A STUDY OF WINTER MAINTENANCE OF BITUMINOUS PAVEMENTS IN TEXAS

BY

EMIL R. HARGETT
RESEARCH ASSOCIATE

Research Report Number 129-2F

Winter Maintenance for Bituminous Pavements

Research Study Number 2-18-68-129

Sponsored by
the Texas Highway Department
in cooperation with
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

April 1970

TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

ABSTRACT

The steady increase in highway maintenance costs has emphasized the need for an extensive study of the entire maintenance problem. A definite demand exists for the immediate application of modern methods of bookkeeping, the use of up-dated equipment, and the utility of new and improved materials technology. In particular, the winter maintenance of flexible pavements calls for attention.

The subject study deals with winter maintenance of flexible pavements and includes a review of the state-of-the-art. By use of field surveys covering materials, equipment, and techniques related to the maintenance of bituminous surfaces basic data were collected. Problem areas were revealed and recommended corrective procedures were outlined. This facet of the study covered eight districts or roughly one-third of the state system. Additionally, questionnaires were circulated to the rest of the state to gather information on problems and successful practices of the other districts.

The significant problem areas that were investigated included:

1. Crack sealing operations—materials, equipment, and techniques.
2. Pot hole repairs—materials, equipment, and techniques.
3. Edge raveling—materials, equipment, and techniques.
4. Development of a simplified test procedure for the evaluation of the workability and stability of cold mixes.
5. A preliminary laboratory investigation of the workability-stability characteristics of commercially available cold mixes.
6. Developmental research work directed toward the upgrading of workability-stability characteristics of cold mixes.
7. The use of surface rolling for a restoration of density and stability to pavement edges and shoulders.
8. A field investigation of the use of fiber mat for reinforcing and sealing extensive patterns of surface cracking.
9. A further investigation of the use of a maintenance paver for the application of cold mixes to distressed areas.
10. A field investigation of special surface cracking problems reported in the Childress District.

Recommended improvements in winter maintenance operations included, among other things, more extensive use of mechanized equipment, improved quality control of patching materials, and consideration of preventative maintenance as a means of minimizing repairs during inclement weather.

SUMMARY AND IMPLEMENTATION

The variety or diversity reflected in the scope of the study of winter maintenance of bituminous pavements introduces a problem of prescribing a simplified procedure for the implementation of the findings and recommendations. In view of the diversity reflected in this study it is considered desirable to restate the recommendations in the form of goals or objectives. The following statements reflect a summary of specific recommendations and a definition of the objectives and goals for implementation:

1. Give primary consideration to carefully scheduled (large scale) preventative maintenance programs that can be performed with mechanical equipment and will serve as a deterrent to costly winter maintenance operations normally performed under adverse conditions with hard labor.
2. Modification of construction practices so as to utilize mechanized equipment and reduce labor costs.
3. Develop power operated maintenance units for the performance of a variety of maintenance operations from one power source such as compressed air.
4. Direct special attention to the problem of upgrading the workability-stability relations of bituminous cold mixes and instituting procedures for the control of these material properties.
5. Furnish all maintenance construction personnel, particularly maintenance construction foremen, with well established guidelines for the performance of typical maintenance operations. These guidelines should reflect the current state-of-the-art and technological developments in the areas of material, equipment, and practices.

Recommendations for the implementation of the programs or practices for the accomplishment of the recommended goals and objectives are outlined as follows:

1. Sponsor additional cooperative research at the Texas Transportation Institute for the determination of the nature of the needs and optimum time for large scale preventative maintenance programs for bituminous pavements. This should be designed to train key highway personnel during the program of research and investigation. (Research and training should be accomplished simultaneously.)
2. Modification of the construction practices so as to utilize mechanized equipment. This may be implemented by adhering to the recommended practices described in the final report. These recommendations may be supplemented by the ingenuity and resourcefulness of the field personnel.
3. A pilot model of a power operated maintenance unit may be developed in the Texas Highway Department Shop under the supervision of a special design committee.
4. The workability-stability relations of bituminous cold mixes may be improved by following the specific recommendations outlined in the final report.
5. Providing maintenance personnel with the current state-of-the-art and guidelines for field practices may be accomplished by scheduling special training programs in addition to the maintenance conferences that are now sponsored by the Texas Highway Department.

TABLE OF CONTENTS

LIST OF FIGURES

A Study of Winter Maintenance of Bituminous Pavements in Texas

Introduction

Throughout the United States highway departments are concerned with the problem of providing economical and high quality bituminous surface maintenance of roads under modern transportation conditions. This is because of (1) increases in cost, (2) an ever greater volume of work to be done, and (3) the complexity of bituminous surface maintenance requirements.

Attention has been focused on the need for research and development efforts that will result in upgrading the quality and increasing the accomplishment of winter maintenance of bituminous pavements.

In response to the growing need for maintenance technology, the Texas Highway Department in cooperation with the Bureau of Public Roads sponsored a two-year study of materials, equipment, and practices for winter maintenance of bituminous pavements in Texas. This systems study was conducted by the Texas Transportation Institute.

This report contains a review of the state-of-the-art as well as a description of pertinent research work.

Survey of the State-of-the-Art and Problem Areas

During the first year of the study the research consisted of a review of the literature and a field survey of the state-of-the-art and problem areas relating to the maintenance of bituminous pavements in Texas. The review of the literature included a HRIS (Highway Research Information Service) search for stored information relating to pavement maintenance and cold weather operations. The field survey consisted of personal interviews and site inspections in eight out of the twenty-five districts in the Texas Highway Department. The districts that were covered by the field survey are shown in Figure 1. The personnel interviewed consisted of maintenance engineers and maintenance construction foremen.

A standard form was prepared for the field survey so as to reflect a consistent sampling of the current practices (state-of-the-art) and problem areas. The basic maintenance operations were categorized as described below:

1. Surface cracks.
2. Pot holes or chuck holes.
3. Edge raveling.
4. Level-up and build-up of low places.
5. Rutting and shoving.
6. Raveling of seal coats.
7. Fat spots and areas of bleeding.
8. Slick surfaces.
9. Raveling and surface failures on paved shoulders.
10. Localized failures in the flexible pavement system.

The field survey was conducted as a "grass roots" survey of the materials, equipment, and techniques relating to the maintenance of bituminous surfaces. This field survey served the twofold purpose of providing a documentary of the state-of-the-art practices worthy of dissemination as well as a description of the problem areas worthy of further research and investigation. During the survey attention was focused on materials, equipment, and techniques used for winter maintenance of bituminous pavements. Summaries of the information obtained from the HRIS search and field survey of the ten districts were reported in Research Report No. 129-1.[1]

During the second year of the study a simplified questionnaire was used to survey the bituminous surface maintenance operations in the remaining seventeen districts. This survey (questionnaire) was used for an

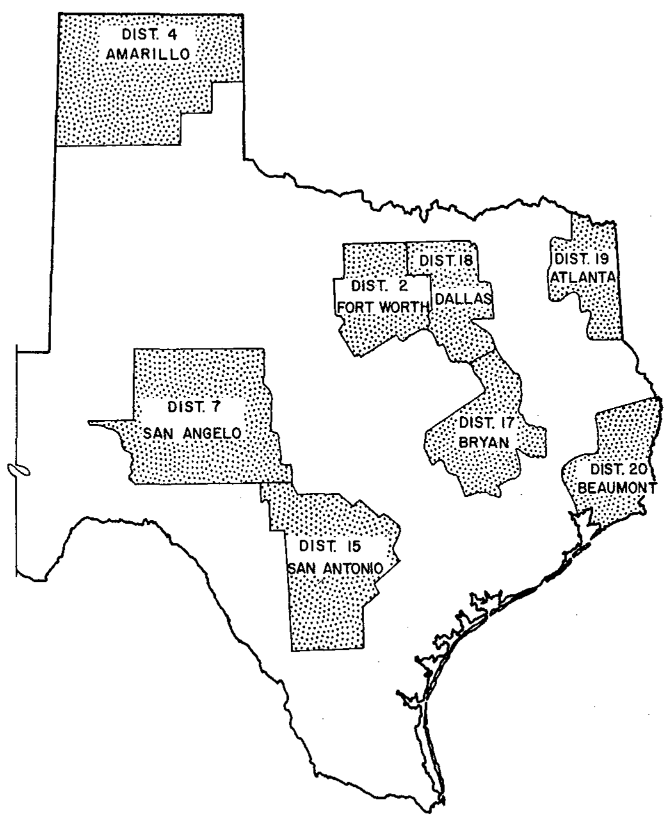


Figure 1. Districts surveyed for bituminous maintenance operations.

extension of the search for information relating to successful practices and problem areas associated with the maintenance of bituminous surfaces. The pertinent data obtained from the field survey and the questionnaire are included in Appendix A of this report. This appended information consists of a brief description of the significant materials, equipment, and techniques used for the performance of the basic maintenance operations (10 basic operations). The basic maintenance operations for which further research was recommended are also listed in the order of concern. The special investigations described in the following section were directed toward the problem areas for which further research was recommended.

Problem Areas and Special Investigations

In addition to reflecting state-of-the-art practices worthy of documentation and dissemination, the survey of bituminous surface maintenance reflected special problem areas for further research and investigation. The significant problem areas that were investigated are listed as follows:

1. Crack sealing operations—materials, equipment, and techniques.
2. Pot hole repairs—materials, equipment, and techniques.
3. Edge raveling—materials, equipment, and techniques.
4. Development of a simplified test procedure for the evaluation of the workability and stability of cold mixes.
5. A preliminary laboratory investigation of the workability-stability characteristics of commercially available cold mixes.
6. Developmental research work directed toward the upgrading of workability-stability characteristics of cold mixes.
7. The use of surface rolling for a restoration of density and stability to pavement edges and shoulders.
8. A field investigation of the use of fiber mat for reinforcing and sealing extensive patterns of surface cracking.
9. A further investigation of the use of a maintenance paver for the application of cold mix to distressed areas.
10. A field investigation of special surface cracking problems reported in the Childress District.

The following subsections contain a further description of the consideration given to the above described problem areas. These subsections reflect a description of the problem area, the study approach used, and the conclusions drawn from the special investigations conducted in these ten problem areas.

Crack Sealing Operations

Cracks in bituminous pavements are caused primarily by thermal contraction, dry weather contraction, and deformation of flexural actions that exceed the range of elastic deformation of the bituminous pavement. The nature and characteristics of thermal and dry weather cracks necessitate hand pouring operations. However, the nature and characteristics of deformation cracks (intensity) preclude the use of hand pouring operations for reasons of economy and productivity. The current problems of limited productivity and high labor costs that are associated with current crack sealing operations are considered the basic problems warranting further research and investigation.

The nature of the investigation which was directed toward the above described problem area consists of a study of materials, equipment, and techniques that may be used to upgrade the current crack sealing operations. This special investigation consisted primarily of a study of the practicality of the following two operations:

1. The use of pressurized heating kettles with flexible hoses for the application of sealing compounds to thermal and dry weather cracks.
2. The use of special overlays (asphalt impregnated mats) for sealing and reinforcing extensive patterns of surface cracking (not arising from base failures).

The use of pressurized heating kettles for the application of the crack sealing material is precluded by the widespread acceptance of catalytically blown asphalt for crack sealing operations. Even though this material has demonstrated excellent performance as a crack sealing material, the high temperatures required for pouring eliminate the use of pressurized equipment for intermittent applications. The heating and fluidity problems associated with the application of catalytically blown asphalt pointed up the need for a further investigation of other materials that are suitable for a safe pressurized operation.

Three sealants that are in common use for sealing joints in airport pavements are listed as follows:[2]

1. Rubberized sealer, hot applied (350°F).
2. Fuel resistant rubberized sealer, hot applied (350°F).
3. A two-part, self-vulcanizing, polysulfide base sealer.

Another material that has sufficient fluidity for a pressurized application is emulsified asphalt (RS-3K produced by Bitucote Products Co.). Rubber Calk 3105 Sealant (a two-component pourable polyurethane product) has reportedly demonstrated good performance for the sealing of bridge decks. However, extensive use of this material for sealing highway surfaces is precluded by the high cost ($10.00/gal).

Commercially available heating kettles* may be equipped with a pump and flexible hoses for the application of emulsified asphalt and the rubberized sealers.

*Pressure-Fill Melting Kettles (RAH-165, RAH-75), Blackwell Burner Co.

A small pressurized unit as described above could also be used for the application of small quantities of asphalt required for small surface repairs such as cracked surfaces, pot holes, and strip seals. A pressurized heating kettle of this type could certainly be used advantageously to reduce the amount of hand pouring of cracks with catalytically blown asphalt.

A number of districts are now sealing localized patterns of surface cracking (not caused primarily by base failures) very effectively with the use of a squeegee and an asphalt mastic. The squeegee is used to force emulsified asphalt or RC-2 asphalt into the cracks. Sand is applied to blot the asphalt on the surface and produce a mastic near the surface of asphalt filled cracks. This treatment may be complemented by the application of a chip seal or a fiber mat[3] to the entire area. Additional information regarding the use of a fiber mat for distressed areas was obtained from field tests conducted in the Abilene and Bryan districts. This report contains a brief summary of the findings resulting from these field tests.

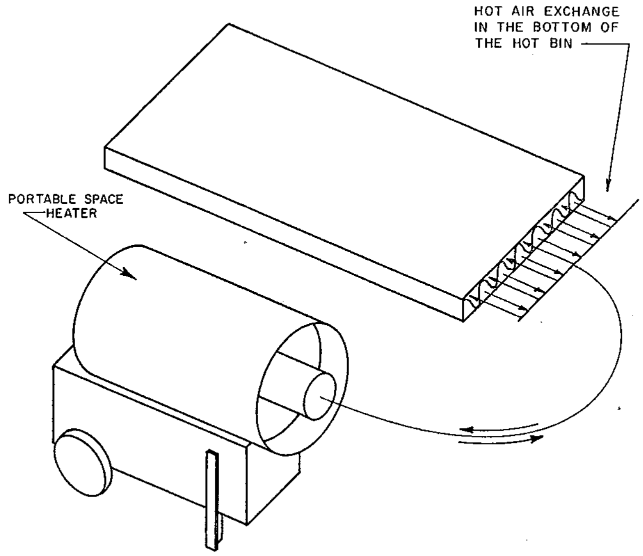


Figure 3. Heating system for portable "hot bins."

Pot Hole Repairs

The highway department's current responsibility for the safety of large traffic volumes on primary routes necessitates prompt repairs in the highway surfaces regardless of the prevailing weather conditions. The maintenance problem is further complicated by the fact that the bulk of the pot hole repair work develops during rainy seasons or other unfavorable weather conditions. In brief, the problem consists of the development of new materials and methodology required to perform high quality pot hole repairs during weather conditions normally considered unsuitable for the application of bituminous materials and mixes that are in common use. The urgency of pot hole repairs on primary routes during unfavorable weather conditions points up the need for research directed toward the upgrading of materials, equipment, and techniques used for pot hole repairs.

Primary consideration was directed toward the design of cold mixes with workability-stability characteristics that are in keeping with the current needs for winter maintenance operations. The research work directed toward the workability characteristics of cold mixes is described in this report. Further consideration was given to the development and use of a "hot bin" for transporting bituminous mixes for pot hole repairs. Figure 2 shows a schematic diagram of a "hot bin" suggested for transporting hot mixes or hot mix-cold lay materials needed for the performance of high quality winter maintenance of pot holes. The suggested "hot bin" design is to include a system of air ducts or flues for pre-heating the mix with a portable heater currently produced with variable heating capacities. The bin should be well insulated so as to minimize the loss of heat during transportation and field placement. Figure 3 shows a schematic diagram of the plan for circulating hot air under the bin of bituminous mix prior to use.

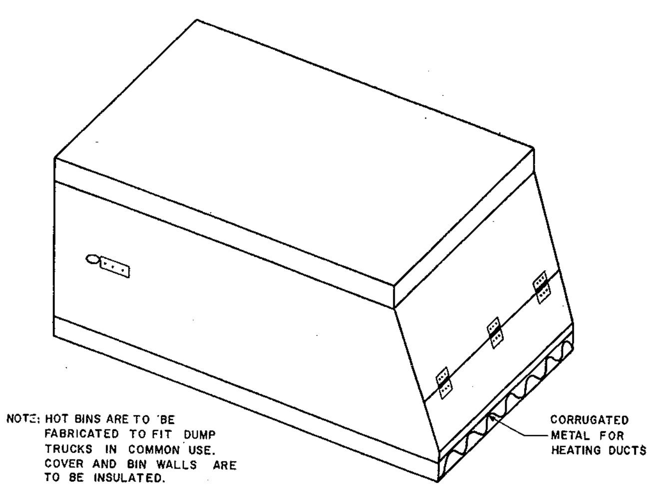


Figure 2. Portable "hot bin" for transporting bituminous mixes.

Three or four cubic yards of cold mix per crew per day is considered an average rate of consumption (laydown rate) for pot hole repairs. Therefore, the material for one day's operation could be pre-heated during the night or early morning. An insulated bin of this type would enable districts such as Dallas and Fort Worth to use hot mixes more effectively for winter maintenance operations. The design (structure) of a hot bin as described in Figure 2 would be further simplified by the use of lightweight aggregate for the production of bituminous mixes for winter maintenance operations. Other favorable features associated with the use of lightweight aggregates in bituminous mixes are discussed in the section describing developmental research work directed toward the upgrading of workability-stability relations of cold mixes.

The volume of pot hole maintenance required by any highway during the late winter (spring thaw and rainy weather) should be noted as an index of the need for overlaying or seal coating programs during the oncoming construction season (summer months). The cause of the distress should be classified so one may design a seal coat or an overlay that is in keeping with the needs of the pavement.

Edge Raveling

The raveling of flexible pavement edges is attributed primarily to the deterioration of the pavement structure under environmental conditions, and the recent increases in automobile traffic on narrow pavements. The problems of primary concern are the high labor costs and the limited productivity of edge raveling maintenance performed primarily through the use of hand labor operations. This investigation was directed toward the development of mechanized practices that will increase productivity and reduce labor costs of edge raveling maintenance.

The edge raveling procedure suggested herein was designed primarily for narrow farm to market roads that are in need of an intermediate level of edge reinforcement as well as additional protection against environmental conditions. The basic operations suggested for performing edge raveling maintenance with the use of mechanized equipment are described on Figure 4. The operations described in Figure 4 are similar to those in common use for widening old pavements.† However, less emphasis is placed on the strengthening of the foundation structure in view of actual needs and the structural limitations of the existing pavement structure.

†U. S. Department of Transportation, Special Report on Use of Equipment and Methods of Maintenance, February 1968.

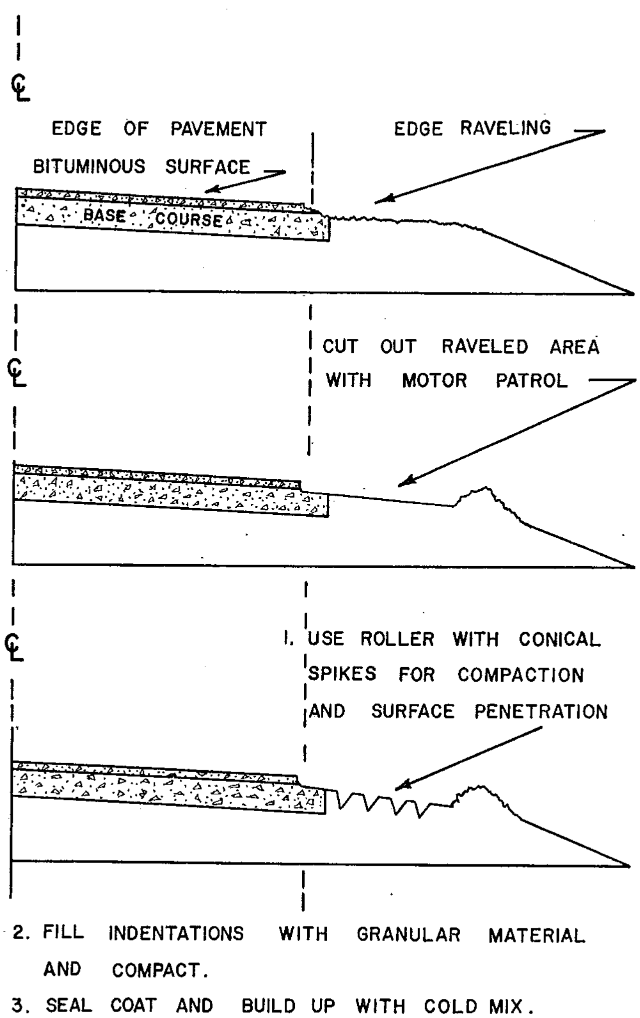


Figure 4. Suggested procedure for performing edge raveling maintenance with mechanized equipment.

Consideration may be given to the use of a modification of the above described procedure for the prevention of costly and extensive edge raveling maintenance. A motor patrol is to be used to cut out the raveled pavement or shoulder material in critical areas. The density and stability of the section cut out with the patrol may be improved with a spiked roller (see Figure 4) or a loaded truck. The moisture content of the soil in shoulder area should be near the optimum value for maximum laboratory density in order to obtain maximum field density from a given level of surface rolling or compaction. A roller with conical spikes may be used to delineate the areas that are in need of additional stability. The areas that reflect a high level of penetration of the conical spikes may be treated with lime or granular material. Due consideration must be given to subsurface drainage when granular material is used.

After using the method described above to restore an acceptable level of stability to the pavement edge, a seal coat should be applied to this critical area to insure a high level of waterproofing. Hot mixes or cold mixes are then used to build the section along the pavement edge up to the desired lines and grades. The bituminous mixes should be well compacted in order to obtain maximum stability and waterproofing.

This is a preventative maintenance operation that can be performed very effectively during the winter months to reduce the volume of edge raveling. The districts in which the pavement edges and shoulders are subjected to a large number of cycles of wetting and drying or freezing and thawing should give serious consideration to the use of this preventative maintenance operation.

Development of a Test Procedure for the Evaluation of Workability and Stability of Cold Mixes

The emphasis that is currently directed toward the problem of winter maintenance of bituminous pavements has increased the demand for variations in the optimization of the workability and stability of bituminous cold mixes. In response to this demand consideration was given to the development of a simplified testing procedure to reflect a measure of the workability and stability of cold mixes at the time of production or at any time prior to use. Primary consideration was given to the development of a simplified testing procedure that would facilitate quality control and promote a better understanding of the workability-stability relations of cold mixes.

The unconfined compression test was selected for the evaluation of the stability of the bituminous cold mixes. The test specimens are prepared by static compaction; which furnished a reliable representation of field compaction. The principal items of testing equipment consist of a testing machine (10,000 lb. capacity) and a split mold as described in Figures 5 and 6.

The testing procedure selected for measuring the workability of the cold mixes consists of a visual inspection and a manual probing of the cold mix at 50°F.

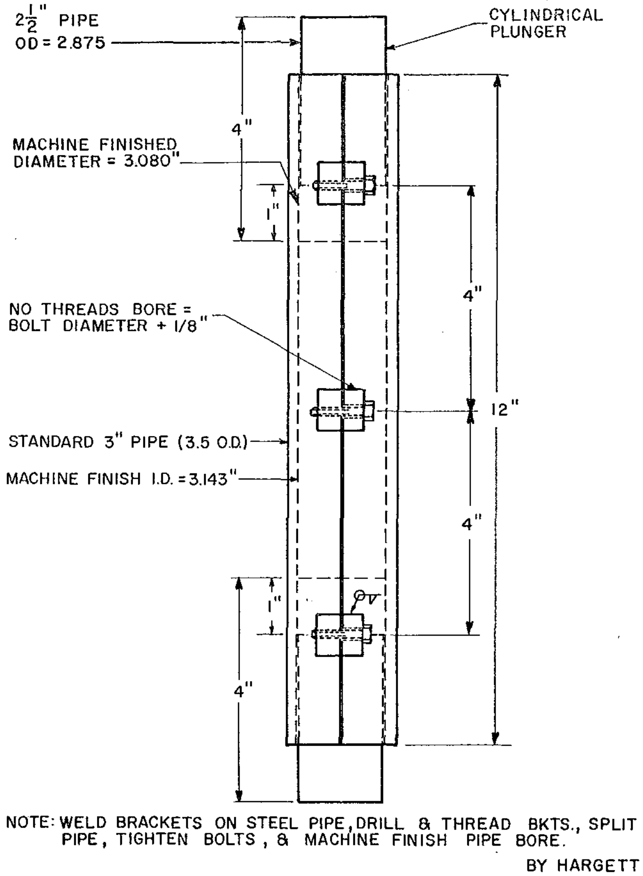


Figure 5. Split mold for static compaction of cold mixes.

Relative ratings of workability can be easily established in the field by maintenance personnel.

A detailed description of the testing procedure is included in Appendix B for convenient reference. The ten steps outlined in Appendix B provided comprehensive testing program for research and evaluation. However, an abbreviated test may be conducted by performing steps 4, 8, and 9 (see Appendix B).

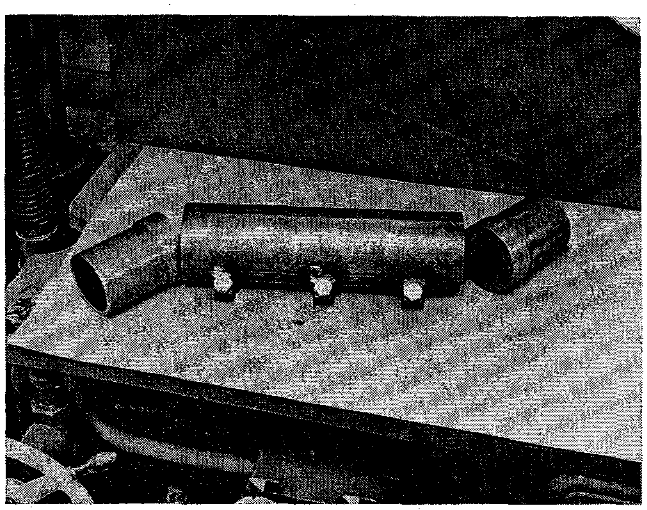


Figure 6. Split mold with plungers for static compaction of cold mixes.

Preliminary Investigation of the Workability-Strength Relations of Commercially Available Cold Mixes

The need for an investigation of the workability-strength relations of commercially available cold mixes was reflected by the field survey of bituminous surface maintenance in eight of the twenty-five districts. The primary concern expressed by the maintenance construction foremen was for a more dependable level of workability in the cold mixes for winter maintenance operations. A preliminary laboratory investigation of workability-strength relations was conducted in response to needs reported by the field personnel. The unconfined compression test previously described was used for the laboratory investigation.

It is difficult to establish rigid specifications for the workability and stability relations for cold mixes since the initial level of workability is introduced at the expense of stability. This property (workability) is affected markedly with age and temperature (low temperatures); thereby further complicating the problem of specifications and controls. For this reason it was considered necessary to broaden the scope of the testing procedure so as to reflect a measure of workability-stability relations at the time the cold mix is produced as well as obtaining indices of the changes in workability-stability relations with time and temperature.

The above described requisites for testing received careful consideration during the development of the unconfined compression testing procedure described in the previous section of this report. This testing procedure furnishes a measure of workability, stress-strain relations, and aging or hardening characteristics. An index of workability was obtained from a manual probing and a visual inspection of the cold mix at a temperature representing an average temperature for typical winter maintenance conditions. A temperature of 50°F was used for the program of laboratory testing described in this report. The stress-strain data from the unconfined compression test furnish indices of strength and flexibility of the compacted cold mix. Relative indices of the aging and hardening characteristics of the cold mixes are reflected by the change in strength properties (unconfined compressive strengths and moduli of elasticity) associated with the drying of these mixes.

The program of unconfined compression testing was directed as a preliminary investigation of the workability-strength relations of cold mixes described in the Texas Highway Department's Specifications under items 332 and 352. The test data reflect a measure of workability at 50°F, unconfined compressive strength at 73°F, modulus of elasticity (modulus of deformation), and strain at maximum stress. Laboratory tests were also conducted to determine the loss in weight (moisture and volatiles) with time at a temperature of 140°F.

Table 1 shows relative ratings of workability and typical averages of unconfined compressive strength, strain at maximum stress, and modulus of elasticity. These test data show that the cold mixes described under

TABLE 1. WORKABILITY-STABILITY RELATIONS OF COMMERCIALLY AVAILABLE COLD MIXES

Type of Mix	Workability A 50°F	Unconfined Compressive Strength, psi @ 73°F	Strain @ Maximum Stress inches × 10-4	Modulus of Elasticity psi @ 73°F
Limestone Rock Asphalt Type "A" Item 332	Good	140	164	20,200
Limestone Rock Asphalt Type "C" Item 332	Good	136	136	28,100
Limestone Rock Asphalt Type "CC" Item 332	Good	139	151	13,100
Hot Mix-Cold Laid Type "AA" Item 332	Acceptable	8	75	13,600
Hot Mix-Cold Laid Type "DD" Item 352	Acceptable	22	68	22,800
Hot Mix-Cold Laid Type "FFF" Item 352	Marginal	22	76	17,000

*The plus 1" aggregate was removed from the mix.

item 332 yielded higher levels of workability and unconfined compressive strength than the mixes described under item 352.

Figure 7 shows typical curves of the weight loss (moisture and volatiles) of the two types of cold mix when subjected to a temperature of 140°F. The rate of weight loss (weight loss vs time) furnishes an index of the susceptibility to hardening or a loss of workability. This analogy of the relationship between weight loss and workability indicates that the material prepared under item 352 is less susceptible to a significant change in workability with time than the material prepared under item 332. Even though these materials are of comparable quality the test data reflect peculiarities in the material properties that should be understood for a more effective utilization of the workability-stability relations.

Typical Hveem stability and cohesiometer values furnished by the Texas Highway Department for cold mixes prepared in accordance with specification items 350 and 352 are reported in Table 2.

This preliminary investigation of workability-stability relations of bituminous cold mixes for winter maintenance pointed up the need for an upgrading of controls and technology relating to workability-stability relations of cold mixes. The preliminary tests also revealed significant differences in the material properties of commercially available cold mixes that should receive careful consideration when selecting materials for winter maintenance operations. It is also believed that the material properties (peculiarities) reflected in the commercially available cold mixes may be utilized more effectively for the performance of winter maintenance operations.

TABLE 2. STABILITY AND COHESIOMETER VALUES HOT MIX-COLD LAID ASPHALTIC CONCRETE

Specification Item	Type of Mix	Hveem Stability Value (Percent)	Cohesiometer Value
350	BB	67	293
350	CC	62	236
350	DD	53	154
352	DD	51	109
352	FFF	48	94

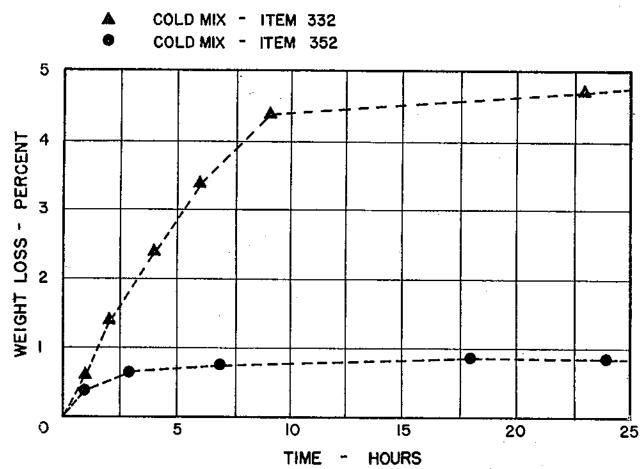


Figure 7. Weight loss at 140°F vs time.

The use of portable "hot bins" as described in Figure 2 is suggested for the districts that are confronted with the problem of performing a large volume of high quality winter maintenance. The use of hot bins for transporting cold mixes would improve the workability of the mix as well as reduce the time normally required for aeration.

Research Work Directed Toward the Upgrading of Workability-Stability Characteristics of Cold Mixes

A limited amount of research and developmental work was directed toward the upgrading of the workability-stability characteristics of the bituminous cold mixes for winter maintenance operations. A rational investigation of the basic factors relating to workability led to the consideration of a pelletization process for cold mix production. This process consists of encapsulating particles of coarse aggregates with a matrix of asphalt and fine aggregate (sand or crusher fines). This pelletization process lends itself to the use of asphalt cement or emulsified asphalt for the production of cold mixes with different levels of stability. The developmental research work relating to the pelletization of bituminous cold mixes is described briefly in this report in view of the promising features associated with this concept.

The first plan for pelletization consisted of the encapsulation of coarse aggregate particles in an asphalt cement and then "fluff" mixing the asphalt coated aggregate with fine aggregate and dust. The basic operations involved in this process are described in Figure 8. This type of mix was envisioned for maintenance and repairs on traffic facilities carrying heavy traffic volumes. There is an increasing demand for such a mix for the performance of high quality winter maintenance. However, one objection to the use of such a mix is the necessity for heating prior to field placement. The use of a "portable hot bin" as described in Figure 2 may be used to heat such a material for high quality winter maintenance operations.

Pelletized mixes were produced in the laboratory by coating lightweight aggregate particles with asphalt cement and then cold mixing (fluff mixing) the asphalt coated particles with lightweight fines and sand. The asphalt cement (AC-10) was heated to approximately 200°F prior to mixing. The heat loss during mixing is a factor that contributes to the pelletization process. A teflon lined pan was used for the mixing operation.

Further consideration was given to the use of the pelletization process for the production of a workable

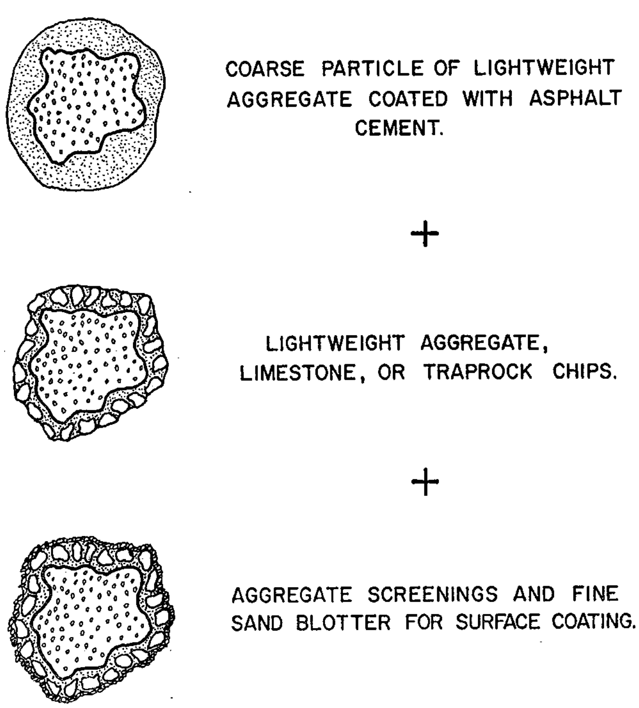


Figure 8. Pelletized cold mix prepared with asphalt cement.

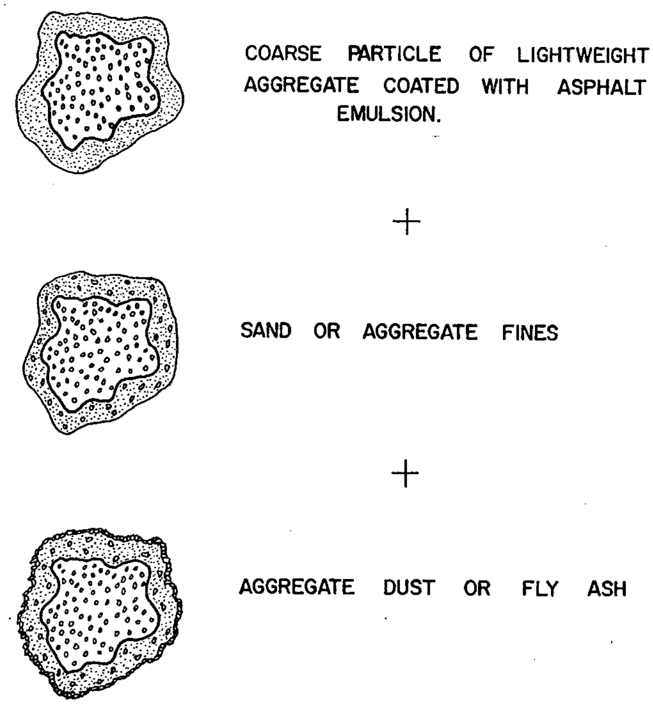


Figure 9. Pelletized cold mix prepared with emulsified asphalt.

cold mix that would require little or no heating prior to field placement. An emulsified asphalt was considered as a suitable substitute for asphalt cement for the production of a mix of this type. The rapid setting emulsified asphalts that are currently available were considered suitable for the development of a matrix of asphalt and fines around the individual particles of coarse aggregate. The basic operations involved in the preparation of a pelletized cold mix with the use of emulsified asphalt are described in Figure 9. The porosity and absorptive characteristics of the lightweight aggregate (coarse particles) facilitate the pelletization of cold mixes prepared with emulsified asphalt.

The above described pelletization process was used for the preparation of trial batches of cold mix for laboratory and field investigation. Mixing (pelletization) was accomplished successfully in a Hobart mixer and in a Barber-Greene Mix-All. The basic production process consists of the addition of a rapid setting emulsified asphalt to a coarse graded fraction of lightweight aggregate during mixing (fluff mixing) so as to encapsulate the individual aggregate particles in a matrix of asphalt and fines. Fine sand and dust are added when the mix shows signs of hardening. Figure 10 shows a sample of pelletized cold mix prepared in the laboratory. The pelletization process may be facilitated by heating the fine aggregate and dust prior to mixing. The details of the production process are further described as follows:

1. Add emulsified asphalt (BLAKAT) to a coarse graded fraction of lightweight aggregate during mixing (fluff mixing). The materials are mixed at air temperature.

2. When the mix shows signs of hardening add fine sand to blot the coatings of asphalt on the aggregate

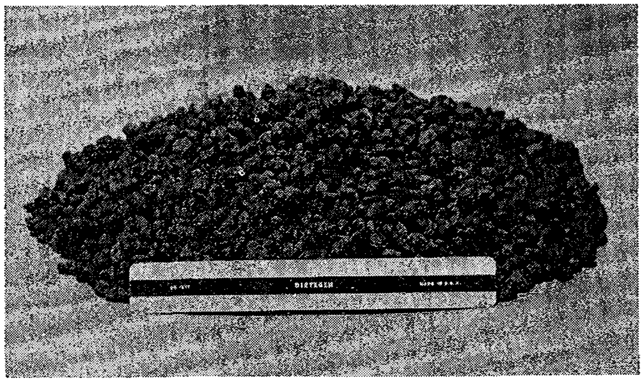


Figure 10. Pelletized cold mix prepared in the laboratory.

particles. The addition of sand preheated to approximately 150°F facilitates the pelletization process.

3. Add preheated fly ash or aggregate dust (approximately 150°F) to further blot the asphalt on the surface of the pellets.

The weights and constituents of the laboratory batches of pelletized cold mix are described as follows:

Lightweight aggregate (percent by weight) =59.3%
Intermediate grade, specific gravity=1.58

Field sand (percent by weight) =16.6%

Specific gravity=2.64

Fly Ash (percent by weight) =11.6%

Specific gravity=2.51

Emulsified Asphalt (percent by weight, residual asphalt) =12.5%

BLAKAT (60% asphalt, 40% water.)

The pelletized mix produced with emulsified asphalt was tested for workability-stability characteristics according to the test procedure (unconfined compression test) used for the testing of the commercially available cold mixes. The laboratory mix yielded a high level of workability, a negligible weight loss when heated at 140°F, and unconfined compressive strengths varying between 65 and 105 psi when tested at 73°F. Three laboratory specimens tested by the Bituminous Section of the Materials and test Laboratory at Austin (THD) yielded an average Hveem stability of 15 and an average cohesiometer value of 99.

Figure 11. Test plots for field testing cold mixes.

One of the favorable characteristics of the pelletized cold mix is reflected in the cohesiometer value (99). An increase in the stability of this type of mix is anticipated in view of the slow rate of hardening or aging of the asphalt matrix. A further evaluation of performance characteristics is to be obtained from field testing. Figure 11 shows the placement of the cold mix in small test plots on FM 2818 west of College Station.

Use of Surface Rolling for a Restoration of Density and Stability to Pavement Edges and Shoulders

The current volume of edge raveling and surface maintenance reflected in pavement edges and shoulders is emphasizing the need for preventative maintenance operations. Even though surface rolling holds definite promise as a construction operation for eliminating the need for surface maintenance, no field investigations were conducted to document the value of operation. The material reported herein reflects preliminary engineering investigation of the practicality of the construction operation in view of current needs.

The use of surface rolling may be used to restore density and stability to pavement edges and shoulders that are subjected to abnormal cycles of wetting and drying or freezing and thawing. The program of surface rolling should be scheduled during the winter and spring months so as to take advantage of a level of natural moisture required for an optimization of the compaction effort.[6] Roller weights, tire pressures, and contact areas should be selected for a maximum densification without developing destructive deflections in the existing pavement structure.[7] The densification should progress from surface downward. Precautions should be taken to prevent the development of significant levels of pore water pressure in the subgrade during the rolling operation.[8]

Surface rolling is not to be considered as a standard construction procedure for the treatment of pavement edges and shoulders that show a lack of structural integrity. It should be considered as a procedure for providing an intermediate level of structural reinforcement for the prevention of costly maintenance. It is believed that the Texas Highway Department can use this construction procedure advantageously during the winter months for an upgrading of the structural integrity of special problem areas. The areas selected for this type of treatment should reflect the professional judgement of highway engineers that understand the advantages and limitations that are associated with this construction operation.

Investigations of the Use of Fiber Mat

Special investigations (field tests) were conducted to determine the suitability of a new polypropylene nonwoven fabric produced for sealing and reinforcing cracked bituminous surfaces. This mat (approximately ½ lb./sq. yd. and less than 1/16″ thick) consists of oriented polypropylene fibers randomly placed on a supporting scrim. The fibers are fused to one another to provide omni-directional strength. The polypropylene fibers being a non-polar hydrocarbon are readily impregnated with asphalt; thereby imparting the strength of the mat to the asphalt.

The investigations relating to the use of the fiber mat consisted of a field inspection and review of the field tests in the Abilene District as well as additional field testing of this material in the Bryan District. These field tests have provided realistic information regarding construction problems, costs, and short term field performance of this new material. The following paragraphs contain a description of the field tests as well as the findings obtained from these tests.

The use of the mat for sealing surface cracks was field tested at three locations in the Abilene District. The field tests were conducted under the supervision of A. L. McKee (Maintenance Engineer, District 8) who furnished a detailed description of his work to be incorporated in this report. The field test sites were selected with the idea of testing the effectiveness of the mat for the following functions:

1. Minimize the reflection of transverse cracks in old pavements through overlays and seal coats.

2. Waterproof and strengthen extensive patterns of surface cracking.

The cracking problems and the test site locations are described as follows:

1. Pavement Condition: Deflection cracks in a flexible pavement. Location: Parking lot at the Abilene District office.

2. Pavement Condition: Transverse cracks in an old concrete pavement widened and overlayed with hot mix asphaltic concrete. Location: The west bound lane of Loop 432 (U. S. 80 Bus Route) in Sweetwater.

3. Pavement Condition: Extensive deflection cracks in the wheel paths of an old flexible pavement. Location: The south bound lane of U. S. 84 North of Roscoe.

The procedure used for the application of the mat to the test sites is outlined as follows:

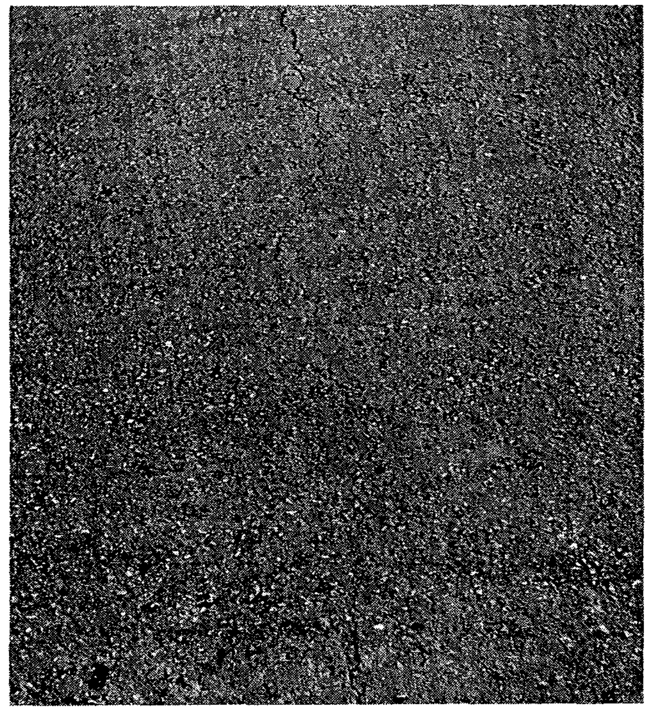
1. Application of cationic emulsion at a rate of approximately 0.25 gallons per square yard to the area to be covered with the mat.

2. Application of the mat (6 ft. wide) to the area coated with asphalt.

3. Application of sand to blot the excess asphalt prior to the release of the test section to traffic.

4. Cover the mat with a seal coat or an overlay after a short curing period (exposed to traffic).

After six months of service the test sections that were treated with the mat were showing less surface cracking distress than the adjacent control sections. The views of Figure 12 (a) and (b) show a reduction in reflection cracking and the structural integrity of the bituminous overlay resulting from the use of the asphalt impregnated mat. The central portion of Figure 12 (a) shows the reduction in reflection cracking; whereas Figure 12 (b) shows the structural integrity developed in the overlay. The core on the left side of the photograph Figure 12 (b) was taken outside the treated area, whereas the two cores on the right side of the photograph were taken from area treated with the mat.



(a) Reduction in reflection cracking.

(b) Cores taken from treated and untreated portion of the reflected crack.

Figure 12. Effects of the use of the fiber mat on reflection cracking and structural integrity of overlay.

After approximately one year of service, Mr. J. C. Roberts (District Engineer, District 8) furnished another series of photographs reflecting favorable performance of the mat treated test sections. The favorable performance characteristics reflected in these photographs are summarized as follows:

1. The highway test sections displayed good surface stability (no shoving).

2. The level of reflection cracking in the bituminous overlay was reduced by the use of asphalt impregnated mat.

3. The mat reduced the level of asphalt bleeding through the overlay from the asphalt filled cracks in the old pavement.

4. The use of the mat improved the structural integrity and water-proofing characteristics of the bituminous overlay.

The use of the fiber mat was subjected to additional field testing in Bryan District (District 17) through the cooperation of James O'Connell and J. O. Sloan (Maintenance Engineer and Maintenance Construction Superintendent, respectively). The site selected for this study was located on the east bound lane of U. S. 190 (Texas 21) east of Bryan. The cracking problem consisted of a concentration of deflection cracking in the area of widening adjacent to the old pavement (concrete pavement). Figure 13 shows the nature of the cracking problem for which the mat was used. It was decided that a three-foot strip of mat (½ of a 6 ft. roll) would adequately cover the distressed area. One roll of the mat (6 ft. wide and 300 ft. long) was cut in half for the test section (approximately 600 ft. long).

The principal construction operations used for the construction of the field test section east of Bryan are outlined as follows:

1. Application of 0.27 gallons of EA-HVRS per square yard to the three-foot strip to be covered with the mat.

2. Application of the mat to the asphalt coated surface. The mat was rolled into the asphalt with a truck.

3. A second application of asphalt (EA-HVRS) at 0.30 gal/sq. yd.) was applied to the mat after a short curing period of approximately two hours.

4. Lightweight aggregate (intermediate grade) was applied to the asphalt coated surface in accordance with the conventional procedure for strip sealing.

Following the construction, the test section was subjected to approximately a week of rainy weather and heavy traffic. The combination of these two factors caused a large percentage of the aggregate to strip from the surface. Type F limestone rock asphalt cold mix was applied to the test section approximately three weeks after construction to protect the mat from the abrasive action of heavy traffic. The cost of this type of surface maintenance operation exceeded one dollar per square yard.

Even though the above described test section was constructed in accordance with the prescribed procedure

Figure 13. Cracking problem for which fiber mat was used (U. S. 190 east of Bryan, Texas).

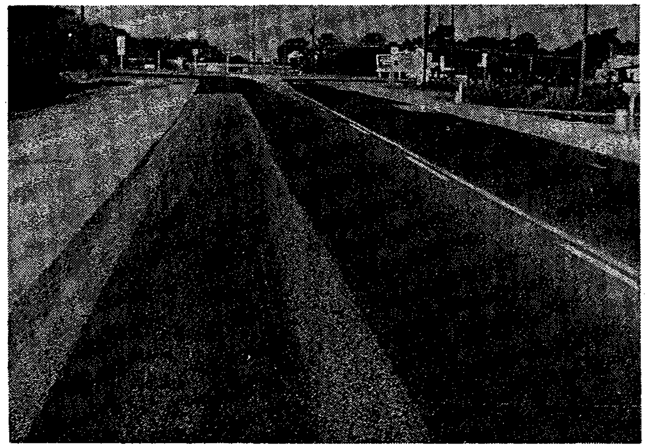


Figure 14. Shoving of fiber mat overlay.

the performance of the fiber mat in the above described test section fell short of the performance obtained from the tests in the Abilene District. The level of performance was attributed primarily to the lack of friction and interlocking between these two surfaces gave rise to lateral displacement or shoving of the overlay. Figure 14 shows the nature of the shoving of the bituminous overlay. It is believed that an excess of asphalt was a factor contributing to the lack of stability (bond) between the old surface and the fiber mat overlay. It is also believed that the lack of stability between these two surfaces coupled with differential deflections between the old concrete pavement and the flexible pavement (widened section) gave rise to the lateral displacement of the overlay.

The principal conclusions resulting from the field studies of fiber mat are summarized as follows:

1. Extensive use of fiber mat for the overlaying of distressed highway pavements is precluded by the high cost of the mat ($0.46 per sq. yd.).

2. The asphalt impregnated mat may be used in conjunction with bituminous overlays to improve the structural integrity and water-proofing characteristics of localized surface failures.

3. The use of fiber mat should not be considered as a solution for problems resulting from a lack of stability in the base course or supporting foundation.

4. The use of fiber mat is not recommended for the sealing of cracks or joints that reflect a high level of differential movement. A high level of differential movement will break the fibers or displace the overlay (see Figure 14).

The Use of a Maintenance Paver for the Application of Cold Mixes to Distressed Areas

The increasing demand for level-up work and overlaying of slick surfaces reported during the field survey emphasized the need for a more extensive use of mechanical equipment and sophisticated construction practices for the performance of these maintenance operations. The favorable results obtained from the use of a maintenance paver in the Beaumont district pointed up some of the promising features that are associated with this construction operation. For a further study of the application of this construction practice to the current needs for bituminous surface maintenance, the author observed the use of the maintenance paver for the application of a cold mix overlay to approximately two miles of U. S. Highway 6 south of Navasota. This report contains a brief review of the significant observations and conclusions regarding the use of this piece of equipment for level-up and overlay work performed by maintenance forces.

The overlaying work south of Navasota consisted of the application of a cold mix (Type Cold Mix Limestone Rock Asphalt) to an old pavement reflecting a low level of skid resistance. The cold mix was applied at the rate of 50 lbs. per square yard. Figure 15 shows the use of the maintenance paver for the application of an eight-foot strip of cold mix to the old surface.

Even though the construction operation is very simple, special precautions must be taken in order to insure high quality construction. The primary problems are associated with the directional and depth controls. The use of a string line and a reference marker attached to the front of the truck provided the directional control needed for good alignment and jointing. However, "operator skill" is the primary factor responsible for the control over the depth of the overlay. One of the principal objections to this piece of equipment is the eight-foot spreader box. This width creates an undesirable condition in surface geometrics and jointing when overlaying 24 ft. pavements.

The use of this piece of equipment offers definite promise as a substitute for some part of the "blade-on" construction since this operation does not expose a large percentage of uncompacted material to unexpected changes in weather (rain). However, due consideration should be given to the additional time required for the aeration and drying of cold mixes prior to compaction. With a well trained crew, this piece of equipment offers promise for the upgrading of winter maintenance of bituminous pavements. Further consideration should be given to the use of the more sophisticated pieces of equipment that are now available. The maintenance paving equipment that is available reflects a number of features that may be utilized for implementation of the winter maintenance of bituminous pavements. The significant features recognized by the author are listed as follows:

1. Optional equipment for heating the screed.

2. Screed crown, or inverted crown, amounting to 3 inches in 8 feet (max).

3. Screed extensions that allow adjustments in paving widths between 8 and 12 feet while stopped or in motion.

4. Ditch plates that may be used to constrict the flow of paving material to any width between 0 and 7 feet. This feature offers definite promise for the repair of raveled edges and for shoulder maintenance.

5. Hydraulically operated hook up, shut-off gate, and screed hoist.

After performing appropriate levels of the basic maintenance operations described in Figure 4, the maintenance paver may be used for the application of the cold mix so as to exercise strict control over the build-up of the critical section. The ditch plates may be inserted for the application of a variety of widths (0-7 feet). This type of operation may be used to reduce labor costs as well as upgrading the quality of construction.

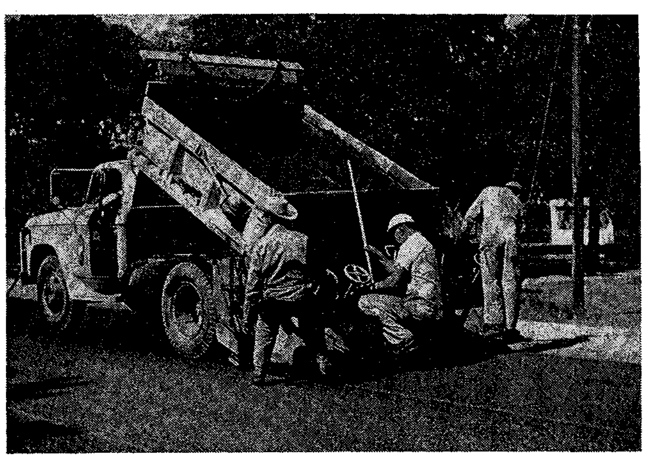


Figure 15. Use of the maintenance paver for the application of a cold mix overlay.

Special Investigations of the Cracking of Bituminous Surfaces in the Childress District

The questionnaire submitted to the maintenance personnel in the seventeen districts not surveyed personally reflected variations in the categorization of the maintenance problems of primary concern. However, the Childress District was the only district in which more than ninety percent of the maintenance construction foremen designated the cracking of bituminous surfaces as the maintenance problem of primary concern. The concern expressed by the maintenance construction foremen over this problem was considered sufficient justification for a field investigation of the nature and magnitude of the problem of bituminous surface cracking in District 25. This report contains a brief summary of findings resulting from a field inspection of the bituminous surface cracking problems in the Childress District.

The major highways in the central portion of District 25 were inspected by the author during February of 1969 so as to obtain a better understanding of the extent and nature of the surface cracking problem reported by the maintenance construction foreman. This field inspection confirmed the unanimous concern of the maintenance personnel in this district over the problem of maintaining cracked surfaces. The nature and extent of the surface cracking indicated that a number of factors are contributing to this distressed condition. The principal sources of surface cracking distress are listed as follows: (a) thermal and dry weather cracks, (b) flexure or deformation cracks, and (c) reflection cracking in bituminous overlays at joints and cracks in old concrete pavements (a + b).

The patterns of thermal and dry weather cracking, and reflection cracking were similar to the typical patterns observed in other districts. However, the nature and extent of flexure of deformation cracking represented a significant departure from the typical patterns observed in the other districts. It is believed that the

Figure 16. Flexure and deformation cracks on State Highway 283 north of Crowell.

flexure and deformation cracking is the result of wheel loadings, environmental conditions, and soil properties that are peculiar to the Texas panhandle. The extent of this type of cracking precludes the use of hand pouring operations for an efficient sealing practice. Figures 16 and 17 show concentrations of flexure and deformation cracks observed on State Highway 283 North of Crowell. The increasing volume of crack sealing work and the limited productivity of hand pouring operations were recognized as the basic problem areas worthy of special investigations.

The practice used for sealing cracks in District 25 consists of hand pouring catalytically blown asphalt into the cracks during the fall and winter months. The catalytically blown asphalt is heated in oil-jacketed melting kettles to a temperature of approximately 500°F prior to pouring. Mr. V. J. McGee (District Engineer) reported favorable results from the use of five oil-jacketed heating kettles for crack sealing operations. He also pointed up the limitations imposed on the safety and productivity of hand pouring catalytically blown asphalt at approximately 500°F. This observation serves to further reinforce previous conclusions regarding the need for the development of a safe procedure for the application of joint sealing compounds through flexible hoses to the distressed area (pressurized application).

The crack sealing material (catalytically blown asphalt) and field practices are yielding high quality performance. However, the limited productivity and high labor costs associated with this operation are considered

Figure 17. Flexure and deformation cracking in the wheel paths on State Highway 283 north of Crowell.

worthy of further investigation in view of the increasing volume of crack sealing work.

The field survey of cracking of bituminous surfaces in the Childress District gave rise to the following conclusions regarding the need for further research and developmental work:

1. The need for pressurized equipment for a safe and efficient application of joint sealing compounds.

2. Further investigation of the basic material properties relating to the design of flexible pavements for the peculiar environmental and soil conditions found in the Texas Panhandle.

The conclusions and recommendations resulting from the special investigations are summarized briefly as follows:

1. Pressurized heating kettles with flexible hoses are needed to increase the productivity of current crack sealing operations. Such a piece of equipment may also be used for the application of small quantities of asphalt for other operations such as pot hole repairs.

2. The use of a fiber mat holds some promise for sealing and strengthening localized areas of surface cracking, but current costs preclude an extensive use of this material.

3. The increasing demand for high quality winter maintenance of bituminous surfaces is emphasizing the need for more strict control over the quality of materials. One method that may be used for upgrading the quality of pot hole repairs consists of the use of a portable hot bin (see Figure 2) for transporting bituminous mixes with a high level of workability. Such a piece of equipment will make it possible to use hot mixes (when available) more extensively for maintenance and repairs.

4. The current volume of edge raveling maintenance is pointing up the need for preventative maintenance as well as mechanized operations that will yield a higher level of productivity. Edge reinforcement and repairs as described in Figure 4 are recommended for the prevention of costly edge raveling maintenance.

5. The increasing demand for a dependable level of workability in bituminous cold mixes used for winter maintenance operations is emphasizing the need for a simplified test procedure and control specifications. The use of the unconfined compression test is recommended for the determination of the strength of compacted specimens. Visual inspections and weight loss determinations are recommended for an evaluation of workability characteristics.

6. Further consideration should be given to the utilization of the material properties (workability characteristics) that are reflected in the cold mixes that are now available.

7. The preliminary investigations of pelletized cold mixes produced promising results in view of current needs for workability and friction textured surfaces. Further studies of plant production and field performance of pelletized cold mixes are recommended.

8. The use of surface rolling is recommended as a special winter maintenance operation for the prevention of costly edge raveling and surface maintenance. This

operation holds definite promise for the strengthening of localized sections that are reflecting a loss in stability due to abnormal cycles of wetting and drying or freezing and thawing.

9. The use of the maintenance paver holds definite promise for the application of cold mixes to existing bituminous surfaces. This equipment may be used advantageously as a substitute for "blade on" operations.

10. The bituminous surface cracking reflected in the Childress District warrants a further investigation of design and related factors.

11. The volume and urgency of bituminous surface maintenance operations are emphasizing the need for a further utilization of power tools for the performance of the typical maintenance operations. In view of this need, further consideration should be given to the development of a mobile, power operated maintenance unit for the performance of systems maintenance operations. Such a unit may be designed for the operation of a variety of pneumatic tools such as saws, tampers, and sprays for the application of carefully controlled quantities of tack coat.

12. Further consideration should be given to the use of gasoline operated power saws for cutting and removing the bituminous surface from localized surface failures.

Bituminous Surface Maintenance Practices and Procedures

This section contains a brief digest of the ten basic operations used for the performance of bituminous surface maintenance in Texas. This digest also reflects the significant conclusions resulting from the special investigations conducted during the second year of this study. Explanations are also included regarding the cause of distress in addition to the state-of-the-art practices and recommended procedures for the maintenance of bituminous surfaces. The ten basic maintenance operations are listed as follows:

1. Surface cracks.
2. Pot holes or chuck holes.
3. Edge raveling.
4. Level-up or build-up of low places.
5. Rutting and shoving.
6. Raveling of seal coats.
7. Fat spots or areas of bleeding.
8. Slick surfaces.
9. Raveling and surface failures on paved shoulders.
10. Localized failures in flexible pavement systems.

Surface Cracks

The two principal causes for the cracking of bituminous pavements are:

1. Thermal and dry weather shrinkage.
2. Load deformations that exceed the range of elastic deformation for the pavement structure.

These two sources of distress reflect crack patterns that are peculiar to the source of distress. Thermal cracks generally appear in a direction normal to the centerline, and develop during the fall and winter due to the contraction of the pavement with decreasing temperatures. Thermal contraction is also one of the principal factors responsible for reflection cracking in bituminous overlays (concrete pavements overlayed with asphaltic concrete). Dry weather cracks are a result of a contraction (shrinkage) of the pavement structure during drying. These cracks develop in the general direction of the highway in soils that are susceptible to shrinkage during dry seasons. Figure 18 shows an example of bituminous surface cracking resulting from dry weather shrinkage.

The sealing of all surface cracks to prevent the intrusion of water into the foundation structure is considered a maintenance operation of primary concern. Thermal and dry weather cracks are sealed under weather conditions that facilitate effective sealing operations, and prior to normal periods of seasonal precipitation. Catalytically blown asphalt and RC-2 asphalt are used extensively for crack sealing operations. Hand pour pots as shown in Figure 19 are used for the application of the crack sealing materials.

Figure 18. Longitudinal cracks caused by dry weather shrinkage.

Figure 19. Hand pour pots used for crack sealing operations.

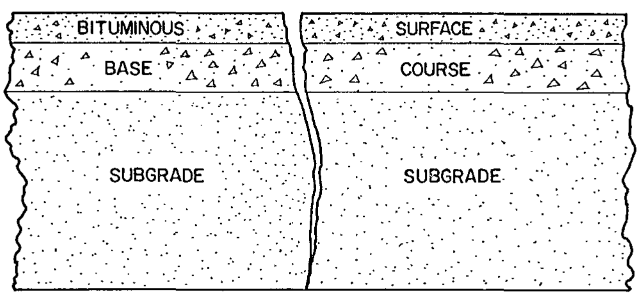
The use of pressurized heating kettles and crack sealing compounds that have sufficient fluidity for use in flexible hoses are recommended to increase the productivity of the crack sealing operation. For the sealing of large dry weather cracks a special sealing operation as described in Figure 20 is recommended.

Flexure or deformation cracks in bituminous surfaces are caused by the loading condition exceeding the range of elastic deformation for the bituminous material. This type of cracking may be caused by surface hardening, inadequate foundation support, or a combination of these factors. Figure 21 shows deformation cracks caused by surface hardening; whereas, Figure 22 shows a typical pattern of surface cracking (alligator cracking) caused by inadequate foundation support.

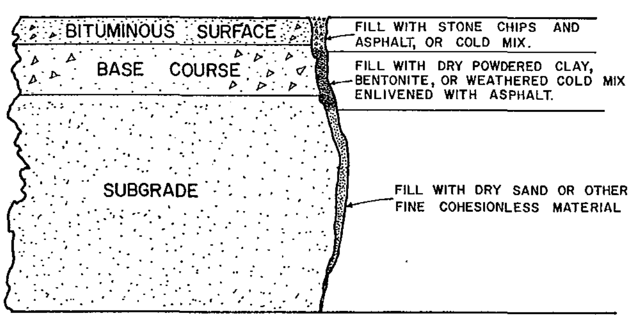
Surface cracking caused by surface hardening (Figure 21) is sealed with a sand-asphalt mastic (squeegee treatment) or a hand pouring operation prior to overlaying. Asphalt impregnated fiber mat may be used for the reinforcement and waterproofing of special or localized areas of surface cracking. However, extensive use of this material is precluded by the current cost. Patterns of surface cracking (alligator cracking) as shown in Figure 22 reflect base related failures which cannot be corrected by surface sealing operations (see localized failures in flexible pavement systems).

Pot Holes or Chuck Holes

Pot holes are small localized failures reflected in the bituminous surface. These failures are caused by surface deterioration which in time exposes the foundation



(A) LAYERS OF FLEXIBLE PAVEMENT AFFECTED BY LARGE DRY WEATHER CRACKS



(B) MATERIALS FOR FILLING DRY WEATHER CRACKS

Figure 20. Suggested procedure for sealing large dry weather cracks.

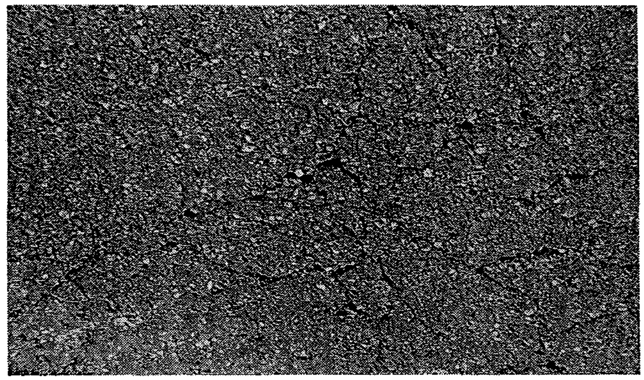


Figure 21. Deformation cracks caused by surface hardening.

structure to the weathering elements (moisture, freezing, etc.).

Pot holes are repaired by removing the loose and unstable base and surface material, tacking the surface of the hole with asphalt, and compacting cold mix or hot mix in the hole to restore the desired surface conditions. After removing loose and unstable material, the pot hole should be thoroughly compacted to insure adequate foundation support for the bituminous surface. Coarse crushed stone may be compacted in the pot hole as described in Figure 23 to increase the stability of this weakened area. The pot hole is tacked with RC or MC asphalt to facilitate adhesion and waterproof the pavement structure. Cold mixes are well aerated and compacted in the hole in two layers or lifts if necessary. The compacted bituminous surface should be slightly higher than the bituminous surface adjacent to the pot hole. This is a special provision for additional consolidation of the cold mix and good surface drainage. Consideration should be given to the use of hot mixes (when available) for pot hole repairs in view of the high quality performances and low costs that are associated with this material.

The repair of pot holes on primary routes during the winter months is a problem of primary concern. Hot bins as described in Figure 2 are recommended for transporting hot mixes, or cold mixes heated to low temperatures, for pot hole repairs during unfavorable

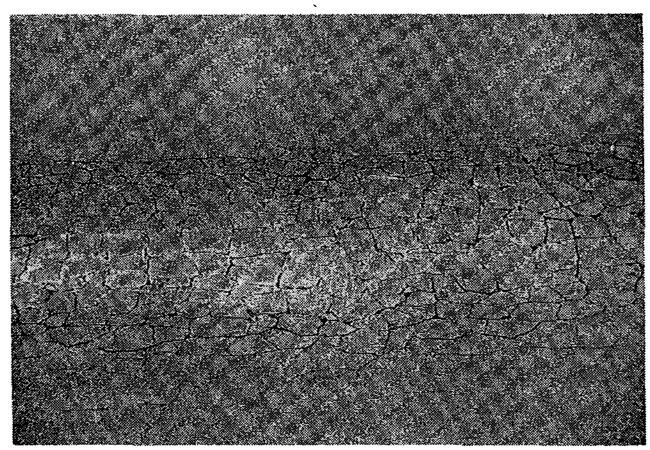
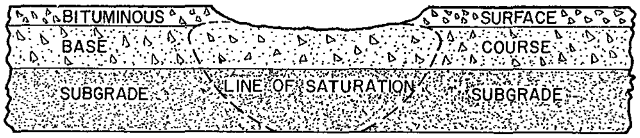
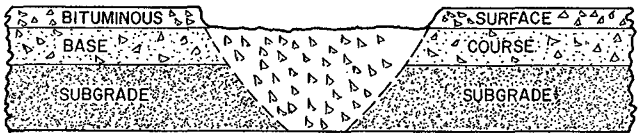


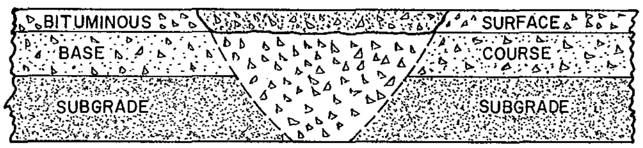
Figure 22. Deformation cracks caused by inadequate foundation support.



1. EXTENT OF DAMAGE RESULTING FROM A LOCALIZED SURFACE FAILURE.



2. (A) CLEAN OUT LOOSE AND SATURATED MATERIAL.
   (B) COMPACT COARSE AGGREGATE IN BASE AND SUBGRADE SOIL.
   (C) FILL HOLE TO BASE GRADE WITH WELL COMPACTED COARSE AGGREGATE.



3. (A) SEAL COARSE AGGREGATE AND TACK EDGES,
   (B) COMPACT COLD MIX TO CONFORM WITH SURFACE GRADE.
   (C) SEAL OR WATERPROOF SURFACE DURING SEASONS OF RAINY WEATHER.

Figure 23. Basic operations for high quality pot hole repairs.

weather conditions. Pelletized cold mixes as described in Figure 9 also offer promise of alleviating the workability-stability problem associated with cold mixes used for winter maintenance operations.

Edge Raveling

Edge raveling consists of a disintegration of crumbling of the bituminous surface at the pavement edge. The primary factors that contribute to edge raveling are listed as follows:

1. Loss of edge support due to erosion of shoulder material (wind and water erosion).

2. Loss of edge support due to cycles of wetting and drying or freezing and thawing.

3. Loading conditions—increases in traffic volume, increases in intensity of wheel loads, and "on and off" actions at the pavement edge.

4. The asphalt pavement becoming hard and brittle.

5. Low level of edge support resulting from original construction and compaction procedures.

Figure 24 shows a typical example of edge raveling on a farm-to-market road.

Raveled edges are repaired by removing the loose and undesirable material, compacting the supporting material, tacking the surface, and compacting a bituminous mix in the raveled area to the desired lines and grades. Rapid curing (RC) and emulsified asphalts

Figure 24. Typical example of edge raveling.

are used for tacking and waterproofing the pavement edge.

Surface rolling of the pavement edges and shoulders may be used advantageously (for special problem areas) for the prevention of extensive edge raveling. However such a program should be carefully planned and supervised in order to obtain the desired results (see pertinent section in report). Such a program should be followed by seal coating so as to insure a dependable level of waterproofing in the surface. Edge reinforcement as described in Figure 4 (or a modification of this concept) is recommended for special edge raveling problems (see description in report).

Level-up or Build-up of Low Places

The low places reflected in bituminous surfaces are caused by differential consolidation or swelling in the flexible pavement system. Differential consolidation and swelling of subgrade materials are considered the principal sources of this distressed condition. These differential movements are reflected in the bituminous surface; thereby necessitating a level-up of the surface to restore the desired riding characteristics.

Low places are leveled up by applying a tack coat to the low area then applying layers or lifts of hot mix or cold mix to bring the surface up to the desired lines and grades. Small or localized depressions are leveled up by hand work as shown in Figure 25. After applying a tack

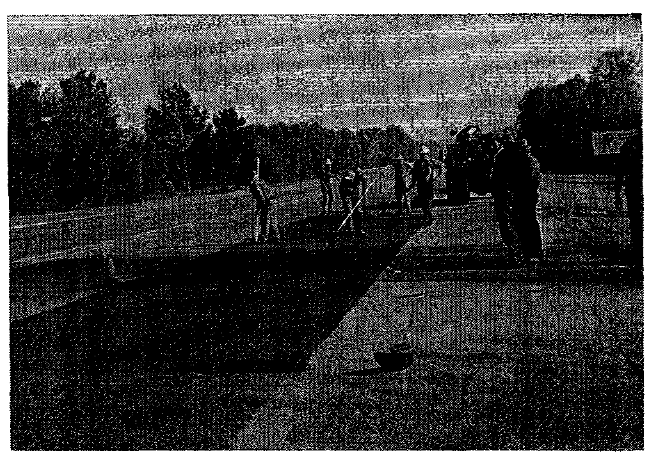


Figure 25. Hand raking cold mix for surface level-up.

coat (RC-2) to the area to be leveled up, the cold mix is applied to the depressed area in lifts not exceeding two inches. Harsh or coarse mixes are recommended for the first lift of multi-lift construction. Each lift of cold mix is to be well aerated and compacted to a high level of density.

Since cold mixes do not possess a high level of imperviousness at the time of construction, extra precautions must be taken to seal and waterproof the surface for winter maintenance operations. Light applications of asphalt and stone screenings may be rolled into the surface to insure a high level of imperviousness.

When surface depressions extend over a large area, level-up construction is accomplished with the use of a motor patrol as shown in Figure 26. Precautions must be taken to obtain acceptable levels of bond, compaction, and waterproofing when applying cold mixes during the winter months. Special precautions should be taken regarding the quantity of cold mix that is exposed to the weather for "blade on" construction.

A more extensive use of the maintenance paver is recommended for the application of small quantities of cold mix to existing pavements. This method of application is recommended as a substitute for "blade on" construction during the winter months in view of the limited amount of uncompacted material that is exposed to the weather (changes in weather).

Rutting and Shoving

Rutting and shoving of bituminous pavements may be categorized as longitudinal rutting and transverse rutting. Longitudinal rutting is caused by a lateral displacement (or consolidation) of base of subgrade material. Transverse rutting is caused by a longitudinal displacement of the surface or base material. Figure 27 shows a typical example of longitudinal rutting, whereas Figure 28 shows a typical example of transverse rutting. Low stability mixes (or base materials) and high asphalt contents are the principal factors that contribute to transverse rutting. This type of failure generally develops at stop intersections or on steep grades.

Longitudinal ruts may be treated as a level-up operation, or a level-up with a seal coat (strip seal). If the longitudinal rutting is caused by a lack of lateral support

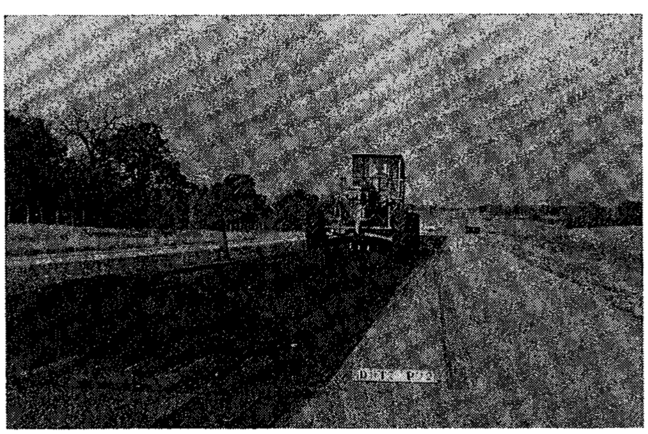


Figure 26. Machine blading cold mix for surface level-up.

Figure 27. Typical example of longitudinal rutting.

in the shoulder area, structural reinforcement as described in Figure 4 may be used with surface rolling to restore an acceptable level of stability to the critical area. The use of surface rolling should be restricted to periods when the natural moisture in the base and subbase material is suitable for further densification with a minimum of surface rolling or compaction.

Transverse ruts as shown in Figure 28 may be "bladed off" with a motor patrol during hot weather. The remaining asphalt rich pavement may be stabilized by rolling heated aggregates into the surface. Heater-planers have also been used successfully for the removal of the displaced asphaltic concrete. Pavement surfaces that are reflecting low stability due to the aggregate combination (gradation) should be removed and replaced with a high stability hot mix. Low asphalt contents are recommended for mixes that are to be subjected to severe stopping or breaking action. If the rutting extends into the base or subgrade it will be necessary to replace the entire section with high stability materials.

Raveling of Seal Coats

Raveling of seal coats consists of a loss of bond or adhesion between the aggregate particles and the asphalt binder. The raveling may result from inadequate binder

Figure 28. Typical example of transverse rutting (plastic instability).

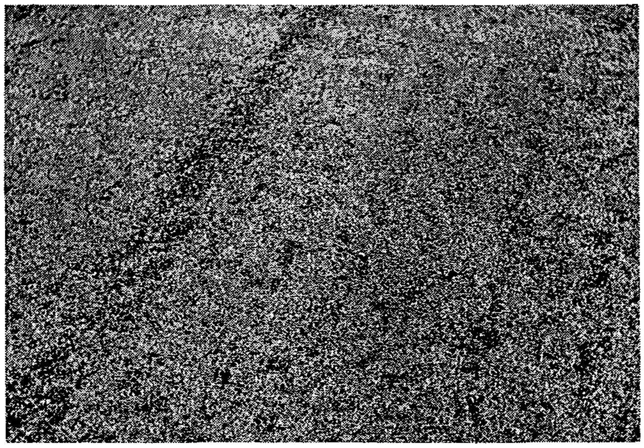


Figure 29. Raveling of a seal coat.

or from a deterioration of the adhesion between the asphalt and aggregate particles. Figure 29 shows a typical example of the raveling of aggregate from a seal coated surface.

Raveling seal coats are normally corrected with a hot mix overlay or another seal coat. However, light applications of emulsified asphalt may be used to arrest raveling resulting from a deficiency of asphalt.

Special precautions should be taken regarding the type and quantity (rate of application) of asphalt needed for lightweight aggregate seal coats. Since the level of absorbed moisture in lightweight aggregate is generally higher than the level of absorbed moisture in natural aggregates, special consideration should be given to the need for drying to prevent stripping.

Fat Spots or Areas of Bleeding

Fat spots or areas of bleeding consist of an accumulation of an excess of asphalt at the pavement surface. Excessive accumulations of asphalt on bituminous concrete surfaces are caused by mixtures that are rich in asphalt, a migration of asphalt to the surface, or a combination of these two conditions. Fat spots on seal coats are caused by excessive rates of application of asphalt, raveling resulting from inadequate rates of application, stripping and raveling, degradation of the aggregate, and submersion of the aggregate in the base course.

There are a variety of corrective measures that may be used successfully for bleeding surfaces. The practices in common use are described as follows:

1. A light application of sharp sand, stone chips, or lightweight aggregate (blotter application).

2. Cover the distressed area with an overlay or a seal coat. (Precautions should be taken to prevent the asphalt from bleeding through the overlay).

3. Remove and replace the distressed surface condition.

Localized and critical areas of bleeding may be corrected by the application of heated aggregates. Rounded high density coarse aggregates may be heated in a hot bin as described in Figure 2. The heated aggregates should be applied (approximately 50% coverage) and rolled into the asphalt rich areas. After the coarse aggregate has been firmly embedded in the asphalt, a friction textured blotter such as lightweight aggregate should be used to blot the remaining asphalt and improve the skid resistance.

Slick Surfaces

The primary factors that contribute to slick bituminous surfaces are listed as follows:

1. Fat spots or areas of bleeding.
2. Polishing of aggregates in service.
3. Surface texture or asperity.
4. Surface coatings or road films that alter the friction characteristics of the highway surfaces.

The factors listed above may contribute individually or collectively to the development of a slick surface condition.

Slick surfaces are generally corrected by overlaying or seal coating unless the slick surface is a result of surface coatings or road films that can be removed. The heater-planer has been used to remove slick surfaces from localized areas. The new surface should consist of a friction textured aggregate such as lightweight aggregate, blast furnace slag, or other aggregates that have well established records of performance. Due consideration should also be given to surface drainage (surface geometrics), since hydroplaning is recognized as one of the principal factors responsible for the loss of tire pavement interaction.

Raveling and Surface Failures on Paved Shoulders

Raveling and surface failures on paved shoulders are caused by the same factors that cause raveling and surface failures within the main traffic lanes. However, the shoulder material may reflect a distress resulting from the oxidization of the asphalt binder. Shoulder maintenance may consist of a combination of the operations previously described. The typical operations consist of crack sealing, pot hole repairs, skin patches (seal coats), overlays, and seal coats.

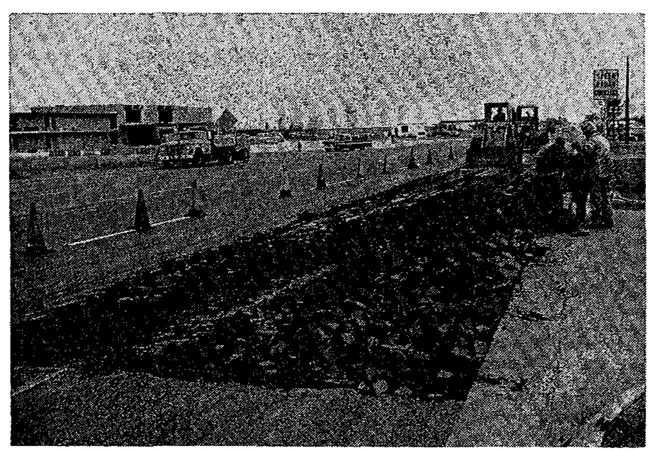


Figure 30. Localized failure in the flexible pavement system.

Shoulder maintenance may be minimized by periodic applications of a seal coat to enliven and waterproof the existing surface. A medium cure asphalt may be used to minimize the effects of oxidization and hardening on shoulders that carry very little or no traffic. Surface-rolling as described elsewhere in this report may be used to compact and strengthen special problem areas.

Paved shoulders that have been subjected to large volumes of heavy traffic usually reflect structural failures in the flexible pavement system. Surface maintenance is not the solution to this type of failure.

Localized Failures in the Flexible Pavement System

Localized failures in flexible pavement are failures resulting from a deterioration of the structural performance of the layered system. Figure 30 shows the removal of the surface course from a localized failure in the flexible pavement system. In most cases the failures are base related failures. Typical maintenance consists of the removal of the unstable material and replacing it with granular material or other materials stabilized with cement, lime, or asphalt. The repaired area should be thoroughly cured and consolidated prior to the application of the finished surface course so as to avoid surface depressions corresponding to the repaired area. The finished surface may be constructed with a seal coat and a hot mix or cold mix asphaltic pavement. A seal coat or a heavy prime coat is needed to provide adequate waterproofing for the repaired area.

The three stabilizing agents in common use (cement, lime, and asphalt) are recommended for specific soil conditions. The conditions for which these stabilizing agents are recommended are described briefly as follows:

1. Cement stabilization is normally preferred for sandy soils. However, cement has been used successfully for the stabilization of practically all soils used for highway construction. The amount of cement required for stabilization varies between 3 and 15 percent of the weight of the soil, approximately one sack per cubic yard is considered sufficient for average needs (1 c.f./c.y.).

2. Lime stabilization is recommended for clayey or high P. I. soils. The weight of lime normally required for the stabilization of soil varies between 3 and 7 percent of the weight of the soil. Approximately one sack per cubic yard is considered adequate for average conditions.

3. Asphalt stabilization is generally used for waterproofing and stabilizing cohesionless soils. The weight of asphalt normally required for stabilization amounts to 3-5 percent of the weight of the soil.

Appendix A

Field Survey Data: Materials, Equipment, and Practices

District 1—Paris: The primary materials used for bituminous surface maintenance in District 1 are RC-2 asphalt, AC-10 asphalt, hot mixes, cold mixes, hot mix-cold lay materials, cement, sand, and aggregates.

The use of sand was reported for filling large dry weather cracks prior to sealing. The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Level-up or build-up of low places.
   (b) Localized failures in the flexible pavement system.
2. Rutting and shoving.
3. Slick surfaces.
4. Raveling of seal coats.
5. Edge raveling.

The basic maintenance operations for which further research was suggested are listed as follows:

1. Raveling of seal coats.
2. Localized failures in the flexible pavement system.
3. Slick surfaces.

District 2—Fort Worth: The primary materials used for bituminous surface maintenance in District 2 are RC-2 asphalt (RC-250), emulsified asphalt, catalytically blown asphalt, asphalt cement, hot mixes, cold mixes, hot mix-cold lay materials, aggregate, lime, and cement.

The special operations that have been used successfully are listed as follows:

1. The use of weathered cold mix or hot mix-cold lay material for filling dry weather cracks. The weathered material is enlivened with kerosene or diesel fuel to improve the workability.

2. The use of dilute applications of emulsified asphalt to arrest stripping and enliven bituminous surfaces (paved shoulders and roadway).

3. Treatment of pavement edges with RC-2 asphalt (RC-250) to enliven the surface and prevent edge raveling.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Level-up or build-up of low places.
2. Pot holes or chuck holes.
3. (a) Edge raveling.
   (b) Localized failures in the flexible pavement system.

4. (a) Surface cracks.
   (b) Rutting and shoving.
   (c) Raveling and surface failures on paved shoulders.

The following special problems were reported for further investigation.

1. The need for a durable and waterproof joint between concrete pavements and asphalt shoulders.

2. The stripping of seal coats from lime treated base courses.

3. The need for an improvement in the workability of some of the cold mixes.

District 3—Wichita Falls: The bituminous surface maintenance materials consist of emulsified asphalt, catalytically blown asphalt, RC-2 asphalt, AC-5 asphalt, sand, aggregates, hot mixes, cold mixes, hot mix-cold lay materials, cement, and lime.

The special operations that have been used successfully are listed as follows:

1. The use of lightweight aggregates for the correction of slick surfaces.

2. Light application of a tack coat to pavement edges for a rejuvenation of the old pavement and a water proofing of the critical area of the shoulder (pavement shoulder transition).

The maintenance operations for which further research was suggested are listed as follows:

1. Surface cracks.
2. (a) Rutting and shoving.
   (b) Fat spots and areas of bleeding.
   (c) Slick surfaces.
3. (a) Pot holes or chuck holes.
   (b) Raveling and surface failures on paved shoulders.
4. (a) Edge raveling.
   (b) Localized failures in the flexible pavement system.
5. Raveling of seal coats.

There were no special problems reported for further research and investigation, and there were no maintenance problems designated as requiring significant expenditures.

District 4—Amarillo: The primary materials used for bituminous surface maintenance in District 4 are RC-2 asphalt, catalytically blown asphalt, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, cement and lime.

The special operations that have been used successfully are listed as follows:

1. Base material (caliche) is used for temporary pot hole repairs on low traffic volume roads during unfavorable weather with the idea of performing permanent and high quality repairs during favorable weather conditions.

2. Pavement edges are treated with a light application of RC-2 asphalt to enliven the pavement edge and prevent edge raveling.

3. Localized areas of surface cracks are sealed with RC-2 asphalt, kerosene, and sand (asphaltic mastic). The asphaltic mastic is worked into the cracks with a squeegee.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Level-up or build-up of low places.
2. Pot holes or chuck holes.
3. (a) Surface cracks.
   (b) Raveling of seal coats.

The following special problems were reported for further investigation:

1. The need for a more effective method for the sealing of extensive crack patterns within the bituminous surface.

2. The need for an investigation of pavement design and actual loading conditions for explanation of the cause for the bituminous surface cracking problems.

3. The need for a more dependable level of workability in the commercially available cold mixes.

District 5—Lubbock: The primary bituminous surface maintenance materials consist of emulsified asphalt, catalytically blown asphalt, RC-2 asphalt, AC-5 asphalt, sand, aggregates, hot mixes, cold mixes, hot mix-cold lay materials, cement, and lime.

The special operations that have been used successfully are listed as follows:

1. Use of light applications of emulsified asphalt to arrest stripping of seal coats.

2. Use of stabilized caliche for pot hole repairs and level-up work.

3. Use of rubberized asphalt to minimize surface cracking and surface rutting.

4. Use of rock dust, blow sand, or fine stone chips for filling cracks prior to sealing.

5. The sealing of concentrated patterns of surface cracks with a squeegee and a mastic consisting of sand and RC-2 (or emulsified asphalt).

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Surface cracks.
   (b) Edge raveling.
2. Pot holes or chuck holes.
3. (a) Raveling and surface faiflures on paved shoulders.
   (b) Localized failures in the flexible pavement system.
4. (a) Slick surfaces.
   (b) Raveling of seal coats.

The basic maintenance operations for which further research was suggested are listed as follows:

1. Localized failures in the flexible pavement system.
2. (a) Surface cracks.
   (b) Rutting and shoving.

3. Slick surfaces.
4. Raveling of seal coats.
5. Level-up or build-up of low places.
6. (a) Pot holes or chuck holes.
   (b) Edge raveling.
   (c) Fat spots or areas of bleeding.
   (d) Raveling and surface failures on paved shoulders.

District 6—Odessa: The primary bituminous surface maintenance materials reported by District 6 consist of emulsified asphalt, emulsified asphalt (EA 105) + 2% latex rubber, AC-5 asphalt, AC-10 asphalt, MC-3 asphalt, cold mixes, sand, and aggregates.

The maintenance operations that have been used successfully are listed as follows:

1. The use of emulsified asphalt (EA 105) including approximately 2% latex rubber for sealing surface cracks.

2. Rolling hard cover stone into fat spots or areas of bleeding.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Surface cracks.
2. Edge raveling.

The basic maintenance operations for which further research was suggested are listed as follows:

1. Surface cracks.
2. Localized failures in the flexible pavement system.
3. (a) Slick surfaces.
   (b) Fat spots or areas of bleeding.
   (c) Rutting and shoving.

District 7—San Angelo: The primary materials used for bituminous surface maintenance in District 7 are MC-3 asphalt, asphalt cement, emulsified asphalt, cold mixes, hot mix-cold lay materials, aggregates, sand, cement, and lime.

The special operations that have been used successfully are listed as follows:

1. Localized areas of surface cracks are sealed with a mixture of MC-3 asphalt, kerosene, and sand (asphalt mastic). The asphaltic mastic is worked into the cracks with a squeegee.

2. The 600-gallon distributors are provided with special compartments for the equipment and hand tools required for typical maintenance operations.

3. Rock asphalt screenings are used for a surface finish on pot holes and level-up work performed by hand. The surface is tacked with emulsified asphalt or MC-3 cutback with kerosene prior to the application of the rock asphalt screenings. This finishing procedure produces a high quality waterproof surface.

4. Light applications of emusified asphalt are applied to seal coats that are stripping.

5. Pavement edges are treated with MC-3 asphalt during the fall and spring to enliven the surface and prevent edge raveling.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Level-up or build-up of low places.
2. Edge raveling.
3. Surface cracks.
4. (a) Rutting and shoving.
   (b) Fat spots or areas of bleeding.

The following special problems were reported for further investigation:

1. The need for a more dependable level of workability in the commercially available cold mixes.

2. The need for a more efficient method for sealing localized patterns for surface cracks.

3. The need for improved mechanical equipment that will facilitate strict control over the rate of application of tack coats.

District 8—Abilene: The primary bituminous surface materials reported by District 8 consist of emulsified asphalt, RC-2 & 3 asphalt, AC-5 asphalt, AC-10 asphalt, hot mix, cold mix, hot mix-cold lay materials, aggregates, caliche, and cement.

The special operations that have been used successfully are listed as follows:

1. The sealing of pavement edges with emulsified asphalt or RC-2 asphalt for a rejuvenation of the old surface and a waterproofing of the critical shoulder area (pavement shoulder transition).

2. The use of a light application of emulsified asphalt diluted with water to arrest the raveling of seal coats.

3. The performance of shoulder maintenance consisting of the removal of loose material, surface rolling, and a light application of emulsified asphalt.

4. The use of emulsified asphalt (EA 105) blended with approximately 2 per cent latex rubber for sealing cracks in bituminous surfaces.

5. The application of hard cover stone (rolled in) to fat spots or areas of bleeding.

6. The use of gasoline and concrete sand to improve the skid resistance in small areas that have become slick due to bleeding.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Localized failures in the flexible pavement system.
   (b) Level-up or build-up of low places.
2. Surface cracks.
3. (a) Edge raveling.
   (b) Slick surfaces.
   (c) Raveling and surface failures on paved shoulders.
   (d) Rutting and shoving.

The basic maintenance operations for which further research and investigation was suggested are listed as follows:

1. (a) Surface cracks.
   (b) Slick surfaces.
   (c) Localized failures in the flexible pavement system.
2. (a) Rutting and shoving.
   (b) Raveling of seal coats.
   (c) Raveling and surface failures on paved shoulders.
3. (a) Pot holes and chuck holes.
   (b) Edge raveling.
   (c) Level-up and build-up of low places.
   (d) Fat spots or areas of bleeding.

District 9—Waco: The primary materials used for bituminous surface maintenance in District 9 are listed as follows: road oil (RO-4), RC-2 asphalt, AC-5 asphalt, emulsified asphalt, catalytically blown asphalt, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, cement, and lime.

The special operations that have been used successfully are listed as follows:

1. The use of lime or cement to stabilize base materials and prevent rutting and shoving problems.

2. The use of dilute applications of emulsified asphalt to arrest the raveling of seal coats.

3. The use of lightweight aggregates and emulsified asphalt (HVRS) for seal coating slick surfaces.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Surface cracks.
   (b) Rutting and shoving.
   (c) Slick surfaces.

The basic maintenance operations for which further research and investigation was suggested are listed as follows:

1. (a) Surface cracks.
   (b) Rutting and shoving.
   (c) Slick surfaces.

District 10—Tyler: The principal materials used for bituminous surface maintenance in District 10 are listed as follows: Catalytically blown asphalt, RC-2 asphalt, AC-5 asphalt, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, and cement.

Satisfactory results were reported from the use of the ten basic maintenance operations described in the questionnaire. There were no special operations reported for which successful performance had been obtained.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Pot holes.

2. Edge raveling.

3. Localized failures in the flexible pavement system.

4. (a) Surface cracks.
   (b) Raveling of seal coats.
   (c) Fat spots and areas of bleeding.

The basic maintenance operations for which further research or investigation was suggested are listed as follows:

1. (a) Edge raveling.
   (b) Level-up and build-up.
   (c) Rutting and shoving.

District 11—Lufkin: The primary materials used for bituminous surface maintenance in District 11 are catalytically blown asphalt, AC-10 asphalt, hot mixes, cold mixes, hot mix cold-lay materials, aggregates, cement and lime.

Special operations that have been used successfully are listed as follows:

1. The use of RC-2 asphalt with sand or rock dust for sealing surface cracks.

2. The use of cold mix blended with base material to strengthen areas reflecting distress from rutting and shoving.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Localized failure in flexible pavement system.

2. Pot holes.

3. Edge raveling.

The basic maintenance operations for which further research or investigation was suggested are listed as follows:

1. (a) Surface cracks.
   (b) Pot holes.
   (c) Fat spots and areas of bleeding.
   (d) Slick surfaces.
   (e) Edge raveling.
   (f) Raveling and surface failures on paved shoulders.
   (g) Localized failures in the flexible pavement system.

District 12—Houston: The primary materials used for bituminous surface maintenance in District 12 are catalytically blown asphalt, AC-10 asphalt, MC asphalt, emulsified asphalt, sand, lime, cement, aggregates, hot mixes, cold mixes, hot mix-cold lay materials, and shell (aggregate).

There were no special operations reported from which successful performance had been established. The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Localized failures in the flexible pavement system.

2. Rutting and shoving.

3. (a) Raveling and surface failures on paved shoulders.
   (b) Level-up and build-up of low places.

4. (a) Surface cracks.
   (b) Pot holes or chuck holes.
   (c) Edge raveling.
   (d) Fat spots.
   (e) Slick surfaces.

The basic maintenance operations for which further research was suggested are listed as follows:

1. Localized failures in the flexible pavement system.
2. Slick surfaces.
3. (a) Level-up and build-up of low places.
   (b) Fat spots.
   (c) Rutting and shoving.

District 13—Yoakum: The primary materials used for bituminous surface maintenance in District 13 are catalytically blown asphalt, RC-2 asphalt, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, cement, and lime.

Satisfactory results were reported from the use of the ten basic maintenance operations. The special refinements in these basic operations are described as follows:

1. The sealing of surface cracks with RC-2 asphalt and fine aggregate.

2. The removal of soft displaced material (with a motor grader) in areas of rutting and shoving and the replacement of this material with a high stability hot mix.

3. The use of hot mix-cold lay material or a seal coat to cover fat spots or areas of bleeding.

4. The use of lime treated base material or lime in the existing material to correct localized failures in the flexible pavement system.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Rutting and shoving.
   (b) Fat spots and areas of bleeding.
   (c) Slick surfaces.
   (d) Localized failures in the flexible pavement system.

The basic maintenance operations for which further research or investigation was suggested are listed as follows:

1. (a) Slick surfaces.
   (b) Level-up and build-up of low places.
   (c) Rutting and shoving.

District 14—Austin: The primary materials used for bituminous surface maintenance in District 14 are emulsified asphalt, MC-3-5 asphalt, asphalt cement, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, cement and lime.

Satisfactory results were reported from the use of the ten basic maintenance operations described in the questionnaire. There were no special maintenance operations reported for which successful performance had been established.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Level-up and build-up of low places.
   (b) Localized failures in the flexible pavement system.

The basic maintenance operations for which further research or investigation are listed as follows:

1. Raveling of seal coats.
2. (a) Surface cracks.
   (b) Edge raveling.
   (c) Level-up or build-up of low places.
   (d) Fat spots or areas of bleeding.
   (e) Slick surfaces.
   (f) Localized failures in the flexible pavement system.

District 15—San Antonio: The primary materials used for bituminous surface maintenance in District 15 are RC-2 asphalt, asphalt cement, catalytically blown asphalt, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, lime, and cement.

The special operations that have been used successfully are listed as follows:

1. A "home made" mixture of sand, crushed stone, and RC-2 asphalt is used to repair pot holes on heavily traveled routes. The mixture is heated (within safe limits) during cold weather to improve the workability.

2. A vibratory roller is used to compact surface repairs (pot holes, level-up, etc.) on primary routes to a high level of density.

3. Large surface cracks and dry weather cracks are filled with sand prior to sealing the surface.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Edge raveling.

2. Level-up and build-up of low places.

3. Raveling and surface failures on paved shoulders.

The following special problems were reported for further investigation:

1. The need for a heater-planer to simplify level-up problems on thick surfaces.

2. The need for a more dependable level of workability in the commercially available cold mixes.

3. The need for additional information regarding the absorptive characteristics (asphalt absorption) of various types of paved shoulders.

District 16—Corpus Christi: The primary materials used for bituminous surface maintenance in District 16 are catalytically blown asphalt, RC-2 asphalt, AC-5 asphalt, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, sand, cement, and lime.

There were no special maintenance operations (or refinements) reported. The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Rutting and shoving.
   (b) Localized failures in the flexible pavement system.
2. (a) Surface cracks.
   (b) Fat spots or areas of bleeding.
3. (a) Pot holes or chuck holes.
   (b) Level-up or build-up of low places.
   (c) Slick surfaces.

The only operation for which further research was suggested is as follows:

1. Localized failures in the flexible pavement system.

District 17—Bryan: The primary materials used for bituminous surface maintenance in District 17 are RC-2 asphalt, catalytically blown asphalt, emulsified asphalt, asphalt cement, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, cement, and lime.

The special maintenance operations that have been used successfully are listed as follows:

1. A limited amount of "home made" cold mix is used for pot hole repairs.

2. Base material (treated and untreated) is used for temporary pot hole repairs on low traffic volume roads during unfavorable weather with the idea of performing permanent and high quality repairs during favorable weather conditions.

3. Pavement edges are treated with light applications of RC-2 asphalt to enliven the surface and minimize edge raveling.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Level-up or build-up of low places.
2. Localized failures in the flexible pavement system.

The following special problems were reported for further investigation.

1. The stripping of seal coats from lime treated base courses.

2. The loss of the imperviousness of emulsified seal coats due to the formation of air bubbles in the asphalt shortly after application.

3. The need for more sophisticated equipment for the application of joint or crack sealing compounds.

4. An improvement in the design and construction of the joint between concrete pavements and asphalt shoulders.

District 18—Dallas: The primary materials used for bituminous surface maintenance in District 18 are RC-2 asphalt, catalytically blown asphalt, emulsified asphalt, asphalt cement, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, cement, and lime.

The special operations that have been used successfully are listed as follows:

1. More extensive use of hot mixes for maintenance operations in view of the availability of small quantities of hot mix from the plants located in the Dallas area.

2. Pot holes reflecting a loss of stability in the immediate area are reinforced by compacting coarse granular material into the supporting soil prior to the application of a tack coat. A coarse graded cold mix or granular material is then used for the first course. The finish course is constructed according to conventional practice.

3. The use of a light application of RC-2 asphalt along the pavement edge to enliven the old surface and minimize edge raveling.

4. The use of dilute applications of emulsified asphalt to arrest stripping and enliven old pavements. (Dilute application consists of 1000 gallons of water and 50-100 gallons of emulsified asphalt.)

5. The use of a heater-planer to remove high spots and fat spots from existing pavements. At the time of the survey, the rental rate for the equipment amounted to approximately $65.00 per hour.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Level-up and build-up of low places.
2. Localized failures in the flexible pavement system.
3. Pot holes or chuck holes.
4. Raveling and surface failures on paved shoulders.

The following special problems were reported for further investigation.

1. The need for an insulated compartment for the transportation of hot mixes for the repair of pot holes and other small surface failures.

2. The need for more sophisticated equipment for the injection of joint sealing compound into surface cracks.

3. The need for an improvement in the design and construction of the joint between concrete pavements and asphalt shoulders.

District 19—Atlanta: The primary materials used for bituminous surface maintenance in District 19 are RC-2 asphalt, asphalt cement, catalytically blown asphalt, cold mixes, hot mix-cold lay materials, aggregates, lime and cement.

The special maintenance operations that have been used successfully are listed as follows:

1. The use of a flame thrower (weed killer) for heating cracked areas so as to obtain good penetration of the joint sealer into the cracks.

2. The use of lightweight aggregate seal coats to restore an acceptable coefficient of friction to slick pavements.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Level-up or build-up of low places.
2. Edge raveling.
3. Surface cracks.

The following special problems were reported for further investigation.

1. The need for mechanical equipment for the application of cold mixes for level-up and surface repairs.

2. More sophisticated equipment for the injection of crack sealing materials into the distressed area.

3. The need for a more dependable level of workability in the commercially available cold mixes.

District 20—Beaumont: The primary materials used for bituminous surface maintenance in District 20 are RC-2 asphalt, asphalt cement, hot mixes, cold mixes, hot mix-cold lay materials, aggregates, cement, and lime.

The special maintenance operations that have been used successfully are listed as follows:

1. To insure a high level of stability for pot hole repairs during rainy weather, the face of the cleaned pot hole is dusted with dry cement and a small percentage of cement is added to the bituminous cold mix.

2. The use of a small mechanical spreader (road runner) for the application of small quantities of cold mix (approximately 35 pounds per square yard) to slick pavements or pavements in need of surface reinforcement.

3. The use of mixtures of shells (shells from marine Mollusks) sand and cement for the repair of base related failures.

The maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Level-up and build-up of low places.

2. Edge raveling.

3. Pot holes or chuck holes.

The following special problems were reported for further investigation:

1. An improvement in the design and construction of the joint between concrete pavements and asphalt shoulders.

2. Localized areas of flexible pavement pumping.

3. The need for a more dependable level of workability in the commercially available cold mixes.

District 21-Pharr: The primary materials used for bituminous surface maintenance in District 21 are emulsified asphalt, RC-2 asphalt, AC-10 asphalt, cold mixes, aggregates, cement, and lime.

The following special operations were reported:

1. The use of emulsified asphalt (EA-HVRS-90 and EA-HVRS-90-K) for seal coat work during winter and summer.

2. The use of emulsified asphalt (EA-HVMS) diluted with three parts of water to one part of emulsion to arrest raveling of aggregate from bituminous surfaces. This diluted material is applied in two applications of 0.03 gallons per square yard or three applications of 0.02 gallons per square yard.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Level-up and build-up of low places.
   (b) Rutting and shoving.
   (c) Raveling of seal coats.
   (d) Slick surfaces.
   (e) Raveling and surface failures on paved shoulders.

The basic maintenance operations for which further research was suggested are listed as follows:

1. (a) Raveling of seal coats.
   (b) Slick surfaces.

District 22—Del Rio: The primary materials used for bituminous surface maintenance in District 22 are catalytically blown asphalt, RC-2 asphalt, RC-4 asphalt, AC-5 asphalt, cold mixes, hot mix-cold lay materials, sand, aggregates, lime, and cement.

The special operations or refinements reported are listed as follows:

1. The use of a rubber squeegee to force asphalt into surface cracks and the use of rock screenings to fill or "choke" the crack openings.

2. An application of heavy liquid asphalt to arrest the raveling of pavement edges.

3. The use of a motor patrol during hot weather to cut the displaced surface material from areas of rutting and shoving. The base material is treated with lime when the rutting and shoving is attributed to low stability base material.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Surface cracks.
   (b) Level-up or build-up of low places.
   (c) Localized failures in the flexible pavement system.
2. Rutting and shoving.
3. (a) Pot holes or chuck holes.
   (b) Edge raveling.
   (c) Raveling of seal coats.
   (d) Raveling and surface failures on paved shoulders.

The basic maintenance operations for which further research was suggested are listed as follows:

1. Rutting and shoving.
2. Localized failures in the flexible pavement system.
3. (a) Surface cracks.
   (b) Pot holes or chuck holes.
   (c) Level-up or build-up of low places.
   (d) Raveling of seal coats.
   (e) Raveling and surface failures on paved shoulders.

District 23—Brownwood: The primary materials used for bituminous surface maintenance in District 23 are RC-2 asphalt, RC-2 asphalt including latex rubber, RC-4 asphalt, AC-5 asphalt, hot mixes, cold mixes, hot mix-cold lay materials, sand, aggregates, cement, and lime.

The special operations or refinements that have been used successfully are listed as follows:

1. The use of RC-2 asphalt with latex rubber for sealing large cracks in asphalt concrete pavements.

2. The use of rock dust and blow sand for filling cracks sealed with RC-2 asphalt (or RC-2 asphalt with latex rubber).

3. The use of emulsified asphalt diluted with warm water to arrest raveling of seal coats. The diluted emulsified asphalt is applied at a rate of about 0.02 gallons per square yard.

4. The use of rubberized asphalt for seal coats or strip seals on pavements subjected to high density traffic.

5. The use of RC-2 asphalt and grade 4 rock for strip sealing raveled edges (sealing of a 12″ strip).

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. (a) Surface cracks.
   (b) Pot holes or chuck holes.
   (c) Level-up or build-up of low places.
   (d) Rutting and shoving.
   (e) Localized failures in the flexible pavement system.

Further research and investigation was suggested for the maintenance problem of pot holes or chuck holes.

District 24—El Paso: The primary materials used for bituminous surface maintenance in District 24 are catalytically blown asphalt, emulsified asphalt (EA-HVMS), RC-2 asphalt, hot mixes, cold mixes, hot mix-cold lay materials, pre-coated aggregates, natural aggregates, cement, and lime.

There were no special operations or refinements reported. The basic maintenance operation that was designated as requiring significant expenditures for materials, labor, or equipment is listed as follows:

1. Level-up or build-up of low places.

Further research and investigation was also suggested for the maintenance problem of level-up or build-up of low places.

District 25—Childress: The primary materials used for bituminous surface maintenance in District 25 are catalytically blown asphalt, RC-2 asphalt, emulsified asphalt, hot mixes, cold mixes, hot mix-cold lay materials, pre-coated aggregates, natural aggregates, sand, lime, and cement.

The special operations or refinements that were reported are as follows:

1. The use of RC-2 asphalt or emulsified asphalt and fine aggregate for strip sealing concentrations of surface cracks.

2. The use of RC-2 asphalt without cover stone to arrest edge raveling.

3. The use of a motor grader during hot weather to remove the displaced surface material from areas of rutting and shoving. The area is leveled up with a cold mix overlay if level-up is necessary.

4. The use of a motor grader to remove localized fat spots or areas of bleeding.

The basic maintenance operations that were designated as requiring significant expenditures for materials, labor, or equipment are listed as follows:

1. Surface cracks.
2. Localized failures in the flexible pavement system.
3. Level-up or build-up of low places.
4. (a) Pot holes or chuck holes.
   (b) Edge raveling.
   (c) Raveling and surface failures on paved shoulders.
5. Slick surfaces.
6. (a) Rutting and shoving.
   (b) Raveling of seal coats.
   (c) Fat spots or areas of bleeding.

The basic maintenance operations for which further research was suggested are listed as follows:

1. Surface cracks.
2. Rutting and shoving.
3. Pot holes or chuck holes.
4. Slick surfaces.
5. (a) Edge raveling.
   (b) Raveling of seal coats.
   (c) Localized failures in the flexible pavement system.
6. (a) Level-up and build-up of low places.
   (b) Fat spots or areas of bleeding.
   (c) Raveling and surface failures on paved shoulders.

Appendix B

Test Procedure for Cold Mixes

Development of a Test Procedure for the Evaluation of Workability and Stability of Cold Mixes

The need for more strict control over the workability and stability of cold mixes has been emphasized by the current demands for significant variations in the optimization of these two material properties. Workability is one of the primary requisites of cold mixes for winter maintenance; however, the cold mix must yield a level of stability that is commensurate with actual needs when compacted. Since workability is normally developed at the expense of stability, there is a need for a simple test procedure that can be used to facilitate the design of cold mixes with levels of workability and stability that are in keeping with the current needs for bituminous mixes for winter maintenance operations. The test procedure developed for the testing and design of bituminous cold mixes consists of an unconfined compression test. The details of this test procedure are described briefly in this report.

The unconfined compression test was selected as the basic test procedure in view of simplicity. However, the entire testing program was designed to yield bulk specific gravity of the mix, specific gravity of the compacted mix, weight loss at 140°F vs time, and stress-strain data obtained from unconfined compression testing.

The principal items of equipment required for this testing procedure are normally available in a laboratory that is equipped for the testing of bituminous mixes. The only special piece of equipment developed for this test consists of a split cylindrical mold with plungers for the compaction of test specimens. The mold is equipped with double plungers; and is split on one side to facilitate the removal of the compacted samples. The double plunger arrangement reduces the loss of compaction force to wall friction during the consolidation of the test sample. The details of the split mold are shown on Figure 5. Figure 6 shows a photograph of the split mold and plungers. This compaction mold is similar to the one designed by Gandhi and Gallaway[4] for the compaction of triaxial test specimens.

The procedure developed for the preparation and testing of unconfined compression test specimens of bituminous cold mixes is outlined as follows:

1. Determine the bulk specific gravity of the cold mix according to the procedure developed by Rice.[5]

2. Test the mix for workability at 50°F by visual inspection and manual probing.

3. Weigh out six samples of cold mix (1500-1900g depending on specific gravity) for laboratory testing. Place the cold mix in pans approximately 1½ inches deep.

4. Cover three of the pans with aluminum foil and heat at 140°F for two hours. At the end of the two hour heating period, compact the material in the split mold shown in Figure 5 with a maximum pressure of 1000 psi (prepare 3 specimens).

5. Oven dry the other three pans of cold mix at 140°F without the aluminum foil cover for a measure of weight loss (water and volatiles) with time. Time intervals suggested for weighing are: 1, 3, 5, 8, 24, and 30 hours.

6. If the stability of the dried material is questioned, compact three test specimens (at 1000 psi) and test for unconfined compressive strength.

7. Determine the weight, volume, specific gravity, and percent voids for the compacted test specimens.

8. Subject the test specimens to approximately 24 hours of temperature controlled conditions (approximate room temperature).

9. Test samples for unconfined compressive strength at a temperature corresponding to the controlled temperature and at a rate of 0.06 inches per minute. Record stress-strain data for each 0.02 of an inch of deformation.

10. Report maximum stress and the corresponding strain as well as the modulus of elasticity of the compacted mix.

The specific gravities of the compacted test specimens are determined by dividing the weights of the test specimens by the compacted volumes. Volumes of the test specimens are determined by multiplying the cross sectional area of the mold by specimen heights (precise measurement). This procedure is considered sufficiently accurate for a relative measure of the density or compaction of the test specimens.

This simple strain (deformation) controlled test procedure furnishes a reliable measure of the unconfined compressive strength of bituminous cold mixes. The simplicity of the test procedure is favored in view of the number of tests required to establish acceptable levels of workability and stability. Evaluations of the test data must reflect cognizance of typical changes in workability-stability relations of the cold mix with them.

REFERENCES

1. Hargett, Emil R., "A Study of Bituminous Surfaces in Texas," Texas Transportation Institute Research Report 129-1, 1968.

2. ASCE Committee Airfield Pavements, "Maintenance Practices for Rigid Pavements," Journal of the Aero-Space Transport Division of the American Society of Civil Engineers, Vol. 94, No. AT 1, Nov. 1968, p. 62.

3. McDonald, Charles H., "Corrective Measures for Pavement Distress on the Urban Street." Presented at 48th Annual Meeting of the Highway Research Board, January 1969.

4. Gandhi, P. M. K. and Gallaway, B. M., "Viscosity Effects on Stress-Strain and Volume Change Characteristics of Asphaltic Materials," Journal of Materials, American Society for Testing and Materials, March 1967, Vol. 2, No. 1, p. 33.

5. Rice, J. M., "Maximum Specific Gravity of Bituminous Mixtures by Vacuum Saturation Procedures," Symposium on Specific Gravity of Bituminous Coated Aggregates, American Society for Testing and Materials, STP No. 191, pages 43-61, 1956.

6. Langfelder, L. J. and Nivrgirkar, V. R., "Some Factors Influencing Shear Strength and Compressibility of Compacted Soils," Highway Research Record No. 177, Highway Research Board, 1967, pp. 4-21.

7. Johnson, A. W. and Sallberg, J. R., Highway Research Board Bulletin 272, 1960, pp. 49-76.

8. Weber, W. G., "Measurement of Excess Hydrostatic Pressure in Soils," Papers on Soils, 1959 Meetings, American Society for Testing and Materials, STP No. 254, 1960, pp. 276-283.