Cold Recycling Using Foamed Bitumen

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ABSTRACT

Distressed Hot Mix Asphalt (HMA) pavements are able to be cold recycled to serve as a structural base for higher-quality and longer-lasting HMA overlays. The relatively new technology of foamed bitumen as the recycling agent has been proved effective through field trials and research projects around the world during the late-1990s. Today, contractors have several reliable production solutions to foamed bitumen stabilization.

Recycling is the ultimate solution to achieving major structural strengthening of the deteriorated pavement. One category of recycling project is characterized by large machines, intense activity and high production rates. These machines have enormous output potential as work progresses linearly, leaving behind a finished pavement structure that normally requires only surfacing for rideability and smoothness. The other category of recycling is done on a smaller scale. Both types of recycling have value for 'green' construction activities.

The construction equipment 'train' consists of the recycling machine, transports for stabilizing agents and water, motor grader and compaction equipment. Careful planning and coordination of this equipment is necessary to achieve optimum pavement structure performance, including durability and strength.

Cold recycling, using foamed bitumen, can be more cost-effective on larger projects where equipment depreciation is amortized over larger material volume. On smaller recycling projects, the advantage may still reside with alternative stabilizing additives. Proper planning and pre-construction cost evaluation will determine which material and technology is superior.

1 Introduction

1.1 Background

One of the more energy-efficient mechanisms for rehabilitation of distressed HMA (Hot Mix Asphalt) pavements is CIR (Cold, In-place Recycling). As described in the ARRA (Asphalt Recycling and Reclaiming Association) *Basic Asphalt Recycling Manual*, CIR "consists of recycling asphalt pavement without the application of heat during the recycling process to produce a rehabilitated pavement". Further, "CIR is undertaken on site and generally uses 100 percent of the RAP (Reclaimed Asphalt Pavement) generated during the process". The equipment utilized for the CIR process is typically mobile so that RAP material transportation costs are avoided or minimized.

The concept of foamed asphalt was developed in 1956 by Professor Ladis Csanyi at Iowa State University Engineering Experiment Station when he introduced steam into hot asphalt cement. The small amount of steam caused the hot asphalt, at the temperature of 350 degrees Fahrenheit (approximately 177 degrees Celsius), to foam like black shaving cream and increase its volume by about fifteen times. Its viscosity also significantly decreased during the foaming process. The first reported use of foamed asphalt was fifty years ago, in 1957, on an Iowa county road. Other early field applications in North America were in Arizona in 1960 and in Canada during the period 1960 to 1962.

In 1968, Mobil Oil Company of Australia modified and improved this process by injecting atomized cold water, instead of steam, into the hot asphalt within a low pressure expansion chamber; Mobil then patented their method for North America. Their action

Figure 1.1-1 typical Cold In-place Recycling project

prevented widespread use of the technology in the United States until this US patent expired. Outside of the United States, Australia, many European countries and South Africa had completed a number of successful recycling projects using foamed asphalt and had developed laboratory testing protocols for this technology.

A number of equipment manufacturers from Europe and the United States also quickly recognized the potential of foamed asphalt for cold in-place recycling applications and began to simplify foaming systems and to improve their reliability and safety. The main advantage of foamed asphalt recycled pavements is that they develop close to full strength immediately after placement and compaction. This, of course, permits opening of the recycled base to traffic to minimize construction delays. In addition, the cost of recycling with foamed bitumen is comparable to the cost of recycling pavements using other additives (such as asphalt emulsion, lime, and Portland cement) depending upon local availability of the selected additives and regional pricing of these alternatives stabilizing agents. The ultimate strength of the recycled material can vary somewhat, depending upon the type and amount of stabilizing additive selected. Combinations of additives may also be selected, under certain conditions.

1.2 Objectives

This presentation has been developed to assist attendees to the TAC (Transportation Association of Canada) 2007 Annual Conference understand the state-of-the-industry for CIR using foamed bitumen. Two of the more recent, larger-scale field projects will be discussed. General cost data for the foamed bitumen recycling application will be presented. Explanation of the technology utilized for introduction of the foamed bitumen into the RAP will be provided and a pictorial record of one of these projects will be depicted. At the end of the presentation, appropriate references for contemporary technical assistance with this technology will be identified.

1.3 Definitions and Terminology

AADT (Average Annual Daily Traffic) – AADT is the most common method of measuring vehicular traffic on a highway system.
ARRA (Asphalt Recycling and Reclaiming Association) – ARRA is an organization consisting of contractor, supplier, affiliate and honorary members commonly interested in the enterprise of "rebuilding a stronger and safer network of highways, streets and roads across the country and around the world". Headquartered in Annapolis, Maryland, USA, ARRA efforts are led by an elected Board of Directors.
BARM (Basic Asphalt Recycling Manual) – The BARM is a publication of ARRA which includes practical and technical information on the topics of rehabilitation strategies, project evaluation, HIR (Hot In-place Recycling), CP (Cold Planing), FDR (Full Depth Reclamation), and CR (Cold Recycling).
CP (Cold Planing) – Cold Planing is the controlled removal of an existing pavement to a desired depth, longitudinal profile, and cross-slope, using specially designed equipment.

CR (Cold Recycling) – Cold Recycling consists of recycling asphalt pavement without the application of heat during the recycling process to produce a rehabilitated pavement. Two sub-categories exist within the CR process: CIR (Cold In-place Recycling) and CCPR (Cold Central Plant Recycling).

CIR (Cold In-place Recycling) – CIR is a rehabilitation treatment involving cold milling of the pavement surface and remixing with the addition of asphalt emulsion, Portland cement or other modifiers to improve the properties, followed by profiling and compaction of the reprocessed material in one continuous operation.

CQS (Cationic Quick Setting) emulsion – CQS is a quick-setting cationic slurry emulsion used for a variety of construction applications.

DOT (Department of Transportation) – The acronym DOT is used to describe any of the individual state highway agencies involved with transportation within their own local jurisdictions.

ESAL (Equivalent Single Axle Load) – Based on the original AASHO Road Test results, an ESAL is defined as the commonly used standard load of 8,165 kilograms (18,000 pounds) over a single vehicle axle.

FHWA (Federal Highway Administration) – The FHWA is major agency of the United States of America Department of Transportation (DOT) charged with the broad responsibility of ensuring that America's roads and highways continue to be the safest and most technologically up-to-date.

FWD (Falling Weight Deflectometer) – The FWD is a non-destructive field testing device used by civil engineers to measure the physical properties of a pavement.

FDR (Full Depth Reclamation) – FDR is the rehabilitation technique in which the full thickness of the asphalt pavement and a predetermined portion of the underlying materials (base, sub-base, and/or subgrade) is uniformly pulverized and blended to provide an upgraded homogeneous base material. FDR is on the roadway without the addition of heat, similar to CIR.

Foamed Asphalt or Foamed Bitumen – Foamed asphalt or bitumen is expanded in volume and softened through controlled addition of air and water in an expansion chamber. The foam mixture then distributed (in controlled volume) through spray nozzles into the mixing chamber of a mobile mixer where the bitumen attaches itself to fines in the mix, creating spot "welds" rather than uniform particle coating.

HMA (Hot Mix Asphalt) – HMA is the combination of aggregates and a binder, mixed at elevated temperatures to reduce viscosity of the binder and used for flexible pavement construction and repair applications.

HR (Hot Recycling) – HR is the process of combining RAP with "virgin" aggregates, new asphalt binder, and/or recycling agents in a central plant to produce a recycled mix. Specially designed or modified batch or drum mix plants use the heat-transfer method to soften the RAP to permit its mixing.

HIR (Hot In-place Recycling) – The HIR process consists of heating and softening the existing asphalt pavement to permit it to be scarified or hot rotary milled to a specified depth. The loosened pavement is then thoroughly mixed with "virgin" aggregate, new binder and/or recycling agents, then placed and compacted with conventional paving equipment.

HVS (Heavy Vehicle Simulator) – The HVS is a mobile test device used by agencies to subject roads to accelerated trafficking. It can simulate 20 years of road deterioration in as little as three months.
QA (Quality Assurance) – QA is the activity of providing evidence needed to establish confidence among all concerned, that quality-related activities are being performed effectively.
QC (Quality Control) – QC is a process for maintaining proper standards in construction or manufacturing by employing systems to ensure that products or services are designed and produced to meet or exceed customer requirements.

2 Foamed Bitumen Process

2.1 Current foaming technology

The currently-employed technology for producing foamed bitumen is much advanced from the Mobil Oil Australia process of adding cold water into a stream of hot asphalt in a low pressure system first used in 1968. A major improvement has been in the design of the expansion chamber; the accuracy of the mixing process has also been greatly improved. Remember, there needs to be a 'controlled' volume of air introduced into the expansion chamber along with the asphalt and water to help activate the foaming process. The illustration to the right (figure 2.1-1) depicts the mechanism for foam creation. The proportioning of air and water flow is critical, as is the temperature of the asphalt cement.

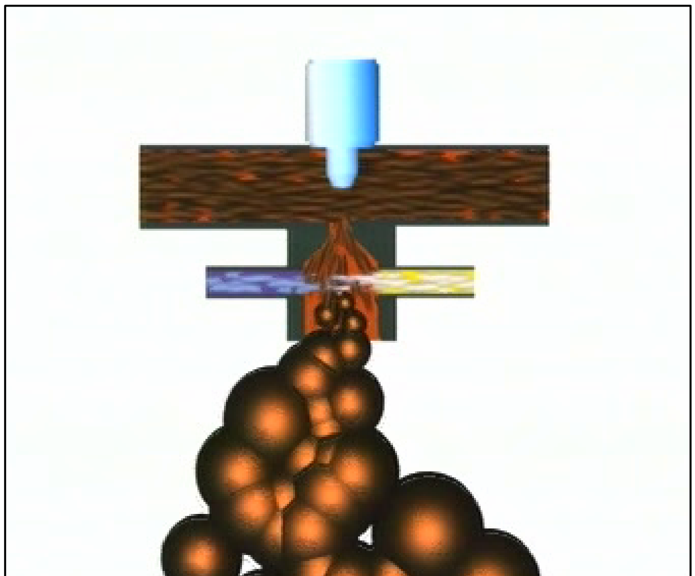

Figure 2.1-1 Foaming action

The relative volume of air compared with water is typically proportioned two parts water to one part air, with the water being equal to between 2-3% by weight of the hot bitumen. When injected into the hot bitumen, the water evaporates abruptly, thus causing explosive foaming of the bitumen in the saturated steam. The bitumen thus expands 15 to 20 times its original volume. The bitumen used for this process is usually ordinary penetrated-graded asphalt cement; its temperature must be carefully controlled in order for the foaming process to produce the requisite volume of foam.
The intensity and effectiveness of the foaming process can most effectively be governed by controlled operation of the basic physical conditions, such as pressure and temperature. In the machines produced by the manufacturer, Wirtgen GmbH, this

process takes place in individual expansion chambers where the water is injected into the hot bitumen, which has a temperature of approximately 180 degrees Celsius (approximately 355 degrees Fahrenheit) and a pressure of approximately 5 bar (approximately 75 pounds per square inch). The foamed bitumen, thus produced "in-situ", escapes the expansion chamber through a nozzle and can then immediately be mixed with the RAP or mineral aggregate to be treated.

2.2 Field techniques

There are a number of manufacturers who commercially offer equipment for the Cold In-place Recycling application. Each manufacturer of this equipment has its own unique system for injecting the stabilization additive(s) into the mixing chamber of the machinery. Most of these systems incorporate some degree of volumetric control of additive; a few use sophisticated microprocessor-controlled systems.

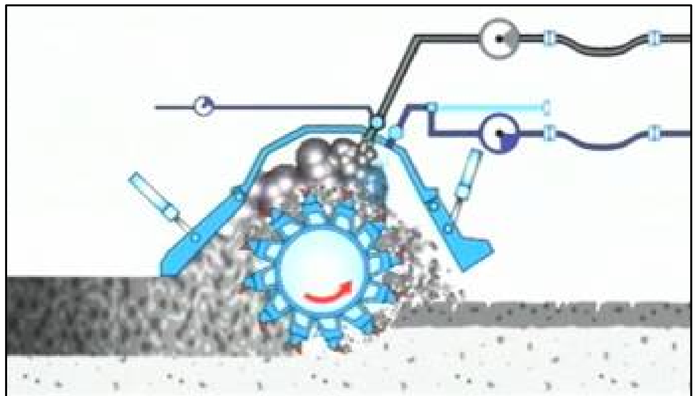
Figure 2.2-1 recycler mixing chamber

The mechanism for adding the stabilizing agent is typically through spray nozzles and one or more spray bars, each with separate control. There are usually automatic and/or manual provisions for keeping the spraying nozzles clean and working efficiently. Nozzles are able to be individually controlled on some systems to vary the effectiveness of the mixing operation. For some recyclers, multiple spray systems may be installed for injection of additive slurry, water to increase material moisture content, and foamed bitumen.

3 Caltrans I 80 construction project

The State of California Department of Transportation North Region designed a CIR project for Interstate Route 80 in Placer County. Project evaluation was the first step in the construction process. It was necessary for a comprehensive site investigation to be conducted in order to quantify the quality and quantity of RAP that will be processed during the recycling procedure. In addition, laboratory determinations of the asphalt foaming characteristics and mix design were completed prior to beginning construction.

Since any recycling procedure may be carried out in either a single step or in two or more stages, determination of the depth or thickness of the pavement deterioration is important. It is not prudent use of resources to pulverize deeper than necessary to remove distressed pavement. While the foaming action may occur in less than 15 seconds, once mixed, the foamed bitumen generally remains workable for long enough to complete initial compacting, grading and finish-rolling operations.

3.1 Equipment train

Foamed asphalt recycling equipment usually operates in a "train" with each piece of equipment closely following the previous machine. For example, the foam mixing machine is usually coupled with an asphalt supply tanker and water supply. Often, the recycler actually pushes the tanker and/or pulls the water supply. For the Caltrans Interstate 80 project, an 11,350 liters (3000 gallons) capacity truck supplied the

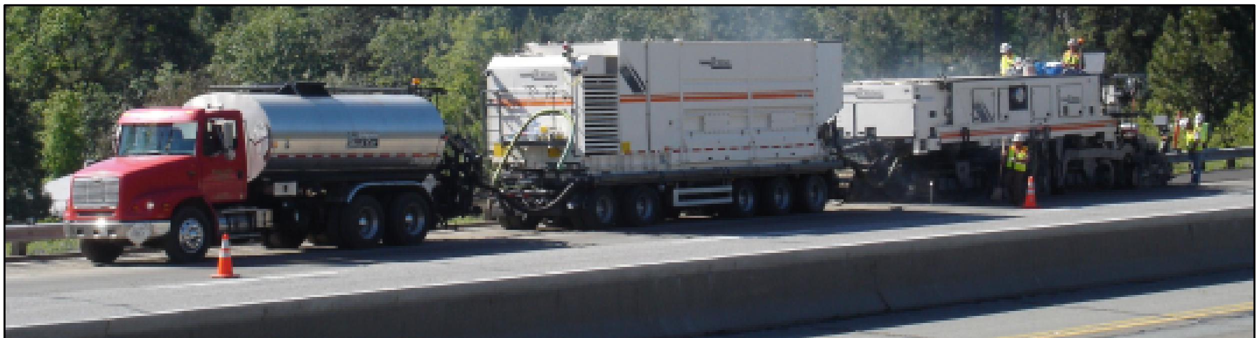

Figure 3.1-1 Bitumen truck, slurry mixer and recycler

bitumen needed for the foaming process. It was connected to a Wirtgen model WM 1000 cement slurry mixer and Wirtgen model WR 4200 recycler with integrated paving screed as shown in the photograph above, figure 3.1-1. The WM 1000 mixer has an on-board water storage tank with 11,000 liters (2906 gallons) capacity, plus cement storage capacity of 30 cubic meters (883 cubic feet). This mixer is a high-performance machine which eliminated the problem of fugitive dust by precision metering and mixing the cement and water prior to pumping this slurry to the cold in-place recycler. [Keep in mind that, for most recycling applications, only a minor addition of cement (approximately 1 percent by weight) is necessary; excessive addition of cement will contribute to formation of shrinkage cracks which can ultimately detract from the long-term reliability and stability of the stabilized base.]

The WM 1000 cement slurry mixer used on the Interstate 80 project pumped its precisely monitored volume of slurry into the cutter chamber of the WR 4200 recycler, where it was uniformly blended with the pulverized pavement. The foamed bitumen was also injected into the mixing just behind the cement slurry, but at the same time as the slurry, to uniformly blend all additives with the pulverized asphalt pavement. The foaming process was utilized on the Caltrans project to take advantage of the temporary alteration of the physical properties of the hot bitumen into a vapor consisting of millions of tiny bitumen bubbles. As the foam dissipated upon cooling (typically in as short as 15 seconds and less than 60 seconds), its volume reduces to its original state but was now attached to the fines in the RAP in a non-continuously bound

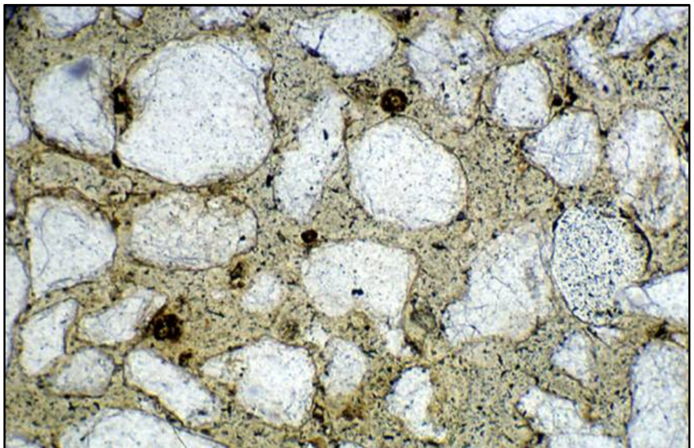

Figure 3.1-2 foam distribution

state. This creates countless individual elastic points of adhesion between the reclaimed asphalt particles to give the material structural value nearly equal that of a HMA base. The photograph (figure 3.1-2) of a compacted RAP specimen shows non-continuous asphalt cement bonding.

Immediately following this recycling train were two tandem axle steel drum rollers and a single pneumatic-tired roller to accomplish necessary compaction of the recycled base to 96 percent relative compaction according to California Test 216 for Theoretical Maximum Density. The contractor on this project had performed a start-up test strip to verify material characteristics and establish a rolling pattern to achieve density. This pattern was maintained throughout the project. Analysis of in-place density readings from nuclear gauge tests, using California Test 375, on this project averaged 98 percent, as shown in Table 3.1-1 below.

Table 3.1-1

Analysis of Density Testing	**Percent of Relative Compaction**
Highest Density Value	99.5
Lowest Density Value	97.1
Average Density Value	98.0
Standard Deviation	0.60

In-place Density Readings from nuclear gauge tests

3.2 FWD (Falling Weight Deflectometer) testing

In the interest of quantifying the relative effectiveness of the recycling process using foamed bitumen, a series of field tests were conducted on two pavement sections within the project's physical limits. One of the sections tested was a portion of the project that had been recycled with foamed bitumen using the Wirtgen WM 1000 and WR 4200 equipment train. The other section was a more typical reconstruction technique using conventional 'mill and fill' procedures. The section thickness for both sections was the same, being approximately 90 millimeters (3.5 inches). Both sections were supported by nearly identical CTB (Cement Treated Bases) and AS (Aggregate Sub-bases). Measured surface modulus in both sections is shown in Figure 3.1-3 on the next page.

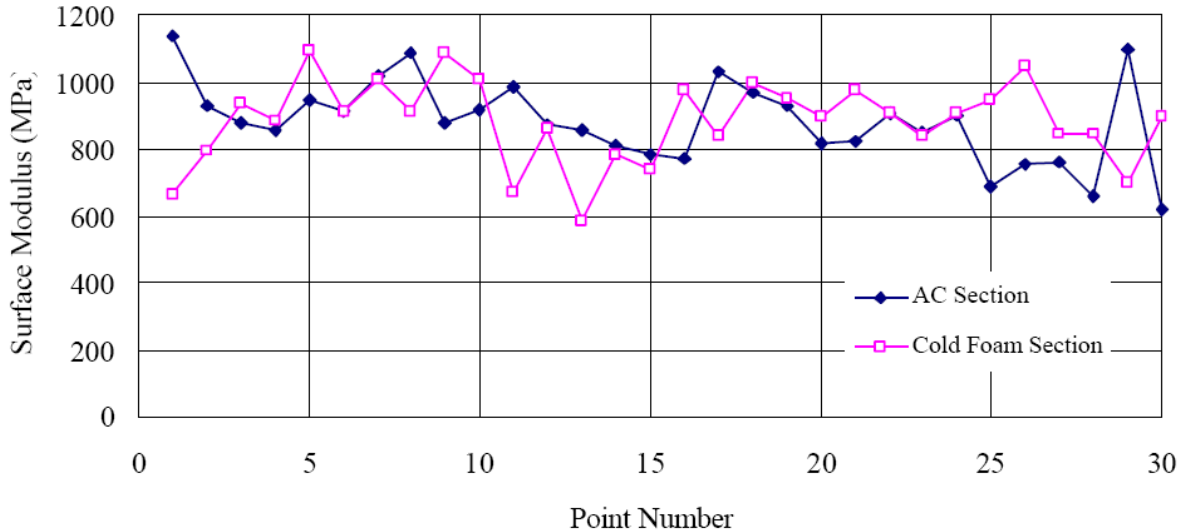

Figure 3.1-3 Falling Weight Deflectometer values

Figure 3.2-3 dynamic cone penetrometer

The dynamic cone penetrometer (DCP) test is commonly used to measure the relative strength of materials planned for incorporation into a pavement structure. By driving a probe of specific cross-section into the layers a minimum of 800 millimeters or deeper, it is possible to predict the performance of the sub-base or sub-grade layers. DCP tests can be done on sandy or other coarse-grained materials for reasonable correlation with the CBR (California Bearing Ratio) test. Correlations to Unconfined Compressive Strength (UCS) values are also possible for some plastic or lightly-cemented soils. Numerous tests are typically done. The data obtained is used for pavement analysis.

Performing the test is simply performed, with recording of penetration depth for the standard test blows. A number of computer programs are available to assist in data analysis.

3.3 Constructability

Due to the layout of the roadway, it was predetermined that pre-grinding of the pavement surface would be necessary in order to maintain existing cross slope in sections where multiple lanes were present and where permanent facilities like guard rail or median barrier were in place. This was done prior to the recycling operation for expediency.

In addition, it was determined through testing that there would be between 10 to 12 percent volume increase between the existing pavement and the recycled material following its expansion through addition of bitumen and cement. In addition, the minor difference in in-place density of the existing pavement prior to recycling and the recycled product was expected to slightly increase the 'bulk' of the homogeneous base. To compensate for this change, pre-grinding was done with depth varying from approximately 12 millimeters (½ inch) to 25 millimeters (1 inch).

3.4 Cure time

For the typical CIR project using foamed bitumen, compaction of the material needs to be completed before moisture content in the material falls too far below optimum moisture content. The rolling pattern selected for this Caltrans project consisted of a breakdown rolling coverage with one steel drum roller, intermediate rolling with two coverages of a second steel drum roller and three coverages of the pneumatic compactor. This rolling pattern was usually completed within 30 minutes following recycling.

Figure 3.4-1 fog sealing operation

Following compaction, the surface of the new base was fog sealed until curing of the base was complete. The pavement design called for minimum 3 days curing prior to overlay; maximum curing time was set at 7 calendar days This is, of course, climate and weather dependent. Of interest to note, because of the historically high traffic volume on this roadway, it was determined that a fog seal of Cationic Quick Setting (CQS1) asphaltic emulsion, with an application rate between 0.03-0.06 liters per square meter (0.008-0.015 gallons per square foot) would be required. Construction activities soon established that this application rate was excessive for the Interstate 80 project, even following placement of sand as a blotter.

Construction vehicles tracked the fog seal and even picked up the surface of the base, exposing uncoated material that would lead to rapid raveling. The practical solution identified was to decrease the application rate by approximately 25 percent residual and to place sand blotter at the rate of between 0.1-0.2 kilograms per square meter (0.5-1.0 pounds per square foot).

Cure time prior to trafficking was discovered to be highly dependent upon ambient temperature variables; higher ambient reduced cure time and lower ambient increased cure time required. For this project, the recycled base was opened to traffic in about 4 hours. [This was prior to the base being sealed with its overlay.] This short closure time greatly improved traffic flow through the construction zone and minimized traffic delays. [Please note that the four hours delay in opening the construction zone to traffic was due to extenuating circumstances on this particular project, where unusually high rainfall occurred during construction and where extremely high truck traffic volumes were being experienced prior to and during construction. It is normally expected that a compacted base can be immediately opened to traffic.]

3.5 "Green" benefits

Probably the most significant contribution to economics that is received from the Cold In-place Recycling process is through the significant reduction in transportation of materials. For example, by re-using the aggregates in the existing pavement structure, it is possible to eliminate the requirement to haul away the RAP from the cold planing operations for stockpiling. CIR also eliminates the added requirement to truck in Hot Mix Asphalt to replace the total volume of RAP removed plus any additional pavement thickness required to achieve the designed improvement in pavement structural stability. For the Caltrans Interstate 80 project, it was calculated that the CIR process using foamed bitumen permitted elimination of 4,700 haul truck round trips between the project and site for RAP stockpiling and the source of HMA for replacement paving. It was estimated that each round trip would approximate 80 kilometers (50 miles) distance. Total projected haul vehicle travel distance savings was 378,115 kilometers (235,000 miles).

3.6 Materials conservation

This I 80 project total linear distance of Cold In-place Recycling was 140.27 kilometers (87.18 miles), with fourteen different segments of construction. It is estimated that the recycled aggregate in the existing pavement represented approximately 101,700 tonnes (112,100 tons) of aggregate and 2540 tonnes (2800 tons) of asphalt cement. Recycling with foamed bitumen eliminated the need to produce new HMA mix for replacement of milled pavement sections, if the 'mill and fill' process had been selected for this project.

Another significant material saving was for diesel fuel. There are actually two elements to this savings. The first component is more difficult to quantify, but the CIR process eliminated the need to produce HMA. Whether this mix would have been provided from a batch plant or drum mix plant is not known, but clearly no diesel fuel or other fuel type was required to fire the burners for heating of aggregates or asphalt cement to produce Hot Mix Asphalt. More easily quantified is the savings in fuel for haul vehicles. Based on an estimated average fuel consumption rate of $0.66 per liter ($2.50 per gallon) for the contractor's fleet of haul trucks, elimination of 378,115 kilometers (235,000 miles) of travel saved $58,750.

3.7 Traffic flow

Traffic on the section of Interstate 80 that was recycled is moderate to heavy, with a relatively large truck traffic proportion. The twenty year Traffic Index ranges from 14.0 to 14.5; Equivalent Single Axle Loads (ESALs) from truck traffic range from 41 to 55 million. Average Annual Daily Traffic (AADT) for the various project sections ranged from 100,000 in the vicinity of Auburn, California with truck volume approximately 8.5 percent to 38,500 in the Colfax vicinity with 16 percent trucks. Maintenance of traffic was a major consideration for selection of Cold In-place Recycling as the preferred construction procedure. Heavy truck traffic in the early morning between 5:00 am and 9:00 am and the moderate grade change between Auburn, elevation 376 meters (1234 feet), and Colfax, elevation 738 meters (2420 feet), encouraged the contractor to compensate for the changes in grade by placing an HMA pavement section at the beginning and end of each completed section of recycled pavement. These 4.5 to 6 meters (15 to 20 feet) long sections of HMA pavement acted as 'shock absorbers' between the 'cured' and 'fresh' recycled pavement sections to prevent truck traffic from causing minor surface irregularities at these interfaces. This technique worked and helped to compensate for frequent (and sometimes) heavy rainfall during the 2005 construction season. The excessive water actually saturated the sub-grade soil underlying the Cement Treated Base and worked its way up through cracks in the CTB to the interface between the recycled material and HMA surface.

The recycled material actually supported traffic for up to 30 days on the mainline and 60 days on the shoulder before being overlaid with HMA. This extended period of unprotected traffic exposure had no detrimental effect on the surface of the recycled material. Keep in mind that this project was the highest volume roadway in the United States to be recycled and, prior to surfacing, immediately opened to traffic. This proved to the contractor and to Caltrans that recycling with foamed bitumen permitted opening of construction sections to traffic within four hours of completion of recycling operations. It further proved that these pavement base sections could remain open to traffic for extended periods of time prior to their overlay with HMA surfaces.

As an added benefit, it was observed that the CIR operation eliminated claims for windshield damage during the recycling operations. In comparison, there were multiple claims for vehicle glass damage where 'mill and fill' operations were done.

4 Alaska Red Dog Mine project

Wirtgen was invited by a general contractor from Anchorage, Alaska to assist them with the development of a specification, work plan and construction of a foamed bitumen test section for the rehabilitation of the primary haul road at the Red Dog Zinc Mine in northern Alaska. This property's remote location encouraged the use of the Cold In-place Recycling application. The stabilization using foamed bitumen was determined to be a practical construction solution following evaluation by Wirtgen's team of experts.

4.1 Site details

The haul road from the mine site, 80 kilometers (50 miles) inland, winds down to the port where the zinc is stored prior to loading onto barges for shipment to processing facilities. Studies of vehicular traffic discovered that an average of thirty-three trucks, loaded to approximately 218 tonnes (240 tons) capacity, made the daily round trip from mine to port and back. Each of these trucks was equipped with eleven axles total. In addition to these haul trucks, the road also carried a selection of belly-dump trucks with 63.5 tonnes (70 tons) gross weight, with five axles, and fuel trucks with nearly 109 tonnes (120 tons) gross weight and seven axles. Assuming no increase in traffic volume or change in axle loads, the calculated load on this haul road would be nearly 26, 500,000 ESALs over a ten year period.

Figure 4.1-1 haul truck with eleven axles

4.2 Roadway condition

The haul road base material had deteriorated with time and heavy loading; it was also showing signs of slight plasticity. Over time traffic had loosened the top layer of rock [nominal size 12 – 50 millimeters (one-half inch to two inches) and had trafficked this material off to the sides of the roadway. Original road construction had placed approximately 300 millimeters (12 inches) of this nominal size rock for a top surface; only about one-half of this material [about 125 millimeters (5 inches) remained in place that was suitable for recycling. The rock layers underlying this layer were too large dimensionally for practical recycling, sized 100 – 150 millimeters (4 – 6 inches) nominal or larger.

Figure 4.2-1

Evaluation of the anticipated traffic loads and volumes indicated that a foamed bitumen layer of 250 millimeters (10 inches) depth would be needed for proper support of haul truck traffic. Therefore, it was determined to add another 125 millimeters (5 inches) of crushed rock to the top of the existing gravel base prior to recycling. A suitable source of rock was locally secured, a crushing plant was set-up, and suitable material was produced with adequate fines to suit the foamed bitumen process.

4.3 Construction

A trial section of the existing haul road was selected for recycling; it was located just inland of the fuel island. The section to be worked was 9.1 meters (30 feet) wide and 7.2 kilometers (4.5 miles) in length. Crushed rock was dumped onto the existing pavement, roughly shaped and then compacted.

Figure 4.3-1 WR 2500 S at work

A Wirtgen WR 2500 was coupled to a water and bitumen supply truck combination unit. It pulverized the recently placed crushed rock and underlying aggregate to a depth of 250 millimeters (10 inches), simultaneously adding 3 percent foamed bitumen along with sufficient water to increase the moisture content of the recycled material to Optimum Moisture Content (OMC) for compaction. The full width of the roadway was processed, including the extreme road edges, to provide stability for fully-loaded haul trucks without lateral surface displacement.

A vibratory pad foot drum compactor was utilized for initial compaction of the recycled material. Following initial compaction, a motor grader profiled the surface of the roadway to facilitate drainage and run-off. A vibratory steel drum roller was utilized to achieve target density in the material, following the rolling pattern developed in the test strip for this work. Following this compaction by vibration, the recycled material was lightly watered, then rolled with a pneumatic roller to achieve a smoother surface texture that would be both impermeable and provide better rideability.


Figure 4.3-1 compaction with pad foot roller

Following this final rolling procedure, a high-float emulsion was applied to the foam stabilized base for sealing. A chip spreader was used to lay down a 12 – 19 millimeters (one-half to three-quarters inch) thick chip seal that was then rolled using the pneumatic compactor to seat the chippings into the emulsion. The processed section of roadway was then opened to haul vehicle traffic without limitations.

4.4 Performance

The Cold In-place Recycled roadway section was carefully monitored for condition during the months following its construction. Comparisons between the foamed bitumen-treated section and untreated sections of the haul road discovered totally acceptable performance from the treated pavement. In comparison, the untreated road showed sections of severe surface distress created by a period of heavy rainfall in the fall.

5 Future considerations

5.1 Foamed bitumen use – construction site evaluation


Figure 5.1-1 WLB-10 foam lab

The critical elements for any highway or other roadway reconstruction project include the forensics of pavement failures and investigation of site conditions for determination of exactly what materials and environmental factors must be considered for the subsequent repair technique. In addition, samples of typical materials from the site need to be tested in the laboratory for suitability for the foaming process. Wirtgen has developed a mobile, laboratory-scale foamed asphalt plant that is ideally suited to establish foamed asphalt mix designs. Agencies, consultants, contractors, Departments of Transportation or other users of foamed asphalt can obtain an advance look at how foamed asphalt will perform with a variety of materials and liquid asphalts. This apparatus, the WLB 10, permits accurate testing of the foaming properties of the liquid asphalt grades to be used, so that best results are obtained during actual construction.

Pavement rehabilitation requirements must also practically consider current as well as future traffic loads and volumes, taking into account those realistic structural coefficients and pavement layer thicknesses that will be actually constructed. Paying attention to these details is imperative for successful construction to be completed. Quality Assurance (QA) and Quality Control (QC) must also be exercised during all construction operations.

5.2 Comparison to alternative techniques

The future of Cold In-place Recycling is extremely promising. Because of the growing concern over conservation of our natural resources and due to continuing increases in the costs for petroleum products, the need to re-use the aggregates and binders in existing pavements is apparent. From a different perspective, the motoring public is increasingly annoyed by construction delays and interference with their daily commutes to shopping, the work place and other destinations. Foamed Bitumen recycling permits a project to be turned over to trafficking immediately following compaction to specified density.

Increasing traffic volume, especially with on-highway trucks, is damaging much of our highway and roadway infrastructure, making improvement of road bases more critical. Since removal and replacement techniques like 'mill and fill' are transportation intensive, the alternatives of in-place procedures are more attractive to agencies and specifers alike.

5.3 DOT and FHWA developments and prognosis

Since the year 2000, several state Departments of Transportation (DOTs) and the Federal Highway Administration (FHWA) Federal Lands Highway Division have completed hundreds of kilometers (miles) of in-place recycling and reclaiming projects. Based on the successes experienced on these projects, it is logical to expect continuing CIR applications to be done by these agencies. It is also expected that other state and federal agencies will evaluate the work already done and prepare contracts for Cold In-place Recycling projects in their jurisdictions.

The specific application of using foamed bitumen rather than another stabilizing agent also shows significant promise for the future. Unlike other stabilizing agents which rely upon coating of the aggregate for effective strength improvement, foamed asphalt relies upon non-continuous binding. Significant volume increase occurs in the foamed state of up to fifteen times; subsequent dispersion of the foam creates countless tiny bubbles of asphalt binder that attach themselves to the fines in the pulverized material. Since many distressed pavements yield a measurable percentage of fines during the recycling process, the requirement for a minimum of 5 percent fines (and maximum of about 20 percent fines) makes this application suitable for the majority of roadways and similar structures.

5.4 Structural benefits

Scientific investigations have concluded that there is measurable structural benefit for creating thick, stabilized layers of road base through the CIR process. It is recognized that the bending stiffness of a stabilized layer is much greater than a layer of similar thickness which is not stabilized.

Using the American Association of State and Highway Transportation Officials table for structural layer coefficients as a guideline, (refer to figure 5.4-1 below) it is known that natural gravel has a coefficient of 0.040 per centimeter (0.10 per inch); graded crushed stone has a slightly higher coefficient of 0,055 per centimeter (0.014 per inch). In comparison, bitumen (normal emulsion) treated base has structural layer coefficient ranging to a maximum of 0.12 per centimeter (0.30 per inch). Foamed asphalt base is even higher to a maximum of 0.14 per centimeter (0.35 per inch), nearly equal to the structural coefficient for HMA bases or surfaces.

AASHTO chart

MATERIAL TYPE	CHARACTERISTIC	STRUCTURAL LAYER COEFFICIENT (per in / cm)
Asphalt surface	Elastic Modulus 2500 to >10,000 MPa	0.20 to 0.44 / 0.080 to 0.170
Asphalt base	Continuous graded, 6% voids	0.20 to 0.38 / 0.080 to 0.150
Foamed asphalt base	10 to 16% voids	0.13 to 0.36 / 0.051 to 0.140
Bitumen-treated base		0.10 to 0.30 / 0.040 to 0.120
Graded crushed stone	CBR > 80%	0.14 / 0.055
Natural gravel, type 1	CBR 65 to 80%	0.12 / 0.047
Natural gravel, type 2	CBR 40 to 65%	0.10 / 0.040
Soil, type 1	CBR 15 to 40%	0.08 / 0.032
Soil, type 2	CBR 7 to 15%	0.06 / 0.024
Cohesionless sand	PI = 0	0.04 to 0.05 / 0.016 to 0.020
Cement-treated stone	UCS 1.0 to 3.0 MPa	0.17 / 0.067
Cement-treated gravel	UCS < 1.0 MPa	0.12 / 0.047

Figure 5.4-1 AASHTO structural layer coefficients chart

5.5 Other benefits

In addition to the structural benefits identified in the previous paragraph, the use of foamed bitumen as a stabilizing agent also helps to significantly reduce or even eliminate the problem of fatigue cracking within pavement structures. Due to the nature of the bond between the dispersed asphalt cement particles and the fines in the mixture, it has been clearly demonstrated that stabilized pavement sections can be significantly displaced without developing structural cracks. Heavy Vehicle Simulator (HVS) testing done in South Africa and by other agencies showed that foam bitumen recycled pavements could be permanently deformed with displacement up to 6 millimeters (one-quarter inch) or more with no cracking. The testing done in South Africa applied 7 million load repetitions of an extremely heavy load, E80, and caused no cracks to form in the 250 millimeters (10 inches) thick stabilized base layer. For this testing, 1 percent Portland cement was added to the material (in addition to 2.3 percent foamed bitumen) to decrease its moisture susceptibility and to increase its strength.

6 References

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10. *Foamed Asphalt Mixes - Mix Design Procedure,* Contract Report CR98-077, June 1999.

7 Additional Information

1. ARRA web site, web address: www.arra.org
2. Dunn Company web site, web address: www.dunnco.com
3. Federal Highway Administration web site, web address: www.fhwa.dot.gov
4. Wirtgen America, Inc web site, web address: www.wirtgenamerica.com