A Review of Asphalt Emulsion Papers in the

Journal of the Association of Asphalt Paving Technologists

1929 – 1970

Performed by:

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AAPT 1929, West Baden, IN: Volume 2

Review performed by Andrew Braham
September 11, 2020

Summary

- 5 papers focused on asphalt emulsion
  - "Types and Characteristics of Emulsions for Asphalt Paving Purposes" by Lester Kirschbraun, pp. 17-21
  - "History and Development of Asphalt Paving Emulsions" by C.N. Forrest, pp. 22-23
  - "Construction Methods Involved in the Use of Emulsions for Asphalt Paving Purposes" E.S. Ross, pp. 23-28
  - "Use of Emulsions in Constructing Penetration Pavements" by C.L. McKesson, pp. 28-33
  - "Cold-Laid Asphalt Paving Mixtures" by Gene Abson, pp. 34-37
- Note, no papers from the first volume focused on asphalt emulsion ☹

Interesting tidbits

- Asphalt emulsions in use for 15-20 years
- Colloid mills a "recent development"
- 50-75% residue typical
- Common uses of asphalt emulsions: ~2.0" structural layer, asphalt macadam, driveways, sidewalks, surface treatment (chip seal)
- Largest anticipated application maintenance, repair, and moderate traffic
- Most discussion revolved around the base penetration of the asphalt binder and its relationship to stability

Types and Characteristics of Emulsions for Asphalt Paving Purposes

- Defined asphalt emulsion, temporary emulsions, and permanent emulsions
- Two types of emulsifying agents defined: substances which
  - Lower surface tension of one phase (fatty acids, resin soaps, sulphonated oils, saponaceous materials, etc.)
  - Swell in contact with the medium in which it is peptized, produce plastic or viscous suspension (starch, casein, colloidal oxides, clay, etc.)
- Some nice discussion on basic chemistry principles of asphalt emulsion
- Oil-in-water emulsions – dehydration before or after coalescence
- Manufactured by paddle mixer, centrifugal pumps,
- colloid mills
- Requirements: suitable asphalt binder, bulk stability (transportation and storage), fine particle size, stability in application, suitable coalescence, consistent viscosity and residue, minimal emulsifier

History and Development of Asphalt Paving Emulsions

- First application in 1906 in United States a "dust layer" with 30% residue
- Most popular application a open graded mix since 1907
- Emulsions should reduce the costs of roads, but can't be a "cure-all"

Construction Methods Involved in the Use of Emulsions for Asphalt Paving Purposes

- First application in 1906 in United States a "dust layer" with 30% residue
- Most popular application a open graded mix since 1907
- 1917 cost of 60 cent/yd^2 for two-inch resurfacing
  - 30,000 veh/day lasted ten years
- A 8.5 mile long, 1.5" thick resurfacing used 12.5% gal/yd^2
- Emulsions must be resistant to freezing conditions after breaking, should be able to break during wet/damp weather
- Can be used as a base, surface, cold patching, and maintenance
- Tack coat use at 0.2-0.3 gal/yd^2; surface treatment 0.25-0.33 gal/yd^2
- Mixtures should have 5.6-6.0% asphalt emulsion, 31% sand, 63% ¾" stone

Use of Emulsions in Constructing Penetration Pavements

- Vehicles changed from iron tires to rubber in late 1910s, existing European roads had adequate structure but poor surfaces, emulsions attractive option
- Two types: penetration pavement (surface treatments) and cold mix
- Key penetration properties: low viscosity, break without drying, quick break, ~50% residue, 175-300 penetration (not <150), high stability
- Key cold mix properties: viscosity not as important, slow set, coalesces without dehydrating, cost of asphalt binder driving force, >60 penetration

Cold-Laid Asphalt Paving Mixtures

- "Speaking very bluntly, the majority of engineers and contractors who have been identified with asphalt pavements of the hot-mix type have an aversion to any cold-mixture composition"
- Three categories: 1) volatile liquefier, 2) asphalt emulsion, 3) very soft asphalt binder
- An "open mixture" is critical
- Earliest cold-mixture known as Amiesite (volatile)
- Quality and aggregate, low dust, temperature control, asphalt binder content, attention to curing all critical
- "Likely that cold mixtures will never be the equal of scientifically designed and proven hot mixtures"

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Devising a Test for the Stability of Bituminous Cold Mixtures, Vol. 3, 1932

Review performed by Andrew Braham
October 14, 2020

Summary

- Progress in developing design of cold mixtures has been very gradual
- Results obtained non-uniform
- Focus on Wisconsin mulch treatment
- A direct shear type test developed
- Equations presented relating displacement to time and displacement and load
- No conclusions were given

Wisconsin mulch treatment

- Desired:
  - Loose surface, amenable to blading, minimal dust, last summer season
- Frequent outcome:
  - Loose, lean surface, dust in two weeks

Evaluated tests (look at those dates!)

- Hubbard's stability machine
- Skidmore's shear machine
- Bureau of Public Roads machine
- Chosen:
  - Based on cohesion of soils and sands
  - Collin (1846), Leygue (1885), Jacquinot & Frontard (1910), Bell (1914), Cain (1916)

Stokes-Zapata Stability Machine fundamentals

$$P = f \times N + k \times A$$

- P = total resistance to sliding along interior plane (IP)
- f = coefficient of friction
- N = normal pressure on IP
- k = coefficient of cohesion
- A = area of IP under pressure

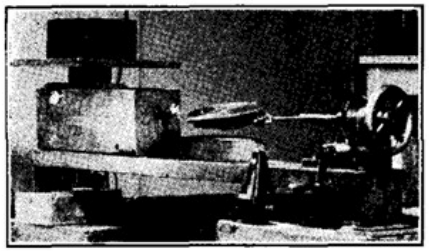
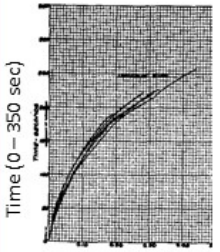


Fig. 1—Stokes-Zapata Stability Machine.

- How it works
  - Two boxes stacked on top of each other
  - Rectangular sample placed inside boxes, half in top box half in bottom
  - Normal force placed on top box
  - Bottom box can slide horizontally, shears sample
  - Displacement (0.238 in/min) and time measured with different normal loads
  - Three loads explored: 481, 911, and 1341 lb/ft²

Sample fabrication

- Multiple samples obtained from around the state
  - Abram's method of Fineness Modulus used, FM ranged from 1.97 – 6.00
- Two sample fabrication methods
  - 4.0"x2.5"x8.0" sample fabricated outside of machine, wide range of variability during testing
  - Mix compacted in machine itself, remixed and retested multiple times – this method used moving forward
- 2-4% slow curing asphalt emulsion, 100-pen residue 60-70%



- Samples with and without asphalt
- Text within graphs illegible
- Equations developed to relate time and displacement
- One set of example results shown below

Type of Mix	Gradation in Terms of F.M.	% Bitumen	Load (N) lbs./sq. ft.	Equation
Non-Bituminous	1.97	None	481	Y=.488X0.59
			911	Y=.742X0.48
			1341	Y=.536X0.47
Bituminous	1.97	4	481	Y=.364X0.57
			911	Y=.390X0.49
			1341	Y=.440X0.44

Conclusions

- No conclusions provided
- No discussion on the paper
- Two tables provided findings
  - Time and displacement above
  - Displacement and load below

Type of Mix	Gradation in Terms of F.M.	% Bitumen	Equation
Non-Bituminous	1.97	None	Y=1.07X
Bituminous	1.97	4	Y=0.70X

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Full citation: Stokes, C. and Zapata, J.. "Devising a Test for the Stability of Bituminous Cold Mixtures," Journal of the Association of Asphalt Paving Technologists, Vol. 3, 1932, pp. 105-109.
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Determination of Characteristics of Asphalt in an Emulsion, Vol. 4, No. 2, 1933

Review performed by Andrew Braham
November 22, 2020

Summary

- Is recovered asphalt emulsion residue representative of original asphalt binder? No!
- Round robin performed: eight labs, seven emulsions, distillation vs. evaporation vs. solvent recovery
- Solvent recover most representative, evaporation least
- Time warp? 1942 paper by Tyler referenced?!?!

Key question (still being asked today!)

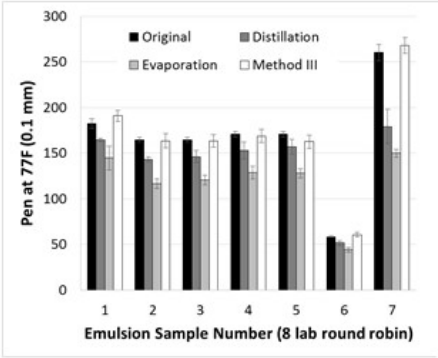
- "Whether the asphalt recovered by ASTM distillation is actually representative of the asphalt present in the dispersed phase of the emulsion"
- McKesson answer: "It definitely is not"

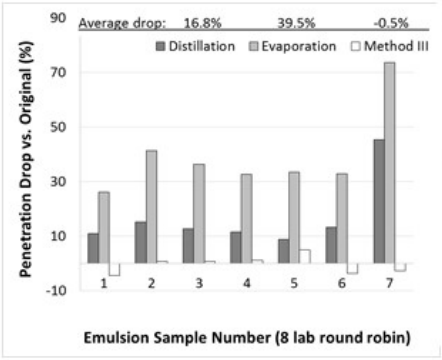
Distillation test: ASTM D244

- Principal objective: determine amount of water, oil, and heavy residue
- Test developed for type types of asphalt emulsion, both high viscosity:
  - High soap content, coarse aggregate mixing emulsion → for patch work
  - Clay emulsion → for industrial purposes

These heavy coating applications did not consider thin, cohesive films of today's uses

Results from round robin: eight labs, seven emulsions





- Residue from distillation produces lower penetration asphalt than base.
- Why?
  - Emulsion brought to 500°F
  - Asphalt binder in presence of steam and emulsifiers, hardens
  - Degree of hardening depends on asphalt binder chemical composition
- ASTM sectional committee exploring simple test method for extraction
  - Solvent recovery recommended (Method III), in appendix
- Round robin (eight labs)
  - Standard distillation
  - Residue by open cup evaporation at 325°F
  - Method III (solvent recovery)
- Round robin results
  - Evaporation had highest percent drop, solvent actually had small average increase
  - Standard deviation tight, average original: 3.9%, distillation: 7.1%; evaporation: 5.9%, solvent: 6.7%

Recommendations

- Require measuring original asphalt binder properties before emulsification
- If frequent sampling difficult, ensure relative differences between original and residue remain constant
- If original asphalt binder not available, establish relationship between ASTM D244 (distillation) and Method III (solvent)

Method III test method (appendix)

- Weigh 200 g emulsion into 750 mL flask
- Add 125 mL ethylene dichloride and 95% ethyl alcohol which will give 50% alcohol solution total when added to solution
- Reflux 30-60 minutes until emulsion broken
- More into separatory funnel, stand 1 hour
- Draw off ethylene dichloride-asphalt layer
- Recover asphalt from solution using Abson's method
- May need to centrifuge mixture if clean separation does not occur, 15 minutes at 1500 rpm
- If stabilizer clumps, may need to filter solution through coarse paper
- Method is qualitative only, usually recover 100 g asphalt for melting point, penetration, and ductility testing

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Full citation: McKesson, C. "Determination of Characteristics of Asphalt in an Emulsion," Journal of the Association of Asphalt Paving Technologists, Vol. 4, No. 2, 1933, pp. 1-8.
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The Testing of Bitumen Emulsions, Vol. 9, 1937

Review performed by Andrew Braham
June 6, 2018

Summary

- Nine "essential properties" of asphalt emulsion defined
- Six tests recommended
- More research needed (☺) in test development for stability
- Samples need to be taken "immediately after delivery," sent to the lab "as soon as possible," and should not be exposed to temperatures other than normal atmospheric temperatures

Interesting tidbits

Asphalt emulsion consumption in the United States (U.S. tons):

1936	2013
237,000	2,282,000

- At time of writing, only anionic asphalt emulsions were in existence
- Material of sample storage containers included iron or wood
- Four tests discussed for aggregate/asphalt emulsion compatibility (two with chemicals, two with aggregate) – the chemical tests were not recommended but the complexity of aggregate tests was acknowledged

Similarities and differences: Testing in Britain 1937 vs. U.S. 2018

Properties	Britain – 1937	United States – 2018
Water content	Heat emulsion with xylene in sand bath	AASHTO T59 Section 4 - Distillation
Inhomogeneity of dispersion	Pass emulsion through #100 sieve (all sieves British)	AASHTO T59 Section 12 – Sieve Test
Storage stability (short term)	Emulsion sit for 7 days, passed through #100 sieve	AASHTO T59 Section 10 – Settlement
Storage stability (long term)	Emulsion sit for 3 months, passed through #25 sieve	AASHTO T59 Section 10 – Settlement
Coagulation at low temperature	Emulsion at -4°C, passed through #25 sieve	AASHTO T59 Section 15 – Freezing
Viscosity	Engler viscometer at 20°C	AASHTO T59 Section 8 – Saybolt viscosity
Rate of break (liability)	Mechanical agitation in a current of air	AASHTO T59 Section 9 - Demulsibility

- Six of the nine essential properties listed in the table above, the three remaining properties are emulsifier content, asphalt binder used in manufacturing, and dispersion
- AASHTO T59 currently has 26 tests for asphalt emulsion that fall into the following categories: composition, consistency, stability, examination of residue, identification, coating, and density
- Three levels of interest in stability: labile/unstable, semi-stable, stable
- In the compatibility section, tests similar to the coating test (AASHTO T59, Section 16) and cement mixing (AASHTO T59, Section 11)

Conclusions

- Need to standardize asphalt emulsion tests on which specifications are based
- There is a strong desire for performance tests of asphalt emulsions
- Of the six tests discussed in the table on the left, only the "Rate of Break" test was deemed satisfactory – note how that other five tests are still being used today
- There is a need for cooperation in international standards for asphalt emulsion

Discussion highlights

- Three discussions by letter, two in person
- "Standardization in test methods could never be attained unless standardization in construction methods also could be accomplished" Mr. C. L. McKesson
- "No one asphaltic product will satisfactorily coat all aggregates under all conditions of application or use." Mr. Downing
- "Anyone who expects an average run of a mixing or "stable" type of emulsion to mix satisfactorily with every type of aggregate and in every type of mixer is doomed to disappointment." Mr. J.S. Miller

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Full citation: Wace, E.G. "The Testing of Bitumen Emulsions," Journal of the Association of Asphalt Paving Technologists, Vol. 9, 1937, pp. 257-308.
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The Stabilization of Soils with Emulsified Asphalt, Vol. 10, 1938

Review performed by Andrew Braham
July 9, 2018

Summary

- Paper divided into eight sections:
  1. Soil characterization
  2. Fundamentals of soil stabilization
  3. Soil characteristics vs. stabilization
  4. Mixing ability of emulsions
  5. Dehydration of emulsion-soil mixes
  6. Effect of emulsion particle size
  7. Effect of asphalt binder type/quantity
  8. In the field

Sections 1 and 2 – Soil characterization and stabilization fundamentals

- Particle size, liquid limit, plastic limit, and plasticity index (PI) critical soil properties
- High PI indicates high clay
- Clayey soil: uniform distribution of small asphalt emulsion particle stabilize
- Sandy soil: asphalt emulsion coats particles
- US Bureau of Air Commerce has specifications for soil stabilization
- Requires mixing tests and dehydration during design, stability after two weeks
- Compression machine developed as a performance test – a mix of unconfined compression/Hveem cohesiometer

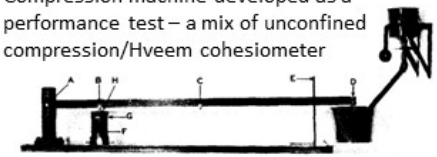

Image from Thurston and Weetman, 1938

Sections 3-7: Various property's influence on compression strength

Property	Influence on Stability
Soil characterization	• Five types of soil stabilized, 4.0% asphalt emulsion residue • Soils had range of P200 (17.2-71.2%) and PI (0.0-17.5%) • No "definite relationship" between either P200 (< 75 µm) or PI and compression strength • Clay defined as 1.0-5.0 µm, colloid < 1.0 µm
Mixing ability	• Three options: chemical (calcium chloride demulsibility), stone coating (1/2 inch aggregate), or cement mixing • Soil mixing test introduced (100 g of P20 in-place material) • Two emulsions, one with 100% cement mixing and the second with 0%, blended at 75/25, 50/50, and 25/75 • From 25/75 blend to 0.0%, cement mixing 66.5% to 0.0% • Soil 1: from 50/50 blend to 25/75, soil mixing 78.5% to 0.5% • Soil 2: from 75/25 blend to 50/50, soil mixing 118.5% to 2.5%
Dehydration	• High dehydration (i.e. evaporation rate) does not result in increased compressive strength • No correlation between dehydration test and drying rate on emulsion-soil mixtures
Emulsion particle size	• Two sizes examined with average of 2.5 and 10.0 µm • 2.5 µm particle size more efficient with lower residue levels → smaller particle size not necessarily better
Asphalt binder type/quantity	• Harder asphalt emulsion residue (lower pen values) increase strength of mixture • There is an optimal level of asphalt emulsion residue (too little or too much has detrimental effect)

Conclusions

- Four critical steps in the field: soil preparation, mixing, curing, compaction
- As clay and colloid increase, compression strength increases - no such relationship when only examining P200
- Cement and soil mixing differentiate over a very narrow range
- Dehydration test does not correlate well with mixture performance
- Particle size influence changes with asphalt emulsion residue level

Discussion highlights

- Three discussions by letter, four in person
- "Particle size, apparently, of the cement does not play near the part of the chemical composition." Mr. J.S. Miller
- "The compression test … is more nearly a "punch" test and should not be confused with a real compression test." Mr. Vokac
- "Asphalts vary in the percentage of saponifiable substances contained according to the origin of the crude oil." Mr. Heine.
- "24 hour absorption does not develop the properties of stabilization" Mr. McKesson
- "It is not apparent in the paper why the authors selected a uniform asphalt content of 4%." Mr. McKesson

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Full citation: Thurston, R., Weetman, B. "The Stabilization of Soils with Emulsified Asphalt," Journal of the Association of Asphalt Paving Technologists, Vol. 10, 1938, pp. 37-85.
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Emulsified Asphalts – Some Characteristics and Properties, Vol. 10, 1938

Review performed by Andrew Braham
August 15, 2018

Summary

- Five day settlement test too long to hold materials before shipping
- "Modified miscibility" test similar to settlement test, but utilize asphalt emulsion residue instead of visual examination
- 372 tests performed on new modified miscibility test
- Only 82 tests run on both traditional five day settlement and modified miscibility
- Downing states modified miscibility can be substituted for ASTM five day settlement

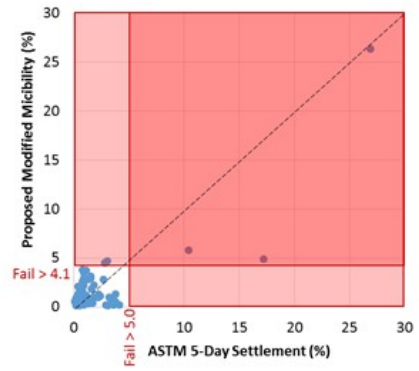
Interesting tidbits

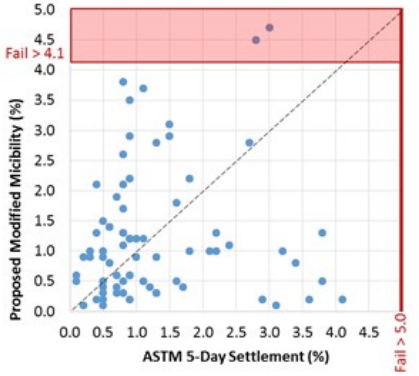
- Downing performed tests for public construction in the City of St. Louis
- Asphalt emulsion consumption in the St. Louis (gallons):

1933	Negligible
1934	230,000
1938	1,670,000

- Of 1,670,000 gallons:
  - 320,000 gallons for penetration (spray) applications
  - 1,350,000 gallons with crushed stone (mixed) applications

Modified miscibility versus traditional ASTM five day settlement





- Modified miscibility procedure summary
  - Dilute asphalt emulsion 1:3 emulsion:water
  - Place 15 cm long tubes in room temperature bath
  - After two hours, take sample from different depths of tube
  - Find asphalt emulsion residue at three different depths
  - Modified miscibility is difference between top and middle or middle and bottom, record greater value
- In 1938, ASTM five day settlement just visual between levels
- A filter paper spot test was used as a secondary test to determine modified miscibility – recommended as a potential field test
- Some field recommendations were also provided
  - In hot weather, add water to aggregate before mixing with asphalt emulsion
  - Avoid oversize asphalt emulsion droplets

Conclusions

- Modified miscibility should be substituted for ASTM five day settlement
- Test adopted by two state highway departments and multiple municipalities
- Cement mixing and dehydration tests, along with modified miscibility, are three most important tests
- Conclusions based on 82 tests, with only 3 that failed the ASTM five day settlement test

Discussion highlights

- One discussions by letter, four in person
- "I join Mr. Downing in hoping that in the future specifications are designed to bring about more practical requirements and definite correlations with field behavior," Mr. Zapata.
- "The modified miscibility test is, perhaps a misnomer – a modified settlement," Mr. Waxman.
- "If an emulsion is not properly stabilized there is a tendency toward coalescence and the formation of large particles," Chairman McKesson.
- "There is a reason for a miscibility test to be used in soil stabilization, where the emulsion is to be diluted, but should this restriction be applied to other mixing emulsions?" Mr. Harsch

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Full citation: Downing, C.A. "Emulsified Asphalts – Some Characteristics and Properties," Journal of the Association of Asphalt Paving Technologists, Vol. 10, 1938, pp. 242-265.
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Characteristic of Various Asphalts as Regards Emulsification

Review performed by Andrew Braham
September 10, 2018

Summary

- There is a variation of properties within the same crude oil sources
- Variation amplified when producing asphalt emulsion
- Three crude oils evaluated: 1) mid-continent with seven sources, 2) Texas with nine sources, and 3) Venezuelan with two sources
- Various tests run on quick and slow set asphalt emulsions:

Quick	Slow
Penetration, demulsibility, viscosity, settlement (5-day)	Penetration, viscosity, settlement (5-day), cement test, dehydration

Interesting tidbits

- In the 1930s, asphalt binder contained 0.61% to 6.4% asphaltous acids or triglycerides
- These asphaltous acids or triglycerides could behave like a soap solution, therefore, they could saponify
- In theory, and asphalt emulsion could be made without a soap solution but just milling the asphalt binder with enough asphaltous acids or triglycerides with alkaline water. This is not common in the 2010s

With the same crude source, comparison of tests

- Penetration
  - Two Texas crude sources compared
  - 141 vs 172 (unit of 0.1 mm)
- Ductility
  - Three mid-continent crude sources compared
  - 60 vs 83 vs 96 (unit of cm)
- Demulsibiltiy (35 cc N/50)
  - One mid-continent crude source compared to one Venezuelan crude source – almost identical answers but with different saponifiable levels
  - 88 vs 88 (unit of %)
- Viscosity
  - Two Texas crude sources compared
  - 23 vs 127 (unit of sec)
- Settlement (5-day)
  - Two Texas crude sources compared
  - 3.0 vs 0.2 (unit of %)
- Cement test
  - Two Texas crude sources compared
  - 0.3 vs 2.3 (unit of %)
- Dehydration, 96 hours, 100°F
  - One mid-continent crude source compared to one Texas crude source
  - 0.69 vs 0.58 (unit of %)
  - NOTE: this test result comparison and conclusion did not make sense to Braham, perhaps a typo?
- There was very little discussion beyond simply providing two sets of numbers and stating their relationship.

Conclusions

- Two methods to produce asphalt emulsion based on properties of asphalt binder: 1) milling asphalt binder with high enough asphaltous acids or triglycerides and only alkaline water ,or 2) milling asphalt binder with a soap solution (water plus emulsifier)
- In 1938, the level of saponifiable substances in asphalt binder ranges from 0.61% to 6.4% but is usually 0.2% to 1.2%
- Even within the same crude oil source there can be a wide range of properties of the asphalt emulsion and asphalt emulsion after milling and distilling

Discussion highlights

- One discussions by letter, four in person, one by Braham
- "I realize that there are numerous reasons for changes in viscosity of an emulsion but particle size distribution has been reported as being an important variable," Mr. Krchma
- "I think I might be able to state that the phenomenon of thixotrophy is important. The thickness of the emulsion is an indication of particle size," Chairman Abson.
- "It is often found that asphalt emulsions simultaneously contain two different types of emulsions, i.e. a water in asphalt emulsion which is dispersed in water… which could influence viscosity," Dr. Mack.
- "The asphalt deposited in the aggregate will be no better than the asphalt was before emulsification" Mr. McKesson
- "Please describe in more detail the three sources of crude oil and any potential reasons for variation within each individual source. In addition, please provide a more robust analysis of your test comparison, specifically with a statistical analysis," submitted by Dr. Andrew Braham, September 2018

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Full citation: Heine, R. M. "Characteristic of Various Asphalts as Regards Emulsification," Journal of the Association of Asphalt Paving Technologists, Vol. 11, 1939, pp. 77-85.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: http://www.andrewbraham.com/1939_v11_p77_Heine.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

A Method for the Recovery of Asphalt from Emulsions

Review performed by Andrew Braham
October 10, 2018

Summary

- Asphalt emulsion residue necessary for penetration and ductility
- Residue generally obtained by either distillation or evaporation
- Distillation and evaporation can create asphalt residue samples with
  - A high level of variability of penetration and ductility
  - A wide variance compared to the original asphalt binder before emulsification

Quote from 1940 applicable in 2018

"This problem of recovering an asphaltic residue from an emulsion has received considerable attention"

Interesting tidbits

- Proposed method very similar to Standard Test Methods in 2018:
  - ASTM D1856: "Recovery of Asphalt From Solution by Abson Method"
  - ASTM D5404: "Recovery of Asphalt from Solution Using the Rotary Evaporator"
- VTRC put out a very nice report comparing ASTM D1856 and ASTM D5404 in 2019 (Developing a Laboratory Protocol for Asphalt Binder Recovery, VCTIR 15-R7)

Proposed recovery method: simplified

- Add ethyl alcohol and anhydrous acetone to asphalt emulsion, stir with a glass rod
  - Stir until asphalt emulsion completely broken
- Pour off supernatant (liquid above solid) layer
- Add ethylene dichloride, asphalt brought into solution
- Boil and filter through coarse filter paper
- Add boiling ethylene dichloride
- Let stand until clean separation
- Remove lower layer of ethylene dichloride and asphalt, recover asphalt by Abson method
  - Abson: 43-210 minutes, average of 68 minutes

Salient points

- Quantity of alcohol or acetone depends on asphalt emulsion type
  - ~50 mL for quick-break
  - Up to 600 mL for slow/stable break
- If asphalt emulsion not completely broken after addition of alcohol and/or acetone, will have trouble in Abson method of recovery
- If "clean separation" not easily obtain, material can be centrifuged
- Difficulties may be encountered with additives settling during the proposed test method
- A stoppered test-tube with side arm (a safety valve) recommended to improve Abson method
- Care should be taken with boiling ethylene dichloride as the boiling point is significantly lower than oil

Conclusions

- Penetration range of 100-200 too wide, recommend 100-150
- Ductility limit too low, currently 60 cm, recommend minimum of 100 cm
- Proposed recovery method faster and less difficult than existing method of distillation and evaporation
- Proposed method run on five samples of asphalt emulsion with original penetration and ductility given, showed "better" correlation to original samples versus evaporation (note – table also included 81 other samples that did not have original numbers)

Discussion highlights

- One discussions in person
- "I feel that the data for the penetration of original asphalt has not been adequate enough to gain any interpretation as to what constitutes a good method of obtaining the residue from these emulsions," Mr. Day
- "I would gather from the procedure used in Mr. Downing's method that soaps or emulsifying agents are separated from the asphalt so that these tests run do not include these foreign materials in the asphalt and do not give an indication as to what may be obtained on the finished film," Mr. Day
- "I feel like the distillation test gives us a fairly accurate indication as to what penetration we have in the film after it applied to the road," Mr. Day (from Arkansas Highway Department data!)

Image of Mr. Downing from Downing, 1940

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Full citation: Downing, C.A. "A Method for the Recovery of Asphalt from Emulsions," Journal of the Association of Asphalt Paving Technologists, Vol. 12, 1940, pp. 123-132.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: http://www.andrewbraham.com/1940_v12_p123_Downing.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

Relation of the Demulsibility Test to the Rate of Break of Asphalt Emulsion

Review performed by Andrew Braham
November 12, 2018

Summary

- Speed of break (asphalt binder coagulate and water evaporate per paper) depends on:
  - Type of asphalt emulsion
  - Type and quantity of aggregate
  - Temperature and relative humidity
- Break can be physical or chemical
- Research looked to correlate demulsibility and actual performance with aggregate

Test setup: Degree of Break Equipment

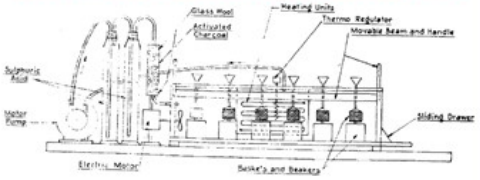


Image from Harsch and Spotswood, 1940.

Interesting tidbits

- 1940 Myers Demulsibility test very similar to AASHTO T59, Section 9: Demulsibiltiy
- Physical break divided into two categories
  - Evaporation of water from emulsion
  - Physical action of stone on emulsion
- Causes of variation with Myers Demulsibiltiy: rapidity of break of different quick breaking emulsions, asphalt binder crude source, emulsifiers, methods of manufacture

1940 tests for stability: breaking the emulsion

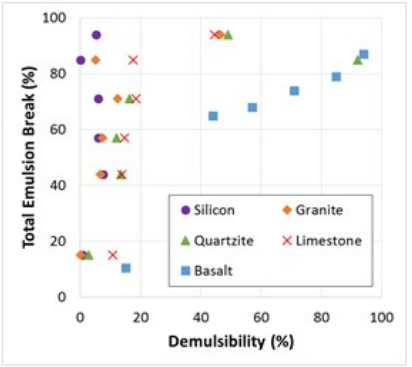
- Chemical: two tests
  - Myers Demulsibiltiy (add calcium chloride)
  - Coroselli method (add calcium bicarbonate)
- Water content: two tests
  - English Lability (add controlled air stream)
  - French "Micmell" (water evaporates until inversion)
- Mineral aggregate: four tests
  - Klinkman (emulsion travels through 20 mesh rock)
  - Weber-Bechler and Jekel (mix rock with emulsion)
  - McKesson basket (immerse rock and drain)

Degree of Break Equipment and Test Method

- Equipment: baskets containing aggregate can be raised and lowered into beakers containing asphalt emulsion
  - Temperature and humidity controlled
  - See image on left
- Add 250 g of aggregate to basket
- Run at 85°F with 56% humidity
- Drop baskets, soak aggregate in emulsion for two minutes
- Raise baskets, drain aggregate for ten minutes (cure)
- Lower drained aggregate into distilled water, agitate up and down for one minute
- Wash aggregate in ethyl alcohol and dry for one hour at 140-150°F
- Weigh asphalt on aggregate ("ten minute" cure)
- Next, repeat test with one hour cure and do not wash ("sixty minute" cure)
- Divided ten minute cure by sixty minute cure, this is the percent total emulsion break

Conclusions

- Considerable difference between different types of aggregate (five types) and different emulsions (six levels of demulsibility, see right)
- Aggregate washings substituted for calcium chloride in demulsibiltiy, aggregates may absorb emulsifier
- Aggregate activity decreased by potential adsorption of emulsifier



- With a physiochemical inert material (such as glass beads), the percent total emulsion break is strictly proportional to evaporation
- In general, emulsions with higher demulsibiltiy break more rapidly (but not across the board)

Discussion highlights

- "There are two schools of thought: fans of the Myers Demulsibilty (rapid, reproducible) or the use of different types of aggregate" Chairman Stanton (paraphrased)
- "The aggregates which seem to have the greatest affinity for water are also inclined to show the least reaction in the breaking of an emulsion by contact." Mr. McKesson
- "The mechanism of adsorption is a physical reaction and as such is not measureable by the Myers demulsibility test." Mr. Harsch

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Full citation: Harsch, R., Spotswood, E. "Relation of the Demulsibility Test to the Rate of Break of Asphalt Emulsion," Journal of the Association of Asphalt Paving Technologists, Vol. 12, 1940, pp. 184-205. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: http://www.andrewbraham.com/1940_v12_p184_Harsch.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

A Practical Consideration of Various Road Asphalt Emulsion Characteristics and Factors Affecting Them

Review performed by Andrew Braham
December 12, 2018

Summary

- Large differences in opinions on what makes a good asphalt emulsion
- Asphalt emulsion may behave inconsistently
- Two potential issues:
  - Emulsions with same lab tests behave differently in the field
  - Emulsions of same type by same manufacturer have different behavior
- Want economical, uniform results from tests

1941 research relating to today

- 1941: "We must look at the characteristics exhibited by the resultant film from the finished emulsion" – Day, AAPT
- 2017: "A specification for chip seal binders to realize improvements similar to those for the PG specifications is needed" – Epps Martin *et al.*, Transportation Research Record (TRR)
- 2017: "Binder test methods…should include emulsion residue properties" – Ilias *et al.*, TRR

Interesting tidbits

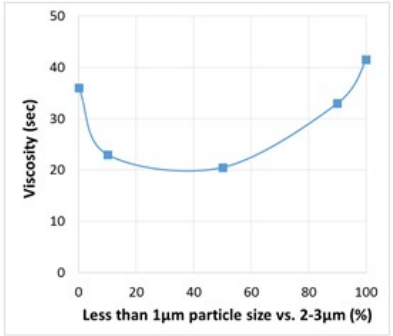
- First observed mention of current asphalt emulsion terminology: rapid setting, medium setting, slow setting
- Emulsifier vs. stabilizer: emulsifier enables asphalt binder to be dispersed; stabilizer prevents coagulation

Testing the asphalt emulsion and asphalt binder residue plus asphalt residue recovery methods

- Three focus areas
  - Fresh asphalt emulsion tests (six tests)
  - Asphalt residue recovery methods (three methods)
  - Asphalt binder residue tests (five tests)
- Fresh asphalt emulsion tests
  - Viscosity: influence of base asphalt binder, refining techniques, particle size
  - Stability: influence of mixing ability and interfacial tension
  - Surface tension: influence on wetting and coating
  - Miscibility: depends on specific gravity of asphalt binder, degree of dispersion, emulsifier, mill clearance, mill speed, temperature of raw materials, and flow rate through mill
  - Dehydration: influence on film thickness and permeability of film
  - Lability (not well understood): point of moisture content when asphalt emulsion coagulates
- Asphalt residue recovery methods:
  - Evaporation, distillation, or chemical break with asphalt binder recovery
- Asphalt binder residue tests:
  - Penetration, ductility, solubility, ash content, specific gravity
  - Behavior dictated by base asphalt binder, and type and quantity of emulsifier

Conclusions

- Viscosity: usually controlled by asphalt binder content, lower salt content lowers viscosity
- Chart on right shows a minimum viscosity with a blend of asphalt binder particle sizes
- A stone coating test is recommended along with cement mixing



- Asphalt emulsion residue versus base asphalt binder:
  - Drop in penetration, ductility, solubility after recovery
  - Increase in ash content, specific gravity after recovery
- For emulsifier, wood rosin hardens residue versus vinsol resin
- Oliensis spot test can determine type and quantity of emulsifier

Discussion highlights

- "Based on discussions, AAPT is not interested in formulating specifications…we have to be concerned with them" Mr. Day
- "Recovering the residue has been given serious consideration in the past and should receive further consideration." Mr. Downing
- "I can't quite agree to the statement that it is commonly accepted that the viscosity should be governed by the asphalt content alone." Mr. Downing

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Full citation: Day, A. "A Practical Consideration of Various Road Asphalt Emulsion Characteristics and Factors Affecting Them," Journal of the Association of Asphalt Paving Technologists, Vol. 13, 1941, pp. 256-267. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: http://www.andrewbraham.com/1941_v13_p256_Day.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

A New Method of Recovering Bitumen from Bituminous Emulsions

Review performed by Andrew Braham
January 11, 2019

Summary

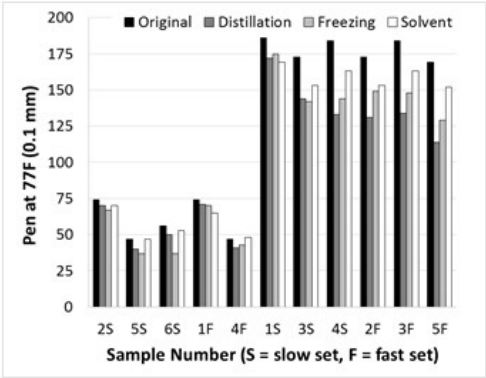
- How can we separate bituminous base from emulsion?
- Two existing methods reviewed (distillation, freezing), one method proposed (solvent)
- Three methods compared to original through penetration
- Solvent method recommended

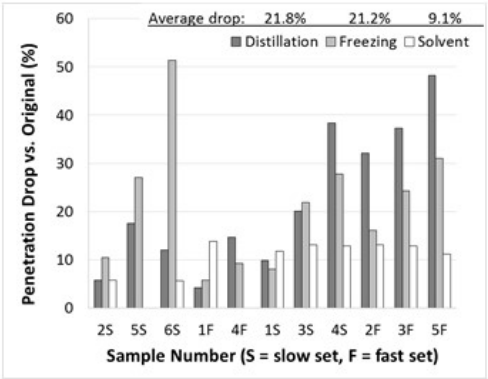
Three methods of recovery

- Distillation (ASTM D244-36T)
  - 500°F for 15 minutes in 1941
  - AASHTO T59-15 has same temperature and time as in 1941
- Freezing (Indiana DOT recommended)
  - Remove water in alcohol bath at -70°F
  - Filter residue, obtain recovered material
- Solvent (proposed)
  - Mix benzene and apply low heat

Interesting tidbits

- Distillation method suspected of 1) removing light oily portions, especially high pen binders, and 2) causing vapor pressure issues in still that increase volatility of light portions
- Freezing method issues: 1) alcohol dissolves some constituents and hardens asphalt and 2) cold temperatures harden asphalt – thought to be less severe than alcohol effects





- If benzene asphalt solutions not centrifuged, higher penetration
  - Emulsifying agent contributes to softening of asphalt residue remaining on aggregate after breaking

Findings

- Freezing method gives residue closer to original penetration than distillation
- Solvent method has gives residue closest to original penetration
- Freezing and solvent methods produced more reproducible results than distillation
- Different solvent method procedures also examined – had very little effect on residue penetration (data not shown)
- Part of penetration loss may occur during the manufacture as asphalt binder is heated

Conclusions

- 11 asphalt emulsions tested
  - Two ranges of original penetration: 50/70 and 150/200
  - Two reactivities: fast set and slow set
  - Seven base asphalts
- Average drop in penetration from original:
  - Distillation: 21.8%
  - Freezing: 21.2%
  - Solvent: 9.1%
- Distillation variability was as high as 25% with distillation but under 5% with solvent method
- Solvent method recommended moving forward

Discussion highlights

- "I would like to ask Mr. Tyler if he considers that the centrifuge method will remove all of the emulsifying agents that may be present? I have in mind the use of emulsified rosin, not of the vinsol type, in which we have a certain and rather high percentage of unsaponifiables, which do remain in the asphalt and are hardening agents." Mr. Miller
- "The other problem Mr. Miller spoke about of recovering the film as it exists on the mineral particle is quite another problem." Mr. McKesson
- "[In order to represent the film on aggregate] we spray the emulsion on a film as thin and even as possible, on a piece of glass that has been covered with a film of glycerine." Mr. Covacevich

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Full citation: Tyler O. "A New Method of Recovering Bitumen from Bituminous Emulsions," Journal of the Association of Asphalt Paving Technologists, Vol. 13, 1941, pp. 268-281.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: http://www.andrewbraham.com/1941_v13_p268_Tyler.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

Soil Stabilization with Emulsified Asphalt

Review performed by Andrew Braham
February 11, 2019

Summary

- High level review of soil, soil-aggregate, and soil-sand with asphalt emulsion in the following areas:
  - Selection of material
  - Design of mixes
  - Construction (preparation, mixing, spreading, compacting, surfacing)
- Other uses: adobe bricks, revetments, bagged, camouflaging

Objective of emulsion-based stabilization

- Adequate resistance to displacement with maximum expected field moisture content
- Increase resistance to capillary absorption
- Increase stability (plastic flow and shearing strength)

Interesting tidbits

- Most subsoils give good support when their moisture content is less than the optimum content for compaction
- It is not expected, nor desired, for an asphalt emulsion stabilized base to remain free from absorbed moisture under service conditions
- Emulsion vs. mechanical stabilization
  - Emulsion absorbs ½ moisture amount
  - Stability 2-8 times higher with emulsion
  - Emulsion increases resistance to capillary absorption

	Soil and soil-aggregate	Soil-sand
Selection of materials	• 20-30% P200 (<0.075 mm) • 10-20% cohesive clay (<0.005 mm) • 5-15% colloidal clay (<0.005 mm) • If 30-50% P200, add sand or gravel • If >50% P200, do not stabilize	• Sand is not cohesive, cohesive clay not available • 1% Portland cement may be used
Design of mixes	• Options: absorption & extrusion test; Texas Modified Bearing Value, triaxial shear, punch shear • Mix with least moisture, usually near plastic limit • Balance absorption and stability, usually 4.5-7.0% asphalt emulsion	• Modified Florida Testing Method used • 100 psi min., 160 - 200 psi better • Pen < 200, tackier • Use surface area formula for emulsion
Construction: Preparation & mixing	• Frim, compacted subgrade required • Mix at central plant or portable unit • Feed water and emulsion into mixing chamber, place in windrow • Avoid excessive water	• If windrowing, no need for subgrade preparation • May need to add additional water
Construction: Spreading & compacting	• Spread and compacted to 95% Proctor Density • Spread 2-6" thick (thinner if rainy) • Place next layer when existing layer is 25% optimal moisture content	• Successful in wet weather • Spread 3-6" thick • Surface at <5% moisture content
Construction: Surfacing	• Prime coat followed by chip seal (low volume) or 2-3" overlay (hot or cold, high volume) • Do not want porous layer because water could penetrate	• Often just a prime coat • If more desired, chip seal or overlay

Conclusions

- Highest level of use during depression (1930's) since agencies had limited funds
- Used on airfields (~8.6 million sq. yds. In 1942), 75% have "A" rating
- A significant amount of good discussion on selection of materials, design of mixes, and construction: information to the left just a brief overview

Novel quotes from Mr. McKesson

- "Violent controversies have rages between the proponents of the various types of stabilizers"
- "It is certainly not the purpose of this writer to pour fuel on this fire of controversy"
- "There is no universal panacea for all subgrade ills"
- "The man who spends two dollars to accomplish what a practical layman would do with one, is not entitled to be called an engineer"
- "With Congressional appropriations now being made in billions instead of thousands, with savings no longer a critical objective, the trend has been toward heavy pavements, perhaps overlooking the splendid service of low-cost alternatives."

Discussion highlights

- "In the lab, asphalt emulsion mixture treatments should be tested with the same equipment as all other asphalt treatments." Mr. Thurston
- "I want to say 'Amen' to Mr. Thurston's points. Asphalt is asphalt no matter how you liquefy it." Mr. Nevitt.

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Full citation: McKesson, C. L. "Soil Stabilization with Emulsified Asphalt," Journal of the Association of Asphalt Paving Technologists, Vol. 14, 1942, pp. 180-198.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: http://www.andrewbraham.com/1942_v14_p180_McKesson.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

Emulsified Asphalt – Sand Pavements

Review performed by Andrew Braham
March 11, 2019

Summary

- Sand-bituminous pavements surprisingly good low cost roads
- Stability of sand important factor
- Design includes gradation of sand, stability of sand, admixtures, and emulsified asphalt
- During construction, subgrade, mixing, moisture content, and compaction all critical
- "Universally satisfactory" pavement type

History of mixed bituminous pavement

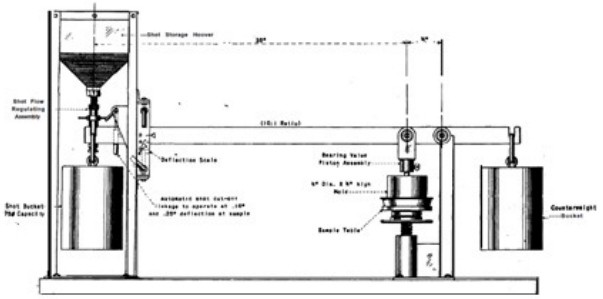
- In addition to novel quotes, McKesson provides novel summary techniques:
- Father: sheet asphalt (healthy, not as active)
- Son: asphaltic concrete (healthy, extravagant)
- Grandson: sand-bituminous mixtures (healthy, vigorous, growing rapidly)

Stability tests examined

- Two stability tests extensively reviewed
  - Florida Bearing Value Test
  - Modified Florida Bearing Value Test
- Untreated sand: Florida Bearing Value Test
  - Run before emulsion added to sand
  - Reproduction difficult
- Paving mixtures: Modified Florida Bearing Value Test (extensive description in paper)
  - Diameter increased from 3" to 4"
  - Coated using surface area formula, new drying regime, special equipment (right)

Design of emulsified asphalt sand pavements

- Design: gradation
  - Not the major factor in securing stable, durable pavements
  - Gradation is not necessarily related to stability
- Design: stability
  - Prime importance, see two tests on the lower right
  - Should consider the sand-admixture blend
- Design: admixtures/fillers
  - Inert material: stone dust, slag dust, loess, or other non-cohesive material → PI more than 6 not permitted
  - Not more than 12% of aggregate blend P200, not more than 40% P20
  - 1% Portland cement may be used under adverse weather conditions or rapid construction (add after emulsion is fully mixed and count as P200 material)
- Design: emulsified asphalt (EA)
  - Percent EA = 0.75×(0.05×R10+0.10×(R200-R10)+0.5×P200)
  - Assume 60% residue of emulsified asphalt, slow setting asphalt emulsion with penetration 150-225 and high dehydration



(Image from McKesson, 1943)

Construction

- Similar to dense grade asphalt concrete
- Construction: subgrade
  - Uniformly and properly compacted subgrade required, sand is ideal
  - For soil, PI>4 and sand placed above
  - Sand Bearing Value > 30 lbs
- Construction: emulsified asphalt sand pavement
  - 6" thick up to 35,000 wheel loads
  - Road mixing or central mixing plants acceptable
  - Sand should be wet during mixing
  - Compact in <3" lifts with rubber tired rollers at optimal moisture content → do not blade wet material over dry compacted material
  - Do not place when rain falling or temperature is below 40°F, do not compact <50°F
- Single or double surface treatment as seal coat

Conclusions

- Asphalt emulsion sand pavements good low cost roads
- Stability of material key for long performance
- Proper design and construction critical
- A precursor to slurry seals? (Braham thought)

Discussion highlights

- "Traditionally, when a pavement is laid the compacted surface should be dry." Mr. Nicholson
- In response to Mr. Nicholson: "This is a significant difference between traditional asphalt concrete and asphalt emulsion based flexible pavement" written response, Dr. Braham, March 2019.

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Full citation: McKesson, C. L. "Emulsified Asphalt – Sand Pavements," Journal of the Association of Asphalt Paving Technologists, Vol. 15, 1943, pp. 273-286.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: http://www.andrewbraham.com/1943_v15_p273_McKesson.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

Construction of Optimum Seal Coats

Review performed by Andrew Braham
May 21, 2019

Summary

- Seal coating an engineering operation
  - Require specialized materials, design, and construction equipment
- Largest current compliant is lack of skid resistance on placed surface
- A "boundary condition" occurs when hydroplaning occurs on an untreated road but would not occur on a road with seal coat

Fundamental requirements

- Strengthen the surface, not the structure
- Seal coat:
  - Permeate existing pavement surface
  - Waterproof surface to protect base
  - Absorb wear of traffic
  - Improve skid resistance
- Improve driving ease → called "luminosity"
  - Better visibility, lower driver fatigue, increased traffic distribution

Material & construction requirements

- Correct application rate and viscosity of asphalt emulsion
  - Low viscosity: run off surface
  - High viscosity: will not flatten on surface nor penetrate existing surface
- Strong but ductile asphalt emulsion residue
- Aggregate contribution not well understood, but needs attention, especially with skid

Skid resistance

- Three situations create different conditions for skid resistance
  - Bituminous surface proper: resisting force equal to product of tire contact pressure, area of contact, coefficient of friction between tire and bituminous surface
  - Surface of projecting particles: same as above, but pressure depends on rigidity of tire and height aggregates project
  - Effect of tire projections on tire as vehicle moves: tire tread constantly readjusts self to changing road surface (independent of wet or dry surface) but consumes energy → will not be further considered because not influence by surface conditions
- Skid resistance on dry surface good because of high coefficient of friction
- Skid resistance on wet surface provides highest benefit of seal coats
  - Skid resistance significantly reduced when a boundary of water forms between tire and pavement surface (hydroplaning)
  - A "boundary condition" occurs when hydroplaning exists on surface without seal coat but does not occur on surface with seal coat
- Boundary condition - machine journal lubrication theory applied
  - Critical vehicle speed a function of a friction factor, pressure on the surface, and viscosity of wetting fluid
- Steps to improve skid resistance (a.k.a. desired finished surface)
  - Increase area of projecting particles
  - Improve quality of projecting particles surface
  - Asphalt emulsion residue must: "flatten" to provide a uniform layer with proper thickness, penetrate voids of existing pavement, resist creeping after placement, and cool for appropriate rigidity long-term
  - Aggregate must provided interlocked layer, have maximum number of contacts with tire, and include "valleys" between particles for drainage, should be uniform between 1/4-3/8" size (no oversized particles) and have surface roughness
- Embedment of aggregate in residue must be maintained

Construction procedures

- Most practices "common sense" but special attention needed for adhesion and retention of aggregate
- Adhesion set by design but early release to traffic can destroy a high quality seal coat – especially at high speeds (can't be offset by more aggregate)
- Additional guidelines to follow
  - Aggregate must be reasonably dry or damp
  - Rolling after aggregate placement critical, will work and lock the aggregate, use pneumatic
  - Number of rollers and required passes must be set for each job
- Time necessary for residue to "work" into aggregate structure and for full curing to occur

Conclusions

- Seal coat fundamentals, observations on recent practice, and increased awareness
- Skid resistance a key outcome of a good seal coat
- Traffic control necessary to prevent aggregate loss

Discussion highlights

- "Seal coating is doing something to the old surface that does very little to increase thickness." Mr. Nevitt.
- "All of us, I think, have had experience with seal coats where the aggregate has crushed under traffic and produced a smooth surface." Mr. McNaughton
- "Would you consider a seal coat a maintenance job or a part of the road reconstruction? How long after a new mat is put down should the road be sealed?" Mr. Feller

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Full citation: Nevitt, H.G. "Construction of Optimum Seal Coats," Journal of the Association of Asphalt Paving Technologists, Vol. 17, 1948, pp. 264-287.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1948_v17_p264_Nevitt.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

Fundamentals in Surface Treatment with Emulsified Asphalt

Review performed by Andrew Braham
April 15, 2019

Summary

- Four surface treatments examined
  - Seal coat
  - Armour coat
  - Single application
  - Double application
- Focus on construction and materials (asphalt emulsion and aggregate)
- Usually 1" or less thickness
- Surface treatments placed on pavement with adequate structure to carry weight
- Negative ionic charges on surfaces of asphalt binder droplets (anionic, quick setting) with high viscosity attracted to positive ionic charge on aggregates
- Can use wet/damp aggregate

Definitions

- Construction/maintenance designed to provide a new or additional wearing surface
- Pavement structure assumed adequate
- Definitions vary slightly around country

History of quick setting asphalt emulsion

- First use: Europe after World War I
- First use in US: Niles Canyon, CA (1927)
  - 0.66 gal/yd^2, 50% residue, 42 lbs gravel
  - Double application, 1000 veh/day
  - Lasted ten years
- Hundreds of millions of gallons successful used in past twenty years in US

Construction of surface treatments

- Asphalt emulsion
  - Water content critical: 40-45% (55-60% residue), creates uniform film
  - Translates to about 5% water content of total weight of aggregate
  - Spring: 200-300 pen asphalt base (softening point 95-105°F)
  - Fall: 150-200 pen asphalt base (softening point 103-110°F)
- Aggregate
  - Ratio of asphalt emulsion to retained cover stone 1/100 gal/yd^2/lb
  - Plus 1/10 gal/yd^2 asphalt emulsion for coating pavement beneath
  - 80-90% cover stone should be retained
- Securing cover retention
  - Sweep existing pavement; use clean, sound, and damp aggregate; proper gradation and asphalt binder to retained aggregate ratio; apply stone immediately after emulsion and spread uniformly; use quick setting emulsion (with adhesion additives if necessary); check retention; sweep loose stone and apply fog seal if desired

Materials of surface treatments

- Material application rates
  - Multiple: 0.33 gal/yd^2, 25-30 (1st) 12-15 (2nd) lbs/yd^2 chips/gravel
  - Single (heavy): 0.4-0.5 gal/yd^2, 40 lbs/yd^2 chips/gravel
  - Single (light): 0.4-0.5 gal/yd^2, 10-20 lbs/yd^2 chips/gravel
- Asphalt emulsion
  - Quick setting anionic asphalt emulsion
  - Heavy: High viscosity (100-400 seconds at 122°F)
  - Light: 150-200 pen, low viscosity (30-100 seconds at 77°F)
- Aggregate
  - Multiple: 3/4" to #8 sieve (1st) 3/8" to #8 sieve (2nd)
  - Single: 3/4" to #8 sieve

Selection of type of surface treatment

- Single application: light
  - "Leaky" pavements, protection from oxidation
  - Coarse textured pavement
- Single application: heavy
  - "Fat"/slippery pavement, want non-skid surface
  - 30-40 lbs/yd^2 chips/gravel
- Double application
  - "Fat"/slippery pavement, want non-skid surface
  - 50 lbs/yd^2 chips/gravel
- "Armour" coat (triple application)
  - 1.0-1.5" total thickness of application
  - Old bituminous or cement concrete pavements with bad cracking, rough from maintenance

More novel quotes from Mr. McKesson

- "There is sometimes a tendency to lose sight of the fact that with surface treatment, as with all types of pavement, there are certain fundamentals which can't be ignored if results are to be uniform & satisfactory"
- "The meritorious old slogan 'anything worth doing is worth doing right' is particularly applicable to surface treatment, where every defect subsequently glares at you and at your clients, the taxpayers"

Discussion highlights

- Why asphalt emulsion is used in Arizona: "no heating is required on the job site, cover material does not need to be dried, no fire hazard to workmen, material can be stored without damage in bad weather, easy to handle." Mr. Brown.

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Full citation: McKesson, C. L. "Fundamentals in Surface Treatment with Emulsified Asphalt," Journal of the Association of Asphalt Paving Technologists, Vol. 17, 1948, pp. 288-303.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1948_v17_p288_McKesson.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

A Brief Consideration of Fundamental Concepts of Asphalt Emulsions

Review performed by Andrew Braham
September 9, 2019

Summary

- "I would like to retrace my steps, go back and try to learn some of the fundamentals of asphalt emulsions"
- Perspectives reviewed
  - Raw materials: water, agent, asphalt
  - Manufacturing process and final products
  - Finished characteristics
- Extensive discussion on RS, MS, and SS asphalt emulsions, specifically how to modify one property without changing another

Misconceptions on emulsion

- "Tricky to handle"
  - Reaction due to lack of knowledge and experience in proper handling
- "Erratic and lack uniformity"
  - Mysteries will be lifted in this review

Big steps forward

- Standard terms from Asphalt Institute
  - RS: rapid set
  - MS: medium set
  - SS: slow set
- Various regional specifications conforming to national specifications
  - ASTM committee D-4 has subcommittee C-4 working on national specifications

Raw materials: water, agent (soap), asphalt

- Water
  - Salt contents and alkalinity measured
  - Softness of water important, hardness mitigated with type and quantity of agent (soap)
- Agent/soap
  - 1.0 to 4.0 soap as percentage of water phase
  - Two types explored: wood resin (mainly sodium abietate) and vinsol resin (could also use sodium oleate, tall oils, potassium soap)
- Asphalt
  - From Arkansas (!), 21 A.P.I. Gravity Smackover Crude
  - 180-200 penetration grade
  - Combination of steam and vacuum distillation

Manufacturing and products

- Mill details
  - Colloid mill, 3600 r.p.m. speed
  - Asphalt = 275°F, soap solution = 100°F, final asphalt emulsion = 165°F
- Produced RS-1, RS-2, MS-1, MS-2, and SS-1
- Emulsion and residue tests very similar to AASHTO M140-18

1950 Tests		2018 Tests	
Emulsion	**Residue**	**Emulsion**	**Residue**
- Residue by evaporate, viscosity (Saybolt), 5-day settlement, sieve test, demulsibility (RS, MS), modified miscibility (MS, SS), stone coating, cement mixing (SS), dehydration	- Ductility, penetration, solubility, softening point, ash content	- Distillation (oil and residue), viscosity (Saybolt or paddle), storage stability, sieve test, demulsibility (RS, HFRS), cement mixing (SS)	- Ductility, penetration, ash content, float test (HFRS, HFMS)

Interesting tidbits

- Average particle size 3 µm for emulsions produced
- It is assumed that if asphalt emulsion residue is "close to the original" it will perform well
- A range of asphalt content from 63-67% yields a change in viscosity from 30 – 100 seconds, but will lower demulsibiltiy and will not pass coating test
  - But, changing to higher molecular weight primary amine salt as agent could meet all tests
- Asphalt binder with higher salt content provides an asphalt emulsion with higher viscosity
- Stone coating tests should be run with aggregates representative of field conditions
- Higher alkalinity of asphalt emulsion improves stone coating test
- Asphalt fractionation in 1950: asphaltenes, hard resins, wax, soft resins, oils
- Excessive oversize asphalt binder droplets caused by improper handling or unclean storage
- Lack of vigilance or sloppy control will cause trouble

Discussion highlights

- "...emphasize the point that while SS-1 and SS-2 might be used instead of MS-1 and MS-2, the reverse is not true." Mr. McKesson
- "Demulsibiltiy on MS and SS types of emulsion is unreliable as an indication of stability or rate of set, but is reliable for RS." Mr. Izatt
- "Movement must be made to more performance related specifications for asphalt emulsions, the 2018 tests have been used for 60+ years." Mr. Braham, 2019.

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Full citation: Day, A. J. "A Brief Consideration of Fundamental Concepts of Asphalt Emulsions," Journal of the Association of Asphalt Paving Technologists, Vol. 19, 1950, pp. 348-368.
Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1950_v19_p348_Day.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

Symposium: Seal Coats or Surface Treatments for Existing Bituminous Treatments

Review performed by Andrew Braham
October 14, 2019

Summary

- Symposium consists of four papers and presentations on seal coats
  - Symposium Introduction by "W. H. Goetz (pp. 233-234)
  - "A Review of Fundamentals in Surface Treatment" by E.C. Herbert (pp. 235-242)
  - "Recent Developments in Equipment used for Sealcoats or Surface Treatments of Existing Bituminous Surfaces" by W.H. Schuelie (pp. 242-253)
  - "Surface Treatments of Existing Bituminous Surfaces" by J.R. Harris (pp. 253-260)
  - "Surface Treatment of Existing Asphalt Pavements" J.T. Pauls (pp. 260-266)
  - Note – each paper began on the same page the previous paper ended
- For this review, only the asphalt emulsion concepts will be covered, but there is loads of interesting information on surface treatments throughout the papers

Symposium Introduction

- Regardless of method of application, interest in qualities of resulting bonding film
  - Hot penetration asphalt binder, cutback, or asphalt emulsion

A Review of Fundamentals in Surface Treatment

- Standards for high quality asphalt emulsions
  - Viscosity: movement toward thicker liquid asphalts (higher viscosity) and larger cover aggregate: better wear and less bleeding
  - Demulsibiltiy: an identification test, high levels are rapid set used for surface treatment. Little correlation between demulsibiltiy and setting time
- Weather (two phenomenal quotes here)
  - "We believe the most certain way to court failure is to put down material on chilled road beds or under humid atmospheric conditions"
  - "These conditions are a particular bugbear in emulsion applications"
  - Higher material temperature (190°F vs 150°F) can offset cooler ambient construction temperatures
- Dry aggregate most desirable except with emulsions, warm aggregate can increase retention

Surface Treatment of Existing Bituminous Surfaces

- Dust free shoulders
  - "Sprinkle" shoulders with 95% water and 5% medium curing emulsion
  - Asphalt = 275°F, soap solution = 100°F, final asphalt emulsion = 165°F
- Rare to use quick breaking emulsions as surface treatments, curing period too long and vulnerable to traffic

Surface Treatment of Existing Asphalt Pavements

- Rapid breaking asphalt emulsions commonly used in surface treatments
  - Higher viscosity developed in recent years very satisfactory: holds stone better, has less runoff, allows for larger stone
  - Emulsion has advantage as it can be used with wet aggregate
  - Asphalt = 275°F, soap solution = 100°F, final asphalt emulsion = 165°F

Discussion highlights (pp. 266-281)

- "It is very easy to carry this matter of high viscosity too far, because actually it would start taking on rubbery or even leathery characteristics, whereas it is definitely desirable to have a type of material there which can readily and easily wet the surface of the aggregate, and as a matter of fact, pull up on the side of the aggregate." Mr. Stevens
- "Perhaps the ideal range of viscosity is somewhere around, should I say, 200 to 300." Mr. Stevens
- "I would like to point out that actually there is a continuing tendency in the field for individuals in using a high viscosity emulsion." Mr. Stevens
- "I believe if we actually analyze what is involved in this fluffing [of emulsion], we would find that it is simply the entrapment of tiny little globules of air. They perform a very important function in adhering that sealcoating material to the road surface." Mr. Stevens
- "We, in the state of Arkansas, primarily seal with emulsion or cutback asphalts." Mr. Swanson.
- "Even these emulsions, that we have discussed need to be warmed substantially." Mr. Pauls
- "I haven't noticed any build-up in spreading emulsion as compared with hot asphalt in relation to the freezing of the nozzles." Mr. Schuelie
- "High speed positive gear pumps that are used by most distributor manufacturers have a tendency to break down the emulsion." Mr. Schuelie
- "Other pumps such as the sliding vane, single screw, twin screw and shuttle types are not considered as satisfactory for pumping emulsions." Mr. Meigs.

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Full citation: Goetz, W. H. "Symposium: Seal Coats or Surface Treatments for Existing Bituminous Treatments," Journal of the Association of Asphalt Paving Technologists, Vol. 24, 1955, pp. 233-281. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1955_v24_p233to281_Symposium.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

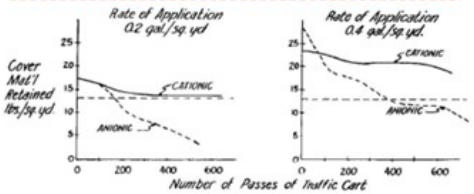
Seal Coat Performance – Interrelation of Variables Established by Laboratory and Field Studies

Review performed by Andrew Braham
November 11, 2019

Summary

- The first AAPT paper found that specifically referenced cationic asphalt emulsion! I was very interested to see when this occurred
- Extremely comprehensive paper on seal coats (a.k.a. chip seals), significant amount of data and discussion to support findings
- Explored asphalt emulsions, cutbacks, hot applied binder (all "binder" in this review)
- Four areas of focus:
  - Viscosity: streaking and runoff of binder
  - Aggregate bonding: wetting of aggregate, viscosity of binder, cohesion of aggregate/binder bond
  - Durability of binder: adhesion
  - Application rate of binder based on aggregate
- Four test methods proposed: 1) asphalt runoff, 2) trafficulator test device (bonding), 3) scuffing/shoving (durability), 4) binder-aggregate relationship (application rate)

Appreciation of Handwritten Figures



(p. 18 of Kari *et al.*, 1962; they don't make them like they used to!)

Four areas of interest for seal coats (chip seals)

- Examined anionic and cationic rapid set emulsion, three cutbacks, two hot applied asphalt binders
- Viscosity: streaking and runoff of binder during spray application
  - Temperature of binder, asphalt distributor spray uniformity, and flowing of binder on the existing pavement surface important
- Aggregate and binder bonding: cohesion
  - Aggregate must be clean, hard, durable, and of proper size to provide good cohesion regardless of type of binder
- Aggregate and binder bonding: adhesion
  - Wetting, development of adhesion critical for long-term performance
- Consistency for "compaction" (now known as seating of aggregate)
  - After chip placement, 50% volume air; after chip seating, 20-30% air
  - At warmer temperatures, aggregate may penetrate existing surface
  - Asphalt emulsions loose water by dehydration, absorption of water into existing surface and aggregate, pressure, and chemical charge

Surface Treatment of Existing Bituminous Surfaces

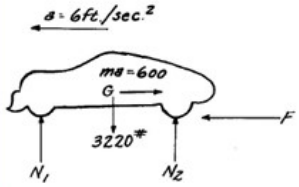
- Reducing the potential for asphalt runoff
  - Quantifies when binder would run off grade due to slope
  - Uniform spread 50-200 centistoke (cSt) coming out of distributor
  - Max slope of 10% required 400 cSt viscosity for emulsion
- Aggregates need to be durable to prevent scuffing and shoving
  - Scuffing/shoving occurs when viscosity is low, during hot weather, or after poor seating of aggregate
  - 6,000 cSt required to prevent scuffing
- Bonding of aggregate and binder
  - Trafficulator simulates traffic on seal coat
  - Recommend maximum value of 1×10^8 cSt
- Ensuring proper application rate for good binder/aggregate relationship
  - Binder application rate (B) a function of stone diameter (D) and existing pavement condition (P_C) → $B = 0.708D + P_C$

Conclusions

- Viscosity of binder related to wetting, compaction (seating), setting (breaking), and durability of seal coat
- Viscosity requirements for various conditions @25°C:
  - Spraying: 50-200 cSt (~47-95 Saybolt Furol sec)
  - Runoff: 400 cSt (~190 Saybolt Furol sec)
  - Scuffing: 6,000 cSt
  - Bonding (cohesion): 1×10^8 cSt
- Current AASHTO M140 specification for viscosity
  - RS-1 group: 20-100 Saybolt Furol sec (25°C)
  - RS-2 group: 75-400 Saybolt Furol seconds (50°C)
- Four tables provided with preliminary specifications based off work described in paper

Discussion highlights

- "What percentage of embedment are you using as a basis in your formula?" Mr. Campen
  - "I would say about one-half of the stone is out of the binder" Mr. McCoy
- "Your slides showed that the cationic emulsion had a better performance than the anionic emulsion." Mr. Tonetti
- "I congratulate you, Mr. McCoy, on this traffic simulator program." Mr. Speer



A free body diagram for accelerating traffic – a Porsche 911? (p. 27 of Mertens *et al.*, 1964)

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Full citation: Kari, W., Coyne, L., McCoy, P," Seal Coat Performance – Interrelation of Variables Established by Laboratory and Field Studies." Journal of the Association of Asphalt Paving Technologists, Vol. 31, 1962, pp. 1-34. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1962_v31_p1to34_Kari.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

The Breaking of Asphalt Emulsions for Surface Treatments

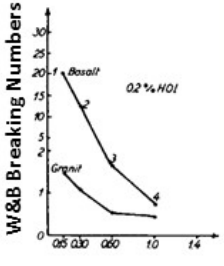
Review performed by Andrew Braham
December 9, 2019

Summary

- Four emulsifier levels and five base levels explored with two aggregate types
- Three laboratory tests explored
  - Automatic scratch strength meter
  - Automatic strength meter
  - Rotating scratch strength meter
- Evaporation rates explored with varying wind speed, humidity, and cloud cover

Varying emulsifier, base, and aggregate

- Weber and Bechler (W&B) number quantified breaking characteristics
- Four levels of potassium oleate (HOI)
  - 0.2, 0.6, 1.0, 1.4%
  - A.K.A. oleic acid, alkali
- Five levels of potassium hydroxide (KOH)
  - 0.15, 0.30, 0.60, 1.0, 1.4%
- Granite: "weak" breaking; Basalt: "strong"
- Verified in the field
- 1.25 kg/m^2 (0.28 gal/yd^2) emulsion application rate
- Influence of aggregate type stronger than emulsifier loading
- Field validated lab results



(p. 354 of Bohn, 1963)

Three laboratory performance tests

- Automatic scratch strength meter
  - Two loading levels: 75 g and 100 g
  - Times to 75 g ranged from 1.2 – 3.5 hours, 100 g 1.6 – 4.3 hours
  - Same trends observed in this lab test (for emulsifier, base, and aggregate) as with the W&B number
  - Portable version made for the field, 300 g took 2.5 hours, much higher wear than traffic moving 20-60 kph (20 kph had lowest wear)
- Automatic strength meter
  - An increase of evaporation velocity (measured with a Gallenkamp apparatus in g/hr) decreased the time to achieve 75 g and 100 g from greater than 10 hours (<2 g/h) to less than five hours (~15 g/hr)
- Rotating scratch strength meter
  - Automatic scratch strength meter struggled on rough surfaces
  - Rotating scratch strength meter used on cationic emulsions and produced similar trends to the anionic emulsions earlier explored

Influence of wind speed, humidity, and cloud cover

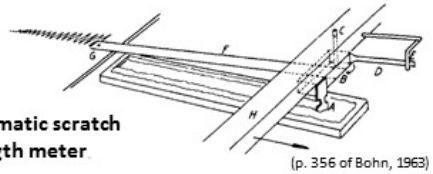
- Evaporation a function of temperature, pressure, humidity, wind speed, and road roughness
- Units of evaporation g/minute of water
- Evaporation increases with increased roughness, wind speed, and humidity
- For quick breaking cationic emulsion
  - Setting time ranged from 1.5 – 6.5 hours
  - Evaporation rate ranged from 0.64 mg/min to 130 mg/min
  - Cloud condition had very little influence
- For stable breaking cationic emulsion
  - Setting time ranged from 5-15 hours
- Adding aggregate (basalt) decreased setting times
  - Setting time ranged from 0.67-1 hour

Conclusions

- Increasing emulsifier content, increasing base content decreases breaking speed
- Granite is less reactive than basalt with an anionic emulsion
- The scratch strength meter and strength meter both correctly predict field performance in the lab with anionic emulsion
- The rotating scratch strength meter correctly predicts field performance in the lab with cationic emulsion
- Increasing wind speed and decreasing humidity decreased evaporation rate, cloud cover negligible

Discussion highlights

- "Certain quantitative tests are badly needed…for covering the rate of break" Mr. Holberg
- "You demonstrated quite well with your data that we are only kidding ourselves when we try to measure the rate of break of a quick breaking emulsion with the demulsibility test." Mr. Goetz
- "I think we can say very frankly and dogmatically this is absolutely impossible, there is no such thing as getting an aggregate from a source, going back again to the same source, and having it perform the same." Mr. Hveem



The automatic scratch strength meter

(p. 356 of Bohn, 1963)

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Full citation: Bohn, A," The Breaking of Asphalt Emulsions for Surface Treatments." Journal of the Association of Asphalt Paving Technologists, Vol. 32, 1963, pp. 353-379. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

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Emulsified Asphalt Slurry Seal Coats

Review performed by Andrew Braham
January 13, 2020

Summary

- Explored influence of: asphalt emulsion content, asphalt binder type, aggregate gradation, and aggregate plasticity on wearing properties of seal coats
- Introduction of Wet Track Abrasion Test (ISSA TB100 or ASTM D3910)

Emulsion content and binder type

- Asphalt emulsion content
  - Successful slurry seal requires 1.5-3.0 gallons of asphalt emulsion per 100 pounds of dry aggregate (13-25%)
  - 59% of aggregates in study met the minimum wear value requirements from wet track abrasion test with 13-25% emulsion
  - 11% of aggregates met wear with <12% asphalt emulsion
- Influence on wear of asphalt penetration
  - Used one asphalt crude source
  - No "appreciable difference" between 60/70 and 200/300 penetration asphalt binder
- Selection of emulsion type
  - Anionic (SS-1 or SS-1h) or cationic (SS-K or SS-Kh)
  - Dependent on adhesion characteristics of sand and crushed dust
  - Cationic slurry seals set faster than anionic

Recommended aggregate gradation: 1964 and 2010

- 1964 recommended gradation between 2020 Type I & Type II (ISSA A105)
- Table below is percent passing recommendations from 1964 and 2010

Sieve size	1964	Type I	Type II	Type III
3/8" (9.5 mm)	100	100	100	100
#4 (4.75 mm)	100	100	90-100	70-90
#8 (2.36 mm)	80-100	90-100	65-90	45-70
#16 (1.18 mm)	50-90	65-90	45-70	28-50
#30 (600 µm)	30-60	40-65	30-50	19-34
#50 (330 µm)	20-45	25-42	18-30	12-25
#100 (150 µm)	10-25	15-30	10-21	7-18
#200 (75 µm)	5-15	10-20	5-15	5-15

- Need 5-15% P200 (passing #200 sieve)
  - Too fine? Cracking and brittle (>15% P200)
  - Too coarse? Streaking, segregation, and sanding (< 5% P200)

Aggregate plasticity

- Clay fines deleterious in slurry seals (similar to hot mix asphalt)
- Sand equivalent should be greater than 40
- Clay forms balls when mixed with water
  - Difficult to disperse and coat with asphalt emulsion

Addition information on

- Equipment and problem areas for aggregate discussed (segregation, streaking, balling/breakdown in mixture, rate of cure), and durability of slurry seals (sanding, raveling, loss of adhesion, scuffing)

Conclusions

- Slurry seals intended to seal pavements that are cracked, checked, pitted, or raveled
- Life span a maximum of five years (2020, six years)
- Wet Track Abrasion Test developed
  - Correlated to >100 field sites
  - Helps select type and quantity of aggregate and asphalt emulsion
  - Provides indication of handling properties of slurry seal and helps determine water content in field
- Four hours of curing in field normally needed to prevent scuffing and loss of slurry
- Slurry will bond only to clean pavement, existing pavement must be swept

Discussion highlights

- "We recommend that porous, rough textured pavement be primed with one part asphalt emulsion to 3-5 parts water" Mr. Kari
- "There is an optimal level of asphalt emulsion to minimize abrasion loss." Mr. Jimenez
- "Use of Hubbard-Filed, Marshall, or Hveem Stabilometer test with slurry seals is not practical." Mr. Kari
- "In early emulsion technology, finely-divided clays were used as emulsifying agents. Therefore, when asphalt, clay, and water are mixed together with sufficient energy, a stable emulsion results." Mr. Nady
- "Clay emulsion formulation requires not only water, clay, asphalt, and energy, but also the presence of flocculants and suitable control of acidity." Mr. Kari

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Full citation: Kari, W., Coyne, L," Emulsified Asphalt Slurry Seal Coats." Journal of the Association of Asphalt Paving Technologists, Vol. 33, 1964, pp. 502-544. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1964_v33_p502_Kari.jpg

Interested in learning more about asphalt emulsions? Search "asphalt emulsion uark"

Asphalt Emulsion Stabilized Soils as a Base Material in Roads

Review performed by Andrew Braham
February 10, 2020

Summary

- Developed evaluation system for soil stabilization that include procedures to:
  1. Select soil for possible stabilization
  2. Evaluate the soil-emulsion system
- R-value procedure primary test method
  - Three stages: before curing, after curing, after vacuum water soak
- Used kneading compactor for compaction
- Best R-values obtained when total liquid content (includes water and emulsion) 1-3% less than optimum moisture content of soil

Good candidate for soil stabilization: 1965 vs. 2020

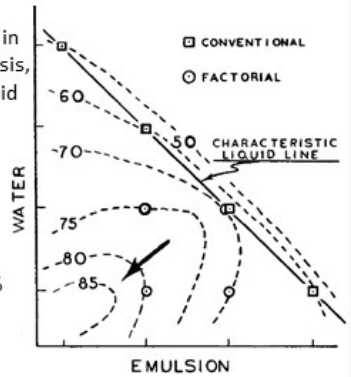
	1965	2020
Passing #200 sieve (%)	3-20	<20
Sand Equivalent	>25	>25
Plasticity Index	<5	<6

Resistance R-value overview

- AASHTO T190 (California Test 103)
- Two measurements
  - R-value: determines thickness of cover required to prevent plastic deformation of soil under wheel loads
  - Expansion pressure: determines thickness/weight of cover required to maintain compaction of soil

Experimental design

- Key definition: liquid content
  - Total water and emulsion contents in percent, calculated on a dry soil basis, asphalt emulsion is considered liquid
- Examined nine soils
- Four combinations of liquid content (ranged from 4-13%, soil dependent)
  1. On liquid limit line
  2. Reduce water content by 1%
  3. Reduce emulsion content by 1%
  4. Reduce water and emulsion by 1%
- Example soil (on right)
  - "Pseudo" maximum R-value = 70
  - "True" maximum R-value = ~85



- Used medium set cationic (SM-K) and slow set anionic (SS-1h)
  - Most of work with SM-K, SS-1h generally required higher liquid content (then dry back before compacting)

Findings

- Uncured R-values
  - Best reflect point at which soil is compacted to highest R-value, most sensitive to changes in liquid content vs. other two stages
  - Higher R-values obtained by increasing emulsion content
  - Optimal formulation 6-7% emulsion and 3-4% water
- Cured R-values (all cured at ambient temperature)
  - Dried back to 3-4% total volatiles at ambient temp, may take days
  - R-value ≥76 expected when stabilized base used vs. aggregate base
  - If <76, lower value taken as minimum required for cured specimen
- Vacuum water soaked R-values (only performed on cured samples)
  - Place samples in water, evacuate air at 100 mm of Hg, one hour, soak for one additional hour; R-value ≥60 after soaking recommended

Density discussion

- Dry basis densities of emulsion stabilized bases often greater than untreated soil at maximum density
- Both original soil and stabilized soil compacted with kneading compactor under similar conditions
- Less compaction effort required for emulsion
- Thought to be from lower surface tension caused by emulsifiers
- "Wetter water" penetrates better, allows for better utilization of compaction effort

Conclusions

- Full test methods developed and outlined for: 1) evaluation system, 2) R-value (very similar to AASHTO T190), 3) optimal moisture
- R-values of uncured, cured, and vacuum water soaked samples can evaluate suitability of emulsion stabilization for given soil type

Discussion highlights

- "It seems to me that the amount of water used in the process of soil stabilization varies with the type of mixing employed (lab vs. field)." Mr. Holberg
- "What does the R-value ≥60 after soaking mean in actual work?" Mr. Campen
  - "Arbitrary selection. Soils that are good have R-values of 70-80. More severe types of soaking have established a min of 60. Soaking generally decreases R-value by 5 or more." Mr. Dunning
- "I hope that this type of design will be used more in the bituminous field." Mr. Davis

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Full citation: Dunning, R., Turner, F. " Asphalt Emulsion Stabilized Soils as a Base Material in Roads." Journal of the Association of Asphalt Paving Technologists, Vol. 34, 1965, pp. 356-395. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1965_v34_p356_Dunning.jpg

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Evaluation of Asphalt-Treated Base Course Materials

Review performed by Andrew Braham
March 9, 2020

Summary

- This review will only discuss asphalt emulsion (SM-K), not asphalt binder or MC-800 which are also covered in the paper
- Existing layer equivalencies for asphalt-treated base course materials from AASHO Design Committee appear to be based on judgement rather than testing
- In general, layer equivalencies depend on:
  - Intensity of wheel load, wheel contact pressure, thickness of layer considered, stiffness of materials, subgrade characteristics, other materials, climate
- Asphalt emulsion also requires consideration of curing conditions
- This research utilized repeated-load triaxial compression tests to develop new layer equivalencies

Equivalency Factor

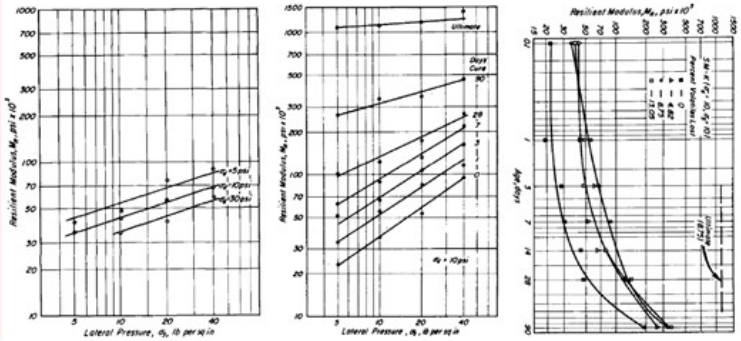
- For this work, definition: number of inches of compacted asphalt treated aggregate that will produce the same level of performance as one inch of asphalt concrete
- If structural coefficient (a) = 0.44 for asphalt concrete and 0.11 for gravel subbase, the equivalency factor for gravel subbase is 4.0
- From AASHO, equivalency factor of crushed rock ranges from 2.0 to 6.7
- From California, gravel equivalency factor ranges from 1.6 to 2.5, depending on traffic

Asphalt Emulsion Test Results

- Used SM-K (sand-mix cationic, medium set) asphalt emulsion with well graded partially crushed gravel, asphalt emulsion residue content = 5.3%
- Three factors for 68°F curing before compaction: time, volume loss, curing type

Time (days)	Vol. Loss (%)	Curing Type
0.0	0.0	Dry
0.5	4.8	Dry
1.0	8.7	Dry
2.0	13.1	Dry
1.0	8.8	Wet
0.0	0.0	Dry

- Figure on left: Resilient modulus vs. lateral pressure, no curing
  - SM-K more dependent on confining pressure vs. asphalt concrete
- Figure in center: Resilient modulus vs. lateral pressure with curing
  - SM-K changes from quasi-granular material to asphalt concrete after curing (ultimate reached from 180 days at 68°F and 14 days at 125°F)
- Figure on right: Resilient modulus vs. curing time
  - With curing, resilient modulus increases with an increasing rate



Layer Equivalency Values

- Surface loading: dual wheel load of 9,000 lbs, contact pressure 90 psi, 3" asphalt concrete, vary base
- Used five-layer elastic system
- SM-K moduli dependent on stress, temp, age

Base material	Summer	Winter
Asphalt concrete	1.00	1.00
Untreated aggregate	2.20	25.00
SM-K treated (uncured)	2.00	14.00
SM-K treated (cured)	1.20	1.50

Conclusions

- No one single layer equivalency can be assigned
- Layer equivalency increases with longer curing, fully cured emulsion almost equals asphalt concrete
- Curing of emulsion highly compromised during winter months – care should be taken with late season work

Discussion highlights

- "From a design standpoint, you must assess the performance of emulsion treated materials for at least two stages of curing, one at the time of construction and the second at full cure." Dr. Monismith
- "Our work, under moderate traffic on a weak subgrade, suggests a layer equivalency factor of 1.7, between the reported cured and uncured numbers by Terrel and Monismith?" Coyne and Kari, written.

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Full citation: Terrel, R., Monismith, C. "Evaluation of Asphalt-Treated Base Course Materials." Journal of the Association of Asphalt Paving Technologists, Vol. 37, 1968, pp. 159-199. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

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A General Method of Design for Seal Coats and Surface Treatments

Review performed by Andrew Braham
April 16, 2020

Summary

- Provides equations for application rate of cover aggregate and asphalt binder for single, double, and triple application
- Review of construction (climate, weather, surface preparation, equipment, construction operations, traffic control)
- 92 pages of paper and discussion!

Key definitions

- Surface treatment
  - One or more alternate applications of asphalt binder and cover aggregate to an unbound layer (soil, gavel, stone, etc.)
- Seal coat
  - One or more alternate applications of asphalt binder and cover aggregate to an exiting bound layer (paved surface)

Key concepts

- A strong foundation is needed (pavement structure must be sound)
- Potential distresses
  - Streaking, flushing/bleeding, loss of cover aggregate, delamination
- Aggregate ALD: average least dimension → average thickness equal to average of smallest dimension of cover aggregate particle
- Equations provided for single size cover aggregate single application, graded aggregate equations, and multiple applications provide for aggregate and binder

Cover aggregate (single size rock, single application)

- Hard, tough, clean, dry stone, cubical (Flakiness Index <35%)
- LA abrasion <20 (high traffic) or <35 (light traffic)
- Single size gradation optimal, 3/8"-1/2" (larger aggregate for heavier traffic)
- Voids fraction and specific gravity important
- Assuming relationship between ALD and thickness holds and voids between cover aggregate particles is 80%, cover aggregate over 1 yd^2:

$$C = 37.4HGE$$

where H = average least dimension of cover aggregate (in)
G = ASTM bulk specific gravity of aggregate
E = wastage factor due to traffic and uneven spread (table)

Asphalt binder (single size rock, single application)

- Hot applied asphalt binder, cutback, asphalt emulsion: residual key
- Should embed every cover aggregate to 70% depth and account for both aggregate absorption and surface absorption
- More asphalt binder needed for single-size gradation vs. dense grade
- Application temperature must ensure even, consistent application
- Higher traffic leads to lower application rate
- Quantity of asphalt binder at 60F should be applied at:

$$B = \frac{1.22HT + S + A}{R}$$

where B = total asphalt binder applied (gal/yd^2)
H = average least dimension of cover aggregate (in)
T = traffic factor (table provided)
R = fraction of residue asphalt in asphalt binder selected
S = surface texture correction (from existing pavement surface)
A = absorption correction from cover aggregate

Conclusions

- Equations provided for single, double, and triple applications, both aggregate and asphalt binder
- Extensive examples for single size rock/graded rock, single/double/triple applications & various scenarios
- Discussion on asphalt emulsion, asphalt cement, and cutback for binder component

Discussion highlights

- Three prepared discussions with an author's closure – we should do this more often in the 2000s!
- Observations from Texas and Mr. Chaffin:
  - Crushed limestone should be precoated
  - Lightweight/synthetic aggregate eliminates windshield damage
  - Be cautious with placing asphalt binder in two applications in cooler weather
  - Wheel paths often smoother, adjust nozzles to lower asphalt application rate longitudinally
- Observations from Canada and Mr. Holberg:
  - Most provinces use cationic asphalt emulsion, projects have been successful for 8+ years
  - Utilize Australian/New Zealand design method
- "I support Dr. McLeod's reference to the fact that a very large percentage of the world's roads are maintained by surface treatments." Mr. Edwards.
- "In emulsion treatments, the water serves three purposes. 1) lowers application viscosity, 2) serves as a carrier for adhesion agents, 3) effects a volume change (film collapse) to ensure bond yet minimize bleeding." Mr. Kari.

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Full citation: McLeod, N." A General Method of Design for Seal Coats and Surface Treatments." Journal of the Association of Asphalt Paving Technologists, Vol. 38, 1969, pp. 537-628. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

To download a clean version of the image, go to: www.andrewbraham.com/1969_v38_p537_McLeod.jpg

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Analysis of Results from the Dynamic Measurements Program on the San Diego Test Road

Review performed by Andrew Braham
May 11, 2020

Summary

- First review that addresses asphalt emulsion as a part of the pavement structure!
- 35 different pavement structures built, this paper examines 4 of those
- Elastic layered analysis utilized (N-Layer program from Chevron)
- Emulsion treated bases ranked 2 and 3 out of four total sections
- Field performance can be correlated to lab

Experimental procedure

- Pavement layers and subgrade characterized (elastic modulus and Poisson's ratio)
- Pavement response predicted using elastic layered analysis, compared to field results
- Adjustments were made in material properties to better match field measurements

Six test sections, 2 emulsion in report

- Class 2 agg., untreated (1 section)
- Type B agg., asphalt concrete (1 section)
- Special agg., emulsion treated (2 sections) ★
  - Cationic, medium set, soft pen (SM-K)

Instrumentation

- Test section 3 (4" HMA, 14" emulsion base)
  - Special agg., emulsion treated
  - Thermo-couple, strain gauges, LVDT set
- Test section 20 (4" HMA, 10" emulsion base)
  - Special agg., emulsion treated
  - Pressure cell, strain gauges, LVDT set

Comparing lab data to field performance: emulsion sections

- August 1966: one month after construction
  - Checked location and operation of strain gauges
  - Determined transverse truck location providing maximum response for front and rear wheels (0.10 feet, front wheels only)
  - 61% subsurface strain gauges not operational, 3 of 8 pressure cells worked, all LVDTs worked, thermocouples "generally" reliable
- February 1967: seven months after construction
  - Elastic modulus controlled by temperature, density, amount of curing, rate of loading, state of stress; poisson's ratio selected to be 0.4
  - Modulus ranged from 52,500 psi directly under asphalt concrete to 36,300 psi at subgrade soil interface for front wheels; 80 and 53 ksi rear
  - Lab versus field comparison ratio (predicted / measured) 0.3 – 2.9

Section	Type of Response	Front Wheel Field Average	Front Wheel Field 10	Front Wheel Predicted	Rear Wheel Field Average	Rear Wheel Field 10	Rear Wheel Predicted	Comparison Ratio (Predicted / Measured) Front	Comparison Ratio (Predicted / Measured) Rear
3 .25' A.C. 1.16' Emulsion Treated	Total deflection, inches	-	-	.004	-	-	.007	-	-
	Surface plus base deflection, inches	.005	-	.003	.015	.001	.004	0.6	0.3
	Strain, micro-inches Surface, longitudinal	151C	17	120C	203C	13	105C	0.8	0.5
	Surface, transverse	308C	46		250T	35		0.4	0.4
	A-level, longitudinal		-	185T	-	-	175C	-	-
	A-level, transverse	87T	13		117C	19		2.1	1.5
	B-level, longitudinal	19T	3	50T	-	-	-	2.6	2.9
	B-level, transverse	17T	3		-	-	-	-	-

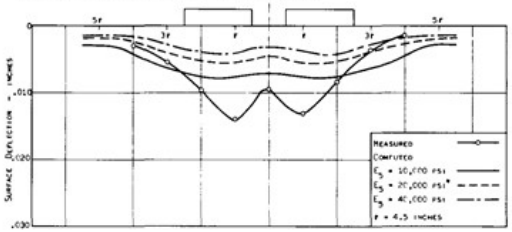
- April 1968: fourteen months after construction
  - Complex modulus higher than expected for base cores
  - Can estimate resilient modulus by:

$\log_e(M_R \times 10^{-3}) = 0.4 \times (\text{density, pcf}) + 2.46 \times (\#4 \text{ to } \#200 \text{ material}) - 0.015 \times (\text{pen, 77F}) - 1.13$

  - Lab versus field comparison ratio (predicted / measured) 0.1 – 1.4
  - Sections 3 and 20 "less satisfactory" than asphalt concrete treated
  - However, ranked 2 and 3 of four for surface longitudinal strain and maximum tensile strain, 1 and 4 of four for deflection

Conclusions

- Emulsion treated bases ranked 2 and 3 out of four, asphalt concrete base best, untreated fourth
- Lab tests should be able to provide theoretical predictions of deflection and strain
- Improvements can be made on embedded equipment and installation in the field
- Measured (solid with circles) versus predicted surface deflection, test section 3



Discussion highlights

- "I think that when one calculates under dual rear wheel (versus one single wheel load) there should be a difference between tangential and longitudinal strain," Mr. Klomp
- "From the data which you have presented some people may obtain the impression that the comparisons between measured and predicted values invalidate the use of elastic theory in the analysis of the response of pavements to loads." Dr. Monosmith
- "Current thinking would indicate that the SS-1h or SS-Kh (cationic) would probably be preferred for most emulsion stabilization constructions." Mr. Finn

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Full citation: Hicks, G., Finn, F. "Analysis of Results from the Dynamic Measurements Program on the San Diego Test Road." Journal of the Association of Asphalt Paving Technologists, Vol. 39, 1970, pp. 153-185. Interested in learning more about asphalt emulsions? Go to training.uark.edu and search "asphalt emulsion"

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