MoDOT
TSR QC/QA
TRAINING/CERTIFICATION
COURSE

Missouri University of Science & Technology

Department of Civil, Architectural, and Environmental Engineering

9-21-06
1-29-07, 11-9-07
4-24-08
5-13-09, 5-14-09, 11-18-09
11-11-10
1-17-11
1-23-15, 4-22-15
1-9-17

TSR
CERTIFICATION COURSE
2016-2017

<table>
<tr><th>Time</th><th>Module</th><th>Location</th><th>Topic</th><th>Instructor</th></tr>
<tr><td>8:00-8:15</td><td>Intro</td><td>Lecture</td><td>Intro/welcome</td><td>Richardson</td></tr>
<tr><td>8:15-9:40</td><td></td><td>Lecture</td><td>TSR</td><td>Richardson</td></tr>
<tr><td>9:50-??</td><td></td><td>Lab</td><td>Lab demo:
• Shipping Sample
• TSR test
Hands-on practice</td><td>Lusher</td></tr>
<tr><td>½ hour</td><td></td><td>Lecture</td><td>Course Review</td><td>Richardson</td></tr>
<tr><td>2 hours</td><td></td><td>Lecture</td><td>Written Exam</td><td>Richardson</td></tr>
<tr><td colspan="5">Once written exam is complete, the attendee can start their proficiency exam. Whether the attendee wants to leave for lunch is their decision. Proficiency exam proctor will be on duty until all attendees have finished their proficiency exam.</td></tr>
<tr><td>?-Until all have finished</td><td></td><td>Lab</td><td>Proficiency Exam</td><td>Lusher</td></tr>
</table>

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1-9-17

AASHTO T283 Tensile Strength Ratio (TSR)

Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

SCOPE

- ***Background***
- TSR Role in QC/QA
- Sampling
- Test procedure
- Field verification

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Why are we concerned with Moisture Sensitivity?

- Stripping will result if the bond is broken between the asphalt cement and aggregate.
  - Resulting in pavement:
    - Rutting
    - Shoving
    - Raveling
    - Cracking

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MOISTURE DAMAGE (STRIPPING)

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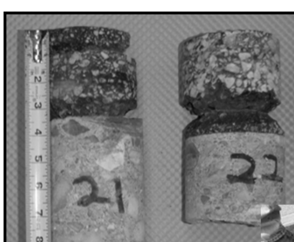

AASHTO TEST METHODS & SPECIFICATIONS

- R35 Volumetric Design Practice
- M323 Volumetric Design Specs
- R30 Mix Conditioning
- T 312 Gyro operation
- T 166 Bulk Sp Gravity of gyro pucks
- T 209 Max Sp Gravity of Voidless Mix (Rice)
- ***T 283 Moisture Sensitivity***
- ***R 47 HMA Sample Splitting***
- ***D 3549 Thickness of Specimens***

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What is Tensile Strength Ratio?

- Moisture Sensitivity of Asphalt Mixtures
- Affects the structural integrity of a mixture.
- Based on the ratio of the tensile strength of a set of conditioned to a set of unconditioned specimens expressed as a %.

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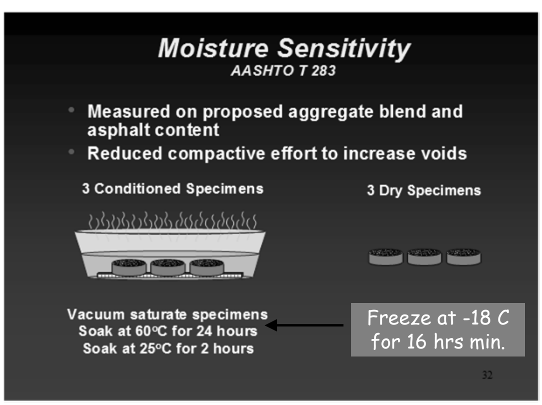

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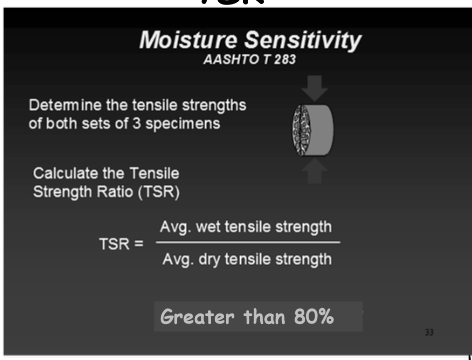
TSR



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TYPICAL TEST RESULTS

- Range in initial mix design: 40-95+ %

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SCOPE

- Background
- ***TSR Role in QC/QA***
- Sampling
- Test procedure
- Field verification

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TSR Role

- ***Mix design/acceptance***
- Field Verification of mix

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DURING MIX DESIGN
In Addition to Field Verification Steps
(One extra day for lab mix at front end)

- Mixture prepared in lab
- After mixing, place mixture in a pan (one specimen per pan) and cool at room temperature for 2.0 ± 0.5 hrs
- Place in oven on perforated shelf (or on spacers) at 60±3° C for 16 ± 1 hrs
- Heat to compaction temperature ± 3°C for 2 hr ± 10 min.

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Non-Moisture Sensitive

- The intent is for Superpave and Plant mix be ***non-moisture-sensitive***
  - Superpave- ***must*** be proven through TSR testing
  - Plant mix- ***may*** be required to be proven through TSR testing

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BB and BP Mixes

- Engineering Policy Guide 401.2.3: Additional TSR testing is warranted if: In the field, if the PI of the fine aggregate fractions has significantly increased or the overall quality of the aggregate has changed

- If a source has a history of stripping, MoDOT may require TSR testing during design and/or production

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MIX DESIGN ACCEPTANCE

- TSR ≥ 70% for ***BB and BP*** mixes (for aggregate fractions containing ≥ 10% minus #30 with PI >3)
- TSR > 80% for ***Superpave*** mixes

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TSR Role

- Mix design/acceptance
- ***Field Verification of mix***

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SUPERPAVE TSR PAY ADJUSTMENT

TSR	% of Contract price
≥90	103
75-89	100
70-74	98
65-69	97
<65	Remove

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SCOPE

- Background
- TSR Role in QC/QA
- ***Sampling***
- Test procedure
- Field verification

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Sampling Field TSR QC/QA

- During production, loose mix samples will be taken and quartered as described in EPG Section 403.1.5
- QC has the option of taking loose mix samples from any point in the production process.
- QA samples should be taken from the same point as the QC, although not at the same time

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LOOSE MIX: TSR Sample

- QC: 1 per 10,000 tons
- QA: 1 per 50,000 tons or one per mix (combination of projects)

[contract with several projects with same mix, totaling < 50,000 tons]

- Random locations by spec (per EPG: not enforced)

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SAMPLING: QC

- QC gets their own TSR sample plus a retained sample for QA
- Depth: full depth of the course (if roadway sample)

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SAMPLING: QA

- QA gets their own "independent" ~250 lb sample, retain 125 lbs

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LOOSE MIX SAMPLING LOCATION

- ***ROADWAY****
- ***PLANT DISCHARGE****
- ***TRUCK***

** Preferred*

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TSR Sampling-Roadway

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CAUTION

- Filling one bucket at a time may render different characteristics bucket-to-bucket---better to place one shovelful per bucket at a time
- Should recombine and quarter

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TSR SAMPLING
Roadway

- Profilograph issues?
- Big hole to fill

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LOOSE MIX SAMPLING LOCATION

- ***ROADWAY****
- ***PLANT DISCHARGE****

- ***TRUCK***

**** Preferred***

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PLANT DISCHARGE

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PLANT DISCHARGE
(Chop Gate-Diverter Chute)

- Divert entire production stream from drum to a loader bucket

- Sample all across the loader bucket, one shovel per box , all boxes
- Repeat until boxes are full
- Cool (beware of dust)
- Close boxes

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PLANT DISCHARGE
(Chop Gate-Diverter Chute), cont'd.

- Re-heat material
- Mix all boxes
- Quarter with templates
- Remove quarters to 4 buckets
- Quarter each bucket
- Pull one puck from each quarter

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TSR SAMPLING
DIVERTER CHUTE

- Contamination issues from diesel used to clean the area

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LOOSE MIX SAMPLING LOCATION

- ***ROADWAY****
- ***PLANT DISCHARGE****
- ***TRUCK***

**** Preferred***

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"Mini-stockpile"

- About 2 tons sampled from silo discharge into a truck
- Dumped
- Back dragged

- Sampled into, say, 4 buckets or boxes
- Back at lab, material is combined, mixed, and quartered , combined into 2 piles
- 4 pucks sampled from each pile

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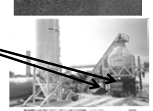
LOOSE MIX SAMPLING LOCATION



- ***ROADWAY****
- ***PLANT DISCHARGE****
- ***TRUCK***

**** Preferred***

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Truck Sampling

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Truck Sampling

CAUTION

- Possible segregation in truck bed
- Sampling methods (eg. length of arms) limit the position of sampling in the truck bed→ non-representative sample
- Safety issues
- Don't leave sample boxes uncovered at this location—may get contaminated with dust and overspray of release agent

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QUARTERING THE SAMPLE

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AASHTO R47

- Quartering templates

- Quartering

- "Quartermaster"

- Riffle splitters

- Incremental (loaf)

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QUARTERMASTER

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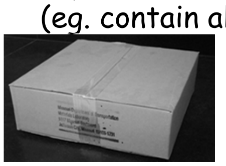
QA TSR Sample

- QA inspector will box up 125 lbs loose mix sample and ship to the Central Lab for testing
- Each box should contain as representative a sample as possible (eg. contain all fines, etc)



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QA TSR Sample, cont'd.

- Central Lab will determine the TSR puck weight to be used from testing one of the boxes
- Central Lab will combine the remaining samples and go through the splitting procedure
- So, field tech needs to know how "Central Lab" will handle (combine) the boxes

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QA TSR Sample

- Field QA should also retain a 125 lb sample ***(Do not send to Central Lab unless asked for. Discard only after issues of favorable comparison between QC and QA have been determined)***

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TSR BOX INFO

- Site Manager ID number
- Mix number
- G_{mm} from sublot taken (QC or QA)
- Specimen weight QC is using

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SCOPE

- Background
- TSR Role in QC/QA
- Sampling
- ***Test procedure***
- Field verification

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TSR FIELD TEST PROCEDURE

- Determine TSR puck weights
- Compact pucks, run specific gravity
- Run Rice specific gravity
- Calculate air voids
- Break dry pucks
- Condition wet pucks
- Break wet pucks
- Calculate TSR
- Inspect conditioned pucks

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EQUIPMENT

- Gyratory compactor & 150 mm diameter molds
- Oven: room temperature up to 176 ±3 °C
- Balance
- Rice specific gravity equipment

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EQUIPMENT, cont'd.

- Water bath at 25 ± 0.5 °C
- Water bath at 60 ± 1 °C
- Plastic bags
- Cling film

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EQUIPMENT, cont'd.

- Vacuum dessicator
- Vacuum pump @ up to 26" mercury
- Timer
- Damp towel

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EQUIPMENT, cont'd.

- 10 ml graduated cylinder
- Freezer @ -18 ± 3 °C
- Load frame (2 in per min movement)
- Indirect tensile strength breaking head

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ESTIMATE TSR PUCK MASS

- Enough to fill a cylinder 150 mm diameter and 95 mm height
- Less 7.0% air voids
- Less side dimples
- The calculation of required mass will be a starting point---experience will fine-tune the actual mass required

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TSR PUCK MASS

- V_{solids} = (Mass)(sp grav)
- $V_{air} = V_{total} - V_{solids}$
- Mix is constantly changing (e.g. bin % changes)
- Exact %'s of each material is changing
- Each material has a different specific gravity
- So, volumes of each material are changing
- So, mix mass must change to keep 7.0% air voids constant

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TSR PUCK MASS

- The following slides present one method for determining mass of puck to result in 7.0% air voids & 95 ± 5 mm tall. The method is not mandatory
- There may be equally useful methods

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TSR PUCK MASS

- Do a weight-volume calculation to get initial mass
- Adjust via the most recent puck history (say, volumetric pucks)
- Fine-tune with experience

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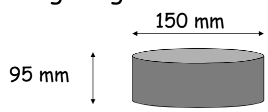
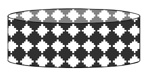
TSR PUCK MASS

Moving target:



Mass to get 7.0% air voids

But…dimples:



So, adjust mass according to how the mix is behaving (info from other compacted pucks)

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CALCULATION OF MASS REQUIRED FOR 7.0% AIR VOIDS

- Obtain $\boldsymbol{G_{mm}}$ for the sampled roadway mat area
- $V_{air} = \frac{100(G_{mm} - G_{mb})}{G_{mm}}$

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CAUTION

- The G_{mm} needs to be representative- if not, the computed air voids will be wrong

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CALCULATION OF MASS REQUIRED FOR 7.0% AIR VOIDS

- From test data of QC or QA volumetric pucks, average several G_{mb} values appropriate for the TSR sampled mat area: $\boldsymbol{G_{mb,meas}}$

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$G_{mb,est}$

- Compute the G_{mb} as if there were no side voids (dimples) = $\boldsymbol{G_{mb,est}}$
- Thus, for the same mass, the volume will be larger, and G_{mb} should decrease
- (Same mass spread over a larger volume)
- So, $\boldsymbol{G_{mb,meas}}$ will be > $\boldsymbol{G_{mb,est}}$

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Mass & G_{mb} of Historical Pucks (Usually Volumetric Pucks)

- Average the mass ($\boldsymbol{M_{meas}}$) of each of the G_{mb} pucks (recent historical data)
- Average the puck height (from gyro printout) h @ N_{des} ($\boldsymbol{h_x}$) of each of the G_{mb} pucks
- Calculate the $\boldsymbol{G_{mb,est}}$

$$Gmb, estimated = \frac{Avg.Mmeas}{\left(\frac{\pi d^2 (avg\ h_x)}{4}\right)}$$

- Where d= diameter of puck (15.0 cm)

And h_x in cm for historical pucks (usually 11.5±0.5 cm)

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CALCULATION of "C" Factor for Historical Pucks

- Calculate "***C*** "

$$C = \frac{Gmb(measured)}{Gmb(estimated)} + experience$$

- *C* > 1.0
- "experience" may be adding ~10g to account for material loss

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CALCULATION OF MASS REQUIRED FOR 7.0% AIR VOIDS in TSR Puck

- Calculate the required ***mass*** for 7.0% air voids (mass = V x Sp Grav)
- Mass = $\dfrac{[(0.93)(\pi)(d^2/4)(h)](Gmm)}{C}$
- If d=15.0 cm and h= 9.5 cm:

$$Mass = \frac{1561.2\ Gmm}{C}$$

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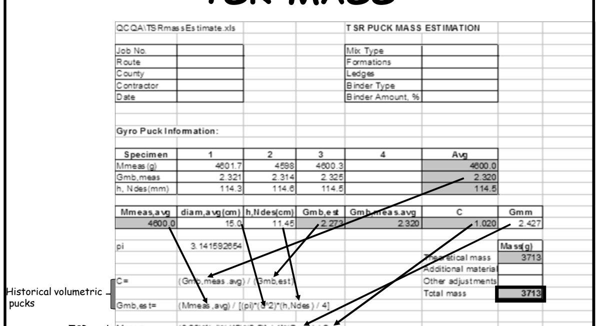
TSR MASS



QCQA\TSRmassEstimate.xls — TSR PUCK MASS ESTIMATION

Job No.		Mix Type	
Route		Formations	
County		Ledges	
Contractor		Binder Type	
Date		Binder Amount, %	

Gyro Puck Information:

Specimen	1	2	3	4	Avg
Mmeas(g)	4601.7	4598	4600.3		4600.0
Gmb,meas	2.321	2.314	2.325		2.320
h, Ndes(mm)	114.3	114.6	114.5		114.5

Mmeas,avg	diam,avg(cm)	h,Ndes(cm)	Gmb,est	Gmb,meas.avg	C	Gmm
4600.0	15.0	11.45	2.273	2.320	1.020	2.427

pi 3.141592654

	Mass(g)
Theoretical mass	3713
Additional material	
Other adjustments	
Total mass	3713

Historical volumetric pucks:
C= (Gmb,meas.avg) / (Gmb,est)
Gmb,est= (Mmeas,avg) / [(pi)*(d^2)*(h,Ndes) / 4]

TSR puck: Mass= (0.93)*[(pi)*(d^2)*(9.5)] / 4]*(Gmm) / C

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TSR MASS

QCQA\TSRmassEstimate.xls

TSR PUCK MASS ESTIMATION

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Route		Formations	
County		Ledges	
Contractor		Binder Type	
Date		Binder Amount, %	

Gyro Puck Information:

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Mmeas,avg	**diam,avg(cm)**	**h,Ndes(cm)**	**Gmb,est**	**Gmb,meas.avg**	**C**	**Gmm**
4600.0	15.0	11.45	2.273	2.320	1.020	2.427

pi 3.141592654

	Mass(g)
Theoretical mass	3713
Additional material	
Other adjustments	
Total mass	**3713**

Historical volumetric pucks

C= (Gmb,meas.avg) / (Gmb,est)

Gmb,est= (Mmeas,avg) / [(pi)*(d^2)*(h,Ndes) / 4]

TSR puck

Mass= (0.93)*[(pi)*(d^2)*(9.5)] / 4]*(Gmm) / C

FIELD VERIFICATION

- The following slides relate to TSR testing of field samples

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DAILY FIELD PROCEDURE-Outline

- Day 1:
  - Sample, quarter, heat to compaction temperature ± 3°C
  - Compact pucks, store at room temperature 24±3hr
    - Run Rice gravity
- Day 2:
  - Determine G_{mb} of pucks
  - Calculate air voids
  - Group into two sets of 3
  - Saturate the Wet set
  - Put Wet set into freezer
  - Start air drying of Dry set

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DAILY PROCEDURE Outline, cont'd.

- Day 3:
  - Test Dry set
  - Start high temperature conditioning of Wet set
- Day 4:
  - Test Wet set
  - Calculate TSR

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TEST PROCEDURE Day 1

- Warm the mix to soften it for quartering, quarter
- Reheat the mix to compaction temperature ± 3 °C.
- Use sufficient mix to achieve 7.0 ± 0.5% air voids in a 95 ± 5 .mm tall puck.
  - Note: SMA mixes require 6.0±0.5% air voids
- Determine Rice gravity (G_{mm})

[must be representative of TSR mix]

DAY 1

- Set gyro to "Height control" mode
- Compact 6+ pucks (actually, will make 1 or more trial pucks; may also wish to compact several extra pucks)
- Store at room temperature for 24 ± 3 hrs.

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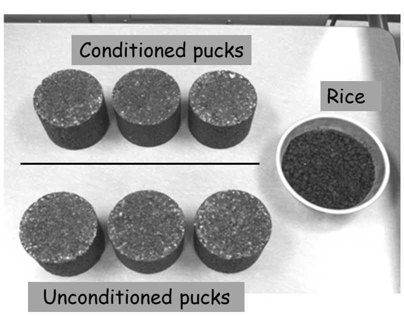
TSR



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DAY 2: Determine Air Voids

- Determine G_{mb} for all 6+ pucks
  (follow T166—thus, pucks need to be tested at 25° C)

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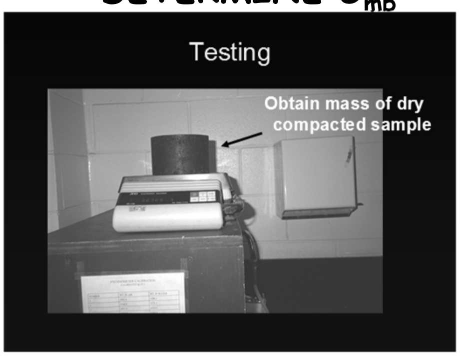
DETERMINE G_{mb}



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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example — Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm³) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm³) [Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.: ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD

* For 15.0 cm diameter specimen [D]		Vacuum SSD Wt. (g) [B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi) [Swet]		Weight in air (g) [A]	3822.4	3759.7		
Avg. Dry ITS (psi) [Sdry]	108	Vol. Absorb H₂O (cm³) [J']	81	86		B'-A
TSR (%) [100Swet/Sdry]		Dry volume of air (cm³) [Va]	110	108		
		70% Sat. (Target VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	3910	3846		A+0.8Va
Air Voids (%)		% Saturation	73	80		100J'/Va
Dry Subset %Air	6.9	in. Hg	22	23	23	
Wet Subset %Air		Time (min)	8	8	8	
Saturation (%)		in. Hg	25	26	24	
		Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

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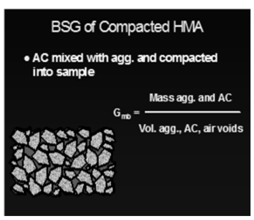
Puck Bulk Specific Gravity

From Example Spreadsheet Spec #1

$$G_{mb} = \frac{A}{B - C}$$



$$G_{mb} = \frac{3725.8}{3735.6 - 2114.3}$$

G_{mb} = ***2.298***

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AIR VOIDS

- $$P_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$$
- P_a = % air voids
- G_{mm}=maximum specific gravity of the voidless mix (Rice sp gravity)
- G_{mb}= sp. gravity of the compacted mix

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Mix Number: Example

Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD

* For 15.0 cm diameter specimen[D]

Avg. Wet ITS (psi)[Swet]		Vacuum SSD Wt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Dry ITS (psi)[Sdry]	108	Weight in air (g)[A]	3822.4	3759.7		
TSR (%)[100Swet/Sdry]		Vol. Absorb H_2O (cm^3)[J']	81	86		B'-A
		Dry volume of air (cm^3)[Va]	110	108		
		70% Sat. (Target VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	3910	3846		A+0.8Va
Air Voids (%)		% Saturation	73	80		100J'/Va
Dry Subset %Air	6.9	in. Hg	22	23	23	
Wet Subset %Air		Time (min)	8	8	8	
Saturation (%)		in. Hg	25	26	24	
		Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time						
	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

DETERMINE %AIR VOIDS

From Example Spreadsheet Spec #1

- Having tested Rice, calculate air voids of each puck:

$$P_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$$

$$Pa = \frac{2.476 - 2.298}{2.476} \times 100 = \mathbf{\textit{7.2 \%}}$$

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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number Example

Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD
* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']		3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]		3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']		81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]		110	108		
		70% Sat. (Target VSSD)		3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)		3910	3846		A+0.8Va
Air Voids (%)		% Saturation		73	80		100J'/Va
Dry Subset %Air	6.9		in. Hg	22	23	23	
Wet Subset %Air			Time (min)	8	8	8	
Saturation (%)			in. Hg	25	26	24	
			Time (min)	1	1	1	

	Dry Subset			Wet Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h			
Time in Freezer (Minimum 16 hrs)				19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)				23h 30m	23h 30m	23h 30m
Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

NOTE: Shaded cells indicate cells needing input values

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AIR VOIDS 2 SIMILAR GROUPS "Wet" and "Dry"

- Group the pucks into 2 groups such that average air voids of each group is about equal
- $$P_{a,\,avg} = \frac{P_{a1} + P_{a2} + P_{a3}}{3}$$
- Testing pucks at extreme end of allowable voids may lead to poor QC/QA comparison

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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number	Example	Gmm =	2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD

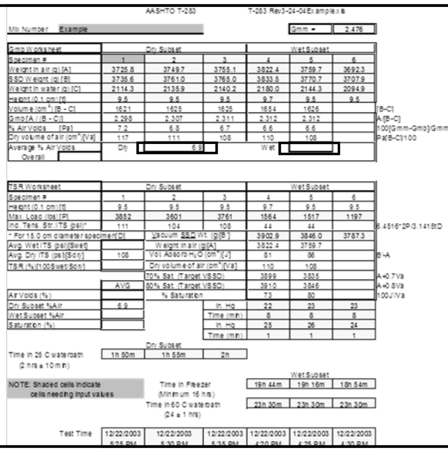
* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']	81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]	110	108		
		70% Sat. (Target VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	3910	3846		A+0.8Va
Air Voids (%)		% Saturation	73	80		100J'/Va
Dry Subset %Air	6.9	in. Hg	22	23	23	
Wet Subset %Air		Time (min)	8	8	8	
Saturation (%)		in. Hg	25	26	24	
		Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

	1	2	3	4	5	6
Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM



AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example | Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.: ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1416tD

* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']	81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]	110	108		
		70% Sat. (Target VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	3910	3846		A+0.8Va
Air Voids (%)		% Saturation	73	80		100J'/Va
Dry Subset %Air	6.9	In. Hg	22	23	23	
Wet Subset %Air		Time (min)	8	8	8	
Saturation (%)		In. Hg	25	26	24	
		Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

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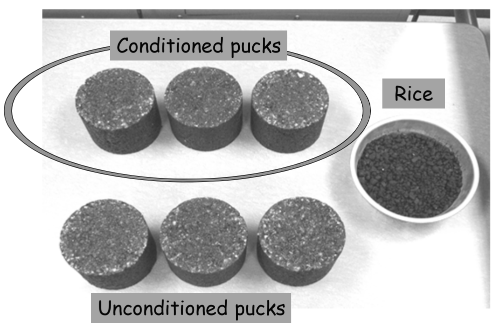
TSR-Conditioned (Wet)



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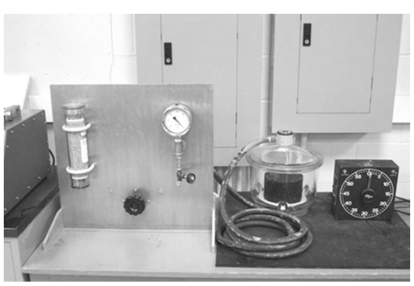
Day 2, Cont'd. Wet Pucks

- Overview: Vacuum saturate the 3 other pucks that are to be "conditioned".



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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number	Example	Gmm =	2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD
* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']		3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]		3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']		81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]		110	108		
		70% Sat. (Target VSSD)		3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)		3910	3846		A+0.8Va
Air Voids (%)		% Saturation		73	80		100J'/Va
Dry Subset %Air	6.9		in. Hg	22	23	23	
Wet Subset %Air			Time (min)	8	8	8	
Saturation (%)			in. Hg	25	26	24	
			Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time						
	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

VACUUM SATURATION
Wet Pucks

- Permissible range: 70-80%
- Pre-calculate partially saturated puck weights at 70 and 80%
- By iteration, progressively vacuum & weigh at intervals until puck weight is in the permissible weight range

85

Day 2: Wet Pucks

- Determine the surface dry weight.

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Apply Vacuum

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VACUUM SATURATION, cont'd.

- Place puck in vacuum chamber and submerge in water (≥ 1" cover and ≥ 1" above chamber bottom)
- Apply 10-26" (suggested 23") mercury vacuum for 5-10 (suggested 8) minutes
- If use high/fast vacuum, may get uneven saturation—poor QC/QA comparison
- Slowly remove vacuum
- Let puck set in water for 5-10 minutes
- Remove puck, quickly surface dry with a damp towel

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Day 2, Cont'd. Wet Pucks

- Determine the saturated surface dry weight (T 166).

If in the 70 -80% saturation weight range, wrap in cling film, place in plastic bag, add 10 ± 0.5 ml water, seal.

- Calculate % saturation

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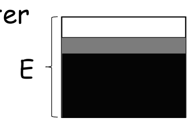
Day 2
Calculation of % Saturation
From Example Spreadsheet Spec. #4

E (puck volume) = B - C

B = puck SSD weight

C = puck weight in water

["B" & "C" from G_{mb} testing]:



E = 3833.5 – 2180.0 = ***1654 cm³***

90

DETERMINE %AIR VOIDS

Specimen #4

- Calculate air voids of each puck:

$$P_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$$

$$Pa = \frac{2.476 - 2.312}{2.476} \times 100 = \mathbf{6.6\ \%}$$

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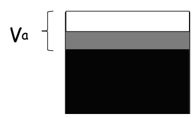
Open Voids

Specimen #4

$$Va(volume\ of\ air\ voids) = \frac{Pa\ E}{100}$$



- $V_a = \frac{(6.6)\ (1654\ cm^3)}{100}$

V_a = ***110 cm³***

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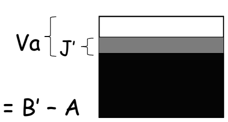
% Saturation

Specimen #4

$$\%Saturation = \frac{100\,J'}{Va}$$



J' (volume of absorbed water) = B' – A

B' = SSD weight after saturation

A = puck dry weight in air ["A" from G_{mb} testing]

J' = 3902.9 – 3822.4 = ***81 cm³***

$$\% Saturation = \frac{100\ (81)}{110} = \mathbf{73\%}$$

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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example | Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs)[P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.: ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1416tD
* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']		3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]		3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']		81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]		110	108		
		70% Sat. (Target VSSD)		3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)		3910	3846		A+0.8Va
Air Voids (%)		% Saturation		73	80		100J'/Va
Dry Subset %Air	6.9		in. Hg	22	23	23	
Wet Subset %Air			Time (min)	8	8	8	
Saturation (%)			in. Hg	25	26	24	
			Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

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Pre-Determined Weights

Specimen #4

- At 70% saturation:
  - $M_{70} = A + 0.7 (V_a)$
  - $M_{70} = 3822.4 + 0.7 (110) =$ ***3899*** *g*
- At 80% saturation:
  - $M_{80} = A + 0.8 (V_a)$
  - $M_{80} = 3822.4 + 0.8 (110) =$ ***3910*** *g*

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% SATURATION, Cont.

- If the saturation is less than 70%, re-vacuum at 26" mercury vacuum for 1 minute. Slowly remove vacuum. Let puck set in water for 5-10 minutes (if this is omitted, QA & QC may not compare)
- Check saturation
- Repeat as necessary
- If the saturation is greater than 80%, puck is considered destroyed and must be discarded.

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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example

Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD

* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']	81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]	110	108		
		70% Sat. (Target VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	3910	3846		A+0.8Va
Air Voids (%)		% Saturation	73	80		100J'/Va
Dry Subset %Air	6.9	in. Hg	22	23	23	
Wet Subset %Air		Time (min)	8	8	8	
Saturation (%)		in. Hg	25	26	24	
		Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

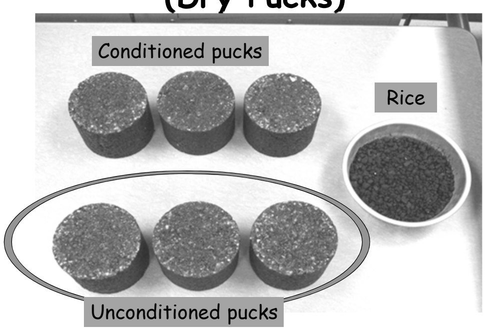
	1	2	3	4	5	6
Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

DAY 2, Cont'd. Wet Pucks

- When saturation is 70-80%, wrap the pucks in cling film, place in bag with 10cc water, seal, and place in freezer at -18 ± 3 °C for at least 16 hrs. Verify temperature throughout the freezer.
- Do not allow specimens to drain after saturation but prior to freezing

97

TSR-Unconditioned (Dry Pucks)



98

DAY 2 Dry Pucks

- Let the 3 unconditioned pucks air dry at room temperature for 24 ± 3 hrs until Day 3
- CAUTION: If tested damp, this may change indirect tensile strength (and TSR)

99

DAY 3
Dry Pucks

- Bag the 3 unconditioned pucks, place in water bath at 25 ± 0.5 C for 2 hrs ± 10 min. Indirect tensile strength is very sensitive to temperature

100

BAGGING/STANDARD TEMPERATURE PROCEDURE

- Place each "dry" puck into a heavy-duty leak-proof plastic bag
- Submerge in the water bath; pucks covered by at least 1 in. of water. Creation of an air bath within the water bath may not give equivalent results
- Remove pucks from water, determine puck thickness (t)

101

DETERMINE THICKNESS (t)
ASTM D3549

- Use a calipers: *dry or wet pucks*
  - average of 4 points around the perimeter
  - Caliper method is more accurate than printout method if puck swells

Or

- Use puck height from gyro printout
- *(dry pucks only)*

102

From Gyro Printout

103

From Gyro Printout

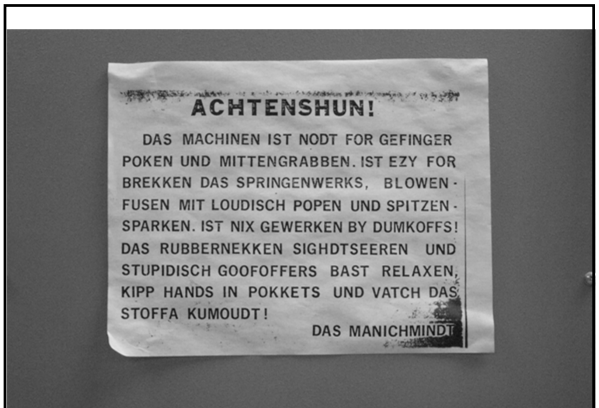
Pine Instrument Company Gyratory Compactor MODE: Set Height

Specimen Size: 150 mm Date: 1/24/15
Pressure: 600 kPa Time: 14:25
Specimen ID: ________ Technician: ________

SPECIMEN HEIGHT (mm) vs. GYRATION NO.

	0	1	2	3	4	5	6	7	8	9
0	116.7	111.2	108.3	106.3	104.7	103.5	102.4	101.5	100.7	100.0
10	99.4	98.8	98.3	97.9	97.5	97.1	96.7	96.4	96.1	95.8
20	95.5	95.2	95.0	94.8	94.5					

104



105

DAY 3, Cont'd. Dry Pucks

- Test for indirect tensile strength (S_1):
- Apply load at 2" travel per minute.
- Record maximum load.

106

CALCULATIONS: DRY TENSILE STRENGTH

- Calculate dry indirect tensile strength, S_1 (psi):

$$S_1 = \frac{2P}{\pi t D}$$

P= load (lbs)

t=dry puck thickness (in.)

D= puck diameter (6 in.)

107

OR Using metric puck measurements:

Indirect Tensile Strength "Dry" ,S_1 (psi)

$$S_1 = \frac{2P}{\pi t D} \times 6.4516$$

P = load (lbs)

t = puck thickness (cm)

D = puck diameter (15.0 cm)

108

Specimen #1

- $S = \frac{2(3852\ lbs)(6.4516)}{\pi(9.5\ cm)(15.0\ cm)}$

- S = 111 psi

109

AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example — Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.: ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD
* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']		3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]		3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']		81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]		110	108		
		70% Sat. (Target VSSD)		3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)		3910	3846		A+0.8Va
Air Voids (%)		% Saturation		73	80		100J'/Va
Dry Subset %Air	6.9		in. Hg	22	23	23	
Wet Subset %Air			Time (min)	8	8	8	
Saturation (%)			in. Hg	25	26	24	
			Time (min)	1	1	1	

	Dry Subset			Wet Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h			
Time in Freezer (Minimum 16 hrs)				19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)				23h 30m	23h 30m	23h 30m
Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

NOTE: Shaded cells indicate cells needing input values

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DAY 3, cont.(Wet Pucks)

- Remove the pucks from bag and place pucks in a water bath at 60 ± 1 C for 24 ± 1 hr. Minimum 1 in. water cover above specimens.
- Unwrap cling film as soon as the film thaws.

111

AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example

Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD

* For 15.0 cm diameter specimen[D]

Avg. Wet ITS (psi)[Swet]		Vacuum SSD Wt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Dry ITS (psi)[Sdry]	108	Weight in air (g)[A]	3822.4	3759.7		
TSR (%)[100Swet/Sdry]		Vol. Absorb H_2O (cm^3)[J']	81	86		B'-A
		Dry volume of air (cm^3)[Va]	110	108		
		70% Sat. (Target VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	3910	3846		A+0.8Va
Air Voids (%)		% Saturation	73	80		100J'/Va
Dry Subset %Air	6.9	in. Hg	22	23	23	
Wet Subset %Air		Time (min)	8	8	8	
Saturation (%)		in. Hg	25	26	24	
		Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time						
	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

DAY 4: Wet Pucks

Place pucks in water bath at 25 ± 0.5° C for 2 hrs ± 10 min. Minimum 1 in. water cover above specimens. Bath must be at 25°C no later than 15 min. after placing hot pucks. Use ice to help achieve this.

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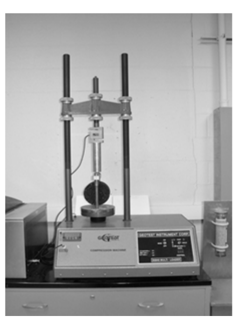
Wet Pucks

113

DAY 4, Cont'd. (Wet Pucks)

- Measure puck thickness (t')- *after soaking, with calipers*
- Test for indirect tensile strength (S_2)



114

Indirect Tensile Testing

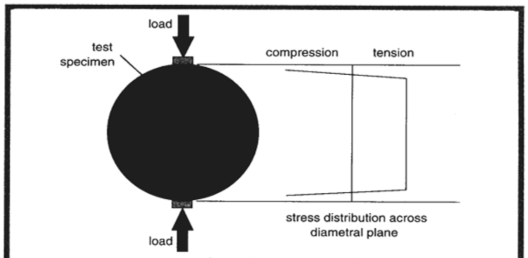


Figure 7.4 Indirect Tensile Test

115

CALCULATIONS WET TENSILE STRENGTH

- Calculate wet indirect tensile strength, S_2 (psi):

$$S_2 = \frac{2P}{\Pi t'D}$$

P= load (lbs)

t'=wet puck thickness (in.)

D= puck diameter (6 in.)

116

OR Using metric puck measurements:

- Wet indirect tensile strength, S_2 (psi)

$$S_2 = \frac{2P}{\pi t' D} \times 6.4516$$

P = load (lbs)

t' = puck thickness (cm)

D = puck diameter (15.0 cm)

117

Specimen #4

- S = 2(1564 lbs)(6.4516)
- π(9.7 cm)(15.0 cm)

- S = 44 psi

118

AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example | Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.: ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD
* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']		3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]		3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']		81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]		110	108		
		70% Sat. (Target VSSD)		3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)		3910	3846		A+0.8Va
Air Voids (%)		% Saturation		73	80		100J'/Va
Dry Subset %Air	6.9		In. Hg	22	23	23	
Wet Subset %Air			Time (min)	8	8	8	
Saturation (%)			In. Hg	25	26	24	
			Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

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CALCULATIONS: TSR

- Calculate TSR:

$$TSR = \frac{S_2}{S_1} \times 100$$

S_2=average of conditioned (wet) pucks tensile strength

S_1=average of unconditioned (dry) pucks tensile strength

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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number	Example	Gmm =	2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD
* For 15.0 cm diameter specimen[D]		Vacuum SSD Wt. (g)[B']		3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]		3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']		81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]		110	108		
		70% Sat. (Target VSSD)		3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)		3910	3846		A+0.8Va
Air Voids (%)		% Saturation		73	80		100J'/Va
Dry Subset %Air	6.9		in. Hg	22	23	23	
Wet Subset %Air			Time (min)	8	8	8	
Saturation (%)			in. Hg	25	26	24	
			Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

CALCULATIONS: TSR

- Specimen #6 ITS is 35 psi, so the average (#4, #5, #6) wet S_2 = 41 psi

$$TSR = \frac{41}{108} \times 100$$

TSR = 38

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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number: Example Gmm = 2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD

* For 15.0 cm diameter specimen [D]		Vacuum SSD Wt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm^3)[J']	81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm^3)[Va]	110	108		
		70% Sat. (Target VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	3910	3846		A+0.8Va
Air Voids (%)		% Saturation	73	80		100J'/Va
Dry Subset %Air	6.9	in. Hg	22	23	23	
Wet Subset %Air		Time (min)	8	8	8	
Saturation (%)		in. Hg	25	26	24	
		Time (min)	1	1	1	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

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SUSPECTED STRENGTH OUTLIER

- If attributable to an air void content different from other 2 pucks, leave in the set
- If a mystery, calculate if statistically is an outlier (ASTM E178)-if so, pitch and do one of the following:
  - Substitute another puck if compacted extra pucks
  - Test a new set of 3
  - Go with 2 pucks in the set
  - Prepare and test a substitute puck---must be assured that the material is the same as what was used for the other pucks

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AASHTO T-283 T-283 Rev3-24-04Example.xls

Mix Number	Example	Gmm =	2.476

Gmb Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Volume (cm^3) [B - C]	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
% Air Voids [Pa]	7.2	6.8	6.7	6.6	6.6		100[Gmm-Gmb]/Gmm
Dry volume of air (cm^3)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids	Dry	6.9		Wet			
Overall							

TSR Worksheet	Dry Subset			Wet Subset			
Specimen #	1	2	3	4	5	6	
Height (0.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
Max. Load (lbs) [P]	3852	3601	3761	1564	1517	1197	
Ind. Tens. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD

* For 15.0 cm diameter specimen[D]	
Avg. Wet ITS (psi)[Swet]	
Avg. Dry ITS (psi)[Sdry]	108
TSR (%)[100Swet/Sdry]	

	4	5	6	
Vacuum SSD Wt. (g)[B']	3902.9	3846.0	3787.3	
Weight in air (g)[A]	3822.4	3759.7		
Vol. Absorb H_2O (cm^3)[J']	81	86		B'-A
Dry volume of air (cm^3)[Va]	110	108		
70% Sat. (Target VSSD)	3899	3835		A+0.7Va
80% Sat. (Target VSSD)	3910	3846		A+0.8Va
% Saturation	73	80		100J'/Va
in. Hg	22	23	23	
Time (min)	8	8	8	
in. Hg	25	26	24	
Time (min)	1	1	1	

	AVG
Air Voids (%)	
Dry Subset %Air	6.9
Wet Subset %Air	
Saturation (%)	

	Dry Subset		
Time in 25 C waterbath (2 hrs ± 10 min)	1h 50m	1h 55m	2h

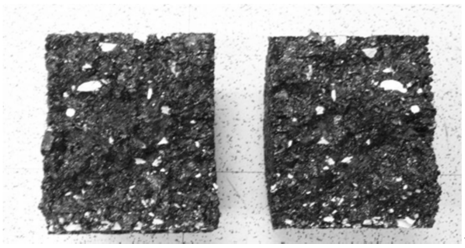
NOTE: Shaded cells indicate cells needing input values

	Wet Subset		
Time in Freezer (Minimum 16 hrs)	19h 44m	19h 16m	18h 54m
Time in 60 C waterbath (24 ± 1 hrs)	23h 30m	23h 30m	23h 30m

Test Time	12/22/2003 5:25 PM	12/22/2003 5:30 PM	12/22/2003 5:35 PM	12/22/2003 4:20 PM	12/22/2003 4:25 PM	12/22/2003 4:30 PM

INSPECT

- Rate the degree of moisture damage on a scale of 0 to 5, with 5 being the greatest amount of stripping



124

SCOPE

- Background
- TSR Role in QC/QA
- Sampling
- Test procedure
- ***Field verification***

125

REPORTING

- Report TSR to the nearest whole %

126

COMPARISON: QC TO QA

TSR -favorable comparison is when QA and QC results are within 10% of each other.

If the difference is 5 to 10%, TSR's are evaluated by MoDOT field office.

If difference is >10%, initiate dispute resolution

QC and QA retained samples may have to be kept for extended periods

127

COMMON ERRORS/ Unfavorable Comparison

- Shaking saturated puck to "adjust" saturated mass
- Using pucks out of the acceptable air void range (7.0±0.5 or 6.0±0.5%)
- Proper water tank temperature not maintained (25 and 60° C)
- Using puck that has been over or under saturated instead of discarding or applying additional vacuum

128

COMMON ERRORS / Unfavorable Comparison

- Using incorrect maximum specific gravity to calculate voids and % saturation.
- Specimen in water bath for the incorrect amount of time.
- Not cleaning breaking apparatus when dirty.
- Not annually verifying breaking machine.

129

COMMON ERRORS / Unfavorable Comparison

- Not molding specimens at correct temperature (if cool, may break aggregate)
- Not aging lab specimens the correct time & temperature (lab-mixed only)
- Not adding 10 ml of water prior to freezing
- Allowing specimens to drain after saturation but prior to freezing.

130

COMMON ERRORS / Unfavorable Comparison

- Using vacuum out of allowable range (10-26 in. Hg)
- Not allowing specimen to "rest" 5-10 minutes after vacuum period.
- Exceeding time of vacuum
- Not air-drying bulked unconditioned pucks for 24 hrs prior to breaking
- Sample contaminated with dust, release agent overspray, etc.

131

COMMON ERRORS / Unfavorable Comparison

- Improper filling of sample into boxes
- Improper mixing and splitting procedures
- One or more mixture re-warmings
- Testing pucks at extreme ends of allowable range of voids [6.5, 7.5] may result in poor QC/QA comparison
- QC and QA not sampling at the same location-type (roadway vs plant) TSR and Rice gravity

132

APPENDIX

Splitting

APPENDIX

Splitting

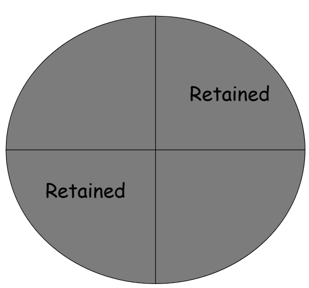
133

TSR Sample Quartering

- ***Sample for TSR is quartered per AASHTO R 47***
- ***Opposing 2 quarters are removed and combined for the retained split.***
- Combine remaining 2 quarters
- Quarter again
- Combine opposite quarters, producing 2 piles
- Quarter each pile. Now have 8 splits.
- Pull 6 pucks.
- Pull Rice if necessary.

134

Opposing 2 quarters are removed and combined for the retained split.



135

- Note-you will need about 175 lbs if you do this step—if not, 75 lbs will work

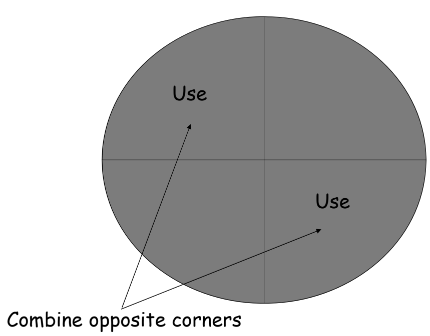
136

TSR Sample Quartering

- Sample for TSR is quartered per AASHTO R 47
- Opposing 2 quarters are removed and combined for the retained split.
- ***Combine remaining 2 quarters***
- Quarter again
- Combine opposite quarters, producing 2 piles
- Quarter each pile. Now have 8 splits.
- Pull 6 pucks.
- Pull Rice if necessary.

137

Combine remaining 2 quarters



138

SAMPLE SIZE

- Need ~ 175 lbs to follow this whole procedure
- Need ~ 75 lbs if you skip the first 3 steps

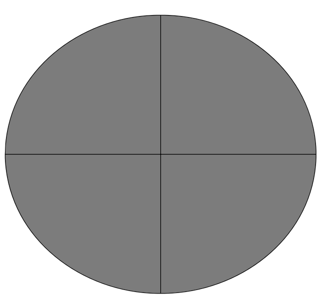
139

TSR Sample Quartering

- Sample for TSR is quartered per AASHTO R 47
- Opposing 2 quarters are removed and combined for the retained split.
- Combine remaining 2 quarters
- ***Quarter again***
- Combine opposite quarters, producing 2 piles
- Quarter each pile. Now have 8 splits.
- Pull 6+ pucks.
- Pull Rice if necessary.

140

Quarter Again



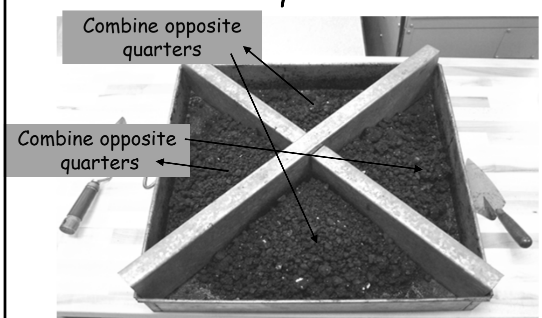
141

TSR Sample Quartering

- Sample for TSR is quartered per AASHTO R 47
- Opposing 2 quarters are removed and combined for the retained split.
- Combine remaining 2 quarters
- Quarter again
- ***Combine opposite quarters, producing 2 piles***
- Quarter each pile. Now have 8 splits.
- Pull 6 pucks.
- Pull Rice if necessary.

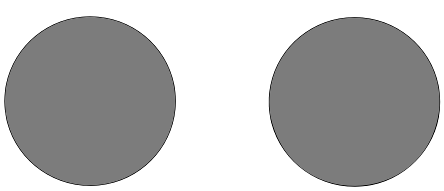
142

Combine opposite quarters, producing 2 piles



143

2 Piles



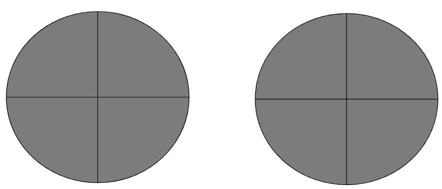
144

TSR Sample Quartering

- Sample for TSR is quartered per AASHTO R 47
- Opposing 2 quarters are removed and combined for the retained split.
- Combine remaining 2 quarters
- Quarter again
- Combine opposite quarters, producing 2 piles
- ***Quarter each pile. Now have 8 splits.***
- Pull 6 pucks.
- Pull Rice if necessary.

145

Quarter each pile. Now have 8 splits.



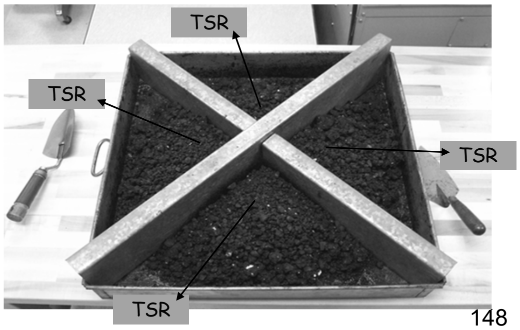
146

TSR Sample Quartering

- Sample for TSR is quartered per AASHTO R 47
- Opposing 2 quarters are removed and combined for the retained split.
- Combine remaining 2 quarters
- Quarter again
- Combine opposite quarters, producing 2 piles
- Quarter each half again. Now have 8 splits.
- ***Pull 6 pucks.***
- ***Pull Rice if necessary.***

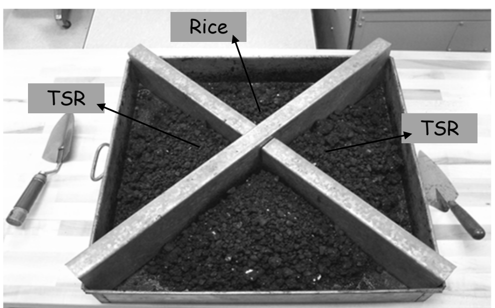
147

Obtain four TSR puck amounts

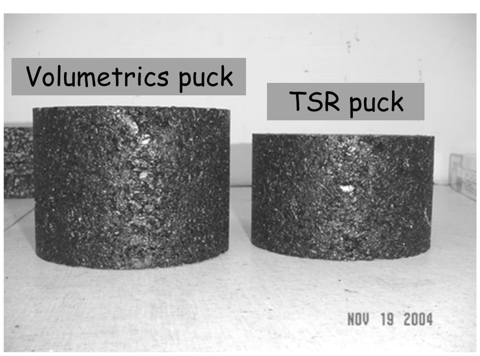


148

Obtain two TSR puck amounts and a Rice



149



150

Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage: Tensile Strength Ratio (TSR): Field-Mixed, Laboratory-Compacted Specimens (AASHTO T 283-14)

1. Per specified sampling frequency, obtain a loose mix field sample to produce a Rice specific gravity test sample (AASHTO T 209) and at least 6 TSR pucks that will be 150 mm (6″) in diameter and 95 ± 5 mm thick after compaction. For QC, approximately 75 pounds of mix will be required for the field sample. QC should obtain an additional 100 pounds to be retained for QA testing. For QA, a 125 lb sample should be sent to MoDOT Central Lab, and an additional 125 lb sample should be retained.
2. Reduce the field sample (AASHTO T 328) into previously determined test sample sizes based on the specific mix.
3. Place each TSR loose mix sample in an oven until it reaches the required compaction temperature ± 3°C (± 5°F).
4. Compact the TSR specimens to 7.0 ± 0.5 % air voids (6.0 ± 0.5% for SMA).
5. Store at room temperature for 24 ± 3 hours.
6. For each puck, obtain the thickness, t, (ASTM D 3549 or from gyro printout) and G_{mb} (AASHTO T 166).

$$G_{mb} = \frac{A}{B - C}$$

A = Dry mass of specimen in air (g)
B = Saturated, surface-dry (SSD) mass of specimen (g)
C = Mass of specimen in water (g)

7. Having obtained G_{mm} for the associated Rice specific gravity test sample, calculate the percent air voids, P_a, for each puck.

$$P_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$$

8. Group the 6 pucks into 2 groups of 3 pucks each such that the average P_a of each group is approximately equal. Designate one group as “dry” or non-conditioned and the other group as “wet” or conditioned.

9. “DRY” GROUP TSR TESTING:

   9.1. After determining G_{mb}, store the pucks (at room temp) for 24 ± 3 hours.
   9.2. Place each designated dry (non-conditioned) puck in a heavy-duty, leak-proof plastic bag. Place each bagged puck in a water bath set at 25 ± 0.5°C (77 ±

1°F) for 2 hours ± 10 minutes, being sure that the pucks are covered by at least 1″ of water.

9.3. Remove the puck(s) from the 25 ± 0.5°C bath, determine thickness, t, and immediately test for indirect tensile strength. [See item #11 below].

10. “WET” GROUP TSR TESTING:

10.1. Place each designated wet (conditioned) puck in a vacuum container (e.g. dessicator) supported at least 1″ from the bottom by a perforated plate. Using potable water, fill the container until the puck is covered by at least 1″ of water.

10.2. Apply a vacuum of 10″ – 26″ (suggested 23″) of mercury (Hg) partial (gauge) pressure for approximately 5 – 10 (suggested 8) minutes.

10.3. During this vacuuming period, prepare for saturation determination by placing a sheet of cling film on a balance and then zeroing the balance.

10.4. At the end of the 5 – 10 minute vacuum period, gradually remove the vacuum and let the puck set submerged in the water for approximately 5 – 10 minutes. NOTE: The time required for some specimens to achieve the correct degree of saturation may be less than 5 minutes. Additionally, some specimens may require more than 26″ of mercury partial pressure or less than 10″ of mercury partial pressure.

10.5. Remove the puck from the vacuum container, quickly surface-dry with a damp cloth, and place the puck on the cling film. Record the saturated, surface-dry (SSD) weight of the puck and calculate the degree of saturation based on the volume of absorbed water as a percentage of the volume of air voids.

$$E = B - C$$

E = Volume of specimen (cm^3)
[Note: B & C are obtained during G_{mb} determination]

$$V_a = \frac{P_a E}{100}$$

V_a = Volume of air voids (cm^3)
P_a = Percent air voids (%)

$$J' = B' - A$$

J' = Volume of absorbed water (cm^3)
B' = SSD mass of specimen after vacuum saturation (g)
[Note: A is obtained during G_{mb} determination]

$$\%Sat = \frac{100\ J'}{V_a}$$

10.6. If the degree of saturation is 70-80%, wrap the puck in the cling film (preserving any moisture that had drained from the puck) and place it in a plastic bag containing 10 ± 0.5 ml of water, and seal the bag. If the saturation level is less than 70%, return the puck to the vacuum container, increase the vacuum to 26″ Hg partial pressure and run at 1-minute intervals (always letting the puck set in the water 5-10 minutes after removal of vacuum) until the saturation requirement is satisfied.
NOTE: When returning the puck to the vacuum chamber, inversion of the puck from the original orientation may facilitate additional air removal and is not disallowed by T 283.

If saturation is greater than 80%, the test is invalid and the puck must be discarded.

10.7. As soon as possible, place the plastic bag containing the puck in a freezer at -18 ± 3°C (0 ± 5°F) for a minimum of 16 hours.

10.8. Upon removing the pucks from the freezer, immediately place them in a water bath set at 60 ± 1°C (140 ± 2°F) for 24 ± 1 hour. As soon as possible, remove the cling film from around the puck. There should always be at least 1″ of water over the pucks.

10.9. Remove the pucks from the 60 ± 1°C bath and place in a 25 ± 0.5°C for 2 hours ± 10 minutes, again assuring at least 1″ of water over the pucks. It may be necessary to use ice to moderate the bath water temperature. No more than 15 minutes should be required to bring the bath water temperature to 25 ± 0.5°C.

10.10. Upon removal of each puck, determine thickness, t′, and immediately test for indirect tensile strength. [See item #11 below].

11. INDIRECT TENSILE TESTING:

11.1. Place the puck between the steel loading strips of the breaking head taking care that the loading strips are diametrically opposed to one another; i.e. the load is applied along the diameter of the puck.

11.2. Place the breaking head into the testing machine.

11.3. Apply the load to the breaking head such that a constant rate of movement equal to 50 mm (2″) per minute is achieved. This is the same load rate as in Marshall testing.

11.4. Record the maximum load and continue loading until a crack is formed along the diameter of the puck.

11.5. Pull the puck apart and visually inspect the interior surface. Check for cracked or broken aggregate and rate the general degree of moisture damage on a scale from 0 to 5, with 5 being the greatest amount of stripping. Record your observations.

12. CALCULATIONS:

12.1. Calculate the tensile strength as follows:

$$S = \frac{2P}{\pi t D}$$

S = Tensile strength (psi)
P = Maximum load (lbs)
t = Puck thickness for “dry” specimen (in.)
t′ = Puck thickness for “wet” specimen (in.)
D = Puck diameter (in.)

12.2. Calculate the tensile strength ratio, TSR, to 2 decimal places as follows:

$$TSR = \frac{S_{(conditioned)}}{S_{(dry)}}$$

$S_{(conditioned)}$ = Average tensile strength of conditioned subset
$S_{(dry)}$ = Average tensile strength of dry subset
Because MoDOT specs are in terms of percent, express TSR as a percentage to the nearest whole number