Washington State
Department of Transportation

Materials Manual

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Engineering and Regional Operations
State Materials Laboratory

LABORATORY PREPARED ASPHALT MIXTURE SPECIMENS WAQTC TM 14

Significance

The objective of asphalt mixture design is to determine the proper combination of asphalt binder, aggregates, and additives that will provide long lasting performance as part of the pavement structure. Mix designing involves laboratory procedures developed to establish the proper proportion of materials for use in asphalt paving mixtures. Correctly designed asphalt mixtures can be expected to perform successfully for many years.

Scope

This practice covers preparing asphalt mixture samples according to an established job mix formula (JMF). The aggregate, asphalt binder, and additives are proportioned based on the JMF and mixed to produce samples for testing or verification of the JMF. These specimens can be used for determining ignition furnace asphalt binder content and aggregate correction factors, performance testing, and other Quality Assurance measures.

There are several practices for batching material in the laboratory. This procedure covers the Iterative Method of batching material and provides a process for checking the accuracy of the batched test samples by confirming the gradation of a batched test sample.

Terminology

- RAP – Recycled Asphalt Pavement
- RAS – Recycled Asphalt Shingles
- Cold feed – Term used to reference plant settings for percentages of the individual constituents.
- Iterative Method – Batching process that is repeated until the desired gradation is achieved.
- Batch Plan – A mathematical process that assists with the batching of the materials.

Apparatus

- Thermometer(s), or other temperature measuring device(s), with a temperature range of 50-500°F.
- Oven: Capable of maintaining 230 ± 9°F.
- Forced air, ventilated or convection oven: Capable of maintaining the temperature surrounding the sample at 325 ± 9ºF.
- Bins, pans, or buckets of adequate size to accommodate fractionated material for each stockpile separated size.
- Labels for each bin that note the aggregate designation and sieve size upon which the material was retained.

- Lids or plastic coverings for bins and buckets to minimize moisture absorption in the fractionated material during storage if necessary.
- Drying/batch containers: Shallow flat metal pans large enough to accommodate a batched sample.
- Balance or scale: Capacity sufficient for the sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g
- Sieves: meeting the requirements of the FOP for AASHTO T 27/T 11.
- Mechanical sieve shaker: meeting the requirements of the FOP for AASHTO T 27/T 11.
- Mechanical washing apparatus (optional)
- Suitable drying equipment: meeting the requirements of the FOP for AASHTO T 255.
- Containers: A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.
- Utensils: Spoons, spatulas, brushes, stirring rods, etc.
- Mixer**:** Of sufficient capacity and design to adequately combine all ingredients.

Material Sampling

1. Obtain representative samples of aggregate, from each stockpile listed on the JMF, according to the FOP for AASHTO R 90.
2. Obtain samples of asphalt binder according to the FOP for AASHTO R 66.
3. Obtain hydrated lime from the supplier listed on the JMF, if used.
4. Obtain anti-stripping agent from the supplier listed on the JMF, if used.
5. Obtain representative recycled material samples, after the material has been processed for hot mix production use, according to FOP for AASHTO R 90, if used.

Note 1: RAP is material recovered from existing roadways during milling operations or pavement removal during construction. Most RAP requires reprocessing to be useable in new asphalt mixtures. Processing may include crushing and screening of the material.

Aggregate Preparation

Obtain quality control gradation reports of the separated sizes or stockpiled materials listed on the JMF. The average gradation, expressed as a percent retained, of each stockpile will be used to verify JMF target gradation. If recycled material (RAP or RAS) is included in the JMF, verify the asphalt binder content and gradation are listed.

The virgin aggregates used in the blend may be batched unwashed or washed, according to agency requirements.

Fractionating of Virgin Aggregate

1. Dry each stockpile sample according to the FOP for AASHTO T 255.
2. After drying, cool and cover, if necessary, to minimize moisture absorption.
3. Select sieves required by the specification. Separate each stockpile sample into individual size fractions according to the FOP for AASHTO T 27/T 11.
4. Carefully empty the material retained on each sieve into a bin, pan, or bucket, and label according to size.

***Note 2**:* To reduce the number of sizes of fractionated aggregates from which the batch is prepared, agencies may allow small amounts to be added from other stockpiles. Stockpiles should meet the criteria in Appendix A, Aggregate Batching.

5. Cover, if necessary, to prevent moisture absorption.

Wash Fractionated Aggregate

When the agency requires, the fractionated aggregate is washed and dried before batching test samples. The adherent fines that are washed out are replaced with material passing the 75 µm (No. 200) sieve during batching.

1. Wash each size of fractionated aggregate according to the FOP for AASHTO T 27/11, except for the material passing the 75 µm (No. 200) sieve or "Dust."

Note 3: Adherent fines may have different properties than sieved minus 75 µm (No. 200) material.

2. Dry according to the FOP for AASHTO T 255.
3. Store in separate bins or buckets, label according to size and cover, if necessary.

RAP

If RAP, RAS, or both, is included in the JMF:

1. Dry the processed recycled material overnight or to constant mass at 125 ± 5°F.

Note 4: Constant mass is achieved when successive mass determinations do not change more than 0.05 percent after an additional 2 hours of drying.

2. Cover and cool.

Aggregate Batch Plan

Batch plans are developed one virgin aggregate stockpile at a time starting with the coarsest stockpile and progressing through the finer stockpiles.

Determine all masses to the nearest 0.1 percent of the sample mass or to the nearest 0.1 g.

1. Calculate the required mass for each stockpile (virgin stockpile, lime, RAP, etc.) by multiplying the desired sample size by the cold feed percentage for each stockpile and record to the nearest 0.1 g. The sum of the individual masses must add up to the desired total sample mass.
2. Calculate the percent retained for each sieve of the aggregate portions using the control gradation average.

3. Calculate the mass per sieve per stockpile. Start with the coarsest virgin aggregate stockpile, multiply the individual mass for that stockpile by the percent retained on each sieve and record to the nearest 0.1 g.
4. Identify the sieve sizes that material from other stockpiles will be added. Document the mass and the contributing stockpile. See Note 2.
5. Calculate a cumulative mass total beginning with the largest sieve on the coarsest stockpile. Begin the cumulative total on subsequent finer stockpiles with the ending cumulative total from the previous stockpile.

Note 5: Cumulative masses are used so that the balance is not re-zeroed between each addition possibly causing a misrepresentation of the total mass. Repeat with each successive stockpile. If cumulative totals are not used, verify mathematically that the batch plan produces the correct mass of virgin aggregate for each stockpile and the total of all virgin stockpiles.

Verification of Aggregate Batch Plan

When the fractionated aggregate is not washed before batching, the minus 0.075 (No. 200) batch plan mass may need to be adjusted to compensate for adherent fines.

1. Batch the desired sample size according to the batch plan, excluding recycled material, if applicable.

Note 6: Refer to the FOP for AASHTO T 308 Table 1 for recommended sample size.

2. Perform washed sieve analysis according to the FOP for AASHTO T 27/T 11.
3. The batched sample percent passing must agree with the Virgin Blend Percent Passing (JMF) within the tolerances of Table 1. If the variation exceeds the allowable difference, adjust the virgin aggregate portion of the batch plan and reverify.

Table 1
Allowable Differences Between Batched and Actual Gradations

Sieves	Allowable Difference (%Passing)
Larger than No. 8	±1.5%
No. 8 to No. 50	±1.0%
Smaller than No. 50	±0.5%

Aggregate Preparation

1. Batch the number of samples at desired sample size according to the batch plan, excluding recycled material, if applicable.

Hydrated Lime

When hydrated lime is mixed with water before incorporating into the mixture, add to the test samples the night before mixing with asphalt binder (approximately 12 hours).

1. Determine the mass of hydrated lime to be added to the test sample based on the percent required in the JMF. For mixtures with RAP, the percentage is applied to the virgin aggregate only.
2. Weigh out the mass of hydrated lime required for each test sample and store in a closed tin with the test sample.
3. Add the hydrated lime to the test sample in an oven proof container.
4. Using a spoon or spatula, thoroughly stir the lime into the dry aggregate sample.
5. Add sufficient water to thoroughly wet all the aggregate and achieve a "Surface Damp Condition."
6. Stir the lime, aggregate and water for approximately five minutes to thoroughly combine. Do not lose any fine material. Spatulas and brushes may be used to clean the fine material from the implements. Do not transfer the mixed sample.
7. Place the mixed sample in the oven, set oven temperature in the mixing temperature range.
8. Dry according the FOP for AASHTO T 255.

Mixing Preparation

1. Heat the mixing equipment such as bowls, mixing paddles, spoons, etc.
2. Heat aggregate samples 20°F above the JMF mixing temperature.

Note 7: Heating aggregate above mixing temperature allows for loss of heat during the addition of the asphalt binder. Over 20 °F higher may burn the asphalt binder when it is added to the hot aggregate.

3. If RAP material is required, heat carefully in a controlled oven for approximately 2 hrs. at 230 ± 9°F.
4. Heat asphalt binder approximately 10°F above the mixing temperature range. Discard unused asphalt binder after the 3 hrs.

Liquid anti-stripping agent

If liquid anti-striping agent is required:

a) Determine the mass of anti-stripping agent to be added to the asphalt binder based on the percent required in the JMF. The percentage is applied to the asphalt binder only.

b) Follow mixing instructions from the anti-stripping agent supplier, as not all products are incorporated in the same manner.

c) Heat the anti-stripping agent to 125 ± 15 ° F or temperature range from manufacturer labeling.

d) Determine and record mass of a clean container.

e) Add asphalt binder, determine and record asphalt binder mass.

f) Calculate the mass of anti-stripping agent to be added.

g) Zero the scale and add calculated mass of anti-stripping agent. Record the measured mass of anti-stripping agent.

h) Discard material if too much anti-stripping agent is added.

Note 8: Use of a small spoon or stirring rod will assist with anti-strip addition.

i) Stir the combined sample thoroughly with a small spoon or stirring rod.

j) Loosely place a lid on the container to prevent dissipation of the additive. Do not secure the lid, expansion could cause injury or loss of material.

k) Place the combined material in an oven at the JMF mixing temperature range. During binder addition ensure product is stirred thoroughly before each use.

Note 9: Because the elastic properties of asphalt binder degrade when held at high temperatures, the asphalt binder must be used within 3 hrs. of achieving the mixing temperature.

Mixing Procedure

1. Prepare an initial specimen at the design asphalt binder content to "butter" the mixing bowl and utensils. Discard the specimen after mixing, scrape the bowl and paddle or whip with a spatula or other suitable tool.
2. Record mass of "buttered" bowl, spatula, and paddle or whip.
3. Remove the spatula and paddle or whip; zero the balance with empty bowl. Introduce the aggregate, mix thoroughly with clean, dry spatula or spoon. Record mass of aggregate, $Mass_{agg}$.
4. If RAP is required, introduce the hot RAP and mix thoroughly with the virgin aggregate. Record this mass. Determine M_{RAP} by subtracting the M_{agg} from the mass of aggregate and RAP.
5. Form a crater in the center of the material.
6. Calculate M_{binder}.
7. Zero the scale and add calculated mass of asphalt binder. Record the measured mass of asphalt binder added.

Note 10: If too much asphalt binder is added, it may be removed by dipping a corner of a paper towel in the center of the asphalt binder.

8. Thoroughly mix for a minimum of two minutes, by hand or mixer, until asphalt binder is uniformly distributed, and aggregate is completely coated.
9. Stop the mixer, if used.
10. Stir mixture with buttered spatula, scraping the center bottom of the mixing bowl.

11. If the aggregate is not thoroughly coated, continue mixing until completely coated.
12. Remove mixture from bowl.
13. Scrape bowl and paddle or whip with buttered spatula. Place all the mixture into a pan.
14. Record mass of empty bowl, spatula, and paddle or whip. Ensure the combined mass and the mass of the initial buttered bowl and utensils is within 0.10 percent of the sample mass of the mixed sample.

Note 11: For a 4700 g sample, 0.10% = 4.7 g. and for a 2100 g sample, 0.10% = 2.1 g.

15. Age the mixed specimen according to AASHTO R 30 or agency requirements.
16. Repeat steps 3 thru 15 for each specimen to be mixed.

Calculations

Trial Batch Plan

Mass of material contributed per stockpile:

$$mass\ per\ stockpile = sample\ size\ \times stockpile\%$$

Where:

mass per stockpile = mass of material from each stockpile in test sample

sample size = desired mass of test sample

stockpile% = percent of each stockpile in the mixture (JMF)

Mass of material contributed to each sieve per stockpile:

$$mass\ per\ stockpile\ per\ sieve = \ mass\ per\ stockpile\ \times \%retained\ per\ sieve$$

Where:

mass per stockpile per sieve = amount of fractionated aggregate from each stockpile for each sieve size

%retained per sieve = percent retained on each sieve (calculated from crushing records)

Anti-stripping agent mass added before heating asphalt binder:

$$M_{additive} = \%additive\ \times M_{heated\ binder}$$

$M_{additive}$ = mass of anti-stripping agent to be added to the mass of measured asphalt binder

%additive = percent of anti-stripping agent, based on mass of asphalt binder, from JMF

$M_{heated\ binder}$ = mass of asphalt binder heated for mixing

Asphalt binder mass

Asphalt binder mass is based on a percent of the mass of "hot" aggregate.

Mixes without RAP

Determine the mass of asphalt binder to be added to a mix without RAP:

$$M_{binder} = \frac{P_b \times M_{agg}}{(100 - P_b)}$$

Where:

M_{binder} = Mass of asphalt binder to be added to the prepared test sample

P_b = Required percent asphalt binder

M_{agg} = Mass of hot test sample

Mixes with RAP

Determine the mass of asphalt binder in the RAP:

$$M_{RAP\ binder} = M_{RAP} \times \frac{P_{bRAP}}{100}$$

Where:

$M_{RAP\ binder}$ = Mass of asphalt binder in the RAP

M_{RAP} = Mass of RAP in sample

P_{bRAP} = Percent of asphalt binder in the RAP

Determine the amount of asphalt binder to be added to mixes with RAP:

$$M_{binder} = \left[P_b \times \frac{\left(M_{agg} + M_{RAP} - M_{RAP\ binder}\right)}{(100 - P_b)}\right] - M_{RAP\ binder}$$

Asphalt Binder

Anti-stripping agent mass

$$M_{additive} = \%additive \times M_{binder}$$

$$M_{additive} = 0.25\% \times 850\ g = 2.1\ g$$

Given:

%additive = 0.25%

M_{binder} = 850 g.

Asphalt binder mass – mixtures without RAP

$$M_{binder} = \frac{P_b \times M_{agg}}{(100 - P_b)}$$

$$M_{binder} = \frac{6.0\% \times 4500.0\ g}{(100\% - 6.0\%)} = \frac{2700.0\ g}{94.0\%} = 287.2\ g$$

Given:

P_b = 6.0 % from JMF

M_{agg} = 4500.0 g hot aggregate

Note 13: A factor can be determined for subsequent specimens by taking P_b divided by 100-P_b. Then the hot aggregate mass is multiplied by this factor for an expedient oil add determination.

Asphalt binder mass – mixtures with RAP

Determine mass of asphalt binder in RAP:

$$M_{RAP\ binder} = M_{RAP} \times \frac{P_{bRAP}}{100}$$

$$M_{RAP\ binder} = 1125.0\ g\ x\ \frac{4.88\%}{100} = 54.9\ g$$

Given:

M_{RAP} = 1125.0 g

$P_{b\ RAP}$ = 4.88%

Determine mass of asphalt binder:

$$M_{binder} = \left[P_b \times \frac{\left(M_{agg} + M_{RAP} - M_{RAP\ binder}\right)}{(100 - P_b)}\right] - M_{RAP\ binder}$$

$$Mass_{binder} = \left[6.0\% \times \frac{(4500\ g - 54.9\ g)}{(100\% - 6.0\ \%)}\right] - 54.9\ g = 228.8\ g$$

P_b = 6.0 percent from JMF

M_{agg} = 3375.0 g

$M_{agg} + M_{RAP}$ = 4500.0 g hot aggregate and RAP

Check of Calculation

$$\left[\frac{(54.9g + 228.8g)}{(4500g + 228.8g)}\right] x\ 100 = 6.0\%$$

Report

- Project name
- Date of batching
- Specimen identification
- Virgin aggregate mass
- RAP mass, if required
- Percentage of asphalt binder in specimen, nearest 0.1 percent
- Asphalt binder mass
- Anti-Strip mass, if applicable
- Conditioning process

APPENDIX—AGGREGATE BATCHING

(Non-Mandatory Information)

The following guidelines should be considered when batching virgin aggregates that have small amounts of retained material that are encountered during the separation phase and will reduce the number of containers required for material storage:

- The percent retained for the sieve to be moved is less than 10 percent. Material meeting this condition must have a retained like size on the next stockpile or batching of the separated size will be required.
- Stockpiles to be combined are from the same source and same parent material. Aggregates from different sources should not be combined.
- The particle shape and texture are essentially the same for the sieve sizes to be combined.

Stockpiles are produced using similar processes (e.g. do not mix stockpiles of crushed material with stockpiles of uncrushed material; do not mix unwashed stockpiles with washed stockpiles, etc.).

Example

Batch a gyratory sample of 4750 g. of asphalt mixture, the aggregate portion will be about *4500 g*. The mixture is to have 25 percent RAP with three virgin stockpiles of 18, 27, and 30 percent.

Batch Mass for the 12.5 to 4.75 mm (1/2 in. to No. 4) stockpile

$$Required\ mass = 4500\ g \times \frac{18\%}{100} = 810.0\ g$$

Stockpile	12.5 to 4.75 mm (1/2 in. to No. 4)	4.75 to 1.18 mm (No. 4 to No. 8)	4.75 to 1.18 mm (No. 4 to No. 8)	RAP
Cold feed %	18%	27%	30%	25%
Batch Mass	810.0 g.	1215.0 g	1350.0 g	1125.0 g

The sum of the batch masses must add up to the original aggregate target mass, in this example: 810.0 g + 1215.0 g + 1350.0 g + 1125.0 g = 4500.0 g.

Mass per sieve for 12.5 to 4.75 mm (1/2 in. to No. 4) stockpile

Sieve Size mm (in.)	%Retained	Batch Mass g	Mass Carried to Next Pile g	Cumulative Batch Mass g
25 (1)	0.0	0.0	0.0	**0.0**
19.0 (3/4)	0.0	0.0	0.0	**0.0**
12.5 (1/2)	3.3	26.7	0.0	**26.7**
9.5 (3/8)	49.4	400.1	0.0	**426.8**
6.25 (1/4)	39.8	322.4	0.0	**749.2**
4.75 (No. 4)	3.5	28.4	-28.4	
2.36 (No. 8)	1.7	13.8	-13.8	
1.18 (No. 16)	0.2	1.6	-1.6	
0.600 (No. 30)	0.0	0.0	0.0	
0.300 (No. 50)	0.1	0.8	-0.8	
0.150 (No. 100)	0.0	0.0	0.0	
0.075 (No. 200)	0.0	0.0	0.0	
Minus 0.075 (No. 200)	2.0	16.2	-16.2	
Total	**100.0**	**810.0**	**-60.8**	

The %Retained column must equal 100.0 percent. The Batch Mass Column should equal 810.0 g.

The Total Batch Mass plus the Mass Carried to Next Pile for sieves smaller than the 6.25 mm (1/4 in.) is 810.0 g + (– 60.8 g) = 749.2 g.

The minus sign shows mass is being removed from this portion of the Batch Plan. It will be added to the next (pile plus sign).

Note 12: Carrying minor amounts of material when batching as in this example reduces the number of fractionated sizes. In case, there are eight less bins from just this stockpile.

The material retained on the 12.5 mm (1/2 in) was 3.3 % and meets the less than 10 percent requirement but doesn't have a like material in the next stockpile, so it must be batched.

Continue with the next stockpile, 4.75 to 1.18 mm (No. 4 to No. 8).

Mass per sieve for 4.75 to 1.18 mm (No. 4 to No. 8) stockpile

Sieve Size mm (in.)	%Retained	Batch Mass g	Mass Carried to Next Pile g	Cumulative Batch Mass g
25 (1)	0.0	0.0	0.0	**749.2**
19.0 (3/4)	0.0	0.0	0.0	
12.5 (1/2)	0.0	0.0	0.0	
9.5 (3/8)	1.3	15.8	0.0	**765.0**
6.25 (1/4)	29.5	358.4	0.0	**1123.4**
4.75 (No. 4)	28.4	345.1 + 28.4	0.0	**1496.9**
2.36 (No. 8)	32.4	393.7 + 13.8	0.0	**1904.4**
1.18 (No. 16)	4.1	49.8 + 1.6	-51.4	
0.600 (No. 30)	1.1	13.4 + 0.0	-13.4	
0.300 (No. 50)	0.6	7.3 + 0.8	-8.1	
0.150 (No. 100)	0.3	3.6 + 0.0	-3.6	
0.075 (No. 200)	0.0	0.0 + 0.0	0.0	
Minus 0.075 (No. 200)	2.3	27.9 + 16.2	-44.1	
Total	**100.0**	**1215.0 + 60.8**	**-120.6**	

%Retained equals 100.0, the batch mass equals the 1215.0 g. with 60.8 g. being carried from the 12.5 to 4.75 mm (1/2 in. to No. 4).

Mass per sieve for 44.75 to 1.18 mm (No. 4 to No. 8) stockpile

Sieve Size mm (in.)	Adjusted QL %Retained	Batch Mass g	Cumulative Batch Mass g
25 (1)	0.0	0.0	**1904.4**
19.0 (3/4)	0.0	0.0	
12.5 (1/2)	0.0	0.0	
9.5 (3/8)	0.0	0.0	
6.25 (1/4)	0.0	0.0	
4.75 (No. 4)	0.2	2.7	**1907.1**
2.36 (No. 8)	20.2	272.7	**2179.8**
1.18 (No. 16)	26.5	357.8 + 51.4	**2589.0**
0.600 (No. 30)	17.1	230.8 + 13.4	**2833.2**
0.300 (No. 50)	14.8	199.8 + 8.1	**3041.1**
0.150 (No. 100)	11.9	160.7 + 3.6	**3205.4**
0.075 (No. 200)	2.8	37.8 + 0.0	**3243.2**
Minus 0.075 (No. 200)	6.5	87.7 + 44.1	**3375.0**
Total	**100.0**	**1350.0 + 120.6**	

The final Cumulative Batch Mass matches the sum of the three virgin stockpiles, 810.0 + 1215.0 + 1350.0 = 3375.0.

FOP LIBRARY WAQTC WAQTC TM 14 (19)

Performance Exam Checklist

WAQTC TM 14

Laboratory Prepared Asphalt Mixture Specimens

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. The tester has a copy of the current procedure on hand?	____	____
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/standardization/check tags present?	____	____
Material Sampling Element		
3. Representative samples of aggregate identified on JMF obtained per FOP for AASHTO R 90?	____	____
4. Representative samples of asphalt binder identified on JMF obtained per FOP for AASHTO R 66?	____	____
5. If required, hydrated lime obtained from supplier?	____	____
6. If required, anti-stripping agent obtained from supplier?	____	____
7. If required, representative samples of recycled material (RAP, RAS) sufficient for production use obtained per FOP for AASHTO R 90?	____	____
Aggregate Preparation Element		
8. Aggregate dried according to FOP for AASHTO T 255?	____	____
9. Aggregate separated into individual size fractions according to FOP for AASHTO T 27_T 11?	____	____
10. Material retained on each sieve placed in separate containers?	____	____
11. Separated aggregates washed, except the portion passing the No. 200 (0.075 mm) sieve, in accordance with FOP for AASHTO T 27_T 11?	____	____
12. Washed aggregate samples dried according to FOP for AASHTO T 255?	____	____
13. If required, recycled material (RAP, RAS) dried overnight or to constant mass at 125 ± 5°F?	____	____
14. All dried and cooled material stored as necessary to prevent moisture absorption?	____	____

Procedure Element	Trial 1	Trial 2
Mixing Preparation Element		
15. Aggregate batch plan developed off JMF and calculated based on cumulative totals?	____	____
16. Number of samples at desired sample size determined by the specific test procedure to be performed?	____	____
17. Mixing equipment (bowls, mixing paddles, spoons/scrapers, etc.) heated?	____	____
18. Aggregate heated 20°F above JMF mixing temperature?	____	____
19. If required, RAP material carefully heated for approximately 2 hrs. at 230 ± 9°F?	____	____
20. Asphalt binder heated 10°F above JMF mixing temperature?	____	____
21. If required, liquid anti-stripping agent incorporated as instructed by supplier or as defined in step 4. a) – k)?	____	____
Mixing Procedure Element		
22. A prepared specimen used to butter all mixing equipment and discarded?	____	____
23. Mass of buttered bowl and paddle recorded?	____	____
24. Heated aggregate introduced into tared empty bowl and mixed thoroughly?	____	____
25. Mass of aggregate recorded?	____	____
26. If required, RAP material introduced with heated aggregate and mixed thoroughly?	____	____
27. Mass of RAP recorded?	____	____
28. Crater formed?	____	____
29. Scale tared and calculated mass of asphalt binder added?	____	____
30. All material thoroughly mixed for a minimum of two minutes or until completely coated?	____	____
31. All mixture placed into pan and mixing equipment scraped back to buttered condition?	____	____
32. Mass of empty bowl and paddle recorded and not more than 0.10 percent of total sample mass has been gained or loss?	____	____
33. If required, mixture specimen aged according to AASHTO R 30?	____	____
34. Steps repeated for each specimen to be mixed?	____	____
35. All calculations performed correctly?	____	____

☐ Tester qualified in performing TM14 Gyratory samples. Date: _____

☐ Tester qualified in performing TM14 including RAP/RAS. Date: _____

☐ Tester qualified in performing TM14 HWTD/IDT/Ideal CT. Date: _____

☐ Tester qualified in performing TM14 to include Anti-strip. Date: _____

☐ Tester qualified in performing TM14 Rice samples. Date: _____

☐ Tester qualified in performing TM14 IFCF samples. Date: _____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Errata to WAQTC TM 15

Laboratory Theoretical Maximum Dry Density of Granular Soil and Soil/Aggregate

WAQTC TM 15 has been adopted by WSDOT with the following changes:

Apparatus

Replace with below:

- **Small Mold Assembly:** includes mold, mold base, and mold follower.
  - **Mold Follower:** Steel plate, with a 12 ±1 mm (0.460 ±0.03 in.) edge thickness fitting inside the mold with 1.5 mm (0.063 in.) maximum space between mold follower and mold wall. For new followers, the diameter tolerance is – 1 mm to – 2 mm (– 0.031 in. to - 0.063 in.) of the inside diameter of the matching mold.

    In-service followers shall have a minimum edge thickness of 10.7 mm (0.420 in.).
- **Large Mold Assembly:** includes mold, mold base, and mold follower.
  - **Mold Follower:** Steel plate, with 14 ± 1 mm (0.550 ± 0.030 in.) edge thickness fitting inside the mold with 1.5 mm (0.063 in.) max. space between mold follower and mold wall. For new followers, the diameter tolerance is – 1 mm to – 2 mm (– 0.031 in. to - 0.063 in.) of the inside diameter of the matching mold.

    In-service followers shall have a minimum edge thickness of 12.6 mm (0.496 in.).

Sample Preparation

Replace step one with below:

1. Obtain a representative sample according to Table 3 below.

Table 3
TM15 Sample Size

	Minimum Mass lb (kg)	
If no more than 15 percent by weight of aggregate exceeds 19 mm (¾ in.)	210	95
If 15 percent or more by weight of aggregate exceeds 19 mm (¾ in.)	330	150

Theoretical Maximum Density Curve Development

Replace with below:

WSDOT Employees – Enter laboratory data into MATS to develop the maximum density chart and maximum density curve.

Non-WSDOT Employees – Enter laboratory data into WAQTC spreadsheet to develop the maximum density chart and maximum density curve. Spreadsheet available at http://waqtc.org/library/library.cfm

LABORATORY THEORETICAL MAXIMUM DRY DENSITY OF GRANULAR SOIL AND SOIL/ AGGREGATE
WAQTC TM 15

Scope

This method is used to establish the theoretical maximum dry density of granular and non-granular soil-aggregate. Use Procedure 1 for material with more than 30 percent retained on the 4.75 mm (No. 4) sieve or Procedure 2 for material with more than 30 percent retained on the 19.0 mm (¾ in.) sieve.

Terminology

- Fine aggregate portion – material passing the 4.75 mm (No. 4) Sieve.
- Coarse aggregate portion – material retained on the 4.75 mm (No. 4) sieve.

Significance

A theoretical maximum dry density chart and curve are developed by determining a laboratory maximum dry density of a representative sample of material passing the 4.75 mm (No. 4) and the material retained on the 4.75 mm (No. 4), and their respective apparent specific gravities (G_{sa}). The theoretical maximum dry density chart and curve address the range of theoretical maximum dry densities due to fluctuations in coarse and fine aggregate of a given material.

To determine the laboratory maximum dry density of the fine aggregate portion, this method allows for use of the FOP for AASHTO T 99/T 180 or by vibratory compactor covered in the method.

This method is for use on granular materials having 30 to 70 percent passing the 4.75 mm (No. 4) or 19.0 mm (3/4 in.) sieve.

Apparatus

- A vibratory spring-loaded compactor – D G Parrott & Son Humphres Maximum Density machine, or equivalent.
- Small Mold Assembly: includes mold, mold base, and mold follower.
    - Mold: approximately 0.003 m^3 (0.1 $ft.^3$) volume. Made of steel tubing meeting ASTM A513 with a 165 mm (6.500 in.) nominal outside diameter, 6 mm (0.250 in.) wall thickness, 152 ±1 mm (6 ±0.03 in.) inside diameter, and a height of 203 ±1 mm (8 ±0.032 in.). For in-service molds, do not to exceed 15 mm (6.060 in.) inside diameter.
    - Mold Base: 16 mm (0.625 in.) steel plate separate from the mold. Grind both surfaces to 15 ±1 mm (0.600 ±0.030 in.) thickness.

— Mold Follower: Steel plate, with a 12 ±1 mm (0.460 ±0.03 in.) edge thickness fitting inside the mold with 1.5 mm (0.063 in.) maximum space between mold follower and mold wall. For new followers, the diameter tolerance is – 1 mm to – 2 mm (– 0.031 in. to - 0.063 in.) of the inside diameter of the matching mold.

- Large Mold Assembly: includes mold, mold base, and mold follower

  — Mold: approximately 0.014 m^3 (0.5 $ft.^3$) volume. Made of steel tubing meeting ASTM A513 with a 267 mm (10.500 in.) nominal outside diameter, 6 mm (0.250 in.) wall thickness, 254 ±1 mm (10 ±0.032 in.) inside diameter, and a height of 254 ±1 mm (10 ±0.032 in.). For in-service molds, do not to exceed 256 mm (10.060 in.) inside diameter.

  — Mold Base: 6 to 8 mm (0.250 to 0.312 in.) steel plate skip welded or fully welded to the mold.

  — Mold Follower: Steel plate, with 14 ± 1 mm (0.550 ± 0.030 in.) edge thickness fitting inside the mold with 1.5 mm (0.063 in.) max. space between mold follower and mold wall. For new followers, the diameter tolerance is – 1 mm to – 2 mm (– 0.031 in. to - 0.063 in.) of the inside diameter of the matching mold.

- Manually operated rammer: 2.5 kg (5.5 lb.) rammer meeting the requirements of the FOP for AASHTO T 99/T 180.

- Measuring device: minimum length 150 mm (6 in.), accurate and readable to 0.25 mm (0.01 in.)

- Sieves: 75 mm (3 in.), 19 mm (¾ in.), and a 4.75 mm (No. 4) conforming to the FOP for AASHTO T 27/T 11

- Balance or Scale: Capacity sufficient for the principal sample mass, readable to 0.1 percent or 0.1 g, and meeting the requirements of AASHTO M 231

- Tamping rod: straight steel, 16 mm (5/8 in.) in diameter and approximately 400 mm (24 in.) long having at least one end rounded to a hemispherical tip

- Straight edge: at least 25 mm (1 in.) longer than the diameter of the mold

- A stopwatch or timer readable to 1 second

- Miscellaneous tools including pans, spoon, trowel, mechanical mixer (optional), etc.

Laboratory Maximum Dry Density

Select the proper method for determining the laboratory maximum dry density of the fine aggregate portion of the sample, refer to Table 1, or as directed by the agency.

Select the proper method for determining the laboratory maximum dry density of the coarse aggregate portion of the sample, refer to Table 2.

Table 1
Fine Aggregate Portion Laboratory Maximum Dry Density Method

Estimated Soil Type	Recommended Test Method
Sandy, non-plastic, permeable soil or non-cohesive soil.	WAQTC TM 15 Vibratory Compactor
Silt, some plasticity, low permeability.	FOP for AASTHO T 99/T 180, T 99 Method A
Sandy/silt, some plasticity, permeable.	WAQTC TM 15 and FOP for AASHTO T 99/T 180, T 99 Method A (use highest results)

Table 2
Coarse Aggregate Portion Laboratory Maximum Dry Density Method

Coarse Aggregate Amount	Test Method
No more than 15 percent by weight of the original aggregate specimen exceeds 19 mm (¾ in.)	WAQTC TM 15 Vibratory Compactor Procedure 1
15 percent or more by weight of the original aggregate specimen is greater than 19 mm (¾ in) but does not exceed 75 mm (3 in.)	WAQTC TM 15 Vibratory Compactor Procedure 2

Sample Preparation

1. Obtain a representative sample according to the FOP for AASHTO R 90, minimum 180 kg. (400 lbs.).

2. Reduce according to the FOP for AASHTO R 76 to a sufficient size to yield amounts required in steps 7 and 8.

3. If the sample is damp, dry until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus maintained at a temperature not exceeding 60°C (140°F).

4. Thoroughly break up aggregations in a manner that avoids reducing the natural size of individual particles.

5. Remove the material retained on the 75 mm (3 in.) sieve.

6. Separate into coarse and fine aggregate portions by passing the remainder of the sample through the 4.75 mm (No. 4) sieve.

7. Fine aggregate:

    a. Obtain a representative sample as described in the FOP for AASHTO T 99/T 180, T 99 Method A.

    Or

    b. Obtain at least three representative test samples of approximately 6 kg (13 lb.) each for the fine aggregate vibratory compactor method.

    c. Obtain a representative sample of the remaining material and determine the apparent specific gravity (G_{sa}) according to AASHTO T 84 or Annex B.

8. Coarse aggregate:

    a. Obtain a representative sample of 19 mm (¾ in) to 4.75 mm (No. 4) of approximately 5 kg (11 lb.) for coarse aggregate vibratory compactor Procedure 1.

    Or

    b. Obtain a representative sample of 75 mm (3 in) to 4.75 mm (No. 4) of approximately 20 kg (45 lb.) for coarse aggregate vibratory compactor Procedure 2.

    c. Obtain a representative sample of the remaining material and determine the apparent specific gravity (G_{sa}) according to FOP for AASHTO T 85 or Annex B.

Laboratory Maximum Dry Density of Fine Aggregate Portion

Determine laboratory maximum dry density of the fine aggregate portion according to the FOP for AASHTO T 180/T 99, T 99 Method A, or the following vibratory compactor method. Refer to Table 1.

Vibratory Compactor Method

1. Determine and record the mass of the clean dry small mold assembly to the nearest 5 g (0.01 lb.). Designate this mass as the M_m.

2. Add enough water to one of the fine aggregate portions to saturate the sample, approximately optimum moisture. Do not over saturate (Note 1).

Note 1: The sample is considered saturated when one to two drops of free water are visible at the base of the mold assembly at the end of the first 2-minute load cycle, Table 3. Refer to Step 11.

3. Mix until homogenous.

4. Place approximately one third of the sample in the mold with mold base attached.

5. Consolidate with 25 strokes of the tamping rod, distribute evenly over the surface, and 25 blows of the manually operated rammer.

6. Repeat Steps 4 and 5 for two subsequent lifts. The surface of the top lift should be finished as level as possible.

7. Place the follower on top of the molded specimen and mount the mold assembly on the jack platform in the compactor. Use spacers between the load spring assembly and follower to adjust the elevation of the mold assembly so the hammers strike near the center of the mass of material in the mold assembly.

8. Elevate the mold assembly with the jack until the load spring assembly seats on top of the follower and apply an initial seating load of approximately 100 lb_f. on the sample.

9. Start the compactor hammers. Continue to elevate the mold assembly, applying the load gradually over the time stated in the Table 3.

Table 3
Load Application Rate

Load lb_f	Time
0 to 500	1 min.
500 to 1,000	30 sec.
1,000 to 2,000	30 sec.

10. Upon reaching 2,000 lb_f at the end of the 2-minute cycle, stop the hammer, release the load on the jack, and return to zero pressure.

11. Determine apparent moisture.

    a. If the material is pumping around the mold follower or excessive amounts of water are seeping from between the mold and mold base, prepare a new sample and begin the test again at Step 1.

    b. If the base of the mold is dry or there is a small amount of water, repeat Steps 7 through 10, four additional times.

12. Remove the mold assembly from the compactor.

13. Measure the height of the compacted specimen.

    a. Lay the straight edge across the top of the mold assembly.

b. Using the measuring device, measure from the bottom of the straight edge to the top of the follower and spacers to the nearest 0.1 mm (0.01 in.). Designate as D.

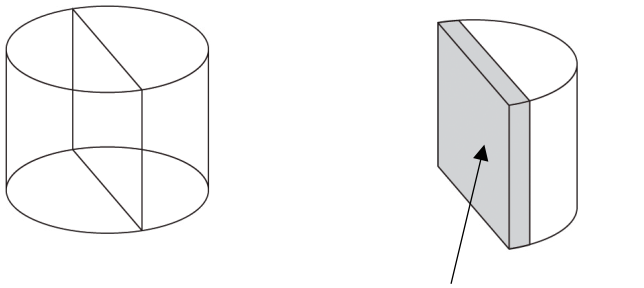
c. Calculate and record the height of the compacted specimen, h_s, by subtracting D and T (thickness of the follower) from the height of the mold h_m. See Annex A..

14. Determine and record the mass of the mold assembly and specimen, M_{ms}, to the nearest 5 g (0.01 lb.).

15. Determine and record the mass of the specimen, M_s, by subtracting M_m from M_{ms}.

16. Remove the specimen from the mold assembly.

17. Use the entire specimen for a moisture content sample or obtain a representative sample by slicing vertically through the center of the specimen. Obtain at least 500 g. (1.1 lb.) from one of the cut faces, ensuring that all the layers are represented. If a vertical face does not exist, take a representative sample.



Slice through the center **Representative moisture content sample**

18. Determine and record the moisture content, w, according to the FOP for AASHTO T 255/T 265.

19. Calculate and record the wet density, ρ_w, of the fine aggregate portion.

20. Calculate and record the laboratory dry density, ρ_d, of the fine aggregate portion.

Laboratory Maximum Dry Density of the Coarse Portion

Vibratory Compactor Method

Note 2: Procedure 1 uses the small mold assembly, this procedure is not recommended for material with aggregate larger than 9.3 mm (3/4 in.).

Procedure 1

1. Determine and record the mass of the small mold assembly to the nearest 5 g (0.01 lb.). Designate this mass as the M_m.

2. Determine and record the mass of the coarse aggregate portion to the nearest 5 g (0.01 lb.). Designate this mass as the M_s. See Note 3.

Note 3: If all the coarse aggregate portion does not fit in the mold assembly or there is some indication that material may have been lost, perform alternate Step 16 to determine M_s.

3. Determine amount of water to add to the coarse aggregate portion by multiplying the mass determined in Step 2 by 0.025 (2.5 percent).

4. Add water to coarse aggregate portion, mix thoroughly.

5. Place approximately one third of the sample in the mold with mold base attached.

6. Tamp the surface lightly with the manually operated rammer to consolidate material and achieve a level surface.

7. Repeat Steps 5 and 6 for two subsequent lifts. Ensure all the coarse aggregate portion is placed in the mold.

8. Place the follower on top of the molded specimen and mount the mold assembly on the jack platform in the compactor. Use spacers between the load spring assembly and follower to adjust the elevation of the mold assembly so the hammers strike near the center of the mass of material in the mold assembly.

9. Elevate the mold assembly with the jack until the loading spring assembly seats on top of the follower and spacers.

10. Apply an initial seating load of approximately 100 lb_f on the sample.

11. Start the compactor hammers. Continue to elevate the mold, applying the load gradually over the time stated in the Table 3.

12. Upon reaching the 2,000 lb_f load at the end of the 2-minute cycle, stop the hammer, release the load on the jack, and return to zero pressure.

13. Repeat Steps 10 through 12 four additional times.

14. Remove the mold assembly from the compactor.

15. Measure the height of the compacted specimen.

    a. Lay the straight edge across the top of the mold assembly.

    b. Using the measuring device, measure from the bottom of the straight edge to the top of the follower and spacers to the nearest 0.1 mm (0.01 in.). Designate as D.

    c. Calculate and record the height of the compacted specimen, h_s, by subtracting D and T (thickness of the follower) from the height of the mold h_m. See Annex A.

16. Alternate method of determining M_s

    a. Remove the specimen from the mold assembly.

    b. Determine the dry mass according to the FOP for AASHTO T 255. Designate as M_s.

17. Calculate and record the laboratory dry density, ρ_d, of the coarse aggregate portion.

Procedure 2

1. Determine and record the mass of the large mold assembly to the nearest 5 g (0.01 lb.). Designate this mass as the M_m.

2. Determine and record the mass of the coarse aggregate portion to the nearest 5 g (0.01 lb.). Designate this mass as the M_s.

Note 4: If all the coarse aggregate portion does not fit in the mold or there is some indication that material may have been lost, perform alternate Step 13 to determine M_s.

3. Place approximately one fifth of the sample in the large mold with mold base.

4. Tamp the surface lightly with the manually operated rammer to consolidate material and achieve a level surface.

5. Place the follower on top of the molded specimen and mount the mold assembly on the jack platform in the compactor. Use spacers between the load spring assembly and follower to adjust the elevation of the mold assembly so the hammers strike near the center of the mass of material in the mold assembly.

6. Elevate the mold assembly with the jack until the loading spring assembly seats on top of the follower.

7. Apply an initial seating load of approximately 100 lb_f on the sample.

8. Start the compactor hammers. Continue to elevate the mold assembly, applying the load gradually over the time stated in the Table 3.

9. Upon reaching the 2,000 lb_f load at the end of the 2-minute cycle, stop the hammer, release the load on the jack, and return to zero pressure.

10. Repeat Steps 3 through 9 four additional times. Ensure all the coarse aggregate portion is placed in the mold on the final lift.

11. Remove the mold assembly from the compactor.

12. Measure the height of the compacted specimen.

    a. Lay the straight edge across the top of the mold assembly.

b. Using the measuring device, measure from the bottom of the straight edge to the top of the follower and spacers to the nearest 0.1 mm (0.01 in.). Designate as D.

c. Calculate and record the height of the compacted specimen, h_s, by subtracting D and T (thickness of follower) from the height of the mold, h_s. See Annex A.

13. Alternate method of determining M_s

a. Remove the specimen from the mold assembly.

b. Determine the dry mass of the specimen according to the FOP for AASHTO T 255. Designate as M_s.

14. Calculate and record the laboratory dry density, ρ_d, of the coarse aggregate portion.

Calculations

Height of specimen in mold (fine or coarse aggregate portion)

$$h_s = h_m - D - T$$

where:

h_s = height of specimen in mold, 0.1 mm (0.01 in.)

h_m = height of mold, 0.1 mm (0.01 in.), Annex A

D = measured distance from the mold top to the follower, 0.1 mm (0.01 in.)

T = thickness of the follower, 0.1 mm (0.01 in.), Annex A

Volume of the specimen in the mold (fine or coarse aggregate portion)

$$V_s = \frac{h_s \times \pi \times \left(\frac{d}{2}\right)^2}{1e^9\, {mm^3}/{m^3}\ or\ 1728\, {in^3}/{ft^3}}$$

where:

V_s = volume of specimen in mold m^3 (ft^3)

d = inside diameter of the mold, 0.1 mm (0.01 in.), Annex A

Mass of fine aggregate portion in the mold assembly

$$M_s = M_{ms} - M_m$$

where:

M_s = mass of specimen in mold assembly, 0.005 kg (0.01 lb.)

M_{ms} = mass of mold assembly and specimen, 0.005 kg (0.01 lb.)

M_m = mass of mold assembly, 0.005 kg (0.01 lb.)

Wet Density of fine aggregate portion

$$\rho_w = \frac{M_s}{V_s}$$

Where:

ρ_w = wet density, kg/m^3 (lb/ft^3)

M_s = mass of specimen in the mold assembly, 0.005 kg (0.01 lb.)

V_s = volume of specimen in mold m^3 (ft^3)

Laboratory maximum dry density fine aggregate portion

$$\rho_d = \left(\frac{\rho_w}{w + 100}\right) \times 100 \quad or \quad \rho_d = \frac{\rho_w}{\left(\frac{w}{100}\right) + 1}$$

Where:

ρ_d = dry density, kg/m^3 (lb/ft^3)

w = moisture content, as a percentage (FOP for AASHTO T 255)

Laboratory maximum dry density of coarse aggregate portion

$$\rho_d = \left(\frac{M_s}{V_s}\right) \times 100$$

Where:

ρ_d = dry density, kg/m^3 (lb/ft^3)
M_s = mass of specimen in the mold assembly, 0.005 kg (0.01 lb.)
V_s = volume of specimen in mold m^3 (ft^3)

Example

Example for small mold fine aggregate portion

Wet mass, M_w	=	6.470 kg (14.26 lb)
Moisture content, w	=	11.3%
Height of mold, h_m	=	203.7 mm (8.02 in.)
Inside diameter of mold, d	=	153.4 mm (6.04 in.)
Measurement from top of mold to follower, D	=	44.5 mm (1.75 in.)
Thickness of the follower, T	=	3.6 mm (0.14 in.)
Mass of specimen and mold assembly, M_{ms}	=	6.400 kg (14.11 lb)
Mass of mold assembly, M_m	=	0.280 kg (0.62 lb)

Height of fine aggregate portion in mold

$$h_s = h_m - D - T$$

$$h_s = 203.7\ mm - \ 44.5\ mm - 3.6\ mm = 155.6\ mm$$

$$h_s = 8.02\ in. - 1.75\ in. - 0.14\ in. = 6.13\ in.$$

Volume of the fine aggregate in the mold

$$V_s = \frac{h_s \times \pi \times \left(\frac{d}{2}\right)^2}{1e^9\ mm^3/_{m^3}\ or\ 1728\ in^3/_{ft^3}}$$

$$V_s = \frac{155.6\ mm \times \pi \times \left(\frac{153.4\ mm}{2}\right)^2}{1{,}000{,}000{,}000\ mm^3/_{m^3}} = 0.002876\ m^3$$

Or

$$V_s = \frac{6.13\ in.\ \times \pi \times \left(\frac{6.04\ in.}{2}\right)^2}{1728\ in^3/_{ft^3}} = 0.1016\ ft^3$$

Mass of fine aggregate portion in the mold

$$M_s = M_{ms} - M_m$$

$$M_s = 6.400\ kg\ - 0.280\ kg = 6.119\ kg$$

$$M_s = 14.11\ lb - 0.62\ lb = 13.49\ lb$$

Wet density of fine aggregate portion

$$\rho_w = \frac{M_s}{V_s}$$

$$\rho_w = \frac{6.119\ kg}{0.002876\ m^3} = 2128\ {}^{kg}/_{m^3}$$

$$\rho_w = \frac{13.49\ lb}{0.1016\ ft^3} = 132.8\ {}^{lb}/_{ft^3}$$

Laboratory maximum dry density of the fine aggregate portion

$$\rho_d = \left(\frac{\rho_w}{w + 100}\right) \times 100 \quad or \quad \rho_d = \frac{\rho_w}{\left(\frac{w}{100}\right) + 1}$$

$$\rho_d = \left(\frac{2128\ kg/m^3}{11.3\% + 100}\right) \times 100 = 1912\ \ kg/m^3 \quad \rho_d = \left(\frac{132.8\ \ lb/ft^3}{11.3\% + 100}\right) \times 100 = 119.3\ lb/ft^3$$

Or

$$\rho_d = \left(\frac{2128\ kg/m^3}{\frac{11.3\%}{100} + 1}\right) = 1912\ kg/m^3 \quad \rho_d = \left(\frac{132.8\ \ lb/ft^3}{\frac{11.3\%}{100} + 1}\right) = 119.3\ lb/ft^3$$

Example for small mold coarse aggregate portion (Procedure 1)

Calculations will be the same for Procedure 2

Height of mold assembly, h_m	=	203.7 mm (8.02 in.)
Inside diameter of mold, d	=	153.4 mm (6.04 in.)
Measurement from top of mold assembly to follower, D	=	42.4 mm (1.67 in.)
Thickness of the follower, T	=	3.6 mm (0.14 in.)
Mass of coarse aggregate in the mold assembly, M_s	=	4.985 kg (10.99 lb)

Height of coarse aggregate portion in mold

$$h_s = h_m - D - T$$

$$h_s = 203.7\ mm - 42.4\ mm - 3.6\ mm = 157.7\ mm$$

$$h_s = 8.02\ in. - 1.67\ in. - 0.14\ in. = 6.21\ in.$$

Volume of the coarse aggregate portion in the mold

$$V_s = \frac{h_s \times \pi \times \left(\frac{d}{2}\right)^2}{1e^9\ mm^3/_{m^3}\ or\ 1728\ in^3/_{ft^3}}$$

$$V_s = \frac{157.7\ mm \times \pi \times \left(\frac{153.4\ mm}{2}\right)^2}{1{,}000{,}000{,}000\ mm^3/_{m^3}} = 0.002915\ m^3$$

$$V_s = \frac{6.21\ in.\ \times \pi \times \left(\frac{6.04\ in.}{2}\right)^2}{1728\ in^3/_{ft^3}} = 0.1030\ ft^3$$

Laboratory maximum dry density of coarse aggregate portion

$$\rho_d = \left(\frac{M_s}{V_s}\right) \times 100$$

$$\rho_d = \left(\frac{4.985\ kg}{0.002915\ m^3}\right) \times 100 = 1710\ {}^{kg}/_{m^3}$$

$$\rho_d = \left(\frac{10.99\ lb}{0.1030\ ft^3}\right) \times 100 = 106.7\ {}^{lb}/_{ft^3}$$

Theoretical Maximum Density Curve Development

Enter the following data into an approved spreadsheet to develop the maximum density chart and maximum density curve.

- Laboratory maximum dry density, ρ_d, of the coarse aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Laboratory maximum dry density, ρ_d, of the fine aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the nearest 0.1 percent if the FOP for AASTHO T 99/T 180, T 99 Method A was used for the fine portion.
- Coarse aggregate apparent specific gravity, G_{sa}, to the nearest 0.001
- Fine aggregate portion apparent specific gravity, G_{sa}, to the nearest 0.001

Example

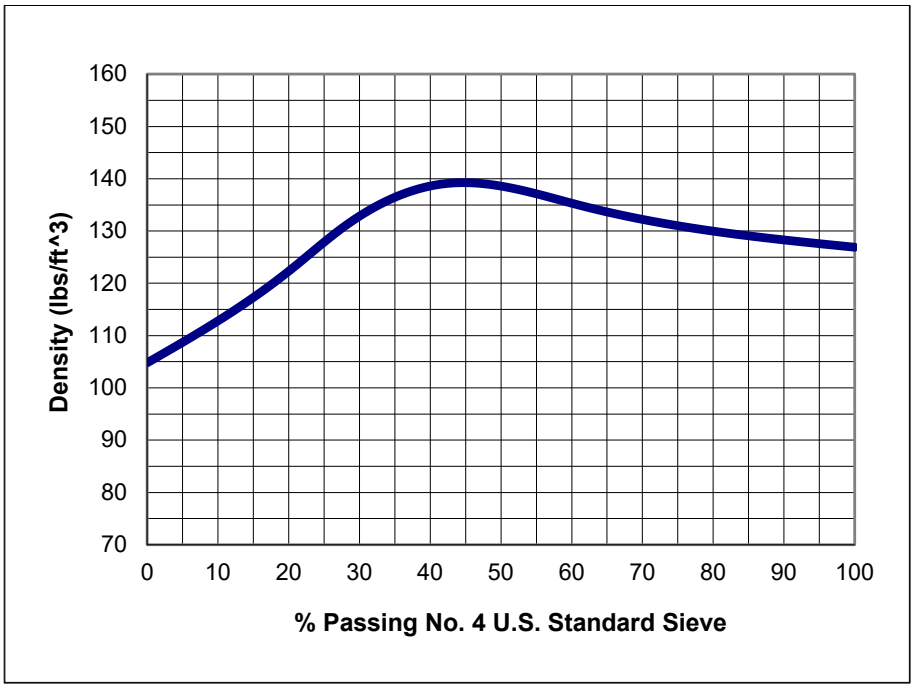
Theoretical Maximum Dry Density Chart

Density Curves			
Pass #4	Maximum	Pass #4	Maximum
0.0	104.8	31.0	133.7
1.0	105.6	32.0	134.5
2.0	106.4	33.0	135.2
3.0	107.1	34.0	135.8
4.0	107.9	35.0	136.4
5.0	108.7	36.0	137.0
6.0	109.5	37.0	137.5
7.0	110.3	38.0	137.9
8.0	111.1	39.0	138.3
9.0	112.0	40.0	138.6
10.0	112.8	41.0	138.9
11.0	113.7	42.0	139.0
12.0	114.5	43.0	139.2
13.0	115.4	44.0	139.2
14.0	116.4	45.0	139.2
15.0	117.3	46.0	139.2
16.0	118.2	47.0	139.1
17.0	119.2	48.0	139.0
18.0	120.2	49.0	138.8
19.0	121.3	50.0	138.6
20.0	122.3	51.0	138.3
21.0	123.4	52.0	138.1
22.0	124.5	53.0	137.8
23.0	125.6	54.0	137.5
24.0	126.8	55.0	137.1
25.0	127.9	56.0	136.8
26.0	129.0	57.0	136.4
27.0	130.0	58.0	136.0
28.0	131.0	59.0	135.7
29.0	132.0	60.0	135.3
30.0	132.8	61.0	135.0

Density Curves			
Pass #4	Maximum	Pass #4	Maximum
62.0	134.6	82.0	129.6
63.0	134.3	83.0	129.4
64.0	134.0	84.0	129.3
65.0	133.6	85.0	129.1
66.0	133.3	86.0	128.9
67.0	133.1	87.0	128.8
68.0	132.8	88.0	128.6
69.0	132.5	89.0	128.4
70.0	132.2	90.0	128.3
71.0	132.0	91.0	128.1
72.0	131.7	92.0	128.0
73.0	131.5	93.0	127.9
74.0	131.2	94.0	127.7
75.0	131.0	95.0	127.6
76.0	130.8	96.0	127.4
77.0	130.6	97.0	127.3
78.0	130.4	98.0	127.2
79.0	130.2	99.0	127.0
80.0	130.0	100.0	126.9
81.0	129.8		

Control Points for Density Curves		
Pass #4	Maximum	Loose
0.0	104.8	87.6
20.5	122.8	99.6
27.4	130.4	103.8
42.5	139.1	105.4
61.1	134.9	96.7
100.0	126.9	81.9

Theoretical Maximum Dry Density Curve



Report

- Results on standard agency forms
- Sample ID
- Laboratory maximum dry density of the coarse aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Laboratory maximum dry density of the fine aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the nearest 0.1 percent (when using the FOP for AASTHO T 99/T 180, T 99 Method A for the fine aggregate portion)
- Coarse aggregate apparent specific gravity (G_{sa}) to the nearest 0.001
- Fine aggregate apparent specific gravity (G_{sa}) to the nearest 0.001
- Theoretical maximum dry density chart
- Theoretical maximum dry density curve

ANNEX A STANDARDIZATION OF THE MOLD ASSEMBLY

(Mandatory Information)

Apparatus

- Calipers having a range sufficient to measure the diameter of the measure being checked and readable to at least 0.1 mm (0.01 in.)
- Inside diameter caliper, 300 mm (12 in.) range
- Straight edge at least 25 mm (1 in.) larger than the mold
- Ruler readable to 0.1 mm (0.01 in.)

Procedure

Determine the height of the mold (h_m)

1. Place the straight edge across the top of the mold with mold base.
2. Using the caliper measure from the bottom of the straight edge to the center mold with base to the nearest 0.1 mm (0.01 in.)
3. Turn the straight edge 90 degrees.
4. Repeat Step 2.
5. Average the two measurements.
6. Designate as h_m

Determine the thickness of the mold follower and spacers (T)

1. Place follower and spacers inside the mold with mold base.
2. Place the straight edge across the top of the mold.
3. Using the caliper measure from the bottom of the straight edge to the center of the top of the follower to the nearest 0.1 mm (0.01 in.).
4. Turn the straight edge 90 degrees.
5. Repeat Step 3.
6. Average the two measurements.
7. Subtract the average measurement from h_m
8. Designate as T.

Determine the inside diameter of the mold (d)

1. Using the caliper measure the inside diameter of the mold to the nearest 0.1 mm (0.01 in.).
2. Turn the mold 90 degrees.
3. Repeat Step 1.
4. Average the two measurements.
5. Designate as d.

ANNEX B APPARENT SPECIFIC GRAVITY (G_{sb}) DETERMINATION

(Mandatory Information)

This procedure covers the determination of apparent specific of coarse and fine aggregate by means of a pycnometer. When the soil is composed of material both larger and smaller than the 4.75 mm (No. 4) sieve, the sample is separated on the 4.75 mm (No. 4) sieve.

Apparatus

- Pycnometer: A flask or other suitable container in which the volume can be reproduced within ±0.1 ml. The volume of the flask shall be at least 50 percent greater than required for the test sample.
- Pycnometer / volumetric flask cover: A glass plate or a metal or plastic cover with a vented opening
- Balance: A balance of sufficient capacity, readable to 0.1 g. Meeting AASHTO M 231, Class G2.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Vacuum lid: A transparent lid with a suitable vacuum connection, with a vacuum opening to be covered with a fine wire mesh
- Vacuum: Capable of evacuating air from the container to a partial vacuum of 13.33 kPa (100 mmHg) or less absolute pressure
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Thermometric devices accurate to 0.5°C (1°F)
- Bleeder valve to adjust vacuum
- Timer

Sample Preparation

1. Sample and reduce the aggregate in accordance with the FOPs for AASHTO R 90 and R 76.
2. Dry the sample sufficiently to obtain a clean separation of fine and coarse material in the sieving operation.
3. Sieve the sample in accordance with the FOP for AASHTO T 27/ T 11 over the 4.75 mm (No. 4) sieve.

Coarse test sample

a. Split or quarter approximately 1000 g of material from the portion retained on the 4.75 mm (No. 4) sieve.

b. Dry to constant mass according to the FOP for AASHTO T 255 at 110 ±5°C (230 ±9°F).

c. Cool to room temperature.

Fine test sample

a. Split or quarter approximately 500 g of material from the portion passing the 4.75 mm (No. 4) sieve.

b. Dry to constant mass according to the FOP for AASHTO T 255/T 265 at 110 ±5°C (230 ±9°F).

c. Cool to room temperature.

Procedure

The procedure is performed on fine and coarse aggregate separately.

1. Determine and record the mass of the dry test sample. Designate as A.
2. Place the test sample in the pycnometer.
3. Add water at approximately 20°C (68°F) until the pycnometer is about ¾ full.
4. Connect the pycnometer to the vacuum system.
5. Apply partial vacuum, 30 mmHg or less absolute pressure, for 20 ± 1 min.
6. Agitate the pycnometer and contents, either continuously by mechanical device or manually by vigorous shaking, at 2-minute intervals. This agitation facilitates the removal of entrapped air.
7. Release vacuum and disconnect the hoses.
8. Fill the pycnometer with water without reintroducing air. Water temperature should be maintained as close to 20 ±0.5°C (68 ±1°F) as possible throughout the procedure.

Note 1: It may be necessary to place the pycnometer in a water bath for 10 minutes after the release of vacuum to stabilize at 20 ±0.5°C (68 ±1°F).

   a. Metal pycnometer (coarse test sample only) – Fill the pycnometer with 20 ±0.5°C (68 ±1°F) water according to manufacturer's instructions and dry the outside.

   b. Glass pycnometer (fine or coarse test samples) – Completely fill the pycnometer with 20 ±0.5°C (68 ±1°F) water, slide the calibrated glass plate over the mouth of the pycnometer making sure there are no air bubbles trapped under the plate. Dry the outside.

9. Determine and record the mass of the pycnometer, sample, and water. Designate as C.

Calculation

Calculate the G_{sa} to three decimal places as follows:

$$G_{sa} = \frac{A}{A + B - C}$$

Where:

A = Mass of dry sample in air, g

B = Mass of pycnometer filled with water at 20°C (68°F), g, determined during the Standardization of Pycnometer procedure

C = Mass of pycnometer, water, and the test sample at to 20 ±0.5°C (68 ±1°F), g

Coarse example:

$$G_{sa} = \frac{2200.3\ g}{2200.3\ g + 7502.5\ g - 8812.0\ g} = 2.470$$

Given:

A = 2200.3 g

B = 7502.5 g

C = 8812.0 g

Report

- Report on standard agency forms.
- Report apparent specific gravities, G_{sa}, to the nearest 0.001

Standardization of Pycnometer

The pycnometer shall be standardized periodically in conformance with procedures established by the agency.

1. Fill the pycnometer with water at approximately 20°C (68°F).
2. Place the metal or plastic cover, or a glass plate on the pycnometer and eliminate all air.

Note B1: When using a metal pycnometer and cover, place the cover on the pycnometer and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling the pycnometer to avoid reintroducing air into the water.

3. Stabilize the pycnometer at 20 ± 0.5ºC (68 ± 1ºF) for 10 ± 1 min.
4. Towel dry the outside of the pycnometer and cover.
5. Determine and record the mass of the pycnometer, water, and lid.
6. Repeat Steps 2 through 5 two more times for a total of three determinations.
7. If the variation of the three masses is within 0.3 g, average the three masses. Designate as “B.”
8. If the variation of the masses is greater than 0.3 g, take corrective action and perform the “Standardization of Pycnometer” again.

Performance Exam Checklist

WAQTC TM 15

Laboratory Theoretical Maximum Dry Density of Granular Soil and Soil/Aggregate

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. The tester has a copy of the current procedure on hand?	____	____
2. All equipment is functioning according to the test procedure, and if required has the current calibration/standardization/check and maintenance tags present?	____	____
Sample Preparation Element		
3. A minimum of 180 kg. (400 lbs.) representative sample material obtained according to FOP for AASHTO R 90?	____	____
4. Representative sample reduced according to FOP for AASHTO R 76 to yield the sample sizes for testing?	____	____
5. If damp, sample dried at a temperature not exceeding 60°C (140°F)?	____	____
6. Material retained on the 75 mm (3 in.) sieve removed?	____	____
7. Coarse and fine aggregate portions separated through the 4.75 mm (No. 4) sieve?	____	____
Fine Aggregate Portion Element		
8. Proper test method selected based on Table 1?	____	____
9. Mass of clean dry small mold determined to the nearest 5 g (0.01 lb.)?	____	____
10. Enough water added to saturate sample and mixed until homogenous?	____	____
11. Each lift consolidated with 25 strokes of tamping rod and 25 blows of manually operated rammer?	____	____
12. Top lift finished as level as possible?	____	____
13. Mold cap placed and spacers utilized so the hammers strike near the center of mass in the mold?	____	____
14. Initial seating load of approximately 100 lbf applied?	____	____
15. Compaction begun and load application rate per Table 3 followed?	____	____
16. Based on the determination of apparent moisture, compaction cycle repeated four additional times or a new sample is prepared and test restarted from Step 1.?	____	____
17. Height of compacted specimen determined and recorded?	____	____
18. Mass of specimen determined and recorded?	____	____
19. Moisture content determined and recorded?	____	____
20. Dry density determined?	____	____

Procedure Element	Trial 1	Trial 2
Coarse Aggregate Portion Element		
21. Proper test method selected based on Table 2?	____	____
Procedure 1 Element		
22. Mass of clean dry small mold determined to the nearest 5 g (0.01 lb.)?	____	____
23. Mass of coarse aggregate portion determined to the nearest 5 g (0.01 lb.)?	____	____
24. Coarse aggregate mass multiplied by 0.025 to determine mass of water to be added?	____	____
25. Water and coarse aggregate mixed thoroughly?	____	____
26. Each lift tamped lightly with manually operated rammer?	____	____
27. Mold cap placed and spacers utilized so the hammers strike near the center of mass in the mold?	____	____
28. Initial seating load of approximately 100 lbf applied?	____	____
29. Compaction begun and load application rate per Table 3 followed?	____	____
30. Compaction cycle repeated four additional times?	____	____
31. Height of compacted specimen determined and recorded?	____	____
32. Dry density determined?	____	____
Procedure 2 Element		
33. Mass of clean dry small mold determined to the nearest 5 g (0.01 lb.)?	____	____
34. Mass of coarse aggregate portion determined to the nearest 5 g (0.01 lb.)?	____	____
35. Approximately one fifth of the sample place in mold?	____	____
36. Lift tamped lightly with manually operated rammer to consolidate and level?	____	____
37. Mold cap placed and spacers utilized so the hammers strike near the center of mass in the mold?	____	____
38. Initial seating load of approximately 100 lbf applied?	____	____
39. Compaction begun and load application rate per Table 3 followed?	____	____
40. Aggregate placement and compaction cycle repeated four additional times?	____	____
41. Height of compacted specimen determined and recorded?	____	____
42. Dry density determined?	____	____

Procedure Element	Trial 1	Trial 2
Apparent Specific Gravity of the Fine and Coarse Portions According to Annex B		
43. Appropriate amount of coarse and fine aggregate portions obtained, dried, and cooled?	____	____
44. Mass of dry test sample(s) determined and recorded?	____	____
45. Test sample(s) placed in pycnometer and 20°C (68°F) water added to about ¾ full?	____	____
46. Partial vacuum applied to pycnometer and contents for 20 ± 1 min. and agitated by mechanical device or manually?	____	____
47. Vacuum released and pycnometer filled with water without reintroducing air?	____	____
48. Water stabilized at 20 ±0.5°C (68 ±1°F), pycnometer cover positioned, and outside dried?	____	____
49. Mass of pycnometer, sample, and water determined and recorded?	____	____
50. Specific Gravity determined?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Performance Exam Checklist

AASHTO T 19M/T 19

Bulk Density ("Unit Weight") and Voids in Aggregate (Rodding Procedure Only)

WSDOT has adopted AASHTO T 19.

Participant Name: _____ Exam Date: _____

Procedure Element	**Trial 1**	**Trial 2**
Record the symbols "P" for passing or "F" for failing on each step of the checklist.		
1. The tester has a copy of the current procedure on hand?	☐	☐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	☐	☐
3. Sample is approximately 125 to 200 percent of quantity required to fill measure?	☐	☐
4. Sample is handled correctly to avoid segregation?	☐	☐
5. Sample is dried in accordance with WSDOT FOP for AASHTO T 255?	☐	☐
Rodding Procedure		
6. Mass of empty unit weight measure is determined and recorded (nearest 0.1 lb)?	☐	☐
7. Measure is filled in three equal layers?	☐	☐
8. Each layer is rodded throughout it's depth 25 times with a hemispherical end of rod but rodding does not penetrating into the next layer?	☐	☐
9. Rodding is evenly distributed over the surface of the sample?	☐	☐
10. Mass of unit weight measure plus contents is determined to the nearest 0.1 lb and recorded?	☐	☐
11. All calculations performed correctly?	☐	☐
12. Bulk density reported to the nearest 1 lb/ft^3?	☐	☐

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for AASHTO T 22

Compressive Strength of Cylindrical Concrete Specimens

WSDOT has adopted the published AASHTO T 22 with errata's below.

AASHTO Test Methods cannot be included in Materials Manual due to copyright infringement.

WSDOT employees can access AASHTO and ASTM test methods in the following web address: http://wwwi.wsdot.wa.gov/MatsLab/BusinessOperations/ASTMLogin.htm

Non-WSDOT employees can order AASHTO's Standard Specifications for Transportation Materials and Methods of Sampling and Testing, using the following web address: https://store.transportation.org

5. Significance and Use

5.2. *Include Note below*.

Note: Testing for determining compressive strength of cylinder specimens shall require a set of two specimens made from the same sample.

7. Specimens

6.3. *Step not recognized by WSDOT.*

6.4. *Determine specimen mass and length as described below.*

Remove any surface moisture with a towel and measure the mass of the specimen using a balance or scale that is accurate to within 0.3 percent of the mass being measured. Measure the length of the specimen to the nearest 1 mm (0.05 in.) at three locations spaced evenly around the circumference. Compute the average length and record to the nearest 1 mm (0.05 in.).

8. Procedure

8.3. *Include Note below*.

Note: The 28-day compressive break may be extended by up to 48 hours if the scheduled 28-day break falls on a Saturday, Sunday, or Holiday. The Regional Materials Engineer must authorize the time extension in writing.

10. Report

10.1. *Include Note below.*

Note: The report shall also include specimen mass and length as determined in 7.4..

Performance Exam Checklist

AASHTO T 22

Compressive Strength of Cylindrical Concrete Specimens

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	The tester has a copy of the current procedure on hand?	____	____
2.	All equipment is functioning according to the test procedure, and if required has the current calibration/standardization/check and maintenance tags present?	____	____
3.	Specimens kept moist between removal from moist storage and testing?	____	____
4.	Diameter of the cylinder recorded to the nearest 0.01 inch by averaging two diameters taken at about mid-height?	____	____
5.	Specimen not tested if individual diameter readings differ more than 2 percent?	____	____
6.	Ends of specimen checked for perpendicularity to the axis?	____	____
7.	Specimen mass and length recorded?	____	____
8.	Ends of specimen checked for plane?	____	____
9.	If ends not plane, specimen sawed or ground to meet tolerance or capped in accordance to either AASHTO T 231 or ASTM C1231? (Refer to AASHTO T 231 or ASTM C1231 procedure and checklist if used)	____	____
10.	Bearing faces wiped clean?	____	____
11.	Load indicator set to zero?	____	____
12.	Spherical seated block parallel to top of specimen prior to applying load?	____	____
13.	If using Unbonded Caps, alignment of specimen checked after application of load but before reaching 10 percent of anticipated load strength?	____	____
14.	Load applied continuously and without shock?	____	____
15.	The designated load rate maintained at least during the latter half of anticipated load strength?	____	____
16.	No adjustment to load rate as ultimate load is being approached?	____	____
17.	Compressive load continued until tester is certain ultimate capacity has been attained?	____	____
18.	Maximum load and type of fracture recorded?	____	____
19.	Specimens broken within permissible time tolerances?	____	____
20.	All calculations performed correctly?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

VACUUM DRYING COMPACTED ASPHALT SPECIMENS FOP FOR AASHTO R 79

Scope

This practice covers the process of drying compacted field and laboratory specimens using a vacuum device in accordance with AASHTO R 79-22.

Overview

The specimens dried by this procedure remain near room temperature, which helps in maintaining specimen integrity during the drying process and allows the operators to run repeated tests on the same sample, if necessary.

Specimens are kept and stored at temperatures above 15°C (60°F) and below 54°C (130°F).

This practice can also be used for drying other construction materials such as concrete, soils, aggregates, and loose asphalt mixtures. Use manufacturer's recommendations for drying other construction materials.

Apparatus

- Vacuum device:
  - Attached to a pump capable of evacuating a sealed chamber to a pressure of 1 kPa (6 mm Hg) when at sea level.
  - Capable of controlling the vacuum, airflow, and temperature in order to properly dry the specimen at close to room temperature.
  - With a display that indicates a pressure value, the dry point in the chamber, and number of cycles.
  - With a plate for removing water from the bottom surface of the specimen chamber.
  - With means to trap moisture that is removed from the sample.
- Chamber (attached to the vacuum device): Large enough to hold cylindrical specimens, 150 mm (6 in.) diameter by 180 mm (7 in.) height, or cubical samples, 150 mm (6 in.) length by 150 mm (6 in.) width by 180 mm (7 in.) height.
- Thermometer: meeting the requirements of M 339/ M 339 or infrared thermometer: accurate to ±5°C (±9°F) to be used to measure surface temperature of the specimen.

Note 1: The thermometer types suitable for use include a handheld infrared thermometer with a D:s ratio of 6:1.

- Balance or scale: Capacity sufficient for the sample mass and conforming to the requirements of M 231, Class G2.

Daily Equipment Preparation

1. Dry the moisture trap (if necessary) and the specimen (vacuum) chamber.
2. Run the device without any specimens. The device should display a pressure value that indicates a known dry point.

Note 1: If the unit fails to achieve a dry point pressure value, as recommended by the manufacturer, check that the lid and all hose connections are well sealed. If needed, refer to the manufacturer's troubleshooting instructions.

Test Specimens

Test specimens may be either laboratory-molded or sampled from asphalt mixture pavement.

Procedure

Note 2: Keeping the device in the off position when not in use can prolong the operating life of its components.

1. Measure the sample temperature with a handheld infrared thermometer. Make sure the specimen surface temperature is above 15°C (60°F).
2. Remove any standing water from the surface of the specimen by using a paper towel or an absorptive cloth.
3. Place the specimen inside the vacuum chamber, closing the lid to the vacuum chamber and moisture trap (if applicable).
4. Initiate the vacuum drying cycle. The pressure is monitored throughout the drying cycle to ensure dry specimen condition pressure is achieved in the device.
5. The device will automatically stop when the specimen is dry.

Note 3: The device is calibrated at the factory or by the operator according to manufacturer's recommended procedures to sense a dry specimen condition.

6. Remove the specimen from the chamber.
7. Determine and record the specimen mass to the nearest 0.1 g.
8. Repeat steps 5 through 7 until specimen weight after vacuum drying cycle is less than 0.3 g from previous drying cycle.

Note 4: Between drying cycles, wipe off any free-standing water in the moisture trap to speed up the specimen drying cycles.

Note 5: Excessive temperature may damage the specimen. Between drying cycles, verify that the specimen temperature has not exceeded 54°C (130°F).

Performance Exam Checklist

FOP For AASHTO R 79

Vacuum Drying Compacted Asphalt Specimens

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	The tester has a copy of the current procedure on hand?	____	____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/standardization/check tags present?	____	____
3.	Device specimen chamber and moisture trap dry?	____	____
4.	Device ran without any specimens and indicates a known dry point?	____	____
5.	Specimen surface temperature above 60°F (15°C)?	____	____
6.	Specimen surfaced dried and placed inside vacuum chamber?	____	____
7.	Vacuum drying cycle initiated after closing chamber and moisture trap lids?	____	____
8.	Specimen removed from chamber and mass determined after drying cycle complete?	____	____
9.	Steps repeated until specimen mass is less than 0.3 g from previous drying cycle mass?	____	____
10.	Free-standing water in moisture trap wiped off between cycles?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Errata to FOP for AASHTO T 89

Determining the Liquid Limit of Soils

WAQTC FOP for AASHTO T 89 has been adopted by WSDOT with the following changes:

Procedure – Method A (Multi-Point) – *Not recognized by WSDOT,* use *Method B (Single-Point):*

DETERMINING THE LIQUID LIMIT OF SOILS FOP FOR AASHTO T 89

Scope

This procedure covers the determination of the liquid limit of a soil in accordance with AASHTO T 89-22. It is used in conjunction with the FOP for AASHTO T 90, Determining the Plastic Limit and Plasticity Index of Soils. The three values are used for soil classification and other purposes.

Apparatus

- Dish: preferably unglazed porcelain or similar mixing dish, about 115 mm (4.5 in.) in diameter.
- Spatula: having a blade 75 to 100 mm (3 to 4 in.) long and about 20 mm (3/4 in.) wide.
- Liquid Limit Device: manually or mechanically operated, consisting of a brass cup, carriage, and base plate and conforming to the critical dimensions shown in AASHTO T 89 Figure 1.
- Grooving Tool: used to cut the soil in the liquid limit device cup and conforming to the critical dimensions shown in AASHTO T 89 Figure 1.

Grooving tool

Alternate Flat Grooving Tool

- Gauge: either part of the grooving tool or a separate metal bar, 10.0 ±0.2 mm (0.394 ±0.008 in.) thick and approximately 50 mm (2 in.) long.
- Containers: corrosion resistant, suitable for repeated heating and cooling, having close fitting lids to prevent the loss of moisture. One container is needed for each moisture content determination.
- Balance: conforming to AASHTO M 231, class G1, sensitive to 0.01 g with a minimum capacity of 100 g.
- Oven: thermostatically controlled, capable of maintaining temperatures of 110 ±5°C (230 ±9°F).
- Graduated cylinders for measuring distilled or demineralized water.

- Sieve: 0.425 mm (No. 40) sieve meeting the requirements of the FOP for AASHTO T 27/T 11.

Adjustment of Liquid Limit Device

The liquid limit device shall be inspected to determine that the device is in good working order; that the pin connecting the cup is not worn to permit side play; that the screws connecting the cup to the hanger are tight; that the points of contact on the cup and base are not excessively worn; that the lip of the cup is not excessively worn; and that a groove has not been worn in the cup. The grooving tool shall be inspected to determine that the critical dimensions are correct.

Note 1: Wear is considered excessive when the point of contact on the cup or base exceeds approximately 13 mm (0.5 in.) in diameter, or when any point on the rim of the cup is worn to approximately 1/2 the original thickness. A slight groove in the center of the cup is not objectionable. If the groove becomes pronounced, the cup shall be replaced. A base that is excessively worn may be refinished as long as it is maintained within the tolerances specified.

Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10.0 ±0.2 mm (0.394 ±0.008 in.).

Note 2: Check the height of the drop, before each new sample, by turning the crank at two revolutions per second while holding the gauge in position against the cup. If a ringing or clicking sound is heard without the cup rising from the gauge, the adjustment is correct. If no ringing is heard or if the cup rises from gauge, readjust the height of the drop. If the cup rocks on the gauge during this checking operation, the cam follower pivot is excessively worn and should be replaced.

Sample

Samples must be prepared per the AASHTO R 58 or R 74. Obtain a sample with a mass of about 100 g taken from the portion of the material passing the 0.425 mm (No. 40) sieve.

The mass required depends upon the method chosen. Method A (multi-point method) requires approximately 100 g. Method B (single point method) requires approximately 50 g.

Procedure – Method A (Multi-Point)

1. Determine mass of empty dry container(s) and lid(s) to the nearest 0.01 g.
2. Place the sample in the dish and thoroughly mix with 15 to 20 mL of distilled or demineralized water by alternately and repeatedly stirring, kneading, and chopping with a spatula. Further additions of water shall be in increments of 1 to 3 mL. Each increment shall be thoroughly mixed with the soil before another increment is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit device shall not be used for mixing soil and water. If too much water is added, the sample shall either be discarded or mixed and kneaded until natural evaporation lowers the moisture content.

Note 3: Some soils are slow to absorb water. It is possible to add water so fast that a false LL value is obtained. This can be avoided by allowing more mixing and/or time. Also, tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water.

3. Add sufficient water to form a uniform mass of a stiff consistency.

4. Place enough material in the cup so that, when squeezed and spread with the spatula, the soil will rest in the cup above the spot where the cup rests on the base and will be 10 mm thick at the point of maximum thickness. Use as few strokes of the spatula as possible, taking care to prevent the entrapment of air bubbles in the sample.
5. Divide the soil in the cup with a firm stroke of the grooving tool. Avoid tearing the sides of the groove or slipping of the soil cake on the cup. Up to 6 strokes are permitted with a stroke from front to back or from back to front counting as 1 stroke. The depth of the groove should be increased with each stroke, and only the last stroke should scrape the bottom of the cup.
6. Lift and drop the cup by turning the crank at a rate of approximately 2 revolutions per second until the two halves of the soil pat come together along a distance of about 13 mm (0.5 in.). Do not hold the base while the crank is turned. Record the number of shocks required to close the groove this distance.

Note 4: Some soils tend to slide on the cup instead of flowing. If this occurs, water should be added, the sample remixed, and the procedure repeated. If the soil continues to slide on the cup, the test is not applicable, and a note should be made that the liquid limit could not be determined.

7. Use the spatula to obtain a moisture content sample by slicing through the soil pat perpendicularly to the groove. Remove the sample extending edge to edge and including the portion of the groove that flowed together. Place it into a suitable container and cover for subsequent moisture determination.
8. Determine the moisture percentage of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil).
9. Place the soil remaining in the cup back in the mixing dish and add 1 to 3 mL of water or use previously prepared portions to which sufficient water has been added to result in a more fluid condition.
10. Repeat Steps 4 through 9, a minimum of two times. The object is to have a determination in all three shock ranges 25-35, 20-30, and 15-25 and span a range of at least 10 shocks.
11. Determine the moisture content of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil). (Remove lids and keep with containers while drying.)

Flow Curve – Method A

Prepare a flow curve on a semi-logarithmic graph with moisture content on the arithmetic vertical axis and the number of shocks on the logarithmic horizontal axis. The flow curve is a straight line drawn as closely as possible through three or more plotted points.

Liquid Limit – Method A

Determine the liquid limit. The moisture content at the intersection of the flow curve and the 25 shock line is the liquid limit.

Procedure – Method B (Single-Point)

1. Determine mass of empty dry container(s) and lid(s) to the nearest 0.01 g.
2. Place the sample in the dish and thoroughly mix with 8 to 10 mL of distilled or demineralized water, and follow the mixing procedure in Method A, Step 1.
3. Follow the procedure in Method A except that the soil pat should be prepared with water to produce a consistency that will close the two halves of the soil pat at least 13 mm (0.5 in.) within 22 to 28 shocks of the cup.

Note 5: Groove closures occurring between 15 and 40 blows may be accepted if variations of ±5 percent of the true liquid limit are tolerable.

4. Return the soil remaining in the cup to the mixing dish and, without adding any additional water, repeat Step 2. If the closure again occurs within the acceptable range and is within 2 shocks of the first, obtain a moisture content specimen as described in Method A.
5. Determine the moisture content of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil).
6. Determine the moisture content of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil). (Remove lids and keep with containers while drying.)

Liquid Limit – Method B

Calculate the liquid limit as follows:

$$LL = (W_N)(N/25)^{0.121}$$

Where:

LL = liquid limit
w_N = moisture content of sample at N blows
N = number of blows

Example:

w_N = 16.0% and N = 23

$$LL = 16.0\% \times \left(\frac{23}{25}\right)^{0.121} = 15.8\%,\ report\ 16\%$$

Or using Table 1 (when number of shocks to closure of gap is 22-28):

$$LL = 16.0\% \times 0.990 = 15.8\%,\ report\ 16\%$$

Table 1

N	$(N/25)^{0.121}$
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014

Use Method A for referee testing to settle a dispute.

Report

- Results on forms approved by the agency.
- LL rounded to the nearest 1 percent.

Performance Exam Checklist

FOP for AASHTO T 89 (Method B Only)

Determining the Liquid Limit of Soils

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Preparation Element		**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	____	____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	____	____
3.	Sample obtained using AASHTO R 58?	____	____
4.	Minimum sample mass meets requirement of AASHTO T 89 Method B?	____	____
5.	Sample mixed with 8 to 10 mL of distilled or demineralized water?	____	____
6.	Additional water added at 1 to 3 mL as necessary until mass is uniform and of a stiff consistency?	____	____
7.	No dry soil added after test has begun?	____	____
8.	If soil was too wet, was sample discarded or allowed to dry?	____	____

Procedure Element			
1.	Sample placed in cup and spread to 10 mm maximum thickness?	____	____
2.	Care taken to avoid entrapment of air bubbles?	____	____
3.	Soil in cup divided through centerline of follower to the bottom of the cup in no more than six strokes?	____	____
4.	Liquid Limit Device counter zeroed and base checked for level?	____	____
5.	Was cup lifted and dropped at two revolutions per second until gap at bottom of groove closed about 0.5 in (13mm) in 22 to 28 blows?	____	____
6.	Blows to closure recorded?	____	____
7.	Was closure in acceptable blow count material?	____	____
8.	Was material removed from cup and placed in a covered container?	____	____
9.	Was procedure repeated a second time from step 1-6 without adding water?	____	____
10	Was second closure within two blows of first closure? If not was test rerun?	____	____
11.	Was sample removed from device and moisture content determined per T 265?	____	____
12.	Were all calculations performed correctly?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS FOP FOR AASHTO T 90

Scope

This procedure covers the determination of the plastic limit and plasticity index of soil in accordance with AASHTO T 90-22. It is used in conjunction with the FOP for AASHTO T 89, Determining the Liquid Limit of Soils. The three values are used for soil classification and other purposes. Two procedures, hand rolling and an alternate rolling method, are covered. The hand rolling method is to be used as the referee method.

Apparatus

- Dish: preferably unglazed porcelain or similar mixing dish, about 115 mm (4.5 in.) in diameter.
- Spatula: having a blade 75 to 100 mm (3 to 4 in.) long and about 20 mm (3/4 in.) wide.
- Rolling Surface:
  - A ground glass plate or piece of smooth, unglazed paper.
  - Plastic Limit Rolling Device: (Optional) A device made of acrylic conforming to the dimensions shown in AASHTO T 90 Figure 1.
  - Paper for Rolling Device: Unglazed paper that does not add foreign matter to the soil during the rolling process. Paper is attached to both the top and bottom plates of the rolling device by either spray-on adhesive or self-adhesive backing. Remove all adhesive from the rolling device after each test to prevent buildup.
- Containers: corrosion resistant, suitable for repeated heating and cooling, having close fitting lids to prevent the loss of moisture before initial mass determination and while sample is cooling before final mass determination. One container is needed for each moisture content determination.
- Balance: conforming to AASHTO M 231, class G1, sensitive to 0.01 g with a minimum capacity of 100 g.
- Oven: thermostatically controlled, capable of maintaining temperatures of 110 ±5°C (230 ±9°F).
- Sieve: 0.425 mm (No. 40) sieve meeting the requirements of the FOP for AASHTO T 27/T 11.

Sample

The plastic limit procedure is often run in conjunction with the liquid limit procedure. If this is the case, the plastic limit sample should be obtained from the soil prepared for the liquid limit test, FOP for AASHTO T 89, at any point in the process at which the soil is plastic enough to be easily shaped into a ball without sticking to the fingers excessively when squeezed. Obtain approximately 10 g of soil to run the plastic limit test.

If the plastic limit only is to be determined, the sample must be prepared according to AASHTO R 58; Dry Preparation of Disturbed Soil and Soil-Aggregate Samples for Test or R 74; Wet Preparation of Disturbed Soil Samples for Test. Obtain about 20 g of material passing the 0.425 mm (No. 40) sieve. Mix the soil with distilled or demineralized water until the mass becomes plastic enough to be easily shaped into a ball. Use approximately 10 g of the soil ball to run the plastic limit test.

Note 1: Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water.

Procedure

1. Determine and record the mass of the container and lid.
2. Pull a 1.5 to 2 g mass test sample from the initial 10 g.
3. Squeeze and form the test sample into an ellipsoidal-shape mass.
4. Use one of the following methods to roll the mass.
   - Hand Rolling Method—Roll the mass between the fingers or palm and the rolling surface with just sufficient pressure to roll the mass into a thread of uniform diameter along its length. The sample must be rolled into the 3 mm (1/8 in.) thread in no longer than 2 minutes.
   - Alternate Rolling Method, Plastic Limit Device Method—Place the soil mass on the bottom plate. Place the top plate in contact with the soil mass. Roll the mass between the plates with sufficient pressure to form the mass into a thread of uniform diameter along its length so that top plate contacts the side rails within 2 minutes. During this rolling process, do not allow the soil thread to contact the side rails. Rolling multiple threads at once is allowed.
5. Break the thread into six or eight pieces when the diameter of the thread reaches 3 mm (1/8 in.).
6. Squeeze the pieces together between the thumbs and fingers of both hands into an ellipsoidal-shape mass and reroll.

   Continue this process of alternately rolling to a thread 3 mm (1/8 in.) in diameter, cutting into pieces, gathering together, kneading and rerolling until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread 3 mm in diameter.

   Crumbling may occur when the thread has a diameter greater than 3 mm (1/8 in.). This shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3 mm (1/8 in.) in diameter. At no time, shall the tester attempt to produce failure at exactly 3 mm (1/8 in.) diameter. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal-shaped mass nearer to the required 3 mm (1/8 in.) final diameter.

Note 2: The crumbling will manifest itself differently with various types of soil. Some soils fall apart in many pieces; others form an outside tubular layer that splits at both ends; splitting progresses toward the middle, and the thread falls apart in small platy particles. Heavy clay requires much pressure to deform the thread, particularly as it approaches the plastic limit, and the thread breaks into a series of barrel-shaped segments each 6 to 9 mm (1/4 to 3/8 in.) long.

7. Gather the portions of the crumbled soil together, place in the moisture content container and cover.
8. Repeat steps one through seven until 10 g of sample have been tested and placed in the covered container.
9. Determine the moisture content of the sample in accordance with the FOP for AASHTO T 255/T 265 (Soil) and record the results. (Remove lids and keep with containers during drying.)

Plastic Limit

The moisture content, as determined in Step 9 above, is the Plastic Limit.

Note 3: It is advisable to run several trials on the same material to ensure a proper determination of the Plastic Limit of the soil.

Plasticity Index

The Plasticity Index (PI) of the soil is equal to the difference between the Liquid Limit (LL) and the Plastic Limit (PL). If either the liquid limit or plastic limit cannot be determined, report the plasticity index as NP (non-plastic). If the plastic limit is equal to, or greater than the liquid limit, report the plasticity index as NP.

$$PI = LL - PL$$

Examples:

No. 1	No. 2
LL = 34 and PL = 17	LL = 16 and PL = 10
PI = 34 – 17 = 17	PI = 16 – 10 = 6

Example Calculation

Container	Container Mass, g	Container and Wet Soil Mass, g	Wet Soil Mass, g	Container and Dry Soil Mass, g	Dry Soil Mass, g
1	14.44	25.21	10.77	23.62	9.18
2	14.18	24.84	10.66	23.90	9.72

Water Mass, g	Moisture Content	Plastic Limit
1.59	17.3%	17
0.94	9.7%	10

Report

- Results on forms approved by the agency
- PL and PI rounded to the nearest 1 percent and reported as a whole number.

WSDOT FOP for AASHTO T 90

Determining the Plastic Limit and Plasticity Index of Soils

WSDOT has adopted the published AASHTO T 90.

AASHTO Test Methods cannot be included in Materials Manual due to copyright infringement.

WSDOT employees can access AASHTO and ASTM test methods in the following web address: http://wwwi.wsdot.wa.gov/MatsLab/BusinessOperations/ASTMLogin.htm

Non-WSDOT employees can order AASHTO's Standard Specifications for Transportation Materials and Methods of Sampling and Testing, using the following web address: https://store.transportation.org

Performance Exam Checklist

FOP for AASHTO T 90

Determining the Plastic Limit and Plasticity Index of Soils

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Preparation Element		**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	_____	_____
3.	Sample obtained using AASHTO R 58?	_____	_____
4.	Minimum sample mass meets requirement of AASHTO T 90?	_____	_____
5.	Sample mixed with distilled, demineralized, or de-ionized water until plastic enough to be easily shaped into a ball?	_____	_____
6.	10 g portion of ball taken from the moist sample material?	_____	_____
Procedure Element			
1.	1.5-2 g portion taken and formed into ellipsoidal mass?	_____	_____
2.	Mass rolled at between 80-90 strokes per minute (using one of the techniques described in T 90) for no more than 2 minutes to form a 3 mm diameter thread?	_____	_____
3.	Thread broken into six or eight pieces and pieces squeezed together into ellipsoidal shape and rerolled until thread crumbles and soil can no longer be rolled into a thread?	_____	_____
4.	Tested material placed in a tared covered container and procedure steps 1-6 repeated until all 10 g of material is tested?	_____	_____
5.	Sample dried in accordance with AASHTO T 265 to determine moisture content?	_____	_____
6.	Were all calculations performed correctly?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for AASHTO T 106

Compressive Strength of Hydraulic Cement Mortar (Using 50-mm or 2-in. Cube Specimens)

WSDOT has adopted the published AASHTO T 106 with errata's below.

AASHTO Test Methods cannot be included in Materials Manual due to copyright infringement.

WSDOT employees can access AASHTO and ASTM test methods in the following web address:
http://wwwi.wsdot.wa.gov/MatsLab/BusinessOperations/ASTMLogin.htm

Non-WSDOT employees can order AASHTO's Standard Specifications for Transportation Materials and Methods of Sampling and Testing, using the following web address:
https://store.transportation.org

10. Procedure

Follow Note below.

Note: For Field fabrication of grout cubes, follow WSDOT Test Method T 813.

Performance Exam Checklist

AASHTO T 106

Compressive Strength of Hydraulic Cement Mortar (Using 50-mm or 2-in. Cube specimens)

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required has the current calibration/standardization/check and maintenance tags present?	_____	_____
3.	Cubes broken within permissible time tolerance?	_____	_____
4.	Cubes tested immediately after removal from saturated lime water storage tank or covered with damp cloth?	_____	_____
5.	Cubes wiped clean of sand, and wiped to surface dry condition prior to testing?	_____	_____
6.	Load applied to specimen faces that were in contact with plane surfaces of mold and checked with straightedge?	_____	_____
7.	Cross-sectional area determined in respect to faces contacting bearing blocks?	_____	_____
8.	Prior to testing each cube, spherically seated block checked for freedom to tilt?	_____	_____
9.	Load rate of 200 to 400 lbf/s (900-1800 N/s) obtained during the first half of the anticipated maximum load?	_____	_____
10.	No adjustment in rate made during the second half of loading?	_____	_____
11.	Total maximum load recorded and compressive strength of cubes averaged and reported to the nearest 10 psi (0.1 MPa)?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State Department of Transportation

WSDOT Test Method T 113

Method of Test for Determination of Degradation Value

1. Scope

a. This method covers the procedure for determining the susceptibility of an aggregate to degrade into plastic fines when abraded in the presence of water.

2. Apparatus

a. Balance – 5000 g capacity, sensitive to 0.1 g

b. Degradation Shaker – Tyler Portable Sieve Shaker CL-305 modified to provide 300 ± 5 oscillations per minute with a 1¾ in (44.5 mm) throw on the cam or a shaker with equivalent movement

c. Washing Canister – Shall be either Plastic or Steel meeting the following:
   - Plastic Canister – 7½ in ± ¼ in (190.5 mm ± 6.3 mm) diameter x 6 ± ½ in (152.4 mm ± 12.5 mm) high. Sidewalls of the plastic canister should meet the bottom at 90 degrees with little or no fillet
   - Steel Canister: Meeting the requirements of AASHTO T 210 (ASTM D 3744)

d. Sand equivalent graduated cylinder and rubber stopper

e. Sand equivalent stock solution

f. Sieves – ½ in (12.5 mm), ⅜ in (9.5 mm), ¼ in (6.3 mm), U.S. No. 10 (2.00 mm) and U.S. No. 200 (0.075 mm) sieves conforming to the requirement of ASTM E11

g. Graduates – 500 ml tall form, 100 ml

h. Interval timer

i. Funnel – Large enough to securely hold the nest of sieves and a mouth that fits into the 500 ml graduate

j. Sieve Shaker – Shaker that meets the requirements of AASHTO T-27

k. Oven – Sufficient size, capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C)

l. Sprayer – Water sprayer, device to produce a low volume stream of water. i.e. 500 ml wash bottle

m. Suitable Containers – Pans for washing and drying

3. Sample Preparation

a. If testing pit run material: dry at 230 ± 9°F (110 ± 5°C) to allow for clean separation from the fine material. Separate the material over the ½ in (12.5 mm) sieve and discard that finer than the ½ in (12.5 mm) and proceed to step 3d.

b. If testing crushed and stockpiled material: dry at 230 ± 9°F (110 ± 5°C) to allow for clean separation from the fine material and proceed to step 3e.

c. If testing quarry material: if necessary, separate the material over the ½ in (12.5 mm) sieve and discard that finer than the ½ in (12.5 mm).

d. Crush the material to be tested to pass the ½ in sieve (12.5 mm).

e. Split out an adequate amount of crushed material (approximately 5000 grams).

f. Sieve the approx. 5000 g split over a ½ in (12.5 mm), ⅜ in (9.5 mm), ¼ in (6.3 mm), and U.S. No. 10 (2.00 mm) screens in a sieve shaker. Steps should be taken to avoid overloading the sieves. Use shaking time determined to meet the requirement of AASHTO T 27 Section 8.2 for the shaker being used.

Note 1: When performing this test for Recycled Concrete Aggregate (RCA) the final sieve for the 5000 g split is the U.S. No. 4 instead of the U.S. No. 10.

g. By splitting or quartering, obtain from the sieved material approximately 550 g of ½ -⅜ (12.5-9.5 mm), 550 g of ⅜-¼ (9.5-6.3 mm), and 1100 g of ¼ -#10 (6.3-2.00 mm).

h. Combine the ½-⅜ (12.5-9.5 mm) with the ⅜-¼ (9.5-6.3 mm).

i. Wash the ½-¼ (12.5-6.3 mm) and ¼-#10 (6.3-2.00 mm) portions separately by placing in a container and adding sufficient water to cover it. Agitate vigorously to ensure complete separation of the material finer than No. 200 (0.075 mm) from coarser particles and bring the fine material into suspension above the coarser material.

Note 2: When performing this test for RCA use the ¼" - #4 instead of the ¼" - #10.

Note 3: The use of a mechanical aggregate washer is NOT permitted in the washing procedure.

Immediately pour the wash water containing the suspended and dissolved solids over a U.S. No. 10 (2.00 mm) sieve, being careful not to pour out the coarser particles. Add a second charge of water to the portion remaining in the container, agitate, and repeat the operation until the wash water is reasonably clear. Return all material retained on the sieve to the container. Repeat the process for the second portion.

j. Place washed portions into suitable containers and dry to a constant weight at 230 ± 9°F (110 ± 5°C).

k. Allow to cool to room temperature.

l. From the washed and dried material, prepare two - 1000 g test samples as follows:

1. Quarter or split the ½-¼ (12.5-6.3 mm) to achieve two 500 ± 1 g portions; hand selection of up to 50 g to attain the 500 ± 1 grams is acceptable.

2. Split the ¼-#10 (6.3-2.00 mm) to achieve two 500 ± 1 g portions; hand selection of up to 50 g to attain the 500 ± 1 grams is acceptable.

3. Combine each of the ½-¼ (12.5-6.3 mm) portions with one of the ¼-#10 (6.3-2.00 mm) portions to create two - 1000 ± 2 g test samples consisting of ½-#10 (12.5-2.00 mm) material.

Note 4: When performing this test for RCA use the ¼" - #4 instead of the ¼" - #10.

4. Procedure

a. Place one test sample in the washing canister, add 200 ± 5 ml of water, cover tightly and place in degradation shaker.

b. Immediately agitate the material for 20 minutes.

c. At the end of the shaking time, empty the washing canister into nested U.S. No. 10 (2.00 mm) and U.S. No. 200 (0.075 mm) sieves fitted into the funnel placed over a 500 ml graduate to catch all wash water.

Note 2: IMPORTANT! It is critical to the test result that material finer than the U.S. No. 200 (0.075 m) is washed off the larger particles into the 500 ml graduate. This process has to be completed using approximately 300 ml of water such that the total amount water used in the test is only 500 ml. (200 ml with shaking, plus the 20-50 ml used for rinsing the canister and lid, plus that remaining to wash the fines off the particles) The process should be slow and meticulous, utilizing a high pressure, low volume spray of water. Use of a 500 ml squeeze type wash bottle has been found to work well for this process. The washing process should take 5 - 10 minutes.

d. Rinse material finer than U.S. No. 200 (0.075 mm) off the lid into the washing canister and then from the washing canister into the nested sieves using minimal amount of water. (20-50 ml).

e. Shake the nested sieves to spread the sample evenly. (Note 3).

f. Wash the sample using only 20-50 ml. of water. (Note 2).

g. Shake the nested sieves to release any water and 200- that may be sitting on the U.S. No. 200 (0.075 mm) sieve. (Note 3).

h. Raise the funnel and tilt slightly, insure that the mouth of the funnel remains over the 500 ml graduate and catches all of the wash water, to allow the sieves to drain easier. Observe the liquid for clarity.

i. Lower the funnel back into the 500 ml graduate.

j. Repeat steps 4e. through 4i. until the liquid in the graduate reaches the 500 ml mark. Do not allow drainage above the 500 ml mark.

Note 3: Shaking should be vigorous enough to move the aggregate but with care such that no spillage of wash water or loss of aggregate occurs.

k. Measure 7 ± 1 ml of sand equivalent stock solution and pour into a sand equivalent cylinder.

l. Bring all solids in the 500 ml graduate into suspension by capping the top with the palm of the hand and turning it completely upside down and back as rapidly as possible, allowing the air bubble to traverse from end to end. Repeat this cycle 10 times, shaking the graduate on the first inversion to release sediment on the bottom.

m. After the tenth cycle, immediately pour the agitated liquid into the sand equivalent cylinder to the 15 ± 0.1 inch. (381 ± 2.5 mm) mark before any settling occurs. (Note 4.)

Note 4: The pour should be immediate and continuous without pause. Allowing the agitated liquid to flow back into the 500 ml graduate and then resuming the pour will allow settling and yield inconsistent results.

n. Insert rubber stopper into the sand equivalent cylinder and mix the contents by turning the cylinder completely upside down and back as rapidly as possible, allowing the bubble to traverse from end to end. Repeat this cycle 20 times.

o. Gently place the sand equivalent cylinder on the table, remove stopper, and immediately start timer. Allow to stand undisturbed for 20 minutes. After 20 minutes read and record the height of the sediment column to the nearest 0.1 in (2.5 mm).

p. Repeat steps 4a. thru 4o. for the second test sample.

5. Calculations

a. Calculate the degradation factors for the two test samples using the following formula:

$$D_1 = \frac{(15\text{-}H_1)}{(15 + 1.75H_1) \times 100} \qquad D_2 = \frac{(15\text{-}H_2)}{(15 + 1.75H_2) \times 100}$$

Note: Table 1 may be used to determine the values of D1and D2 by finding the corresponding H value.

b. Average the two degradation factors if they meet the requirements of Section 6, Repeatability:

$$D = \frac{(D_1+D_2)}{2}$$

Where:

D = Degradation Factor
D_1 = Degradation Factor for the first test sample
D_2 = Degradation Factor for the second test sample
H_1 = Height of Sediment in first sand equivalent cylinder
H_2 = Height of Sediment in second sand equivalent cylinder

c. Report the Degradation Factor (D) to the nearest whole number.

d. Degradation Factors range from 0 to 100, with higher values representing the best materials.

6. Repeatability

a. The two test samples, D_1 & D_2 must agree within 6 points.

b. Repeat the entire test if variation between the test samples exceeds 6 points, see following calculation:

$$\text{Absolute Value } (D_1\text{-}D_2) > 6$$

Table 1 Degradation Value "D"

$$D = \frac{(15\text{-}H)}{(15 + 1.75H)} \times 100$$

H	D	H	D	H	D	H	D	H	D
0.0	100	3.1	58	6.1	35	9.1	19	12.1	8
0.1	98	3.2	57	6.2	34	9.2	19	12.2	8
0.2	96	3.3	56	6.3	33	9.3	18	12.3	7
0.3	95	3.4	55	6.4	33	9.4	18	12.4	7
0.4	93	3.5	54	6.5	32	9.5	17	12.5	7
0.5	91	3.6	54	6.6	32	9.6	17	12.6	6
0.6	90	3.7	53	6.7	31	9.7	17	12.7	6
0.7	88	3.8	52	6.8	30	9.8	16	12.8	6
0.8	87	3.9	51	6.9	30	9.9	16	12.9	6
0.9	85	4.0	50	7.0	29	10.0	15	13.0	5
1.0	84								
1.1	82	4.1	49	7.1	29	10.1	15	13.1	5
1.2	81	4.2	48	7.2	28	10.2	15	13.2	5
1.3	79	4.3	48	7.3	28	10.3	14	13.3	4
1.4	78	4.4	47	7.4	27	10.4	14	13.4	4
1.5	77	4.5	46	7.5	27	10.5	13	13.5	4
1.6	75	4.6	45	7.6	26	10.6	13	13.6	4
1.7	74	4.7	44	7.7	26	10.7	13	13.7	3
1.8	73	4.8	44	7.8	25	10.8	12	13.8	3
1.9	71	4.9	43	7.9	25	10.9	12	13.9	3
2.0	70	5.0	42	8.0	24	11.0	12	14.0	3
2.1	69	5.1	41	8.1	24	11.1	11	14.1	2
2.2	68	5.2	41	8.2	23	11.2	11	14.2	2
2.3	67	5.3	40	8.3	23	11.3	11	14.3	2
2.4	66	5.4	39	8.4	22	11.4	10	14.4	1
2.5	65	5.5	39	8.5	22	11.5	10	14.5	1
2.6	63	5.6	38	8.6	21	11.6	10	14.6	1
2.7	62	5.7	37	8.7	21	11.7	9	14.7	1
2.8	61	5.8	37	8.8	20	11.8	9	14.8	0
2.9	60	5.9	36	8.9	20	11.9	9	14.9	0
3.0	59	6.0	35	9.0	20	12.0	8	15.0	0

Performance Exam Checklist

WSDOT TM 113

Method of Test for Determination of Degradation Value

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
Equipment		
1. Balance - 5000g capacity, sensitive to 0.1g- Calibrated?	____	____
2. Degradation Shaker – 1¾" throw, 300 ± 5 oscillations per minute – Verified?	____	____
3. Canister – plastic, 7½ in diameter x 6 in high, walls meet floor at 90 deg with min fillet, or steel meeting AASHTO T210, or ASTM D 3744?	____	____
4. Sand Equivalent Cylinder & Rubber Stopper?	____	____
5. Sand Equivalent Stock Solution?	____	____
6. Sieves – ½, ⅜, ¼, No. 10, No. 200 – Verified?	____	____
7. Graduates – 500 ml tall form & 100 ml?	____	____
8. Interval Timer – Verified?	____	____
9. Funnel – Large enough to hold the sieves with a mouth that fits in the 500 ml graduate?	____	____
10. Sieve Shaker(s) – Verified?	____	____
11. Oven – verified at 230 ± 9°F.- Calibrated?	____	____
12. Sprayer – produces a low volume stream of water?	____	____
13. Containers – suitable for drying and washing?	____	____
Procedure		
1. a. Pit Run – Dried and separated over the ½ in, ½-discarded?	____	____
b. Processed material – Dried?	____	____
c. Quarry material – prepared for crushing?	____	____
2. Material crushed to pass the ½"?	____	____
3. Split out approx. 5000g?	____	____
4. Separate the material over the ½, ⅜, ¼, and No. 10?	____	____
5. Split or quarter approx. 550g ½-⅜, 550g ⅜-¼, & 1100g ¼-No. 10?	____	____
6. Combine the ½-⅜ with the ⅜-¼?	____	____

Procedure Element		Trial 1	Trial 2
7.	Hand wash the ½-¼ and ¼-No. 10 separately?	____	____
8.	Dry the portions in suitable containers at 230 ± 9 to a constant weight?	____	____
9.	Split of quarter the two sizes into two 500 ± 1g portions, hand selection ok to 50g?	____	____
10.	Combine to create two 1000 ± 2g, ½ - No. 10 test samples?	____	____
11.	Place one sample into a canister, cover with 200 ± 5 ml water, cover & shake for 20 min?	____	____
12.	Empty canister into the nested No. 10 & No. 200 fitted in the funnel over the 500 ml grad.?	____	____
13.	Rinse the lid into the canister and then the canister into the nested sieves?	____	____
14.	Shake the sieves to spread the sample?	____	____
15.	Wash using only 20-50 ml.?	____	____
16.	Shake the sieves to release trapped water and then lift observing liquid for clarity?	____	____
17.	Repeat 14-16 until water reaches the 500 ml mark – water not to exceed 500 ml?	____	____
18.	No loss of fines or liquid during the washing process?	____	____
19.	Place 7 ± 1 ml of SE Stock Solution in a SE Graduated Cylinder?	____	____
20.	Turn capped 500 ml upside down & back allowing bubble to traverse 10 cycles?	____	____
21.	Immediately pour into a SE Cylinder to the 15 ± 0.1 mark – no settling allowed?	____	____
22.	Rubber stopper inserted and SE Cylinder turned upside down & back 20 cycles?	____	____
23.	Place gently, remove stopper, start timer, allow to sit undisturbed for 20 min?	____	____
24.	Record height of column to nearest 0.1 in?	____	____
25.	Repeat for second sample?	____	____
26.	Calculations performed correctly?	____	____
27.	Second sample must be within 6 points?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State Department of Transportation

WSDOT Test Method T 123

Method of Test for Bark Mulch

1. Scope

a. This method covers a procedure for determining the sieve analysis and material finer than No. 4 sieve using a loose volume bucket.

2. Equipment

a. A mechanical sieve shaker.

b. Sieves – Sieves conforming to the requirements of ASTM E11. Breaker sieves may be used.

c. Volume Bucket – A container calibrated in 1 gal. increments from 1 to 5 gal. A 5-gal. bucket may be used when calibrated as follows:

On a level surface calibrate the container by gradually filling it with water in 1 gal. increments. Mark the inner wall of the container after the addition of each gallon

3. Procedure

a. Air dry (140°F max) the sample for 15 hours, ± 4 hours.

b. Reduce the sample to testing size per the FOP for AASHTO R 76.

c. Place the sample in the volume bucket and record the volume as the total volume.

d. Shake the sample over the 2 in and No. 4 sieves. Using breaker sieves inserted between the two specified sieves so the No. 4 sieve will not be **overloaded**. Use caution to avoid over sieving as the wood material breaks down.

e. The material retained on the 2 in sieve is measured in the volume bucket and recorded.

f. The material on the breaker sieves is added to the material retained on the No. 4 sieve and the volume measured in the volume bucket and recorded.

g. The percent passing is calculated as follows:

$$100 - \frac{(\text{Volume on sieve} \times 100)}{\text{Total Volume}} = \%\ \text{passing}$$

Performance Exam Checklist

WSDOT T 123

Method of Test for Bark Mulch

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	The tester has a copy of the current procedure on hand?	____	____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	____	____
3.	Bark mulch sample air dried for 15 ± 4 hrs (@ 140°F max)?	____	____
4.	Five (5) gallon bucket calibrated in 1 gal. increments?	____	____
5.	Sample reduced according to FOP for AASHTO R 76 and placed in calibrated bucket?	____	____
6.	Volume of sample in bucket recorded as total volume?	____	____
7.	Sample screened in the shaker through 2 in screen, breaker screens and No. 4 screen?	____	____
8.	Do not over shake to prevent degrading of sample?	____	____
9.	Remove 2 in screen and damp material in calibrated bucket and record volume as volume on 2 in screen?	____	____
10.	Place all breaker screen material down to No. 4 screen in bucket and record volume as volume on No. 4 screen?	____	____
11.	All calculations performed correctly?	____	____
12.	Report results?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State
Department of Transportation

WSDOT Test Method T 125

Determination of Fiber Length Percentages in Wood Strand Mulch

1. Scope

1.1. This test method covers the determination of the percentage, by mass, of fiber strands in a wood strand mulch sample meeting the specified requirements.

1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1. AASHTO Standards:

M 231	Weighing Devices Used in the Testing of Materials
R 76	Reducing Samples of Aggregate to Testing Size

3. Summary of Test Method

3.1. A sample of wood strand mulch is separated into individual fiber strands and the length, width and thickness of each strand is measured. The fiber stands are then separated into two categories; Strands meeting specified requirements and Strands not meeting specified requirements. The percentage of wood fiber strand is then computed and compared to the requirements of the specification. (See Calculation below)

4. Apparatus

4.1. *Balance* – shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231 for general-purpose balance required for the principle sample mass being tested.

4.2 *Measuring device* – capable of reading to the nearest 1⁄16th inch (can either be one device or two separate devices)

5. Sampling

5.1 Split a bale of wood strand mulch into three approximately equal sections. From the interior face of each section obtain a minimum of 150 g of fiber strand, taking care not to damage the material.

5.2 Recombine the three 150 g samples and reduce the combined sample to a minimum sample size of 100g, in accordance with FOP for AASHTO R 76, Method B Quartering.

6. Sample Preparation

6.1. Air dry the sample to a Constant Mass as defined in AASHTO T 265.

7. Procedure

7.1. Spread the sample on a clean flat surface large enough to permit careful inspection of each strand. Measure the length, width and thickness of each strand in the 100g sample.

7.2. Compare the measurements of each strand to the specified requirements and separate the strands into two categories:

Strands meeting specified requirements

Strands not meeting specified requirements

7.3. Determine the total mass of each category.

8. Calculation

8.1. Report the following information:

8.1.1. Calculate the percentage of fiber strand meeting the specified requirements to the nearest one percent as follows:

$$P = [(S) / (S+N)] \times 100$$

Where:

P = percent of strands meeting the required specifications

S = mass of strands meeting required specifications

N = mass of strands not meeting required specifications

Performance Exam Checklist

WSDOT Test Method 125

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	____	____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	____	____
3.	Sample reduced to correct size?	____	____
4.	Sample dried and cooled, if necessary?	____	____
5.	Sample properly measured?	____	____
6.	Strands separated into "meeting specification" and "not meeting specifications" categories?	____	____
7.	Dry mass of each category determined to nearest 0.1 g?	____	____
8.	Calculation performed correctly?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Performance Exam Checklist

AASHTO T 196

Air Content of Concrete (Volumetric Method)

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	Bowl filled in two equal layers?	____	____
2.	Each layer rodded 25 times?	____	____
3.	Bowl tapped (sharply) 10 to 15 times after rodding each layer?	____	____
4.	Excess concrete removed with strike-off bar or plate?	____	____
5.	Flange of bowl wiped clean?	____	____
6.	Using funnel, water added, then alcohol added, then final water added until liquid level appears in neck?	____	____
7.	Funnel removed & water adjusted to zero mark using rubber syringe?	____	____
8.	Screw cap is attached and tightened?	____	____
Initial Reading			
9.	Unit inverted and agitated at 5 second intervals for a minimum of 45 seconds and until concrete is free from base?	____	____
10.	Unit vigorously rolled ¼ to ½ turn forward and back several times with base at a 45° angle. Then turn base about ⅓ turn and rolling process resumed.	____	____
11.	Was meter checked for leaking?	____	____
	a. If leak was found, was test started over with new sample?	____	____
12.	Apparatus placed upright, top loosened and allowed to stand until air rises to the top?	____	____
	a. < 0.25 percent change in 2 minutes (without excessive foam), initial reading recorded to the nearest 0.25%?	____	____
	b. More than 6 minutes to stabilize or excessive foam, was test discarded and new test run?	____	____

Procedure Element	**Trial 1**	**Trial 2**
Confirmation of Initial Meter Reading		
13. 1 minute rolling repeated and liquid level checked?	____	____
14. Confirmation reading > 0.25 percent of initial, new reading recorded as new initial reading, repeat 1 minute rolling	____	____
15. Level of liquid read < 0.25 percent change, final meter reading recorded to nearest 0.25%?	____	____
16. Apparatus disassembled and checked for undisturbed concrete	____	____
Calculations		
17. Correction factor from Table 1 subtracted for use of 2.5 pts or more of alcohol?	____	____
18. If required, number of calibration cups of water added to air content?	____	____
19. Air content reported to the nearest 0.25 percent air?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for AASHTO T 231

Capping Cylindrical Concrete Specimens

WSDOT has adopted the published AASHTO T 231.

AASHTO Test Methods cannot be included in Materials Manual due to copyright infringement.

WSDOT employees can access AASHTO and ASTM test methods in the following web address:
http://wwwi.wsdot.wa.gov/MatsLab/BusinessOperations/ASTMLogin.htm

Non-WSDOT employees can order AASHTO's Standard Specifications for Transportation Materials and Methods of Sampling and Testing, using the following web address:

https://store.transportation.org

Performance Exam Checklist

AASHTO T 231

Capping Cylindrical Concrete Specimens

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. The tester has a copy of the current procedure on hand?	_____	_____
2. All equipment is functioning according to the test procedure, and if required has the current calibration/standardization/check and maintenance tags present?	_____	_____
3. Sulfur mortar heated to approximately 130°C (265°F), as determined by an all-metal thermometer?	_____	_____
4. Oldest material in pot not been used more than five times?	_____	_____
5. Capping plate or device warmed slightly before use?	_____	_____
6. Capping plate lightly oiled prior to use?	_____	_____
7. Molten sulfur mortar stirred immediately prior to pouring each cap?	_____	_____
8. Ends of specimen dry enough to preclude steam or foam pockets?	_____	_____
9. Capping plate and alignment guides used effectively?	_____	_____
10. Sufficient material used to cover cylinder end and allowed to harden?	_____	_____
11. Caps examined for pockets or hollow areas?	_____	_____
12. Caps checked for planeness?	_____	_____
13. Cylinders kept moist after capping?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Performance Exam Checklist

AASHTO T 288 Checklist

Determining Minimum Laboratory Soil Resistivity

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element *Laboratory method of Determining Minimum Resistivity*		**Trial 1**	**Trial 2**
1.	Sample dried at 140 F, and screened through # 10 sieve?	_____	_____
2.	Quartered or split out 1500 grams of passing #10 material?	_____	_____
3.	150 ml of distilled water added to the 1500 gram and thoroughly mixed?	_____	_____
4.	Sample covered with a wet cloth and allow to stabilize or cure for 12 hours?	_____	_____
5.	Sample placed & compacted in soil box in layers and the excess trimmed off with a straightedge?	_____	_____
6.	Resistivity measured with the instrument?	_____	_____
7.	Soil removed and retained from box and 100 ml of distilled water added and thoroughly mixed?	_____	_____
8.	Soil box cleaned with distilled water?	_____	_____
9.	Repeat procedure by increasing moisture content by 100 ml until minimum resistivity can be established?	_____	_____
10.	Record the lowest value during the repeated measurements?	_____	_____
11.	Report the resistivity reading.	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Errata to FOP for AASHTO T 304

Uncompacted Void Content of Fine Aggregate

WAQTC FOP for AASHTO T 304 has been adopted by WSDOT with the following changes:

Report

Replace first bullet with below:

- The Uncompacted Voids (U_m) in percent to the nearest 1 percent.

UNCOMPACTED VOID CONTENT OF FINE AGGREGATE FOP FOR AASHTO T 304

Scope

This procedure covers the determination of the loose uncompacted void content of a sample of fine aggregate in accordance with AASHTO T 304-22. When measured on an aggregate of a known grading, void content indicates the aggregate's angularity, sphericity, and surface texture compared with other fine aggregates tested in the same grading. When void content is measured on an as-received fine aggregate grading, it can indicate the effect of the fine aggregate on the workability of a mixture in which it is used.

Apparatus

- Cylindrical Measure – approximately 100 mL right cylinder made of seamless smooth wall metal, inside diameter approximately 39 mm and inside height approximately 86 mm, with a metal bottom at least 6 mm thick, which is firmly sealed to the cylinder with means for aligning the axis of the cylinder with that of the funnel (see Figure 1).
- Funnel – the lateral surface of the right frustum of a smooth metal cone at least 38 mm high sloped 60 ± 4 degrees from the horizontal with an opening of 12.7 ± 0.6 mm diameter with a volume of at least 200 mL or with a supplemental glass or metal container to provide the required volume (see Figure 2).
- Funnel Stand – A three or four-legged support capable of holding the funnel firmly in position 115 ± 2 mm above the top of the cylinder with the axis of the funnel colinear (within a 4 degree angle and a displacement of 2 mm) with the axis of the cylindrical measure. A suitable arrangement is shown in Figure 2.
- Glass Plate – minimum 4 mm thick, approximately 60 mm by 60 mm used to calibrate the cylindrical measure.
- Pan – flat metal or plastic pan of sufficient size to contain the funnel stand and to prevent loss of material.
- Metal spatula with a straight edged blade approximately 100 mm long, and at least 20 mm wide with an end cut at a right angle to the edges.
- Scale or balance accurate and readable to ±0.1 g within the range of use, capable of weighing the cylindrical measure and its contents.

Figure 1

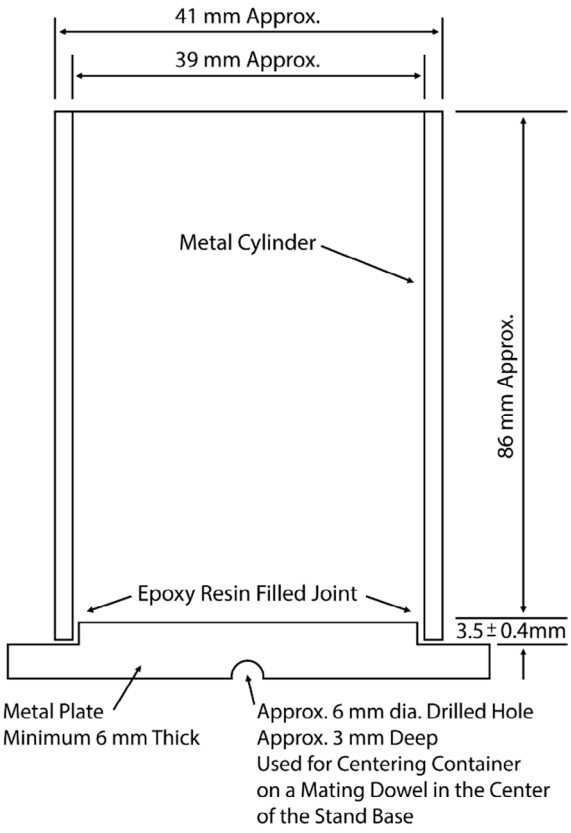
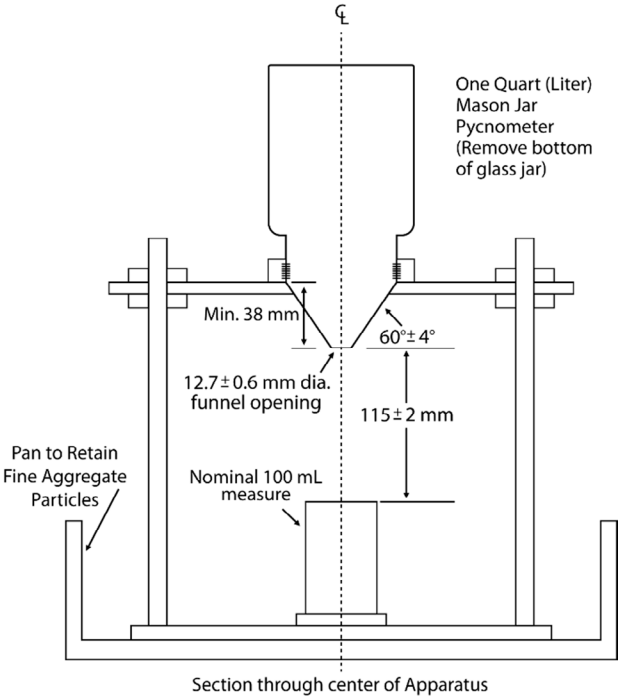


Figure 2



Preparation of Test Samples

Obtain the standard graded sample from one of the following:

1. Use the sieve analysis samples from the FOP for AASHTO T 27/11.
2. Store the dry separate size fractions obtained from one (or more) sieve analysis in separate containers for each size.

   OR:

1. Obtain sample according to the FOP for AASHTO R 90
2. Reduce according to the FOP for AASHTO R 76
3. Wash sample over a 150-µm (No. 100) or 75-µm (No. 200) sieve according to FOP for AASHTO T 27/11.
4. Dry to constant mass according to the FOP for AASHTO T 255.
5. Using sieves in Table 1, separate into individual size fractions according to FOP for AASHTO T 27/11
6. Weigh out and combine the following quantities of material identified in Table 1.

Table 1

Individual Size Fraction		
Passing	**Retained On**	**Mass g**
No. 8 (2.36 mm)	No. 16 (1.18 mm)	44.0 ± 0.2
No. 16 (1.18 mm)	No. 30 (600 µm)	57.0 ± 0.2
No. 30 (600 um)	No. 50 (300 µm)	72.0 ± 0.2
No. 50 (300 um)	No. 100 (150 µm)	17.0 ± 0.2
	Total	190.0 ± 0.2

Specific Gravity of Fine Aggregate

The fine aggregate bulk specific gravity (G_{sb}) is used to determine the uncompacted void content. Use the G_{sb} from the source if it is known. If it is unknown determine the G_{sb} on the minus No. 4 (4.75 mm) material according to AASHTO T 84.

If the G_{sb} of some size fractions differ by more than 0.05 from the G_{sb} typical of the complete sample, the G_{sb} of the fraction (or fractions) being tested must be determined.

Note 1: An indicator of differences in specific gravity of various particle sizes is a comparison of specific gravities run on the fine aggregate in different gradings. Specific gravity can be run on gradings with and without specific size fractions of interest. If specific gravity differences exceed 0.05, determine the specific gravity of the individual 2.36 mm (No. 8) to 150 um (No. 100) sizes for use either by direct measurement or by calculation using the specific gravity data on gradings with and without the size fraction of interest. A difference in specific gravity of 0.05 will change the calculated void content about 1 percent.

Procedure

1. Record the mass of the empty measure to the nearest 0.1 g.
2. Mix test sample with the spatula until it appears to be homogeneous.
3. Position the jar and funnel section in the stand and center the cylindrical measure as shown in Figure 2.
4. Using a finger, block the opening of the funnel, pour the test sample into the funnel.
5. Level the material in the funnel with the spatula.
6. Withdraw finger allowing the sample to freely flow into the cylindrical measure.
7. After the funnel empties, strike-off excess fine aggregate from the cylindrical measure with a rapid single pass of the spatula with the width of the blade vertical using the straight part of its edge in light contact with the top of the measure.

   Until strike-off is complete, avoid vibration or disturbance which could cause compaction of the material in the measure.

Note 2: After strike-off, the cylindrical measure may be tapped lightly to compact the sample to make it easier to transfer the container to scale or balance without spilling any of the sample.

8. Brush adhering grains from the outside of the container.
9. Determine and record the mass of the cylindrical measure and contents to the nearest 0.1 g.
10. Recombine the sample from the pan and cylindrical measure.
11. Stir until homogenous.
12. Repeat Steps 3 through 9.
13. Determine net mass of aggregate in measure by subtracting mass of the measure from the mass of measure and fine aggregate.
14. Calculate the uncompacted void content (U_s) of each determination to the nearest 0.1 percent.
15. Average the results of the two determinations (U_m) to the nearest 0.1 percent.

Calculations

Calculate the uncompacted voids for each determination:

$$U_s = \frac{V - \left(\frac{F}{G_{sb}}\right)}{V} \times 100$$

Where:

U_s = uncompacted voids in the material to the nearest 0.1 percent

V = volume of cylindrical measure, mL

F = net mass, g, of fine aggregate in measure

G_{sb} = Bulk dry specific gravity of fine aggregate

Calculate the average uncompacted voids for the two determinations:

$$U_m = \frac{U_1 + U_2}{2}$$

Where:

U_m = the average uncompacted void content to the nearest 0.1 percent

U_1 = first determination

U_2 = second determination

Example:

$$U_s = \frac{99.8\ mL - \left(\frac{146.2\ g}{2.636}\right)}{99.8\ mL} \times 100 = 44.4\%$$

Where:

U_s = uncompacted voids in the material to the nearest 0.1 percent

V = 99.8 mL

F = 146.2 g

G_{sb} = 2.636

The average uncompacted voids for the two determinations:

$$U_m = \frac{48.7\% + 49.9\%}{2} = 49.3\%$$

Where:

U_m = the average uncompacted void content to the nearest 0.1 percent

U_1 = 48.7%

U_2 = 49.9%

Report

- The Uncompacted Voids (U_m) in percent to the nearest 0.1 percent.
- The specific gravity value used in the calculations.

ANNEX — CALIBRATION OF CYLINDRICAL MEASURE

(Mandatory Information)

1. Apply a light coat of grease to the top edge of the dry, empty cylindrical measure.
2. Determine the mass of the measure, grease, and glass plate to the nearest 0.1 g.
3. Fill the measure with freshly boiled, deionized water at a temperature of 18 to 24ºC (64.4 to 75.2ºF).
4. Record the temperature of the water.
5. Place the glass plate on the measure, being sure that no air bubbles remain.
6. Dry the outer surfaces of the measure.
7. Determine the combined mass of measure, glass plate, grease, and water to the nearest 0.1 g.

Calculations

Calculate the volume of the measure as follows:

$$V = 1000 \times \frac{M}{D}$$

Where:

V = volume of cylinder, to the nearest 0.1 mL

M = net mass of water, g

D = density of water kg/m^3 (see Table B1 in the FOP for AASHTO T 99/T 180 for density at the temperature used)

Example

$$V = 1000 \times \frac{99.6}{997.99} = 99.8\ mL$$

Where:

V = volume of cylinder, to the nearest 0.1 mL

M = 99.6 g

D = 997.99 kg/m^3, density of water at 21ºC (69.8ºF)

Performance Exam Checklist

FOP FOR AASHTO T 304

UNCOMPACTED VOID CONTENT OF FINE AGGREGATE

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Preparation of Test Samples Element	**Trial 1**	**Trial 2**
1. Sample obtained per FOP for AASHTO R 90?		
2. Sample reduced to testing size per FOP for AASHTO R 76?		
3. Sample washed over 150-µm (No. 100) or 75-µm (No. 200) sieve in accordance with FOP for AASHTO T 27_T 11?		
4. Sample dried to constant mass?		
5. Separated into individual size fractions?		
6. Material weighed out and combined per Table 1?		
7. Fine aggregate bulk specific gravity (Gsb) determined according to procedure?		
Procedure Element		
8. Cylindrical measure calibrated according to Annex?		
9. Mass of empty measure recorded to nearest 0.1 g?		
10. Test sample mixed until it appears homogeneous?		
11. Cylindrical measure centered on stand per Figure 2?		
12. Finger used to block funnel opening?		
13. Test sample poured in funnel and leveled with spatula?		
14. Finger withdrawn and sample allowed to freely flow into cylindrical measure?		
15. After funnel empties, excess material struck off with spatula correctly?		
16. Care taken to avoid any vibration or disturbance?		
17. Adhering grains brushed off before weighing the cylindrical measure?		
18. Mass of the cylindrical measure and contents determined to nearest 0.1 g?		
19. Sample recombined and stirred until homogenous?		
20. Procedure Steps 3 through 9 repeated?		
21. Uncompacted void content (U_s) calculated for each determination to nearest 0.1 percent?		
22. Results of both determinations (U_m) averaged to nearest 0.1 percent and reported to the nearest 1 percent?		

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Errata to AASHTO T 324

Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures

AASHTO T 324 has been adopted by WSDOT with the following changes:

7. Determining Air Void Content

7.3. Determine the air void content of the specimens in accordance with T 269. The recommended target air void content is 7.0 ± 1.0 percent for laboratory-compacted SGC cylindrical specimens and 7.0 ± 1.0 percent for laboratory-compacted slab specimens. Field specimens may be tested at the air void content at which they are obtained.

8. Procedure

8.6.1. Select a test temperature of 50° C.

Tester Qualification Practical Exam Checklist

AASHTO T 324

Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	_____	_____
3.	Specimen height is 62 ± 1.0 mm (2.44 ± 0.04 in.) or 38.1 mm (1.5 inch) minimum for cores?	_____	_____
4.	Specimen meets air void tolerance of 7.0 + 1.0 %?	_____	_____
5.	Specimens placed in molds and loaded into trays with a maximum gap of 7.5 mm between molds?	_____	_____
6.	Tray mounted in machine and securely fastened?	_____	_____
7.	Sample data and testing parameters entered into computer? (e.g., sample name, agg source, wheel speed, maximum rut depth, number of passes, and water temperature)	_____	_____
8.	Wheels gently lowered and samples allowed to soak at testing temperature for 45 minutes?	_____	_____
9.	Wheel tracking device shut off when test parameters are reached?	_____	_____
10.	Test data obtained for charting and analysis?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

BULK SPECIFIC GRAVITY (G_{mb}) AND DENSITY OF COMPACTED ASPHALT MIXTURES USING AUTOMATIC VACUUM SEALING METHOD FOP FOR AASHTO T 331

Scope

This method covers the determination of bulk specific gravity (G_{mb}) of compacted asphalt mixture specimens in accordance with AASHTO T 331-22.

Overview

This method is used when specimens have open or interconnecting voids or absorb more than 2.0 percent of water by volume, or both, according to the FOP for AASHTO T 166.

Bulk specific gravity (G_{mb}) determined by this method may be lower, and air voids higher, than the results determined according to the FOP for AASHTO T 166. The differences may be more pronounced for coarse and absorptive mixtures. This procedure should be followed during laboratory mix designing if it will be used for control or assurance testing.

Test Specimens

Test specimens may be either laboratory-molded or sampled from asphalt mixture pavement. For specimens it is recommended that the diameter be equal to four times the maximum size of the aggregate and the thickness be at least one and one half times the maximum size of the aggregate.

.

Terminology

Constant Mass: The state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Bag cutter: knife or scissors
- Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.
- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.
- Water bath: For immersing the specimen in water while suspended under the balance or scale and equipped with an overflow outlet for maintaining a constant water level. Thermometer for measuring the temperature of the water bath shall have a temperature range of at least 20 to 45°C (68 to 113°F) and an accuracy of ±0.25°C (±0.45°F)
- Oven: Capable of maintaining a temperature of 52 ±3°C (126 ±5°F) for drying the specimens to a constant mass.
- Thermometer for measuring the room temperature: Accurate to ±0.5°C (±0.9°F) and with a temperature range of at least 15 to 45°C (59 to 113°F)

- Plastic bags: puncture resistant impermeable plastic bags that will not stick to the specimen and capable of withstanding temperatures up to 70°C (158°F). Between 0.100 mm (0.004 in.) and 0.152 mm (0.006 in.) thick. The bag correction factor (apparent specific gravity) is supplied by the manufacturer.
  - Small bag: less than 35 g with an opening between 235 mm (9.25 in.) and 260 mm (10.25 in.)
  - Large bag: 35 g or more with an opening between 375 mm (14.75 in.) and 394 mm (15.5 in.)

Note 1: The bag correction factor is usually located in the operator's manual. See the manufacturer's recommendations to ensure proper handling of bags.

- Specimen sliding plates: removable level and smooth-sided planar filler plates shall be inserted into the chamber to keep the samples of various heights level with the seal bar while being sealed.
- Specimen support plate: a plate with a cushioning membrane on top large enough to fully support the specimen and can easily slide on top of the smooth-sided plates.
- Vacuum chamber and sealing device: meeting the requirements of AASHTO T 331
- Vacuum gauge: meeting the requirements of AASHTO T 331

Procedure

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.
   a. Oven method
      i. Initially dry overnight at 52 ±3°C (125 ±5°F).
      ii. Determine and record the mass of the specimen. Designate as M_p.
      iii. Return the specimen to the oven for at least 2 hours.
      iv. Determine and record the mass of the specimen. Designate as M_n.
      v. Determine percent change by subtracting the new mass determination, M_n, from the previous mass determination, M_p, divide by the previous mass determination, M_p, and multiply by 100.
      vi. Continue drying until there is no more than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
      vii. Constant mass has been achieved; sample is defined as dry.
   b. Vacuum dry method according to the FOP for AASHTO R 79.
2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as A.

Note 1: 3000 to 6000 g laboratory compacted specimens may be considered room temperature after 2 hr. under a fan. Cooling time may be reduced for smaller specimens.

3. Fill the water bath to overflow level with water at 25 ±1°C (77 ±1.8°F) and allow the water to stabilize
4. Seal the specimen.
   a. Use a large bag for 150 mm (6 in.) in by 50 mm (2 in.) or greater specimens. Use a small bag for smaller specimens.
   b. Set the heat-sealing bar temperature according to manufacturer's directions.
   c. Inspect the bag for holes and irregularities.
   d. Determine and record the mass of the bag. Designate as B.
   e. Adjust filler plates in the vacuum chamber, adding or removing plates as needed.
   f. Place specimen support plate on top of filler plates.
   g. Place the bag on top of the specimen support plate in the vacuum chamber.
   h. Insert the specimen into the bag with the smoothest plane of the specimen on the bottom.

Note 2: Inserting the specimen into the bag may be done inside the chamber while holding the bag open with one hand over the sliding plate and gently inserting the specimen with the other hand. There should be about 25 mm (1 in.) of slack between the presealed bag end and the specimen.

   i. Grab the unsealed end of the bag on each side.
   j. Gently pull and center the bag over the seal bar, overlapping at least 25 mm (1 in.). Ensure that there are no wrinkles in the bag along the seal bar before closing the lid.
   k. Close the lid and engage the lid-retaining latch.

Note 3: The vacuum pump light will illuminate "red," and the vacuum gauge on the exterior of the chamber will become active, or a digital reading will show the vacuum state. It is normal for the bag to expand or "puff up" during this process.

   l. Once sealed, the 'de-vac' valve will open, and air will enter the chamber, causing atmospheric pressure to collapse the bag around the specimen.
   m. Disengage the lid-retaining latch, and carefully remove the sealed specimen from the chamber. Gently pull on the bag where it appears loose. Loose areas indicate a poor seal and the process must then be restarted at Step 4 with a new bag and a new initial mass.
5. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.
6. Fully submerge the specimen and bag shaking to remove the air bubbles. Ensure no air is trapped under the bag or in the bag creases. Place the specimen on its side in the suspension apparatus.
7. Allow water level and scale to stabilize.
8. Determine and record the submerged weight to the nearest 0.1 g. Designate this submerged weight as E.

Note 4: Complete Steps 4 through 7 in 1 min. or less to reduce potential for bag leaks.

9. Cut the bag open.
10. Remove the specimen from the bag.
11. Determine the mass of the specimen. Designate as C.
12. Compare this mass, C, with initial dry mass determined in Step 2, A.
    If more than 0.08 percent is lost or more than 0.04 percent is gained, return to Step 1.
13. Calculate G_{mb} and record to three decimal places.

Calculations

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g

M_n = new mass measurement, g

Calculate the bulk specific gravity (G_{mb}) using the following formula:

$$G_{mb} = \frac{A}{C + B - E - \left(\frac{B}{F}\right)}$$

Where:

G_{mb} = bulk specific gravity

A = mass of dry specimen in air, g

B = mass of the bag in air, g

C = final mass of the specimen after removal from the sealed bag, g

E = mass of the sealed specimen underwater, g

F = bag correction factor (apparent specific gravity), provided by the bag manufacturer

Example

$$G_{mb} = \frac{4833.6\ g}{4833.6\ g + 50.2\ g - 2860.4\ g - \left(\frac{50.2\ g}{0.756}\right)} = 2.470$$

Given:

A = 4833.6 g

B = 50.2 g

C = 4833.6 g

E = 2860.4 g

F = 0.756

Report

- Results on forms approved by the agency
- Sample ID
- G_{mb} to the nearest 0.001

Performance Exam Checklist

FOP for AASHTO T 331

Bulk Specific Gravity (G_{mb}) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	The tester has a copy of the current procedure on hand?		
2.	All equipment is functioning according to the test procedure, and if required has the current calibration/standardization/check and maintenance tags present?		
3.	Water bath of suitable size to entirely submerge and suspend the specimen with an adequate holder?		
4.	Water bath equipped with an overflow outlet?		
5.	Plastic bag meets requirements?		
6.	Specimen dried to constant mass?		
7.	Specimen cooled to 77 ± 9°F (25 ± 5°C) and dry mass, A, determined?		
8.	Water bath filled to overflow and allowed to stabilized at 77 ± 1.8°F (25 ± 1°C)?		
9.	Appropriate size bag selected and mass, B, determined?		
10.	Filler plates adjusted as needed?		
11.	Specimen inserted into bag with smoothest plane on bottom?		
12.	Bag centered and overlapping seal bar at least 1 in. (25 mm) with no wrinkles?		
13.	Lid closed and latched to engage operation?		
14.	Specimen carefully removed and inspected for poor seal?		
15.	If poor seal process restarted at Step 4?		
16.	Sealed specimen fully submerged, ensuring no air is trapped and bag is not touching water bath sides?		
17.	Once water level and balance stabilize, submerged weight, E, determined?		
18.	Specimen removed from bag and mass, C, determined?		
19.	If mass, C, has more than 0.08 percent lost or more than 0.04 percent gained than mass, A, process restarted at Step 1?		
20.	All calculations performed correctly?		

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Test Method T 417

Method of Test for Determining Minimum Resistivity and pH of Soil and Water

1. Scope

a. This method covers the procedure for determining the minimum resistivity and pH of soil or water samples at metal culvert locations. These values are used to assist in determining the type of metal culvert materials and protective coating that are permissible at each location.

b. This test method is divided into the following parts:

(1) Method of field resistivity survey and sampling for laboratory tests.

(2) Method of determining pH of water.

(3) Method of determining pH of soil.

(4) Laboratory method of determining minimum resistivity.

2. Method of Field Resistivity Survey and Sampling for Laboratory Tests

a. Scope

The field resistivity test is an indication of the soluble salts in the soil or water; it is used primarily as a guide for selecting samples that will be tested in the laboratory. The natural soil in each channel or culvert location and the structural backfill material are tested by a portable earth resistivity meter, and samples are selected on the basis of these tests. These samples are tested in the laboratory using a soil box to determine the minimum resistivity that will be used in the culvert-type determination.

b. Apparatus and Materials

(1) Portable earth resistivity meter, suitable for rapid in-place determination of soil resistivity.

(2) Field probe(s).

(3) Steel starting rod, for making hole (in hard ground) for inserting probe(s).

(4) Sledgehammer 4 lbs (1.8 kg).

(5) Distilled,deionized, or other clean water that has a resistivity greater than 20,000 ohm-cm.

c. Recording Data

Record test data in a field record book for use in selecting samples and also for use in analyzing laboratory test data.

d. Test Procedures

(1) In the channel of a proposed culvert site, insert the field probe into the soil between 6 in (152.4 mm) and 12 in (304.8 mm) and measure the resistivity. Follow the manufacturer's instructions for use of the meter. Remove the field probe and pour about 2 oz (59 ml) of distilled water into the hole.

(2) Reinsert the probe while twisting to mix the water and soil, then measure the resistivity.

(3) Withdraw the probe and add an additional 2 oz (59 ml) of distilled water.

(4) Reinsert the probe and again measure the resistivity of the soil.

(5) Multiply the lowest probe reading by ten to determine the minimum field soil resistivity and record this result. Note the multiplication factor of **ten** for soil resistivity readings when using the field probe.

(6) In addition to the single probe method described above another method is available for determination of soil resistivity in the field. Refer to the manufacturer's instructions as well as ASTM G 57 if the 4 probe "Wenner" method is being employed to determine the soil resistivity in the field.

e. Selection of Soil Samples for Laboratory Tests

(1) Make sufficient resistivity determinations at various locations in the channel or culvert site area to adequately represent the entire area. Should the soil appear consistent at a test site, take two resistivity determinations to verify. Additional readings should be taken if different soils are present.

(2) If the resistivity is reasonably uniform within the limits of the project, soil samples from three different locations will be sufficient. If, however, some locations show resistivities that differ significantly from the average of the determinations for the area being surveyed, additional soil samples should be taken to represent these locations — particularly those with resistivities significantly below the average.

For example, if the soil resistivities throughout the surveyed area are all at or near an average value of 20 ohm meter, three samples will be enough. If any of the locations tested have resistivities markedly below this average, for example 8 ohm meter,then such "hot spots" should definitely be represented by additional samples. Scattered locations of higher resistivity, for example 30 ohm meter or more, do not require additional samples.

Judgment must be exercised both in the field testing and sampling, and in evaluating the laboratory tests. In all cases, take a minimum of three samples per project.

Samples should be about 10 lb (4.5 kg) each and should be identified as to material type and location.

3. Method of Determining pH of Water

a. Scope

This method is suitable for use in the field or laboratory for determining the pH of water samples.

b. Apparatus and Materials

(1) 5 oz. (148 ml) or larger nonmetallic wide-mouth container,e.g., glass jar,beaker,or wax coated paper cup.

(2) pH meter.

(3) pH standard solution of pH 7.

c. Recording Data

Record test data in a field record book and report the results to the Project Engineer and in the Regional Soils Report.

d. Method of Sampling

(1) To avoid contamination from container, dip the wide-mouth container into the water to be tested, swirl to rinse and pour out contents.

(2) Dip the container into the water again to obtain a sample.

(3) Pour off any film which is on the surface of the sample before testing.

e. Standardization of pH Meter

Follow the instructions provided with the pH meter.

f. Use of pH Meter to Determine pH of Water

Follow the instructions provided with the pH meter.

g. Precautions

Follow the manufacturer's instructions for use of the meter and observe the usual precautions for making chemical tests.

Note: Field pH readings may be taken at any period other than flood flow. For water which has a pH of less than 6, take a 1 L (minimum) sample for laboratory analysis.

4. Laboratory Method of Determining pH OFSOIL

a. Scope

This method covers the laboratory procedure for determining pH of soil samples selected as indicated in Section 2.

b. Apparatus and Materials

(1) pH meter suitable for laboratory testing.

(2) Suitable containers constructed of glass or wax coated paper, with moisture proof covers.

(3) pH buffer solutions of pH 4.0, 7.0 & 10.0 (or those recommended by the pH meter manufacturer for meter standardization.)

(4) Distilled water and wash bottle.

(5) Thermometer (if required) readable to 0.2°F (0.1°C).

(6) U.S. No. 8 (2.36 mm) sieve.

(7) Balance, with sufficient capacity and readable to 0.1% of the sample mass, or better, conforming to the requirements of AASHTO M 231.

(8) Oven capable of maintaining a temperature of 140°F(60°C) around sample.

(9) Glass stirring rod.

c. Initial Preparation of Test Samples

(1) As received samples are to be tested for pH in a "moist" condition. If the soil as received is too wet to facilitate proper screening and reduction to test size it shall be air dried or dried to a "moist" condition in an oven at a temperature not to exceed 140°F (60°C).

(2) Split or quarter a sufficient amount of the moist sample to yield approximately 100 g of material after the material has been pulverized or mulled, taking care not to crush rock particles or naturally occurring grains, and screened over a U.S. No. 8 (2.36 mm) sieve. Discard any material retained on the U.S. No. 8 sieve. Only natural material passing the U.S. No. 8 sieve is to be used for the test.

d. Procedure for pH Determination

(1) Place a 30.0 ± 0.1 gram sample of prepared soil into the test container.

(2) Add 30.0 ± 0.1 grams of distilled water to the soil sample. Stir the sample to obtain a slurry and cover.

(3) Allow the sample to stand for a minimum of 1 hour, stirring every 10 to 15 minutes.

(4) Standardize the pH meter in accordance with the manufacturer's instructions.

(5) Stir the sample with a glass rod immediately prior to placing the pH meter electrode into the sample. Place the electrode in the sample taking precaution to ensure good contact between the electrode and the soil slurry. DO NOT place the electrode into any soil that may have accumulated in the bottom of the container, only into the soil slurry.

(6) Allow the electrode to remain immersed in the soil slurry for a sufficient time for the meter to stabilize. Refer to the manufacturer's instructions for recommended pH determination procedure and stabilization time.

(7) Read and record the pH of the sample to the nearest tenth of a whole number. If the meter reads to the hundredth place it shall be rounded to the nearest tenth place.

(8) Clean pH meter electrode and store in accordance with the manufacturer's instructions.

e. Precautions

(1) Follow all manufacturer's recommendations regarding proper use of the pH meter.

f. Report

(1) Report the pH value to the nearest tenth of a whole number.

5. Laboratory Method of Determining Minimum Soil Resistivity

a. Scope

This method covers the procedure for determining the minimum resistivity of soil samples selected as indicated in Section 2.

b. Apparatus and Materials

(1) Resistivity meter suitable for laboratory testing.

(2) Soil box calibrated for use with resistivity meter.

(3) U.S. No. 8 (2.36 mm) sieve.

(4) Non-absorbent pans, bowls or other containers of sufficient size to eliminate spilling during mixing, moisture conditioning, and sample handling.

(5) Oven capable of maintaining a temperature of 140°F (60°C) around sample.

(6) Balance, with sufficient capacity and readable to 0.1% of the sample mass, or better, and conform to the requirements of AASHTO M 231.

(7) Distilled or deionized water.

(8) Spoon or spatula.

(9) Graduated cylinder or other suitable device of sufficient size to accurately add quantities of moisture to sample.

(10) Straightedge

c. Preparation of Soil Samples

(1) Dry the sample as received from the field to a constant mass at a temperature not to exceed 140°F (60°C). (Air drying is also acceptable.) Split or quarter a sufficient amount of the dried material to yield a suitable sample after the material has been pulverized or mulled, taking care not to crush rock particles or naturally occurring grains, and screened over a U.S. No. 8 (2.36 mm) sieve. Discard any material retained on the U.S. No. 8 sieve. Only natural material passing the U.S. No. 8 sieve is to be used for the test.

d. Measuring the Resistivity of Soil Sample

(1) Split or quarter an amount of prepared soil that will fill approximately 4 times the volume of the soil box being utilized to determine resistivity.

(2) Add approximately 10% by weight of distilled water to the sample and mix thoroughly. Allow the sample to stand in a moisture proof container for a minimum of 12 hours.

(3) Re-mix the sample and immediately compact it (moderate compaction with the fingers is sufficient) slightly over the top of the soil box that has been cleaned with distilled water prior to use. Strike the material level to the top of the soil box with a straightedge.

(4) Measure the resistivity of the soil in accordance with the instructions furnished with the meter *and record the value*.

(5) Remove the soil from the soil box and recombine it with the remainder of the original sample then add an additional 5% by *original dry soil* weight of distilled water and thoroughly mix.

(6) Rinse the soil box with distilled water then immediately place the soil in the soil box and compact as described in step 3.

(7) Measure the resistivity of the soil in accordance with the instructions furnished with the meter and record the value.

(8) Repeat steps 5 through 7 until a minimum value can be determined.

(9) Record the lowest value measured during the repeated measurements in the soil box. The multiplication factor for the soil box is one, *(do not assume this as this value should be verified or reconciled with the manufacturer's recommendations provided with the soil box)* so a direct reading of the meter is the value used.

(10) Report the minimum resistivity of the soil in ohms-cm.

6. Laboratory Method of Determining Water Resistivity

a. Measuring the Resistivity of a Water Sample

(l) Thoroughly clean the soil box of all soil particles and rinse the soil box a minimum of three times with distilled water.

(2) Fill the soil box with distilled water and measure its resistivity.

(3) If the distilled water in the soil box measures infinite resistivity, empty the soil box of distilled water, fill with the test water, measure its resistivity, and record the measured value.

(4) If the distilled water in the soil box measures less than infinite resistivity, continue to rinse with distilled water until the box is absolutely clean. This condition is indicated by an infinite resistivity measurement when the box is filled with distilled water.

b. Recording Data

Record data in a field record book and report the results to the Project Engineer and in the Regional Soils Report.

7. Minimum Requirements

a. Metal pipe may be used at locations where the pH and soil resistivity are within the limits specified in the *Hydraulics Manual* M 23-01 for Aluminum (Aluminum Coated) Steel Pipe, Aluminum Pipe, and Galvanized (Zinc Coated) Steel Pipe.

Performance Exam Checklist

Method T 417 Checklist

Determining Minimum Resistivity and pH of Soil and Water

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
Determining pH of H_2O		
1. pH meter standardized in accordance with manufacturer's instructions?	____	____
2. H_2O sample placed in suitable non-metallic container for testing?	____	____
3. pH of H_2O determined in accordance with pH meter manufacturer's instructions?	____	____
4. pH recorded and reported to the nearest one tenth of a whole number?	____	____
Determining pH of soil		
1. Sample dried (if required) to a moist condition at a temperature not to exceed 140°F (60°C)?	____	____
2. Sample cooled, pulverized or mulled, and screened over a U.S. #8 sieve?	____	____
3. Only natural material passing U.S. #8 sieve used for test?	____	____
4. Approximately 100 grams of passing#8 material selected for testing?	____	____
5. 30 ± 0.1 grams of soil and 30 ± 0.1 grams of distilled H_2O added to suitable non-metallic testing container?	____	____
6. Sample immediately stirred to produce slurry and covered?	____	____
7. Sample allowed to stand for 1 hour, stirring every 10 to 15 minutes?	____	____
8. pH meter standardized in accordance with manufacturer's instructions?	____	____
9. Soil stirred immediately prior to pH determination?	____	____
10. pH of soil slurry correctly determined?	____	____
11. pH of soil read, rounded (if necessary) and reported to the nearest one tenth of a whole number?	____	____

Procedure Element	Trial 1	Trial 2
Determining minimum resistivity of soil		
1. As received sample dried to a constant mass at a temperature not to exceed 140°F (60°C)?	____	____
2. Sample cooled, pulverized or mulled, and screened over a U.S. #8 sieve?	____	____
3. Only natural material passing U.S. #8 sieve used for test?	____	____
4. Approximately 4 times the volume of the soil box of material passing the U.S. #8 sieve split or quartered for testing?	____	____
5. 10% by weight of distilled H_2O added to sample?	____	____
6. Sample mixed, covered and allowed to stand for a minimum of 12 hours in a moisture proof container?	____	____
7. Sample re-mixed, moderately compacted in soil box and resitivity determined?	____	____
8. Resistivity value recorded?	____	____
9. Sample from soil box removed, placed with remainder of sample and additional 5% by original dry soil weight of distilled H_2O added?	____	____
10. Sample remixed and resistivity determined and recorded?	____	____
11. Steps 8 and 9 repeated until minimum resistivity can be determined?	____	____
12. Minimum resistivity of soil reported in ohms/cm?	____	____
Determination of H_2O resistivity.		
1. Soil box thoroughly cleaned and rinsed at least three times with distilled H_2O?	____	____
2. Soil box filled level full with distilled H_2O and resistivity determined?	____	____
3. Resistivity from step #2 measures as infinite?	____	____
4. If yes, soil box emptied and resistivity of test sample determined and recorded?	____	____
5. If no, soil box further cleaned until condition described in step 3 satisfied?	____	____
6. Resistivity of H_2O sample reported in ohms/cm?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State Department of Transportation

WSDOT Test Method T 421

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (170/2070 Type) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Inspection

1. Scope

The purpose of this test method is to document the inspection of Traffic Controller Cabinets to ensure compliance with *Standard Specifications* and Contract Documents.

2. Reference Documents

- WSDOT *Standard Specifications* 9-29.13
- Caltrans Transportation Electrical Equipment Specifications
- FHWA-IP-78-16, Type 170 Signal Controller System Hardware Specification
- NEMA Standards Publication TS-1, Traffic Control Systems
- NEMA Standards Publication TS-2, Traffic Controller Assemblies with NTCIP Requirements
- AASHTO/ITE/NEMA Publication ATC 5301, Advanced Transportation Controller (ATC) Cabinet Standard

3. Safety

There is no PPE required for this test method. All items are visual inspection only, with no power source applied to the Unit Under Test (UUT).

4. Apparatus

An Electro-Static Discharge (ESD) Wrist Strap with cord and alligator clip shall be worn when handling Circuit Card Assemblies (CCA's) to prevent ESD damage. The Wrist Strap shall be connected via the cord and alligator clip to chassis in order to maintain the card handler at the same electrical potential as chassis ground.

5. Procedure

5.1 Incoming Inspection

When the Traffic Controller Cabinet arrives for testing, the contractor representative (typically the contractor's vendor) should have an appointment scheduled. Within seven (7) calendar days of arrival, the contractor representative shall assemble and demonstrate the Traffic Controller Cabinet. If assembly is not completed within these seven (7) calendar days, disposition of the Traffic Controller Cabinet is at the discretion of the Electrical Materials Laboratory personnel. Inspect the Traffic Controller Cabinet for any damage during shipping. Note any deficiencies.

5.2 Notify Project Office

Notify the project office and the contractor of the receipt of the Traffic Controller Cabinet. Note all Points-of-Contact who shall be copied on all communications and test results for this project.

5.3 Assess Traffic Controller Cabinet Compliance

The contractor representative shall provide all work necessary to assemble the Traffic Controller Cabinet at the State Materials Laboratory. The Traffic Controller Cabinet shall be inspected to ensure that it is in compliance with *Standard Specifications* and Contract Documents. Ensure that all of the required equipment is installed per these *Standard Specifications* and Contract Documents. In the event of a conflict, Contract Documents take precedence over the *Standard Specifications*. The results of successful completion of this test method shall be acceptance for further testing.

At a minimum, the following items shall be inspected against the Contract Documents and *Standard Specifications*:

1. Mylar Prints (cabinet drawings) – verify the minimum quantity per the Contract Documents are supplied by the vendor and that they match the Contract Documents
2. Labeling – verify that all labels match the cabinet drawings
3. Air Filter – verify the correct size, type, and quantity are installed
4. Wiring Laced and Clamped – verify all wiring is secured
5. Field Wire Terminal Blocks – verify correct type is installed
6. Police Keys – verify the correct quantity is supplied, if specified
7. Door Keys – verify the correct quantity is supplied, if specified
8. Door Locks – verify the correct type is installed as specified
9. Police Panel Switches – verify presence as specified
10. Circuit Breakers – verify minimum quantity and rating are installed as specified
11. Transient Suppressor – verify presence and if specified, correct type
12. Modem(s) – verify presence and type, if specified
13. Cabinet Finish – verify correct type, if specified
14. RFI Suppressor – verify presence and if specified, correct type
15. Door Light Switch(es) – verify correct quantity as specified
16. Pedestrian Switches – verify presence and if specified, quantity
17. Cabinet Lights – verify correct quantity and orientation as specified
18. 120 V_{ac} Outlet – verify presence as specified
19. Ground Fault Circuit Interruptor – verify presence as specified
20. Equipment Clearance – verify as specified
21. Load Switches – verify quantity and type as specified
22. Intersection Display Panel – verify presence if specified, and match against intersection drawing

23. Cabinet Ground Bus Bar – verify presence as specified
24. Isolated 120 V_{ac} bus bar (neutral) – verify presence as specified
25. Phase Selector(s) – verify quantity and type as specified
26. Flash Transfer Relay(s) – verify quantity and type as specified
27. Supplemental Resistor Load – verify presence if specified
28. Two Position Door Stop – verify presence as specified
29. Emergency Indicator Lights – verify presence if specified
30. Railroad Pre-Emption – verify presence if specified
31. Cabinet Construction – verify type if specified
32. Detector Panel – verify presence if specified
33. Detector Panel Shorting Plug (NEMA only) – verify presence if specified
34. Plastic Document Envelope – verify presence if specified
35. External Logic package (NEMA only) – verify presence and type, if specified
36. Absence of Red Assembly (170 and 2070 only) – verify presence of jumper plug area on output file
37. PROM Module (170 only) – verify PROM module is present, if controller is 170 Type
38. Dallas Chips (170 only) – verify Dallas chips, if specified and controller is 170 Type
39. AC Isolator – verify correct quantity and type, if specified
40. DC Isolator – verify correct quantity and type, if specified
41. Aux File (170 and 2070 only) – verify presence and that it is correctly populated per drawing, if specified
42. Manuals and Cut-Sheets – verify the minimum quantity is supplied for each component, if specified in the Contract Documents
43. DB9 Socket and C20 Plug (170 only) – verify presence if specified
44. C2 Plug and Cable (170 only) – verify presence if specified
45. Document Drawer – verify presence as specified
46. Controller – verify quantity and type as specified
47. CMU Door Interlock Switch (170 and 2070 only) – verify presence, if specified
48. Stop Time Switch – verify presence and quantity, if specified
49. Conflict Monitor – verify presence and type as specified
50. Inside Auto/Flash Switch – verify presence, if specified
51. Loop Amplifiers – verify quantity and type, if specified

6. Report

Record any deficiency that does not meet the above minimum requirements. Inspection tests shall be recorded in MATS as “As Received” if sufficient, and “As Shipped” if deficient but corrected. Inspection tests that do not apply shall have neither option checked. The overall test result shall be recorded as a “Pass” or “Fail” for test T421 in MATS.

Performance Exam Checklist

Method T 421 Checklist

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (170/2070 Type) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Inspection

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. Cabinet inspected for damage during shipping.	_____	_____
2. Project Office and Contractor notified of receipt.	_____	_____
3. Traffic Controller Cabinet assessed for compliance.	_____	_____
4. Report.	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Test Method T 422

Test Method for NEMA Type Traffic Controller Cabinet and 300 Series (Type 170/2070) Traffic Controller Cabinet Transient Line Voltage Test (Spike Test)

1. Scope

The purpose of this test method is to evaluate Traffic Controller Cabinet operation when subjected to Line Voltage Transients of 300 V_{ac} ±5% (285 V_{ac} to 315 V_{ac}). This test method only applies to NEMA type Traffic Controller Cabinets and 300 Series (Type 170/2070) Traffic Controller Cabinets.

2. Reference Documents

- Caltrans Transportation Electrical Equipment Specifications
- FHWA-IP-78-16, Type 170 Traffic Signal Controller System Hardware Specification
- NEMA Standards Publication TS-1, Traffic Control Systems
- NEMA Standards Publication TS-2, Traffic Controller Assemblies with NTCIP Requirements

3. Safety

This test is conducted with 300 V_{ac} line transients produced by the Transient Voltage Generator. Safety glasses shall be worn to provide eye protection in the event of an arc flash.

Exercise proper electrical cord handling to reduce the risk of electrical shock.

4. Apparatus

Beckman Model 3020, Berkeley Varitronics Model 3021, or device capable of generating line Voltage transients of 300 V_{ac}.

5. Procedure

5.1 Setup

Ensure the Transient Voltage Generator Output Control is in the "AC OFF" position and the Traffic Controller Cabinet Main is in the "OFF" position. Connect the Transient Voltage Generator to a 120 V_{ac}, 60 Hz power source (standard wall outlet). On the Transient Voltage Generator, set the Meter Control to "Generator Output", Phase Control to "Auto", Noise Power to "On", and Noise Output Level to minimum. Connect the Traffic Controller Cabinet to the Transient Voltage Generator.

5.2 Test Execution

Set the Transient Voltage Generator Output Control to "POS Pulse". Power up the traffic Controller Cabinet. Program the controller to cycle on minimum recall. Ensure the Traffic Controller Cabinet is operating normally.

On the Transient Voltage Generator, adjust the Output Level to 300 V_{ac}, ±5% (285 V_{ac} to 315 V_{ac}). Allow the Traffic Controller Cabinet to run in this configuration for ten minutes. Ensure the Traffic Controller Cabinet is operating normally during these ten minutes.

After the ten minutes has elapsed, adjust the Output Level to minimum on the Transient Voltage Generator. Switch the Output Control to "AC OFF", wait a moment, then switch to "NEG Pulse". Ensure that the Traffic Controller Cabinet resumes normal operation.

On the Transient Voltage Generator, adjust the Output Level to 300 V_{ac}, ±5% (285 V_{ac} to 315 V_{ac}). Allow the Traffic Controller to run in this configuration for ten minutes. Ensure the Traffic Controller Cabinet is operating normally during these ten minutes.

After the ten minutes has elapsed, adjust the Output Level to minimum on the Transient Voltage Generator. Switch the Output Control to "AC OFF". Switch the Traffic Controller Cabinet Main to the "OFF" position.

5.3 Test Completion

Disconnect the Traffic Controller Cabinet from the Transient Voltage Generator. Disconnect the Transient Voltage Generator from the 120 V_{ac}, 60 Hz power source (standard wall outlet). Return all test equipment to their proper storage location.

6. Report

During Test Execution the Traffic Controller Cabinet must conduct normal operation throughout all test conditions. During phase cycling, the Traffic Controller Cabinet shall not skip intervals, it shall not place false calls or produce false indications while in dwell, it shall not disrupt normal sequences in any manner, and it shall not change timings. Any of these conditions is considered a fail.

Record any deficiency that does not meet the above minimum requirements. The overall test result shall be recorded as a "Pass" or "Fail" for test T 422 in MATS.

Performance Exam Checklist

Test Method for NEMA Type Traffic Controller Cabinet and 300 Series (Type 170/2070) Traffic Controller Cabinet Transient Line Voltage Test (Spike Test) Method T 422 Checklist

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. Setup	_____	_____
2. Test Execution	_____	_____
3. Test Completion	_____	_____
4. Report	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State Department of Transportation

WSDOT Test Method T 423

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (Type 170/2070) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Conflict Monitor Testing

1. Scope

The purpose of this test method is to evaluate the operation of the Conflict Monitor Unit (CMU) which is supplied with each Traffic Controller Cabinet. This test method may also be used to test Conflict Monitor Units submitted for testing as piece parts upon request. To provide harmonization within this document, the nomenclatures "Conflict Monitor", "Signal Conflict Monitor", "Malfunction Management Unit", "Monitor Unit", and "Conflict Monitor Unit" used in the reference documents are synonyms and will be referred to in this document as "CMU".

2. Reference Documents

- WSDOT *Standard Specifications* 9-29.13
- AASHTO/ITE/NEMA Publication ATC 5301, Advanced Transportation Controller (ATC) Cabinet Standard
- Caltrans Transportation Electrical Equipment Specifications
- FHWA-IP-78-16, Type 170 Traffic Signal Controller System Hardware Specification
- NEMA Standards Publication TS-1, Traffic Control Systems
- NEMA Standards Publication TS-2, Traffic Controller Assemblies with NTCIP Requirements

3. Safety

Voltages up to 135 V_{ac} may be present on the test apparatus when energized. Caution should be exercised when operating the test apparatus. Only the interface of the CMU (buttons and switches) shall be touched while energized. Electro-Static Discharge (ESD) Wrist Straps Shall be removed prior to energizing circuits.

4. Apparatus

An Electro-Static Discharge (ESD) Wrist Strap with cord and alligator clip shall be worn when handling de-energized Circuit Card Assemblies (CCA's) to prevent ESD damage. The Wrist Strap shall be connected via the cord to the Traffic Controller Cabinet chassis ground or the ESD mat in the testing area in order to maintain the card handler at the same electrical potential as chassis ground. The Wrist Strap shall be removed prior to energizing circuits.

Metalized, static shielding bag to protect the CMU from Electro-Static Discharge (ESD) while transporting it between the Traffic Controller Cabinet and the testing area.

Electro-Static Discharge (ESD) Mat connected to earth ground for queueing of the CMU to test.

Conflict Monitor Tester, or device capable of simulating supply voltage failures and conflicting field output circuit "ON" conditions.

5. Procedure

5.1 Removal and Test Apparatus Installation

For CMU's supplied with a Traffic Controller Cabinet: Ensure the Traffic Controller Cabinet is off prior to removing the CMU. Attach one end of the ESD Wrist Strap to a convenient wrist, and the other end to a convenient chassis ground point of the Traffic Controller Cabinet. Disconnect the Red Interface Cable if equipped. Disconnect any RS-232 or Ethernet cable connections from the front of the CMU, if equipped. Remove the CMU from the Traffic Controller Cabinet and place in a static shielding bag for transport to the test area. Disconnect the ESD Wrist Strap from the chassis ground point of the Traffic Controller Cabinet.

For CMU's submitted for testing as piece parts: Open packaging at the testing area. If the CMU is not in a static-shielding bag, place it in one at this time.

Proceed to move the CMU to the testing area if not already done. Connect one end of the ESD Wrist Strap to the ESD Mat of the testing area. Ensure the Conflict Monitor Tester is off. Connect the CMU to the Conflict Monitor Tester. Take off the ESD Wrist Strap and leave the other end connected to the ESD Mat.

5.2 Setup

Remove the vendor supplied Conflict Programming Card and replace it with a complete diode-equipped Lab Test Card. Power up the Conflict Monitor Tester and open the control program from the PC connected to the tester. Select the Conflict Monitor Unit type for the Unit Under Test (UUT). Select the manufacturer, model number, and enter the serial number for the UUT.

Select the correct test type and optional tests for the configuration of the CMU to be tested. Options vary from configuration to configuration and cannot be covered here. The only consistent option is the type of test to be run, which is "Certification" as we are certifying the CMU.

5.3 Test Execution

Once all identifying information has been entered, click on the appropriate control program button to start the test. Follow all prompts to test completion.

5.4 Test Completion

Upon successful completion of all tests, note the test results. If there are any deficiencies, print out the test report to refer to later. Close the control program and power down the Conflict Monitor Tester. Remove the Lab Test Card and re-install the vendor supplied Conflict Programming Card. Put on the ESD Wrist Strap, remove the CMU from the Conflict Monitor Tester, and place it in a static shielding bag. Return all test equipment to their proper storage location.

5.5 Re-Installation and Power-Up

For CMU's supplied with a Traffic Controller Cabinet: Transport the CMU from the testing area to the Traffic Controller Cabinet under test. Ensure the Traffic Controller Cabinet is off. Attach one end of the ESD Wrist Strap to a convenient wrist, and the other end to a convenient chassis ground point of the Traffic Controller Cabinet. Remove the CMU from the static shielding bag and re-install into the Traffic Controller Cabinet. Remove the ESD Wrist Strap from chassis ground and the wrist. Power up the Traffic Controller Cabinet and ensure that the CMU is functioning properly. Depending on the model, it may need a configuration reset.

For CMU's submitted for testing as piece parts: Properly package the CMU for shipment to its final destination.

6. Report

Record any deficiency that results in a "FAIL" on the test report in MATS. Verification tests shall be recorded in MATS as "As Received" if sufficient, and "As Shipped" if deficient but corrected. Verification tests that do not apply shall have neither option checked. The overall test results shall be recorded as a "Pass" or "Fail" for test T 423 in MATS.

Performance Exam Checklist

WSDOT Test Method T 423

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (Type 170/2070) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Conflict Monitor Testing

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		**Trial 1**	**Trial 2**
1.	Removal and Test Apparatus Installation	_____	_____
2.	Setup	_____	_____
3.	Test Execution	_____	_____
4.	Test Completion	_____	_____
5.	Re-Installation and Power-Up	_____	_____
6.	Report	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State
Department of Transportation

WSDOT Test Method T 424

Test Method for NEMA Type Traffic Controller Cabinet and Advanced Transportation Controller (ATC) Cabinet Power Interruption Test

1. Scope

The purpose of this test method is to evaluate Traffic Controller Cabinet operation when subjected to power interruptions of 450 milliseconds, and power interruptions greater than 500 milliseconds. This test shall be performed at nominal voltage and room temperature. This test only applies to NEMA Type Traffic Controller Cabinets and Advanced Transportation Controller (ATC) Cabinets.

2. Reference Documents

- AASHTO/ITE/NEMA Publication ATC 5301, Advanced Transportation Controller (ATC) Cabinet Standard
- NEMA Standards Publication TS-1, Traffic Control Systems
- NEMA Standards Publication TS-2, Traffic Controller Assemblies with NTCIP Requirements

3. Safety

No PPE is required to perform this this test.

Observe proper electrical cord handling to reduce the risk of electrical shock.

4. Apparatus

Bermar Corporation model PLM-103P Power Interruption Simulator, or device capable of simulating power interruption with adjustable interruption intervals.

5. Procedure

5.1 Setup

Ensure the Power Interruption Simulator power switch is in the "OFF" position and the Traffic Controller Cabinet Main is in the "OFF" position. Connect the Power Interruption Simulator to a 120 V_{ac}, 60 Hz power source (standard wall outlet). Connect the Traffic Controller Cabinet to the Power Interruption Simulator. Power up the Power Interruption Simulator and then the Traffic Controller Cabinet. Program the controller to cycle on minimum recall. Ensure the Traffic Controller Cabinet is operating normally.

5.2 Test Execution

Set the Power Interruption Simulator to interrupt power at 450 millisecond intervals. Observe operation of the Traffic Controller Cabinet. The Traffic Controller Cabinet shall continue normal operation as though no power interruption has occurred. Repeat this test three times, noting the results.

Set the power Interruption Simulator to interrupt power at an interval greater than 500 milliseconds. Observe operation of the Traffic Controller Cabinet. The Traffic Controller Cabinet shall revert to its startup sequence upon each restoration of power. Repeat this test three times, noting the results.

5.3 Test Completion

Restore normal power to the Traffic Controller Cabinet. Ensure normal operation resumes. Power down the Traffic Controller Cabinet, then the Power Interruption Simulator. Disconnect the Traffic Controller Cabinet from the Power Interruption Simulator. Disconnect the Power Interruption Simulator from the 120 V_{ac}, 60 Hz power source (standard wall outlet). Return all test equipment to their proper storage location.

6. Report

During Test Execution the Traffic Controller Cabinet must conduct operation in accordance with the above conditions. Any deviation from these conditions is considered a fail.

Record any deficiency that does not meet the above minimum requirements. The overall test result shall be recorded as a "Pass" or "Fail" for test T424 in MATS.

Performance Exam Checklist

WSDOT Test Method T 424

Test Method for NEMA Type Traffic Controller Cabinet and Advanced Transportation Controller (ATC) Cabinet Power Interruption Test

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		**Trial 1**	**Trial 2**
1.	Setup	_____	_____
2.	Test Execution	_____	_____
3.	Test Completion	_____	_____
4.	Report	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Test Method T 425

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (Type 170/2070) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Environmental Chamber Testing

1. Scope

The purpose of this test method is to evaluate Traffic Controller Cabinet operation at environmental extremes. The environmental extremes in this document are derived from the reference documents listed below. To maintain uniformity and efficiency, all environmental extremes and test conditions listed in this document shall take precedence over those listed in each reference document. This test method will subject the Traffic Controller Cabinet to environmental conditions ranging from -30°F (-34°C) with no humidity control to 165°F (74°C) with 18% humidity at line Voltages ranging from 95 V_{ac} to 135 V_{ac}.

2. Reference Documents

- AASHTO/ITE/NEMA Publication ATC 5301, Advanced Transportation Controller (ATC) Cabinet Standard
- Caltrans Transportation Electrical Equipment Specifications
- FHWA-IP-78-16. Type 170 Traffic Signal Controller System Hardware Specification
- NEMA Standards Publication TS-1, Traffic Control Systems
- NEMA Standards Publication TS-2, Traffic Controller Assemblies with NTCIP Requirements

3. Safety

The environmental chamber produces extreme environmental conditions. Exercise caution to prevent injury to personnel and damage to equipment. A Respirator Hood Assembly connected to a supply of breathable air, grade D shall be worn when working inside the chamber at extreme temperatures. Leather gloves shall be worn when handling surfaces inside the chamber at extreme temperatures. Slip-resistant footwear shall be worn inside the chamber at all times.

4. Apparatus

A chamber in which the Unit Under Test (UUT) can be subjected to the environmental conditions specified in section 1 and provide safe access. A temperature recording device shall record the temperature inside the chamber during the test with an accuracy of ±3°F. The air inside the chamber shall be circulated so that no more than a 3°F variance will occur. The chamber control shall maintain constant absolute humidity from 109°F (43°C) to 165°F (74°C).

Variable Voltage transformer capable of delivering 95 V_{ac} to 135 V_{ac} at a frequency of 60 Hz ±3Hz.

Digital Multi-Meter (DMM) capable of measuring Voltage with a minimum resolution of 1 Volt.

Resistance load device to simulate each traffic signal light the UUT shall be equipped to operate.

5. Procedure

5.1 Low-Temperature, Low-Voltage Test:

5.1.1 Test Conditions:

a) Environmental chamber door: closed

b) Temperature: -30°F (-34°C)

c) Voltage: 95 V_{ac} (see below for exceptions)

d) UUT door(s): open

e) Humidity control: off

5.1.2 Test Procedure:

5.1.2.1 Place UUT into environmental chamber. While at room temperature, adjust the variable Voltage transformer output to 95 V_{ac} (100 V_{ac} for ATC Cabinets, 102 V_{ac} for UUTs equipped with both a 2070 Controller and a standard 2010ECL Conflict Monitor Unit). This Voltage shall be monitored with the DMM. Verify that the UUT is fully operational.

5.1.2.2 Set the UUT Controller to operate at minimum recall. Lower the environmental chamber temperature to -30°F (-34°C) at a rate not to exceed 30°F (18°C) per hour. The UUT shall be on during the temperature ramp-down.

5.1.2.3 Once the temperature has stabilized at -30°F (-34°C), verify the items listed in Table 1 to ensure proper operation.

5.1.2.4 Remove power from the UUT. The UUT shall soak at -30°F (-34°C) for a period of 3 hours.

5.1.2.5 Restore power to the UUT. Verify that the UUT initiates its start-up sequence and resumes cycling on minimum recall.

5.1.2.6 Verify the items listed in Table 1 to ensure proper operation.

5.1.2.7 Upon satisfactory completion of this test, proceed to the Low-Temperature, High-Voltage Test.

5.2 Low-Temperature, High-Voltage Test:

5.2.1 Test Conditions:

a) Environmental chamber door: closed

b) Temperature: -30°F (-34°C)

c) Voltage: 135 V_{ac}

d) UUT door(s): open

e) Humidity control: off

5.2.2 Test Procedure:

5.2.2.1 While at -30°F (-34°C) with the humidity control off, adjust the variable Voltage transformer output to 135 V_{ac}. This Voltage shall be monitored with the DMM.

5.2.2.2 Allow the UUT to cycle on minimum recall for a period of 1 hour.

5.2.2.3 After 1 hour, verify the items listed in Table 1 to ensure proper operation.

5.2.2.4 Upon satisfactory completion of this test, proceed to the High-Temperature, High-Voltage Test.

5.3 High-Temperature, High-Voltage Test:

5.3.1 Test Conditions:

a) Environmental chamber door: closed

b) Temperature: 165°F (74°C)

c) Voltage: 135 V_{ac}

d) UUT door(s): open

e) Humidity control: in accordance with Table 2

5.3.2 Test Procedure:

5.3.2.1 With the UUT cycling on minimum recall, raise the environmental chamber temperature to 165°F (74°C) at a rate not to exceed 30°F (18°C) per hour. The UUT shall be on during the temperature ramp-up.

5.3.2.2 Set the humidity controls not to exceed 95% relative humidity over the temperature range of 40°F (4°C) to 109°F (43°C). When the temperature reaches 109°F (43°C), readjust the humidity control to maintain constant humidity; 109°F (43°C) wet bulb which results in the relative humidities shown in Table 2.

5.3.2.3 Allow the UUT to soak at 165°F (74°C), constant humidity for a period of 10 hours.

5.3.2.4 After 10 hours, verify the items listed in Table 1 to ensure proper operation.

5.3.2.5 Upon satisfactory completion of this test, proceed to the High-Temperature, Low-Voltage Test.

5.4 High-Temperature, Low-Voltage Test:

5.4.1 Test Conditions:

a) Environmental chamber door: closed

b) Temperature: 165°F (74°C)

c) Voltage: 95 V_{ac} (see below for exceptions)

d) UUT door(s): open

e) Humidity control: in accordance with Table 2

5.4.2 Test Procedure:

5.4.2.1 While at 165°F (74°C) with constant humidity, adjust the variable Voltage transformer output to 95 V_{ac} (100 V_{ac} for ATC Cabinets, 102 V_{ac} for UUTs equipped with both a 2070 Controller and a standard 2010ECL Conflict Monitor Unit). This Voltage shall be monitored with the DMM.

5.4.2.2 Allow the UUT to cycle on minimum recall for a period of 1 hours.

5.4.2.3 After 1 hour, verify the items listed in Table 1 to ensure proper operation.

5.4.2.4 Upon satisfactory completion of this test, proceed to the Nominal-Temperature, Nominal-Voltage Test.

5.5 Nominal-Temperature, Nominal-Voltage Test:

5.5.1 Test Conditions:

a) Environmental chamber door: closed

b) Temperature: 68°F (20°C)

c) Voltage: 120 V_{ac}

d) UUT door(s): open

e) Humidity control: off

5.5.2 Test Procedure:

5.5.2.1 While at 165°F (74°C) with constant humidity, adjust the variable Voltage transformer output to 120 V_{ac}. This Voltage shall be monitored with the DMM.

5.5.2.2 Lower the environmental chamber to 68°F (20°C) at a rate not to exceed 30°F (18°C) per hour. The UUT shall be on during the temperature ramp-down.

5.5.2.3 Allow the UUT to cycle on minimum recall for a period of 1 hour.

5.5.2.4 After 1 hour, verify the items listed in Table 1 to ensure proper operation.

6. Report

6.1 A failure shall be defined as any occurrence which results in other-than-normal operation of the UUT; refer to 6.2 for details. If a failure occurs, the UUT shall be repaired or components replaced by the vendor, and the test during which the failure occurred shall be restarted from the beginning.

6.2 The UUT is considered to have failed if any of the following occur:

a) If the UUT skips intervals or interval portions, places false calls, presents false indications, exhibits disruption of normal sequence, produces changes in timing, or

b) If the UUT fails to satisfy the requirements of any portion of section 5

6.3 An analysis of the failure shall be performed and corrective action taken before the UUT is retested in accordance with this document. The analysis must outline what action was taken to preclude additional failures during the tests.

6.4 Upon completion of the tests, the UUT shall be visually inspected. If material changes are observed which will adversely affect the life of the UUT, the cause and conditions shall be corrected before material acceptance.

6.5 Record and report all findings, corrective actions, and pass/fail results taken on the test report. Verification tests shall be recorded in MATS as "As Received" if sufficient, and "As Shipped" if deficient but corrected. Inspection tests that do not apply shall have neither option checked. The overall test result shall be recorded as a "Pass" or "Fail" for test T425 in MATS.

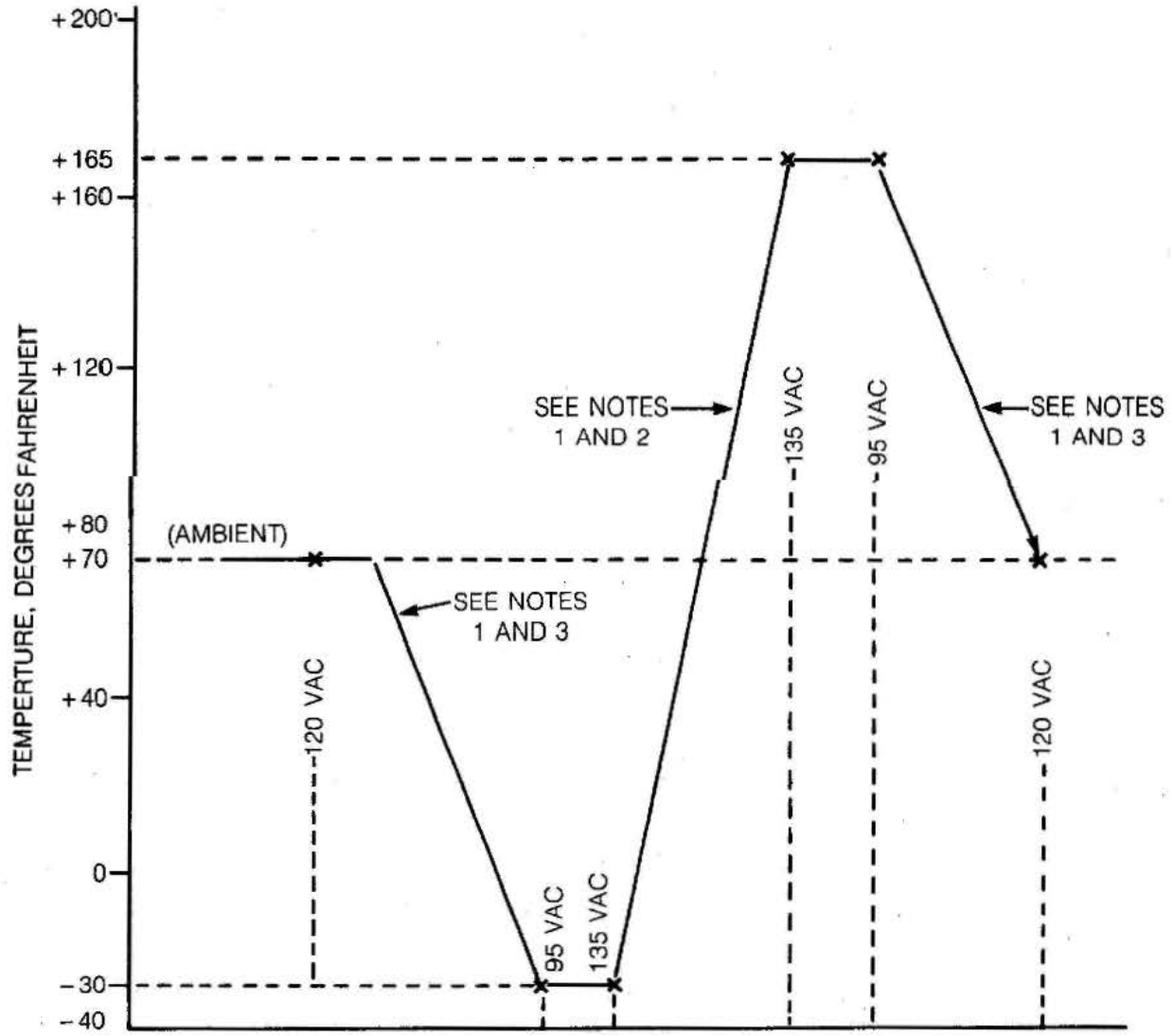
Table 1 Functional Verification

Item Number	Item Description
1	Verify the function of the intersection display panel switches (if equipped).
2	Verify the function of the police panel switches.
3	Verify the function of the stop-time switch (inside).
4	Verify the function of the auto/flash switch (inside).
5	Reserved for future use.
6	Verify the function of external logic (NEMA, if equipped).
7	Verify the function of the loop detection panel (if equipped).
8	Verify the function of the pre-emption pushbutton on the door (NEMA, if equipped).
9	Verify the function of the pre-emption switches on the phase selectors.
10	Verify the operation of the emergency indication light (if equipped).
11	Verify the CMU/MMU is functioning properly.

Table 2 Wet-Bulb Dry-Bulb Relative Humidity at Barometric Pressure of 29.92 inHg (Sea Level)

Dry Bulb		Relative Humidity, Percent (For Dynamic Testing)	Wet Bulb	
°F	°C		°F	°C
40	4.4	75	37	2.8
50	10.0	80	47	8.3
60	15.6	83	57	13.9
70	21.1	86	67	19.4
80	26.7	87	77	25.0
90	32.2	89	87	30.6
100	37.8	89	97	36.1
110	43.3	90	107	41.7
120	48.9	70	109	42.8
130	54.4	50	109	42.8
140	60.0	38	109	42.8
150	65.6	28	109	42.8
160	71.1	21	109	42.8
165	73.9	18	109	42.8

Figure 1 Environmental Test Profile



NOTE 1 – The rate of change in temperature shall not exceed 30°F (18°C) per hour.

NOTE 2 – Humidity controls shall be set in accordance with the humidities given in Table 2 during the temperature change between the Low-Temperature and High-Temperature tests.

NOTE 3 – If a change in both Voltage and temperature are required for the next test, the Voltage shall be selected prior to the temperature change.

Performance Exam Checklist

WSDOT Test Method T 425

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (Type 170/2070) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Environmental Chamber Testing

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	Test Setup – Place UUT into the Environmental Chamber	_____	_____
2.	Low-Temperature, Low-Voltage Test	_____	_____
3.	Low-Temperature, High-Voltage Test	_____	_____
4.	High-Temperature, High-Voltage Test	_____	_____
5.	High-Temperature, Low-Voltage Test	_____	_____
6.	Nominal-Temperature, Nominal-Voltage Test	_____	_____
7.	Report	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State
Department of Transportation

WSDOT Test Method T 427

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (Type 170/2070) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Loop Amplifier Testing

1. Scope

The purpose of this test method is to evaluate the operation of individual Loop Amplifiers which are supplied with each Traffic Controller Cabinet. This test method may also be used to test Loop Amplifiers submitted for testing as piece parts upon request.

2. Reference Documents

- AASHTO/ITE/NEMA Publication ATC 5301, Advanced Transportation Controller (ATC) Cabinet Standard
- Caltrans Transportation Electrical Equipment Specifications
- FHWA-IP-78-16, Type 170 Traffic Signal Controller System Hardware Specification
- NEMA Standards Publication TS-1, Traffic Control Systems
- NEMA Standards Publication TS-2, Traffic Controller Assemblies with NTCIP Requirements

3. Safety

Voltages up to 135 V_{ac} may be present on the test apparatus when energized. Caution should be exercised when operating the test apparatus. Only the interface of a Loop Amplifier (buttons and switches) and the interface of the test apparatus (buttons and switches) shall be touched while energized. Electro-Static Discharge (ESD) Wrist Straps shall be removed prior to energizing circuits.

4. Apparatus

An Electro-Static Discharge (ESD) Wrist Strap with cord and alligator clip shall be worn when handling Circuit Card Assemblies (CCA's) to prevent ESD damage. The Wrist Strap shall be connected via the cord to the Traffic Controller Cabinet chassis ground or the ESD mat in the testing area in order to maintain the card handler at the same electrical potential as chassis ground. The Wrist Strap shall be removed prior to energizing circuits.

Metalized, static-shielding bag to protect each Loop Amplifier from Electro-Static Discharge (ESD) while transporting between the Traffic Controller Cabinet and the testing area.

Electro-Static Discharge (ESD) mat connected to earth ground for queueing of Loop Amplifiers to test.

ATSI Loop Amplifier Tester model QC-330, or device capable of supplying operating power to the Loop Amplifier Unit-Under-Test (UUT) and capable of simulating Class 1, Class 2, and Class 3 vehicle calls (0.12µH, 0.3µH, and 3.0µH inductance signals, respectively, supplied to the UUT).

5. Procedure

5.1 Removal and Setup

For Loop Amplifiers supplied with a Traffic Controller Cabinet: Ensure that the Traffic Controller Cabinet is off prior to removing Loop Amplifiers. Attach one end of the ESD Wrist Strap to a convenient wrist, and the other end to a convenient chassis ground point of the Traffic Controller Cabinet. Remove each Loop Amplifier and place each in a separate static-shielding bag for transport to the testing area. Once all Loop Amplifiers have been removed, disconnect the ESD Wrist Strap from the chassis ground point of the Traffic Controller Cabinet.

For Loop Amplifiers submitted for testing as piece parts: Open packaging at the testing area. If any Loop Amplifiers are not in a static-shielding bag, place them in one at this time.

For all Loop Amplifiers: Proceed to move all Loop Amplifiers to the testing area if not already done. Connect one end of the ESD Wrist Strap to the ESD mat of the testing area. Remove each Loop Amplifier from its static-shielding bag and place on the ESD mat to prevent ESD damage while in queue for test.

Ensure the Loop Amplifier Tester is off. Connect a Loop Amplifier to the Tester. Remove the ESD Wrist Strap and leave the other end connected to the ESD mat. Power up the Loop Amplifier Tester.

5.2 Initial Condition

If the UUT is so-equipped, ensure that Delay timing, Extension timing, and all other options are off. Ensure that the Loop Amplifier is set to Presence mode, not Pulse mode. Repeat this process for each channel with which the UUT is equipped.

5.3 Sensitivity Adjustment

Set the sensitivity of each channel to minimum. Press the “Class 1” button for Channel 1 and note the duration of the “Call” indication. Increment the sensitivity for Channel 1 until the “Call” indication lasts more than two seconds. Repeat this process for each channel with which the UUT is equipped.

5.4 Pulse Mode Test

Set Channel 1 to Pulse mode. Press and hold the “Class 1” button for Channel 1. The “Call” indication should come on briefly to verify a Pulse condition. Wait three seconds. While still holding the “Class 1” button, press the “Class 2” button. A second “Call” indication should come on briefly to verify a second vehicle Pulse condition. If not, this test fails. Release the buttons and set Channel 1 back to Presence mode. Repeat this process for each channel with which the UUT is equipped.

5.5 Delay Timing Test

Set Channel 1 Delay timing to three seconds. Press and hold the “Class 1” button for Channel 1. The “Call” indication should blink for three seconds, then become steady on. If not, this test fails. Release the button and set Channel 1 Delay timing back to zero. Repeat this process for each channel with which the UUT is equipped.

5.6 Extension Timing Test

Set Channel 1 Extension timing to three seconds. Press and release the “Class 1” button for Channel 1. The “Call” indication should be steady on for three seconds, then off. Press and release the button again, wait two seconds, then press and release again. The “Call” indication should be steady on for a total of five seconds, then off. If not, this test fails. Set the Channel 1 Extension timing back to zero. Repeat this process for each channel with which the UUT is equipped.

5.7 Sustained Presence and Sustained Presence Recovery Test

Press and hold the “Class 3” button for Channel 1. Hold the button for at least ten seconds. The “Call” indication should be steady on for the duration of this action. Release the button for one second, then press it again. The “Call” indication should turn off for a moment, then turn back on indicating a new “Call”. Release the button and the “Call” indication should turn off. If not, this test fails. If this test fails, return to section 5.3 to readjust the sensitivity and retry this test. If this test fails after three sensitivity adjustments, the UUT is considered faulty. Repeat this process for each channel with which the UUT is equipped.

5.8 Test Completion

Upon successful completion of all tests on all channels, power down the Loop Amplifier Tester. Attach the ESD Wrist Strap to one wrist, remove the Loop Amplifier from the tester, and place it in a static-shielding bag. Repeat this process for each Loop Amplifier submitted for testing. Return all test equipment to their proper storage location.

5.9 Re-Installation and Power-Up

For Loop Amplifiers supplied with a Traffic Controller Cabinet: Transport all Loop Amplifiers from the testing area to the Traffic Controller Cabinet under test. Ensure the Traffic Controller Cabinet is off. Attach one end of the ESD Wrist Strap to a convenient wrist, and the other end to a convenient chassis ground point of the Traffic Controller Cabinet. Remove each Loop Amplifier from its separate static shielding bag and re-install into the Traffic Controller Cabinet. Once all Loop Amplifiers are re-installed, remove the ESD Wrist Strap from chassis ground and the wrist. Power up the Traffic Controller Cabinet and ensure that all Loop Amplifiers are functioning.

For Loop Amplifiers submitted for testing as piece parts: Properly package the Loop Amplifiers for shipment to their final destination.

6. Report

Record any deficiency that does not meet the above minimum requirements. Verification tests shall be recorded in MATS as “As Received” if sufficient, and “As Shipped” if deficient but corrected. Verification tests that do not apply shall have neither option checked. The overall test result shall be recorded as a “Pass” or “Fail” for test T427 in MATS.

Performance Exam Checklist

WSDOT Test Method T 427

Test Method for NEMA Type Traffic Controller Cabinet, 300 Series (Type 170/2070) Traffic Controller Cabinet, and Advanced Transportation Controller (ATC) Cabinet Loop Amplifier Testing

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		**Trial 1**	**Trial 2**
1.	Removal and Setup	_____	_____
2.	Initial Condition	_____	_____
3.	Sensitivity Adjustment	_____	_____
4.	Pulse Mode Test	_____	_____
5.	Delay Timing Test	_____	_____
6.	Extension Timing Test	_____	_____
7.	Sustained Presence and Sustained Presence Recovery Test	_____	_____
8.	Test Completion	_____	_____
9.	Re-Installation and Power-Up	_____	_____
10.	Report	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Test Method T 428

Test Method for Traffic Controller Compliance Inspection and Test Procedure

1. Scope

The purpose of this procedure is to provide a documented method for the steps involved with the inspection and testing of the completed Traffic Controller Cabinets.

2. Reference Documents

- WSDOT *Standard Specifications* 9-29.13
- WSDOT Test Method T 421, Traffic Controller Cabinet Inspection Procedure
- WSDOT Test Method T 422, Transient Voltage Test (Spike Test) Procedure (optional)
- WSDOT Test Method T 423, Conflict Monitor Test Procedure
- WSDOT Test Method T 424, Power Interruption Test Procedure
- WSDOT Test Method T 425, Environmental Chamber Test Procedure
- WSDOT Test Method T 427, Loop Amplifier Test Procedure

3. Safety

Utilize PPE and observe safety practices as defined in WSDOT Test Methods T 421, T 422, T 423, T 424, T 425, and T 427.

4. Apparatus

Utilize equipment as defined in WSDOT Test Methods T421, T422, T423, T424, T425, and T427.

Combination resistor/LED load bank to simulate each traffic signal light in operation.

EDI Model SM662 Isolator Test Cards to test field termination wiring.

Field termination test probe consisting of two 1N4148 diodes wired in parallel.

Opticom strobe system tester to test pre-emption devices.

Suitable jumper to test pedestrian field terminals.

5. Procedure

5.1 Perform Traffic Controller Cabinet Inspection Procedure in accordance with WSDOT Test Method T 421.

5.2 Perform Environmental Chamber Test Procedure in accordance with WSDOT Test Method T 425.

5.3 If required by Contract Documents or otherwise requested, perform Transient Voltage Test (Spike Test) Procedure in accordance with WSDOT Test Method T 422.

5.4 Perform Conflict Monitor Test Procedure in accordance with WSDOT Test Method T 423.

5.5 If equipped, perform Loop Amplifier Test Procedure in accordance with WSDOT Test Method T 427.

5.6 If applicable, perform Power Interruption Test Procedure in accordance with WSDOT Test Method T 424.

5.7 Verify the GFCI is operational.

5.8 Verify the vent fan(s) is(are) operational.

5.9 Verify the cabinet door light switch(es) is(are) operational.

5.10 Verify the correct operation of the master controller, if so equipped.

5.11.1 Verify the correct operation of vehicle test switches, if so equipped.

5.11.2 Verify the correct operation of pedestrian test switches, if so equipped.

5.12.1 Verify the correct operation of vehicle (loop sensor) field terminals. This will require the use of EDI Model SM662 Isolator Test Cards and a field termination probe.

5.12.2 Verify the correct operation of pedestrian field terminals. This will require the use of a suitable jumper.

5.13.1 Verify the correct operation of pre-emption (phase selector) cards, if so equipped.

5.13.2 Verify the correct operation of pre-emption (phase selector) test switches, if so equipped.

5.13.3 Verify the correct operation of pre-emption (phase selector) field terminals, if so equipped. This will require the use of an Opticom strobe system tester.

5.14 Verify the correct operation of railroad pre-emption cards, if so equipped.

5.15 Verify the correct operation of the internal “auto/flash” switch.

5.16 Verify the correct operation of the internal “stop time” switch.

5.17 Verify the correct operation of the external police panel switch(es).

5.18 Set up cabinet to run on minimum recall with a combination resistor/LED load bank. Run a performance test for a period of no less than 72 hours.

6. Report

Record any deficiency that does not meet the above minimum requirements. Report any corrective actions taken on the test report. The overall test result shall be recorded as a “Pass” or “Fail” for test T 428 in MATS.

Performance Exam Checklist

WSDOT Test Method T 428

Test Method for Traffic Controller Compliance Inspection and Test Procedure

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		**Trial 1**	**Trial 2**
1.	Perform Traffic Controller Cabinet Inspection T421	_____	_____
2.	Perform Environmental Chamber Test T425	_____	_____
3.	If required or requested, perform Transient Voltage Test T422	_____	_____
4.	Perform Conflict Monitor Test T423	_____	_____
5.	Perform Loop Amplifier Test T427	_____	_____
6.	Perform Power Interruption Test T424	_____	_____
7.	Perform T428 Specific Compliance Inspection and Tests	_____	_____
8.	Report	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State
Department of Transportation

WSDOT Test Method T 430

Test Method for Uninterruptible Power Supply (UPS) System Compliance Inspection and Test Procedure

1. Scope

The purpose of this test method is to provide a documented method for the steps involved with the inspection and testing of an Uninterruptable Power Supply (UPS) system.

2. Reference Documents

- WSDOT *General Special Provisions* 8-20.2(9-29.13).OPT1.GR8
- WSDOT *General Special Provisions* 8-20.3(14).OPT1.GR8
- NEMA Standards Publication PE-1, Uninterruptible Power Systems (UPS) – Specification and Performance Verification
- IEC Standards Publication 62040-3: Uninterruptible Power Systems (UPS) – Method of specifying the performance and test requirements
- IEEE Standards Publication 1188 – Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) batteries for Stationary Applications

3. Safety

Use proper lifting techniques whenever handling equipment, parts, or batteries.

Always assume electrical connections or conductors are live. Exercise caution when working with electrical connections as high voltages could be present. Wear insulating gloves and use insulated tools when working with any electrical connections.

Batteries should be handled with extreme care as they can cause severe injury. Spilled electrolyte can destroy clothing, burn skin, or cause blindness. Always wear eye protection and wear rubber gloves when working with batteries.

4. Apparatus

DATAQ Instruments model DI-718B Data Logger or device capable of simultaneously logging ac load Voltage, UPS Battery set dc input current, UPS Battery set dc input Voltage, and UPS Battery set temperature.

Simpson model 06713 current shunt or device capable of providing a current measurement range up to 100 Amperes through a 50 milliVolt conversion drop.

DATAQ Instruments WinDAQ software or software capable of accessing and processing playback of logged data from the data logger. Through linear interpolation, this data will be used to produce a test report detailing calculated operational duration and power efficiencies based on different load values.

Passive load designed to operate on 120 V_{ac}. Power rating shall vary based on Contract Documents.

5. Procedure

5.1 Incoming Inspection

When the Uninterruptible Power Supply (UPS) Cabinet arrives for testing, the contractor representative (typically the contractor's vendor) should have an appointment scheduled. Within seven (7) calendar days of arrival, the contractor representative shall assemble and demonstrate the Uninterruptible Power Supply (UPS) Cabinet. If assembly is not completed within these seven (7) calendar days, disposition of the Uninterruptible Power Supply (UPS) Cabinet is at the discretion of the Electrical Materials Laboratory personnel. Inspect the Uninterruptible Power Supply (UPS) Cabinet, battery set, and any accessories for damage during shipping. Note any deficiencies.

5.2 Notify Project Office

Notify the project office and the contractor of the receipt of the Uninterruptible Power Supply (UPS) system. Note all Points-of-Contact who shall be copied on all communications and test results for this project

5.3 Assess Uninterruptible Power Supply (UPS) System Compliance

The Uninterruptible Power Supply (UPS) System shall be inspected to ensure that it is in compliance with General Special Provisions and Contract Documents. Ensure that all of the required equipment is installed per these General Special Provisions and Contract Documents. In the event of a conflict, Contract Documents take precedence over the General Special Provisions. At a minimum, the following items shall be inspected against the Contract Documents and General Special Provisions:

1. Cabinet Construction (cabinet type, door lock type, lighting type, etc.)
2. System Components (controller type, battery type, accessories, etc.)
3. System Documentation (serial numbers, drawings, component manuals, etc.)

5.4 Assess Uninterruptible Power Suply (UPS) System Performance

5.4.1 Setup

The contractor representative shall provide all work necessary to assemble the UPS system at the State Materials Laboratory. Upon delivery, the battery set shall be installed and the UPS system shall be made fully operational by the contractor representative.

Two sets of data will be recorded for the duration of this test, one manually recorded and one automatically recorded via Data Logger. Once the UPS system is fully operational, the Data Logger shall be installed to monitor operation while under load. The following parameters shall be monitored: ac load Voltage, UPS battery set dc current, UPS battery set dc Voltage, and UPS battery set temperature. Power down the UPS system. Connect the ac load Voltage monitor in parallel with the ac test load. Do not connect the ac test load to the UPS cabinet at this time. Install a current shunt in series with the negative line of the UPS battery set. Connect the UPS battery set dc current monitor across the series current shunt between the UPS battery set and the UPS cabinet. Connect the UPS dc Voltage monitor across the UPS battery set terminals. Finally, connect the UPS battery set temperature monitor to the case of the upstream-most UPS battery. Power up the UPS system.

Manually recording of data shall be performed at regular intervals during this test. This data will be taken from the UPS system Inverter Display. The following items are to be recorded:

- VIN (line Voltage in to the Inverter in V_{rms})
- VOUT (output Voltage from the inverter to the test load in V_{rms})
- IOUT AC (output current from the Inverter to the test load in A_{ac})
- BATT TEMP (battery temperature in degrees Celsius)
- FREQ IN (line frequency in to the Inverter in Hertz)
- OUTPUT PWR (output power from the Inverter to the test load in Watts)
- BATT VOLT (battery Voltage to the Inverter in V_{dc})
- CHGR CUR (battery charging current in A_{dc})
- kWh (accumulated output energy in kilo-Watthours)
- Remain Tm (remaining battery runtime in hours and minutes)

5.4.2 Test Execution

Allow the UPS cabinet to fully charge the UPS battery set prior to test. The UPS battery set is considered fully charged when the charging current is less than 500 milliAmperes and the battery set Voltage is 53.5 ±0.5 V_{dc}.

Verify the UPS system is not connected to a load, that it is connected to both line input and the UPS battery set, and the system is operational. The system is now at its initial condition. Start the Data Logger for automatically recorded data and take note of the first set of Inverter Display readings for manually recorded data.

Connect the test load to the UPS system and verify the load is operating. The size of the test load shall be specified in the Contract Documents. With the test load connected, disconnect the line input to the UPS system. The UPS system shall switch from line input operation to battery operation with no interruption of power to the test load. The system is now at its test condition. Take note of the next set of Inverter Display readings for manually recorded data. Continue to manually record Inverter Display readings at regular intervals until the UPS system powers down (this occurs when battery Voltage reaches 42.0 ±0.5 V_{dc}).

5.4.3 Test Completion

After the UPS system powers down, stop the Data Logger and disconnect the test load. Disconnect all Data Logger monitors from the UPS system. Reconnect the line input to the system and allow the UPS battery set to fully charge. Note the time required for the UPS battery set to fully charge.

After the UPS battery set is fully charged, remove all laboratory equipment and prepare the UPS system for shipment. Return all test equipment to their proper storage location.

6. Report

Compile the manually recorded data into a spreadsheet for evaluation. Use the Data Logger software to compile automatically recorded data into plots for each of the channels monitored. Using linear interpolation, calculate the operational duration and power efficiencies for different load values. The data recorded between the two methods should reasonably align with each other.

Inspect the plots detailing the ac load Voltage (Output Voltage), UPS battery set dc current (Batteries Current), UPS battery set dc Voltage (Batteries Voltage), and UPS battery set temperature (Batteries Temperature). There shall be no spikes or drops (glitches) observed in the plots throughout the duration of the test. The plot values shall be within the battery manufacturer's recommended values in order for the test to be considered successful. The operational duration (Battery Life) shall be within the battery manufacturer's recommended values in order for the test to be considered successful.

Record any deficiency that does not meet the above minimum requirements. Report any corrective actions taken on the test report. The overall test result shall be recorded as a "Pass" or "Fail" for test T 430 in MATS.

Performance Exam Checklist

Method T 430 Checklist

Test Method for Uninterruptible Power Supply (UPS) System Compliance Inspection and Test Procedure

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. Setup	____	____
2. Test Execution	____	____
3. Test Completion	____	____
4. Report	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State Department of Transportation

WSDOT Standard Operating Procedure SOP 615

Determination of the % Compaction for Embankment & Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge

1. Scope

This procedure covers the procedures for determining the in-place density, moisture content, gradation analysis, oversize correction, and determination of maximum density of compacted soils and untreated surfacing materials using a nuclear density device in the direct transmission mode.

2. References

a. AASHTO T 99 for Method of Test for Moisture-Density Relations of Soils

b. AASHTO T 180 for Method of Test for Moisture-Density Relations of Soils

c. T 255 – WSDOT FOP for AASHTO for Total Moisture Content of Aggregate by Drying

d. T 272 – WSDOT FOP for AASHTO for Family of Curves – One Point Method

e. T 310 – WSDOT FOP for AASHTO for In-Place Densities and Moisture Content of Soils and Soil-Aggregate by Nuclear Methods (Shallow Depth)

f. WAQTC TM 15 Laboratory Theoretical Maximum Dry Density of Granular Soil and Soil/Aggregate

3. Test Location

When selecting a test location, the tester shall visually select a site where the least compactive effort has been applied. Select a test location where the gauge will be at least 6 in (150 mm) away from any vertical mass. If closer than 24 in (600 mm) to a vertical mass, such as in a trench, follow gauge manufacturer correction procedures.

When retesting is required due to a failing test; retest within a 10-foot radius of the original station and offset.

4. Nuclear Density Test

Determine the dry density and moisture content of soils and untreated surfacing materials using the nuclear moisture-density gauge in accordance with WSDOT FOP for AASHTO T 310, and record in the Materials Testing System (MATS), WSDOT Form 350-074, Field Density Test, or other form approved in writing by the State Materials Engineer.

5. Oversize Determination

a. AASHTO T 99 and WAQTC TM 15

A sample weighing a minimum of 4.08 kg (9 lbs) will be taken from beneath the gauge. Care shall be taken to select material that is truly representative of where the moisture density gauge determined the dry density and moisture content.

There are two methods for determining the percentage of material retained on the No. 4 sieve:

1. Method 1 – material that allows for the easy separation of fine and coarse aggregate.
    a. Dry the sample until no visible free moisture is present (material may still appear damp but will not be shiny).
    b. Determine and record the mass of the sample to the nearest 0.1 percent of the total mass or better.
    c. Shake the sample by hand over a verified No. 4 (4.75 mm) sieve taking care not to overload the sieve. Overloading for a No. 4 (4.75 mm) sieve is defined as; A retained mass of more than 800 g (1.8 lbs), on a 12 inch sieve, or 340 g, (0.75 lbs); on an 8 inch sieve after sieving is complete.

        Note 1: If the tester suspects a sieve will be overloaded the sample can be separated into smaller increments and recombined after sieving.
    d. Determine and record the mass of the material retained on the No. 4 (4.75 mm) sieve to the nearest 0.1 percent of the total mass or better and record.
2. Method 2 – recommended for crushed surfacing materials, materials with high clay content, or other granular materials that are at or near the optimum moisture content for compaction.
    a. Determine and record the mass of the sample to the nearest 0.1 percent of the total mass or better and record.
    b. Shake sample by hand over a verified No. 4 (4.75 mm) sieve. Do not overload the sieve. (See Section 1a and Note 1 for overload definition and information on how to prevent overloading of a sieve)
    c. Shake material until no particles are observed passing the No. 4 (4.75 mm) sieve
    d. Rinse the sample with water
    e. Continue rinsing the material until it is visibly free of any coating or minus No. 4 material.
    f. Place the washed material, retained on the No. 4 (4.75 mm) sieve, into a tared container and blot until no visible free moisture is present on the material (material may still appear damp but will not appear shiny).
    g. Determine and record the mass of the material retained on the No. 4 (4.75 mm) sieve to the nearest 0.1 percent of the total mass or better.

b. AASHTO T 180

1. Follow either Method 1 or Method 2 in 5 a. with the following exception; sieve the material over a ¾ in (19.0 mm) sieve.

2. Do not overload the ¾" (19.0 mm) sieve. Overloading of a ¾" (19.0 mm) sieve is defined as: A retained mass of more than 3.2 kg (7.04 pounds) on a 12 inch sieve or 1.4 kg (3.08 pounds) on an 8 inch sieve after sieving is complete.

6. Calculations

a. Calculate the percent retained as follows:

$$\% \text{ retained (Pc)} = 100 \times \frac{\text{mass retained on sieve}}{\text{original mass}} \text{ (round to nearest percent)}$$

b. Calculate percent passing as follows:

$$\% \text{ passing} = 100 - \% \text{ retained}$$

c. Calculate the dry density as follows:

$$d = \frac{100}{100 + W} (m)$$

Where:

d	=	dry field density of total sample, pcf
m	=	total field wet density, pcf
W	=	moisture content of total field sample

d. Calculate the corrected theoretical maximum density as follows:

$$D_d = \frac{100 \times (D_f) \times (k)}{[(D_f) \times (P_c) + (k) \times (P_f)]}$$

Where:

D_d	=	corrected dry density of combined fine and oversized particles, expressed as lbs/ft^3.
D_f	=	dry density of fine particles expressed as lbs/ft^3, determined in lab.
P_c	=	percent of coarse particles, by weight.
P_f	=	percent of fine particles, by weight.
k	=	62.4 x Bulk Specific Gravity.

Calculate in-place dry density to the nearest 0.1 lbs/ft^3.

Note 2: If the specific gravity of the coarse particles has been determined, use this value in the calculation for the "k" value. If the specific gravity is unknown then use 2.67. Either AASHTO T 85 or WAQTC TM 15 Apparent Specific Gravity may be used to determine the specific gravity of the coarse particles.

e. Calculate the percent of compaction using the following equation:

$$\% \text{ compaction} = \frac{\text{Dry Density (lbs/ft}^3\text{)}}{\text{corrected theoretical maximum density (lbs/ft}^3\text{)}}$$

7. Density Curve Tables

The Materials Testing System (MATS) Density Curve Tables is the WSDOT preferred method for determining the corrected theoretical maximum density.

a. MATS calculates the corrected theoretical maximum density in accordance with AASHTO T 99 and T 180 ANNEX A1. (Correction of Maximum Dry Density and Optimum Moisture for Oversized Particles) and reports the results in the Density Curve Table.

b. To determine the corrected theoretical maximum density using the Density Curves Table enter the Table at the line corresponding to the % passing or % retained (T 99 & T 180 requires percent retained, T 606 requires percent passing), read across to the column labeled Max this number is the Corrected Theoretical Maximum Density.

8. Report

a. Report the results using one or more of the following:
   - Materials Testing System (MATS)
   - WSDOT Form 350-074 and 351-015
   - Form approved in writing by the State Materials Engineer

b. Report the percent of compaction to the nearest whole number.

Performance Exam Checklist

WSDOT Standard Operating Procedure SOP 615

Determination of the % Compaction for Embankment & Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. The tester has a copy of the current procedure on hand?	____	____
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	____	____
Gradation Analysis		
3(A) Method 1		
1. Sample Dried to a SSD condition (dried until no visible free moisture present) and mass recorded?	____	____
2. Sample allowed to cool sufficiently prior to sieving?	____	____
3. Sample was shaken by hand through the appropriate sieve for a sufficient period of time?	____	____
4. Recorded mass of material retained on the appropriate sieve?	____	____
5. Calculated and recorded percent of material retained and passing the appropriate sieve?	____	____
3(B) Method 2		
1. Mass of sample determined prior to washing?	____	____
2. Material charged with water in suitable container and agitated to suspend fines?	____	____
3. Sample decanted over required sieve for a sufficient amount of time without overloading sieve?	____	____
4. Retained material dried to SSD condition and mass determined?	____	____
5. Recorded mass of material retained on appropriate sieve?	____	____
6. Calculated and recorded percent of material retained and passing appropriate sieve?	____	____
Correction for Coarse Particles		
7. Appropriate MATS Density Curve Table used to determine the corrected theoretical maximum density, based on the percent passing or retained on the appropriate sieve?	____	____
8. All calculations performed correctly?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Test Method T 802

Method of Test for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)

1. Scope

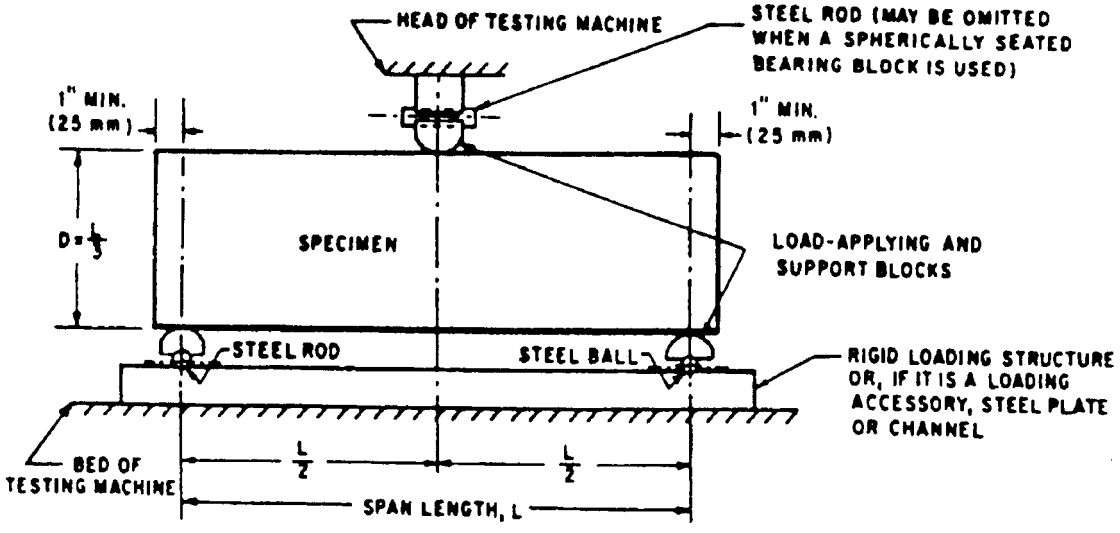
a. This method is similar to AASHTO T 177 and covers the procedure for determining the flexural strength of concrete by the use of a simple beam with center-point loading.

2. Apparatus

a. The center-point loading method shall be used in the laboratory. The testing machine shall conform to the requirements of Sections 15, 16, and 17 of the Methods of Verification of Testing Machines (AASHTO T 67). In the field, a manually operated calibrated jack shall be used in conjunction with the field testing machine supplied by the Regional Materials Engineer. The apparatus shall incorporate the following requirements. The load shall be applied at the center point of the span, normal to the loaded surface of the beam, employing bearing blocks designed to ensure that forces applied to the beam will be vertical only and applied without eccentricity. The direction of the reactions shall be parallel to the direction of the applied load at all times during the test. The load shall be applied at a uniform rate and in such a manner as to avoid shock. The edges of the load-applying block and of the supports shall not depart from a plane by more than .002 in (0.051 mm).

b. Caliper – A 12 in (1300 mm) long caliper accurate to 0.01 in (0.25 mm).

Figure 1 Diagrammatic View of Apparatus for Flexure Test of Concrete be Center-point Loading Method



NOTE—Apparatus may be used inverted.

3. Test Specimen

As nearly as practicable, the test specimen, as tested, shall have a span three times its depth. The test specimen shall be formed and stored as prescribed in WSDOT Test Method No. 808.

4. Procedure

a. Turn the specimen on its side with respect to its position when molded, and center it on the supporting bearing blocks. The load-applying block shall be brought in contact with the upper surface at the center line between the supports.

b. Bring load applying block in full contact with the beam surface by applying a 100 lbs (3.1 N) preload. Check to ensure that the beam is in uniform contact with the bearing blocks and the load applying block.

c. If load is applied with a hand pump, load the beam by applying the load at a rate of one full pump stroke per second. When the applied load is about 4,000 lbs (125 N), reduce the full pump stroke to about a 12-pump stroke and maintain the one second stroke rate. Rate of load application for screw power machines, with the moving head operating at 0.05 in (1.3 mm) per minute when the machine is running idle, is acceptable.

5. Measurement of Specimens

a. Determine the beam dimensions, width (b) and depth (d), by averaging two measurements for width and two measurements for depth. The measurements shall be taken at the failure plane to an accuracy of 0.05 in (1.3 mm).

6. Calculation

a. The modulus of rupture is calculated as follows:

$$R = \frac{3P1}{2bd^2}$$

Where:

R = Modulus of rupture in psi or MPa
P = Maximum applied load indicated by the testing machine in lb•f or N
l = Span length in inches or mm
b = Average width of specimen in inches or mm
d = Average depth of specimen in inches or mm

7. Report

a. The report shall include the following:

(1) Identification number,
(2) Average width,
(3) Average depth,
(4) Span length in inches or mm,
(5) Maximum applied load in lb•f or N,
(6) Modulus of rupture calculated to the nearest 5 psi (0.03MPa),
(7) Defects in specimen, and
(8) Age of specimen.

b. All test results will be reported on DOT Form 350-042.

Performance Exam Checklist

WSDOT Test Method T 802

Method of Test for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element			
Preparation		**Trial 1**	**Trial 2**
1.	Copy of current procedure available at test site?	_____	_____
2.	In the field, Jack properly calibrated?	_____	_____
3.	Beam turned on its side with respect to its position when molded, and centered on the supporting bearing blocks?	_____	_____
4.	Load applying block brought into contact with the beam at the center line between the supports?	_____	_____
5.	100 lbs (3.1 N) preload applied and the beam then checked to ensure uniform contact with the bearing blocks and load applying block?	_____	_____
6.	Load applied to the beam at the proper uniform rate?	_____	_____
Equipment			
1.	Where required are calibration/verifications tags present on equipment used in this procedure?	_____	_____
2.	All equipment functions according to the requirements of this procedure?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for C 805[1]

Rebound Hammer Determination of Compressive Strength of Hardened Concrete

1. Scope

1.1 This test method covers the determination of a rebound number of hardened concrete using a spring-driven steel hammer.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards

C 125	Terminology Relating to Concrete and Concrete Aggregates
C 670	Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
E 18	Test Methods for Rockwell and Rockwell Superficial Hardness of Metallic Materials

3. Significance and Use

3.1 This test method is not intended as the basis for acceptance or rejection of concrete because of the inherent uncertainty in the estimated strength.

4. Apparatus

4.1 **Rebound Hammer** – Consisting of a spring-loaded steel hammer that when released strikes a steel plunger in contact with the concrete surface. The spring-loaded hammer must travel with a consistent and reproducible velocity. The rebound distance of the steel hammer from the steel plunger is measured on a linear scale attached to the frame of the instrument.

Note 1: Use type N rebound hammers that are commercially available to accommodate testing of various sizes and types of concrete construction.

4.2 **Abrasive Stone** – Consisting of medium-grain texture silicon carbide or equivalent material.

4.3 **Test Anvil** – Approximately 150 mm (6 in) diameter by 150 mm (6 in) high cylinder made of tool steel with an impact area hardened to 66 ± 2 HRC as measured by test method ASTM E 18. An instrument guide is provided to center the rebound hammer over the impact area and keep the instrument perpendicular to the surface.

[1]This FOP is based on ASTM C 805 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.

4.4 **Verification** – Rebound hammers shall be serviced and verified annually and whenever there is reason to question their proper operation. Verify the functional operation of a rebound hammer using the test anvil described in Section 4.3. During verification, support the test anvil on a bare concrete floor or slab. The manufacturer shall report the rebound number to be obtained by a properly operating instrument when tested on an anvil of specified hardness.

Note 2: Typically, a rebound hammer will result in a rebound number of 80 ± 2 when tested on the anvil described in Section 4.3. The test anvil needs to be supported on a rigid base to obtain reliable rebound numbers. Verification on the test anvil does not guarantee that the hammer will yield repeatable data at other points on the scale. The hammer can be verified at lower rebound numbers by using blocks of polished stone having uniform hardness. Some users compare several hammers on concrete or stone surfaces encompassing the usual range of rebound numbers encountered in the field.

5. Test Area and Interferences

5.1 **Selection of Test Surface** – Concrete members to be tested shall be at least 100 mm (4 in) thick and fixed within a structure. Smaller specimens must be rigidly supported. Avoid areas exhibiting honeycombing, scaling, or high porosity. Do not compare test results if the form material against which the concrete was placed is not similar. Troweled surfaces generally exhibit higher rebound numbers than screeded or formed finishes. If possible, test structural slabs from the underside to avoid finished surfaces.

5.2 **Preparation of Test Surface** – A test area shall be at least 150 mm (6 in) in diameter. Heavily textured, soft, or surfaces with loose mortar shall be ground flat with the abrasive stone described in Section 4.2. Smooth-formed or troweled surfaces do not have to be ground prior to testing. Do not compare results from ground and unground surfaces.

5.3 Do not test frozen concrete.

Note 3: Moist concrete at 0°C (32°F) or less may exhibit high rebound values. Concrete should be tested only after it has thawed. The temperatures of the rebound hammer itself may affect the rebound number. Rebound hammers at -18°C (0°F) may exhibit rebound numbers reduced by as much as two or three units (1 unit = 1 whole number).

5.4 For readings to be compared, the direction of impact, horizontal, downward, upward, or at another angle, must be the same or established correction factors shall be applied to the readings.

5.5 Do not conduct tests directly over reinforcing bars with cover less than 0.75 in (20 mm).

***Note 4*:** The location of reinforcement may be established using reinforcement locators or metal detectors. Follow the manufacturer's instructions for proper operation of such devices.

6. Procedure

6.1 Hold the instrument firmly so that the plunger is perpendicular to the test surface. Gradually push the instrument toward the test surface until the hammer impacts. After impact, maintain pressure on the instrument and, if necessary, depress the button on the side of the instrument to lock the plunger in its retracted position. Read the rebound number on the scale to the nearest whole number and record the rebound number. Take ten readings from each test area. No two impact tests shall be closer together than 25 mm (1 in). Examine the impression made on the surface after impact, and if the impact crushes or breaks through a near-surface air void, disregard the reading and take another reading.

7. Calculation

7.1 Discard readings differing from the average of ten readings by more than six units and determine the average of the remaining readings. If more than two readings differ from the average by six units, discard the entire set of readings and determine rebound numbers at ten new locations within the test area.

8. Report

8.1 Report the following information for each test area:

8.1.1 Date and time of testing.

8.1.2 Identification of location tested in the concrete construction and the type and size of member tested.

8.1.2.1 Description of the concrete mixture proportions including type of coarse aggregates if known.

8.1.2.2 Design strength of concrete tested.

8.1.3 Description of the test area including:

8.1.3.1 Surface characteristics (trowelled, screeded) of area.

8.1.3.2 If surface was ground and depth of grinding.

8.1.3.3 Type of form material used for test area.

8.1.3.4 Curing conditions of test area.

8.1.3.5 Type of exposure to the environment.

8.1.4 Hammer identification and serial number.

8.1.4.1 Air temperature at the time of testing.

8.1.4.2 Orientation of hammer during test.

8.1.5 Average rebound number for test area.

8.1.5.1 Remarks regarding discarded readings of test data or any unusual conditions.

10. Precision and Bias

See ASTM C 805 precision and bias.

Performance Exam Checklist

FOP for ASTM C 805

Rebound Hammer Determination of Compressive Strength of Hardened Concrete

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element			
Preparation		**Trial 1**	**Trial 2**
1.	Copy of current procedure available at test site?	_____	_____
2.	Hammer properly serviced and calibrated or verified?	_____	_____
3.	Test location properly prepared?	_____	_____
4.	Test location meets minimum size requirement?	_____	_____
5.	Ten acceptable readings taken in each test area?	_____	_____
6.	Readings properly spaced in test area?	_____	_____
7.	Test readings properly converted to estimated strength?	_____	_____
8.	Test information properly recorded?	_____	_____
9.	All calculations performed correctly?	_____	_____
Equipment			
10.	Are calibration/verifications tags present on equipment used in this procedure?	_____	_____
11.	All equipment functions according to the requirements of this procedure?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State Department of Transportation

WSDOT Test Method T 808

Method for Making Flexural Test Beams

1. Scope

a. This method covers the procedures for molding and curing Portland cement concrete flexural test beams.

2. Equipment

a. Test beam molds, 6 in × 6 in × 21 ± ½ in (150 mm × 150 mm × 550 ± 13 mm) or 8 in × 8 in × 26 ± ½ in (200 mm × 200 mm × 670 ± 13 mm).

b. Vibrator, capable of 7,000 vibrations per minute with a diameter not less than ¾ in (19.0 mm) or greater than 1½ in (38.1 mm).

c. Tamping Rod – The tamping rod is a round, straight steel rod ⅝ in (16.0 mm) diameter and approximately 24 in (610 mm) long, having the tamping end rounded to a ⅝ in (16.0 mm) diameter hemispherical tip.

d. Mallet – A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb (0.57 ± 0.23 kg).

e. Assorted tools such as scoops, shovels, etc.

3. Procedure

a. For laboratory made beam specimens, mix sufficient concrete to make all the required specimens from one batch. Each beam specimen requires approximately .45 ft^3 (0.015 m^3) of concrete.

For field-made beam specimens, the concrete sample is obtained in accordance with WSDOT Test Method No. 803, Method of Sampling Fresh Concrete. Making of the beam specimens shall begin within 15 minutes of remixing the sample.

b. Mold specimens as near as practicable to the place where they are to be stored during the first 24 hours.

c. Assemble the molds on a rigid surface free from vibration and other disturbances. Remix the concrete to a uniform appearance. When the method of consolidation is by internal vibrators, the mold is filled in a single layer. Make sure that each shovel or scoop of concrete is representative of the batch. When the method of consolidation is by rodding, the mold is filled in two layers with each layer being rodded one time for each 2 in^2 (1290 mm^2) of surface area. The rodding should be distributed evenly over the entire surface. On the succeeding layers, the rod should not penetrate the previous layer more than ½ in (13 mm). After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with a mallet.

d. Insert the vibrator at intervals not to exceed 6 in (150 mm) along the centerline of the long dimension of the beam. For specimens wider than 6 in (150 mm), use alternating insertions along two lines at least 2 in (50 mm) away from the sides of the mold. Withdraw the vibrator so that no air voids are left in the concrete. Then tap the mold lightly 10-15 times with mallet.

e. Finish the surface of the concrete by striking off with a straightedge. Use the minimum amount of manipulation necessary to leave a flat surface that has no depressions or projections larger than ⅛ in (3.2 mm) and is level with the sides of the mold.

f. The top surface of the laboratory-made specimen shall be covered with a saturated towel and a plastic sheet to prevent moisture loss from the concrete.

For the field made specimen, the top surface of the beam shall be sprayed with the same curing compound as is used for the pavement and covered with a plastic tarpaulin.

4. Storage and Handling

The method of storing and handling the beam specimen depends on the purpose for which the beam is intended. Two methods are provided as follows:

a. Laboratory Method – Beam for determining the acceptability of a contractor-provided paving mix.

Cover the beam to prevent moisture loss and allow beam to remain undisturbed for an initial cure period of 24 ± 4 hours at a temperature of 60° to 80°F (16° to 27°C). After the initial cure period, the beam will be removed from the mold and within 30 minutes stored in saturated limewater at 73.4° ± 3°F (23° ± 2°C) for a minimum of 20 hours prior to testing. Surface drying of the beam between removal from the limewater and completion of testing shall be prevented. Relatively small amounts of drying of the test beam surfaces induces tensile stress in the extreme fibers that will markedly reduce the indicated flexural strength.

b. Field Method – Beam for determining the flexural strength of the inplace pavement.

After applying the curing compound to the top surface, cover the beam specimen with white reflective sheeting and allow beams to remain undisturbed for an initial cure period of 24 ± 4 hours at ambient conditions. After the initial cure period, remove the specimen from the mold and cure the specimen either by:

(1) Burying the specimen in wet sand making sure that the specimen is never allowed to become surface dry. Temperature of the sand should be similar to the concrete pavement temperature, or

(2) Wrap the beam in a saturated towel, place in a plastic bag, and seal the opening. The plastic should be at least 4 mils thick. Leave the specimen on the pavement in the vicinity where it was molded until time to test. Take specimen to the testing location and store in lime water at 73.4° ± 5°F (23° ± 2.8°C) for 24 ± 4 hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen.

Note: The beam specimen must be kept in a surface moist condition or wet environment for the entire time in storage **and** testing. Even minor amounts of surface drying of the specimen induces extreme fiber stresses which can markedly reduce the flexural strength.

5. Testing

a. Beam specimens are tested for flexural strength in accordance with WSDOT Test Method No. 802.

Performance Exam Checklist

WSDOT T 808

Method for Making Flexural Test Beams

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. Copy of current procedure available at test site?	____	____
2. Making of test specimens begins within 15 minutes for sampling?	____	____
3. Assemble of molds on a rigid surface free from vibration and other disturbances?	____	____
4. Concrete remixed to a uniform appearance?	____	____
5. When method of concrete consolidation is by rodding:		
a. Mold filled in two layers?	____	____
b. Each layer rodded one time for each 2 in^2 (1290 mm) of mold surface area?	____	____
c. Rodding, evenly distributed over the entire surface area?	____	____
d. After rodding each layer, mold tapped lightly 10-15 times with mallet?	____	____
6. When method of concrete consolidation is by internal vibrators:		
a. Mold filled in a single layer?	____	____
b. Vibrator inserted at intervals not to exceed 6 in (150 mm) along the centerline of the long dimension?	____	____
c. For molds wider than 6 in (150 mm), vibrator inserted along two alternating lines at least 2 in (50 mm) away from sides of mold?	____	____
d. Mold tapped lightly 10-15 times with mallet?	____	____
7. Top of mold properly finished?	____	____
8. Top of mold properly treated to prevent moisture loss?	____	____

Equipment

1. Where required are calibration/verifications tags present on equipment used in this procedure?	____	____
2. All equipment functions according to the requirements of this procedure?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Test Method T 813

Field Method of Fabrication of 2 in (50 mm) Cube Specimens for Compressive Strength Testing of Grouts and Mortars

1. Scope

This method covers the fabrication of 2 in (50 mm) cube specimens for compressive strength testing of grouts and mortars.

2. Equipment

a. **Specimen Molds** – Specimen molds for the 2 in (50 mm) cube specimens shall be tight fitting. The molds shall not have more than three cube compartments and shall not be separable into more than two parts. The parts of the molds, when assembled, shall be positively held together. The molds shall be made of hard metal not attacked by the cement mortar. For new molds, the Rockwell hardness number shall not be less than HRB 55. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall conform to the tolerances of Table 1.

Table 1 Permissible Variations of Specimen Molds

Parameter	2 in Cube Molds		50 mm Cube Molds	
	New	In Use	New	In Use
Planeness of Sides	<0.001 in	<0.002 in	<0.025 mm	<0.05 mm
Distance Between Opposite Sides	2 in ± 0.005 in	2 in ± 0.02 in	50 mm + 0.13 mm	50 mm + 0.50 mm
Height of Each Compartment	2 in + 0.001 in to -0.005 in	2 in + 0.01 in to -0.015 in	50 mm + 0.25 mm to -0.013 mm	50 mm + 0.25 mm to -0.38 mm
Angle Between Adjacent Faces*	90 + 0.5°	90 + 0.5°	90 + 0.5°	90 + 0.5°

*Measured at points slightly removed from the intersection. Measured separately for each compartment between all the interior faces and the adjacent face and between interior faces and top and bottom planes of the mold.

b. **Base Plates** – Base plates shall be made of a hard metal not attacked by cement mortar. The working surface shall be plane and shall be positively attached to the mold with screws into the side walls of the mold.

c. **Cover Plates** – Cover plates shall be made of a hard metal or glass not attacked by cement mortar. The surface shall be relatively plane.

d. **Tamper** – The tamper shall be made of a nonabsorptive, nonabrasive, nonbrittle material such as a rubber compound having a Shore A durometer hardness of 80 + 10, or seasoned oak wood rendered nonabsorptive by immersion for 15 minutes in paraffin at approximately 392°F (200°C), and shall have a cross-section of ½ in × 1 in (13 mm × 25 mm) and a length of about 5 to 6 in (125 to 150 mm). The tamping face shall be flat and at right angles to the length of the tamper.

e. **Trowel** – A trowel which has a steel blade 4 to 6 in (100 to 150 mm) in length, with straightedges.

3. Field Procedure

a. Three or more specimens shall be made for each period of test specified.

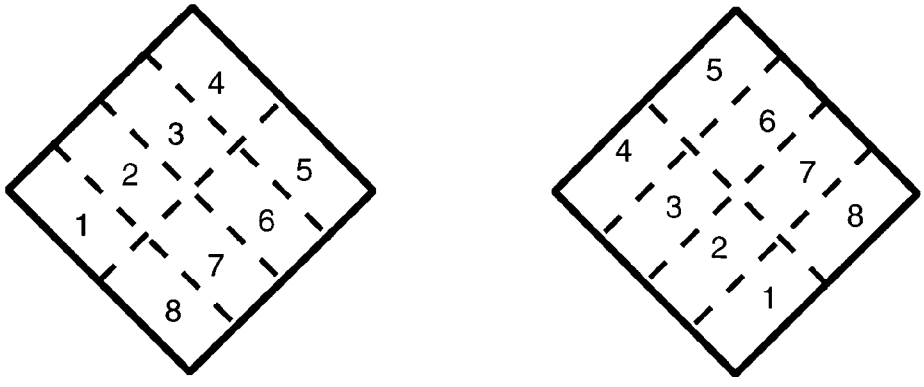
b. All joints shall be water tight. If not water tight, seal the surfaces where the halves of the mold join by applying a coating of light cup grease. The amount should be sufficient to extrude slightly when the halves are tightened together. Repeat this process for attaching the mold to the base plate. Remove any excess grease.

c. Apply a thin coating of release agent to the interior faces of the mold and base plate. (WD-40 has been found to work well as a release agent.) Wipe the mold faces and base plate as necessary to remove any excess release agent and to achieve a thin, even coating on the interior surfaces. Adequate coating is that which is just sufficient to allow a distinct fingerprint to remain following light finger pressure.

d. Begin molding the specimens within an elapsed time of not more than 2½ minutes from completion of the mixing.

e. For plastic mixes, place a first layer of mortar about 1 in (25 mm) deep in all the cube compartments (about one-half the depth of the mold). Tamp the mortar in each cube compartment 32 times in about 10 seconds making four rounds, each round perpendicular to the other and consisting of eight adjoining strokes over the surface of the specimen, as illustrated in Figure 1, below. The tamping pressure should be just sufficient to ensure uniform filling of the molds. The four rounds of tamping (32 strokes) shall be completed in one cube before going on to the next. When the tamping of the first layer is completed, slightly over fill the compartments with the remaining mortar and then tamp as specified for the first layer. During tamping of the second layer, bring in the mortar forced out onto the tops of the molds after each round of tamping, by means of gloved fingers and the tamper, before starting the next round of tamping. On completion of tamping, the tops of all the cubes should extend slightly above the tops of the molds.

Figure 1



Rounds 1 and 3 Rounds 2 and 4

f. Bring in the mortar that has been forced out onto the tops of the molds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mold. Then, for the purpose of leveling the mortar and making the mortar that protrudes above the top of the mold of more uniform thickness, draw the flat trailing edge of the trowel (with leading edge slightly raised) once lightly along the length of the mold. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion over the length of the mold.

g. When fabricating fluid mixes, steps e. and f. need not be followed. Instead, the cube mold is filled with mortar and cut off to a plane surface with a sawing motion over the length of the mold.

h. Immediately after molding, place cover plate on top of the mold, cover the sample with wet burlap, towels, or rags, seal it in a plastic sack in a level location out of direct sunlight, avoid freezing of cubes and record the time. Allow the sample to set undisturbed, away from vibration, for a minimum of four hours or as recommended by manufactures instructions before moving.

i. Deliver the sample to the Regional or State Materials Laboratory **in the mold** with the cover plate in wet burlap, towels or rags sealed in a plastic bag within 24 hours. **Time of molding MUST be recorded on the Concrete Transmittal.** If delivery within 24 hours is unachievable, contact the Laboratory for instructions on caring for the cubes.

j. Once received in the lab, the molded sample is to be immediately placed in a moist curing room, with the upper surfaces exposed to the moist air but protected from dripping until the sample is a minimum of 20 hours old or has cured sufficiently that removal from the mold will not damage the cube. If the specimens are removed from the mold before they are 24 hours old they are to be kept on the shelves of the moist curing room until they are 24 to 36 hours old.

k. When the specimens are 24 to 36 hours old, immerse them in a lime-saturated water storage tank (Note 1). The specimens are to remain in the storage tank until time of test. (Curing test specimens of material other than hydraulic cement shall be in conformance with the manufacturer's recommendations.)

Note 1: The storage tank shall be made of noncorroding materials. The water shall be saturated with calcium hydroxide such that excess is present. Stir the lime-saturated water once a month and clean the bath as required by AASHTO M 201.

Performance Exam Checklist

WSDOT Test Method T 813

Field Method of Fabrication of 2 in (50 mm) Cube Specimens for Compressive Strength Testing of Grouts and Mortars

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	_____	_____
3.	Three cubes made for each time period of test?	_____	_____
4.	All joints (mold halves, mold to base plate) shall be water tight?	_____	_____
5.	Adequate coating of release agent applied to interior surfaces of the mold?	_____	_____
6.	Molding began within 2½ minutes from completion of mixing?	_____	_____
7.	Molding performed in two lifts? (Not necessary if mix is fluid.)	_____	_____
8.	Lifts tamped 32 times, made up of 4 rounds of 8, each perpendicular to the other? (Not required if mix is fluid.)	_____	_____
9.	For second layer, mortar forced out of the mold brought back in before each round? (Not required if mix is fluid.)	_____	_____
10.	Mix extends slightly above the mold at the completion of tamping?	_____	_____
11.	Mortar smoothed by drawing flat side of trowel across each cube at right angles?	_____	_____
12.	Mortar leveled by drawing the flat side of trowel lightly along the length of mold?	_____	_____
13.	Mortar cut off flush with mold with edge of trowel using sawing motion?	_____	_____
14.	Time of molding recorded?	_____	_____
15.	Cover plate placed on top of the mold and covered with wet burlap, towel or rag?	_____	_____
16.	Covered sample sealed in a plastic sack in a level location out of sunlight?	_____	_____
17.	Sample delivered to the laboratory in the mold within 24 hours?	_____	_____
18.	Transmittal includes the time of molding?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT Test Method T 818

Air Content of Freshly Mixed Self-Compacting Concrete by the Pressure Method

1. The air test will be performed in accordance with WSDOT FOP for WAQTC T 152 with the following modifications to the procedure:

   a. Change item 3 to read: Fill the base completely in one lift.

      Note: Filling the base with concrete by using multiple scoops or by pouring from a bucket or similar container has been found to be acceptable.

   b. Change item 4 to read: Do not consolidate the concrete by rodding, vibration, or tamping. When the base is filled, lightly tap around the exterior of the base with a rubber mallet to allow entrapped air bubbles to escape.

   c. Delete items 5 through 11.

Performance Exam Checklist

WSDOT T 818

Air Content of Freshly Mixed Self Compacting Concrete by the Pressure Method

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	____	____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	____	____
3.	Container filled in one layer, slightly overfilling?	____	____
4.	Sides of the container lightly tapped with the mallet?	____	____
5.	Concrete struck off level with top of container using the bar and rim cleaned off?	____	____
6.	Inside of cover cleaned and moistened before clamping to base?	____	____
Using a Type B Meter			
7.	Both petcocks open?	____	____
8.	Air valve closed between air chamber and the bowl?	____	____
9.	Water injected through petcock until it flows out the other petcock?	____	____
10.	Water injection into the petcock continued while jarring and tapping the meter to insure all air is expelled?	____	____
11.	Air pumped up to initial pressure line?	____	____
12.	A few seconds allowed for the compressed air to stabilize?	____	____
13.	Gauge adjusted to the initial pressure?	____	____
14.	Both petcocks closed?	____	____
15.	Air valve opened between chamber and bowl?	____	____
16.	Sides of bowl tapped with the mallet?	____	____
17.	Air percentage read after lightly tapping the gauge to stabilize the hand?	____	____
18.	Air valve closed and then petcocks opened to release pressure before removing the cover?	____	____
19.	Air content recorded to 0.1 percent?	____	____
20.	All calculations performed correctly?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

This checklist is derived, in part, from copyrighted material printed in ACI CP-1, published by the American Concrete Institute.

WSDOT Test Method T 819

Making and Curing Self-Compacting Concrete Test Specimens in the Field

1. The cylinders will be made and cured in accordance with WSDOT FOP for AASHTO R 100 with the following modifications:

   9. Molding Specimens

      9.2 Casting Cylinders is revised to read:

      Place the concrete in the mold using a scoop, blunted trowel or shovel. Molds shall be filled in one layer by pouring material from a suitable container into the mold. Do not rod, vibrate, or tap the mold.

      Note: Filling the mold with concrete by using multiple scoops or by pouring from a bucket or similar container has been found to be acceptable.

      9.3 Consolidation is deleted

      9.4 Finishing is revised to read:

      Strike off the surface of the concrete level with the top of the mold using a float, trowel or steel strike off bar. Immediately after finishing place a plastic cylinder lid on the cylinder.

Performance Exam Checklist

Making and Curing Self-Compacting Concrete Test Specimens in the Field
WSDOT T 819

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	Molds placed on a level, rigid, horizontal surface free of vibration?	_____	_____
3.	Making of specimens begun within 15 minutes of sampling?	_____	_____
4.	Concrete poured into the mold using a suitable container?	_____	_____
5.	Mold filled in one lift?	_____	_____
6.	Excess concrete struck off?	_____	_____
7.	Specimens covered immediately with plastic cylinder lid?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Performance Exam Checklist

ASTM C 882

Bond Strength (Diagonal Shear)

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		**Trial 1**	**Trial 2**
1.	Confirmation that the concrete lab will be ready to mix mortar?	_____	_____
2.	Half cylinders taken from moisture room?	_____	_____
3.	Elliptical surface acid washed, rinsed with water and allowed to dry?	_____	_____
4.	Half cylinders placed in cylinder molds awaiting the epoxy and mortar?	_____	_____
5.	Epoxy mixed using manufacturer's mix ratio and directions?	_____	_____
6.	With elliptical surface maintained horizontal, coat the surface with epoxy?	_____	_____
7.	Epoxy layer thickness 10 to 15 mils (0.3 mm to 0.4 mm)?	_____	_____
After the epoxy coating:			
8.	Fill up the remainder of the mold with fresh plastic mortar?	_____	_____
9.	New mortar rodded and the top smoothed off?	_____	_____
10.	Specimens (epoxy/mortar) cured for two (2) days or fourteen (14) days at 100% relative humidity?	_____	_____
11.	Compressive load determined as per WSDOT Test Method T 22?	_____	_____
12.	Compressive strength calculated based on elliptical surface area?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Washington State Department of Transportation

WSDOT Test Method T 915

Practice for Conditioning of Geotextiles for Testing

1. Scope

a. This practice covers a procedure for conditioning geotextile specimens for testing and establishes atmospheric conditions which are acceptable for testing when the standard atmosphere for testing cannot be obtained due to local laboratory conditions.

2. Applicable Documents

a. ASTM Standards.

D 123	Terminology Relating to Textiles
D 1776	Practice for Conditioning Textiles for Testing
D 4439	Terminology for Geotextiles
D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles
D 4595	Standard Test Method for tensile Properties of Geotextiles by the Wide-Width Strip Method
D 4632	Standard Test Method for Breaking Load and Elongation of Geotextiles (Grab Method)

3. Definitions

a. Atmosphere for Testing Geotextiles – Air maintained at a relative humidity of 55 ± 25 percent relative humidity and temperature of 70° ± 4°F (21° ± 2°C).

b. Geotextile – Any permeable textile used with foundation, soil, rock, earth, or any other geotechnical material, as an integral part of a manmade product, structure, or system.

c. Specimen – A specific portion of a material or laboratory sample upon which a test is performed or which is taken for that purpose.

d. Preconditioning – Atmospheric conditioning of a test specimen prior to testing in a specified environment in which the specimen is allowed to come to equilibrium with that specified preconditioning environment.

4. Summary of Practice

a. Specimens are preconditioned by soaking them in distilled water for a specified period of time and are tested at ambient laboratory room temperature and humidity conditions without allowing the specimens time to come to equilibrium with the ambient testing atmosphere.

5. Uses and Significance

a. The conditioning prescribed in this practice is designed to obtain reproducible test results on geotextiles.

6. Apparatus

a. Water filled pan for soaking specimens.

b. Equipment for recording the temperature of the air and the water, and the humidity of the air.

7. Procedure

a. Precondition specimens by immersing them in distilled water maintained at a temperature of 70° ± 4°F (21 ± 2°C). The time of immersion must be sufficient to wet-out the specimens thoroughly, but must be a minimum of two hours. To obtain thorough wetting, add not more than 0.05 percent of a nonionic neutral wetting agent to the water.

b. After the specimens have been thoroughly wetted, remove each specimen from the water, and allow excess water contained in the pores of the specimen to drain from the specimen for a period of time less than or equal to one minute. After the specimen has drained during the maximum allowed time period of one minute, the specimen test must begin before nine minutes of time have elapsed from the end of the draining period.

Note 1: If more than a total of nine minutes from the time the specimen is removed from the water is allowed to elapse before the specimen test is actually begun, the specimen should not be considered to be thoroughly wetted. If this occurs, the specimen should be reimmersed for a minimum of two hours before a test is attempted again for that specimen. Thorough wetting is needed to ensure that the specimen is not affected by the ambient humidity conditions during testing if those ambient conditions are not at the standard atmosphere for testing.

c. The atmosphere for testing, geotextiles must be maintained at a temperature of 70° ± 4°F (21 ± 2°C). and a relative humidity of 55 ± 25 percent.

d. If dry testing of the geotextile is required in addition to wet testing, the specimens must be conditioned in the atmosphere for testing as stated in Section 7.3. Specimen conditioning shall be accomplished in this case by allowing the specimens to reach moisture equilibrium in the atmosphere for testing. Equilibrium is considered to have been reached when the change in the mass of the specimen in successive weighings made at intervals of not less than two hours does not exceed 0.1 percent of the mass of the specimen. Specimen immersion requirements do not apply to specimens which are to be tested dry. Specimens tested dry must be tested in the atmosphere for testing as previously defined.

Performance Exam Checklist

WSDOT T 915

Practice for Conditioning of Geotextiles for Testing

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	The tester has a copy of the current procedure on hand?	____	____
2.	All equipment is functioning according to the test procedure, and if required has the current calibration/standardization/check and maintenance tags present?	____	____
3.	Were test specimens, pre-conditioned in distilled water with not more than 0.05 % of a nonionic neutral wetting agent added at 70 ± 4° F (21 ± 2° C), thoroughly wetted and soaked for a minimum of 2 hours?	____	____
4.	Were test specimens removed for testing and allowed to drain for 1 minute?	____	____
5.	Was testing of specimen started before 9 minutes had elapsed from end of draining period?	____	____
6.	If more than 9 minutes had elapsed, was test specimen returned to water bath for a minimum of 2 hours?	____	____
7.	Was atmosphere for testing done at temperature of 70 ± 4° F (21 ± 2° C) and relative humidity of 55 ± 25%?	____	____
8.	If dry testing is required, were the specimens conditioned according to question, number 3 above?	____	____
9.	Was successive weighing done at intervals of 2 hours min. to determine max loss of 0.1 percent?	____	____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for ASTM C1231

Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens

WSDOT has adopted the published ASTM C1231.

AASHTO Test Methods cannot be included in Materials Manual due to copyright infringement.

WSDOT employees can access AASHTO and ASTM test methods in the following web address:
http://wwwi.wsdot.wa.gov/MatsLab/BusinessOperations/ASTMLogin.htm

Non-WSDOT employees can order AASHTO's Standard Specifications for Transportation Materials and Methods of Sampling and Testing, using the following web address:
https://store.transportation.org

Performance Exam Checklist

ASTM C 1231

Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required has the current calibration/standardization/check and maintenance tags present?	_____	_____
3.	Depressions in specimen ends checked?	_____	_____
4.	Neoprene pads meet dimensional requirements?	_____	_____
5.	Neoprene pads do not exceed the maximum reuse limits?	_____	_____
6.	Unbonded caps not used for concrete with compressive strength below 1500 psi or above 12,000 psi?	_____	_____
7.	If recommended, pads and specimen ends dusted with corn starch or talcum powder prior to testing?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for ASTM C 1611

Standard Test Method for Slump Flow of Self-Consolidating Concrete

1. Scope

1.1 This test method covers the determination of slump flow of self-consolidating concrete.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (**Warning**: Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 ASTM Standards

C 143/C 143M
: Test Method for Slump of Hydraulic-Cement Concrete

C 172
: Practice for Sampling Freshly Mixed Concrete

C 173/C 173M
: Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 670
: Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.2 AASHTO Standards

T 119M/T 119
: Standard Test Method for Slump of Hydraulic-Cement Concrete

T 347
: Slump Flow of Self-Consolidating Concrete (SCC)

2.3 WAQTC Standards

TM 2
: Sampling Freshly Mixed Concrete

3. Terminology

3.1 Definitions of terms specific to this standard:

3.1.1 *halo*, *n* – An observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the slump cone.

3.1.2 *spread*, *n* – The distance of lateral flow of concrete during the slump-flow test.

3.1.3 *stability*, *n* – The ability of a concrete mixture to resist segregation of the paste from the aggregates.

3.1.4 *viscosity*, *n* – Resistance of a material to flow under an applied shearing stress.

4. Summary of Test Method

4.1 A sample of freshly mixed concrete is placed in a mold shaped as the frustum of a cone. The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete allowed to spread. After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions, and slump flow is the average of the two diameters.

5. Significance and Use

5.1 This test method provides a procedure to determine the slump flow of self-consolidating concrete in the laboratory or the field.

5.2 This test method is used to monitor the consistency of fresh, unhardened self-consolidating concrete and its unconfined flow potential.

5.3 It is difficult to produce self-consolidating concrete that is both flowable and nonsegregating using coarse aggregates larger than 1 in (25 mm). Therefore, this test method is considered applicable to self-consolidating concrete having coarse aggregate up to 1 in (25 mm) in size.

6. Apparatus

6.1 **Mold** – The mold used in this test method shall conform to that described in FOP for AASHTO T 119.

6.2 **Base Plate** – The base plate on which the mold rests shall be nonabsorbent, smooth, rigid, and have a minimum diameter of 36 in (915 mm).

Note 1: Field experience and results from the round robin test program have shown that base plates made from sealed/laminated plywood, acrylic plastic, or steel are suitable for performing this test.

6.3 **Strike-off Bar** – As described in FOP for WAQTC T 152.

7. Sample

7.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. Sample in accordance with FOP for WAQTC TM 2.

8. Procedure

8.1 The slump-flow test shall be performed on a flat, level, nonabsorbent base plate. Position and shim the base plate so it is fully supported, flat, and level.

8.2 Filling the Mold – WSDOT requires the use of Procedure B.

8.2.1 Filling Procedure B (Inverted Mold) – Dampen and place the mold, with the smaller opening of the mold facing down, in the center of a flat, moistened base plate or concrete surface. Using a suitable container, fill the entire mold continuously (Note 2). The mold shall be held firmly in place during filling. Do not rod or tamp the SCC. Slightly overfill the mold.

Note 2: Filling the mold with concrete by using multiple scoops or by pouring from a bucket or similar container has been found to be acceptable.

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike-off bar. Remove concrete from the area surrounding the base of the mold to preclude interference with the movement of the flowing concrete. Remove the mold from the concrete by raising it vertically. Raise the mold a distance of 9 ± 3 in (225 ± 75 mm) in 3 ± 1 seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from start of the filling through removal of the mold without interruption within an elapsed time of 2½ minutes.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter of the resulting circular spread of concrete to the nearest ¼ in (5 mm). When a halo is observed in the resulting circular spread of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter of the circular spread at an angle approximately perpendicular to the original measured diameter.

8.5 If the measurement of the two diameters differs by more than 2 in (50 mm), the test is invalid and shall be repeated.

9. Calculation

9.1 Calculate the slump flow using Eq 1:

$$\text{Slump flow} = \frac{(d^1 + d^2)}{2}$$

where:

d^1 = the largest diameter of the circular spread of the concrete, and

d^2 = the circular spread of the concrete at an angle approximately perpendicular to d^1

9.2 Record the average of the two diameters to the nearest ¼ in (5 mm).

10. Report

10.1 Report the slump flow to the nearest ¼ in (5 mm).

10.2 Report results on concrete delivery ticket (i.e., Certificate of Compliance).

10.3 The name of the tester who performed the field acceptance test is required on concrete delivery tickets containing test results.

11. Precision and Bias

See ASTM C1611/C 1611M for precision and bias.

Performance Exam Checklist

WSDOT FOP for ASTM C 1611/C 1611M

Standard Test Method for Slump Flow of Self-Consolidating Concrete

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	_____	_____
3.	Sample was taken per WSDOT FOP for WAQTC TM 2?	_____	_____
4.	Molds and base plate dampened and base plate is flat, level, and fully supported?	_____	_____
5.	Mold filled completely (slightly overfilled)?	_____	_____
6.	Mold struck off level with top opening?	_____	_____
7.	Excess material removed from base plate and mold raised 9 ± 3 inches, in 3 ± 1 seconds?	_____	_____
8.	After flow stabilized, measured largest diameter (including halo if necessary)?	_____	_____
9.	Second measurement taken approximately perpendicular to first measurement?	_____	_____
10..	First and second measurements agree within 2″?	_____	_____
11.	Slump flow was reported as an average of the two measurements?	_____	_____
12.	Slump flow reported to the nearest ¼″?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for ASTM C 1621/C 1621M[1]

Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring

1. Scope

1.1 This test method covers determination of the passing ability of self-consolidating concrete by using the J-Ring in combination with a slump cone mold. The test method is limited to concrete with maximum size of aggregate of 1 in (25 mm).

1.2 The values stated in either inch-pounds or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 The text of this standard references notes that provide explanatory material. These notes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (***Warning:*** Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

2. Referenced Documents

2.1 ASTM Standards

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M
Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M
Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 1611/C 1611M
Test Method for Slump Flow of Self-Consolidating Concrete

[1]This Test Method is based on ASTM C 1621/C 1621M and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.

3. Terminology

3.1 Definitions

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 Definitions of terms specific to this standard:

3.2.1 **Halo** – An observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the slump cone.

3.2.2 **J-ring** – An apparatus consisting of a rigid ring supported on sixteen ⅝ in (16 mm) diameter rods equally spaced on a 12 in (300 mm) diameter circle 4 in (100 mm) above a flat surface as shown in Figure 1.

3.2.3 **J-ring flow** – The distance of lateral flow of concrete using the J-Ring in combination with a slump cone.

3.2.4 **Passing ability** – The ability of self-consolidating concrete to flow under its own weight (without vibration) and fill completely all spaces within intricate formwork, containing obstacles, such as reinforcement.

4. Summary of Test Method

4.1 A sample of freshly mixed concrete is placed in a slump mold (inverted position) that is concentric with the J-Ring (Figure 2). The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete is allowed to pass through J-Ring and subside (Figure 3).

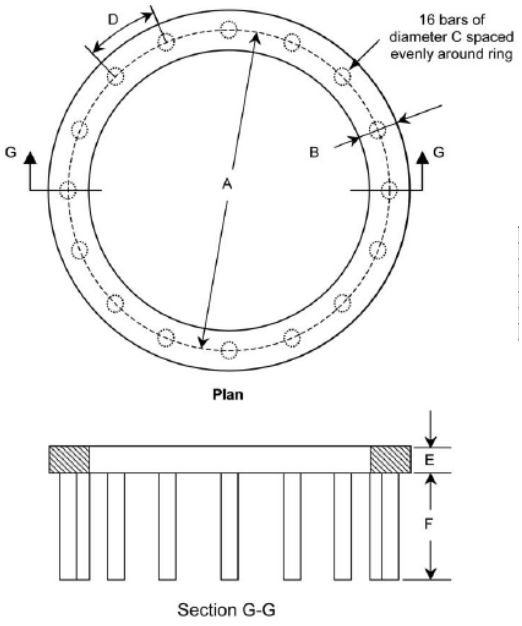
The diameters of the concrete, in two directions approximately perpendicular to each other, are measured and averaged to obtain the J-Ring flow. The test is repeated without the J-Ring to obtain the slump flow.

The difference between the slump flow and J-Ring flow is an indicator of the passing ability of the concrete.

5. Significance and Use

5.1 This test method provides a procedure to determine the passing ability of self-consolidating concrete mixtures. The difference between the slump flow and J-Ring flow is an indication of the passing ability of the concrete. A difference less than 1 in (25 mm) indicates good passing ability and a difference greater than 2 in (50 mm) indicates poor passing ability. The orientation of the slump cone for the J-Ring test and for the slump flow test without the J-Ring shall be the same.

Figure 1



Dimension	in	mm
A	12.0 ± 0.13	300 ± 3.3
B	1.5 ± 0.06	38 ± 1.5
C	0.625 ± 0.13	16 ± 3.3
D	2.36 ± 0.06	58.9 ± 1.5
E	1.0 ± 0.06	25 ± 1.5
F	4.0 ± 0.06	200 ± 1.5

5.2 This test method is applicable for laboratory use in comparing the passing ability of different concrete mixtures. It is also applicable in the field as a quality control test.

6. Apparatus

6.1 J-Ring – The apparatus shall consist of a steel (or equivalent nonabsorbent, rigid material) ring measuring 12 in (300 mm) in diameter at the center of the ring and 1 in (25 mm) in thickness, and sixteen ⅝ in (16 mm) diameter smooth steel rods spaced evenly around the ring measuring 4 in (100 mm) in length (see Figure 1).

6.2 Mold – The mold (slump cone) used in this test method is as described in FOP for AASHTO T 119.

6.3 Base Plate – A nonabsorbent, rigid plate having a diameter of at least 36 in (915 mm).

Note 1: Field experience has shown that base plates made from sealed or laminated plywood, rigid plastic, or steel are suitable for performing this test.

6.4 Strike Off Bar – As described in FOP for WAQTC T 152.

6.5 Measuring Device – A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid length measuring instrument marked in increments of ¼ in (5 mm) or less.

7. Sample

7.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with FOP for WAQTC TM 2.

8. Procedure

8.1 Perform the test on a flat, level, and nonabsorbent base plate. Position and shim the base plate so that it is fully supported and level. Pre-moisten base-plate with a damp towel, rag, or sponge. Rest the J-Ring at the center of the base plate.

Figure 2 J-Ring Setup with Inverted Mold Filled with Concrete

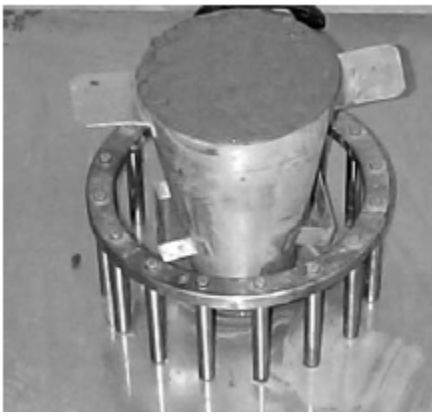


Figure 3 Ring Flow

8.2 WSDOT uses only Procedure B.

8.1.2 Filling Procedure B (Inverted Mold) – Dampen the mold, and place it on the base plate with the smaller opening facing down and concentric with the J-Ring. Support the mold and fill the mold in one lift (Note 2). Heap the concrete above the top of the mold.

Note 2: Filling the mold with concrete by using multiple scoops or by pouring from a bucket or similar container has been found to be acceptable.

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike off bar. Remove concrete from the area surrounding the mold to preclude interference with the movement of the flowing concrete. Raise the mold a distance of 9 ± 3 in (230 ± 75 mm) in 3 ± 1 s by a steady vertical lift with no lateral or torsional motion. Complete the entire procedure from start of the filling through removal of the mold without interruption within an elapsed time of 2½ min.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter (*d*1) of the resulting circular flow of concrete. When a halo is observed in the resulting circular flow of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter (*d*2) of the circular flow at approximately perpendicular to the first measured diameter (*d*1). Measure the diameters to the nearest ¼ in (5 mm). Determine the J-Ring flow in accordance with Section 9 of this test method.

8.5 Conduct a slump flow test without the J-Ring in accordance with Test Method C 1611/C 1611M. Use the same filling procedure as used with the J-Ring. Complete the tests with and without the J-Ring within 6 min.

9. Calculation

9.1 Calculate J-Ring flow according to the following equation:

$$\text{J-Ring flow} = \frac{d^1 + d^2}{2}$$

9.2 Calculate the slump flow according to the following equation:

$$\text{Slump flow} = \frac{d^1 + d^2}{2}$$

9.3 Calculate the difference between slump flow and J-Ring flow to the nearest ½ in (10 mm). This number represents the passing ability of the concrete.

10. Blocking Assessment

10.1 Identify blocking assessment according to Table 1.

Table 1 Blocking Assessment

Difference Between Slump Flow and J-Ring Flow	Blocking Assessment
0 to 1 in (0 to 25 mm)	No visible blocking
> 1 to 2 in (>25 to 50 mm)	Minimal to noticeable blocking
> 2 in (>50 mm)	Noticeable to extreme blocking

11. Report

11.1 Report the filling procedure (A or B) that was used.

11.2 Report the J-Ring flow as the average of the two measured diameters to the nearest ½ in (10 mm).

11.3 Report the slump flow (without the J-Ring) as the average of the two measured diameters to the nearest ½ in (10 mm).

11.4 Report the passing ability as the difference between the slump flow and J-Ring flow to the nearest ½ in (10 mm). Identify the blocking assessment.

11.5 Report results on concrete delivery ticket (i.e., Certificate of Compliance).

11.6 The name of the tester who performed the field acceptance test is required on concrete delivery tickets containing test results.

12. Precision and Bias

See ASTM C 1621/C 1621M for precision and bias.

Performance Exam Checklist

WSDOT FOP for ASTM C 1621/C 1621M

Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	_____	_____
3.	Sample was taken per WSDOT FOP for WAQTC TM 2?	_____	_____
4.	Molds and base plate dampened and base plate is flat, level and fully supported?	_____	_____
5.	Mold is centered in J-Ring and centered on base plate?	_____	_____
6.	Mold filled completely in one lift (slightly overfilled)?	_____	_____
7.	Mold struck off level with top opening?	_____	_____
8.	Excess material removed from base plate and mold raised 9 ± 3 inches, in 3 ± 1 seconds?	_____	_____
9.	After flow has stabilized, measure largest diameter (including halo)?	_____	_____
10.	Second measurement taken approximately perpendicular to first measurement?	_____	_____
11.	Measurements made to nearest ¼″?	_____	_____
12.	Test performed within 6 minutes of FOP for ASTM C 1611?	_____	_____
13.	All calculations performed correctly?	_____	_____
14.	Results reported to the nearest ½″?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Performance Exam Checklist

ASTM D 2628 AASHTO M220

Test for High and Low Temperature Recovery of Elastomeric Joint Seals for Concrete Pavements

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. Sample is cut into 5-inch pieces?	_____	_____
2. Specimens for high and low temperature recovery tests (2 each) lightly dusted with talc?	_____	_____
3. Specimens deflected between parallel plates to 50% of the nominal width using a compression device clamp assembly?	_____	_____
High Temperature Recovery		
1. Clamp assembly containing the compressed specimens placed in an oven capable of maintaining 212 ± 2°F (100 ± 1°C) and kept there for 70 hours?	_____	_____
2. Clamp assembly removed from the oven after 70 hours?	_____	_____
3. Unclamped the assembly and carefully removed the specimens?	_____	_____
4. Specimens allowed to rest on a wooden surface at room temperature for 1 hour?	_____	_____
5. Recovered width of the specimens measured in the center of the 5-inch length at the top of the longitudinal edge using a dial caliper or other measuring device?	_____	_____
6. Data entered into the computer data base where % Recovery is automatically calculated?	_____	_____
Low Temperature Recovery		
1. Clamp assembly containing the compressed specimens placed in a refrigerated chamber capable of maintaining -20 ± 2°F (-29 ± 1°C) and kept there for 22 hours?	_____	_____
2. Clamp assembly removed from the chamber after 22 hours?	_____	_____
3. Unclamped the assembly and carefully removed the specimens?	_____	_____
4. Specimens transferred to a wooden surface in the chamber and allowed to recover for 1 hour?	_____	_____
5. Specimens removed from the chamber and measured the recovered width in the center of the 5-inch length at the top of the longitudinal edge using a dial caliper or other measuring device?	_____	_____
6. Data entered into the computer data base where % Recovery is automatically calculated?	_____	_____

Recovery, % = recovered width × 100/nominal width

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

WSDOT FOP for ASTM D 6931

Standard Test Method for Indirect Tensile (IDT) Strength of Asphalt Mixtures

WSDOT has adopted ASTM D 6931 as published at wwwi.wsdot.wa.gov/MatsLab/BusinessOperations/ASTMLogin.htm with the following changes:

6. Specimens

6.1 Laboratory-Molded Specimens – Prepare the 150 mm (5.9 in) laboratory-molded specimens in accordance with WSDOT FOP for AASHTO T 312, to a height of 62 ± 1.0 mm (2.44 ± 0.04 in). A minimum of three replicates shall be prepared for each mixture.

6.1.1 Air void (Va) of test specimen shall be 7.0 ± 1.0 %.

7. Procedure

7.1 Section 7.1 shall be deleted in its entirety.

8. Calculation

8.1 Calculate the IDT strength as follows:

$$S_T = \frac{2F}{3.14\,(hd)}$$

Where:

S_T = Indirect tensile strength (psi)
F = Total applied vertical load at failure (lbs)
h = Height of specimen (inches)
d = Diameter of specimen (inches)

Tester Qualification Practical Exam Checklist

Determining Indirect Tensile Strength of Compacted Bituminous Mixtures

FOP for ASTM D 6931

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	**Trial 1**	**Trial 2**
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	_____	_____
3.	Specimen height is 62 ± 1.0 mm (2.44 ± 0.04 in) or 38.1 mm (1.5 in) minimum for cores?	_____	_____
4.	Specimen meets air void tolerance of 7.0 + 1.0 %?	_____	_____
5.	Specimen placed in water bath at 77 + 2°F (25 + 1°C) for a minimum of 30 minutes but not longer than 120 minutes?	_____	_____
6.	Press turned on and operating at a deformation rate of 2 in per minute?	_____	_____
7.	Specimen placed on lower loading strip?	_____	_____
8.	Upper loading strip lowered onto specimen with light contact?	_____	_____
9.	Upper and lower loading strips parallel with each other?	_____	_____
10.	Load applied at 2 in per minute?	_____	_____
11.	Total applied vertical load recorded?	_____	_____
12.	Indirect tensile strength in psi calculated and recorded correctly?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____

Tester Qualification Practical Exam Checklist

FOP for ASTM D 6931

Determining Indirect Tensile Strength of Compacted Bituminous Mixtures

Participant Name: _____ Exam Date: _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	The tester has a copy of the current procedure on hand?	_____	_____
2.	All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	_____	_____
3.	Specimen height is 62 ± 1.0 mm (2.44 ± 0.04 in) or 38.1 mm (1.5 in) minimum for cores?	_____	_____
4.	Specimen meets air void tolerance of 7.0 + 1.0 %?	_____	_____
5.	Specimen placed in water bath at 77 + 2°F (25 + 1°C) for a minimum of 30 minutes but not longer than 120 minutes?	_____	_____
6.	Press turned on and operating at a deformation rate of 2 in per minute?	_____	_____
7.	Specimen placed on lower loading strip?	_____	_____
8.	Upper loading strip lowered onto specimen with light contact?	_____	_____
9.	Upper and lower loading strips parallel with each other?	_____	_____
10.	Load applied at 2 in per minute?	_____	_____
11.	Total applied vertical load recorded?	_____	_____
12.	Indirect tensile strength in psi calculated and recorded correctly?	_____	_____

Comments: First Attempt: Pass _____ Fail _____ Second Attempt: Pass _____ Fail _____

Examiner Signature: _____ WAQTC #: _____