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FOAMED ASPHALT BASE STABILIZATION

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Introduction

Foamed asphalt base stabilization is a roadway recycling process in which all of the pavement and some of the underlying material is pulverized and treated with a foamed asphalt additive to produce an improved, stabilized base. This status report presents lessons learned from current usage in California of the base stabilization process called *foamed asphalt, cold foamed asphalt* or *expanded asphalt*, hereafter referred to as *foamed asphalt*.

Foamed Asphalt Discovered and Defined

Hot liquid asphalt cement (350°F/177C) reacts when a small amount of cold water is injected into it, as discovered in 1956 by Professor Ladis Csanyi at the Engineering Experiment Station at Iowa State University at Ames. The foaming action expands the asphalt, making the asphalt mixable much in the way that beating an egg white makes it easier to mix with dry ingredients. Particles stick together and form a paste which does not harden immediately.

Foamed asphalt, according to Muthen, Lewis and Vos, in "Mix Design Procedure for Foamed Asphalt," a paper presented in South Africa in 1999, is:

"a mixture of pavement construction aggregates and foamed bitumen. The foamed bitumen … is produced by a process in which water is injected into the hot bitumen resulting in spontaneous foaming. The physical properties of the bitumen are temporarily altered when the injected water, on contact with the hot bitumen, is turned into vapor which is trapped in thousands of tiny bitumen bubbles. However, the foam dissipates in less than a minute and the bitumen resumes its original properties. In order to produce foamed asphalt, the bitumen must be mixed with the aggregates while still in the foam state."

Muthen, Lewis and Vos further reported that for decades following its discovery, foamed asphalt was not utilized in North America, even though it had been patented for use in North America by Mobil Oil. Europe and South Africa were first to adopt the process. Initially, the process called for steam to be injected into the bitumen, but this process was not widely used because it required specialized equipment, namely boilers, on the construction site. Mobile Oil of Australia, having acquired the patent, modified the process to use cold water instead of steam in 1968; this made foamed asphalt more economical and, therefore, more acceptable. See figure 1 for a diagram of the foamed asphalt process as it is used in California today.

Construction Process

While the foaming action may take less than 15 seconds, once mixed with aggregates the foamed asphalt remains workable for long enough to complete compacting, grading and finish-rolling. Aggregates may include pulverized material from the existing roadway, soils, additional processed or native aggregates, or additives such as cement or fly ash.

Foamed asphalt recycling equipment is usually run in a "train" with one piece of equipment closely following the next. For example, the recycling or mixing machine can be coupled with an asphalt supply tanker and a water cart. The recycler propels the tanker in front and pulls the water cart behind. Typically, the foamed asphalt is compacted with a sheepsfoot roller, then rough graded, compacted with a smooth, steel-drum roller, then fine graded, and finally finished by pneumatic rubber tire roller.

Often a roadway can be recycled and reconstructed at a rate of one to two lane miles per day, and the finished pavement can be opened to traffic within a few hours of production. A chip seal or hot mix overlay can be placed within two days.

Benefits

Foamed asphalt boasts low engineering and production costs, produces a high quality product, and is more environmentally friendly than traditional demolition and re-construction because it recycles materials from the existing roadway. Benefits include:

Cost. Binder material and transportation costs are reduced because foamed asphalt requires less binder and water than other types of cold mixing. Use of materials from the existing roadway reduces the need to acquire and transport "virgin" materials, which are rising in cost as permits become more difficult to obtain for new aggregate extraction sites (pits and quarries) in California. Unlike asphalt emulsions which are processed, the liquid asphalt cement is pure, making it more economical. Costs can be low enough that "small jurisdictions may be able to put a project together within [their] maintenance budget, as opposed to new construction," suggests Dick Stuart, General Manager of Western Stabilization (quoted in *Better Roads,* July 2003).

Environmental. The re-use of existing pavement conserves material and energy since old paving material is not hauled away and discarded. Reduced truck traffic to and from the job site translates into reduced fuel consumption and vehicle emission levels. Energy is also conserved because only the bitumen needs to be heated. Air quality is not as severely impacted because no evaporation occurs and volatiles are not released, as they would be in conventional asphalt construction.

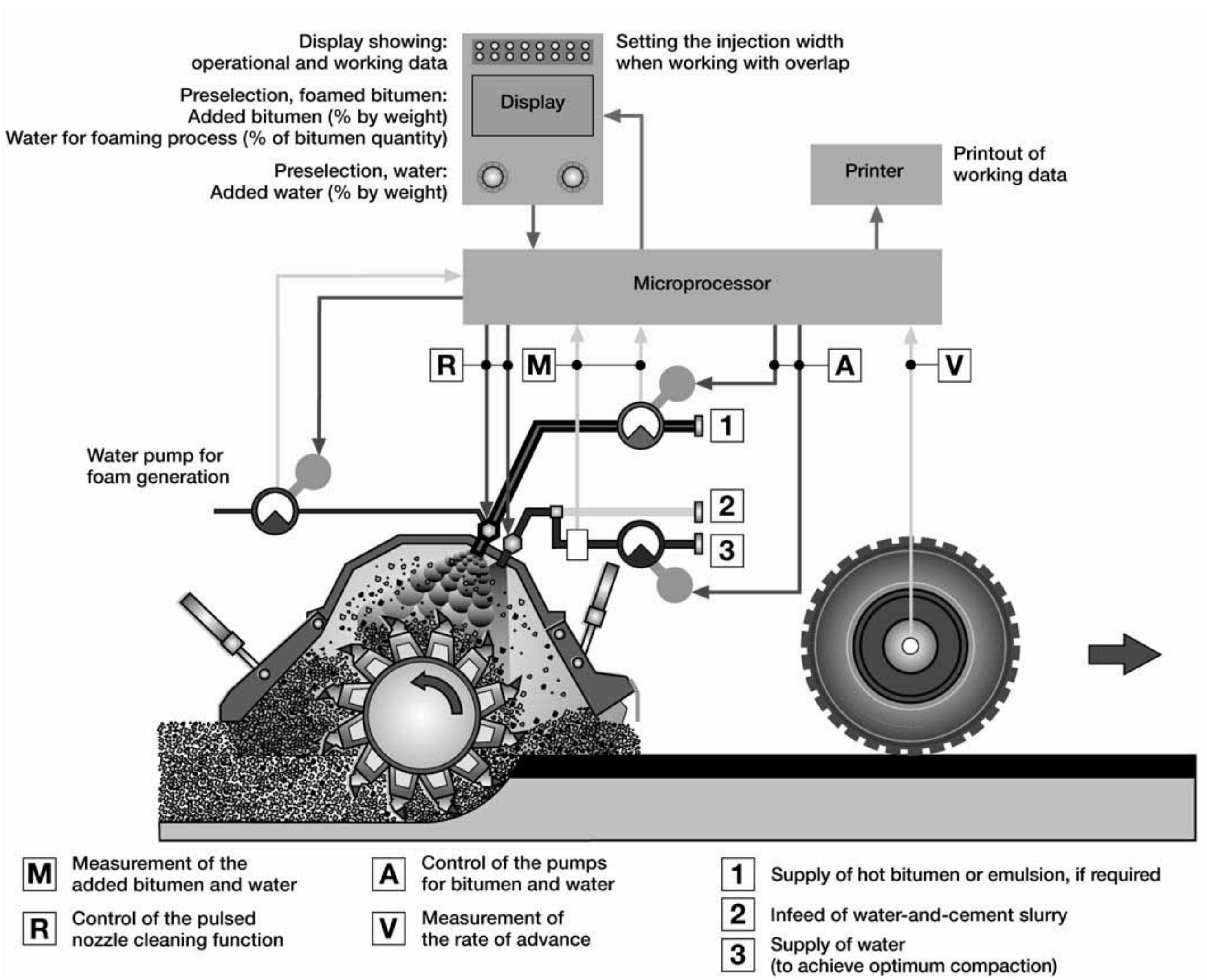
Material Properties. The foamed asphalt process rebuilds the roadway from the bottom up, and can eliminate symptomatic problems associated with the existing road bed, such as reflective cracking and shallow base failure. Foamed asphalt is more flexible and fatigue resistant than cemented materials, with strength characteristics approaching those of cemented materials, and it can be used with a wider range of aggregate types than other cold mix processes. Foamed binder increases sheer strength and reduces moisture susceptibility of granular materials.

Construction. Compared to conventional road construction methods, such as dig-out and overlay or gut-out and rebuild, foamed asphalt decreases the amount of time that workers spend in the work zone. Distance from a hot mix asphalt (HMA) plant is not a factor, since all heating and mixing is done at the work site. Weather does not significantly affect the workability or the quality of the finished product, allowing work to be completed in cold weather and even in light rain. Material can be stockpiled with no binder run-off or leaching.

FIGURE 1

The Foamed Asphalt Recycling Process

Graphic courtesy of Wirtgen GmbH



Traffic. Foamed asphalt can be compacted immediately, and can carry traffic almost immediately following compaction. Often the entire process from pulverizing and injecting to final rolling can be completed in 30 to 45 minutes.

California's Experience

In the United States, the first reported use of foamed asphalt was by the Georgia Department of Transportation, in Ware County in 1982. In California, public agencies began to consider using the process in 1998/1999, when Western Stabilization of Dixon, California, sponsored an information session in the Sacramento area to introduce foamed asphalt to Caltrans and to county and city transportation and road departments. Glenn, Yuba and Solano counties volunteered to host demonstration projects. Western Stabilization agreed to provide pulverizing/foaming equipment pro bono while the county agencies would provide materials, personnel and such equipment as graders and compacting rollers. The demonstrations took place during May 2000.

Caltrans has since used foamed asphalt on SH20 west of I-5, on SH89 in Plumas County, on SH132 in Modesto and on SH220 on Ryer Island in Solano County. Led by Joseph "Joe" Peterson, PE, Caltrans' North Region Materials Engineer, Caltrans has also assisted local agencies in learning how to work with foamed asphalt.

Over eighteen foamed asphalt projects have been completed in California by FHWA (one project), by Caltrans (four projects), and by five counties and two cities (over a dozen local projects). See table 1 for a summary of the completed foamed asphalt projects in California. For this report, I contacted individuals in all of these jurisdictions,[1] and all but one, Glenn County, were enthusiastic about foamed asphalt and expected to use the process again.

The four foamed asphalt projects completed by Caltrans total approximately 3.5 million square feet of roadway. Baldwin Construction, Argonaut Construction, and Teichert Construction were the prime contractors for these projects, all of which used Western Stabilization as the specialty subcontractor to perform the pulverizing and foamed asphalt injection, which was done using a Wirtgen 2500 or a Wirtgen 3000 machine with self-cleaning chambers as the pavement recycling system.

The FHWA foamed asphalt project completed in California reconstructed 1.3 million square feet of Old Marysville Road, a forest development highway located in portions of the Plumas and Tahoe National Forests and maintained by Yuba County under a cooperative agreement. The project employed Baldwin Construction as the prime contractor and Durham Stabilization as the specialty subcontractor. Durham Stabilization used a CMI 650 Foam System, modified to perform similarly to a Wirtgen.

In addition to these federal and state projects, nearly 2.9 million square feet of California's urban, rural and residential roads have been reconstructed in local projects by counties and cities. Of these local agencies, Yuba County is one of the most active in using foamed asphalt. Kevin Mallen, Director of Public Works, and Van Boeck, Managing Engineer, who led the county's participation in the May 2000 demonstration, completed their fifth foamed asphalt project in November 2003. According to Van Boeck, the process has been cost effective and the county will continue to use it.

Although they did not participate in the May 2000 demonstrations, Yolo County, like Yuba County, was an early adopter of the foamed asphalt process, and has undertaken several large projects. Darlene Comingore, Senior Civil Engineer for the Department of Planning and Public Works, believes the process to be cost-effective because materials are recycled (and credited to Yolo County's recycling efforts), and because traffic can be allowed back onto the treated section within a short period of time.

Glenn County, host to a demonstration project in 2000, was the only jurisdiction interviewed dissatisfied with the

[1] Sixteen interviews were conducted for this report. Individuals included one representative from FHWA, two from Caltrans, nine from cities and counties, and four contractors. They provided specific information on foamed asphalt projects in California and their experiences working with the foamed asphalt process.

TABLE 1

Completed Foamed Asphalt Projects in California

	Surface Area (sf)	Road Length	Depth	Riding Course	Prime Contractor/ Specialty Sub-contractor	Additive	Cost* (per sf)
FHWA							
Old Marysville Rd[1a]	731,680	5.2 mi	5”	4” AC	Baldwin Construction/ Durham Stabilization	2.5% asphalt & 1% cement	$0.30
Old Marysville Rd[1b]	570,280	4.8 mi	8”	3” AC	Baldwin Construction/ Durham Stabilization	2.5% asphalt & 1% cement	$0.32
CALTRANS							
SH20	1.5M			AC	Baldwin Construction/ Western Stabilization	1% cement	
SH89	1.2M			AC	Baldwin Construction/ Western Stabilization	1% cement	
SH220	382,000			chip seal	Argonaut Construction/ Western Stabilization	1% cement	
SH132	361,290			AC	Teichert Construction/ Western Stabilization	4% fly ash	
GLENN COUNTY							
Road P	130,000			double chip seal & AC leveling	In-house/Western Stabilization (foaming machine only)		
TEHAMA COUNTY							
Kauffman Avenue	150,000	1.8 mi					
Residential		1000 ft					
Sherwood Road		1 mi					
YUBA COUNTY							
Hammonton/Smartville Rd	1.1M	7 mi	9-12”				$0.24
McGowan Parkway	74,480						$0.56
Spenceville Road	242,580						$0.39
Ella Avenue							
Wheatland Road							
YOLO COUNTY							
Several projects[2a]	467,188	6-7 mi			Teichert Construction/ Durham Stabilization		$0.37[2b]
AMADOR COUNTY							
Site 1	348,500		6”				$0.34
Site 2	122,000		6”				$0.45
CITY OF CHICO							
City street	89,661						$0.25 - $0.35
CITY OF DAVIS							
Residential streets	160,000				Teichert Construction/ Western Stabilization		$0.70

*Cost of performing the foaming, excluding the asphalt and cement costs, but including the full train (foamer, sheepsfoot roller, two graders, steel drum roller and rubber tire roller). Figures may have been rounded.

1a Existing AC surface over lime stabilized clayey base

1b Existing AC surface over aggregate base

2a Several large projects on predominantly rural, agricultural roads with high ADT

2b The county requested that the project be pre-pulverized by the subcontractor; by this change order, the county received a credit back of $0.37 per sf end smoothness of the foamed asphalt, which may have been a result of their "non-standard" use of equipment for the process. The Glenn County Department of Public Works (DPW) operates in a rural, agricultural region with limited resources and a small population. They generate their own aggregate and perform most road projects in-house. The demonstration project was performed on Road P between County Road 24 and 25. Unlike other demonstration counties, Glenn County chose to use its own workforce and equipment to perform all of the work for the demonstration, with the exception of the foaming machine provided by Western Stabilization. They used only one grader, and did not use a sheepsfoot roller or rubber tire roller. The resulting smoothness of the finished foamed asphalt pavement did not meet Glenn County's expectations. Even after placing a double chip seal on top of the foamed asphalt, an additional asphalt concrete (AC) leveling course was required. Douglas Holvik, Director of the Glenn County Public Works and Development Services Agency, indicated that the process did not suit their particular needs.

Lessons Learned

Limited number of contractors. Adoption of the foamed asphalt process in the US has been delayed by the limited availability of equipment capable of making foamed asphalt application efficient and economical. Currently, only two contractors in Northern California specialize in the foamed asphalt process: Western Stabilization and Durham Stabilization. In Southern California, another company, Pavement Recycling, uses the Canadian Sotar machine for foamed asphalt. A fourth company, Anrak, has obtained machines and is considering entering the field. Presumably, as the demand from agencies increases, more specialty contractors will enter the field.

"Equipment" versus "method" specification. Initially, Caltrans contracts for foamed asphalt projects used "equipment" specifications particularly suited to the Wirtgen machinery. Many local agencies patterned their contracts for foamed asphalt projects after Caltrans', adopting similar special provisions for "equipment." The Caltrans specifications have since been reviewed by a committee of Caltrans pavement engineers and industry representatives. Future contracts for foamed asphalt projects will use a "method" specification that opens up the specialized foaming process to contractors with alternative equipment. FHWA has already performed one project in California using this "method" specification.

Pre-construction testing. Joe Peterson, Caltrans' resident foamed asphalt expert, believes that "pre-engineering is very important." Because the mix design uses actual, in-situ materials that can vary widely in composition, placement, and quality, advance testing is necessary to achieve optimum mix design. Testing should confirm the suitability of the sub-grade to react positively with the stabilizing agents and to accurately determine subsurface moisture.

Most agencies, however, lack the specialized equipment and in-house expertise needed to perform the pre-construction analysis and design. In California, only Caltrans and one engineering geotechnical consulting firm have the equipment needed to develop the "R" resistivity value of the in-situ material and the Traffic Index (or TI, based on vehicle trips, especially of trucks, over the proposed design period). Others must outsource this pre-construction work; some have had to go out-of-state. As demand increases the number of geotechnical firms equipped to perform pre-construction testing will probably increase.

Testing performance specifications. Many jurisdictions require test strips to determine whether the contractor and equipment will be able to perform to specifications. In Yolo County, the Department of Planning and Public Works requires that the contractor complete a test strip before proceeding with in-place asphalt foaming to assure that the completed project will meet all of the intended targets of the design. Yuba County management and staff affirm that they now have sufficient experience with foamed asphalt to confidently evaluate each project from the

outset, and have therefore discontinued including the test strip as a bid item on their projects

Even when a test strip is required, some jurisdictions remain concerned about the ultimate conformance of the final product to initial design intent. On FHWA's Old Marysville Road project, Edward Hanson indicated that the "final product did not meet the anticipated design values," although in the after tests the "project turned out looking and riding very good." On the other hand, Amador County was pleased with initial foamed asphalt results; however, after only five months portions of Site 1 showed cracks, mostly internal, in the two inch AC overlay. Investigation is underway to determine the cause.

Use of pre-pulverizing equipment. An existing roadway can be pulverized and foamed in one pass, or the existing roadway can be pre-pulverized then re-pulverized and foamed in a second pass. The one-pass method is highly suitable for a roadway with shallow asphalt (only two or three inches) and very consistent depth, but can also be used with success in other circumstances.

Caltrans does not presently allow pre-pulverization on state highway projects out of concern that the equipment might break down and cause severe traffic delay. However, Robert Durham, of Durham Stabilization, said that he prefers pre-pulverizing, because it actually seems to decrease the chance of other equipment breakdown during the re-pulverizing and foaming process.

Use of pre-pulverizing equipment may require adding another lane to the work zone. A pre-pulverizer run on the center-line of a two-lane road will close the entire roadway for the duration of reconstruction. However, a foamed asphalt train without pre-pulverizing equipment can be run in a single lane, leaving the opposite direction open to traffic. For this reason, pre-pulverization may be more acceptable on local roads where detours are available, or for very low volume roads where the entire road can be closed.

For the FHWA project on Old Marysville Road, Durham Stabilization used CMI pre-pulverizing equipment on the center-line in advance of two other CMI machines which applied the foam mixture. The pre-pulverizer had difficulty processing large aggregates (cobbles) and did break down. However, the break down did not cause undue delay. The follow-up machines performing the foaming process were still able to complete that day's operations, and the contract requirement to allow free flow traffic (ADT 1500-2000) by the afternoon was met. With pre-pulverization, the process averages about one road-mile or two lane-miles per day.

Pre-pulverization has also been used with success by the City of Davis on residential streets. According to Nancy McKee, Project Engineer for the Davis Public Works Department, treated sections were pre-pulverized in order to remove some material, so that proper cross-sections could be re-established. Ms. Mckee also noted that traffic was restricted on the residential streets for only the short time that it took to complete the operation, and that residents were not severely inconvenienced. Under a conventional pavement rehabilitation operation (requiring a crew to dig out, replace, and compact), residents would have been inconvenienced for several days, instead of hours.

Adding aggregate to existing base material. New aggregate can be added to the base material and pulverized along with this existing pavement to augment a structural section, to restore a cross-section, to re-establish a crown, or even to increase the percentage of fines required for compaction. Both Yuba and Amador counties have had success using additional aggregate. On some projects, Yuba County provided the additional aggregate outside the contract specifications; on others, the county included the extra aggregate as a bid item.

Roadways with curbs and gutters. Roadways with curb and gutter sections can also be candidates for the asphalt foaming process, as demonstrated by the City of Davis project on residential streets. Nancy McKee, Project Engineer, said that the roadway immediately adjacent to the gutter and curb was left untouched, so that it would be possible to retain a smooth transition to the rest of the structural section. Ms. McKee indicated that the process worked very well.

Smoothness. The foamed asphalt process appears to be a viable option in rural areas, as long as the surface is sufficiently smooth that an agency can use chip seals as the riding surface, and avoid a costly asphalt concrete (AC) leveling or riding course. Many agencies prefer to use chip seals for the riding course due to the high cost of AC, which in rural areas of this state can run well in excess of $50/ton, and because the agency can save additional labor costs by performing the work in-house.

Given the quick-setting action of the foaming process, compacting and grading must be performed by very efficient and well-qualified equipment operators in order to achieve the level of smoothness necessary for chip seals to be used for the riding course and to afford a smooth ride. On one Yuba County project, the recycling, compacting and grading performed during daylight hours produced a very smooth surface, which would have been an excellent candidate for a chip seal riding course. However, it should be well-noted that the portion worked at dusk and night did not turn out so smooth. And, as illustrated by the experience of the Glenn County demonstration project, chip sealing a surface that is not sufficiently smooth to begin with will not produce a satisfactory result, and may require placement of an additional AC leveling course anyway.

Note also that the use of an AC riding course will not guarantee smoothness either. Several completed foamed asphalt projects in California which have AC riding courses have undulations and rough paving seams. When AC is used for the riding surface, a leveling course may be required, as well. Although a very good inspector can require the paving machine operator to make appropriate adjustments that will decrease roughness and undulations, two layers of AC may still be necessary.

When the foamed asphalt is sufficiently smooth, chip seals can be used as the riding course. The SH220 project, which used a chip seal riding surface on a low-volume (AADT 260, Peak Month ADT 340) road on Ryer Island (accessible only by ferry), is currently performing and riding well, according to both Caltrans and Solano County personnel.

Conclusion

Foamed asphalt base stabilization produces a stronger, longer-lasting pavement at a fraction of the cost and time than would be required for conventional reconstruction. Foamed asphalt is a viable, cost-effective, environmentally-sensitive method to rehabilitate a roadway or street which has significantly deteriorated from wear, or which was not originally constructed with a proper structural section.

Some agencies are hesitant, however, to try foamed asphalt, because they lack experience with the process, because of the scarcity of available testing consultants and their perceived high-costs, or because the life expectancy for the product can not yet be accurately predicted. In answer to concerns regarding the life expectancy of sections rehabilitated with foamed asphalt, I might point out that all of us who have spent our working careers trying to build, rebuild and maintain roadways, have seen conventionally implemented projects fail. We also realize that the determination of a structural section is dependent upon many factors, including but not limited to, evolving design criteria and construction practices, the abilities of the construction supervisors, the quality of materials used and ultimately the practice of long term maintenance.

In my opinion, this process is well worthwhile. All agencies should take interest. Foamed asphalt, which recycles the existing roadway materials, should be especially interesting to rural agencies on limited budgets and without ready, available access to raw materials and asphalt plants.

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All photographs courtesy of Caltrans.

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