SPECIAL SPECIFICATION

3101

Emulsion Treatment (Road Mixed)

1. **Description.** Mix and compact emulsion, additives, water, and base with or without asphalt concrete pavement, in the roadway.

2. **Materials.** Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications. Notify the Engineer of the proposed material sources and of changes to material sources. The Engineer will verify that the specification requirements are met before the sources can be used. The Engineer may sample and test project materials at any time before compaction. Use Tex-100-E for material definitions.

   A. **Emulsion.** Provide an asphalt-emulsion that meets the requirements of Table 2.

   B. **Flexible Base ("Add Rock").** Furnish base material that meets the requirements of Item 247, “Flexible Base,” for the type and grade shown on the plans, before the addition of emulsion.

   C. **Additive.** Determine the amount and type of additive, if any, during the mix design. When an additive is required, the total amount in the mix will not exceed 1.0 % by weight of material.

      1. **Lime.** When lime is required, furnish lime that meets the requirements for DMS-6350, “Lime and Lime Slurry,” and DMS-6330, “Lime Sources Prequalification of Hydrated Lime and Quicklime.” Use hydrated lime or commercial lime slurry, as shown on the plans.

      2. **Cement.** When cement is required, furnish hydraulic cement that meets the requirements of DMS-4600, “Hydraulic Cement,” and the Department’s Hydraulic Cement Quality Monitoring Program (HCQMP). Sources not on the HCQMP will require testing and approval before use.

   D. **Mix Design.** Submit a mix design to the Engineer for approval, before the start of the project. Include the optimum moisture content, maximum dry density, percent additive, percent “add rock”, percent existing material, and optimum percent asphalt emulsion required to meet the mixture requirements in Table 1. Prepare specimens for all tests except AASHTO T 307 in accordance with Tex-113-E. Perform additional mix designs based on existing material variability, as directed by the Engineer.
Table 1
Laboratory Mixture Design Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. indirect tensile strength (ITS), psi</td>
<td>Tex-226-F</td>
</tr>
<tr>
<td>Dielectric value</td>
<td>Tube Suction Test (TST)</td>
</tr>
<tr>
<td>Min. unconfined compressive strength, psi</td>
<td>Tex-117-E</td>
</tr>
<tr>
<td>Min. retained unconfined compressive strength (UCS), psi</td>
<td>Tex-117-E^-1</td>
</tr>
<tr>
<td>Resilient modulus</td>
<td>AASHTO T 307</td>
</tr>
<tr>
<td>Seismic modulus</td>
<td>Free-free Resonant Column</td>
</tr>
</tbody>
</table>

1. Indirect tensile strength specimens will be cured 72 hr. at 104°F before testing.
2. After determination of the final dielectric value, conduct UCS in accordance with Tex-117-E on the dielectric specimens.

Table 2
Emulsified Asphalt Properties

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue from distillation, %</td>
<td>ASTM D 244</td>
<td>63</td>
<td>-</td>
</tr>
<tr>
<td>Oil distillate by distillation, %</td>
<td>ASTM D 244</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Sieve Test, %</td>
<td>ASTM D 244</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Penetration, 25°C, dmm</td>
<td>ASTM D 5</td>
<td>55</td>
<td>95</td>
</tr>
</tbody>
</table>

E. Water. Furnish water free of industrial waste and other objectionable material.

3. Equipment. Provide machinery, tools, and equipment necessary for proper execution of the work. Provide rollers in accordance with Item 210, “Rolling.” Provide proof rollers in accordance with Item 216, “Proof Rolling,” when required.

Provide a self-propelled mixer capable of fully mixing the existing road to the depth required, incorporate the asphalt emulsion and water, and mix the materials to produce a homogeneous material. Provide a mixer with a minimum power of 400 HP. Provide a machine capable of mixing not less than 8 ft. (2.4 m) wide and up to 12 in. (30.5 cm) deep in each pass. The mixer must contain a system for adding asphalt emulsion with a full width spray bar consisting of a positive displacement pump interlocked to the machine speed so that the amount of emulsion being added is automatically adjusted with changes in machine speed. The emulsion injection system will be capable of incorporating up to 7 gal. per square yard of emulsion. Provide individual valves on the emulsion injection system spray bar that are capable of being turned off as necessary to minimize emulsion overlap on subsequent passes.

4. Construction. Construct each layer uniformly, free of loose or segregated areas, and with the required density and moisture content. Provide a smooth surface that conforms to the typical sections, lines, and grades shown on the plans, or as directed.

A. Preshaping. Shape the existing material in accordance with applicable bid items to conform to typical sections shown on the plans and as directed before the addition of
asphalt-emulsion. Incorporate water and add rock during this operation, if needed. Compact the material to support equipment and/or traffic, and to provide depth control during mixing.


Complete the entire operation of mixing the existing road, incorporating add rock, water, and asphalt emulsion in one pass. Ensure that each adjacent pass of the mixer overlaps the previous pass by a minimum of 6 in. Use multiple passes if the quality control requirements specified in Section 5 are not met. If an additional pass of the mixer significantly improves dispersion of the emulsion, use this additional pass for the entire project.

After mixing, the Engineer will sample the mixture at roadway moisture and test in accordance with Tex-101-E, Part III, to determine compliance with the following gradation requirements:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3/4 in.</td>
<td>100</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>85</td>
</tr>
</tbody>
</table>

C. Application of Additive.

Uniformly apply additive in advance of the mixer. Minimize dust and scattering of additives by wind. Do not apply additives when wind conditions, in the opinion of the Engineer, cause blowing additive to become dangerous to traffic or objectionable to adjacent property owners.

1. Lime. Uniformly apply lime using dry or slurry placement as shown on the plans, or as directed. Add lime at the percentage determined in the mix design. Apply lime only on an area where mixing can be completed during the same working day.

Start lime application only when the air temperature is at least 35°F and rising or is at least 40°F. The temperature will be taken in the shade and away from artificial heat. Suspend application when the Engineer determines that weather conditions are unsuitable.

a. Dry Placement. When necessary, sprinkle in accordance with Item 204, “Sprinkling.” Distribute the required quantity of hydrated lime with approved equipment. Only hydrated lime may be distributed by bag. Do not use a motor grader to spread hydrated lime.

b. Slurry Placement. Provide slurry free of objectionable materials, at or above the approved minimum dry solids content, and with a uniform consistency that will allow ease of handling and uniform application. Deliver commercial lime
slurry to the jobsite or prepare lime slurry at the jobsite or other approved location by using hydrated lime as specified.

Distribute slurry uniformly by making successive passes over a measured section of roadway until the specified lime content is reached.

2. **Cement.** Uniformly apply cement using dry placement unless otherwise shown on the plans. Add cement at the percentage determined in the mix design. Apply cement only on an area where mixing, compacting, and finishing can be completed during the same working day. Before applying cement, bring the prepared roadway to approximately optimum moisture content. When necessary, sprinkle in accordance with Item 204, “Sprinkling.” Distribute the required quantity of dry cement with approved equipment.

3. **Emulsion.** Uniformly apply emulsion as specified in Section 3.A, “Mixing.” Add emulsion at the percentage determined in Section 2.D, “Mix Design.” Apply emulsion only on an area where mixing and compaction can be completed during the same working day.

   Suspend emulsion application if the weather forecast calls for freezing temperatures within 7 days after incorporation of the emulsion. Finish emulsion application before the historical weather database predicts freezing temperatures within 7 days after completion of the emulsion portion of the project. Suspend application when the Engineer determines that weather conditions are unsuitable.

D. **Compaction.** Compact the mixture using density control, unless otherwise shown on the plans. Multiple lifts are permitted when shown on the plans or approved.

   Begin rolling longitudinally at the sides and proceed toward the center, overlapping on successive trips by at least one-half the width of the roller unit. On superelevated curves, begin rolling at the low side and progress toward the high side. Offset alternate trips of the roller. Operate rollers at a speed between 2 and 6 mph, as directed.

   Perform initial compaction using a heavy tamping roller applying high amplitude and low frequency. Maintain the heavy tamping roller within 500 ft. of the mixer at all times. Continue rolling until the heavy tamping roller “walks out” of the material. Walking out for the heavy tamping roller is defined as light being evident between all of the pads at the material–heavy tamping roller drum interface.

   After the completion of heavy tamping rolling, remove remaining tamping marks. Cut no deeper than the depth of the tamping marks. Achieve desired slope and shape to the lines and grades shown in the plans. Perform final surface shaping on the same day as the asphalt emulsion is incorporated.

   Use a vibratory roller and pneumatic roller to compact the bladed material. Do not finish-roll in vibratory mode. If necessary, use a light spray of water to aid in final compaction density and appearance.

   The Engineer will use a portable seismic pavement analyzer to determine field seismic modulus and compare to seismic modulus reported in the mix design.
Rework material that fails to meet or that loses required moisture, density, stability, or finish within 24 hours of completion of compaction. Add additional emulsion and additives at 100% of the percentages determined during mix design. Reworking includes loosening, adding material or removing unacceptable material if necessary, mixing as directed, compacting, and finishing. Continue work until specification requirements are met. Perform the work at no additional expense to the Department.

When an area fails to meet or loses required moisture, density, stability, or finish more than 24 hours after completion of compaction and before the next course is placed or the project is accepted, remove the unacceptable material and replace with new material that meets the mix design requirements. Compact and finish until specification requirements are met. Perform the work at no additional expense to the Department.

1. **Ordinary Compaction.** Roll with approved compaction equipment, as directed. Correct irregularities, depressions, and weak spots immediately by scarifying the areas affected, adding or removing treated material as required, reshaping, and recompacting.

2. **Density Control.** The Engineer will determine roadway density of completed sections in accordance with Tex-115-E. The Engineer may accept the section if no more than 1 of the 5 most recent density tests is below the specified density and the failing test is no more than 3 pcf below the specified density.

   Compact the bottom course to at least 95% of the maximum density determined in accordance with Tex-113-E, unless otherwise shown on the plans. Compact subsequent courses treated under this Item to at least 97% of the maximum density determined in accordance with Tex-113-E, unless otherwise shown on the plans.

E. **Curing.** Cure the finished section until the moisture content is at least 2 percentage points below optimum, or as directed before applying the next successive course or prime coat. Do not allow equipment or traffic on the finished course during curing, unless otherwise approved. The Engineer may allow traffic on the finished course during curing if proof rolling indicates adequate stability. Proof roll in accordance with Item 216, “Proof Rolling.” If deformation occurs, do not allow traffic to return to the finished section until the mixed material is firm enough to accommodate traffic without deformation. Apply seals or additional courses within 14 calendar days of final compaction.

When the plans show no specific detour, the Contractor will provide one-way traffic control until proof rolling permits the return of normal traffic to the compacted material.

5. **Quality Control.** The Contractor is responsible for quality control (QC) of the process and the completed base. The Engineer will provide sampling frequencies.

   A. **Asphalt Emulsion.** A representative from the asphalt emulsion supplier will check the mixing and curing properties at the beginning of the project, and will make recommendations for design changes to the Engineer.
B. **Moisture Content.** Use Tex-103-E to check moisture content before addition of emulsion. Check the moisture content on the same day emulsion is applied. If rain has occurred after testing and before emulsion addition, recheck the moisture content. Adjust by moisture addition (water truck) or aeration if the average moisture content is not within 1% of the mix design recommendation. Recheck the moisture content if manipulation has occurred.

C. **Emulsion Content.** Apply the amount of asphalt emulsion recommended in the mix design. The Engineer must approve changes in asphalt emulsion content or supplier. Check the percentage of emulsion added using meter readings or truck weigh tickets, the quantity of material reclaimed (depth, width, and length) and estimated in-place density determined by Tex-113-E (mix design or field check) or nuclear density gauge. Determine emulsion content on the first day of processing during the first emulsion transport. Adjust equipment calibration if necessary. Check emulsion content again if adjustments are made. Determine subsequent emulsion content as directed by the Engineer, but not less than once per day.

D. **Density.** Obtain samples to the full depth of reclamation before rolling and store in a sealed container for no longer than 2 hours. Compact in accordance with Tex-113-E and adjust mixing and compaction operations to achieve maximum dry density established in the mix design.

6. **Measurement.**

   A. **Emulsion.** Emulsion will be measured by the gallon.

   B. **Additive.**

      1. **Lime.** When lime is furnished in trucks, the weight of lime will be determined on certified scales, or the Contractor must provide a set of standard platform truck scales at a location approved by the Engineer. Scales must conform to the requirements of Item 520, “Weighing and Measuring Equipment.”

         When lime is furnished in bags, each bag must indicate the manufacturer’s certified weight. Bags varying more than 5% from that weight may be rejected. The average weight of bags in any shipment as determined by weighing 10 bags taken at random must be at least the manufacturer’s certified weight.

         a. **Hydrated Lime.**

            (1) **Dry.** Lime will be measured by the ton (dry weight).

            (2) **Slurry.** Lime will be measured by the ton (dry weight) of the hydrated lime used to prepare the lime slurry at the jobsite.

         b. **Commercial Lime Slurry.** Lime slurry will be measured by the ton (dry weight) as calculated from the minimum percent dry solids content of the slurry, multiplied by the weight of the slurry in tons delivered.
2. **Cement.** Cement will be measured by the ton (dry weight). When cement is furnished in trucks, the weight of cement will be determined on certified scales, or the Contractor must provide a set of standard platform truck scales at a location approved by the Engineer. Scales must conform to the requirements of Item 520, “Weighing and Measuring Equipment.

When cement is furnished in bags, indicate the manufacturer’s certified weight. Bags varying more than 5% from that weight may be rejected. The average weight of bags in any shipment, as determined by weighing 10 bags taken at random, must be at least the manufacturer’s certified weight.

C. **Emulsion Treatment.** Emulsion treatment will be measured by the square yard of surface area. The dimensions for determining the surface area are established by the widths shown on the plans and lengths measured at placement.


Furnishing and delivering new base will be paid for in accordance with Item 247.6.B, “Flexible Base (Roadway Delivery).” Mixing, spreading, blading, shaping, compacting, and finishing new or existing base material will be paid for under Section 7.B, “Emulsion Treatment.” Removal and disposal of existing asphalt concrete pavement will be paid for in accordance with pertinent Items or Article 4.2, “Changes in the Work.”

Additives and emulsion used for reworking a section will not be paid for directly but will be subsidiary to this Item.

Sprinkling and rolling, except proof rolling, will not be paid for directly but will be subsidiary to this Item unless otherwise shown on the plans. When proof rolling is shown on the plans or directed by the Engineer, it will be paid for in accordance with Item 216, “Proof Rolling.”

Where subgrade is constructed under this Contract, correction of soft spots in the subgrade or existing base will be at the Contractor’s expense. Where subgrade is not constructed under this Contract, correction of soft spots in the subgrade or existing base will be in accordance with pertinent Items or Article 4.2, “Changes in the Work.”

A. **Emulsion.** Emulsion will be paid for at the unit price bid for “Emulsion.” This price is full compensation for materials, delivery, equipment, labor, tools, and incidentals.

B. **Lime.** Lime will be paid for at the unit price bid for “Lime” of the specified type (Hydrated (Dry), Hydrated (Slurry), or Commercial Lime Slurry). This price is full compensation for furnishing lime.

C. **Cement.** Cement will be paid for at the unit price bid for “Cement.” This price is full compensation for furnishing cement.
D. **Emulsion Treatment.** Emulsion treatment will be paid for at the unit price bid for “Emulsion Treatment (Existing Base),” or “Emulsion Treatment (Mixing Existing Material and New Base),” for the depth specified. No payment will be made for thickness or width exceeding that shown on the plans. This price is full compensation for shaping existing material, loosening, mixing, pulverizing, spreading, applying additives and emulsion, compacting, finishing, curing, curing materials, blading, shaping and maintaining shape, replacing mixture, disposing of loosened materials, processing, hauling, preparing secondary subgrade, water, equipment, labor, tools, and incidentals.
Appendix A
**Tube Suction Test**

This method determines the dielectric constant of base materials and soils. The dielectric constant is an indicator of the ability for moisture to migrate through the materials.

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**Apparatus**

- Apparatus outlined in Test Method Tex-101-E, Part II
- Apparatus outlined in Test Method Tex-103-E, Part I
- Apparatus outlined in Test Method Tex-113-E
- Apparatus outlined in Test Method Tex-114-E
- Oven maintained at 60 ± 5°C (140 ± 9°F)
- Latex membrane (Diameter = 6”; Height = 14”)
- Plastic sheet disk (Diameter = 6”)
- Filter paper (Diameter = 6”)
- Flat-bottomed plastic or steel pan, wide and shallow, for soaking specimens
- Adek Percometer™

**Materials**

Distilled or deionized water

**Procedure**

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prepare the base or subgrade soil sample as in Test Method Tex-101-E, Part II. Use Test Method Tex-113-E (draft) or Tex-114-E depending on the materials to determine the optimum moisture content (OMC) and maximum dry density (MDD) of the material for molding the test specimens.</td>
</tr>
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<tr>
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</tr>
</tbody>
</table>
|   | Obtain a representative sample of prepared material in sufficient quantity to prepare three (3) specimens. Bring the material to optimum moisture using distilled or deionized water.  

**Note:** Ions in regular tap water can influence the results of the test by increasing the osmotic suction component of the aggregate. |
|   | Compact each specimen at optimum moisture content and maximum dry density according to Test Method Tex-113-E (draft) or Tex-114-E depending on the materials. The specimens should be 6 in. (152.4 mm) in diameter and 8 ± 0.25 in. (203.2 ± 6.4 mm) in height.  

**Note:** The surface of each specimen should be made as smooth as possible after compaction. Remove or reposition any coarse aggregate protruding from the specimen surface and fill any large voids as necessary. However, application of fines across the whole specimen surface should be avoided. |
|   | Weigh each specimen in the mold to the nearest estimated 0.001 lb. (0.5 g.) and record as \( W_{\text{TOTAL}} \). Subtract the weight of the mold (\( W_{\text{MOLD}} \)) from \( W_{\text{TOTAL}} \) and record the weight of the specimen as \( W_{\text{OMC}} \). Measure the height of the specimen using a micrometer and record the height as \( H \). |
|   | Weigh two porous stones (previous dried at 60 ± 5 °C (140 ± 9 °F)) and record the weights as \( W_{\text{STONE}} \). |
|   | Place a filter paper on top of one porous stone, carefully flip over the specimen and mold assembly, and placed it over the porous stone. Place the whole set in the hydraulic press to extrude the specimen from the mold. |
|   | Once the specimen is extruded, place the other porous stone on top of the specimen. |
|   | Run unconfined compressive strength (UCS) of one of the specimens at OMC and record it as \( U_{\text{OMC}} \). Save the other two specimens for determining dielectric value. |
|   | Place the specimen with the two porous stones in an oven equipped with a circulating fan and maintained at 60 ± 5 °C (140 ± 9 °F) for 48 ± 2 hours. |
|   | Remove the specimen from the oven and allow it cooling down at ambient temperature for at least 2 hours. Weigh the specimen with the two porous stones to the nearest 0.001 lb. (0.5 g.) and record the weight as \( W_{\text{DRY}} \). |
|   | Use the Adek Percometer\textsuperscript{TM} to take five initial dielectric readings on the specimen surface as the first day reading. Four readings should be equally spaced around the perimeter of the specimen, and the fifth should be in the center as shown in Figure 1. The probe should have a surcharge with a load of 5 ± 0.5 lb. (2.3 ± 0.23 kg) to ensure adequate contact of the probe on the top surface of the specimen. |
Note: This pattern should be followed each time dielectric values are measured.

1. Place a plastic sheet disk between the top of the specimen and the top porous stone, as shown in Figure 2. Place a latex membrane around the specimen with the aid of an expander and roll the membrane down to cover half of the bottom porous stone.

2. Place the sample in a flat-bottomed stainless steel or plastic pan and fill the pan with distilled/deionized water. The water depth should come up to about a 0.25 in. above the top of the bottom stone, as seen in Figure 3. The water bath should be maintained at this depth throughout the testing. Avoid splashing the specimen surfaces with water during the test.

   **Hint:** Make a mark on the pan to indicate the full level.

3. Take five dielectric value readings on the top surface of the specimen daily for 10 days. Take the readings at the same time during each day, if possible.

4. The test is completed when the elapsed time exceeds 10 days. Measure and record final surface dielectric values.

5. Run the unconfined compressive strength for each specimen and record it as the residual strength ($U_{RES}$) after 10-day capillary soaking period. Weigh the specimen only and record it as $W_{WET}$.

6. Determine the final moisture content of the specimen according to Test Method Tex-103-E, Part I, but use the entire sample instead in the procedure. Record the weight of the oven-dry aggregate particles as $W_S$.

### Calculations

- Calculate the actual gravimetric moisture content (MC, %) of the specimen, which should close to the optimum moisture content from the moisture-dry density relationship,

$$MC = 100 \frac{(W_{TOTAL} - W_{MOLD} - W_S)}{W_S}$$

Where:

- $W_{TOTAL}$ = Weight of the specimen and compaction mold, lb. (g.)
- $W_{MOLD}$ = Weight of the compaction mold, lb. (g.)
- $W_S$ = Oven dry weight of the soil particles after the test, lb. (g.)
• Calculate the gravimetric moisture content ($MC_{INITIAL}$, %) of the specimen after the 2-day drying period,

$$MC_{INITIAL} = 100 \left( W_{DRY} - W_{STONE} - W_{S} \right) / W_{S}$$

Where:

$W_{DRY} =$ Dry weight of the specimen after 2-day drying period with the two porous stones, lb. (g.)

$W_{S} =$ Oven dry weight of the soil particles after the test, lb. (g.)

• Calculate the gravimetric moisture content loss ($MC_{LOSS}$, %) of the specimen after the 2-day drying period,

$$MC_{LOSS} = MC - MC_{INITIAL}$$

Where:

$MC =$ Gravimetric moisture content when molded the specimens, %

$MC_{INITIAL} =$ Gravimetric moisture content after 2-day drying period, %

• Calculate the gravimetric moisture content ($MC_{FINAL}$, %) of the specimen after the 10-day soaking period,

$$MC_{FINAL} = 100 \left( W_{WET} - W_{S} \right) / W_{S}$$

Where:

$W_{WET} =$ Wet weight of the specimen after 10-day soaking period, lb. (g.)

$W_{S} =$ Oven dry weight of the soil particles after the test, lb. (g.)
Calculate the gravimetric moisture content gain (MC\text{\textsubscript{GAIN}}, \%) of the specimen after the 10-day soaking period,

\[ \text{MC}_{\text{GAIN}} = \text{MC}_{\text{FINAL}} - \text{MC}_{\text{INITIAL}} \]

Where:

\[ \text{MC}_{\text{INITIAL}} = \text{Gravimetric moisture content after 2-day drying period, \%} \]
\[ \text{MC}_{\text{FINAL}} = \text{Gravimetric moisture content after 10-day soaking period, \%} \]

- Calculate the retained ratio of unconfined compressive strength (R, \%) of the specimen after 10-day soaking period,

\[ R = 100 \left( \frac{U_{\text{RES}}}{U_{\text{OMC}}} \right) \]

Where:

\[ U_{\text{OMC}} = \text{Unconfined compressive strength at optimum moisture content, psi (MPa)} \]
\[ U_{\text{RES}} = \text{Unconfined compressive strength after 10-day soaking period, psi (MPa)} \]

**Graphs**

- Plot the dielectric constant versus time curve for each specimen.

**Test Report**

- Report the maximum dielectric value as the final dielectric value of the specimens after soaking.

- Report the initial and final gravimetric moisture content, the moisture content loss after 2-day drying period and the moisture gain after 10-day soaking period. The final moisture content is indicative of the water content this aggregate may attain in the field given the availability of water.
• Report the percentage retained ratio of the unconfined compressive strength after 10-day capillary soaking period with respect to the UCS at optimum moisture content.

**Notes**

• Specimens with final dielectric values less than 10 are expected to provide a good performance, while those with dielectric values above 16 are expected to provide poor performance as base materials. Specimens having final dielectric values between 10 and 16 are expected to be marginally moisture susceptible.

• The 10-day capillary soaked unconfined compressive strength (UCS) of the specimens should not be less than 75% of the original unsoaked UCS for good pavement performance.

![Figure 1. Using the Adek Percometer™](image)
Figure 2. Specimen assembly for tube suction testing
Expose half of the stone side to the water

Ensure that the membrane and the plastic disk seal the top of the specimen from the water

Figure 3. Capillary soaking set up
Appendix B
Resonant Column Test for Base and Soils

This method determines the modulus properties of unbounded soil-aggregate mixtures by using wave propagation techniques.

Definitions

- **Maximum Dry Density** ($D_a$) – maximum value obtained by the compaction curve using the specified compactive effort.
- **Optimum Water Content** ($W_{opt}$) – the water content at which the soil can be compacted to the maximum dry density.
- **Maximum Young’s Modulus** ($Y_{M_{max}}$) – Maximum modulus optimized at a certain compactive effort and moisture condition, typically dry of optimum moisture.
- **Compressive Velocity** ($V_c$) – the compressive wave (P-wave) velocity traveling through the soil or base material medium
- **Shear Velocity** ($V_s$) – the shear wave (S-wave) velocity traveling through the soil or base material medium

- **Resonant Frequency** ($f_r$) –

Apparatus:

- Accelerometer
- Instrument hammer
- Data Acquisition system
- Free-Free Resonant Column Software
- A balance with a minimum capacity of 35 lb. (15 kg), accurate and readable to 0.5 g or 0.1% of the test mass, whichever is greater.
- Porous Stones
- Texas Triaxial Cells
Part I: Determining the Relationship between Water Content and Young’s Modulus of Base and Soil Materials

Preparing Sample: Prepare the material according to 'Part II, Preparing Samples for Compaction and Triaxial Tests' of Test Method "Tex-101-E, Preparing Soil and Flexible Base Materials for Testing." Do not use previously laboratory compacted materials.

NOTE: For wetted stabilized materials taken from the roadway, see appropriate test method for preparation procedure for specification compliance, density, and/or modulus.

- Cement Stabilization: Test Method "Tex-120-E, Soil-Cement Testing"
- Lime Stabilization: Test Method "Tex-121-E, Soil-Lime Testing"

8. Procedure: The following table lists the steps necessary to determine the relationship between water content and the Young’s modulus of base and soil materials.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
</table>
| 1    | Use the following test methods for the determination of optimum water content and maximum dry density of the material:  
|      | a. Test Method Tex-113-E, Base Material  
|      | b. Test Method Tex 114-E, Soil |
| 2    | After each specimen is molded during Tex-113-E to establish a moisture/density (M/D) relationship, test each specimen molded for the M/D relationship. |
| 3    | Ensure that a nail is placed on the bottom of molded specimen. |
| 4    | Extrude the specimen from the mold. |
| 5    | Start the data collection program by double-clicking on the Desktop Link for the Free-free Resonant Column test program. Click on continue and you will see a screen like in Figure 1. |
| 6    | For each specimen, determine the diameter, length, and mass of the specimen being tested.  
|      | Note: This information can be updated in an Excel spreadsheet along with the results when exiting the program. However, it is recommended to enter it before testing the specimen to minimize the possibility for error. |
| 7    | Place the specimen on the testing platform. |
| 8    | Ensure the accelerometer and hammer is activates by checking if the light on the signal |
Secure the accelerometer on the bottom of the specimen by placing the magnetic accelerometer on the nail face place at compaction. (See Figure 2)

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Secure a thumb tack or place a coin on top of the specimen</td>
</tr>
<tr>
<td>11</td>
<td>Press the RUN/ENABLE button to start the acquisition cycle.</td>
</tr>
<tr>
<td>12</td>
<td>Trigger the data acquisition by tapping the hammer near the center of the end of the specimen opposite to the accelerometer. <strong>Note:</strong> If the trigger times out, click on the red square beneath the CALC PEAK button to re-queue the data acquisition cycle. The square will turn green when re-queued. The screen will then look somewhat like Figure 3.</td>
</tr>
<tr>
<td>13</td>
<td>Drag the cross hairs with the cursor to the resonant frequency associated with torsional (shear) wave. Press CALC PEAK for the program to place the cursor in the vicinity of the frequency where the resonant peak should be. Move the cursor either by pressing NEXT PEAK or PREV PEAK, by dragging the cross hair, or by depressing the diamonds under the graph, to the appropriate resonant frequency. <strong>Note:</strong> The value for this resonant frequency, $f_S$, is automatically adjusted as the cursor is positioned on the peak. The resonant frequency associated with the shear waves should be less than that of the compression frequency.</td>
</tr>
<tr>
<td>14</td>
<td>If the data is of high quality, save the resonant frequencies of the compression and/or shear waves by pressing the YES button. If the specimen is not struck properly, press NO to repeat Steps 12 to 14 to acquire a quality data. <strong>Note:</strong> The values are stored in the Average Frequency Displays and the LED shows the number of samples taken for the specimen</td>
</tr>
<tr>
<td>15</td>
<td>Repeat Steps 13 and 14 at least two more times to obtain a good average on the specimen. The frequency readings should be within 5% among the three repeats. The SAVE AVG FREQ buttons are enabled as soon as the process is repeated correctly 3 times <strong>Note:</strong> Make sure that if the shear frequency is being measured that it is recorded in all three samples taken. If a shear frequency is only measured once or twice, a “false” shear frequency will be reported. If this happens, click on RESET to restart the testing (sometimes you will have to trigger the hammer by tapping it on a hard surface so that the system will reset). If the results do not seem reasonable, simply press the NO button to discard the record.</td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>9</td>
<td>To save the average frequencies click on the SAVE AVG FREQ button (refer to Figure 4). The button will become disabled and grayed out as an indication that the averages for this specimen have been stored in memory. To save the raw data as well, click on the TIME HISTORY button after the SAVE AVG FREQ button. Click on the TIME HISTORY button, a window will come up for you to choose a name for the data file and to save it (refer to Figure 5).</td>
</tr>
<tr>
<td>10</td>
<td>To test the next specimen, click on NEW SPECIMEN (Figure 6) and repeat Steps 2-8 (omit Step 3). When finished testing click on the STOP button, the data acquisition program will close and will ask you to select the filename to save the test results. Notice that the default name is “NewFile.xls”. If this is the first time this particular specimen has been tested, select the default filename. If however, the specimen was previously tested and a file already exists with those results, choose that file to update the data (Figure 7).</td>
</tr>
<tr>
<td>11</td>
<td>In Excel, click on FILE, then SAVE AS and name the file. Testing is done (Figure 8).</td>
</tr>
<tr>
<td>12</td>
<td>Report the average Young’s Modulus per specimen at each moisture content and develop a Modulus-Density/Moisture curve, as seen in Graph 1.</td>
</tr>
</tbody>
</table>

**Computer Program**

The following worksheet (TEX145.xls) may be used to calculate the Modulus-Density/Moisture curve.

**Test Record**

Record test data on the 'M/D & Triaxial Test Worksheet,' Form 1176.

**Graph**

Plot the dry density against the percent of molding moisture on 'Plot of Sample Modulus-Density Curve.'
**Graph 1**: Plot of Sample Modulus-Density Curve.

**Report Test Results:**

- Plot Moisture Content vs. Young’s Modulus (YM) to the nearest 1 ksi. (MPa).
- Maximum Young’s Modulus ($YM_{\text{max}}$) to the nearest 1 ksi. (MPa).
- Water Content at $YM_{\text{max}}$ to the nearest 0.1%.
**Part II: Determining the Residual Young’s Modulus of Base and Soil Materials**

**After Drying and Partial Saturation**

**Preparing Sample:** Prepare the material according to 'Part II, Preparing Samples for Compaction and Triaxial Tests' of Test Method "Tex-101-E, Preparing Soil and Flexible Base Materials for Testing." Do not use previously laboratory compacted materials.

**Procedure:** The following table lists the steps necessary to determine the relationship between water content and the Young’s modulus of base and soil materials.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
</table>
| 1    | Use the following test methods for the determination of optimum water content and maximum dry density of the material:  
Test Method Tex-113-E, Base Material  
Test Method Tex 114-E, Soil |
<p>| 2    | Mold a specimen at optimum moisture and maximum dry density for soils and base materials. These specimens are 6 in. (152.4 mm) in diameter and 8 in. (203.2 mm) in height ∀ 0.25 in. (6.4 mm). |
| 3    | Test the specimen after molding the specimen to maximum dry density and optimum moisture, in accordance to ‘Part I: Determining the Relationship between Water Content and Young’s Modulus of Base and Soil Materials’, Steps 5 to 11 |
| 4    | Measure the mass of the specimen and porous stones after this initial test at optimum conditions. Record the mass as Initial Optimum Mass of Specimen and Porous Stone, ( M_0 ) (lbs.). |
| 5    | Place the specimens with dry porous stone in an oven maintained at 140 ± 9 °F (60 ± 5 °C) for 48 ± 4 hours. |
| 6    | Test the specimen every 24 hours during drying phase, in accordance to ‘Part I: Determining the Relationship between Water Content and Young’s Modulus of Base and Soil Materials’, Steps 5 to 11. |
| 7    | Measure and record the mass of the specimen and porous stones after every test, during the drying cycles. Allow the specimen to cool before measuring the mass. |
| 8    | Once the specimen has been dried, replace the bottom porous stone with a saturated porous stone and place a circular piece of plastic between the top of the specimen and the top porous stone. (See Figure 9) |
| 9    | Measure and record the mass of the specimen and saturated porous stones. Record the mass as “Initial Dry Mass of Specimen and Porous Stone”, ( M_{0\text{dry}} ) (lbs.). |
| 10   | Place a latex membrane on the specimen/porous stone assembly and place the specimen in a soaking pan as seen in Figure 10. |</p>
<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Test the specimen every 24 ± 2 hours until, in accordance to ‘Part I: Determining the Relationship between Water Content and Young’s Modulus of Base and Soil Materials’, Steps 5 to 11.</td>
</tr>
<tr>
<td>12</td>
<td>Measure and record the mass of the specimen and porous stones after every test, during the wetting cycles.</td>
</tr>
<tr>
<td>13</td>
<td>The test is completed when the elapsed time exceeds 240 hours.</td>
</tr>
<tr>
<td>14</td>
<td>Report the time, modulus and moisture contents for all cycles.</td>
</tr>
</tbody>
</table>

**B. Calculations:** Use the following equations to determine the volume, the percent water content, and the dry density of each specimen.

- Calculate the percent water content (WC):

  
  \[ WC = \frac{\left( M_W - M_D \right) - M_D}{100} \]

  Where:
  - \( M_W \) = wet mass of the sample, lb. (kg)
  - \( M_D \) = dry mass of the sample, lb. (kg)
a. Figure 1: Initial Screen for Concrete Free-free Resonant Test

Figure 2: Testing Assembly
**Figure 3:** Waiting to trigger acquisition.

**Figure 4:** Saving Average Resonant Frequencies to cache
Figure 5: Saving Time History to tab delimited excel file.
Figure 6: Click on “New Specimen” to Continue Testing

Figure 7: Excel sheet used for Young’s Modulus data calculation
c. **Figure 8:** Saving Young’s Modulus results with different filename.