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# TRANSVERSE CRACKING IN ASPHALT PAVEMENTS

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## PREFACE

This study looks at transverse cracking in asphalt pavement from three viewpoints:

1. 3-R crack repair
2. Mix design
3. Maintenance

Some possible alternatives are discussed to deter the formation of transverse cracks in new overlays through improved mix design and construction practices, through the use of fabrics and relief layers, and through the use of fog seals.

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# INTRODUCTION

Transverse cracking in asphalt pavements has been studied by scientists and engineers for many years.

Generally, they have all agreed that the only way a more or less straight crack can occur in an asphalt pavement is by a tensile force.

These tensile forces are due to one or more causes. Some of the internally induced stresses are caused by volatile loss in the asphalt, selective absorption of asphalt in a mix by the aggregate and temperature changes.

Some of the external forces acting on a pavement are shrinkage of the subgrade through moisture loss, temperature change or curing of cement or lime treated subgrades.

Other contributors to transverse cracking are sandy mixes, sandy subgrade, low traffic volumes, low penetration asphalt cement, clay filler and accelerated oxidation due to a pavement being open textured and permeable. (1, 2)

In the introduction to the 1966 symposium referenced above, Vaughn Marker stated "...several interrelated factors are probably at work at the same time in any situation wherein cracking of asphalt paving is occurring."

This thought should be kept in mind as we enter this study/there is no single cause, therefore there is no single cure.

## SEVERITY OF TRANSVERSE CRACKING

For the purpose of this study, our Interstate System was driven and the number of transverse cracks determined.

Our Interstate System consists of 266 miles of portland cement concrete, 20 miles of roadway that is not up to Interstate standards, and 342 miles of asphalt concrete surface.

Of the 342 miles of asphalt concrete surface, 53 miles had crack spacing of 3 feet to 100 feet with an average spacing of 19 feet; 54 miles had crack spacing of 10 feet to 200 feet with an average spacing of 36 feet; 27 miles had crack spacing of 35 feet to 140 feet with an average spacing of 58 feet; 61 miles had crack spacing of 100 feet to 5,900 feet with an average spacing of 830 feet and; 147 miles showed no cracking.

Almost all of the 147 miles with no cracking had been overlaid between 1977 and 1979.

## CLIMATE

"Oklahoma has a continental type climate with pronounced seasonal and geographic ranges in temperature and precipitation. The vast, open plains of the western two-thirds of the state are somewhat less subjected to the warm moist winds from the Gulf of Mexico and are consequently cooler and drier than the eastern third. In the eastern section, showers are more frequent, especially during late summer and early fall, because of the more humid atmosphere and the influence of the hilly, wooded terrain.

Hot, drying winds from the south and west sometimes occur during the summer months. These winds, in conjunction with clear sunny skies, contribute to rapid evapotranspiration of soil moisture. An average of 75 percent of the annual precipitation falls during the growing season, March to October inclusive.

Temperatures vary less across the state than precipitation. Mean annual temperatures range from 63.8° at Idabel, in the extreme southeast part of the state, 53.6° at Boise City in the western part of the Panhandle. Average July temperatures are from 78° in the Panhandle to 82° in the southeastern half of Oklahoma. January averages range from 32° in the northwest to 44° in the extreme southeast. Maximum temperatures of 100° or higher may be expected in Oklahoma from June to September inclusive. The summers are long with occasional periods of very high daytime temperatures. The winters are relatively short and mild, although minimum temperatures of zero or lower have been recorded at one or more stations in all except 3 of the 48 winters on record. Snow is a rather infrequent occurrence in the southeast but has been recorded in the Panhandle in all months except July and August. Generally, other sections of the state record no snow from May to September inclusive." (3)

Table 1 shows some of the record temperatures as well as data for the past thirty years for six different locations in the state.

## SOILS

Soils in Oklahoma can be grouped or classified in very general terms according to the general geology and physiographic areas of the state in which they occur. (3) These areas may be described as follows:

Quaternay - These soils are found in northwestern and southwestern parts of the state. They are aeolian (windblown) deposits of sands and silts. Generally non-plastic and silty. Depths are highly variable. Origin is from major rivers and streams.

Tertiary - High plains: These soils are found in the Panhandle of northwestern parts of the state. They are alluvial (undifferentiated) deposits of clays, silty clays, limy clays and sands. Depths are highly variable.

Cretaceous - Gulf Coastal Plain: These soils are found in the southeastern part of the state. They are marine deposits of sorted sands, sandy clays and clays. Depths are highly variable. Also, they are residual silty clays and clays that can be highly plastic with large swelling potentials. These soils are developed over limestones or marls and shallow in depth (20 ft.).

TABLE 1 CLIMATOLOGICAL DATA (1949-1979)

| | AREA | | | | | |
|---|---|---|---|---|---|---|
| | Northwest | Northeast | Central | Southwest | Southeast | Panhandle |
| No. of years below 0° F. | 18 | 7 | 8 | 1 | 3 | 25 |
| 30 year low temperature | -15° F | -7° F | -4° F | -4° F | -10° F | -24° F |
| *10 year low temperature | - 9° F | -5° F | -3° F | +1° F | - 1° F | -16° F |
| | | | Record Information | | | |
| Lowest ever recorded | -24° F | -26° F | -24° F | -19° F | -16° F | -25° F |
| Coldest Month (Average low) | 24° F | 26° F | 27° F | 27° F | 32° F | 20° F |
| Average No. of days below freezing | 105 | 90 | 85 | 90 | 70 | 130 |

*The 10 year low temperature is the lowest ambient temperature we should expect once every 10 years based on the thirty year data.

Permian - Western Prairie Plains, Rolling Plains, Sandstone Hills, Gypsum Hills: These soils are all residual sands, sandy clays, silty clays and clays developed from shales and sandstones. They have low to high plasticity and are generally shallow in depth (20 ft.). They cover large areas in central and western parts of the state.

Pennsylvanian - Northern Limestone Plains and Hills, Eastern sandstone Plains and Hills, Eastern Prairie Plains: Same as Permian. They are in east central and eastern parts of the state.

Pennsylvanian or Mississippian - Some Older - Quachita Highlands: Same as Permian. They are primarily in the southeastern part of the state. They are also colluvial soil deposits that are highly variable in thickness and plasticity. They occur at random. There are some essentially non-soil areas in the Quachita and other named mountain areas.

Mississippian - Ozark Highlands and Ozark Prairie: These soils are residual clays, gravelly clays and gravels developed from cherty limestones and dolomites. They are highly variable in depth and in plasticity. They occur in northeastern parts of the state.

Devonian Through Precambian - Arbuckle Plains and Wichita and Arbuckle Limestone Hills: These soils are residual clays with assorted alluvial outwash. Depths are variable but generally shallow. Plasticity ranges from low to high. There are also large areas that are essentially non-soil. These occur in southern Oklahoma.

Alluvial Deposits - All major rivers, streams, and creeks have associated with them flood plain and alluvial terrace deposits that cut through or cover all of the above soil types described. These alluvial soils vary highly in soil type, depth and plasticity.

## AGGREGATES

Limestone is the most commonly used aggregate for producing hot-mix asphalt in Oklahoma.

A typical aggregate blend would be 80% limestone and 20% sand.

Since limestone will polish over a relatively short period of time, we replace some of the coarse aggregate in our surface courses with a nonpolishing aggregate on most of our highways.

The non-polishing aggregates we use are sandstone, dolomitic sandstone, cherty limestone, crushed chert, crushed gravel and occasionally, slag.

## REFINERIES

In 1979, 98% of the asphalt cement used in Oklahoma was produced by eight refineries within the state.

Table 2 shows this usage as well as the refining process and PVN (from McLeod).

TABLE 2 OKLAHOMA REFINERIES

| Refinery No. | % of 1979 Usage | Refining Process | PVN |
|---|---|---|---|
| 1 | 40 | Vacuum to 135 pen then air blown | -0.8 |
| 2 | 19 | Air blown | -0.7 |
| 3 | 13 | Vacuum then air blown | -0.7 |
| 4 | 8 | Vacuum to 135 pen then air blown | -0.2 |
| 5 | 8 | Air blown | -0.3 |
| 6 | 5 | Air blown | -0.9 |
| 7 | 3 | Air blown | -0.2 |
| 8 | 2 | Air blown | -0.2 |

# METHODS TO DETER REFLECTIVE CRACKING IN 3-R TYPE WORK

Crack reflection in asphalt overlays has been recognized as a major concern for some time. Infiltration of moisture into the subgrade through these cracks may cause heaving and pavement deterioration at the cracks resulting in a loss of riding comfort.

Reflective cracks are caused by movement of the pavement below the overlay. Many techniques have been used in an attempt to minimize crack reflection through the new overlay.

## (I) FABRICS

One method used to retard crack reflection through asphalt overlays is the use of fabrics. Fabrics provide a stress relieving interlayer and retard moisture infiltration.(4)

Fabrics may be divided into two groups: (1.) strip types which are heavy grade fabrics placed only over the crack to be treated, and (2.) full coverage or lane-width fabric types, which are much lighter. (Approx. 4 ounces per sq. yd.)

Strip fabrics are more effective in the treatment of cracks or joints with high potential for movement. Due to the relatively high cost of materials and hand labor, they do not appear to be cost effective for general use as a crack treatment.

Full width fabrics may be placed on a leveling course, the milled or planed asphalt, or the old asphalt pavement. They are placed over a thick asphalt tack coat which saturates them. The fabric is then covered by an asphalt concrete overlay or an asphalt friction course. Fabrics presently used are of polypropylene or polyester filaments and are nonwoven.

Mechanical methods of application of full width fabrics have been devised which result in a minimal amount of hand labor. Full width fabrics have proven to be an effective deterrent to reflective cracking for alligator or block type cracking. They have not shown to be as effective in the treatment of transverse cracking.

Studies indicate that fabric treatment is more effective in temperate regions which are not subject to extreme temperature changes.

The cost of full fabric coverage including tack coat is approximately equivalent to one inch of asphalt concrete overlay. Costs of asphalt are escalating as the availability becomes more uncertain. As contractors become more experienced in the application of fabrics, lower application costs should result.

A judicious use of our dwindling road user tax dollars mandates that alternate construction practices be considered. The use of fabrics should be included as one of the alternates considered for the prevention or retardation of reflective cracks through overlays. (5)(6)

## (II) HEATER SCARIFICATION

Heater scarification is a means of surface recycling existing asphalt pavements. Scarifying is more readily accomplished when the asphalt is softened by the heat.(7) The process consists of heating and scarifying the asphalt to a depth of 1/2 to 3/4 inches. Admixtures may be added to alleviate surface oxidation and rejuvenate the pavement.(8) Recompaction is then performed. An overlay is sometimes placed over the treated pavement.

Advantages attributed to heater scarification include: correction of surface distortion, thinner overlays which require less correction at manholes and junctures with curb and gutter, a good bond between the treated pavement and the overlay, and rearrangement through scarification may inhibit reflection cracking in the overlay.(9)

## (III) ASPHALT RUBBER

Another approach being used to retard crack reflection through asphalt overlays is by the use of a rubber-asphalt mixture. One technique tested by the University of California with experimental projects in Arizona and Colorado,(8)(10)(11) consists of a thin layer (1/4" to 3/8") of asphalt-rubber of low stiffness and high deformibility at the interface between the underlying and overlay pavements. This usage has become known as a stress absorbing membrane interlayer, or SAMI.

The rubber used in the projects was from discarded tires and consisted of approximately one-fourth of the rubber-asphalt mixture.

Seal coats using rubber asphalt as the binder have been tested in both Texas and Oklahoma.(12)(13) These studies are recent and insufficient time has passed for conclusive findings.

It does appear that a rubber-asphalt membrane interlayer may be an effective tool in relieving stress at points of discontinuities in the underlying pavement and the overlay. Construction techniques have not been developed to the point that valid cost comparison can be determined.

## (IV) COLD MILLING

Cold milling is a term applied to the removal of asphalt or portland cement concrete pavements by a milling or planing machine. This process may be used in correcting surface irregularities or for the removal of the pavement for recycling purposes.

Some advantages attributed to cold milling are: surfaces may be milled to close tolerances, a good surface texture may be obtained, operations are not easily hampered by adverse weather, high production rates are obtainable,(14) salvaged material is reusable, and greater depths may be obtained relative to heater scarification.

As new construction costs continue to rise, many states are spending their dwindling funds on 3-R type work. Cold milling may deserve a close examination.

(V) FILLERS See Maintenance Report

(VI) DRAINAGE

Drainage, as it relates to the pavement structure, is an item that should be considered in 3-R projects.

A buildup of soil or turf at the shoulder edge may hamper rainfall runoff and require periodic removal.

If the original roadway was constructed in a dry period or if underground water sources were encountered and not adequately provided for during construction, they may be the cause of subgrade failures and pavement deterioration.

Draining of accumulated subsurface water may be a major undertaking.(5) The placement of drainage pipe parallel to and outside the lane or shoulder to a sufficient depth to drain the subgrade may be necessary.

Deepening of roadway ditches may be of benefit in correcting some subgrade drainage problems.

(VII) CRACK REPAIR See Maintenance Report

(VIII) OVERLAYS

Overlays are a means of improving skid resistance, retarding infiltration, correcting structural inadequacies, eliminating surface irregularities in order to provide a smooth riding surface, and prolonging the life of a roadway.

Measurements of rutting, skid tests, crack surveys, tests for structural adequacy, and traffic information are all prerequisites in determining overlay needs.

In Oklahoma, thin overlays (those less than 4 inches thick) have been used almost exclusively. The 3-R program in the past has been used for interstate and high type highways of relatively recent construction. The original pavement design has proven to be adequate structurally and only thin overlays are needed to restore the roadway to good service.

Current 3-R projects include lower type highway projects with minimal pavement sections. Although thick overlays may be indicated, the need to spread limited funds through a broad area results in little use of thick overlays.

## (IX) MISCELLANEOUS

The use of open-graded asphalt concrete base for the control of reflective cracking has been used in Tennessee with good results and is used routinely in Arkansas. The open-graded mixture with large interconnecting voids relieves the motion of the underlying pavement before it creates stresses in the upper layers of the overlay. Drainage of the open-graded mix, such as daylighting at the shoulder, should be provided.

The minimum recommended thickness of the crack relief layer is 3½ inches. A 2" binder course of sufficient coarseness so that it will not penetrate into the voids of the open-graded mix is applied over the crack-relief course. A surface course is then applied.

The state of Arkansas has used this type overlay over both PCC and asphalt pavements. It has over 200 lane miles of this type overlay in place and considers it a viable method of reducing inherit failures such as cracking in the overlay.(15)

# ASPHALT MIX DESIGN FOR SURFACE COURSES

## I. CURRENT PROCEDURES

When a contractor is awarded a State contract, he submits materials he proposes to use to produce the asphalt mixture specified.

### Mineral Aggregates

Table 3 is a list of the quality tests that are performed on the aggregates prior to any mixtures being prepared.

### Asphalt Mixtures

If the aggregates pass all of the quality tests, mixes are then prepared and molded. We use the automatic gyratory-shear method of molding as developed by the Texas Highway Department. (16)

As a point of interest, this method of molding gives results similar to the Marshall 75 blow method of compacting (based on comparison of ten plant produced mixtures).

The molded specimens are then measured for height and weighed in air and water and their specific gravities calculated.

The bulk impregnated specific gravity of the combined aggregates is determined and used in calculating the maximum theoretical specific gravities of the asphalt mixtures. This method, if performed by an experienced technician, yields results comparable to AASHTO test method T 209.

Table 4 lists the requirements for the three types of mixtures that are normally used in overlay projects.

## TABLE 3 - PHYSICAL PROPERTIES OF AGGREGATES

| Test | Aggregates to be used in:<br>Asphalt Concrete | <br>Open Graded Friction Course |
|---|---|---|
| L. A. Abrasion, (Max. % wear) | | |
| Each Source | 40 | N.A. |
| Combined Sources | N.A. | 30 |
| Sand Equivalent (min.) | | |
| Combined Sources, | | |
| Wearing course | 45 | 45 |
| Base or binder | 40 | N.A. |
| *Mechanically fractured Faces (min. %) | | |
| Combined sources | 70 w/2 | 70 w/2 |
| Durability, DC factor (min.) | | |
| Wearing course, Combined sources | 40 | 40 |
| *Insoluble Residue (min.) | | |
| Combined sources | ** | 30 |
| ***Flat or Elongated pieces (max. %) | | |
| Each source | 15 | 15 |
| Clay balls and sand clusters (max. %) | | |
| Each source | 1.5 | 0 |
| Sticks and roots | 0.5 | 0 |

*If natural gravel is to be used as a source of insoluble residue, it shall be crushed so that at least 70% of the material retained on the No. 4 (4.75 mm) sieve has 2 or more mechanically fractured faces and no more than 30% passing the No. 10 (2.00 mm) sieve.

**When specified on the plans or in the proposals, the coarse aggregate used in the asphalt concrete surface course, shoulders excepted, shall contain not less than 30% insoluble residue.

***A flat or elongated piece is one in which the length is greater than 5 times the average thickness.

## TABLE 4 - REQUIREMENTS FOR ASPHALT MIXTURES

| Percent Passing Sieve Size (mm) | Asphalt Concrete** Type B | Asphalt Concrete** Type C | Open Graded Friction Course* |
|---|---|---|---|
| 3/4" (19.0) | 100 | 100 | |
| 1/2" (12.5) | 80-100 | 95-100 | 100 |
| 3/8" (9.5) | 70-90 | 80-100 | 90-100 |
| No. 4 (4.75) | 50-70 | 55-75 | 25-45 |
| No. 10 (2.00) | 35-50 | 40-55 | 0-10 |
| No. 40 (0.425) | 15-30 | 18-33 | - |
| No. 80 (0.180) | 9-21 | 10-22 | - |
| No. 200 (0.075) | 3-9 | 4-10 | 0-5 |
| Penetration Grade Asphalt Cement | 85-100 | 85-100 | 85-100 |
| % Asphalt soluble in Solvent (% of total mix) | 4.4-7.5 | 4.4-7.5 | As designed |
| Molded Density (% of max. theo.) | 94-98 | 94-98 | N.A. |
| Hveem Stability | 35 Min. | 35 Min. | N.A. |

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*Natural sand will not be allowed in this mix. A minimum of 55% of the aggregate shall be retained between the 3/8" (9.5 mm) sieve and the No. 4 (4.75 mm) sieve.

**When used in the wearing course, at least 50% of the material passing the No. 200 (0.075 mm) sieve shall be crushed stone, crushed rock or mineral filler.

If the mixtures meet these requirements, we then issue the contractor a job mix formula, specifying the % of each aggregate and the % asphalt cement he is to use.

For asphalt concrete, this job mix formula is intended to yield a mixture such that the lab molded density will be 96% of the maximum theoretical specific gravity except on intersection modifications and low traveled roads.

On intersection modifications, we set the job mix formula for asphalt cement 0.3% below and on low traveled roads, 0.3% above the normal job mix formula.

## SAMPLING & TESTING

Sampling and testing is done in accordance with the following AASHTO methods, except as noted. All OHD L- methods are given in Appendix "A".

| | |
|---|---|
| **Aggregate:** | |
| Sampling | T 2 |
| Material passing the No. 200 (0.075 mm) sieve | T 27 |
| Wear (Los Angeles Abrasion) | T 96 |
| Clay balls, sand clusters, etc. | OHD L- 9 |
| Fractured faces | OHD L-18 |
| Sand equivalent | T 176 |
| Durability factor | T 210 |
| Insoluble residue | OHD L-25 |
| **Mixtures:** | |
| Mechanical analysis of extracted aggregates | T 30 |
| Sampling | T 168 |
| Bitumen Content | OHD L-26 |
| **Mix Design:** | |
| Bulk impregnated specific gravity | OHD L- 7 |
| Compacting bituminous mixtures | OHD L- 8 |

| | |
|---|---|
| Specific gravity of compacted mixtures | OHD L- 14 |
| Test for Hveem stability | OHD L- 16 |

### Penetration Grade Asphalt Cement:

| | |
|---|---|
| Testing as outlined: | M-20 |
| Sampling, Refinery | T-40 |
| Sampling, project site or mixing plant | OHD L- 5 |

## CONSTRUCTION REQUIREMENTS

### Temperature:

The maximum temperature of heating the aggregates and asphalt cement is 325° F (163° C) for asphalt concrete.

For the open graded friction course, the maximum aggregate temperature is 260° F (127° C) and the maximum asphalt cement temperature is 280° F (138° C).

The minimum air temperature for placing asphalt concrete is 35° F (2° C) when rising or 40° F (4° C) when falling.

The minimum air temperature for placing the open graded friction course is 60° F (16° C).

### Compaction:

Asphalt concrete must be compacted to 95% of the lab molded density.

A pneumatic tired roller must be used on the asphalt concrete wearing course in conjunction with the steel wheel rollers normally used.

The open graded friction course is rolled one time with a steel wheel roller and traffic is withheld for 2 hours or until the mixture has cooled within 10° F (6° C) of ambient temperature.

## II ALTERNATIVES CONSIDERED FOR IMPROVED PAVEMENT PERFORMANCE

### Voids, Permeability and Compaction

Vaughn Marker ~~(4)~~ (1), on compaction of asphalt pavements, stated, "It is probably the most important aspect of construction contributing to the durability and performance of these pavements and the aspect we continue to have the most difficulty with."

Oklahoma indeed has a problem with achieving proper compaction. It was recently discovered that between 40 and 45 percent of the independent assurance samples taken from active surfacing projects for compaction determinations had failed.

Studies (17,18,14) have shown that as the void content increases, the penetration of the recovered asphalt cement decreases significantly over a period of time.

The optimum air void content appears to be a maximum of 7-8% on freshly placed pavements with a minimum of 3% after traffic compaction (18,19).

Since the contractors are apparently using our density requirement (a minimum of 95% of lab molded density) as a target value rather than a minimum value, our specifications need to be revised.

It would be much better to require a target value of 96% of lab molded density with no density below 95% of lab molded.

Another alternative would be to require a target roadway density of 93% of the maximum theoretical density with no density below 92% of maximum theoretical. This alternative has the advantage of removing the variability in the lab molded specific gravities.

One method to aid in the enforcement of this would be to require a test strip be placed and the rolling pattern established before construction begins.

The cost of implementing this would be minimal in comparison to the price we are now paying for asphalt concrete in place.

## Asphalt Content

As stated previously in this report, the job mix formula for asphalt cement is set such that the lab molded density will be 96% of the maximum theoretical density. It has been our experience in Oklahoma that this is the maximum we can specify for asphalt cement and still avoid hot weather problems, such as flushing, rutting, shoving, and in general, low stability mixtures on high volume roads.

Others (20) have found that asphalt content can have a critical effect on thermally induced stresses and that a properly designed asphalt mix can produce high bond within the matrix and a resulting high internal resistance to thermal stresses.

Our specifications allow a tolerance of ± 0.4% from the job mix formula for the asphalt cement in our asphalt concrete. This is approximately equal to ± 1% variation in our % lab molded density.

Since asphalt cement costs much more than aggregate and because we pay for asphalt cement based on the job mix formula, many contractors will try to produce the asphalt mix below the job mix formula.

Of the 393 extractions performed by the central laboratory personnel since June 1st this year, 56.6% were below job mix formula and 28.3% were above job mix formula. This includes 10.7% of the mixes below the -0.4% tolerance.

We need to develop better field control for the % asphalt cement actually being used in the asphalt concrete.

## Education of Personnel

Two important aspects of asphalt pavement that cannot be over emphasized are proper compaction and proper asphalt content.

More emphasis should be put on these items during our in-house training schools.

## Asphalt Quality

Much work has been done by McLeod (21,22) on low temperature performance of asphalt cements.

Based on McLeod's work, we can expect our asphalt concrete pavements to show transverse cracks at about +10° F (-12° C).

The 85-100 penetration grade asphalt cements produced for use in Oklahoma have Pen-Vis Numbers (PVN) from +0.1 to -0.9 with 78% of the asphalt cement used in 1979 having a PVN -0.7 or less.

McLeod's work would indicate that we should use a higher penetration grade asphalt cement. However, since we do get some flushing of our asphalt pavement with the 85-100 penetration grade asphalt we are now using, it would be impractical to use a higher penetration asphalt cement.

Other work (23) has shown that specimens made with absorptive aggregate and high penetration asphalt cement cracked more than specimens made with lower penetration asphalt cement when subjected to wet-dry cycles.

Kandhal (24) has found that in Pennsylvania, AC-20 can be successfully used even with a PVN of -1.25.

Benson (25) found that good resistance to thermal cracking can be expected if, after ten years, penetration of the extracted asphalt is no less than 25.

In order to prevent the problems associated with high temperatures, it would not be feasible for Oklahoma to change to a softer grade of asphalt cement, but to put more emphasis on other variables.

## Traffic Volume

As stated previously in this report, we set our job mix formula for asphalt cement to yield a lab molded density of 96% of the maximum theoretical density for high volume roads, 0.3% more asphalt cement for low volume roads and 0.3% less for intersections.

We have just recently started using the higher asphalt content on low volume roads and it is too early to determine the benefits in reducing transverse cracking.

## Antistripping Agents

We do not use antistripping agents in our dense graded mixes. We do not feel that we have a stripping problem.

We do add 0.5% of an approved antistripping agent to our open graded friction course. This mix is permeable and we feel the antistripping agent is needed for insurance against the pumping action caused by the water and traffic.

## Combined Gradation

Our asphalt concretes are dense graded mixes. In fact, sometimes too dense to allow the minimum voids in the mineral aggregate (VMA) as recommended by the Asphalt Institute (26,27).

With a low VMA, there is not sufficient room between the aggregate particles to allow enough asphalt to be added and still have 4% air voids.

We need to require a minimum VMA of 16% for our asphalt concrete Type C, 15% for Type B and 13% for Type A.

## Cold Mix Design

We have many miles of soil asphalt base in Oklahoma, especially in the northwest quadrant. This is a blend of sandy soil and MC-800.

This has been an economical base for us.

The specifications are very open, with only a P.I. and percentage passing the No. 200 (0.075 mm) sieve for control of the soil aggregate.

The percent of MC-800 to be added is determined by the following equation:

$$P = 1.5 + .005\ (-10) + .01\ (-40) + .06\ (-200)$$

Where: P = the percent of MC-800 to be added on the basis of dry weight of the soil

(-10), (-40) and (-200) = the percentage of soil passing the respective sieves.

The percent MC-800 indicated by this equation is generally on the low side, and it is not uncommon for the field engineer to increase the recommended percentage.

If we are going to continue to use this chart, we need to have P = % residual asphalt rather than % MC-800. This would increase the % MC-800 by about 0.5% to 1.0%.

This mix is prone to develop transverse shrinkage cracks through the years it is in service due to the loss of volatiles. But, because of the economy of producing this material, we have tolerated its short comings.

## Fillers

Filler is usually defined as the material passing the No. 200 (0.075 mm) sieve. This filler combines with the asphalt cement to form a mortar that is the binder phase of an asphalt concrete mixture.

The binder, so formed, has very different properties from the asphalt cement.

Work done by others (28,29) would indicate that a Kaolinite-asphalt mortar would be much stiffer than a limestone-asphalt mortar and therfore, much more susceptible to cracking.

We feel that a sand equivalent requirement of 45 minimum is effective in controlling the amount of Kaolinite and other clays that are used in our surface courses.

## Aggregate Quality

Many studies (20,23,30) have been made on the effect absorptive aggregates can have on the performance of asphalt concrete.

The amount of asphalt an aggregate absorbs may not be as detrimental as the way in which it absorbs.

If the absorption is quick and non-selective, additional asphalt cement can be added without detrimental effect.

If, however, the absorption is selective and occurs over a period of time the resulting asphalt concrete will become dry, brittle, and more susceptible to transverse cracking.

At least two sources of limestone in Oklahoma cannot be used in asphalt concrete that is to be held in a storage bin overnight. If these mixes are held at 275° F (135° C), they will turn brown over a very few hours.

We need to develop a specification and test to eliminate this type of absorptive aggregate.

## Asphalt Modifiers

There are many asphalt modifiers on the market today. Most are expensive and have not been in use long enough for their effectiveness to be evaluated.

One additive that does show promise is sulphur.

Studies in Canada (31,32) have indicated that sulphur-asphalt binders have good low temperature characteristics as well as good stability and flow properties.

Lime has been shown (34) to be effective in reducing the oxidation rate of asphalt cement.

By reducing the oxidation rate we could expect the asphalt pavement to remain flexible longer and better able to resist the tensile forces that cause cracking.

## MAINTENANCE OF TRANSVERSE CRACKS
(Routinely & Prior to Overlays)

Transverse cracks present upon initial development in flexible pavements pose no apparent threat to the rideability, strength, or serviceability of the pavement. However, the recognition of these initial or hairline cracks as to their potential as indicators of deterioration and an evaluation of the appropriate corrective maintenance is essential to the future serviceability of the flexible pavement.

The first or initial stage of transverse cracking appears as a hairline crack and is not usually visible at highway speeds. Frumm & Phang (35) have stated that these cracks permit the ingress of water which in turn increases the rate of stripping and, in some cases, results in a depression of the crack due to pumping of the fine granular base material. In other cases, water entering these cracks can result in the formation of an ice lens below the crack which produces an upward lipping of the crack edges. Both of these effects result in rough-riding qualities and often further secondary cracks are produced which parallel the major cracks.

### I. FOG SEAL

A proven, accepted preventive maintenance procedure used to restore bituminous pavement, fill in cracks and prevent raveling is an asphalt emulsion fog seal. This fog seal consists of a very light application of diluted, slow-breaking asphalt emulsion, usually SS-1. The asphalt emulsion is diluted with water at the varying rate of 1:1 to 1:10 parts emulsion to water and applied at the rate of 0.1 to 0.2 gallons (of diluted material) per square yard, depending on the texture and porosity of the old pavement. Cover aggregate is not required, and under normal conditions the break is rapid, permitting traffic within an hour. The cost varies with the amount of dilution and the distance of the emulsion haul; however, based on a mean of 1:5 parts emulsion to water and an average haul distance statewide, this procedure can be accomplished for approximately $.03 per square yard using existing distributors which are available to each routine maintenance crew. The economical advantages, the availability of routine materials and equipment, the ease of application under traffic and the rejuvenating qualities associated with the fog seal makes it an ideal preventive maintenance practice in the treatment of initial or hairline cracking.

## II. CRACK POURING

The second stage of development of transverse cracking is an increase in the size of the cracks. As cracks become 3/8" or larger with no surface irregularity, the fog seal procedure is no longer effective.

The ingress of water into these larger cracks can be prevented by a annual crack pouring procedure and is necessary to sustain the flexible pavement integrity. Several different types of pouring or filling apparatuses have been proven satisfactory for this operation ranging from a hand pouring pot to a trailer mounted joint seal melter-applicator. The choice of equipment is usually based on what is available and the ingenuity of the users. The end result apparently is not affected by the type of equipment used. However, the type of material used and the cleaning and preparation of the crack prior to pouring has proven to be of great importance.

A research program entitled "Sealing Cracks in Flexible Pavements" (36) analized eight (8) of the more frequent used types of crack pouring sealants, including asphalt cements, cutbacks, emulsions and rubberized asphalts. The rubberized asphalt was superior to the other sealants in the bond-ductility test. The results indicate that the asphalt cements and the emulsions are too stiff i.e. they fail in adhesion and/or cohesion under the tensile strain at low temperatures and will not function adequately as a "sealing" material. The performance of the cutback asphalts were only slightly better than the asphalt cements and emulsions.

The current average cost of crack pouring, including labor, equipment and materials, is approximately $3.00 per gallon. This includes all types of materials other than rubberized asphalt which, when used, will increase the cost to $5.50 per gallon. The type of sealant and crack pouring procedure used varies with the availability and budgetary limitations of materials and equipment.

## III REPAIR OF SURFACE IRREGULARITIES

The third stage of further deteriorating cracks is surface irregularities or roughness. The irregularities associated with cracks of this stage may have depressions or an upward lipping and require an additional procedure in conjunction with crack pouring.

It is necessary to level and/or fill any surface irregularities. This can be accomplished with a motor grader by cutting the upward lipping and/or tight blading aggregate filler into depressions. Any other suitable method of cutting and/or filling can be used. The elimination of these irregularities and the completion of the crack pouring will vary in cost based on the number of irregularities to be corrected, the method used, and the type of equipment available.

## IV CUT OUT PATCHING

The fourth and final stage of crack development is surface and base failures caused by the continuing ingress of water into the cracks.

To extend the service life of the flexible pavement, these failures must be repaired. The procedure for this type of permanent repair is to cut out and replace the deteriorated area and/or any wet material. The success of this repair can be directly related to good preparation of the hole, subgrade, and the amount of compaction used. The cost of patching ranges from thirty-five dollars ($35.00) to one hundred dollar($100.00) per ton depending on the type of patching required.

All existing transverse cracks must be sealed, poured, leveled, or filled, and localized disintegration repaired. These procedures are necessary to to maintain and extend the serviceability of the existing flexible pavements as an alternate to total reconstruction.

## SUMMARY AND CONCLUSIONS

A crack inventory was made of the asphalt pavement portion of our interstate highway system.

This study was devoted to an in depth review of our current practices and procedures as they relate to our 3-R program, asphalt mix design, and maintenance of cracks.

A literature review was made to determine possible causes and treatments of transverse cracks.

It became apparent during the transverse cracking study that factors contributing to transverse cracking vary from one geopgraphic area to another, and any recommendations should acknowledge this fact and be tempered accordingly.

1. It was concluded that the use of fabric should be included as one of the alternates considered for the prevention or retardation of reflective crack through overlays and to retard moisture infiltration.

2. It was the opinion of the committee that Oklahoma does not have enough experience in the use of asphalt rubber relief layer, open graded stress relief layer, or heater scarification for any conclusive findings.

3. Cold Milling is an effective treatment of asphaltic surface prior to the

use of fabric and as a leveling operation prior to overlays.

4. Recommendations are made to increase the field compaction requirement in the Oklahoma Department of Transportation Specification. ✓

5. A better method needs to be developed for field control of the per cent of asphalt cement used in the asphalt concrete mix.

6. Better training of field personnel in the importances of proper compaction and asphalt content is needed. ✓

7. The specification should be changed to require a minimum VMA for asphalt concrete. ✓

8. A specification and test is needed to eliminate the use of certain absorptive aggregates. ✓

9. It was concluded that the use of fog seal to restore bituminous pavements should be continued. ✓

10. Rubberized asphalt is more effective as a crack pouring material. ✓

11. It was concluded that crack pouring, leveling and the patching of failures should be a required procedure prior to, or in conjunction with, asphaltic concrete overlays.

(1) Vaughn Marker, "Symposium - Asphalt Paving for the Seventies" Proceedings of the Association of Asphalt Paving Technologists, Vol. 40 (1971) Pg. 248

(2) Dr. W. G. Mullen - "Prepared Discussion" Proceedings of the Association of Asphalt Paving Technologist" Vol. 35 (1966) Pg. 318

(3) F. Gray and H. M. Galloway "Soils of Oklahoma" Oklahoma State University publication MP-56 (July, 1959)

(4) Robert A. Eaton "Reflection Cracking Studies at Thule Air Base, Greenland Using AC 2.5 and Fabrics" - 1980.

(5) E. B. McDonald "Reduction of Reflective Cracking by use of Imperious Membrane" South Dakota Department of Highways Study, Project F-044-2(8)

(6) N. F. Coetzee "An Analytical Study of the Applicability of A Rubber Asphalt Membrane to Minimize Reflective Cracking in Asphalt Concrete Overlay Pavements: University of California (1978).

(7) Terrence Carmichael "Modeling Heater Techniques For In-Place Recycling of Asphalt Pavements" AAPT Meeting San Antonio, Texas (1977).

(8) B. A. Vallerga "Applicability of Asphalt - Rubber Membranes in Reducing Reflection Cracking" AAPT Symposium, Louisville, Ky. 1980.

(9) _______"Surface Recycling" National Cooperative Highway Research Program Synthesis of Highway Practice 54, (1978) Pg. No. 9.

(10) Dennis E. Donnelly "Reflection Cracking Crumb Rubber Demonstration Kannah Creek, Colorado" FHWA Demonstration Project NO. 37 (1979).

(11) George B. Way "Prevention of Reflective Cracking in Arizona" AAPT Symposium, Louisville, Ky. 1980.

(12) Jack Stewart "Seal Coat Construction at Rocky, Oklahoma Using Asphalt Rubber as the Binder" FHWA Demonstration Project NO. 37 (1979).

(13) Kenneth D. Hankins "Experimental seal Cost Construction" FHWA Demonstration Project NO. 37 (1978).

(14) Jack Mandy "Milling Bituminous Surfacing in North Dakota" Highway Focus Vol. 10 No. 1 Pg. 40.

(15) J. M. Hensley "Open Graded Asphalt Base For the Control of Reflective Cracking" AAPT Symposium, 1980.

(16) Robert F. Kriegel "The Motorized Gyratory-Shear Molding Press" Investigation Project NO. 35, Texas Department of Highways, Feb. 1964.

(17) Freddy Roberts, Oral presentation on the "Importance of Compaction Asphalt Mixtures" at the conference on Improved Asphalt Pavement through Effective Compaction, Arlington, Texas, Jan. 1980.

(18) J. York Welborn, "Asphalt Hardening - Fact and Fallacy" Public Roads, Vol. 35, No. 12 (Feb. 1970).

(19) "Superintendents Manual on Compaction of Hot Mix Asphalt Pavement." Published by the National Asphalt Pavement Association.

(20) G. M. Tuckett, G. M. Jones and G. Littlefield "The Effects of Mixture Variables on Thermally Induced Stresses in Asphalt Concrete." Proceedings of the Association of Asphalt Paving Technologists, Vol. 39 (1970) Pg. 703.

(21) N. W. McLeod "A 4-Year Survey of Low Temperature Transverse Pavement Cracking on Three Ontario Test Roads." Proceedings of the Association of Asphalt Paving Technologists, Vol. 41 (1972) Pg. 424.

(22) N. W. McLeod "The Case for Grading Asphalt Cements by Penetration at 77° F (25°)" Proceedings of the Canadian Technical Asphalt Association, Vol. 20 (1975).

(23) Ernest Zube "Cracking of Asphalt Pavemnets Associated with Absorptive Aggregates" Proceedings of the Association of Asphalt Paving Technologists, Vol. 35 (1966) Pg. 270.

(24) P. S. Kandhal "Low Temperature Shrinkage Cracking of Pavements in Pennsylvania Proceedings of the Association of Asphalt Paving Technologists, Vol. 47 (1978) Pg. 73.

(25) P. E. Benson, Research Report 175-2F "Low Temperature Transverse Cracking of Asphalt Concrete Pavements in Central and West Texas" Texas Transportation Institute, Sept., 1976.

(26) "Design of Hot Asphalt Mixtures" The Asphalt Institute Educational Series NO. 3 (ES-3), JUly 1979.

(27) "Mix Design Methods for Asphalt Concrete" The Asphalt Institute Manual Series No. 2 (MS-2) 4th Edition, March, 1974.

(28) Watson, Hudson & Howell "Evaluation of Mineral Fillers in Terms of Practical Pavement Performance" Proceedings of the Association of Asphalt Paving Technologists, Vol. 28 (1959) Pg. 316.

(29) V. P. Puzinauska "Filler in Asphalt Mixtures" The Asphalt Institute Research Report 69-2, Feb. 1969.

(30) Dah-Yinn Lee "The Relationship Between Physical and Chemical Properties of Aggregates and Their Asphalt Absorption" Proceedings of the Association of Asphalt Paving Technologists, Vol. 38 (1969) Pg. 242.

(31) Kennepohl, Logan and Bean "Conventional Paving Mixes with Sulphur-Asphalt Binders." Proceedings of the association of Asphalt Paving Technologists, Vol. 44 (1975) Pg. 485.

(32) Meyer, Hignell, Kennepohl and Haas "Temperature Susceptibility Evaluation of Sulphur-Asphalt Mixtures" Proceedings of the Association of Asphalt Paving Technologists, Vol. 46 (1977) Pg. 452.

(33) Plancher, Green and Peterson "Reduction of Oxidative Hardening of Asphalts by Treatment with Hydrated Lime" Proceedings of the Association of Asphalt Paving Technologists, Vol. 45 (1976) Pg. 1.

(34) Yearly Summeries, National Oceanie and Atmospheric Administration, Department of Commerce, United States of America.

(35) H. J. Fromm and W. A. Phang "A Study of Transverse Cracking of Bituminous Pavements: Proceeding of the Association of Asphalt Paving Technologist, Vol. 41 (1972) Pg. 383.

(36) Ismail M. Basha, Phillip G. Manke "Sealing Cracks in Flexible Pavements" Oklahoma State University, Project 77-02-3, Publication No. r(s)-20, May 1979.

# APPENDIX A

## OKLAHOMA TESTING METHODS

Revised 10-9-80

# Method of Sampling Bituminous Material
## OHD-L-5

SCOPE:

1. These methods apply to the sampling of liquid bituminous materials at the receiving point, project site or mixing plant.

PURPOSE:

2. Random samples of materials that have been approved at source to check uniformity of production and possible contamination by handling and/or storage.

TIME AND PLACE:

3. a. Truck transports at time of unloading.

   b. Storage tanks. Preferably during circulation at or near working temperature.

   c. Mixing Plant. During circulation at working temperature.

SIZE OF SAMPLE

4. Approximately 2/3 quart.

CONTAINERS:

5. Approximately one quart friction lid cans. ( A supply of cans is maintained by the Materials Division for this purpose.)

PROTECTION AND PRESERVATION OF SAMPLES:

6. a. Care shall be taken that the samples are not contaminated with dirt, cleaning solvents, or other extraneous matter and that the sample containers are perfectly clean and dry before filling.

   b. Immediately after filling, the sample containers shall be tightly closed and properly marked for identification on the container itself or on a shipping tag attached to the container. When necessary to clean outside of container after filling, use only a clean dry rag.

   c. Samples of emulsions will not be taken during freezing temperatures and shall be packaged to protect from freezing during shipment.

   NOTE: These samples shall be taken in one-quart plastic containers.

   d. Samples shall be shipped or delivered promptly to the Materials Division laboratory. (Any delay in shipment defeats the purpose of the sample.)

SAMPLING:

7. a. Truck Transports. Sample to be taken by means of a sampling valve (3/8 inch to 1/2 inch) located in the discharge or unloading line during the unloading of the approximate middle one-third of the load. The first flow through the sampling valve of one or two gallons shall be wasted after which the sample shall be drawn directly into the sample containers.

   b. Mixing Plant. Sample to be taken from a sampling valve located in the return line between the pump and storage tank. The first flow from the sampling valve of one or two gallons to be wasted after which the sample shall be drawn directly into the sample container.

   c. Storage Tank. Sample taken during the circulation of tank contents. Sampling procedure the same as for (b), Mixing Plant.

   d. Storage Tank. Circulation not in operation at the time of sampling. Obtain sample by means of weighted bottle or other suitable sample thief. Quickly lower sample thief to near bottom of tank and withdraw at a rate of speed so that the sample thief is not completely filled when removed. Sample thief should be cleaned each time it is used and dipped two or three times in the material being sampled before taking the sample. Immediately after taking, pour sample from sample thief directly into sample containers.

Revised 10-9-80

# Method of Test for Bulk Impregnated Specific Gravity of Aggregate

OHD-L-7

## SCOPE:

1. This test method covers procedures for determination of the bulk impregnated specific gravity of aggregates used for bituminous mix aggregates, and is applicable to both coarse and fine aggregate and to blended aggregate including mineral filler (but not to mineral filler by itself).

## APPARATUS:

2. The apparatus shall consist of the following:

   a. A balance having a capacity of at least 5,000 grams and sensitive to 0.1 gram.

   b. Large oven, thermostatically controlled, sensitive to $5^{o}$ F. in approximate range of 225 to 325 degrees F.

   c. Metal container (approx. 5" in dia. x 6" height) equipped with wire handle for suspending in water.

   d. Immersion assembly for weighing container and contents in water.

   e. Pans of size suitable for retaining 1500 grams of aggregate.

   f. One metal strip about 1 inch wide for stirring contents of each container.

## MATERIAL:

3. The asphaltic material to be used in conducting this test shall be AC (85-100) penetration asphalt cement.

## PREPARATION OF SAMPLE:

4. Prepare a representative sample of the aggregate in the following approximate quantities:

Coarse Aggregate ------------------1500 grams
Blended Aggregate -----------------1500 grams
Fine Aggregate --------------------1000 grams

Be sure the sample represents prototype grading.

## TEST PROCEDURE

5. a. Dry sample to constant weight at a temperature not less than 230° F., nor greater than 300° F., cool to approximately 140° F. and weigh to 0.1 gram.

   b. Heat AC (85-100) penetration asphaltic cement to 280 ± 5° and pour sufficient amount into the container to fill to about one-third its depth. Insert metal stirrer and allow asphalt to cool to 77 ± 2° F. (Should cool for not less than 15 hours).

   c. Weigh container and contents in air at room temperature and in water at 77 ± 2° F.

   d. Place container and contents and the sample of aggregate in oven at 280 ± 5° F., and leave both until temperatures are equalized (a minimum of four hours).

   e. Remove aggregate and container with contents from oven and add aggregate to asphalt, stirring thoroughly as aggregate is gradually added to the hot asphalt; continue stirring for 2 minutes after all the aggregate is added. After stirring, tap the container gently on a hard surface several times to bring the entrapped air bubbles to the surface of the asphalt.

   If air bubbles do appear, place the container and contents back in the oven.

   After approximately one hour, remove the container and tap it gently on a hard surface several times again (this step may be repeated 3 or 4 times if necessary to remove all of the entrapped air).

   Cool to 77 ± 2° F. (Should cool for not less than 15 hours.) During the cooling period, flame surface of asphalt to remove air bubbles if they are present.

   f. Weigh container plus stirrer plus asphalt plus aggregate in air at room temperature and in water at 77 ± 2° F.

## CALCULATIONS:

6. a. Calculate the bulk impregnated specific gravity from the following formula:

$$\text{Bulk Impregnated Specific Gravity} = \frac{A}{(D-E)-(B-C)}$$

Where:

A = Weight of oven-dry aggregate in grams.

B = Weight of container plus stirrer plus asphalt in air.

C = Weight of container plus stirrer plus asphalt in water.

D = Weight of container plus stirrer plus asphalt plus aggregate in air.

E = Weight of container plus stirrer plus asphalt plus aggregate in water.

b. To calculate the per cent asphalt absorbed by the aggregate when the bulk specific gravity (oven dry basis) and the bulk impregnated specific gravity are known, use the following formula:

$$\text{Percent AC Absorbed} = \frac{1}{\text{(Bulk sp.gr.}} - \frac{1}{\text{Bulk Imp.Sp.Gr.)}} \times 100$$

<u>REPRODUCIBILITY:</u>

7. Duplicate determinations should check within 0.02. If the values within the 0.02 tolerance, and average is used. If the duplicate tests are not within the 0.02 tolerance, repeat tests are made in duplicate until duplicate test values check within the tolerance.

Revised 9-17-80

## Method of Compacting Bituminous Mixtures for Stabilometer Value

## OHD-L-8

SCOPE: 1. This method of preparation of test specimens of bituminous mixtures employs gyratory shearing action of the mixture at low initial pressures, allowing orientation of the aggregate particles. The specimens are compacted to simulate the conditions possible in the actual road surface when proper construction procedures are used in placement of the material. The specimens are intended for use in determining the Hveem stability value, density and bulk specific gravity of bituminous mixtures.

APPARATUS: 2. The apparatus shall consist of the following:

a. Molding Assembly: 30 ton hydraulic jack with gauge, 4 in. diam. x 4 in. high steel molds, base plate, compression ram, handles for gyrating, and guide ring.

b. Bent Spoon.

c. Wide mouth funnel.

d. Height measuring device.

NOTE: The 30 ton hydraulic jack with gauge should be calibrated by the Central Laboratory before it is put into use and approximately every two years thereafter.

COMPACTION TEMPERATURES: 3. The recommended compacting temperatures are as follows:

a. Road mix surfacing . . . . . . . . . 75° F. Plus or Minus 5°

b. Plant Mixed surfacing (Hot Mix-Cold Laid) with Liquid Asphalt . . 140° F. Plus or Minus 5°

c. Asphalt Concrete and Bit. Base, Coarse Aggregate Type with Asphaltic Cement . . . . . . . . . . 250° F. Plus or Minus 5°

d. Bit. Base Fine Aggregate Type with Asphaltic Cement . . . . . . . . 180° F. Plus or Minus 5°

NOTE: The molding cylinder should be heated to approximately the same temperature as the material to be molded to prevent the cooling of the material and to facilitate the removal of the molded specimen.

PROCEDURE: 4. a. Wipe out the heated molding cylinder with a rag lightly moistened with kerosene. (Note). Place several drops of oil on the bottom disk of the guide ring and center the molding cylinder in the guide ring. Insert the base plate with the large diameter up, and place a paper gasket over the base plate.

b. By means of the bent spoon and wide mouth funnel, fill the cylinder approximately one-third full and press the mix down lightly with the spoon. Fill the cylinder two-thirds full and press it down. Place the remainder of the mix in the cylinder and level off with the spoon. Cover the mix with a paper gasket. Be very careful at all times to avoid segregation or loss of material while placing it in the cylinder.

c. Fasten the compression ram firmly in the reaction head of the press and center the molding assembly on the platen of the jack. Close the release valve on the jack.

d. Apply pressure until the gauge registers 50-100 p.s.i. (31.8-63.5 p.s.i. on 4" diameter specimen). Attach handles to the molding cylinder and impart a gyratory motion to the cylinder until three complete revolutions have been made. The top and bottom of the cylinders shall be in continuous contact with the top and bottom discs of the guide ring during the gyration. Repeat application of 50 p.s.i. gauge pressure and gyration until further movement of the molding cylinder is extremely difficult. When the proper degree of compaction has been reached, one full stroke of the jack should cause the dial pointer to move approximately 200 p.s.i. (127.0 lbs./sq. in. on 4" dia. specimen). At the conclusion of each gyratory movement, and particularly at the conclusion of the last movement, be sure that the molding cylinder is not tilted, but seats squarely on the lower guide ring.

e. Apply a gauge pressure load of 2500 p.s.i. (1588 p.s.i. on 4 in. dia. specimen) to the specimen at the approximate rate of one jack stroke per second. Hold the specimen at 2500 p.s.i. for approximately 5 seconds. Open the release-valve on the jack, allow the platen to fall, and remove the guide ring and base plate from the assembly. Close the release-valve, fit the molding cylinder over the extraction ring and center the cylinder under the ram. Press the molded specimen out of the mold by raising the platen. Mark the top of the specimen. Set the specimen aside to cool until it may be handled safely for measuring.

f. Measure the height of the specimen (average of four measurements). The specimen shall be 2 3/32" ± 1/16" high, except Bit. Base, F.A. Type shall be 2 1/2" ± 1/16". If the height is not within this tolerance the specimen shall not be used, and the weight of the sample required to produce a specimen of the proper height shall be calculated according to the following formula:

$$\text{Weight (grams) of sample to be used} = \frac{2\ 3/32''}{H} \times W$$

Where:

W = Weight (grams) of specimen.

H = Height (inches) of specimen.

g. The compacted specimens are now ready for testing in accordance with OHD-L-16.

NOTE: When the automatic gyratory-shear molding press manufactured by Rainhart is used, their procedures shall be followed.

Revised 10-9-80

# Method of Test for Field Determination of Clay Lumps in Aggregate

OHD-L-9

## SCOPE:

1. This method of test covers the field procedure for determining the amount of clay lumps, mud balls, and sand clusters in aggregates without correction for moisture. This method of test is also applicable to the determination of the amount of sticks and roots.

## APPARATUS:

2. The apparatus shall consist of the following:

   a. Balance - Balance or scale capable of weighing the sample to the nearest gram.

   b. Container - A container of such size and shape to permit spreading the sample in a thin layer on the bottom.

   c. Sieves - Sieves conforming to the Standard Specifications for Sieves for Testing Purposes (AASHTO Designation M-92).

## SAMPLES:

3. a. Test sample shall be obtained from representative samples by quartering or by the use of a splitter. Minimum weights of test samples shall be:

   Coarse Aggregate - 5000 grams

   Fine Aggregate - 1000 grams

   b. Samples shall be tested without drying, unless they are too wet to permit adequate separation by sieving. In this case, the sample may be air-dried until it reaches a moisture content which will permit sieving.

## PROCEDURE:

4. a. The test sample is sieved (either hand or machine sieving is permissible) over the #4 sieve. Care must be taken that flooding of the sieve does not occur. (i.e., not more than 200 gms. is retained on the #4 sieve on any one sieving.)

b. The portion of the sample retained on the #4 sieve is spread in a thin layer over the bottom of a large flat container and the clay lumps, mud balls, and sand clusters are picked out and weighed to the nearest gram. Normally, clay balls can be broken down with slight pressure of the fingers. Questionable fragments should be soaked for 4 hours, then examined for slaking or softening.

CALCULATION:

5. The percentage of clay lumps shall be calculated to the nearest 0.1 per cent in accordance with the following formula:

$$\%\ \text{Clay Lumps} = \frac{\text{wt. of clay lumps}}{\text{wt. of total test sample}} \times 100$$

The percentage of clay lumps reported shall be based on the average of a minimum of 3 test samples.

# Method of Test for
# Specific Gravity and Weight per Cubic Foot of Compressed Bituminous Mixtures

## OHD-L-14

## SCOPE:

1. These methods of test cover the procedures for determining the bulk specific gravity, as defined in the Standard Definitions of Terms Relating to Specific Gravity (AASHTO Designation M-132), and the weight per cubic foot of compressed bituminous mixtures.

   Method A: This method is used for specimens sufficiently uniform in size and shape to be accurately measured for volume. The specimens must have smooth surface texture. (Section 4).

   Method B: This method is used for dense-graded specimens cut or cored from pavements and specimens of such texture that accurate volume determination by measurement cannot be obtained. (Section 5).

   Method C: This method is used for specimens pervious to water. (Section 6).

## APPARATUS:

2. The apparatus shall consist of the following:

   (a) Balance. A balance having a capacity of 5 Kg or more, sensitive to 0.5 gm, fitted with suitable suspension apparatus and basket to permit weighing the specimen while immersed in water.

   (b) Container. A container of suitable size for immersing specimen in water with overflow device to permit a constant water level.

   (c) Measuring device. A device capable of measuring the height and diameters of specimens to the nearest 1/64 in.

## TEST SPECIMEN:

3. Test specimens may be either laboratory molded from bituminous mixtures or cut or cored from pavements.

## PROCEDURE:

### Method A (Note)

(a) Measure the height and diameter of the specimen to the nearest 1/64 in., taking an average of three readings.

(b) Determine the weight of the specimen in air to the nearest gram after it has been standing at room temperature for at least one hour.

(c) Calculate the specific gravity in the following manner:

$$S.G. = \frac{0.0777 \times A}{D^2H} \qquad (1)$$

Where:

S.G. = Specific Gravity
A = Weight of specimen in air in grams
D = Diameter of specimen in inches
H = Height of specimen in inches

For a specimen with a diameter of 4 inches, (1) becomes:

$$S.G. = 0.004856 \times \frac{A}{H}$$

## Method B

5\. (a) Determine the weight of the specimen in air to the nearest gram after it has been standing at room temperature for at least one hour.

(b) Immerse the specimen in water at 25° C (77° F.) until it has reached temperature equilibrium, then determine the weight of the specimen while immersed in water at 25° C. (77° F.) to the nearest gram using the apparatus described in section 2.

(c) Calculate the bulk specific gravity in the following manner:

$$B.S.G. = \frac{A}{A-C} \qquad (2)$$

Where:

B.S.G. = Bulk specific gravity
A = Weight of specimen in air in grams
C = Weight of specimen in water in grams

## Method C

6\. (a) Determine the weight of the specimen in air to the nearest gram after it has been standing at room temperature for at least one hour.

(b) Paint the specimen on all surfaces with a coat of paraffin sufficiently thick to seal all surface voids. Chill the coating in air at 25° C. (77° F.) for 30 minutes and then determine the weight of the coated specimen in air to the nearest gram.

(c) Immerse the coated specimen in water at 25° C. (77° F.) until it has reached temperature equilibrium, then determine the weight of the coated specimen in water to the nearest gram using the apparatus described in Section 2.

(d) Obtain or, if unknown, determine the bulk specific gravity of the paraffin used in coating the specimen.

(e) Calculate the bulk specific gravity in the following manner:

$$\text{B.S.G.} = \frac{A}{(D-E) - \frac{(D-A)}{F}} \qquad (3)$$

Where:

B.S.G. = Bulk Specific gravity
A = Weight of specimen in air in grams
D = Weight of paraffin - coated specimen in air in grams
E = Weight of paraffin - coated specimen in water in grams.
F = Bulk specific gravity of paraffin.

7. The formula for determining the weight per cubic foot of the specimen is as follows:

Weight per cubic foot = B.S.G. x 62.4

NOTE: Method A is to be used only when the specimen is uniform in size and shape and relatively free from surface irregularities. Each specimen must be checked carefully to determine the proper method to use.

Revised 10-9-80

# Method of Test for Resistance to Deformation of Bituminous Mixtures by Means of the Hveem Stabilometer

OHD-L-16

## SCOPE:

1. This method of test covers the procedure for determining the resistance to deformation of compacted bituminous mixtures by measuring the lateral pressure developed from applying a vertical load by means of the Hveem stabilometer.

## APPARATUS:

2. The apparatus shall consist of the following:

   (a) Oven, thermostatically controlled to 140 ± 5 F.

   (b) Hveem Stabilometer, with accessories, including adjustable base; assembly tool; steel follower, 3.985 in. diameter, 5.5 in. high; brass dummy specimen, 4.0 ± .0005 in. diameter, 5.5 in. high; and rubber bulb for introducing air into the stabilometer.

   (c) Testing machine, 50,000 lb. capacity, minimum.

## TEST SPECIMENS:

3. (a) Test specimens shall be prepared according to Method of Compacting Bituminous Mixtures for Stabilometer Value (Oklahoma Highway Department Designation: OHD-L-8).

   (b) The size of the test specimens shall be 4 inches in diameter and 2-3/32 ± 1/16 inches in height.

## ADJUSTMENT OF STABILOMETER:

4. (a) Refer to Method No. Calif. 902 for details on the mechanics of the Hveem Stabilometer including its operation, calibration and the installation of the Neoprene Diaphram.

   (b) Adjust bronze nut on base of stabilometer so than an effective height of 2.0 in. is obtained when the stabilometer shell is in position on the base. The effective height is defined as that depth of the test specimen which acts against the liquid phase of the stabilometer. Secure stabilometer shell to base by tightening with fingers the nut on lower portion of shell.

   (c) Put brass dummy specimen in place in the stabilometer. Apply a slight load of from 100 to 200 lbs. on the testing machine dial to the dummy specimen to make certain the dummy is held firmly in place. Turn the pump to a pressure of exactly 5 psi. Tap the stabilometer dial lightly with the fingers in order to be sure needle is resting on 5 psi pressure. Adjust the turns indicator dial to zero. Turn pump handle at approximately two turns per second until the stabilometer reads 100 psi. The turns indicator dial should then read 2.00 ± 0.05 turns. If it does not, the air in the cell must be adjusted by means of the rubber bulb, and the displacement measurement must be repeated after each air change until the proper number of turns is obtained. Release horizontal and vertical pressures and remove brass dummy specimen. The stabilometer is now ready for testing specimens.

(d) Adjust testing machine to give a constant movement of 0.05 in. per minute with no load applied. The hydraulic machines must be run several minutes before oil warms sufficiently to maintain a constant speed.

PROCEDURE:

5. (a) Test specimens at 140 ± 5 F. (Note.)

(b) Place the test specimen in the stabilometer. Make sure that the specimen goes into the stabilometer straight with tamped end up and that it is firmly seated level on the base.

(c) Place follower on top of specimen and adjust pump to give a horizontal pressure of 5 psi. (The 5 psi pressure should be exact as a deviation of only 1 lb. has considerable effect on the final value.)

(d) Start vertical movement of testing machine base at speed of 0.05 in per min., and record the stabilometer gauge readings when the vertical pressures are 500, 1,000, 2,000, 3,000, 4,000, 5,000 and 6,000 lbs. total load.

(e) Stop vertical loading exactly at 6,000 lbs. and immediately reduce the load to 1,000 lbs.

Turn displacement pump so that the horizontal pressure is reduced to exactly 5 psi. This will result in a further reduction in the vertical load reading which is normal and for which no compensation is made. Set the turns displacement indicator dial to zero. Turn pump handle at approximately two turns per second until the stabilometer gauge reads 100 psi.

During this operation, the vertical load registered on the testing machine will increase and in some cases, exceed the initial 1,000 lb. load. As before, these changes in testing machine loading are characteristic and no adjustment or compensation is required.

(f) Record the number of turns indicated on the dial as the displacement of the specimen. The turns indicator dial reads in 0.001 in., and each 0.1 in. is equal to one turn. Thus, a reading of 0.250 in. indicates that 2.50 turns were made with the displacement pump. This measurement is known as turns displacement of the specimen.

## CALCULATIONS:

6. Calculation of Stabilometer values:

$$S = \frac{22.2}{\frac{P_h D}{P_v - P_h} + .222}$$

Where:

$P_v$ = vertical pressure (typically 400 psi)

$P_h$ = horizontal pressure (stabilometer reading in psi)
($P_h$ taken at the instant $P_v$ is 400 psi)

D = displacement on specimen.

## REPORTING:

7. Report the results of the stabilometer test as the numerical value obtained as shown under "Calculations." This value represents the relative resistance to lateral deformation on a scale ranging from 0 for liquids to 100 for a solid.

NOTE: Bring the specimen to room temperature in the case where it is desired to test with whatever moisture may be present in the mixture.

Revised 10-9-80

# Method of Test for
# Percentage of Crushed Particles

OHD-L-18

## SCOPE:

1. This method of test covers the test procedure for determining the percent, by weight, of crushed particles in aggregates to be used in highway construction and maintenance.

## APPARATUS:

2. The apparatus shall consist of the following:

   (a) Balance: A balance having a capacity of 3,000 grams and sensitive to 1.0 gm.

   (b) Sieves: Sievec conforming to the Standard Specifications for Sieves for Testing Purposes (AASHTO Designation: M-92).

## SAMPLES:

3. A portion of a representative sample shall be obtained by quartering or the use of a riffle splitter. This portion shall be sieved over a No. 4 sieve. The test sample shall consist of the material retained on the No. 4 sieve (Note). The minimum size of the test sample shall be 1000 gms.

NOTE: Coated aggregate should be washed to facilitate detection of unfractured particles.

## P ROCEDURE:

4. The test sample shall be spread out on a work table using enough area so that the individual particles may be closely inspected. Separate the particles having the required number of fractured faces. The particles having fractured faces shall be weighed and the weight recorded as weight of crushed particles.

## CALCULATIONS:

5. The percent of crushed particles shall be calculated as follows:

$$\text{\% Crushed Particles} = \frac{\text{wt. of crushed particles}}{\text{wt. of total test sample}} \times 100$$

The results, to the nearest whole number, are reported as percent of crushed particles.

Revised 1-12-78

# Method of Test for Total Insoluble Residue in Coarse Aggregate

OHD-L-25

## SCOPE:

1. This method of test is intended for the determination of acid insoluble material in coarse aggregates.

## APPARATUS:

2. The apparatus for this test will consist of the following:

   (a) Half-gallon jars.

   (b) Hydrochloric Acid Technical Grade

   (c) #200 Mesh Sieve

## PROCEDURE:

3. (a) Crush sample so that all material is less than one-half inch.

   (b) Split the coarse aggregate portion of the sample to approximately 200 grams, weigh accurately, and place in clean, labeled half-gallon jar. (In triplicate).

   (c) Add 400 ml of water and slight excess of concentrated hydrochloric acid over amount needed to react with available carbonate, approximately one ml per gram of rock. Stir mixture over a period of days until all reaction ceases.

   (d) Wash the insolubles free of excess ions by filling jar with tap water, allowing all of the material to settle (about 48 hours) and pour off the clear solution. Procedure is repeated three times.

   (e) After the third wash cycle, wash the insolubles into a shallow pan and roll between thumb and forefinger to crumble any friable particles; wash over a #200 sieve, dry at 100-105° C and weigh.

## REPORT:

4. Report insolubles retained on the #200 sieve as percent of total sample used.

# OKLAHOMA METHOD OF TEST FOR QUANTITATIVE EXTRACTION OF BITUMEN FROM BITUMINOUS PAVING MIXTURES

## OHD-L-26

## SCOPE:

1. This method covers procedures for the quantitative determination of bitumen in hot-mixed paving mixtures and pavement samples.

   NOTE 1. Although bitumen, by definition, is material soluble in carbon disulfide, trichlorethylene is used in this method for safety reasons. Benzene or 1,1,1-trichloroethane may also be used. A small amount of methanol may be added if necessary to aid extraction.

2. The paving mixture is extracted with trichlorethylene or 1,1,1-trichlorethane using the extraction equipment applicable to the particular method. The bitumen content is calculated by difference from the weight of the extracted aggregate, moisture content, and ash from an aliquot part of the extract.

## APPARATUS:

3. (a) Oven, capable of maintaining the temperature at 210° to 300° F.

   (b) Pan, suitable.

   (c) Balance, capable of weighing 4,500 g to an accuracy of 0.5 gm.

   (d) Hot Plate, electric, 700-w, low, medium and high settings.

   (e) Graduate, 1000 or 2000-ml capacity.

   (f) Ignition Dish, 125-ml or larger capacity.

   (g) Balance, capable of weighing 500 gm. to an accuracy of 0.1 gm.

## REAGENTS:

4. (a) Ammonium Carbonate. Saturated solution of reagent grade ammonium carbonate ($(NH_4)_2CO_3$).

   (b) Trichlorethylene, Technical Grade, Type 1, Fed. Spec. O-T-634 latest revision.

   (c) 1,1,1-Trichloroethane, conforming to Federal Specification O-T-620 (Int.Amd.3).

## PREPARATION OF SAMPLE:

5. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan and warm to $250^{\circ}$ F., only until it can be handled. Separate the particles of the mixture as uniformly as possible using care not to fracture the mineral particles. Normally, 1000-g samples are used for extraction. For routine testing, smaller samples may be used when the maximum size aggregate therein is less than 1/4 in. The precision of the method becomes less as the aggregate size increases, due to variation in samples. This procedure may be used on mixtures containing aggregate larger than 1 in. by using samples weighing at least 1000 g. They may be tested by extracting 1000 g at a time.

## WATER DETERMINATION:

6. Quarter and weigh to the nearest 0.5 gm. a minimum of 500 g of material into a tarred pan. Place the pan and samples in an oven and dry to constant wt. at a temperature not to exceed $250^{\circ}$ F. Care shall be taken not to overheat the sample for an extended period of time. Weigh the sample to the nearest 0.5 gm. and record moisture loss.

## Method A

## APPARATUS:

7. In addition to the apparatus listed in Section 3, the following apparatus is required for Method A:

   (a) Extraction Apparatus, consisting of a bowl approximating that shown in Fig. 1 of AASHTO Test Method T-164 and an apparatus in which the bowl may be revolved at controlled variable speeds not to exceed 3600 rpm. The apparatus shall be provided with a container for catching the solvent thrown from the bowl and a drain for removing the solvent. The apparatus preferably shall be provided with explosion-proof features and installed in a hood to provide ventilation.

   NOTE 2: Similar apparatus of larger size may be used.

   (b) Filter rings, to fit the rim of the bowl.

## PROCEDURE:

8. (a) Determine the moisture content of the sample in accordance with Section 6.

   (b) Weigh to the nearest 0.5 gm. a 500 to 2500 g sample into the bowl, or use the previously dried moisture sample.

   (c) Cover the sample in the bowl with trichlorethylene and allow sufficient time for the solvent to disintegrate the sample (not over 1 hr.). Place the bowl containing the sample and the solvent in the extraction apparatus. Fit the filter ring around the edge of the bowl. Clamp the cover on bowl tightly and place a beaker under the drain to collect the extract.

(d) Start the centrifuge revolving slowly and gradually increase the speed to a maximum of 3600 rpm or until solvent ceases to flow from the drain. Allow the machine to stop, add 200 ml of trichlorethylene and repeat the procedure. Use sufficient 200 ml solvent additions (not less than three) so that the extract is clear and not darker than a light straw color. Collect the extract and the washings in a suitable graduate.

(e) Remove the filter ring from the bowl and dry in air. Remove as much of the mineral matter adhering to the ring as possible and add to the aggregate in the bowl. Dry the contents of the bowl on a hot plate and then to constant weight in an oven at 200° to 300° F.

(f) Record the volume of the total extract in the graduate. Agitate the extract thoroughly and immediately measure approximately 100 ml or 1/10 of the extract into an ignition dish. Evaporate to dryness on a hot plate. Ash residue at a dull red heat (500° to 600° C), cool, and add 5 ml of saturated ammonium carbonate $(NH_4)_2CO_3$ solution per gram of ash. Digest at room temperature for one hour. Dry in an oven at 100° C to constant weight, cool, and weigh to the nearest 0.1 gm. The use of saturated ammonium carbonate may be omitted.

CALCULATIONS:

9. (a) Calculate the weight of ash in the total volume of extract as follows:

$$\text{Total ash, g} = G \frac{V_1}{V_1 - V_2}$$

Where:

$G$ = ash in aliquot in grams,

$V_1$ = total volume in milliliters, and

$V_2$ = volume after removing aliquot in milliliters.

(b) Calculate the percentage of bitumen in the sample as follows (Note 3):

Bitumen content of dry sample, per cent

$$= \frac{(W_1 - W_2) - (W_3 + W_4)}{W_1 - W_2} \times 100$$

Where:

$W_1$ = weight of sample,
$W_2$ = weight of water in sample,
$W_3$ = weight of extracted mineral matter, and
$W_4$ = weight of ash in extract.

NOTE 3: The ash wt. may be estimated in routine field testing if apparatus for determining ash wt. is not available.

## Method B

### APPARATUS:

10. In addition to the apparatus listed in Section 3, the following apparatus is required for Method B:

(a) Extraction Apparatus, as shown in Fig. 2 of AASHTO Test Method T-164

(b) Glass Jar, cylindrical, plain 6-in. OD, 18-in. high, made of heat-resistant glass.

(c) Cylindrical Metal Frames, two, 5-in. OD and 6-3/4 in. high. The lower frame shall have legs 1-7/8 in. high to support the frame above the solvent level. The upper frame shall have stub legs which fit in recesses provided in the top rim of the lower frame. Both frames shall contain 10 to 12 mesh cones with a base of 4½ in. in diameter and 6-3/4 in. side length, mounted inside the top rim of each frame. A bail handle shall be provided on the inside of the top rim of each frame.

(d) Condenser, 6¼ in. in diameter with ¼-in. ID tubing water inlet and outlet assembled so that no soldered joint comes in direct contact with the condensing solvent vapor.

NOTE 4: Similar apparatus of larger size may be used.

(e) Filter Paper, medium grade, fast filtering, 33 cm in diameter.

### PROCEDURES:

11. (a) Determine the moisture content of the sample in accordance with Section 6.

(b) Dry and weigh to the nearest 0.5 gm. two sheets of filter paper with a sample pan. Fold each sheet separately on its diameter and fold twice again, one fold being made over the other to make three segments. Open to form a hollow three-ply cone with a single one-ply seam and place in wire cones of extractor frames.

(c) Prepare sample as outlined in Section 5 or use the previously dried moisture sample.

(d) Place approximately 1/2 of the sample in each of the filter paper-lined cones.

(e) Pour approximately 600 ml of trichlorethylene into the glass jar and place the frame with the supporting legs in the jar. The solvent level must be below the tip of the cone in this frame. Place the top frame on the bottom frame so that the stub legs fit into the round holes in the top rim of the lower frame.

(f) Place the loaded jar on the electric hot plate and cover the jar with a condenser. Circulate a gentle steady flow of cold water through the condenser. Adjust the heat so that the solvent boils gently and a steady flow of condensed solvent drips into the top cone. Take care to adjust the heat so that the filter cones do not overflow. Continue extraction until the solvent running from the tip of the lower cone appears a light straw color when viewed against a white background. Shut off the heat but not the condenser water, and allow to stand until cool enough to handle.

(g) Remove the frames with filter paper and extracted aggregate from jar. Dry the aggregate and filter papers on a hot plate and then to constant weight in an oven at 220° to 300° F.

(h) Transfer the extract to a 1000-ml graduate. Rinse the jar with solvent until clean and add solvent to the extract. Record the total volume. Determine the total ash in the extract as described in Section 8 (f) or ash the total extract.

CALCULATIONS:

12. (a) Calculate the total weight of ash as described in Section 9 (a).

(b) Calculate the percentage of bitumen as described in Section 9 (b).