Special Report

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Asphalt Alternatives

Asphalt Pavement Contractor Options in a Market of Escalating Petroleum Prices and Dwindling Asphalt Supply

by Gayle King and Helen King

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EXECUTIVE SUMMARY

The uncertainty of liquid asphalt price and supply in 2008's erratic petroleum crude markets placed tremendous strain on the asphalt industry's competitive position and ability to complete work. This report reviews a number of short- and long-term alternatives that the industry might implement to counter such trends, if and when they occur in the future. With crude prices already below $50 per barrel, 2008 may be exceptional. However, recent events warn that petroleum resources are limited, and refining trends to produce more fuel from heavy vacuum tower bottoms will continue. Further, highway agencies are asking for perpetual or "long-life" pavements while reporting ever-increasing traffic loads. How can the asphalt industry proactively maintain its competitive quality when supply and market sectors place more stringent demands on paving materials?

The immediate answer to reducing dependence on virgin asphalt is the increased use of asphalt from other sources, including reclaimed asphalt pavement (RAP), shingles, and natural asphalt sources such as rock asphalt, tar sands, Gilsonite, and Trinidad Lake Asphalt. Given available quantities and cost, optimizing RAP utilization should be a critical short-term goal.

Warm-mix asphalt (WMA) technology is particularly timely, facilitating the mixing and placement of much higher RAP concentrations. A number of demonstration projects with up to 50 percent RAP have been constructed to show that warm-mix technologies can remove the conventional construction and environmental constraints of high RAP mixes. On-going monitoring will determine if pavement life equals that of conventional asphalt.

Numerous agencies allow up to 5 percent asphalt shingle waste in some asphalt applications, replacing up to 30 percent of the virgin asphalt. Old tear-off shingles represent 90 percent of the potential product stream, but have presented problems of contamination from nails, wood and, albeit extremely rare, asbestos, when they are not properly processed and evaluated. New manufacturing waste and shingle tabs represent 10 percent of the available supply of roofing shingles, providing readily usable asphalt, if two concerns are addressed in processing and mixing. The asphalt from the shingle must be dispersed uniformly in the mix, and the resulting mix must provide long-term resistance to cracking.

High transportation costs and few localized sources have limited the use of natural asphalt sources such as rock asphalt, Gilsonite, and Trinidad Lake Asphalt. Economics

improve with escalating asphalt prices, but each of these sources has constraints precluding them as the solution to long-term asphalt supply.

Oil extracted from tar sands is very similar to heavy petroleum crude, and huge investments have already been made by major oil companies to recover these materials. Given large deposits in the Athabasca region of western Canada (exceeding Saudi oil reserves) and smaller deposits in Utah, this source of potential quality bitumen should remain viable for the near future. However, current processing alternatives favor the coking of these residues on-site. Some bitumen is now becoming available, but developing these fields to favor asphalt supply requires huge amounts of electrical energy (oil companies have requested that Canada build a local nuclear power plant).

Oil shale and coal technologies could potentially be developed to produce paving materials, but present many technical barriers. Oils extracted from shale are used as asphalt additives to improve adhesion. However, oil shale and coal tar contain certain poly-nuclear aromatic compounds which have been associated with worker health issues. The Asphalt Paving Environmental Council has supported significant research efforts to differentiate asphalt from coal tar. Any use of coal tar products will have to overcome these product safety issues, possibly by using processes such as hydrogenation to reduce aromaticity. However, current initiatives to create “clean coal” technology hinge largely upon gasification or other technologies that would not produce heavy liquid residues.

If there are few near-term alternatives for replacing asphalt binders, then what available, cost-effective materials can dilute or extend it without sacrificing constructability or performance?

Sulfur

During the oil crisis of the early 70’s, sulfur was inexpensive, and agencies conducted many field trials with various asphalt-sulfur blends and processes. Follow-up studies indicate that 30-40 percent of the asphalt weight can be replaced by elemental sulfur without significant performance loss. However, toxic H_2S fumes are emitted from asphalt-sulfur blends at temperatures above 270°F. Shell’s recent SEAM technology has addressed this concern during initial construction, but the industry has not yet determined how to track these mixes so that the RAP that eventually results from these pavements can be safely recycled. WMA technology makes both the safe placement and future reuse of sulfur-extended RAP viable, but sulfur-extended asphalt must NEVER be overheated. Further, sulfur is twice as dense as asphalt, with a 40 percent substitution by weight replacing only 20 percent of the asphalt volume. To maintain volumetrics in a given mix, any asphalt removed from the formulation must be replaced by twice its weight in sulfur.

A third issue is cost; given the density difference, sulfur must be less than half the cost of asphalt per ton to be economically feasible. The 70’s field trials came to an abrupt halt when asphalt prices dropped and sulfur prices rose dramatically. Only recently had the marketplace made sulfur costs feasible--until a 1000 percent spike the summer of 2008 took it near $500 a ton (or $1000 to replace each ton of asphalt). Projections from Qatar and Kazakhstan suggest a rapidly increasing supply is imminent, particularly as large plants using Sasol technology are built to convert natural gas to liquid fuels.

Some estimates project sulfur prices will fall back to the $50/ton range in the early 2010's.

Crumb rubber

Waste crumb rubber is also widely cited as an asphalt modifier/extender. Up to 20 percent rubber can be blended with asphalt cement in wet processes which potentially produces binders of comparable quality to polymer modified asphalts. At the elevated prices of the 2008 asphalt market, crumb rubber was cheaper per ton and added value as an asphalt modifier with improved performance. Unfortunately, although crumb rubber densities are similar to asphalt, a direct substitution of asphalt-rubber binder by volume does not usually achieve the desired mixture performance attributes. Asphalt-rubber is now most widely used for open- or gap-graded friction courses, particularly in warmer climates. Crumb rubber gap-graded SMA mixes often require 8 percent asphalt rubber, and open-graded crumb rubber mixes may require 9-10 percent binder. Alternatives using polymer modified asphalt and fibers are usually specified around 6 percent asphalt content. Hence, the asphalt-rubber friction courses are performing well as value-added mixes, but any reductions in asphalt quantity by extending with rubber are largely lost through the increased asphalt content.

In the long-term, more solutions for asphalt extenders and/or synthetic asphalt can be developed. Because of the huge material quantities consumed in paving, the progress of the burgeoning bio-fuels market can anticipate the kinds of materials or by-products that might be available on a commercial scale. Other countries are more advanced than the U.S. in energy alternatives. A list of "Urgent Issues" compiled at a 2008 Australian conference includes "Bitumen alternatives / extenders" stating, *"Global demand for bitumen will eventually outstrip global supply . . . the era of cheap bitumen is limited. Finding an alternative source is a challenge of global magnitude. Vegetable-based alternatives have been developed, but as yet are more expensive. Research is continuing in algal and cellulose resin technologies."*

Vegetable oil

New paving materials using renewable resources are now available, but most use some form of vegetable oil (soybean, corn, sunflower, and canola) as the starting raw material. Vegetable oil molecules contain an acidic functional group and double bonds, making them excellent candidates for making polymers and resins. Products ranging from rejuvenator or extender oils to bio-polymers and resin-like synthetic binders have been developed, but few are currently available in U.S. markets. Given the rising cost of agricultural commodities, these alternatives remain costly and are used primarily for specialty applications such as colored asphalt.

Although vegetable oils appear to be a viable source, it is important to remember the 2008 experience when many new ethanol plants had a significant impact on escalating agricultural commodity prices. It is hard to imagine that the world's food supply would be sacrificed for liquid fuels and paving materials. Hence, short-term biotech scenarios will likely be based on the various oils that are pressed or extracted from grains. However, long-term options with true economic value will likely require a search for bio-materials of lower cost that will not compete for the land and water resources now used for food production.

Although economical long-term bio-solutions show some promise, many years of laboratory and field research are needed. The two technologies cited in the Australian report, algal biomass and cellulose resins, have rarely been mentioned in U.S. asphalt industry publications; nor have commercial European and Australian bio-binders such as “Vegecol” and “Ecopave” received much attention in U.S. literature.

As the liquid fuels industry continues to search for long-term green solutions for ever-more stringent Kyoto restrictions on CO_2 production, biomass options are becoming more compelling. Biomass can come from a number of sources, including wood chips, saw grass, agricultural waste such as corn stalks and straw, or algae. Land-produced biomass is typically 80 percent cellulose and 20 percent lignin. Cellulose is a dense polymer chain of sugar molecules, and lignin is a hard, polymer-like structure made up primarily of phenolic compounds. Three different types of processes to convert cellulose containing biomass to liquid fuels are now being evaluated by the research community.

Fermentation: Newly developed enzymes can break down the cellulose into sugars and then ferment them to produce ethanol. These enzymes are currently very expensive, so research is heavily focused on methods of reducing cost and/or recovering for reuse from batch to batch. Lignin is not affected by the enzyme, and is therefore left behind as a solid by-product. If this technology is commercially successful, huge quantities of the lignin by-product could become available. Lignin has been evaluated as an asphalt extender, but its solid physical form is not very amenable to handling. Nor is there clear enhancement of performance, although the hindered phenolic functional groups could provide a limited resistance to oxidative aging. It would be much more logical to find physical or chemical means to break down the complex lignin polymer into smaller molecules which might then create heavy liquids, or liberate the phenols so they might be reacted into tough phenolic resin compounds that could serve as paving binders. Very little published research is available in this field, and significant expenditures will probably come only if cellulose fermentation technology is commercially successful.

Fast Pyrolysis: As with coking of coal or petroleum residuals, biomass can be heated to very high temperatures in the absence of oxygen to break down the cellulose and lignin into smaller molecules that might then be processed into liquid fuels and possibly asphalt. Recent research at Iowa State is investigating the use of various biomass fast pyrolysis products as asphalt extenders in amounts up to 9 percent by weight.

Gasification: Using newly developed processes similar to coal gasification technology, biomass can be converted to combustible gases. The various gases might then be used directly as an energy source, or they might be further processed to make liquid fuels or chemicals.

Algal biomass is particularly attractive from a global energy perspective, because it grows extremely fast in fresh or salt water, needs few nutrients, loves sewage sludge, and consumes vast amounts of CO_2 when grown in fairly small ponds. This sounds like a dream to industries faced with paying large sums for Kyoto carbon credits, such as the coal-burning utility industry. Currently, agencies are funding research for algal use in aviation fuels. Unfortunately, algal biomass solutions have thus far not been seriously exploited for paving alternatives.

What can NAPA and NCAT do to prepare for change?

Long-term fundamental research leading to the next universal paving binder is critical to the interest of the asphalt industry, and NAPA will continue to play an important role in setting national priorities and generating initiatives that foster change. Some specific actions that might be considered:

Committee for Asphalt Research and Technology (CART)

- CART committee analysis of short-, intermediate, and long-term options discussed here as well as those suggested by NAPA members.
- CART workshop to brainstorm alternatives.
- Developing a series of short-, intermediate-, and long-term research needs specific to technologies thought to be most promising.
- Lobbying for funding those needs through national research channels on a NAPA-prioritized basis.

National Center for Asphalt Technology

- Strengthening the relationship between NCAT and Auburn's Center for Bioenergy and Bioproducts. (Note: NCAT is already supporting this center by testing their biofuels in vehicles running on the NCAT Test Track.)
- Information exchange and brainstorming session with biotechnology experts (at Auburn or on a larger scale), with a clear explanation of the issues involved. Perhaps they can create proposals and gain funding through their own initiatives, with support from NAPA-defined research needs.

NAPA leadership

- Familiarization in intermediate and long-term solutions of potential interest, particularly in the area of biotechnology.
- Inviting biomass experts (such as government experts participating on technical projects such as algal biomass conversion to jet fuel) to participate in NAPA Annual and Midyear Meetings and present/discuss their goals and progress. Inviting FHWA engineers responsible for funding recommendations to participate in those discussions.
- Lobbying for current research dollars, such as those going to Western Research Institute (WRI) and Asphalt Research Consortium (ARC), to be directed to investigate highest priority needs.

Summary of Liquid Asphalt Alternatives

Additive	Replacement % of Liquid Asphalt	Cost	Potential Availability	What's Needed	Constraints
Non-Virgin Asphalt Sources					
High RAP using WMA	Up to 50%	$	Very High	Specs	HMA quality
RAP Fines	Depends on P200	$	High	Specs	P200
Asphalt Shingles	Up to 5%	$	High	Specs	Contaminants
Virgin Binders/ Oils for 100% RAP	Up to 100%	$	High	Research, Specs	Binder quality
Rock Asphalt	1-20%	$	Limited	Data for HMA, Specs	Distance from pits
Gilsonite	approx. 8%	$$	Moderate	Softer materials for blending	Hardness
Trinidad Lake Asphalt	approx. 10%	$$	Moderate	Currently used	Hardness, Filler content
Other Bituminous Materials					
Tar Sand (Oil Sand)	Up to 100%	$	Very High Growing fast	Research, specs	Separation of clay; HMA quality
Oil Shale	Up to 100%	$$$	Very High?	Research, specs	HMA temperature susceptibility
Coal Tar	Up to 10%	$	High?	Compatibility with asphalt/ address health issues	Safety & Environmental; temperature susceptibility
Non-Bituminous Asphalt Extenders					
Sulfur	Up to 40%	$ - $$	High	Address H_2S	H_2S at high temperatures
Crumb Rubber	Up to 20%	$$$	High	Currently used	HMA quality
Petroleum-Based Synthetic Binders					
Epoxy Asphalt	100%	$$$$	Low	Currently used	Cost; works with only one asphalt
Colored Binders Oil/Resin/ Polymer	100%	$$$$	Moderate	Field data, Specs	Cost
Bio-Technologies Using Renewable Resources					
Activate & Replay Soy-based	100%	$$$$	?	Research for RAP & HMA, field trials, data, specs	Cost, HMA quality
Vegecol (Colas)	100%	$$$$	?	Specs	Cost, curing time
Compogreen (Screg)	100%	$$$$	?	Specs	Cost, 2-4" lifts, curing time
GEO320 (Ecopave)	100%	$$$	?	Data /Specs	Cost, field projects
Bioflux (Shell)	100%	$$$$	?	Specs	Cost, curing time
RapsAsphalt (Vialit)	100%	$$$$	?	Specs	Cost, curing time
Biophalt & Appia (Eiffage)	100%	$$$$	?	Field data / specs	Cost, curing time
BioStyrelf (Total)	15-30%	$$$	?	HMA Research	Softness, slow curing
Bio-Polymers	Up to 100%	$$$$	?	Research	Degrade in environment
Lignin	Up to 100%	$$$	Could be High	Research, field data, specs	Availability & Cost?
Biomass Fast Pyrolysis	2-9%, Up to 100%	$$	Could be High	Research, field data, specs	HMA quality, commercial availability
Road Oyl	Up to 100%	?	?	HMA Research	HMA quality, cost, curing
Algae Fuel	Up to 100%	?	Very High	HMA Research	No conversion technology