AGGREGATES

Section 3 - Tests

Start with Scales

Scales are used in virtually all aggregate test procedures

- **WYDOT MTM 801**
- **Most specifications require a 0.1 percent accuracy level**
- **Accuracy should be checked once a month and every time the scale or the lab trailer is moved.**
- **Level the balance and check**
- **For usage of 10,000 grams or less, the verification weights are: 100, 1000, 5000, and 10,000 grams**

Scales (continued)

- **For usage of 10,000 grams or more, the verification weights are: 5,000, 10,000, and 15,000 grams**
- **For both ranges, the verification weights are: 100, 1,000, 5,000, 10,000 and 15,000 grams**
- **Allowable tolerance is + or – 0.1% of the weight used**
- **If <u>any</u> recorded weight exceeds the allowable range, discontinue use of balance for recalibration or repair.**
- **Keep a signed copy of the balance sheet with the balance.**

Scales

Section 3 - 4

Balance Verification Worksheet

Manufacturer: **METTLER**
Model: **PE 11**
Serial #: **J98627**

D	E	C
A	Front	B

Verification Weight (grams)	100	1000	5000	10,000	15,000
Tolerance (grams)	0.1	1	5	10	15
Allowable Range (grams)	99.9-100.1	999.0-1001.0	4995.0-5005.0	9990.0-10,010.0	14,985.0-15,015.0
Reading A					
Reading B					
Reading C					
Reading D					
Reading E					

Meets allowable range requirements for all Verification Weights:

YES ☐ NO ☐

Date: ____________________

Signature:________________

Section 3 - 5

Balance Verification Worksheet

Manufacturer: **METTLER**
Model: **PE 11**
Serial #: **J98627**

D	E	C
A	Front	B

Verification Weight (grams)	100	1000	5000	10,000	15,000
Tolerance (grams)	0.1	1	5	10	15
Allowable Range (grams)	99.9-100.1	999.0-1001.0	4995.0-5005.0	9990.0-10,010.0	14,985.0-15,015.0
Reading A	100.1	1000.2	5000.6	10,000.8	15,006.1
Reading B	100.0	1000.8	5000.9	10,001.4	15,007.0
Reading C	100.1	1000.7	5001.1	10,001.8	15,007.9
Reading D	100.0	1001.2	5001.6	10,003.0	15,008.4
Reading E	99.9	999.2	4998.2	9,996.4	14,992.2

Meets allowable range requirements for all Verification Weights:

YES ☐ NO ☐

Date: ____________________

Signature:________________

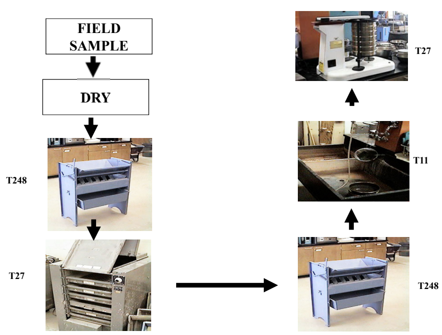
Section 3 - 6

Aggregate Tests

- **Gradation – WYDOT MTM 814.0 and 815.0**
  - **AASHTO T 11 – Material finer than #200 by washing**
  - **AASHTO T 27 – Sieve analysis of fine and coarse aggregate**

Section 3 - 7

Field Sample



Section 3 - 8

AASHTO T 27 – Sieve Analysis

- **Summary: A sample of dry aggregate is separated over a series of progressively smaller sieves to determine size distribution.**
  - **Used with AASHTO T 11 for total gradation**
  - **Used for fineness modulus**

Section 3 - 9

Aggregate Sizing: Sieve Screens

- ¼ inch and larger - measure actual size of opening
- #4 to #200 - measure number of wires (or openings) per inch
- Note that #4 ≠ ¼" (=0.187")

Section3 - 10

AASHTO T 27- Sieve Analysis (continued)

- **Significance: Total gradation influences water or asphalt demand workability, strength, void content, VMA, stability.**

Section3 - 11

AASHTO T 27 (Coarse Aggregate Equipment)

- **Balance: required accuracy is 0.1% of sample mass**
- **Sieves: 1", ¾", ½", 3/8", and #4**
- **Oven: 230± 9°F - 110 ± 5°C**
- **Large mechanical shakers**

Section 3 - 12

COARSE AGGREGATE GRADATION T 27

Section 3 - 13

COARSE AGGREGATE GRADATION T 27

Section 3 - 14

THERE ARE VARIOUS MANUFACURERS

Section 3 - 15

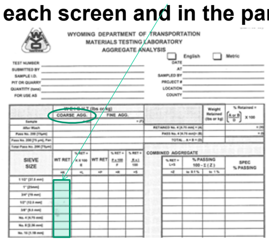
AASHTO T 27 (Coarse Aggregate continued)

- Check equipment (Always No. 1!)
- Dry sample to constant mass and record
- Check sample size to be sure it meets minimum allowable weight (MTM 814)
- Nest the sieves in the proper order

Section 3 - 16

AASHTO T 27(Coarse Aggregate continued)

- Pour the material into the sieve stack and vibrate the necessary length of time
- Determine the mass of material retained on each screen and in the pan



Section 3 - 17

AASHTO T 27(Coarse Aggregate continued)

- Check the mass retained on each screen to determine if a screen was overloaded. If overloaded, rescreen the materials, half at a time
  - The mass in kg/m² of sieving surface shall not exceed the product of 2.5 * sieve opening in mm (next pages)
- Determine the percentage passing and retained on #4
- Split the -#4 to 300 g or greater.

Section3 - 18

Maximum Allowable Quantity of Material Retained on a Sieve, kg

	Nominal dimensions of Sieve				
Sieve Opening Size, mm	203.2-mm dia	254-mm dia	304.8-mm dia	350 by 350 mm	372 by 580 mm
125	c	c	c	c	67.4
100	c	c	c	30.6	53.9
90.0	c	c	15.1	27.6	48.5
75.0	c	8.6	12.6	23.0	40.5
63.0	c	7.2	10.6	19.3	34.0
50.0	3.6	5.7	8.4	15.3	27.0
37.5	2.7	4.3	6.3	11.5	20.2
25.0	1.8	2.9	4.2	7.7	13.5
19.0	1.4	2.2	3.2	5.8	10.2
12.5	0.89	1.4	2.1	3.8	6.7
9.50	0.67	1.1	1.6	2.9	5.1
4.75	0.33	0.54	0.8	1.5	2.6

Maximum Allowable Weight

Sieve Size	
1"	2.5 x 25.4 mm= **63.5 kg/m2** A = 372.0 mm (15") x 580.0 mm (23") = .372 mm x .580 mm = 0.21576 m2 0.21576 m2 x 63.50 kg = 13.7 kg or **30.1 lb.**
3/4"	2.5 x 19.0 mm= **47.50 kg/m2** A = 0.21576 m2 0.21576 m2 x 47.50 kg = 10.2 kg or **22.5 lb**
1/2"	2.5 x 12.5 mm= **31.25 kg/m2** A = 0.21576 m2 0.21576 m2 x 31.25 kg = 6.7 kg or **14.8 lb**
3/8"	2.5 x 9.5 mm= **23.75 kg/m2** A =0.21576 m2 0.21576 m2 x 23.75 kg = 5.1 kg or **11.3 lb**
#4	2.5 x 4.75 mm= **11.88 kg/m2** A = 0.21576 m2 0.21576 m2 x 11.88 kg = 2.6 kg or **5.64 lb**

AASHTO T 11
Material Finer than #200

- **Summary: A sample is washed over a #200 sieve and the loss in mass is determined.**
- **Significance: Minus #200 fraction influences water demand, flowability and workability, asphalt demand, VMA, stiffness, stability.**

AASHTO T 11 Equipment

- Balance: required accuracy is 0.1% of sample mass
- Sieves: one #200 and a #8 on top
- Container: sufficient to contain sample and water
- Oven: 230 ± 9°F - 110 ± 5°C

Section 3 - 22

WASHED SIEVE ANALYSIS T 11

Section 3 - 23

AASHTO T 11 (continued)

- Check equipment
- Obtain fine aggregate sample (300 g minimum)
- Dry the test sample to a constant weight
- Place the sample in a wash pan and cover with about 2” of water

Section 3 - 24

AASHTO T 11 (continued)

- Agitate sample to separate fine particles. Spoon or similar tool OK. Spray nozzle OK if no material splashed on sides. (AASHTO T 11 2000)
- Pour wash water containing suspended fines over the nested #8 and #200 sieves.
  - The nesting sieves reduce splash and minimize loss of sample

Section3 - 25

AASHTO T 11 (continued)

- Avoid decantation of coarse particles
- Add water, agitate and decant (do not use any tools, hands, etc. on the #200 screen)
- Repeat until water exiting wash pan and below #200 screen is clear
  - Place a white evaporating dish below the water stream
- Return all material on #200 sieve to the wash sample by flushing

Section 3 - 26

AASHTO T 11 (continued)

- Dry the wash sample to constant mass in an oven at 230 ± 9°F
- Calculate the amount of material passing the #200 sieve by washing
  - Washed material passing #200
    = dry weight before wash – dry weight after wash

Section 3 - 27

AASHTO T 27
Fine Aggregate Equipment

- Balance: required accuracy is 0.1% of the sample mass
- Sieves: #4 and smaller
- Small mechanical sieve shaker
- Oven

Section 3 - 28

FINE AGGREGATE GRADATION T 27

Section 3 - 29

THERE ARE VARIOUS MANUFACTURERS FOR SIEVE SHAKERS

Section 3 - 30

SIEVES AND BRUSHES

Section 3 - 31

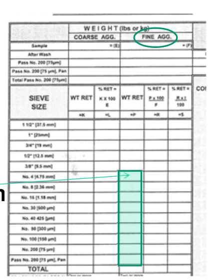
AASHTO T 27 (Fine Aggregate Continued)

- Pour dried sample from the wash sieve into sieves using brush to remove material from pan
- If there is more than 200 grams on an 8" sieve, add another sieve or hand sieve smaller amounts
- Turn the mechanical sieve shaker on for a sufficient period (usually 5-10 minutes)

Section 3 - 32

AASHTO T 27 (Fine Aggregate Equipment)

- Hand check sieve with largest amount retained for sufficient shake time
  - Hand tap 25 times at 6 locations in 1 minute.
  - If more than 0.5% passes, resieve.
- Determine the mass of material retained on each sieve and in the pan and record.



Section 3 - 33

Maximum Allowable Quantity of Material on a Sieve (g)

8" Sieve

Sieve Size	Grams
2"	3600
1.5"	2700
1.0"	1800
¾"	1400
½"	890
3/8"	670
#4	330
<#4	200

Sieve Opening Size, mm	203.2-mm dia
125	c
100	c
90.0	c
75.0	c
63.0	c
50.0	3.6
37.5	2.7
25.0	1.8
19.0	1.4
12.5	0.89
9.50	0.67
4.75	0.33

(Page 3-19)

Aggregate Splitting

- **AASHTO T 248 (WYDOT MTM 805.0) – Aggregate Splitting**
- **Summary: the reduction of large samples of aggregate to the appropriate size for testing.**

Aggregate Splitting (continued)

- **Significance: it is important that the smaller samples are most likely to be a representation of the larger samples and thus of the total supply.**
- **Throat Opening 50% larger than Largest Particle. (MTM)**
- **Fine aggregate must be drier than saturated surface dry.**
- **Pour into hopper and distribute evenly without using hands.**

SPLITTING T 248

Section 3 - 37

Liquid Limit

- AASHTO T 89 (WYDOT MTM 812.0) – Determining the liquid limit of soils prepared in accordance with AASHTO T 87 (WYDOT MTM 802.0)
- Summary: A sample of minus #40 (425µm) material is tested in a Liquid Limit device at increasing moisture contents until the material flows. The moisture content at that point is the liquid limit.

Section 3 - 38

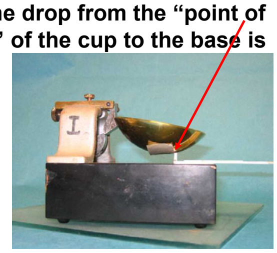
Liquid Limit (continued)

- Significance: Liquid Limit is an indicator of clay content which affects compressibility, permeability, strength, stability, moisture susceptibility and density.

Section3 - 39

Liquid Limit (continued)

- Inspect the cup and grooving tool for excessive wear as described in the MTM.
- Verify the drop from the "point of contact" of the cup to the base is 10mm.



Section3 - 40

Liquid Limit

- The 100 gram or greater sample should be prepared from a dry state.
- Material passing a #40 sieve (0.0167") .
- Mix to moisture content less than the LL.
- Remove plastic limit sample.

Section3 - 41

Liquid Limit

- Put moist soil in the cup, level

Section3 - 42

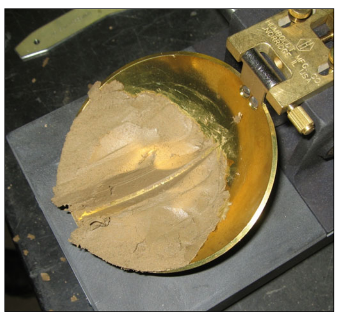
Liquid Limit

- Make a groove in the soil
- Standard allows a maximum of six strokes.
- The final stroke should scrape the bottom of the cup.

Section3 - 43

Liquid Limit

- Soil with groove



Section3 - 44

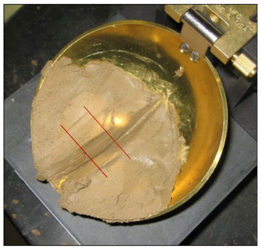
Liquid Limit

- Turn the crank at 2 rps, dropping the cup
- Count drops until groove closes for ½"
- The test is acceptable between 16 and 36 shocks

Section3 - 45

Liquid Limit

- Count drops until the groove closes for ½”
- Sample through the closed distance and determine the moisture content
  - Weigh
  - Dry
  - Reweigh
  - Plot on graph
- If the groove closes in less than 25 drops, report as “NV”, No Value



Section3 - 46

Liquid Limit

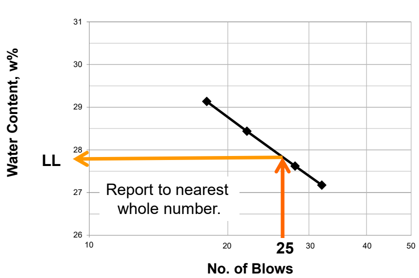
- Add more water and repeat the process until it takes less than 25 blows to close the gap

No. of Blows	Water Content, %
32	27.2
28	27.6
22	28.4
18	29.1

Section3 - 47

Liquid Limit

Liquid Limit = 28



Section3 - 48

One Point Test

- A lot of testing has been done to determine the slope of the line on the previous page.
- An average slope based on thousands of Liquid Limit Tests is 0.121
- Using this, the Liquid Limit can be estimated by $LL = w_n\left(\frac{25}{n}\right)^{-0.121}$

$$\text{Correction Factor} = \left(\frac{25}{n}\right)^{-0.121}$$

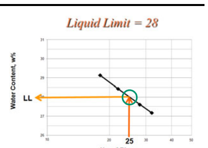
$$LL = \text{Correction Factor} \cdot w_n$$

Correction Chart

Correction Chart			
Number of Blows	Correction Factor	Number of Blows	Correction Factor
16	0.947	27	1.009
17	0.954	28	1.014
18	0.961	29	1.018
19	0.967	30	1.022
20	0.973	31	1.026
21	0.979	32	1.030
22	0.985	33	1.034
23	0.990	34	1.038
24	0.995	35	1.042
25	1.000	36	1.045
26	1.005		

One Point Liquid Limit

- Example:



Correction Factor from Table in MTM 812.0 pg. 4

- w_n = 27.2%, n = 32
- Correction Factor = 1.030
- LL = 1.030 x 27.2 = 28.0 = 28

- w_n = 29.1%, n = 18
- Correction Factor = 0.961
- LL = 0.961 x 29.1 = 27.96 = 28

One Point Liquid Limit

- Perform a One Point Test with a Blow Count between 36 and 16, preferably between 30 and 20.
- Obtain water content sample where the two halves meet.
- Record Data on bottom of T-166 Sheet

TOTAL			WET WT (lbs or kg)	
FRACTURED FACES %	One or more	Two or more	DRY WT (lbs or kg)	
FLAT & ELONGATED %	1:5 Ratio		WET - DRY = MOISTURE	
FINENESS MODULUS: see M.T.M., Sect. 602.0:			% MOISTURE=(MOISTURE/ DRY WT)x100	

BLOWS = 22	Tin No.	Wet+Tare= AA	Dry + Tare= BB	Tare = CC	Moisture = AA - BB = DD	Dry Wt = BB - CC = EE	% MOISTURE (DD / EE) x 100	x Corr. Factor =	= 0.985	PLASTIC INDEX (PI) =LL - PL
LIQUID LIMIT (LL)	7A	48.65	42.66	21.55	5.99	21.11	28.37 %	27.9 %	28%	12%
PLASTIC LIMIT (PL)	38D	41.25	38.62	22.18	2.63	16.44	16.0%	=	16%	

Section3 - 52

Plastic Limit

- AASHTO T 90 (WYDOT MTM 813.0) – Determining the Plastic Limit and Plastic Index of Soils
- Summary: A sample of minus #40 material is rolled to 1/8" diameter at decreasing moisture contents until it crumbles. The moisture content at that point is the Plastic Limit; the difference between LL and PL is the PI.
- Significance: Same as Liquid Limit

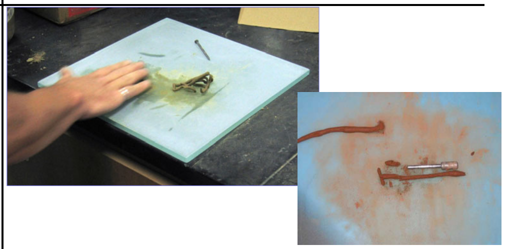
Section 3 - 53

Plastic Limit

- Material passing a #40 sieve (0.0165")
- Add moisture until plastic (while preparing the LL sample).
- Test is performed <u>after</u> the LL test.
- Roll into 'worms' 1/8" in diameter
- Repeat, removing moisture, until 'worms' break up at or before reaching 1/8" diameter, approximately 15-20 g.
- Weigh, dry, reweigh (Record at Bottom of T-166 sheet)
- Calculate moisture content
  - *This is the 'Plastic Limit'*

Section3 - 54

Plastic Limit



'Non-plastic' refers to material that cannot be rolled into 1/8" worms at any moisture content or PL > LL. It does not bind to itself.

Section3 - 55

Compaction Tests

- **AASHTO T 99 – "Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5 lb) Rammer and a 305-mm (12-in.) Drop"**
- **AASHTO T 180 – Moisture – Density of soils using 25 blows of a 10 lb rammer at an 18 in. drop for each of 5 lifts**
- **AASHTO T191 – Density of soil in-place by the sand cone method**
- **Nuclear Moisture-Density**

Section 3 - 56

AASHTO T 99 (Compaction)

- **AASHTO T 99 – Moisture – Density; Standard Proctor**
- **Significance: Used for specification compliance for soils and CTB. Used with AASHTO T 191.**

Section 3 - 57

AASHTO T 99 (Compaction continued)

- Summary: A series of samples (3-5) are compacted in a 4 in diameter mold at varying moisture contents. The results are used to plot a dry unit weight vs. moisture content curve from which the maximum dry weight and optimum moisture content are determined.

Section3 - 58

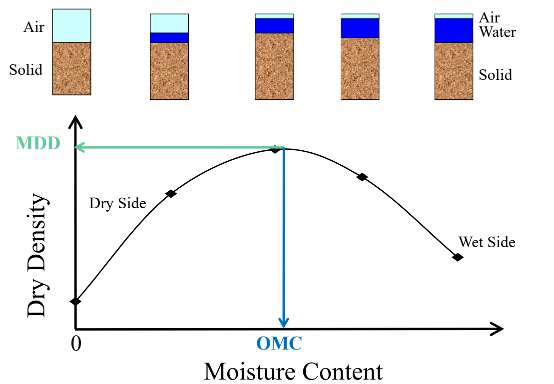
Moisture/Density Testing

- Soil compacted in mold with hammer
  - Weigh, determine moisture content
  - Perform at several moisture contents
  - Calculate moisture content and dry density
- Plot Moisture/Density Curve
  - Dry Density *v* Moisture Content
- Peak of curve gives:
  - MDD: Maximum Dry Density
  - OMC: Optimum Moisture Content

Section3 - 59

Moisture/Density Testing

Section3 - 60



Section3 - 61

Optimum Moisture Content

Section3 - 62

AASHTO T 180 (Compaction)

- **AASHTO T 180 – Moisture – Density; modified proctor.**
- **Summary: Similar to AASHTO T 99 with greater compactive effort.**
- **Significance: used for specification compliance for untreated bases. Used with AASHTO T 191. Results in higher dry weight and lower optimum moisture content than AASHTO T 99.**

Section 3 - 63

AASHTO T 191 (compaction)

- AASHTO T 191 – Density of soils in-place by sand cone method (MTM 212.0)
- Summary: A sample of compacted material is removed and weighed. The resulting hole is filled with calibrated sand of a known unit weight. The weight of material removed vs. sand to fill the hole is compared to determine in-place density. In-place moisture is also determined.
- Significance: Results are used with AASHTO T 99 or AASHTO T 180 to determine relative density and specification compliance.

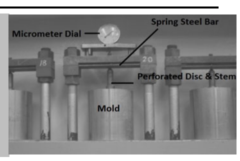
AASHTO T 190

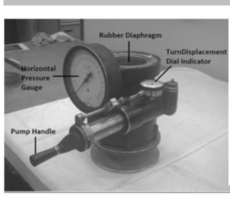
Strength and Stability

AASHTO T 190 – Resistance R Value and Expansion Pressure of Compacted Soils (MTM 833.0) 2004

- Summary: Consists of 3 parts
  - Exudation Pressure Test
  - Swell Pressure Test
  - Stabilometer Test

Parts of Hveem Stabilometer Test





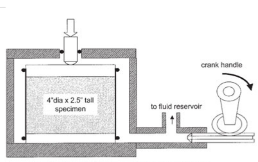


FIG. 1—*Schematics of the Hveem stabilometer.*

FIGURE 7: HVEEM STABILOMETER

AASHTO T 190 (continued)

- Results:
  - R Value
  - Moisture Sensitivity
- Significance: R-Value is used in surfacing thickness design; affects total surfacing thickness and special handling requirements.

Section3 - 67

ASTM D 5821 (Coarse Aggregate Angularity)

- ASTM D 5821 (MTM 817.0) – Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
- Summary: The percentage of aggregate larger than #4 with one or more fractured faces is determined
- Significance: Internal friction of coarse aggregate affect the workability, consolidation, strength, stability, and VMA of asphalt mixes. More fractured faces will result in a higher internal friction.

Section 3 - 68

ASTM D 5821 (Coarse Aggregate Angularity Continued)

- Typically only performed during the aggregate production phase.
  - Weight of Sample is based on Nominal Maximum Particle Size.
  - Determine whether each particle has no fractured faces, one fractured face, two or more fractured faces, and place each into separate piles.
  - A fractured face is whenever one-quarter or more of the maximum cross section area, when viewed normal to that face, is fractured with sharp and well-defined edges (excluding small nicks).
- Not a strong correlation between results & HPM resistance to rutting, but a simple replacement test does not exist at this time.

Section3 - 69

AASHTO T 304
(Fine Aggregate Angularity)

- AASHTO T 304 (Method A) – Standard Test Method for Uncompacted Void Content of Fine Aggregate (MTM 824.0)
- Summary: The void content of a loose sample of #8 to #100 fine aggregate is determined as a percent of the original mass.

Individual Size Fraction	Mass, g
No. 8 to No. 16	44
No. 16 to No. 30	57
No. 30 to No. 50	72
No. 50 to No. 100	17
	190 g

Section 3 - 70

AASHTO T 304
(Fine Aggregate Angularity Continued)

- Significance: Void content is influenced by particle shape, texture and gradation. It can be an indicator of: water demand in concrete; flowability or workability; influence of fine aggregate on VMA; and bituminous concrete stability

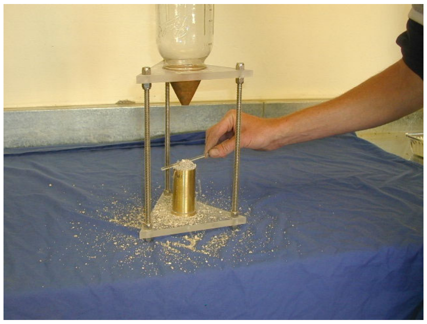
Section3 - 71

AASHTO T 304
(Fine Aggregate Angularity Continued)

- Typically only performed during the aggregate production phase.
- Not a strong correlation between results and HPM resistance to rutting but a simple replacement test does not exist at this time.

Section3 - 72

Fine Aggregate Angularity Apparatus



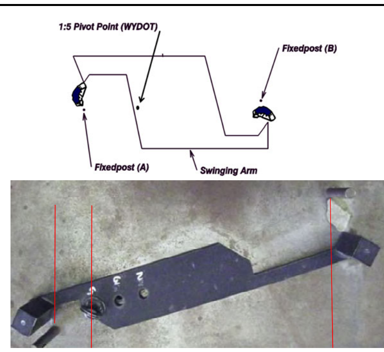
Section3 - 73

ASTM D4791 (Flat and Elongated Particles)

- **ASTM D4791 – Flat and Elongated Particles in Coarse Aggregate (MTM 835.0)**
- **Summary: Individual particles of aggregate are measured to determine the ratio of length to thickness.**
- **Significance: Flat and elongated particles affect workability and consolidation and may indicate degradation.**

Section 3 - 74

Measuring Flat and Elongated Particles



Section 3 - 75

AASHTO T 176 (Clay Content)

- AASHTO T 176: Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test (MTM 836.0)
- Summary: A sample of fine aggregate is mixed with a flocculating solution (calcium chloride) in a graduated cylinder. The cylinder height of suspended clay and sedimented sand is measured.
- Significance: Clay content would affect the aggregate surface area and the asphalt content

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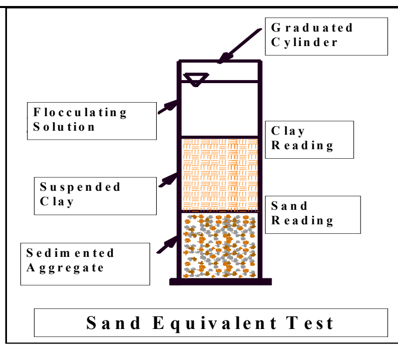
Sand Equivalent Test



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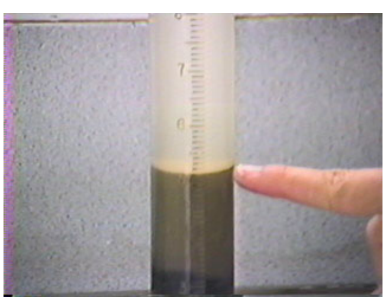
Sand Equivalent Test



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AASHTO T 96 (Durability)

- **AASHTO T 96 – Resistance to Degradation by Abrasion and Impact in the Los Angeles Machine (MTM 818.0) 2004**
- **Summary: A sample of coarse aggregate is placed in a steel drum along with a certain number of steel spheres. The drum is rotated 500 times and the sample is then washed over a #12 sieve. The difference in mass between initial and final mass is the % loss**
- **Significance: Abrasion loss is related to aggregate quality or durability.**

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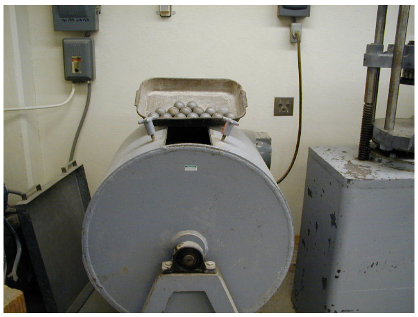
Los Angeles Machine



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AASHTO T 104 (Soundness)

- **AASHTO T 104: Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate**
- **Summary: An aggregate sample is exposed to repeated immersions in saturated solutions of sodium or magnesium sulfate followed by oven drying.**
- **Significance: The percent loss over various sieves is related to the freeze/thaw resistance of the aggregate.**

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AASHTO T 112 (Deleterious Material)

- AASHTO T 112: Clay Lumps and Friable Particles in Aggregate
- Summary: Wet sieving aggregate size fractions over specified sieves. The percentage of mass lost is reported as the percentage of clay lumps.
- Significance: The percent to clay lumps will affect the optimum asphalt content and the performance of the asphalt mix.

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Aggregate Tests Summary

TEST	DESIGNATION
*Coarse and *Fine Gradation	AASHTO T 11 & T 27
Fine Aggregate Angularity	AASHTO T 304
*Coarse Aggregate Angularity	ASTM D 5821
Flat & Elongated Pieces	ASTM D 4791
*Liquid Limit	AASHTO T 89
*Plastic Limit	AASHTO T 90
Durability	AASHTO T 96
Compaction	AASHTO T 99, T 180, & T 191
Strength (R-Value)	AASHTO T 190
*Splitting	AASHTO T 248
Clay Content	AASHTO T 176
Soundness	AASHTO T 104
Deleterious Material	AASHTO T 112

* Tests Included in the performance test

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Homework!!!

- Using the shortcut buttons on your calculator, find:
  - The Average and Standard Deviation
    - 22 and 48 and 3.6
    - 24 -42 4.8
    - 21 53 5.2
    - 17 -47 7.3
    - 23 49 3.9

- $\bar{x}$ = 21.4 12.2 4.96
- S = 2.70 51.82 1.460

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