

Tensile Strength Ratio









Tensile Strength Ratio

2025 Updates

- 2024 2025 NO updates
- 2023 Updates
- AASHTO T283:
 - 60 C Water Bath: The thermometer for measuring the temperature of the water bath shall meet the requirements of M339M/M339 with a temperature range of at least 55 to 65°C (131 to 149°F) and an accuracy of ±0.25°C (±0.45°F) (see note 2),
 - NOTE 2: Thermometer types to use include:
 - ASTM E1 Mercury Thermometer
 - ASTM E879 thermistor thermometer
 - ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, Class A
 - IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, Class AA
 - o **25 C Water Bath**: Meeting the requirements of M339M/M339 with a temperature range of at least 20 to 30°C (68 to 86°F) and an accuracy of \pm 0.13°C (\pm 0.22 °F) (see note 2),
 - NOTE 2: Thermometer types to use include:
 - ASTM E1 Mercury Thermometer
 - ASTM E879 thermistor thermometer
 - ASTM E1137/E1137M Pt-100 RTD Platinum Resistance, special order
 - IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, special order
 - Freezer: Meeting the requirements of M339M/M339 with a temperature range of at least -25 to -10°C (-13 to 14°F) and an accuracy of ± 0.75°C (± 1.35 °F) (see note 3),
 - NOTE 3: Thermometer types to use include:
 - ASTM E1 Mercury Thermometer
 - ASTM E2877 digital metal stem thermometer
 - ASTM E230/E230M thermocouple thermometer, Type T, Special Class
 - IEC 60584. thermocouple thermometer, Type T, Class 1

- Oven: The thermometer for measuring the oven temperature shall meet the requirements of M339M/M339 with a range of at least 25 to 185°C (77 to 365°F) and an accuracy of ± 0.75°C (± 1.35°F) (see note 4),
 - NOTE 4: Thermometer types to use include:
 - ASTM E1 Mercury Thermometer
 - ASTM E230/E230M thermocouple thermometer, Type T, Special Class
 - IEC 60584: thermocouple thermometer, Type T, Class 1

2022 Updates

- 2022 entire manual has been updated.
 - o Several updates for TSR testing Jeff will go over this.

Course Content

Tensile Strength Raito

Updates

TSR Presentation

Background

TSR Role in QC/QA

Sampling for TSR

AASHTO R47 Reducing

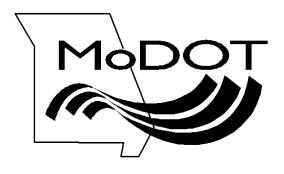
Equipment

Estimation of Puck Mass

AASHTO T283 Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage.

Field Verification

TSR Proficiency



AASHTO T283 TENSILE STRENGTH RATIO (TSR)

Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

Revision March 4, 2022

1

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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SCOPE

- Background
- TSR Role in QC/QA
- Sampling for TSR
- Reducing AASHTO R47
- Equipment
- Estimation of Puck Mass
- 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)





Left, HMA sample with no moisture damage Right, HMA sample with moisture damage. Notice the amount of uncoated aggregate on the right?

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Stripping





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AASHTO Test Methods & Specifications (Specs.)

- R35 Volumetric Design Practice
- M323 Volumetric Design Specs.
- R30 Mix Conditioning
- T312 Gyro operation
- T166 Bulk Specific Gravity of gyratory pucks
- T209 Max Specific Gravity of Voidless Mix (Rice)
- T 283 Moisture Sensitivity
- R 47 HMA Sample Splitting
- D 3549 Thickness of Specimens

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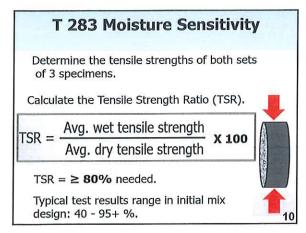
T 283 Moisture Sensitivity

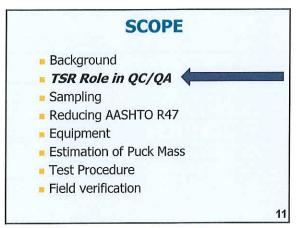
- Measured on proposed aggregate blend and asphalt content.
- Reduced compactive effort to increase voids.
- Uses a minimum of 6 specimens, divide into two sets a dry-set and a wet-set.

Dry Set Unconditioned Wet Set Conditioned

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T 283 Moisture Sensitivity 3 Conditioned Specimens WET SET Vacuum saturate specimens Freeze at -18°C for 16 hrs. Soak at 60°C for 24 hrs. Soak at 25°C for 2 hrs.





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TSR Role in QC/QA Mix design/acceptance Field Verification of mix

Non-Moisture Sensitive

- The intent is for Superpave (sect 403) and Plant mix (sect 401) to 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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Section 401: BB and BP Mixes

- 401.2.1 (Standard Spec):
- During mix design, TSR required when PI exceeds 3 for any individual aggregate fraction with 10% or more passing the #30 sieve.
- 401.9 (Standard Spec):

During production QA checks PI once per project: if an individual aggregate fraction PI > 2 points above mix design value, TSR is required.

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Section 401: 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

■ TSR > 80% for *Superpave* mixes

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TSR Role in QC/QA

- 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 for TSR Reducing AASHTO R47 Equipment Estimation of Puck Mass Test Procedure Field verification

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TSR Field Sample Timing QC/QA

- Sample 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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TSR Field Sampling Frequency QC/QA

- **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 403 spec. (per EPG not enforced).

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TSR Field Sampling - QC

- **QC:** Gets their own TSR sample, plus a retained sample for QA.
 - **Location:** Truck sample, plant discharge, or behind the paver*.
 - *Behind paver, need full depth of the course. (Roadway is Last Resort)
 - **Size:** 75-125 lbs., plus another 125lbs. retained for QA.

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TSR Field Sampling - QA

- **QA:** Gets their own "independent" ~250 lb. sample, retains 125 lbs.
 - Location: Truck sample, plant discharge, or behind the paver*.
 - *Behind paver, need full depth of the course. (Roadway is Last Resort)
 - ■Same place as QC, but at a different time.
 - **Size:** Gets their own independent ~250 lb. sample, retains 125 lbs.

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CAUTION

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

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Loose Mix Sampling Location

- Truck
- Asphalt Plant Discharge
- Roadway*
 - *Last Resort

SAFETY: Always wear PPE when sampling asphalt.



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TRUCK SAMPLING

Preferred

Use a platform with rails.



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Truck Sampling

- Obtain at least 3 approximately equal increments from random locations.
- Remove approximately 6 inches of the surface material from the sampling area.
- Obtain a random increment from the exposed surface and place in buckets or boxes.
- Move to the next location and repeat the process until enough material is collected.
- Combine to form a sample of the required size, close the container and mark with ID. 27

Truck Sampling Issues

- Possible segregation in truck bed.
- Sampling methods (e.g., 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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PLANT DISCHARGE SAMPLING



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Plant Discharge

(Chop Gate-Diverter Chute)

- Divert entire production stream from drum to a loader bucket.
- Sample across the loader bucket, one shovel per box, all boxes.
- Repeat until buckets/boxes are full.
- Cool (Beware of dust).
- Close bucket/boxes.
- Write sample information the containers.

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Plant Discharge

Diverter Chute Issues

 Contamination issues from diesel used to clean the area.

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MINI-STOCKPILE SAMPLING



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Mini-Stockpile - Option 1

- About 2 tons sampled from silo discharge into a truck.
- Dumped
- Back dragged
- Obtain approximately equal increments from at least 1 foot from the edge.
- Insert the shovel, exclude underlying material.
- Place the sample increments into clean buckets or boxes, close container, identify.

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TSR Sampling-Roadway

- Before compaction
- Using a template or a square nose shovel, clearly mark out an area to be removed.
- Remove all mixture within the area.
- Do Not contaminate sample with underlying material.
- Place material into clean containers.
- Close or cover containers.
- Mark information on outside of containers.

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TSR Sampling-Roadway Roadway Issues

- Profiler issues?
- Big hole to fill.

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QA TSR Sample

- Field QA should sample a 125 lb. sample.
 - Ship to the lab at least 4 FULL boxes of TSR sample the size of 13" x 13" x 4.5"
- 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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QA TSR Sample

- QA inspector will box up 125 lbs. of loose mix sample and ship to the Central Lab for testing
- Each box should contain a representative sample that includes all fines, etc.





*** Send to MoDOT Laboratory
4 - FULL boxes of TSR sample the size
of 13" x 13" x 4.5"

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QA - TSR Box Information

On each full box of asphalt, write the following ON THE SIDE of the box:

- 1. AWP ID number.
- 2. Mix number.
- 3. G_{mm} from sublot taken (QC or QA).
- 4. Specimen weight QC is using.

Note: Permanent marker on the side of the box is the preferred method of labeling.



QA TSR Sample

- Central Lab will determine the TSR puck weight to be used from testing one of the boxes.
- Central Lab will combine the remaining boxes and go through the AASHTO R47 procedure.

Communicate: Field techs and Laboratory techs. if boxes were filled one-at-a-time in the field, then the **first box** may not be the same as the other **three**. Communicate to the laboratory if the boxes were filled this way.

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SCOPE

- Background
- TSR Role in QC/QA
- Sampling for TSR
- Reducing AASHTO R47
- Equipment
- Estimation of Puck Mass
- Test Procedure
- Field verification

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Reducing

- Re-heat and combine field samples by mixing all boxes.
- EPG: The sample will be thoroughly mixed and quartered in accordance with AASHTO R47, or with an approved splitting/quartering device. Two opposite quarters will be retained for testing during the dispute resolution process, if necessary. The remaining two quarters will be mixed and quartered again and then tested.
- R47, See your "Bituminous Technician Manual"

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SCOPE Background TSR Role in QC/QA Sampling for TSR Reducing AASHTO R47 Equipment Estimation of Puck Mass Test Procedure Field verification

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Equipment

- Gyratory compactor & 150 mm diameter molds (section 403).
- Oven: room temperature up to 176 ±3 °C.
- Balance
- Rice specific gravity equipment.

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Equipment

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

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Equipment

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

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Equipment

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

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SCOPE

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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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Estimate TSR Puck Mass

- V_{solids} = (Mass)/(specific gravity)
- Vair = Vtotal Vsolids
- Mix is constantly changing:
 - Bin % changes.
 - Exact %'s of each material is changing.
 - Each material has a different specific gravity.
- So, volumes of each material are changing.
- So, puck mix mass must change to keep 7.0% air voids constant.

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TSR

Estimate 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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Estimate TSR Puck Mass

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



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Estimate TSR Puck Mass

Moving target:

(15.0cm)
150 mm

(9.5cm)
95 mm

Mass to get 7.0% air voids

But...character of the dimples changes:



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

E /

Calculation of Mass Required For 7.0% AIR VOIDS Step # 1

- From historical test data of QC or QA volumetric pucks, average several G_{mb} values appropriate for the TSR sampled mat area: G_{mb,meas}
- Average the mass (M_{meas}) of each of the G_{mb} pucks.
- Average the puck height (from gyro printout) h @ N_{des} (h_x) of each of the G_{mb} pucks.

 h_x in "cm" for historical pucks. (Usually 11.5 ± 0.5 cm)

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G_{mb,est} Step #2

- Next, compute the G_{mb} as if there were no side voids (dimples) = $G_{mb,est}$
- Gmb, $estimated = \frac{Avg.Mmeas}{\binom{\pi d^2(avg h_X)}{4}} \underset{hx}{|}$

Note: d and h are in cm

- Thus, for the same mass, the volume will be larger for G_{mb,est} and so G_{mb,est} will be smaller (Same mass spread over a larger volume)
- So, $G_{mb,meas}$ will be $> G_{mb,est}$

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Calculation of Mass Required For 7.0% AIR VOIDS Step # 3

Calculate "C" Step #1

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

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

Step #2

Apply "C" to TSR pucks

Calculation of Mass Required For 7.0% AIR VOIDS Step # 4

• Obtain G_{mm} for the sampled roadway mat area.

$$Vair = \frac{100(G_{mm} - G_{mb})}{G_{mm}}$$

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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 Step # 4

 Calculate the required puck *mass* for 7.0% air voids (Mass = Vol x Sp Gravity).

Mass =
$$\frac{[(0.93)(\pi)(d^2/4)(h)](Gmm)}{6}$$

h = 9.5 cm for TSR pucks

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Alternate Equation Step #4, cont'd.

- If (d=15.0 cm) and (h = 9.5 cm):
- $Mass = \frac{1561.2 \, Gmm}{C}$

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	E	xam	ple '	TSF	R Mas	S	eva	ARGEL
					ric Puc			
		assEstimate xls			TSR PUCK MASS			
	Job No.				Ma Type		1	
	Route				Fermations			
	County				Ledges			
	Contractor				Binder Type			
	Date				Binder Amount, %			
	Gyro Puck Int	form a tion:						
	Specimen	1	2	3	4	Avg		
	Limeas(g)	4601.7	4599	4600.3		46,00 0		
	Gmb,meas	2.321	2314	2 325		2 3 2 0	Step	#1
	h, Ndes(mm)	114.3	114.6	114.5		114.5		
	Mmeasavg	dlam,avg(cm)	h, Ndes(cm)	Gmb.est	Gmb.measavg	C	Gmm	1
	4500 0	15.0	11 45	2273	2.320	1 020	2 427	
	gi	3 141592654	1	1		//	Ma 22(0)	
		1	V			The aretical mass	3713	
	Step #3:	1	1		//	Additional material		
and the second	CZ STEP #FO	(Gromess avg)	/ Gmb est			Other adjustments		1
istorical volumetric			1			Total mass	3713	
icks	Step #2:	(Umeas avg) / (g	cindizon N	dea) / 4]	//			
2000000	Step #4:							
	Dieb ma-	(0.93)"((ci)"(d'2)"	OF SHILL ATTOR	min) / C				

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SCOPE	
 Background TSR Role in QC/QA Sampling for TSR Reducing AASHTO R47 Equipment Estimation of Puck Mass Test Procedure 	
Field verification	63

Example TSR Mass Using 3 Volumetric Pucks

	QCQA\TSRmassEstimate.x	ssEstimate.xls			TSR PUCK MASS ESTIMATION	ESTIMATION		
	Job No.				Mix Type			
	Route				Formations			
	County				Ledges			
	Contractor				Binder Type			
	Date				Binder Amount, %			
	Gyro Puck Information:	ormation:						
	Specimen	-	2	က	4	Avg		
	Mmeas(g)	4601.7	4598	4600.3		4600.0		
	Gmb, meas	2.321	2.314	2.325		2.320	Step #1	
	h, Ndes(mm)	114.3	114.6	114.5		114.5		
					\			
	Mmeas,avg	diam,avg(cm)	h,Ndes(cm)	Gmb,est	Gmb, meas.avg	၁	Gmm	
	4600.0	15.0	11,45	2.273	2.320	1.020	2.427	
				1				
	id	3.141592654	7				Mass(g)	
			\downarrow			Theoretical mass	3713	
	Step #3:		\ _			Additional material		
	C=	(Gmb, meas.avg)	/ (Gmb,est)			Other adjustments		
Historical volumetric 🗕	Sten #2:		→			Total mass	3713	
bucks	Gmb,est=	(Mmeas,avg) / [(/ [(pi)*(d^2)*(h,Ndes) / 4]	es) / 4]				
	Sten #4:			/				
TSR puck	TSR puck Mass=	$(0.93)^{*}[(pi)^{*}(d^{2})^{*}(9.5)] / 4]^{*}(Gmm) / C$	(9.5)] / 4]*(Gn	лт) / С				

TSR Field Test Procedure Overview

- 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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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.

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Procedure

 The following slides relate to TSR testing of *field* samples and to *lab-mixed* samples after the first day.

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DAILY PROCEDURE Outline

- Day 1:
 - Sample, quarter, heat to compaction temperature [for lab-mixed, heating time is 2 hr. ± 10 min.]
 - Compact pucks
 - Run Rice gravity
 - Determine G_{mb} of pucks
 - Calculate air voids
 - Group into two sets of 3
 - Saturate the Wet set
 - Put Wet set into freezer
 - Set aside Dry set

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DAILY PROCEDURE Outline

- Day 2:
 - Start high temperature conditioning of Wet set.
- Day 3:
 - Test strength of Dry and Wet set
 - Calculate TSR

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TEST PROCEDURE: Day 1

- Warm the mix to soften it for quartering, (no specified temperature or time), then quarter.
- Reheat the mix to compaction temperature ± 3 °C.

(Field mix: *no specified time*; Lab mix: *2 hr. ± 10 min.*)

- Compact: 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]

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DAY 1

- Set gyro to "Height control" mode.
- Compact 6+ pucks.
 (Actually, will make one or more trial pucks; may also wish to compact several extra pucks).



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Tender Pucks

- · Extrude the puck from the mold.
- · Remove mold lid and 1st paper disc.
- Cool for few minutes for stability before handling.
 Pucks will be <u>tender</u> while hot!
- Without distorting the puck, move it from gyratory to a cooling table.

In this move, flip the puck over before sitting it down on the cooling table to remove the 2nd paper disc.

- ID the puck
- Allow to cool at room- temperature.
- · Determine air voids by AASHTO T166.

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DAY 1: Determine Air Voids

■ Determine G_{mb} for all 6 pucks. (Follow <u>AASHTO T166</u> - Pucks need to be tested at **25** ± **1**° **C**).

Note:

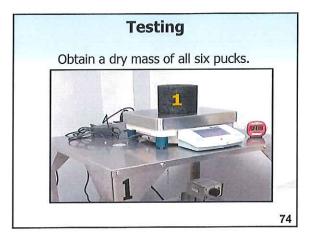
See your Bituminous Technician Manual for AASHTO T166 Bulk Specific Gravity,

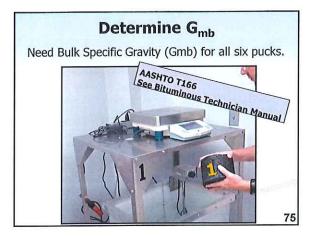
And AASHTO T269 Percent Air Voids. See your Superpave Manual for AASHTO T209 Maximum Specific Gravity.

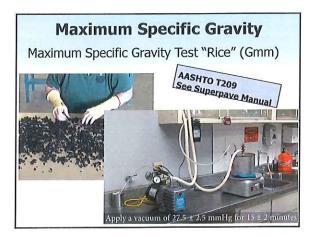


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Gmb Worsahest		Dry Subtest			Wet School		1	Enl
ficecimen #	1000	7	,	4	8	- 5		
Weight in an (g) (A)	3722.6	3749.7	3755.1	3432.4	27537	2642.3	4	
SSO Weight (c) IEI	2725.6	37610	37650	2833.5	3770 7	3767.9	1	
Weight in wider (p.) [C]	21142	2132.9	21,40.2	2160.0	31113	2054.9	4	
Heatt 9 t cm st	2.5	9.5	1.5	9.7	9.5	9.5	A Longitude	
Complement of Co.	1471	1575	1825	1654	1525		8-51	
9mb (4 /18 - C)	2.298	2.797	2311	2312	2.312		4(8-C)	
NATVOCS PA	1.2	6.3	6.7	6.5	6.6		tog Gmm Gmt/Gmm	
Dry volume of ex (orn) (v.e.) Average % Air Volds	117	1111	168	Vet.	103	_	FA(8-C)/100	
Creat							1	
TSR Warlahard	1	Dry Subert	- No. 100	U.S. 100	Wat Subret		1	
Specimen #	1 1	1 2	1 1		5		1	
Height 0 I cm II	9.5	8.5	3.5	9.7	9.5	9.5	1	
Mac Leaf (he Pl	2612	3(01	2751	1004	1517	1157	1	
hd Tore Striffs (sey	111	104	108	44	44		1.4516'2P/3.1415D	
*For 15 5 cm dameter spe	Contt!	Charge and Sept	Wt (2)(8)	3997.3	20110	3767.3	Supplied to the	
1+2 Wet (15 (20) (5 net		Wegatioaire	(274)	3822.4	3759.7	-	1	
Are Do ITS (call 5cm)	104	Vet Absorb H	2 (cm)(J)	61	64		3-7	
TSR (%11005 web 5 cm)		Dry volume of a	A (may (VA)	110	105		1	
Liconaudan Contra		75% Sat (Tarpet		3859	2638		3-37/3	
	AVG	10% Sat Clarge	(VESO)	2910	3648		1-08/8	
Ale Violde (%)		% 5 aturatio		73	20		100JNs	
Dry Subset 142ir	5.2		in Ha	22	23	23		
Wet Subset title		3	Torre (min)				4	
Saluration (%)]	in, Hg	2	25	24	4	
		Dry Subset	Time (ma)				1	
Time in 25 C varieties	19.50	In Min	23					
(Z to a a 10 min)					Wat Section .		-	
NOTE: Studed calls Indical		Time of the		195 4477	19h 16m	150 5401	J	
cels needing input y	alije s	(Stinferum 16		-	-		1	
		Time in 60 Clust		23h 33m	23h 30m	23th 30th	1	

Puck Bulk Spe From Example Sprea	
$G_{mb} = \frac{A}{B-C}$	BSG of Compacted HIWA • AC mixed with agg, and compacted into sample
$G_{mb} = \frac{3725.8}{3735.6 - 2114.3}$	Mass agg. and AC Gug = Vol. agg., AC, air vold
Gmb = 2.298	78

Mix Number Example					Gmm =	2.476	
Gmb Worksheet		Dry Subset			Wet Subset		
Specimen #	1	2	8	4	5	9	
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 - Cl	1621	1625	1625	1654	1626		[B-C]
Gmb [A / (B - C)]	2.298	2.307	2.311	2.312	2.312		A/[B-C]
[W Air Voids [Pa]	7.2	8.9	6.7	9.9	9.9		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			
Cveral							
TSR Worksheet		Dry Subset			Wet Subset		
Specimen #	1	2	е	4	5	9	
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 speci	imen[D]	Vacuum <u>SSD</u> Wt. (g)[B']	/t. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	ع)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H ₂ O (cm³)[J]	(cm³)[J]	81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm³)[Va]	r (cm³)[Va]	110	108		
•		70% Sat. (Target VSSD)	VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	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)	_	_	_	
Time in 25 C waterbath	1h 50m	Dry Subset 1h 55m	2h				
(2 hrs ± 10 min)					Wet Subset		
NOTE: Shaded cells indicate		Time in Freezer	ī	19h 44m	19h 16m	18h 54m	
cells needing input val	lues	(Minimum 16 hrs)	hrs)				
		Time in 60 C waterbath (24 ± 1 hrs)	erbath	23h 30m	23h 30m	23h 30m	
Test Time	12/22/2003 5.25 DM	12/22/2003 5:30 PM	12/22/2003 5.35 PM	12/22/2003	12/22/2003	12/22/2003	
	0.20 F W	0.50 T M	N	4.20 F IVI	4.62 T	1.00.4	

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

- $P_a = \%$ air voids
- G_{mm} = Maximum specific gravity of the voidless mix (Rice sp gravity)
- **G**_{mb}= Spec. gravity of the compacted mix

80

79

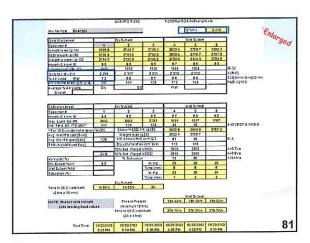
Determine %Air Voids From Example Spreadsheet Puck #1

 Having tested Maximum Specific Gravity, (Rice), calculate air voids of each puck:

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

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

80



Section Example Example								
Dry Subset 3 4 5 6 5.8 3749.7 3755.1 3822.4 3759.7 3692.3 5.6 3761.0 3765.0 3833.5 3770.7 3707.9 4.3 2135.9 2140.2 2180.0 2144.3 2094.9 4.3 2135.9 2140.2 2180.0 2144.3 2094.9 3.8 1625 1625 1624 1626 9.5 9.5 3.8 1625 1624 1625 1626 9.5	П					Gmm =	2.476	
2 3 4 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	ksheet		Dry Subset			Wet Subset		
5.8 3749.7 3755.1 3822.4 3759.7 3692.3 4.3 2135.9 2140.2 2180.0 2144.3 2094.9 4.3 2135.9 2140.2 2180.0 2144.3 2094.9 5 9.5 9.5 9.7 9.5 9.5 8 2.307 2.311 6.6 6.6 6.6 7 111 108 Wet 110 108 9 5 9.5 9.7 9.5 9.5 1 108 4.4 4.4 147 1 108 4.4 4.4 147 1 104 108 4.4 4.4 147 1 104 108 4.4 4.4 147 1 104 108 4.4 4.4 147 2 360.1 3761 166 6.6 6.6 2 360.1 3761 166 9.5 9.5 9.5	#	1	2	က	4	5	9	
5.6 3761.0 3765.0 3833.5 3770.7 3707.9 4.3 2135.9 2140.2 2180.0 2144.3 2094.9 5.3 9.5 9.5 9.7 9.5 9.5 5.8 1625 1624 1626 9.5 8.8 2.307 2.311 6.6 6.6 9.5 7 111 10.8 110 10.6 110 7 111 10.8 110 10.6 110 8 6.6 9.5 9.5 9.5 9.5 9.5 3.60.1 3.761 156.4 151.7 1197 1. 1.04 1.08 4.4 4.4 149 1. 1.04 1.08 4.4 4.4 149 1. 1.04 1.08 4.4 4.4 149 2. 3.60.1 3.761 1.664 1.57 1.197 3. 3.60.1 1.08 4.4 4.4	air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
4.3 2135.9 2140.2 2180.0 2144.3 2094.9 5 9.5 9.5 9.7 9.5 9.5 4.4 1625 1625 1654 1626 9.5 2.307 2.311 2.312 2.312 9.5 2.307 2.311 2.312 2.312 9.5 3. 6.6 6.6 6.6 6.6 4. 111 108 110 108 5 9.5 9.5 9.7 9.5 9.5 5 3601 3761 1564 1517 1197 1 104 108 44 44 1197 5 3601 3761 382.4 3759.7 3846.0 3787.3 8 √ol. Absorb H ₂ O (cm)[J] 81 86 8 8 9 Vol. Absorb H ₂ O (cm)[J] 382 3835 23 33 9 No. Sat (Target ∨SSD) 3899 3835 24 38 <td>ght (g) [B]</td> <td>3735.6</td> <td>3761.0</td> <td>3765.0</td> <td>3833.5</td> <td>3770.7</td> <td>3707.9</td> <td></td>	ght (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
5 9.5 9.5 9.7 9.5 9.5 44 1625 1625 1626 9.5 9.5 9.5 28 2.307 2.311 2.312 2.312 2.312 7 6.8 6.7 6.6 6.6 6.6 6.6 7 111 108 Wet Wet Wet Wet Wet 9 9.5 9.5 9.7 9.5 9.5 9.5 9.5 5 9.5 9.5 9.7 9.5 9.5 9.5 9.5 5 9.5 9.5 9.7 9.5 9.5 9.5 9.5 5 9.5 9.5 9.7 9.5 9.5 9.5 9.5 5 9.5 9.5 9.7 9.5 9.5 9.5 9.5 5 9.5 9.5 9.7 9.5 9.5 9.5 9.5 6 9.5 9.5 9.7 9.5	water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
4 1625 1625 1626	1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
2 (a) 2.307 2.311 2.312 2.312 (a)	,m³) [B - C]	1621	1625	1625	1654	1626		[B-c]
2 6.8 6.7 6.6 6.6 6.6 6.6 6.6 6.6 6.6 6.6 6.6 6.6 6.6 6.6 7 7 7 7 7 7 7 7 7 7 8 7 8 9 9 9 9 <th< td=""><td>(B - C)]</td><td>2.298</td><td>2.307</td><td>2.311</td><td>2.312</td><td>2.312</td><td></td><td>A/IB-C]</td></th<>	(B - C)]	2.298	2.307	2.311	2.312	2.312		A/IB-C]
7 111 108 110 108 y 6.9 Wet 110 108 y 6.9 Wet Wet Subset 5 9.5 9.5 9.5 9.5 5 9.5 9.5 9.5 9.5 5 3601 3761 1564 1517 1197 10 108 44 44 44 44 104 108 44 44 44 44 44 104 108 44		7.2	8.9	6.7	6.6	9.9		100[Gmm-Gmb]/Gmm
y 6.9 Wet Wet Subset Dry Subset 3 4 5 6 5 9.5 9.5 9.7 9.5 9.5 104 3761 1564 1517 1197 10 104 108 44 44 44 1 104 108 44 44 44 1 104 108 44 44 44 4 108 44 44 44 44 4 108 3802.9 3846.0 3787.3 8 Weight in air (g)[A] 3822.4 3759.7 3787.3 8 Voi. Absorb H ₂ O (cm²)[V] 81 8 8 9 Voi. Absorb H ₂ O (cm²)[V] 110 108 73 10 Noi. Absorb H ₂ O (cm²)[V] 3899 3835 90 10 % Sat (Target VSSD) 3910 3846 8 10 % Sat (Target VSSD) 373 25 26	ie or air (cm.)[vaj	111	111	108	110	108		Pa[B-C]/100
Dry Subset Wet Subset 2 3 4 5 6 5 9.5 9.5 9.5 9.5 9.5 10 3761 1564 1517 1197 1 104 108 44 44 1197 1 104 108 382.4 3759.7 3787.3 Weight in air (g)[A] 81 86 382.4 3759.7 3787.3 Noi. Absorb H₂O (cm²)[J²] 81 86 8 8 Dry volume of air (cm²)[Va] 110 108 3835 23 6 80% Sat. (Target VSSD) 3899 3835 23 23 8 8 8 8 8 8 9% Saturation in. Hg 25 26 24 1 1 1 1 1 0m 1h 55m 2h 25 26 24 1 1 1 1 1 1	% Air Voids	Dry	6.9		Wet			
Dry Subset Wet Subset 2 3 4 5 6 5 9.5 9.7 9.5 9.5 9.5 3761 1564 1517 1197 1 108 44 44 1197 1 108 44 44 1197 1 108 44 44 44 4 108 44 44 44 4 108 44 44 44 4 108 44 44 44 4 108 44 44 44 4 108 44 44 44 4 44 44 44 44 4 44 44 44 44 4 44 44 44 44 8 8 8 8 8 90 8 8 8 8 100 8								
2 3 4 5 6 6 5 9.5 9.5 9.7 9.5 9.5 9.5 104 108 44 44 1107 1197 1108 144 44 1197 1108 144 44 1197 1108 144 44 1197 1108 144 44 1197 1108 144 144 144 1108 170% Sat. (Target VSSD) 3910 3846 1109	ksheet		Dry Subset			Wet Subset		
52 9.5 9.7 9.5 9.5 12 3601 3761 1564 1517 1197 10 108 44 44 1197 104 108 44 44 1197 104 108 3802.9 3846.0 3787.3 8 Vol. Absorb H₂O (cm²)[J²] 81 86 80 Dry volume of air (cm²)[Va] 110 108 708 To% Sat. (Target VSSD) 3899 3835 80 B 80% Sat. (Target VSSD) 3910 3846 8 % Saturation in. Hg 22 23 23 B 8 8 8 8 In. Hg 25 26 24 Time (min) 1 1 1 Dry Subset 1 1 1 Time in Freezer 19h 44m 19h 16m 18h 54m (Minimum 16 hrs) 23h 30m 23h 30m 23h 30m	# "	1	2	က	4	5	9	
22 3601 3761 1564 1517 1197 1 104 108 44 44 1197 1 104 108 44 44 1197 2 104 108 378.0 378.0 3787.3 8 Weight in air (g)[A] 81 86 3759.7 3787.3 8 Vol. Absorb H₂O (cm³)[V³] 81 86 88 88 9 70% Sat. (Target VSSD) 3910 3846 88 8 9 8 8 8 8 8 9 73 80 23 23 9 73 80 24 1 1 1 1 1 1 1 1 1 1 1 2 2 26 24 24 1 1 1 1 1 1 1 1 1 1 1	.1 cm) [t]	9.5	9.5	9.5	9.7	9.5	9.5	
1 104 108 44 44 44 44 44 44 44 44 44 44 44 44 44	d (lbs) [P]	3852	3601	3761	1564	1517	1197	
Vector of Meight in air (9][8] 3902.9 3846.0 3787.3 8 Vol. Absorb H₂O (cm²)[J²] 81 86 8759.7 9 Vol. Absorb H₂O (cm²)[J²] 110 108 7759.7 10 Absorb H₂O (cm²)[J²] 110 108 86 86 10 Dry volume of air (cm²)[V³] 3899 3835 3835 23 10 Sat. (Target VSSD) 3910 3846 88 7 7 1 1<	. Str.:ITS (psi)*	111	104	108	44	44		6.4516*2P/3.1415tD
Aveight in air (g)[A] 3822.4 3759.7 Ansile 108 Vol. Absorb H₂O (cm³)[V³] 81 86 Percentage AvG Dry volume of air (cm³)[V³] 110 108 Percentage AvG 80% Sat. (Target VSSD) 3899 3835 Percentage AvG 80% Sat. (Target VSSD) 3910 3846 Percentage Fe.9 % Saturation 73 80 Percentage Fe.9 Percentage 22 23 23 Time (min) 8 8 8 Reservable In. Hg 25 26 24 Time (min) 1 1 1 In. Hg 25 26 24 In. Hg 25 26 24 In. Hg 25 26 24 In. Hg 1 1 1 In. Hg 25 26 24 In. Hg 25 26 24 In. Hg 1 1 <t< td=""><td>cm diameter spec</td><td>imen[D]</td><td>Vacuum SSD W</td><td>/t. (g)[B']</td><td>3902.9</td><td>3846.0</td><td>3787.3</td><td></td></t<>	cm diameter spec	imen[D]	Vacuum SSD W	/t. (g)[B']	3902.9	3846.0	3787.3	
108 Vol. Absorb H₂O (cm²)[J]	ITS (psi)[Swet]		Weight in air (g	(J)[A]	3822.4	3759.7		
AVG Bry volume of air (cm³)[Va] 110 108 108 100 108 100 108 100 108 100 108 100	TS (psi)[Sdry]	108	Vol. Absorb H ₂ O	(cm²)[J']	81	98		B'-A
AVG 80% Sat. (Target VSSD) 3899 3835 Page No. Sat. (Target VSSD) 3910 3846 Page No. Sat. (Target VSSD) Page No. Sat. (Target VSSD) Page No. Sat. (Target Min. Hg 22 23 23 23 23 Page No. Sat. (Target Min. Hg Page No. Sat. (Min. Hg <t< td=""><td>100Swet/Sdry]</td><td></td><td>Dry volume of air</td><td>r (cm³)[Va]</td><td>110</td><td>108</td><td></td><td></td></t<>	100Swet/Sdry]		Dry volume of air	r (cm³)[Va]	110	108		
AVG 80% Sat. (Target VSSD) 3910 3846 Page 1 6.9 % Saturation in. Hg 22 23 23 Time (min) 8 8 8 8 in. Hg 25 26 24 Time (min) 1 1 1 In. H50m Time (min) 1 1 1 Int 50m 1h 55m 2h 2h 24 Int 50m 1h 55m 2h 1 1 Int values Time in Freezer 19h 44m 19h 16m 18h 54m Itime in 60 c waterbath 23h 30m 23h 30m 23h 30m			70% Sat. (Target	VSSD)	3899	3835		A+0.7Va
6.9 % Saturation 10. Hg 22 23 23 Image (min) 8 8 8 8 Image (min) 8 8 8 8 Image (min) 8 8 8 8 Image (min) 1 1 1 1 Image (min) 1 1 1 1 Image (min) 2h 2h 24 24 Image (min) 2h 1 1 1 Image (min) 1h 2h 1 1 Image (min) 1h 1h 1h 1h 1h Image (min) 1h		AVG	80% Sat. (Target \	VSSD)	3910	3846		A+0.8Va
6.9 in. Hg 22 23 Time (min) 8 8 8 In. Hg 25 26 26 In. Hg 25 26 26 In. Hg 25 26 26 Time (min) 1 1 1 1 1 Time (min) 1 1 1 1 1 Time in Freezer 19h 44m 19h 16m 1 Time in 60 C waterbath 23h 30m 23h 30m	(%)		% Saturation		73	80		100J'/Va
Time (min) 8 8 8 8 8 8 8 8 8 8 8	et %Air	6.9		in. Hg	22	23	23	•
in. Hg 25 26 26 Time (min) 1 1 1 Dry Subset 1h 50m 1h 55m 2h Wet Subset Time in Freezer (Minimum 16 hrs) Time in 60 C waterbath 23h 30m 23h 30m	set %Air			Time (min)	8	8	8	
Dry Subset Time (min) 1 1 1h 50m 1h 55m 2h Wet Subset Micate Time in Freezer 19h 44m 19h 16m ut values (Minimum 16 hrs) 23h 30m 23h 30m Time in 60 C waterbath 23h 30m 23h 30m	n (%)			in. Hg	25	26	24	
1h 50m			400	Time (min)	_	_	_	
Wet Subset 19h 44m 19h 16m	5 C waterbath	1h 50m	Uly Subset	2h				
Wet Subset Time in Freezer 19h 44m 19h 16m (Minimum 16 hrs) 23h 30m 23h 30m	± 10 min)							
Time in Freezer 19h 44m 19h 16m ues (Minimum 16 hrs) Time in 60 C waterbath 23h 30m 23h 30m						Wet Subset		_
(Willimum 16 mls) Time in 60 C waterbath 23h 30m 23h 30m	naded cells indicate	<u> </u>	Time in Freez	.er	19h 44m	19h 16m	18h 54m	
2011 30111 20111	ils needing input va	Ines		ırs)	20 you	200 dcc	20 ACC	
\\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-			I ITTE IN OU C Wate	Path L	23FI 3UFFI	Z3N 30III	23FI 3UIII	

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

12/22/2003 5:30 PM

12/22/2003 5:25 PM

Test Time

AIR VOIDS Two Similar Groups "Wet" and "Dry"

Group the pucks into 2 groups such that average air voids of each group is about equal.

Pa, avg. =
$$\frac{Pa1 + Pa2 + Pa3}{3}$$

 Testing pucks at extreme end of allowable voids may lead to poor QC/QA comparison.

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Mix Marrier Example					ŭna•	2,474	1
Sinc than sheet		Dry Subset			Wit Subert		1
Seacmen #		7	2	4		4	1
Creines in as set 141	3775.3	3749 7	2755.1	3972.4	3759.7	3692.3	1
SSO Weight (a) El	3774.6	2751.0	37/50	38335	3770.7	2707.9	1
melett in water (a) FCI	2114.2	2105.9	2140 2	21000	71443	7094.9	1
Height (0.1 cm) 16	9.5	9.5	9.5	9.7	9.5	25	
reuneren's B - Cl	1521	1025	1125	1554	1525	9 9 9 9	B-CI
GTC GA/(E+C)	2 2 9 9	2 307	2.311	2312	2 312		A/B-C
SAY Voice IPal	72	5.8	67	6.4	3.5		toggamaans; an
On volume of an ion (Val.		111	109	113	100		P48-C(100
Cremit Control	Dry		H	Wet		П	
TER Armonaut		Dry Subset			Wet Subjet.		1
Snacmen #	1	2	1	- 4		- 5	1
Height in 1 cm/life	9.5	9.5	9.5	9.7	2.5	9.5	1
War Land Charles	3952	3401	3751	1554	1517	1197	
trá Tera St. ITS iguir	111	134	178	44			5 451572FIG 141510
*For 150 cm cameler age :	MANUE !	Yacuum 550		2922.9	3045 0	37673	
fag Trat iTS ten (Swet)		Wegtins	(2)(4)	31724	3750.7		ł
4.4 CY (T3 (50) [50)]	191	Vol. Absorb H.		81	86		E-A
TSR (% \$1000 m # 5 dy)		Dry volume of		157	114		0.0000000
		70% Sat. (Targe		3899	3135		A-27/a
	AVS	09% 3st (Targe		2312	3645	_	A+DEVA
Az Veids (%)		5 SMIR		73	80		1003774
Cn Swad 44r	6.9		in Ho	22	23	2)	
Wat Bobart SAIr		1	Time (min		1		
Seturation (%)			in Ha	25	25	24	
		Dn Subset	Tre (met				,
Tyme in 25 C waterbath (2 type 10 min)	m ton	nita	25				
HOTE: Staded cults include		True in Fre	era.	125 ALT	With Store	181 541	3
cats neading input va		Stonynt	hest.	1000			3
		Time in FOC as				23h 20m	

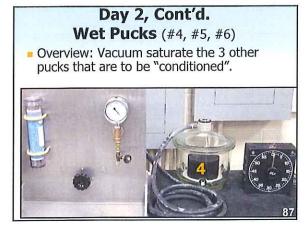
83



Mix Number Example					Gmm =	2.476	
Gmb Worksheet		Dry Subset			Wet Subset		
Specimen #	_	2	3	4	2	9	
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	9.9		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 #	_	2	8	4	5	9	
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]	men[D]	Vacuum SSD Wt. (g)[B']	Vt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H ₂ O	(cm²)[J]	81	98		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm³)[Va]	r (cm³)[Va]	110	108		
		70% Sat. (Target VSSD)	VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	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	œ	
Saturation (%)			in. Hg	25	26	24	
			Time (min)	1	1	_	
		Dry Subset					
Time in 25 C waterbath	1h 50m	1h 55m	2h				
(2 hrs ± 10 min)					Wet Subset		
NOTE: Shaded cells indicate		Time in Freezer	Zer	19h 44m	19h 16m	18h 54m	
cells needing input values	nes	(Minimum 16 hrs)	hrs)				
· ·		Time in 60 C waterbath	erbath [23h 30m	23h 30m	23h 30m	
		(24 ± 1 hrs)					
Test Time	12/22/2003 5.25 PM	12/22/2003 5-30 PM	12/22/2003 5-35 PM	12/22/2003	12/22/2003	12/22/2003	
_	N 102.0	2000	200.0	1.52.1	1.501 181	2 - 00:+	

Unconditioned "Dry Set" (#1, #2, #3) The unconditioned set should be set aside at room temperature until the conditioned set is ready for strength testing. Dry Set Unconditioned





Vacuum Saturation Wet Pucks (#4, #5, #6)

- 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.

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Day 1: Wet Pucks (#4, #5, #6)

Determine the surface dry weight.Calculate the degree of saturation.



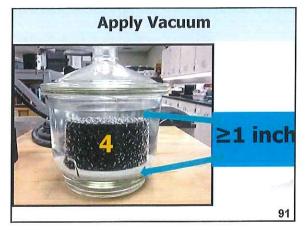
89

89

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 (it's more important to achieve vacuum than stay within time limits).
- This step is pulling air out of the puck and creating a vacuum inside the puck.
- If use high/fast vacuum, may get uneven saturation—poor QC/QA comparison.

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Vacuum Saturation

- Slowly remove vacuum.
- Let puck set in water for 5-10 minutes. During this time, the puck is pulling water in. Don't shortcut this step.
- Remove puck, quickly surface dry with a damp towel.

92

92

- Day 1, Cont'd. Wet Pucks

 Determine the saturated surface dry weight. (T166 Bulk Specific Gravity)
- If in the **70 -80% saturation** weight range, wrap in plastic wrap, place in plastic bag, add **10** \pm **0.5 ml water**, seal.
- Calculate % saturation.



Calculation of % Saturation From Example Spreadsheet Puck #4

E (puck volume) = B - C

B = puck SSD weight

C = puck weight in water
["B" & "C" from G_{mb} testing]:



$$E = 3833.5 - 2180.0 = 1654 \text{ cm}^3$$

94

94

Determine % Air voids Puck #4

Calculate air voids of each puck:

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

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

95

95

Open Voids Puck #4

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



$$V_a = (6.6) (1654 \text{ cm}^3)$$

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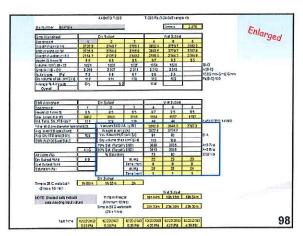
T-283 Rev3-24-04Example.xls

Mix Number Example		ı	_		Gmm =	2.476	
Gmb Worksheet		Dry Subset			Wet Subset		
Specimen #	-	,	3	4	5	9	
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]	9.6	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	8.9	6.7	9.9	9.9		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							
I SK Worksneet		Dry Subset			Wet Subset		
Specimen #	-	2	3	4	5	9	
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]	men[D]	Vacuum SSD Wt. (g)[B']	Vt. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H ₂ O (cm³)[J]	(cm [°])[J']	81	86		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm³)[Va]	ir (cm³)[Va]	110	108		
		70% Sat. (Target VSSD)	VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	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	1h 50m	1h 55m	2h				
(2 hrs ± 10 min)					Wet Subset		
NOTE: Shaded cells indicate		Time in Freezer	zer	19h 44m	19h 16m	18h 54m	
cells needing input values	nes	(Minimum 16 hrs)	hrs)				
		Time in 60 C waterbath	erbath [23h 30m	23h 30m	23h 30m	
		(24 ± 1 hrs)					
Test Time	12/22/2003 5:25 DM	12/22/2003 5:30 DM	12/22/2003 5-35 DM	12/22/2003	12/22/2003	12/22/2003	
_	0.20 F IVI	0.30 F IVI	U.35 P IVI	4.20 r IVI	4.23 F IVI	4.30 r IVI	_

% Saturation
Puck #4

% Saturation =
$$\frac{100 \text{ J'}}{Va}$$
 $Va\{J' \in J' \text{ (volume of absorbed water)} = B' - A$

B' = SSD weight after saturation
A = puck dry weight in air ["A" from G_{mb} testing]
$$J' = 3902.9 - 3822.4 = 81 \text{ cm}^3$$
% Saturation = $\frac{100 \text{ (81)}}{110}$ = 73%



Pre-Determined Weig Specimen #4	ghts
 Note: for water, M ≈ V At 70% saturation: M₇₀ = A + 0.7 (V_a) M₇₀ = 3822.4 + 0.7 (110) = 3899 g 	70%
 At 80% saturation: M₈₀ = A + 0.8 (V_a) M₈₀ = 3822.4 + 0.8 (110) = 3910 g 	80%
	99

% Saturation (wet pucks)

- If the saturation is **less than 70%, revacuum** 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.

100

100

DAY 1, Cont'd. (wet pucks)

- When saturation is 70-80%, wrap the pucks in plastic wrap, place in bag with 10ml 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.







101

DAY 2: Wet Pucks

Remove the pucks from freezer, remove from bag, and thaw pucks in a water bath at 60° ± 1 °C for 24 ± 1 hr. Minimum 1 in. water cover above specimens. Unwrap plastic wrap as soon as the film thaws.

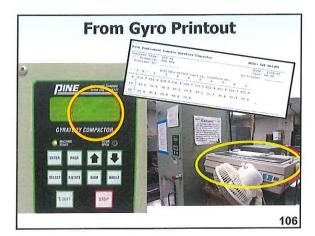


102





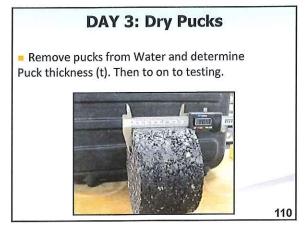
Determine Thickness (t) ASTM D3549 Use calipers: to measure dry pucks Average of 4 points around the perimeter. Caliper method is more accurate than printout method if puck swells. Or use puck height from gyro printout.

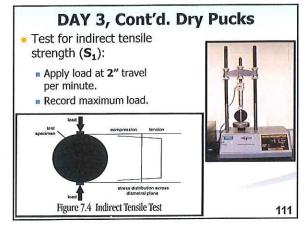


WAR ARE STORM		
Pine Instrument Company Gyratory Compactor	НО	DE: Set Height
Specimen Size: 150 mm / Prossure: 600 kPa Specimen ID:		Dâte: 1/24/: Time: 14:25 ician:
	7 8 9	-
0 116.7 111.2 108.3 106.3 104.7 103.5 10 10 99.4 98.8 98.3 97.9 77.5 97.1 9		
20 95.5 95.2 95.0 94.8 94.5		



DAY 3: Dry Pucks 3 Unconditioned pucks. Place each "dry puck" into a heavy-duty leak-proof plastic bag. Place into a water bath at 25 ± 0.5 C for 2 hrs. ± 10 min. Unconditioned Specimens Water level must be Above the puck by at least 1 inch. Note: This creates an air bath Inside the bag.







Calculations: Dry Tensile Strength

Calculate dry indirect tensile strength,S₁ (psi):P

$$S_1 = \frac{2 P}{\pi tD}$$

P= load (lbs.)

t = dry puck thickness (in.)

D= puck diameter (6 in.)

$$\pi$$
= 3.14159

113

113

OR

Using metric puck measurements:

Indirect Tensile Strength "Dry", S1 (psi)

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

P = load (lbs.)

t = puck thickness (cm)

D = puck diameter (15.0 cm)

 π = 3.14159

114

Puck #1

S = 2(3852 lbs.)(6.4516) π (9.5 cm)(15.0 cm)

S = 111 psi

 π = 3.14159

115

no Workshall		Dry Sybert			WESTON		7	Enla
HOTEL F	- 1	2	1	4	5	- 6	1	
eight in air (g) [4]	3725.0	3749.7	3758 1	3622.4	3758.7	3492.3	1	
D Weight (c) E)	3725.6	3751.0	2755.0	3473.5	3774.7	3707.5	1	
	2114.2	2120.9	2140.2	2130.0	2144.2	2004.2		
elaht in water in ICI	95	9.5	95	9.7	9.5	95	1	
Hatti (0.1 cm) (6 - Cl	1521	1575	1125	1554	1575	-14-	re-cr	
		2 307	2211	2.112	2312	_	VIB-CI	
-0 ta / (0 - C1	7.2	4.8	57	6.5	44	_	100'Gmm-Gmd/Gmm	
Ar Voice IFal			109	110	108		Para Ct 102	
y volume of all (cm/)(va) erace to All Voids	117 Cvi	111		Wet	120	_	Page C(100	
Dien	3850	20			-		4,	
RANGEMAN		One Subset			Wethintel		3	
arimen #	1	1 2	1	- 1		- 6	1	
est O ten H	9.5	9.5	94	9.7	9.5	9.5	1	
er Load Sout IFI	3872	2501	3761	4504	1517	1117		
7455 St 173 (ps)	111	104	126	44	44		6.4515129/3.1415/0	
er 150 cm dameter sast		Vacauri Sau V	(E ISTE)	2902.9	2846.0	3787.3		
: Wet ITS tear Even	-	Westinari		3922.4	3759.7	1000	and the same of th	
: Do iTS (pal/3col	108	YEL ADSOUBLE	(CTU)	81	25		84	
A (% (1005-es)5-0-1		Cry valume of a	r tem syst	110	104		1900 1	
W1411003-113311		70% Sit Clared		1609	3335		A+37Va	
	AVG	10's S.M. (Target		2910	3848		4-37/4	
Volta (%)	-	% Saturation		23	80		100J/Va	
144 514.6	49	40,000,000	in Ha	77	73	23	200000	
M Supert NAY		1	Time (man)			- 1		
Custon (%)		1	in Ha	24	25	24		
CUR ON (TI)	_	4	Time (min)	-			1	
		Dry Budget	1100					
ne m 25 C arterbelb	10 50m	10.550	25					
	10.797	10,2211	-60					
(2 hrs a 10 min)					WASON			
TE Shaded calls Indicate		TownFee	1	196.44%	10n 10m	12h 54=	1	
	1923	(Vorum 1)		127 64 7	1911	THE PARTY NAMED	•	
cets needing input val	ues .	Time n 60 Carr		410 31m	73h 30m	124 25m	1	
		1二年の代します	M Satz	E 202 2977	4.60 (00)	S.C.C.C.	4	

116

Calculations Wet Tensile Strength

■ Wet indirect tensile strength, S₂ (psi).

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

P = load (lbs.)

t' = wet puck thickness (in.)

D = puck diameter (6 in.) π = 3.14159

117

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Example

Mix Number

T-283 Rev3-24-04Example.xls

Gmm =

							_
Gmb Worksheet		Dry Subset			Wet Subset		
Specimen #	1	2	3	4	2	9	
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	9.9	9.9		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			
TSR Worksheet		Dry Subset			Wet Subset		
Specimen #	1	2	33	4	2	9	
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 spec	specimen[D]	<u>Vacuum SSD</u> V	vt. (9)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H ₂ O	(cm²)[J]	81	98		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm³)[Va]	ır (cm³)[Va]	110	108		
		70% Sat. (Target VSSD)	VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	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)	_	_	_	
		Dry Subset					
Time in 25 C waterbath	1h 50m	1h 55m	2h				
(2 hrs ± 10 min)					Wet Subset		
NOTE: Shaded cells indicate		Time in Freezer	zer	19h 44m	19h 16m	18h 54m	
cells needing input values		(Minimum 16 hrs)	hrs)				
		Time in 60 C waterbath	erbath	23h 30m	23h 30m	23h 30m	
		(24 ± 1 hrs)					
Test Time	12/22/2003	12/22/2003	12/22/2003	12/22/2003	12/22/2003	12/22/2003	
	5:25 PM	5:30 PM	5:35 PM	4:20 PM	4:25 PM	4:30 PM	

OR

Using metric puck measurements:

■ Wet indirect tensile strength, S₂ (psi).

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

P = load (lbs.)

t' = puck thickness (cm)

D = puck diameter (15.0 cm)

 π = 3.14159

118

118

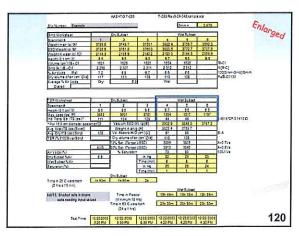
Puck #4

S = $\frac{2(1564 \text{ lbs.})(6.4516)}{\pi (9.7 \text{ cm})(15.0 \text{ cm})}$

S = 44 psi

 π = 3.14159

119



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T-283 Rev3-24-04Example.xls

Mix Number Example	ı	ı		_	Gmm =	2.476	
Gmb Worksheet		Dry Subset			Wet Subset		
Specimen #	1	2	3	4	5	9	
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	8.9	6.7	9.9	9.9		100[Gmm-Gmb]/Gmm
Dry volume of air (cm ³)[Va]	117	111	108	110	108		Pa[B-C]/100
Average % Air Voids Overall	Dry	6.9		Wet			
TSR Worksheet		Dry Subset			Wet Subset		
Specimen #	1	2	3	4	5	9	
Height (0.1 cm) [t]	9.6	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		5.4516*2P/3.1415tD
* For 15.0 cm diameter specimen[D]	men[D]	<u>V</u> acuum <u>SSD</u> Wt. (g)[B']	/t. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H ₂ O	(cm²)[J']	81	98		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm³)[Va]	r (cm³)[Va]	110	108		
		70% Sat. (Target VSSD)	VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	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	80	
Saturation (%)			in. Hg	25	26	24	
			Time (min)	_	1	_	
		Dry Subset					
Time in 25 C waterbath	1h 50m	1h 55m	2h				
(2 hrs ± 10 min)					Wet Subset		
NOTE: Shaded cells indicate		Time in Freezer	zer	19h 44m	19h 16m	18h 54m	
cells needing input values	sen	(Minimum 16 hrs)	hrs)				
		Time in 60 C waterbath	erbath	23h 30m	23h 30m	23h 30m	
		(24 I IIS)					
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

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.

Report TSR to the nearest whole %

121

121

Calculations: TSR

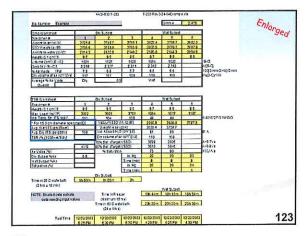
Specimen #6 ITS is 35 psi, so the average (#4, #5, #6) wet S₂ = 41 psi

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

$$TSR = 37.96 = 38\%$$

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T-283 Rev3-24-04Example.xls

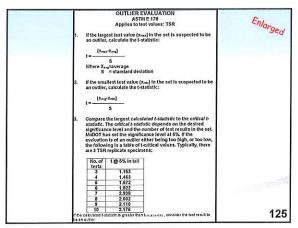
Mix Number Example					Gmm =	2.476	
Gmb Worksheet		Dry Subset			Wet Subset		
Specimen #	1	2	3	4	5	9	
Weight in air (g) [A]	3725.8	3749.7	3755.1	3822.4	3759.7	3692.3	
SSD Weight (g) [B]	3735.6	3761.0	3765.0	3833.5	3770.7	3707.9	
Weight in water (g) [C]	2114.3	2135.9	2140.2	2180.0	2144.3	2094.9	
Height (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	9.9	9.9		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 #	_	2	က	4	5	9	
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]	imen[D]	<u>V</u> acuum <u>SSD</u> Wt. (g)[B']	/t. (g)[B']	3902.9	3846.0	3787.3	
Avg. Wet ITS (psi)[Swet]		Weight in air (g)[A]	g)[A]	3822.4	3759.7		
Avg. Dry ITS (psi)[Sdry]	108	Vol. Absorb H_2O (cm ³)[J]	(cm²)[J']	81	98		B'-A
TSR (%)[100Swet/Sdry]		Dry volume of air (cm ³)[Va]	r (cm³)[Va]	110	108		
		70% Sat. (Target VSSD)	VSSD)	3899	3835		A+0.7Va
	AVG	80% Sat. (Target VSSD)	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)	_	_	_	
_		Dry Subset					
Time in 25 C waterbath	1h 50m	1h 55m	2h				
(2 hrs ± 10 min)			'		Wet Subset		
NOTE: Shaded cells indicate		Time in Freezer	zer	19h 44m	19h 16m	18h 54m	
cells needing input values	lues	(Minimum 16 hrs)	hrs)				
		Time in 60 C waterbath (24 ± 1 hrs)	erbath [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	

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

124

124



125

Example

- Triplicate dry set: 111, 108, 104 psi
- Average = 107.7 psi
- Standard deviation = 3.51 psi
- $t_{max} = (x_{max} x_{avg})/S$
- = (111 107.7)/3.51 = 0.940
- $t_{min} = (x_{avg} x_{min})/S$
- = (107.7 104)/3.51 = 1.054
- From table: t_{critical} = 1.153
- Is 111 an outlier? (Is 0.940 > 1.153?) No
- Is 104 an outlier? (Is 1.054 > 1.153?) No

126

OUTLIER EVALUATION

ASTM E 178

Applies to test values: TSR

 If the largest test value (x_{max}) in the set is suspected to be an outlier, calculate the t-statistic:

2. If the smallest test value (x_{min}) in the set is suspected to be an outlier, calculate the t-statistic:

3. Compare the largest calculated t-statistic to the critical t-statistic. The critical t-statistic depends on the desired significance level and the number of test results in the set. MoDOT has set the significance level at 5%. If the evaluation is of an outlier either being too high, or too low, the following is a table of t-critical values. Typically, there are 3 TSR replicate specimens:

No. of	t @ 5% in tail
tests	
3	1.153
4	1.463
5	1.672
6	1.822
7	2.938
8	2.032
9	2.110
10	2.176

If the *calculated t-statistic* is greater than $t_{critical}$ (α =5%), consider the test result to be an outlier.



SCOPE Background TSR Role in QC/QA Sampling for TSR Reducing AASHTO R47 Equipment Estimation of Puck Mass Test Procedure Field Verification

128

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.

129

Common Errors/ Unfavorable Comparison

- Shaking saturated puck to "adjust" saturated mass.
- Using pucks out of the acceptable air void range $(7.0 \pm 0.5 \text{ or } 6.0 \pm 0.5\%)$.
- 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.

130

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.

131

131

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.

132

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 T166-tested unconditioned pucks for 24 hrs. prior to breaking.
- Sample contaminated with dust, release agent overspray, etc.

133

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 locationtype (roadway vs plant) TSR and Rice gravity.

134

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APPENDIX

Sample Splitting

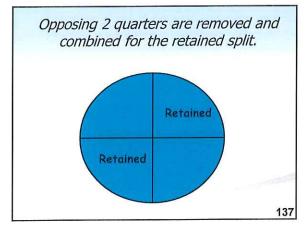
135

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.

136

136



137

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

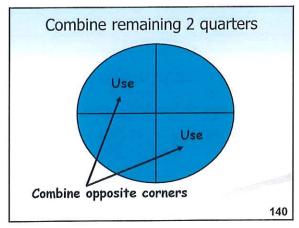
138

TSR Sample Quartering

- Sample for TSR is quartered per AASHTO R47.
- 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.

139

139



140

Sample Size

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

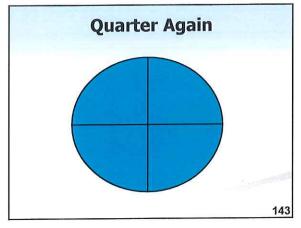
141

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

142

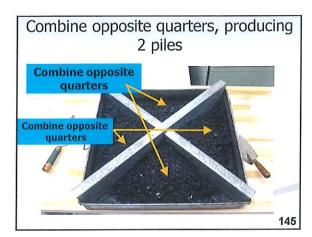


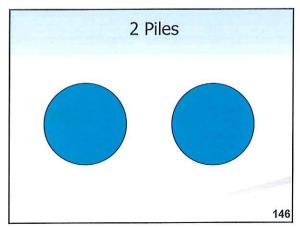
143

TSR Sample Quartering

- Sample for TSR is quartered per AASHTO R47.
- 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.

144



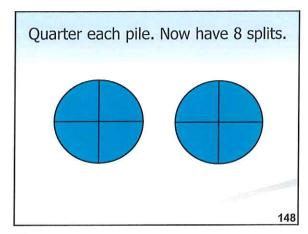


146

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 pile. Now have 8 splits.
- Pull 6 pucks.
- Pull Rice if necessary.

147

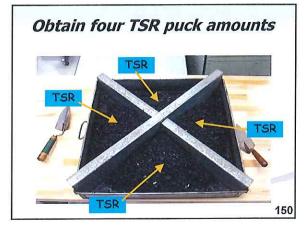


TSR Sample Quartering

- 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.

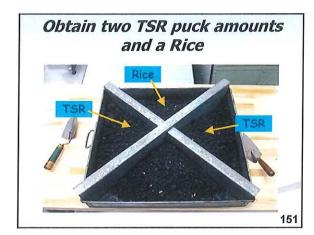
149

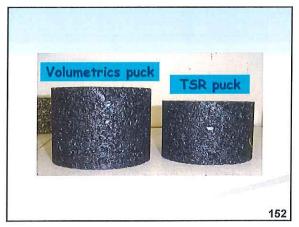
149



150

TSR 50





TENSILE STRENGTH RATIO CERTIFICATION PROFICIENCY EXAMINATION

Revised 2022

Applicant		
Employer		

TENSILE STRENGTH RATIO (TSR) TECHNICIAN CERTIFICATION PROFICIENCY CHECKLIST AASHTO T 283

Revised: 03/22/2022

Trial#	1	2	R
Sample Preparation and Grouping:			
Obtained field-mixed asphalt mixture sample in accordance with AASHTO R97 with enough material to complete all tests.			
2. Compact ≥ 6 pucks to spec: 95 ± 5 mm thick and 7.0 ± 0.5% air voids.			<u> </u>
3. Determine specimen thickness (t)			
 Obtain G_{mb} (bulk specific gravity) for each puck. Using an associated G_{mm} (Rice) using AASHTO T209, calculate % air voids for each puck. Sort into 2 groups of 3 pucks each so that <u>average air voids of each</u> 			
group are approximately equal.			
"Dry" (Non-conditioned) Testing:		_	
7. Before proceeding, be sure pucks have air-dried for 24 \pm 3 hrs. <u>after Gmb</u> determination.			
8. Place each dry puck in its own water-proof bag. Place bagged dry pucks in warm-water bath for 2 hrs. ± 10 min. with 1" of water above surface of specimens.			
9. Test each puck in indirect tension; record maximum load for each. Calculate tensile strength for each.			
10. Calculate average tensile strength for dry set of pucks (Sdry).			
"Wet" (Conditioned) Testing:			
11. Place puck in vacuum vessel with at least 1" of water below and above the puck; subject to vacuum saturation for 5-10 min. within specified vacuum range.			
12. Remove vacuum; keep puck submerged for another 5-10 min.			
13. Having already zeroed out a piece of plastic wrap on the balance, remove puck, quickly surface-dry it, and place it on the balance.			
14. Determine degree of saturation (i.e., is the weight displayed on the balance within the range needed?).			
 If saturation < 70%, repeat vacuum procedure using more time and/or vacuum. 			
16. If saturation > 80%, discard specimen.			
17. If degree of saturation is 70-80%, tightly wrap plastic film around puck, place sealed puck in plastic bag along with 10 ml water, seal outer bag and place in freezer for at least 16 hrs.			

18. Remove pucks from freezer and plastic bag; quickly place pucks into hot-water bath for 24 ± 1 hr. (1" of water above surface of specimens); remove plastic wrap as soon as possible.	
19. After 24 ± 1 hr. in hot-water bath, transfer pucks to warm-water bath for	
2 hrs. ± 10 min.	
20. Obtain specimen thickness (t) then test each puck in indirect tension; record maximum load for each. Calculate tensile strength for each.	
21. Calculate average tensile strength for conditioned set of pucks	
(Sconditioned).	
22. Calculate TSR: $TSR = \frac{S_{conditioned}}{S_{dry}} \times 100\%$ (to nearest whole number)	
Pass?	
Fail?	
ExaminerDate	

Reviewer_____