planks covered with $4\frac{1}{2}$ inches of concrete. This method shows promise of economical construction costs. Although this method has been used to a limited extent in other areas, it has not been tried on any Pennsylvania highway bridges.

To compare the different deck constructions, the bridge has been instrumented with strain gauges and deflectometers. These instruments are used to determine wheel load distributions, deflections, and stresses at many locations in the bridge.

One of the major problems is that bridge decks deteriorate and crack quite rapidly. Repair is not only expensive but is also inconvenient. Deterioration begins when the deck cracks slightly, allowing the penetration of moisture that causes the reinforcing steel to corrode and the concrete to crack even further. Deterioration is being monitored on the experimental bridge, and different deicing agents are applied during inclement weather to compare their effects on the rate of deterioration.

To date, only minor differences have been observed between the two different bridge constructions. The real test will come next spring when a four-wheel vehicle with 80,000 pounds on each wheel will be used.

The first cycle of research at the facility will continue through June 1974. At that time a new set of pavements and a new bridge will be installed for the second cycle.

"Weight will be applied until the bridge is no longer serviceable," commented Dr. Barnoff. "Then the bridge will be replaced and there will be more pavement tests—possibly more bridge tests with a different kind of bridge."

REPLACEMENT OF CUTBACKS WITH EMULSIFIED ASPHALT

W. J. Kari*

Engineers have long recognized that dissolving asphalt in gasoline and kerosene to produce RC and MC liquid asphalts results in a compromise product. Road performance is sacrificed for ease of handling. A low priority is placed on air pollution and fire requirements. The entire cutback system is viable only when there is an excess of energy fuels at low cost. The public concern for pollution, road and road maintenance costs, ecological imbalances, and resource depletion already has led to regulation, additional costs, and constraints to highway construction. Clearly, the programs for cutback replacement, started over 20 years ago, must be accelerated.

The need for improved road performance in urban and high-volume roads led to the replacement of cutbacks with asphalt cement in surface-mix construction. Emulsified asphalts replaced, in large measure, the use of cutbacks in maintenance surface treatments. As a result, the percentage of cutbacks used in road construction dropped from about 35 percent in 1952 to less than 20 percent in 1972.

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Air pollution considerations have created new problems with cutbacks. Solvents having less photochemical reactivity, commonly called "complying solvents," were tried. This approach was not feasible. The quantity of these special solvents was limited, costs were high, and control of cutback viscosity in storage was a problem.

To reduce vapor emissions at cutback storage locations, vapor pressure requirements were imposed in some areas. Costly storage and vapor return systems were required.

The concern for fire has led to restrictions. In critical fire areas, such as forests, cutback use is either prohibited or permitted only at select times of the year.

The cutback reformulation and special handling procedures have not resulted in a satisfactory solution to the problems of pollution or fire hazards. Also, the use of cutbacks has resulted in the annual loss of over one million tons (about 300 million gallons) of needed energy fuel. The HRB Committee on General Asphalt Problems, on reviewing the performance problems, fire hazards, pollution, and need for conservation of energy fuels, recommended that alternate materials for cutbacks be developed. Emulsified asphalt construction provides a viable alternative.

Most cutback construction can be done with emulsified asphalts. The recommended uses of emulsified asphalts as substitutes for cutbacks are given in Table 1.

All surface treatment and penetration macadam construction can be done with rapid-set type emulsified asphalts. CRS-1 and RS-1 are used in sand seal and penetration macadam construction. CRS-2 and RS-2 are used for

Table 1. Recommended use of emulsified asphalts to substitute for the use of cutback asphalts.

TYPE	Emulsified Asphalts													
	Anionic							Cationic						
GRADE / AASHO Designation	RS-1	RS-2	MS-1	MS-2	MS-2h	SS-1	SS-1h	CRS-1	CRS-2	CMS-2S*	CMS-2	CMS-2h	CSS-1	CSS-1h
ASPHALT BASE COURSES														
Plant Mix														
Open-graded aggregate - low pass No. 8 & No. 200			X	X	X						X	X		
Clean sand - 100%+ pass No. 4 0-10% pass 200						X	X			X			X	X
Graded aggregate - up to 12% pass 200						X	X			X			X	X
Mixed-in-Place or Travel Plant														
Open-graded aggregate - low pass No. 8 & No. 200			X	X	X						X	X		
Clean sand - 100%+ pass No. 4 0-10% pass 200						X	X			X			X	X
Graded aggregate - up to 12% pass 200						X	X			X			X	X
Sandy soil - to 20% pass No. 200						X	X			X			X	X
ASPHALT SURFACE, COLD LAID														
Sandy soil - to 20% pass No. 200							X			X				X
Graded aggregate - up to 12% pass 200							X			X				X
Open-graded aggregate - 3/8" max., 0-2% No. 200				X	X						X	X		
PENETRATION MACADAM	X							X						
SEAL COATS AND SURFACE TREATMENTS														
Fog Seal - light application without cover						X^1	X^1						X^1	X^1
Sand Seal - light application with sand cover	X							X						
Chip Seal	X	X						X	X					
Slurry Seal							X^2							X^2
PRIME COAT														
Tightly Bonded Surface														
Open Surface														
TACK COAT	X					X^1	X^1	X						X^1
DUST PALLIATIVE						X^1	X^1							X^1
PATCHING MIX														
Immediate Use			X^2	X^2	X^2						X^2	X^2		
Stockpile														

1 Diluted with water
2 Emulsion/Aggregate System evaluation required

* Designation of the Uniform Pacific Coast Specifications for Emulsified Asphalt

chip seals, although CRS-1 and RS-1 are occasionally used. The choice of using the cationic or the anionic grade is dependent on the aggregate and weather conditions.

Tack coats can be done with CRS-1 and RS-1. When a very light tack is needed, one of the mixing grade products, SS-1, CSS-1, SS-1h or CSS-1h, is diluted with water and applied. This gives a very light, uniform tack coat.

One maintenance technique, slurry seals, can only be done with emulsified asphalts. One of the mixing-grade emulsions can be used. However, the trend is to controlled set products such as QS-h and CQS-h (QS-Kh). Although these are not yet included in AASHO specifications, they are widely used. The quick-set emulsified asphalt slurry seals develop tensile strength rapidly by a controlled chemical reaction. The slurry has early traffic and rain resistance. Thus the need for traffic control is reduced.

Not all cutback applications can be suitably done with emulsified asphalts meeting current AASHO specifications. Prime coats and stockpile patching mixes made with cutbacks perform better.

Prime coats require a binder that penetrates soil or untreated aggregate. Because emulsified asphalts consist of discrete particles of asphalt ranging from about 2 to 8 microns in size, they will not penetrate dense, tight surfaces. If the spaces between soil particles are small, the soil acts as a filter, screening out the emulsified asphalt particles. The emulsified asphalt particles collect on the surface, forming a sticky, black skin. There are, however, emulsions that will penetrate fine soils. These emulsions contain oils and resins to lower binder viscosity and aid in soil penetration. Several agencies use these emulsions. Work is needed to develop functional AASHO specifications for emulsified primes.

The need for a prime has been the subject of heated debate in engineering circles for years. Are they really functional? Primes appear to be most useful on untreated bases to protect the surface from wind, rain, and traffic erosion during construction. With full-depth asphalt construction and when using asphalt stabilized bases, a prime coat is not needed.

Stockpile patching mixes can be made successfully with emulsified asphalts of the MS and CMS type. No specific grade is designated in Table 1 because selection of emulsified asphalt grade and type is dependent on the aggregate. In most cases, a special formulation is required, one containing oils and cutters in addition to asphalt. These additives are needed to give the mix workability, stockpile life, and setting rate needed by the customer. Special stockpile emulsions are used by several user agencies. Again, work is needed to develop stockpile binders, construction specifications, and AASHO product specifications.

Cold-mix base and surface construction can easily be done with emulsified asphalt in place of cutbacks. However, the best techniques for emulsified asphalt construction are not necessarily the same as for cutbacks. The benefits of emulsified asphalts, i.e., ease and speed of mixing, high production rates, and mix uniformity, are best achieved in high-volume, cold-mix stabilization plants. The plants can be portable, as shown in Figure 1, or fixed, as shown in Figure 2. Alternatively, travel plants can be used. Travel plants are sometimes advantageous, as was the case on a recent airport shoulder stabilization project. The work was done at night so runway use was not affected. The grade level was maintained so the aircraft had a shoulder for emergencies.

Mixed-in-place construction, where asphalt is sprayed on the aggregate followed by blade mixing, is more difficult with emulsified asphalts than cutbacks. Emulsified asphalts of the MS and CMS type quickly revert to asphalt and rapidly develop high cohesive strength. If construction is delayed, the

Figure 1. Portable emulsified asphalt mix plant.

Figure 2. Emulsified asphalt cold-mix plant.

high tensile strength of the mix makes it more difficult to compact and to finish to a smooth surface. This coupled with the usual mixed-in-place problems of achieving mix uniformity, coating, and proper pavement thickness, makes emulsified asphalt blade mix construction difficult.

Cold-mix emulsified asphalt surface course design requires an aggregate modification. More binder is required than with hot mix, since the asphalt content of emulsified asphalts is 60 to 70 percent of the total. Increased voids in the mineral aggregate are needed to accommodate the increased fluids. If the voids in the mineral aggregate are low, the emulsion mix must be cured to optimum moisture prior to compaction, a time-consuming, hard-to-control, risky business.

Open-graded emulsion mixes have increased in use. These mixes are made with aggregates having little or no fines. There is interest in these open-textured, free-draining pavements to improve skid resistance. Plant-mixed CMS-2h open-graded surface mixes are used extensively in high-rainfall areas such as the Pacific Northwest.

The treatment of dust with emulsified asphalt also differs from cutbacks. Since emulsions do not penetrate into fine materials, it is necessary to do some mixing. About 5 to 20 percent CSS-1 or SS-1 emulsified asphalt is diluted with 80 to 95 percent water and sprayed on the dusty surface. It is immediately mixed thoroughly with a drag broom or by towing a section of link fence. In some cases, a rotary mixer is attached to the back of a tank truck.

There are proprietary dust oil emulsions that contain a blend of resins, oil, and asphalt. These are spray-applied. The oil-resin-asphalt blend penetrates because of the low viscosity of the oil.

Summary

Cutbacks already have been replaced in many paving applications by processes using asphalt cement. The remaining applications can be handled by emulsified asphalt. Current AASHO emulsified asphalt grades handle most work, either as direct substitutes or with changes in construction procedures. Emulsified primes, stockpile materials, and dust palliatives, although not in AASHO specifications, have been developed and are specified by some user agencies. The major need is to make known the available product and construction technology through FHWA research implementation programs, demonstrations, and state-of-the-art reports.