Contribution of Aggregates in HMA- Evolution of Testing

2024 Southeast Asphalt User Producer Group

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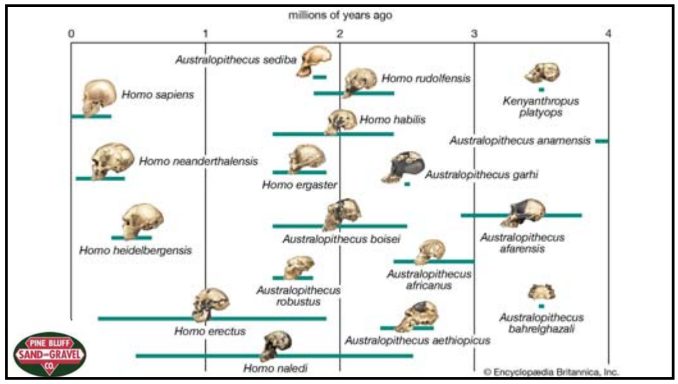
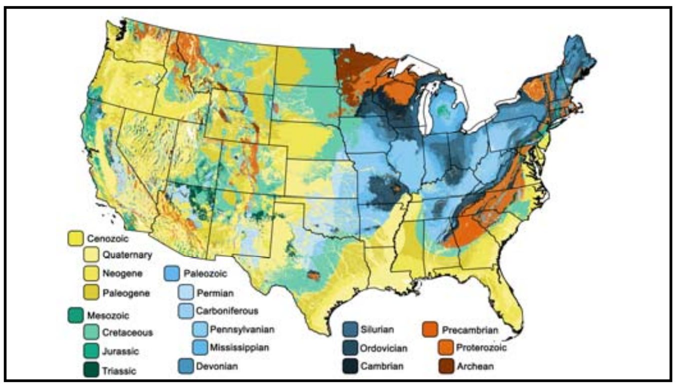
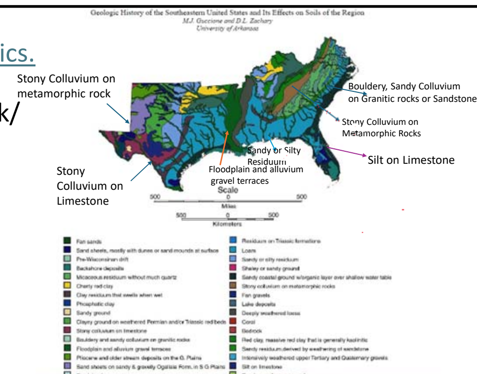
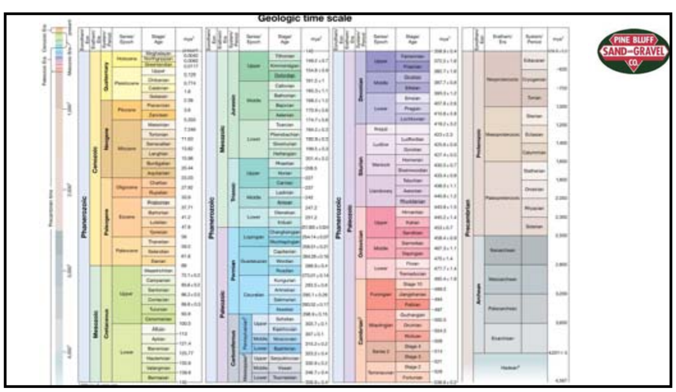
Pine Bluff Sand and Gravel Co



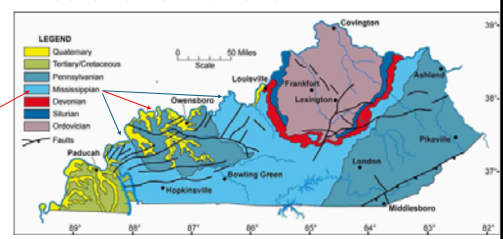


http://soilphysics.okstate.edu/S257/book/geology/





Kentucky Limestone Formations



Mississippian Stratas are found Throughout KY & near Ohio R. such as:

- St. Louis
- St. Genivieve
- Warsaw
- Fort Payne

- Limestone quarried near the Ohio River can have silica contents between 10 and 20%.

Histogram of HMA

1903 – 8 patents to warren bitulithic -Big Rock Asphalt

1910 –Judge ruled that ½" mix did not infringe on patent

1939 – Marshall Mix Design – fine agg mix designs

Still used by many Cities/Counties and Countries

1948 Hveem Design –Coarse Agg . Designs

Film Thickness

1962 Goode and Lufsey Max. Density -0.45 power

Volumetrics

Norman McCloud and Bruce Marshall

VMA/VFA/ Gsb/ Gmm

'90's -Superpave -controlled strain/ high gyratory effort, favored coarse agg structure, maximized modulus of mix. --2015- BMD brings lower gyratory effort and finer mixe back into vogue.

NCHRP Report 405 – Aggregate Test related to Asphalt Concrete Performance in Pavements –by Ken Kandhal – 1998 (poll naming properties that relate to performance.)

- Gradation and Size-related to fatigue and permanent deformation
- Variation in Bulk Specific Gravity and absorption- affects VMA measure
- Particle Shape, Surface Texture, Angularity- fatigue and permanent def.
- Cleanliness and Deleterious Materials
- Polish resistance and frictional characteristics
  - Micro Deval –potholes, raveling, popouts
- Minerology and Petrography
- Chemical Properties

Histogram of Aggregates Testing for Asphalt Pavement Applications

1907 Fuller Thompson First Gradation curve

Early 1900's – Unit Wt. and Gravity

(1812 Mohs Hardness)

1920's

– L.A. Abrasion

- Soundness and Deleterious Materials

1948 Hveem Design –Coarse Agg . Designs

- Film Thickness

'60s-Micro Deval

1962 - Goode and Lufsey Max. Density -0.45 power

(Particle Shape) – 60's

Flat and Elongated

Flakeyness

Friction BPN

'90's -Superpave -introduce aggregate angularity . Fixed angle gyratory seeking high modulus mixtures leads to coarse agg structure .

--2015- BMD brings lower gyratory effort and finer mixe back into

Test related to performance per NCHRP 405-'98

Permanent Deformation

- Top size NMS
- Uncompacted voids of fine agg
- Gradation properties D_{60} and D_{10}
- Flat and Elongated

Potholes, Raveling, Popouts

- Micro Deval
- Magnesium and sulfate soundness

Stripping

- **Methylene Blue**
- Gradation properties D_{60} and D_{10}

Fatigue

- **Gradation**
- **Uncompacted voids in Coarse agg.**
- **Flat and elongated**
- **Uncompacted voids in fine agg.**

Typical tests required of quarried aggregate

- Chemical Analysis ex. Limestone (CaCO3, MgO3 SiO2) , Once for every new ledge, and upon request.
- Petrographic Analysis (C 295 and D4992) Standard Guide for Petrographic Analysis for Concrete and Standard Practice for Evaluation of Rock to be used for Erosion Control Stone. COE requires this once every 5 years.
- Physical tests, typically use ASTM C33
  - Gradation (C33)
  - Gravity and Absorption (C 127)
  - Soundness (Usually sodium sulfate soundness) 5 cycles. (C88)
  - LA Abrasion (c131)
  - Unit weight (C29)
  - Deleterious Materials (ex. Clay lumps, Coal and Lignite and lightweight chert) (C 123/1C142)
  - Freeze / Thaw slab (D5312) (every 5 years)

  Sometimes required:
  - Proctor for base Rock. ASTM D 698 Std/D1557 - Modified
  - Magnesium sulfate soundness. (C88) test (D5313)
  - Wet/Dry (D5313) 80 days duration. or CRD 169.
  - Resistivity (when placed in moist conditions and in proximity of high electrical currents)
  - Fine Aggregate Angularity (uncompacted voids)(C1252)
  - Flat and Elongated (D4791)
  - Various test for potential Alkali Reactivity (C 1260, C 1567, C 1293)
  - Laboratory Friction (Silica content, LOI, British Pendulum w/ polish wheel, Dft with three wheel polish)
  - Micro Deval (D6928)
  - Compressive Strength (D2938) (very rare)

Aggregate Selection
Marshall Design/Hveem Design: Roberts 1966

- Although Hveem did not specifically develop an aggregate evaluation and selection procedure, one is included here because it is integral to any mix design. A typical aggregate evaluation for use with either the Hveem or Marshall mix design methods includes three basic steps:

1. **Determine aggregate physical properties**. This consists of running various tests to determine properties such as:
   1. Toughness and abrasion
   2. Durability and soundness
   3. Cleanliness and deleterious materials
   4. Particle shape and surface texture
2. **Determine other aggregate descriptive physical properties**. If the aggregate is acceptable according to step #1, additional tests are run to fully characterize the aggregate. These tests determine:
   1. Gradation and size
   2. Specific gravity and absorption

3. **Find the optimum blend of aggregates that fit volumetrics**

2006

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 557

Aggregate Tests for Hot-Mix Asphalt Mixtures Used in Pavements

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Mississippi State, MS

John E. Haddock
Purdue University
West Lafayette, IN

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PT Soilens
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TRANSPORTATION RESEARCH *CIRCULAR*

Number 479, December 1997
ISSN 0097-8515

AGGREGATE TESTS FOR HOT-MIX ASPHALT: STATE OF THE PRACTICE

by Prithvi S. Kandhal, National Center for Asphalt Technology
Frazier Parker, Jr., Highway Research Center, Auburn University
Rajib B. Mallick, National Center for Asphalt Technology

NCHRP Report 557: Aggregate Tests for Hot-Mix Asphalt Mixtures Used in Pavements (White et al. 2006)

Evaluated mix performance of both lab and purwheel and compared it to multiple aggregate properties measured.

Found:
Micro deval 15% Max
Magnesium sulfate soundness –20% Max
Fine agg gradations performed equal to coarse. And soundly discounted need for restricted zone.

This publication gives the state of the practice only, as obtained from a review of specifications from 45 states. Aggregate tests for HMA have been categorized as follows:

1. Particle Shape and Surface Texture (Coarse Aggregate)
2. Particle Shape and Surface Texture (Fine Aggregate)
3. Porosity or Absorption
4. Cleanliness and Deleterious Material
5. Toughness and Abrasion Resistance
6. Durability and Soundness
7. Expansive Characteristics
8. Polishing and Frictional Characteristics

TRANSPORTATION RESEARCH

CIRCULAR

Number 479 December 1997

Aggregate Tests for Hot-Mix Asphalt

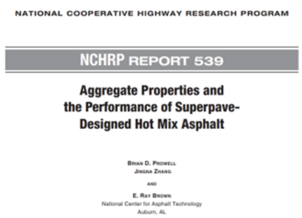
State of the Practice

NCHRP 479 Review of State Agg Specifications '94

- Flat and Elongated -81% (5:1)
- Deleterious Materials – 71%
- Sand Equiv. – 69% (max 45)
- Fractured Faces – 60% (2 faces)
- Max. Water Abs.-95% (5% max)
- Uncompacted voids – recommended by FHWA in 1993.
- LA Abrasion -95% (40 or 45 max loss)
- Soundness Sodium or Magnesium - 95% (Mag <20% loss) (Sodium <12%)
- Aggregate friction –75% Carbonate or limestone content or insoluble residue. Others use BPN or field skid numbers.

NCHRP 539-2005

- There is a need to emphasize the collection and reporting of aggregate property data for both in-service pavements and accelerated loading facilities. More effort needs to be placed on capturing aggregate property data in national studies related to HMA performance.


NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 539

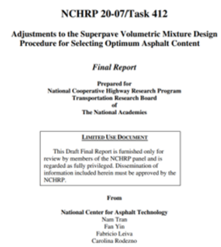
Aggregate Properties and the Performance of Superpave-Designed Hot Mix Asphalt

Brian D. Prowell
Jingna Zhang

and

E. Ray Brown
National Center for Asphalt Technology
Auburn, AL

2019 NCHRP


NCHRP 20-07/Task 412

Adjustments to the Superpave Volumetric Mixture Design Procedure for Selecting Optimum Asphalt Content

Final Report

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
of
The National Academies

Limited Use Document

This Draft Final Report is furnished only for review by members of the NCHRP panel and is regarded as fully privileged. Dissemination of information included herein must be approved by the NCHRP.

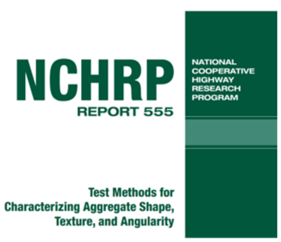
From

National Center for Asphalt Technology
Nam Tran
Fan Yin
Fabricio Leiva
Carolina Rodezno

Also Gerry Huber and Bill Pine

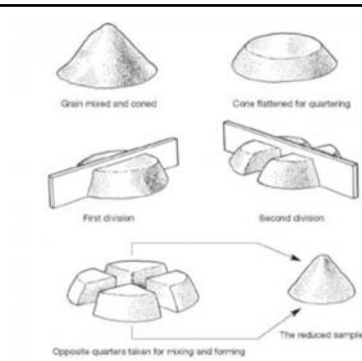
- Agg shape and texture
- Aggregate Specific Gravity: highway agencies are recommended to establish a process to ensure that the specific gravity of all mineral aggregates in the mixture are correct during mix design and production. In addition to new aggregates, the specific gravity of the aggregates in recycled materials should also be tightly controlled.
- Asphalt Absorption in a mixture – suggest investigation std procedure of two hour aging

2007-NCHRP 555


NCHRP
REPORT 555
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Test Methods for Characterizing Aggregate Shape, Texture, and Angularity

- Developed specification and procedure for AIMs aggregate imaging device.



Evaluation of Aggregate Durability Performance Test Procedures

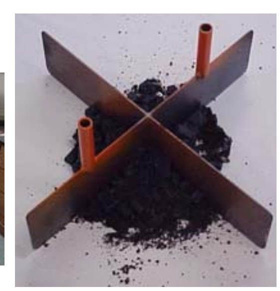
2012 Final Report TRC-0905

- by Stacy G. Williams, Ph.D., P.E. Director, CTTP Research Associate Professor Department of Civil Engineering University of Arkansas
- And Joshua B. Cunningham, M.S. Department of Civil Engineering University of Arkansas

Findings in brief

- High Variability in all test results except Magnesium sulfate soundness and micro deval.
- Only the soundness test was found to have a relationship to a lab performance test (TSR).

Splitting Samples



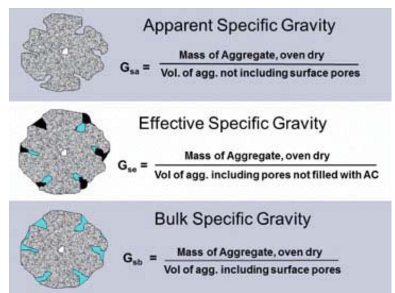
Aggregates in HMA

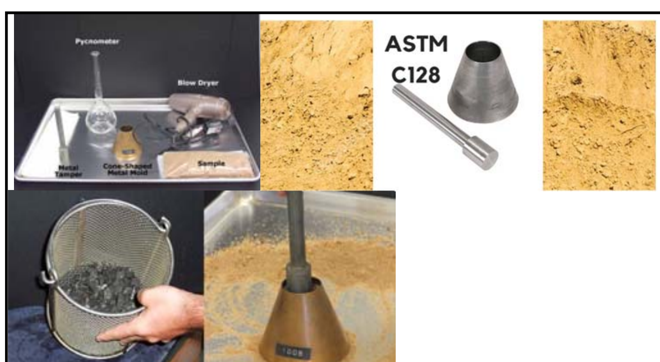
- Particle Shape and Surface Texture (Coarse Aggregate and Fine)
- Porosity or Absorption
- Cleanliness and Deleterious Material
- Toughness and Abrasion Resistance
- Durability and Soundness
- Expansive Characteristics
- Polishing and Frictional Characteristics

Specific Gravity/Absorption Coarse & Fine Aggregate (AASHTO T84 and T85)

Mass/Volume Relationship

- Specific Gravity





Importance of knowing significance of testing variation

- AASHTO T84 Specific Gravity and Absorption of Fine Aggregate (ASTM C128)
- AASHTO T85 Specific Gravity and Absorption of Coarse Aggregate (ASTM C127)

	Acceptable range of 2 results	Multilab Precision
Gsb - Coarse	0.025	0.038
Gsb- Fine	0.032	0.066
Absorption	0.31	Fine 0.66 coarse 0.42

Note: 2% is lowest max. rate of water absorption for most hma agg, however higher absorptions can be accommodated up to 5%.

What is the significance of these allowable variations in Gsb-example assumes one agg.

VMA1 = 100 (Gmb 2.42)(Ps 95)/ (**Gsb 2.6**) =**11.6**

VMA 2 = 100(2.42)(0.95)/**(Gsb 2.625)** = **12.4**

VMA 3 = 100 (2.42)(0.95)/**(Gsb 2.638)** = **12.9**

Table 1: Specific gravity of different types of rock.

Sl.No	Rock Types	Specific Gravity
1	Talc	2.7 – 2.8
2	Gypsum	2.3 – 2.4
3	Coal	1.1 – 1.4
4	Graphite	2.2 – 2.3
5	Granite/ Leucogranite	2.6 – 2.7
6	Limestone	2.3 – 2.7
7	Dolomite	2.8 – 2.9
8	Marble	2.4 – 2.7
9	Gneiss	2.6 – 2.9
10	Amphibolite	2.9 – 3.04
11	Quartzite	2.6 – 2.8
12	Slate	2.7 – 2.9
13	Phyllite	2.67 – 2.8
14	Schist	2.39 – 2.8

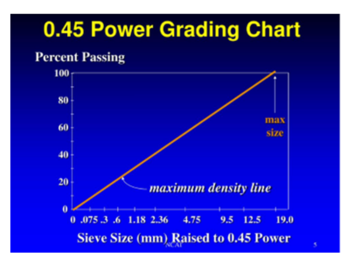
.45 Power Curve

- AAPT 1962 Goode and Lufsey introduced "A new graphical chart for evaluating aggregate gradations – presented their method for identifying the maximum density line. Their interpretation consisted of drawing a straight line from the origin of the chart to the percentage point plotted for the largest sieve with material retained.
- Goode and Lufsey used the term "effective aggregate size."

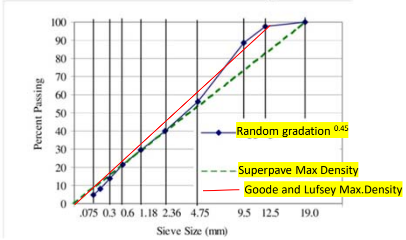
Another significant aggregate measure is the blended gradation plotted on the 0.45 power curve

Original Superpave tutorial. (0.45 Power Curve Maximum Density Line)

Is the Maximum Size equal to the Maximum Size Measured in the nest of sieves or is the top point plotted to the NMS or is it plotted to the Superpave definition of maximum size.



0.45 Power Curve Maximum Density Line 12.5mm NMS.
(Ervin S Goode and Leslie A Lufsey, 1960's)



Marshall Mix Design Procedure

Typical Marshall Design Criteria

Mix Criteria	Light Traffic (< 10^4 ESALs)		Medium Traffic (10^4 – 10^6 ESALs)		Heavy Traffic (> 10^6 ESALs)	
	Min.	Max.	Min.	Max.	Min.	Max.
Compaction (number of blows on each end of the sample)	35		50		75	
Stability (minimum)	2224 N (500 lbs.)		3336 N (750 lbs.)		6672 N (1500 lbs.)	
Flow (0.25 mm (0.01 inch))	8	20	8	18	8	16
Percent Air Voids	3	5	3	5	3	5

The Bailey Method is a detailed mass/volume study of both coarse and fine aggregates. The bottom line, the more you know about your aggregates, the more consistent you can be in production .

Regardless of how you developed your original mix design we know that Voids (VMA) is created in the mix by straying from the true maximum density and we know that aggregate gradation affects VMA .

Coarse aggregate structures tend to have higher laboratory resilient modulus.

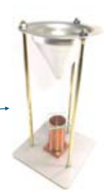
Source Approval Testing (Aggregates)

Aggregate Chemical (XRF)

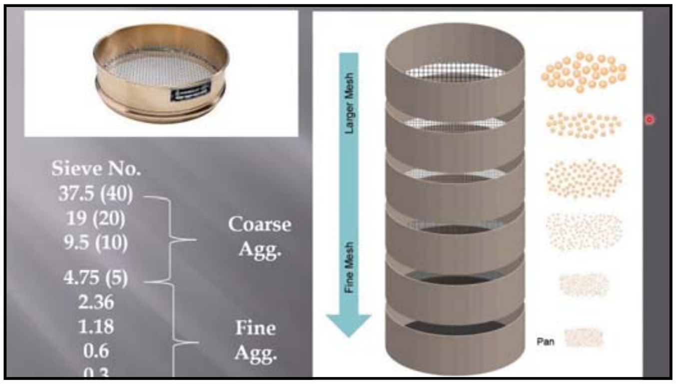
PARTICLE SHAPE AND SURFACE TEXTURE
(COARSE AGGREGATE)

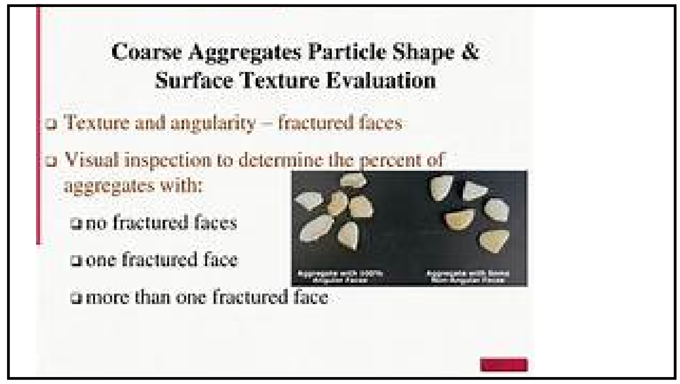
- ASTM D3398 Index of Aggregate Particle Shape and Texture
- ASTM D4791 Flat or Elongated Particles in Coarse Aggregate
- ASTM D5821 Determining the Percentage of Fractured Particles

(FINE AGGREGATE)
- ASTM D3398 Index of Aggregate Particle Shape and Texture
- AASHTO (ASTM C1252) Uncompacted Void Content of Fine Aggregate



--Prior to Superpave, Limit for natural sands ranged from 15% to 50%
---Superpave introduced Min. uncompacted void contents , Method A , (individual size/mass portions) and/or Method C (as received) for crushed stone.
---- Arbitrary Limits of natural sand between 10 and 15% are commonly named in States specifications. Practitioners observe that these small quantities of sand can improve compactibility.





•The L.A. Abrasion test is an empirical test; it is not directly related to field performance of aggregates. Field observations generally do not show a good relationship between L.A. abrasion values and field performance. Wu et al. (1998) found that L.A. abrasion loss was unable to predict field performance.

Source Approval Testing (Aggregates)

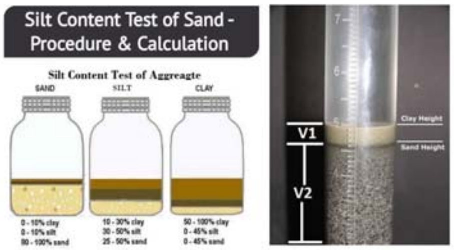
Organic Impurities In Fine Aggregate (AASHTO T21)

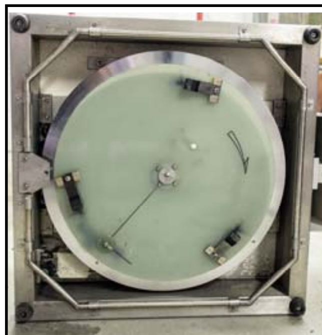
- Used for detecting deleterious organic materials in fine aggregates

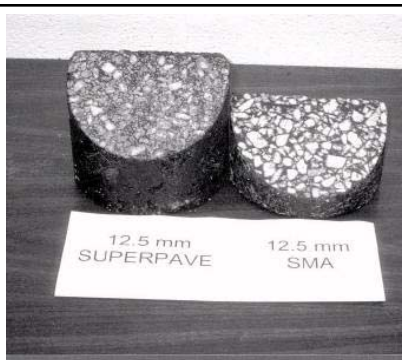
Soundness (AASHTO T104)
Magnesium Sulfate (Epsom Salt) Soundness – 5 Cycles

Aggregate's resistance to disintegration by weathering.

(ie) freeze/thaw – 5 cycles
Magnesium Sulfate Solution
- Max percent loss -- 15%







Heitzman and Moore

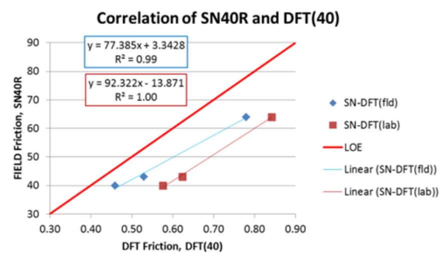


Figure 7 Correlation of Laboratory and Field Terminal Friction Values (7)

Source Approval Testing (Aggregates)

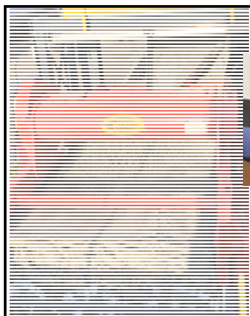
Accelerated Polishing of Aggregates Using the British Wheel (AASHTO T279)

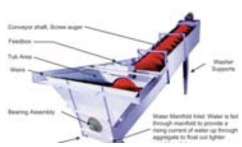
What is below is as important as what is above.

Stockpile at Quarry

CAT 797 Dump Truck – 400 Ton load

Komatsu 960E-2K-
360 ton payload

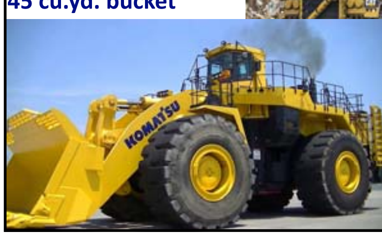




FRONT END LOADERS MOVE LOTS OF ROCK- invented in late 1800's. Loader with detachable bucket since 1930's. And they keep getting bigger!

Komatsu WA1200-6;
220.5 Tons;
45 cu.yd. bucket

Caterpillar 994K; 242 Tons
43 cu.yd. Bucket



What is the biggest loader in the world?
The world's largest front end wheel loader is the Komatsu P&H L-2350, with a phenomenal 72.5 tonne payload capacity and 272 tonne operating weight.

What is the largest loader that Caterpillar make?
Caterpillar's largest wheel loader is the 994K. It has an operating weight of 242 tonnes and a payload capacity of up to 40.8 tonnes.

No 1 and No 2

No 10