Solution to your Growing RAP Stockpiles

Summary: Asphalt producers have been recycling for more than 30 years and recycled asphalt pavement (RAP) has become the number one recycled material in the US, with about 67 million tons recycled in 2011. Despite this impressive record in many areas of the country there is more RAP available than can be used. The limiting factors range from specification limits and equipment capabilities to process/quality control.

What about other forms of asphalt technology? Cold recycling has been around for as long as HMA recycling. There have been many advances in materials processing, binders and central plant mix production over the years. Is it time to revisit cold recycling?

There are opportunities for increasing the RAP reuse in asphalt pavement construction. One opportunity being looked at in Mid-Atlantic region is cold central plant recycling (CCPR) where RAP, with small percentages of foamed asphalt, is blended at a central plant to produce an engineered mix as a base below a new asphalt pavement surface. CCPR offers an opportunity to increase the utilization of RAP for asphalt producers that have excess RAP. CCPR can open new markets for an asphalt producer in CCPR base material, and maximum recycling of available materials. This article explains the background of foamed asphalt, advantages of CCPR, mix design of CCPR mixes, with the aim of clearing the doubts about performance of foamed asphalt stabilized base (FASB) mixes.

Background: Foamed asphalt stabilized base (FASB) combines combinations of reclaimed asphalt pavement (RAP), recycled concrete (RC), and/or graded aggregate base (GAB) with a foamed asphalt binder to produce a stabilized base material. The foamed asphalt content is usually too low to fully coat all of the aggregate particles, as is the case in hot mix asphalt (HMA). Instead, the foamed asphalt coats only the fine aggregates which then form localized FASB “spotweld” bonds between the coarser aggregate particles (Wirtgen, 2010) that lead to increased cohesion and stiffness of the aggregate assemblage.

Foamed asphalt stabilization can be performed either through cold in-place recycling (CIR) of HMA or via cold central plant recycling (CCPR). FASB holds the potential to incorporate significant quantities of recycled materials into paving projects. Its structural properties are expected to fall somewhere between conventional untreated GAB and HMA. As an added benefit, FASB has the potential for reducing the cost of conventional flexible paving.

Foamed asphalt stabilization of recycled materials (mostly RAP) with/without virgin aggregate has gained great attention worldwide. It has been implemented over the past several decades in South Africa (Jenkins et al., 2000; Asphalt Academy, 2002; Long and Theyse, 2004; Saleh, 2004; Jenkins et al., 2007), Australia (Ramanujam and Jones, 2007), Europe (Schimmoller et al., 2000; Nunn and Thom, 2002; Loizos et al., 2004; Loizos, 2007; Khweir, 2007), and more recently and to a lesser extent in the U.S. (Marquis et al., 2003; Mohammad et al., 2003, 2006; Romanaschi et al., 2004; Kim and Lee, 2006; Kim et al., 2007; and Fu et al., 2008).

As compared to other recycled road materials, improvement methods such as asphalt emulsion and Portland cement stabilization, foamed asphalt treatment has shown significantly better performance as reported by researchers. Ramanujam and Jones (2007) reported a direct comparison between foamed asphalt (with lime) treatment and emulsion treatment (with Portland cement) in which the foamed asphalt section showed significantly better performance in terms of handling early traffic and also superior rain resistance before placement of the wearing course. Compared to recycled road base materials treated with Portland cement or other cementitious agents, foamed asphalt mixes (which may include small amounts of Portland cement as well in the form of active fines) have the additional benefit of improved flexibility and reduced brittleness. Jenkins et al. (2000), on the other hand, found that foamed asphalt and asphalt emulsion stabilized mixes have comparable strength, stiffness, and moisture susceptibility. However, foamed asphalt stabilization is often preferred because the asphalt emulsion treatment introduces extra moisture into the mix and requires considerably longer curing periods before the road can be opened to traffic. Muthen (1999) demonstrated that foamed asphalt treated materials exhibit higher stiffness in comparison to emulsion treated materials at ambient temperature and can resist higher strains before failure.

Advantages: A new type of pavement that uses foamed asphalt is making inroads in the national capital area and becoming the pavement of choice for private and federal projects. Global Resource Recyclers, Inc. (GRR) introduced an alternative pavement product using the Foam Stabilizing Base (FSB) technology that uses 100% recycled asphalt pavement as an aggregate source. It is blended with 2% hot bitumen oil and water in a patented foaming chamber. The benefits of FSB products include:

- It is easier to install because it has an ambient temperature and therefore not as hot as traditional asphalt.
- Jobs take less time: The FSB pavement can be used almost immediately after construction. It can be opened to traffic soon after the rolling is complete, because no cooling is necessary.
- There is less chance of cracks, potholes and failure. It eliminates thermal cracks caused by freeze/thaw cycles that are a main cause of asphalt pavement failure.
- It is less expensive than HMA to produce, ($25 per ton less) and will look and perform like a pavement that is made with 100% traditional hot mix asphalt.

- It also is more environmentally friendly than traditional bitumen stabilizers, because it consumes fewer natural resources and less energy during its manufacture and installation and produces fewer greenhouse-gas emissions from cradle to grave.
- It helps achieve LEED certification.

Mix Design and Construction: Foamed asphalt stabilization provides a potentially fast, cost-effective, and environmentally friendly flexible pavement construction strategy if designed and produced effectively. Several FASB mix design procedures already exist, e.g., ARRA (2001), Asphalt Academy (2002), Mohammad et al. (2003), Kim and Lee (2006), Wirtgen (2010), and others. Most of the methods are based on Marshall compaction and a combination of Marshall stability and indirect tensile (IDT) strength under wet vs. dry conditions. Global Resource Recyclers (GRR) follows the Maryland state highway administration’s (SHA) provisional specification to develop mix designs. Key provisions from this specification governing aggregate gradation requirements and FASB mix requirements are reproduced below as Table 1 and Table 2, respectively.

Table 1 Aggregate Blend Requirements

GRADATION (T 27)	
Sieve Size	**Percent Passing**
1 ½”	100
¾”	65-100
No. 4	25-50
No. 200	3-8
OTHER	
PI (T 90)	<1 0%

Table 2 FASB Mix Requirements

Design Parameters	Value
Aggregate Blend Compaction: T 180D Maximum Dry Density, pcf	≥120
Specimen compaction:	
Marshall compaction: T 245 - number of blows per face, or	75
Gyratory compaction: T 312, number of gyrations	25
Indirect Tensile Strength: modified T 283	
Minimum Wet Tensile Strength, psi, for material stockpiled >2 days.	50
Minimum Tensile Strength Ratio (TSR), %	70
Foamed Asphalt Expansion Characteristics @ 160, 170, & 180°C	
Minimum Half-Life of Foamed Expansion, sec(1)	8
Minimum Expansion Ratio(2)	10

(1) Total time for foamed asphalt to settle to half of the maximum foamed volume. See Section A.1.3.4 of the *Wirtgen Cold Recycling Technology Manual* (2010) for the half-life test procedure. Alternate suitable equipment can be substituted for the Wirtgen WLB 10 S laboratory unit.

(2) Maximum foamed asphalt volume divided by non-foamed asphalt volume. See Section A.1.3.4 of the *Wirtgen Cold Recycling Technology Manual* (2010) for the expansion ratio test procedure. Alternate suitable equipment can be substituted for the Wirtgen WLB 10 S laboratory unit.

Materials:

Aggregates

Crushed RAP gradation from GRR plant in Forestville, MD is shown in Figure 1.

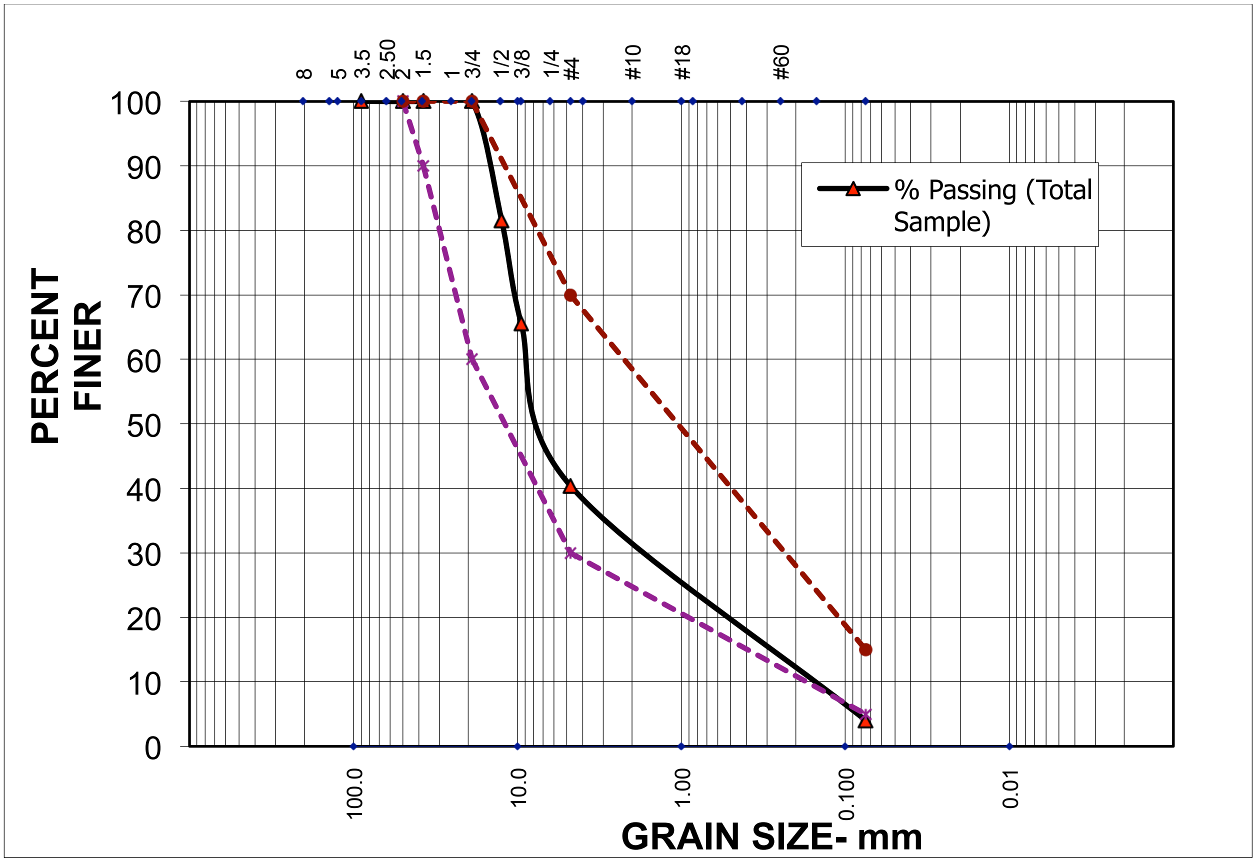
Small amounts of Portland cement were included as active fines in some of the mix designs. Adding 1% of Portland cement is a common practice in FASB design (Wirtgen, 2010). Cement serves several important roles in FASB mixtures.

- Improved foamed asphalt dispersion in the mix. Foamed asphalt coats the fines and makes asphalt mastic. The asphalt mastic forms partial bonds with larger aggregates (Ruckel *et al.*, 1983).
- Increased adhesion of the asphalt mastic to the aggregate (Wirtgen, 2010).

- Increased initial rate of strength gain (curing) and the stiffness of the mix. Strong but brittle cementitious bonds usually form faster than the weaker but ductile bonds of foamed asphalt (Fu *et al.*, 2008).
- Reduction of moisture susceptibility of FASB (Fu *et al.*, 2008)

However, excessive use of cement should be avoided to avoid rigidity and shrinkage cracking of the brittle cementitious bonds (Fu *et al.*, 2008).

Figure 1 Gradation of GRR RAP



Binders

PG 64-22 binder from NuStar Refinary was used

The binder used in FASB mixtures must have adequate foaming characteristics to insure proper foamed asphalt dispersion in the mixture. The best binder for foaming purposes is the one that expands the most and stays foamed as long as possible. These characteristics are quantified in terms of the expansion ratio (ER) and half-life ($t_{1/2}$).

- ER is defined as the ratio of maximum foamed volume to original liquid asphalt volume. Values for ER typically range between 10 to 20.

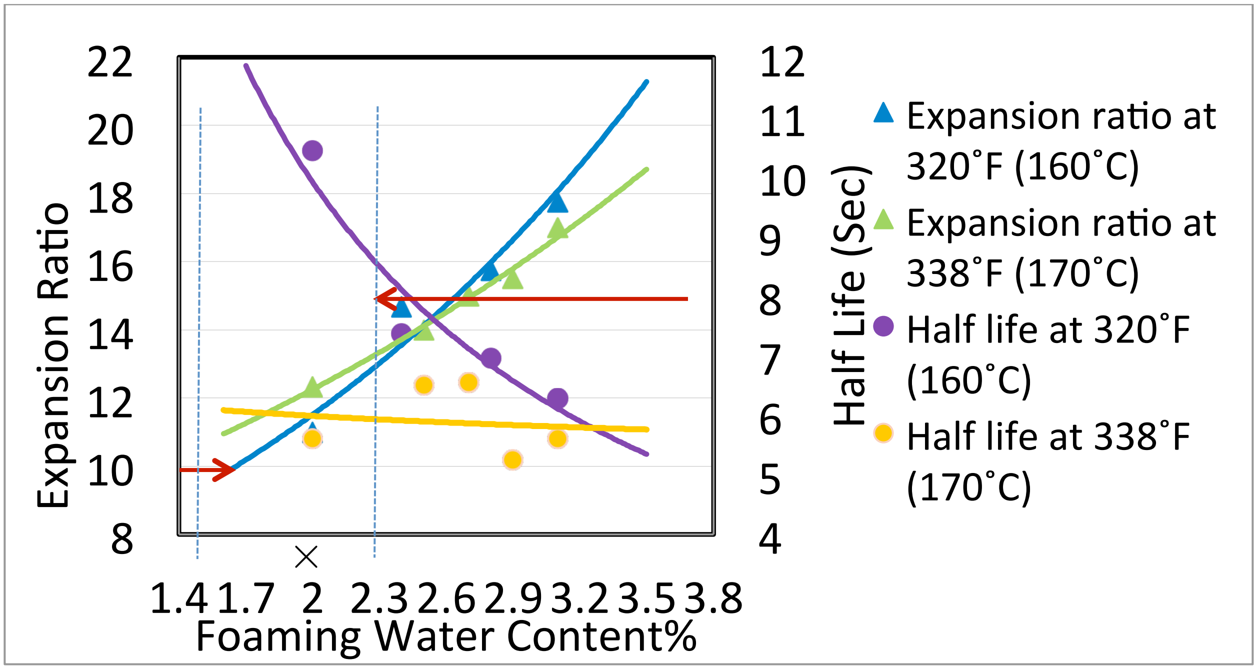
- $t_{1/2}$ is defined as the time in seconds for the foam volume to dissipate to half of its initial maximum value. Typical values for $t_{1/2}$ range from 6 to 15 seconds.

A minimum ER of 8 and a minimum $t_{1/2}$ of 6 seconds are typical foaming requirements provided in literature (Wirtgen, 2010).

Foaming temperatures typically range from 300ºF to 360ºF and foaming water contents typically range from 2 to 3%. For a given binder, increasing the asphalt temperature and foaming water content generally increases the ER but decreases the $t_{1/2}$ (Wirtgen, 2010). The objective of the binder foaming tests is to determine the temperature and foaming water content that optimizes the foamed asphalt ER and $t_{1/2}$.

Three replicate tests were performed on each binder at different temperatures and foaming water contents to measure the ER and $t_{1/2}$ values according to the Wirtgen Cold Recycling Technology manual (Wirtgen, 2010). The optimum foaming water content was obtained as the average of the foaming water content that met the minimum ER of 8 and the foaming water content meeting the minimum $t_{1/2}$ of 6 seconds. In cases where both the ER and $t_{1/2}$ requirements can be met at multiple temperatures, the lowest temperature is chosen. Figure 2 shows the foaming test results for binder at 320ºF (160ºC).

Figure 2 Binder Characteristics for GRR Binder



Mix Designs

Various steps included in the mix design are as follows:

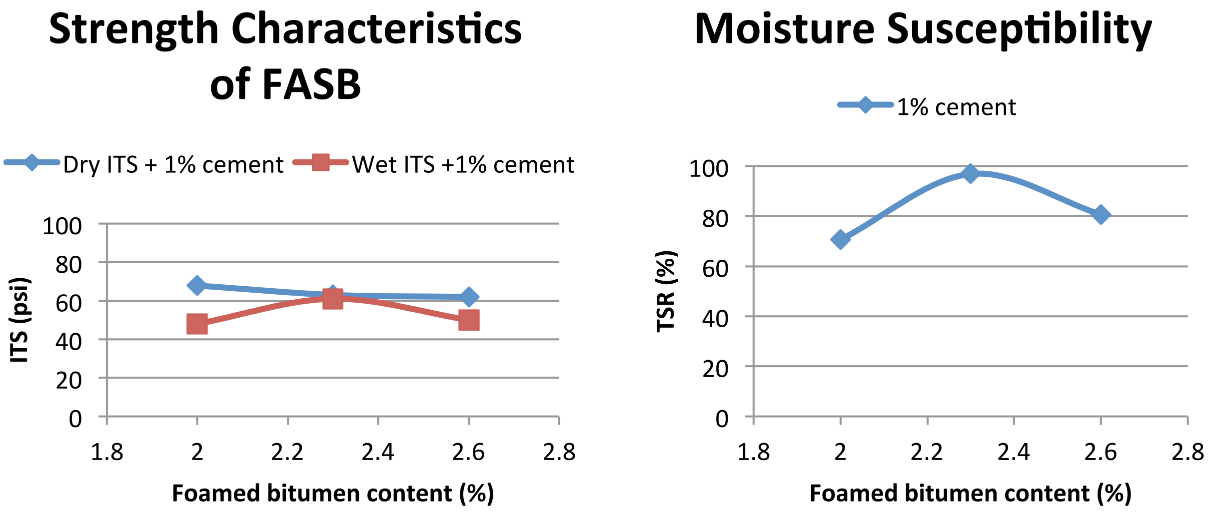
Blending of aggregate: 100% RAP and 1% Portland cement

Mixing, compacting and curing: Mixing was done in patent chamber at GRR lab followed by compaction using Marshall methods; curing was done for 72 hours for the compacted specimens in a temperature controlled oven at 104 ^{0}F.

Indirect tensile strength (ITS): The indirect tensile (IDT) strength, originally designed for evaluating the moisture susceptibility of HMA, is an accepted method for evaluating FASB mixtures for mix design purposes. The South African TG2 (Collings *et al.*, 2002) and Wirtgen (Wirtgen, 2004) design procedures both employ IDT and uniaxial compressive strength (UCS) tests in the dry condition for mix design optimization purposes and advise a minimum requirement for moisture susceptibility. Moisture susceptibly in terms of a tensile strength ratio (TSR) is defined as the ratio of the IDT strength in the soaked condition to the IDT strength in the unsoaked condition. TSR minimum criteria typically vary from 50% to 75% depending on climatic condition. The Maryland provisional specification for FASB design requires a minimum TSR of 70% along with a minimum soaked IDT strength of 50 psi.

For foamed asphalt mixtures the performance under soaked conditions is more important than in dry condition. Especially in mid-atlantic region the base course moisture content is high for most of the year; hence forth the soaked condition ITS is set up at 50 psi as bench mark. GRR mix with 100% RAP +1% cement was showing higher ITS and TSR values than required by specification; this will assure to the stake holders that our foamed asphalt mixes will perform better even in worst climate conditions. Figure 3 below shows the results of our mix ITS values.

Figure 3 Laboratory ITS and TSR values for 100% RAP Mixes



Conclusions:

- With the addition of 2.3% foamed binder, 100% RAP mixes shown better performance in soaked condition
- At 2.3% foamed binder content, 100% RAP mix has shown 92% of tensile strength ratio; which means that it did not lose significant bond strength after soaking for 24 hours at 77 ^{0}F
- Most of the processed RAP with the addition of 1% cement will meet the gradation criteria required to produce FASB mixes
- FASB mixes are good alternative to maximize the use of RAP and profitability, for HMA producers
- GRR has mobile plants; which can transport, set-up and capable of produce 200T/hour depending on the need of contractors

By:

Chandra K. Akisetty, Ph.D., P.E., M. ASCE.

Chandra@grrinc.net