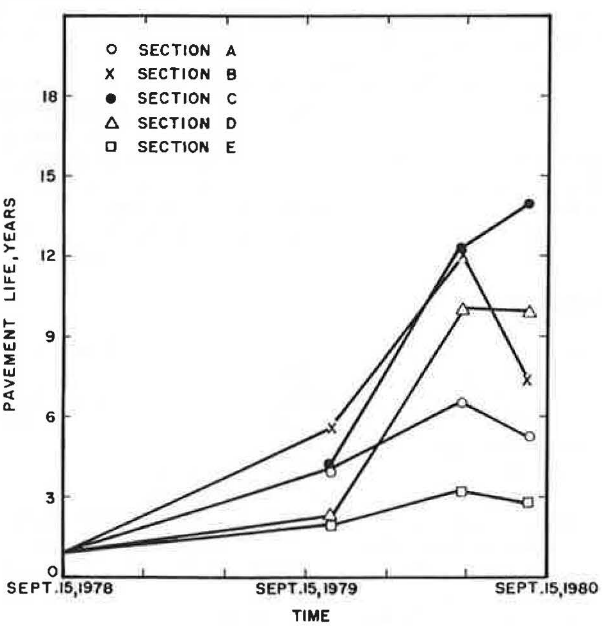
One important observation that can be made from Figures 3 and 4 is that the performance of all sections after reconstruction improves up to about seven to eight months. After that, except for section C, the performance begins to deteriorate. The rate at which the performance improves or deteriorates can be judged by observing the slope of the lines in Figures 3 and 4. The rate of improvement for sections A and E is much lower than that of the other sections. However, the rate of deterioration of section B is much higher than that of any other section. The performance of section C was steadily improving one year after construction.

The gradual improvement observed after construction in the performance of the recycled sections can

Table 2. Percentage improvement in structural performance of test sections after reconstruction.

Item	Section A			Section B			Section C			Section D			Section E		
	10/23/ 79	5/7/ 80	8/20/ 80	10/23/ 79	5/7/ 80	8/20/ 80	10/23/ 79	5/7/ 80	8/20/ 80	10/23/ 79	5/7/ 80	8/20/ 80	10/23/ 79	5/7/ 80	8/20/ 80
DMD	3	20	13	17	34	28	10	31	31	−4	24	23	0	5	6
SCI	57	41	33	71	61	53	49	49	47	39	35	27	0	16	6
BCI	−18	−9	−18	0	−18	−9	−9	−9	−9	−18	9	0	−18	−18	−18
SP	22	16	14	34	28	24	18	16	16	18	14	12	8	14	10
W_5	−17	−3	−10	−37	−17	−20	−10	17	7	−27	0	−7	−40	−17	−30
Overlay thickness	47	65	56	58	85	67	47	86	90	29	79	78	25	40	36
Pavement life	344	656	489	511	1233	711	344	1256	1444	156	1011	1000	122	256	211
Avg pavement modulus	900	667	600	1733	1733	1233	767	1067	1067	583	633	533	367	567	517
Subgrade modulus	−17	0	−6	−17	3	3	−8	17	17	−17	0	11	−6	3	3

Figure 4. Pavement life before and after reconstruction.



be expected because the deflections taken on a newly laid asphalt pavement a few days after its construction will subsequently decrease in magnitude (up to a certain time). The reasons for this reduction in magnitude are (a) densification of the bituminous material under wheel loads, and (b) gradual development of creep-actuated stiffening properties of the bituminous material. Although the expected densification of the bituminous material due to wheel loads is generally achieved in the first few months of the pavement service period, the development of the full stiffening properties may take some additional time. It is evident that the stiffening properties of section C were still developing one year after its construction, while the stiffening properties of the other sections realized their full potential about seven or eight months after their construction and then started to deteriorate.

Pavement and Subgrade Modulus

To investigate the mechanism of the variation of the stiffening properties with time for the sections, average pavement modulus (average of all the bituminous layers) was computed from the deflection measurements by assuming the pavement structure as a two-layer medium. The pavement modulus values were determined from a consideration of the corresponding average SP and DMD values and assuming a Poisson's ratio value for the pavement and the subgrade equal to 0.45 (16).

The variation with time of section pavement modulus is shown in Figure 5. It can be seen that the average pavement modulus for section A started to decrease almost immediately after construction, while that of section B reached its highest value about four months after construction and then started to decrease drastically. The average pavement modulus value for section C increased to about one year after construction and those of sections D and E increased to about eight months after construction and then slowly began to decrease. The average pavement modulus of section B is substantially larger than that of other sections; the greater thickness of section B, as compared with other sections, may be a contributing factor to its larger value of pavement modulus. Section C has the next largest pavement modulus.

The variation of subgrade modulus with time, computed from corresponding DMD and SP values (16), is shown in Figure 6. Monthly precipitation values are also plotted in Figure 6. It can be seen that, immediately after construction, the subgrade moduli of all the sections decreased and, after that, there was no significant gain in the moduli values, as shown in Table 2. This trend, with respect to values of subgrade modulus, is also substantiated by the BCI and W_5 values, which are indicative of subgrade strength. Substantial amounts of rain at the site during the time of construction may help to explain the reduction in values of subgrade modulus. As can be expected, the subgrade modulus behavior for all the sections is approximately the same. A recent study concludes that there is a statistically significant cross correlation between precipitation and the value of subgrade modulus. Further discussion of this topic is beyond the scope of this paper.

SUMMARY

Five test sections are being monitored on KS-96 near Scott City, Kansas, to study the structural performance characteristics of recycled pavements. Central-plant hot-recycling and in-place cold-recycling processes (with and without rejuvenating agent) were used in the construction of four test sections; the fifth section has a 4-in surface course overlay. A comparative evaluation is presented based on the Dynaflect deflection measurements being obtained at regular intervals on all test sections.

It was found that the structural performance of the different sections is not necessarily directly related to their SN obtained from the recommended values of layer coefficients found in the literature for recycled materials. This would suggest that further studies are needed to evaluate realistic

Figure 5. Variation of pavement modulus of sections with time.

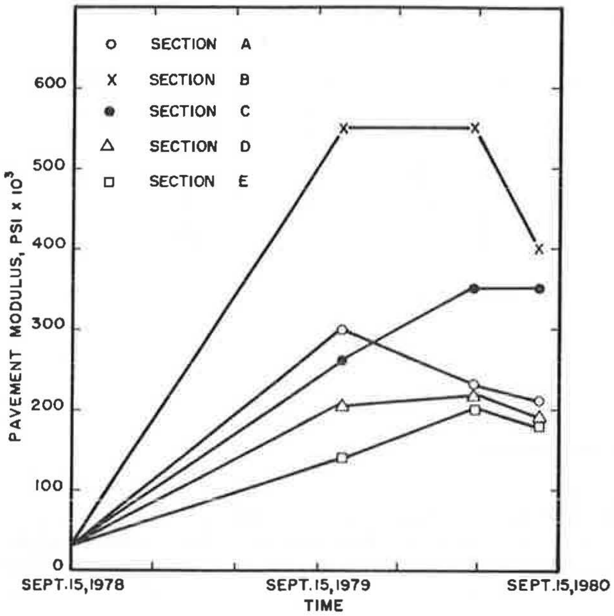
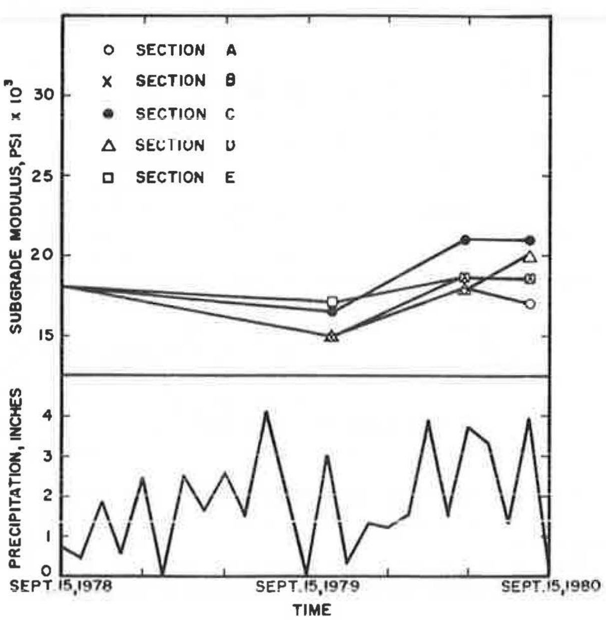


Figure 6. Subgrade modulus and monthly precipitation.



values of layer coefficients for recycled materials, which should adequately reflect their structural performance.

Based on the criteria of required overlay thickness and pavement life, section C, which has a 3.5-in in-place cold-recycled layer (without rejuvenating agent), is found to be superior than the other sections. The performance of section B with 4 in of surface course overlay and of section D with 3.5 in of in-place cold-recycled layers (with 2 percent ARA-1) is comparable to that of section C. Section E, which has structural layers similar to section D but is 2.25 in less in thickness, is the weakest section, thereby accentuating the effect of thickness on structural performance. Section A, which has a 5.25-in hot-recycled bituminous layer and also the highest SN, has a poor structural performance compared with sections B, C, and D.

As far as the average pavement modulus is concerned, section B developed a modulus value initially much higher than those of the other sections. However, after about 7-8 months, the modulus value for this section began to decrease rather abruptly and attained a value only slightly higher than the modulus of section C, which showed a steady gain in magnitude for almost 10-11 months. The average pavement modulus of section A began decreasing almost immediately after the section was built.

Subgrade moduli in all sections showed remarkably similar characteristics, as can be expected, and also exhibited some susceptibility to rain.

ACKNOWLEDGMENT

Most of the work presented in this paper was accomplished while I was with the Geotechnical Section of the Kansas Department of Transportation. The contents of this paper reflect my views, and I am solely responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Kansas Department of Transportation or the Federal Highway Administration. The help received from Darrel D. Steele is readily acknowledged. Partial support from the Professional Development Program at National Soil Services, Inc., is also acknowledged.

REFERENCES

1. Recycling of Bituminous Pavements. ASTM, Special Tech. Publ. 662, 1978.
2. Proceedings of the National Seminar on Asphalt Pavement Recycling. TRB, Transportation Research Record 780, 1980, 141 pp.
3. S.S. Bandyopadhyay. Design and Structural Condition Evaluation of a Cold Recycled Pavement. Symposium on Advances in Pavement Materials Characterization, ASTM, Houston, Dec. 1981.
4. S.S. Bandyopadhyay. Sample Size of Pavement Deflections. Journal of Civil Engineering Design, Vol. 2, No. 4, 1980, pp. 339-346.
5. S.S. Bandyopadhyay. Developing a Functional Subsystem of Overlay Design Using Dynamic Deflections. Journal of Civil Engineering Design, Vol. 2, No. 4, 1980, pp. 443-457.
6. S.S. Bandyopadhyay. Dynamic Deflections of Pavements--Measurements, Interpretations, and Applications. Proc., International Symposium on Bearing Capacity of Roads and Airfields, Norway, June 1982.
7. S.S. Bandyopadhyay. Pavement Deflections--Static and Dynamic. Public Works Journal, Vol. 113, No. 1, Jan. 1982, pp. 48-49.
8. S.S. Bandyopadhyay. Determining Sample Size of Pavement Deflections by Nomograph. Civil Engineering, ASCE (in preparation).
9. S.S. Bandyopadhyay. Pavement Distress Identification and Condition Evaluation. In Civil Engineering for Practicing and Design Engineers, Pergamon Press (in preparation).
10. S.S. Bandyopadhyay. Flexible Pavement Evaluation and Overlay Design. Transportation Engineering Journal, ASCE (in preparation).
11. R.W. Kinchen and W.H. Temple. Asphaltic Concrete Overlays of Rigid and Flexible Pavements, Final Report. Louisiana Department of Transportation and Development, Baton Rouge, Oct. 1980.
12. G. Peterson. Predicting Performance of Pavements by Deflection Measurements. Research and Development Unit, Utah Department of Transportation, Salt Lake City, 1975.

13. Interim Guide for Design of Pavement Structure--1972. AASHO, Washington, DC, 1972.
14. J.A. Epps. State-of-the-Art Cold Recycling. TRB, Transportation Research Record 780, 1980, pp. 68-100.
15. Asphalt Overlays and Pavement Rehabilitation. Asphalt Institute, College Park, MD, Manual Series 17, Nov. 1977.
16. K. Majidzadeh. Dynamic Deflection Study for Pavement Condition Investigation, Final Report. Ohio Department of Transportation, Columbus, June 1974.

Notice: The Transportation Research Board does not endorse products or manufacturers. Trade and manufacturers' names appear in this paper because they are considered essential to its object.

Publication of this paper sponsored by Committee on Pavement Rehabilitation Design.

Application of Asphalt Rubber on New Highway Pavement Construction

GENE R. MORRIS, NAN JIM CHEN, AND JOSEPH A. DI VITO

Asphalt rubber has been used for many years as a stress-absorbing membrane (SAM) or stress-absorbing membrane interlayer (SAMI) for both rigid and flexible pavement overlay systems in Arizona with satisfactory performance. In 1977, a new experimental application of asphalt rubber was used to build a low-volume highway pavement between Dewey and I-17 on AZ-169. Several experimental pavement sections were placed. After four years of service, only two sections are still in excellent condition with no cracks or ruts observed to date. One section consisted of a cement-treated base and the other a lime-fly ash-treated base. Each section received a SAMI and a 1-in wearing course. Other test sections failed, and constant patching is required to maintain a minimal level of service. Generally, cement-treated bases will always have shrinkage cracks that easily reflect through any asphalt concrete surface layer if without special treatment to retard crack propagation. A finite-element procedure was used as an aid in explaining why a SAMI can be used effectively to eliminate reflective cracks. It was found that SAMIs can significantly reduce crack tip stresses due to thermal and traffic loads and provide longer service life of the asphalt concrete surface layer.

In the early 1960s, asphalt rubber was originally used as a patching material for alligator-cracking-type failures in Arizona (1,2). Later it was developed as a stress-absorbing membrane (SAM) and stress-absorbing membrane interlayer (SAMI) for rehabilitation and overlay of cracked pavements (3-7). Asphalt rubber has also been used as a joint and crack seal material and as a waterproof membrane for the control of expansive clay subgrades.

Coetzee and Monismith (8) investigated the effectiveness of a SAMI as an overlay system over rigid pavements by inducing thermal and symmetrical traffic loading across a crack. Results of this study concluded that a SAMI can reduce stresses in overlays and can also prolong the service life of a typical overlay.

Many field studies of SAM and SAMI have been undertaken by the Arizona Department of Transportation. In 1977, a new area for application of asphalt rubber was introduced in the construction of a low-volume road with a cement-treated base (CTB). This paper discusses this new asphalt-rubber application.

CONSTRUCTION AND PERFORMANCE

The Dewey project, as it is often referred to, is on AZ-169 between mileposts 4.8 and 14.5 and is located approximately 80 miles north of Phoenix. It was constructed as a new connecting highway between Dewey, Arizona, and I-17. Currently, the average daily traffic (ADT) is approximately 1000 with 6 percent trucks. The embankments and grades were constructed in 1976 and surfacing was placed in August 1977. This project consisted of five test sections and one control section.

The original pavement design (before it was decided to build test pavements) called for stage construction of 6 in of full-depth asphalt concrete with an open-graded asphalt concrete friction course (ACFC) on the compacted subgrade. Initial surfacing was 2 in and the remaining 4 in was designated for future surfacing.

Subgrade material is primarily decomposed granite, clayey sand, and gravel with a plasticity index ranging as high as 69. The average project elevation is approximately 4400 ft, and winter months are often severe.

The characteristics of the control section and the five test sections are as follows:

1. Control section, station 262-520: The subgrade was compacted to 100 percent of maximum density (36-ft width). Two inches of asphalt concrete were placed on the compacted subgrade. Asphalt concrete was made with an AR2000 asphalt.
2. Test section 1, station 520-555, Lime-Fly Ash-Treated Base: Three percent quicklime and 12.5 percent fly ash (by weight of subgrade material) were added to in-place subgrade soil and thoroughly mixed to a depth of 6 in and then compacted to 100 percent of maximum density. An asphalt-rubber membrane was placed across the entire roadway, shoulders, and cut ditches. A 1-in ACFC was placed as a wearing course.
3. Test section 2, station 555-590, CTB: Four and one-half percent (by weight of subgrade material) portland cement was added to the in-place subgrade soil. This was thoroughly mixed to a depth of 6 in and then compacted to 100 percent of maximum density. An asphalt-rubber membrane was placed across the entire roadway, shoulders, and cut ditches. A 1-in ACFC was placed as a wearing course.
4. Test section 3, stations 590-640 and 670-765: The subgrade was compacted to 100 percent of maximum density. Asphalt rubber then was placed across the entire roadway, shoulders, and cut ditches. A 1-in ACFC was placed as a wearing course.
5. Test section 4, station 640-670: Same treatment as test section 3 except that an asphalt-rubber membrane was placed 2 ft down into the subgrade.