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AUGUST 2014
100 PERCENT RAP

The paving industry’s epic journey of vision, persistence to produce full recycled asphalt pavement mix

BY BOB FRANK AND DANIEL BROWN
For nearly 40 years, garage inventors have designed, built and operated a variety of asphalt plants capable of producing 100 percent recycled asphalt pavement (RAP) hot mix. A few have enjoyed success and operate today. Many other designs were never commercialized, and those plants sit idle across the country. This is a story of successes and near misses, of men who risked a comfortable retirement searching for elusive solutions. It's a story of entrepreneurs risking it all.

Interest in RAP plants is growing around the world. Traditional asphalt plant manufacturers are introducing plans for their own RAP plants. Some of them have designs similar to the innovations described here. Public agencies are getting on board, too. In 2015 New York City will mandate a minimum 30 percent recycle content with no ceiling for all pavements under city jurisdiction. New York State DOT is considering accepting 100 percent recycled mix for temporary pavement and shoulders pending development of specs for plant approval.

The American history of RAP plants begins in the late 1970s with Robert Mendenhall. Mendenhall received numerous patents on a variety of asphalt recycling components including center-entry RAP collars. He also manufactured two models of RAP Plants; Eagle One, a mobile asphalt recycler; and the Golden Eagle, a smaller stationary unit intended for use with conventional asphalt plants.

The Eagle One was intended to be fed directly by a milling machine that dumped into a hopper. The hopper fed RAP into a parallel flow dryer with direct fired propane burner. RAP entered the drum under the burner’s flame, where a heat shield protected the material from radiant energy of the flame.

Mendenhall sold several mobile recyclers.

The Eagle One could produce mix at something less than 100 tons per hour, and the Golden Eagle worked along at about 15 to 20 tons per hour. Neither model had the benefit of pollution control, so attempts to operate plants in urban areas did not survive long.

Frank Geloewski remembers setting up and operating a Golden Eagle plant in Totowa, N.J., in 1984. At that time, it was among the first attempts to recycle in the state. “The plant produced smoke that could be seen for 20 miles,” Geloewski said. “We had the plant set up to discharge into the drag conveyor to the silos. The plan was to have the batch plant feed the silos at the same time. In reality the recycle plant fed the silos with no virgin material or recycling agent resulting in a mess. The product was burnt, hard to handle and stunk. In 1986 the plant was sold to a contractor in Utah.”

CYCLEAN, INC.
MICROWAVE HEATING
Chronologically, Mendenhall’s direct-fired dryers were followed by microwave tunnels for heating RAP. Jeppson (1) was granted the first patent for a microwave unit in 1981, and that patent was followed closely by a patent issued in 1982 to Don Alexander and Robert Sindelar—also for a microwave tunnel. The Alex-Sin microwave tunnel was put into production in 1992-93 as part of the Cyclean Cool-Flow dryer invented by Robert Nath, Assistant Secretary of Transportation in the Reagan Administration.

Cyclean, Inc. was originally founded by Nath in 1983 in Woodland Hills, Calif. The company got its start with a multi-year contract to supply the city of Los Angeles with 100 percent recycled mix in 1987. According to Thomas Harshorn, former vice president of plants with Cyclean, the city of Los Angeles used a Cyclean plant to recycle more than 1 million tons of asphalt, for a savings of approximately $10 million during the five-year contract.

Cyclean plants were also operated in Georgia, Texas, Michigan, Pennsylvania and the Netherlands. The Cyclean business plan promoted the idea of producing virgin-quality hot mix made with 70 to 100 percent RAP. The company would sell systems, license the technology, and then form joint ventures or serve as a subcontractor on a project.

In the Cyclean plant, RAP was fed into a conventional drum with special burners and heated to 260 degrees. From the drum, the RAP went into the microwave tunnel with eight 100kW microwave generators. The units were expensive to buy and even more costly to operate. At best the microwave tunnel only raised the temperature of the RAP by 10 degrees. The microwave tunnel was followed by a continuous mixer where rejuvenator was added to

The Voyager 120 plant from the Astec family is a highly portable plant designed to produce mixes with up to 30 percent RAP. A spokesperson for the company shared that helping customers use RAP is a key position for Astec. The Astec Double Barrel® drum runs 90 percent RAP and the Double Barrel HR, which is the high RAP option, is designed to efficiently run upwards of 60 percent. Innovations such as the V-Pack™ stack temperature control system from Astec help operators use higher percentages of RAP in mixes as well.

Photo courtesy of Astec industries.
restore the original characteristics to the asphalt cement (AC).

Witco Corp. was a supplier of the rejuvenating agents, Hartshorn said. Recycling with aromatic oils produced better viscosity results than using naphthenic or paraffinic cutting oils.

In building the Cyclean plant, Nath used generic plenum heaters. Air was heated by a burner system, and the hot air circulated through the Cyclean drum. Build-up on the dryer flights was a problem that required weekly attention. Combustion gases and moisture-laden air would go through a baghouse that filtered out the dust.

To protect the bags in the baghouse, Nath coated the bags with a layer of diatomaceous earth called NeutraLite. The precoat captured oil droplets during production and was pulsed off the bags at the end of the day. "Yes, we were expert at changing out a set of bags on a weekend," Hartshorn said. "Coating the filters was a help to longer bag life."

Alexander said the Cyclean plant was slow to produce mix when running in the parallel flow mode with heating in the microwave tunnel. However, after turning off the microwaves and switching to counterflow mode, the machine could produce close to 300 tons per hour.

**A TECHNICAL ANALYSIS OF MIX PROPERTIES WAS PRESENTED DURING THE 2014 TRANSPORTATION RESEARCH BOARD MEETING OF APH60 SUBCOMMITTEE ON FLEXIBLE PAVEMENT CONSTRUCTION AND REHABILITATION THAT CONFIRMED EQUAL PERFORMANCE OF HIGH RAP MIXES TO CONVENTIONAL PAVEMENTS.**

Jeppson in U.S. Pat. No. 4,594,022 as well as in U.S. Pat. Nos. 4,319,856, 4,175,885, 4,252,459 and 4,252,497 describes various methods and apparatus for heating pavements with microwave energy.

**DON ALEXANDER, ROBERT SINDELAR**

**ALEX-SIN PLANT**

Next in the order of progression is the Alex-Sin plant, invented in 1992 by Don Alexander and Robert Sindelar. The Alex-Sin plant is unique among RAP plants because it uses both direct and indirect heating and is equipped with numerous small burners.

The plant has a ceramic insulated heating chamber that resembles a semi-trailer van. Inside the chamber is a conventional shell dryer. Underneath the dryer, in the mid-section, is a 22-foot combustion zone with seven 75 MMBTU burners. Approximately 700 stainless steel fins are welded to the outside of the drum surface. "Those fins have a tri-purpose," Alexander said. "They move the air, agitate the air, and act as heat sinks.
on the outside of the drum transferring heat from combustion gases to the interior of the dryer."

Most hot combustion gases exit the insulated heating chamber at the material discharge end and are drawn by the exhaust fan through a center pyrolyzer tube inside of the dryer in counterflow to the RAP.

The feed end of the drum is made of aluminum with aluminum fins on the outside. Alex-Sin uses proprietary hot flights in this zone that are heated by combustion gases from the heating chamber. The exhauster draws hot gases through the flights at the front where the material is the coldest. The combination of heated aluminum shell and heated flights dries the RAP, and cools combustion gases in the pyrolyzer tube to improve efficiency.

Maintaining mix temperature on the Alex-Sin plant was more complex than with traditional plants. Because the stainless steel dryer shell is heated directly by the seven burners their output is restricted by infrared readers so shell temperature doesn’t exceed 900 degrees. The first three burners typically fire at 100 percent because the cold RAP keeps shell temperatures cool. The last four burners are modulated to keep the drum at only 900 degrees F, a temperature that heats RAP gently, avoids coke build-up inside the dryer and maintains desired mix discharge temperature.

The Alex-Sin plant was moved to California, produced mix to pave the host contractor’s parking lot, and is shut down now because burners do not comply with South Coast Air District NOx emission standards for asphalt plants. "So far the plant has not been proven for commercial use," Rick Gove said. "It has demonstrated that it can produce 250 to 300 tons per hour of mix at a temperature of 300 degrees F using 100 percent RAP feeds with moisture content near 5 percent and not exhaust any fines or volatile organic compounds to the atmosphere."

**RAP TECHNOLOGIES MODIFIED CONVENTIONAL PLANT**

The modified conventional plant, patented by Robert Frank, consists of standard hot mix components as were used in the FHWA High RAP Demonstration Project 39 of the 1980s. The singular exception is a pollution control system that is optimized to remove blue smoke in addition to airborne particulates. A rotary shell dryer with a direct fired burner dries RAP as if it were fresh aggregate. No attempt is made to minimize formation of blue smoke because a special pollution control device removes it. Neither is RAP protected from radiant energy of flame because recycling agents are added to replace maltene oils lost during service and recycling.

The All-RAP Plant is equipped with three cold feed bins to meter three RAP fractions. Separating sand from stone facilitates production of most conventional gradations for both dense and open graded designs. Individual RAP fractions are surprisingly consistent and require infrequent mix design changes to comply with typical job mix formulas. A variety of generic recycling agents have been used successfully, and many are waste-derived to earn the 100 percent recycled designation. Work is underway to produce high performance polymer modified mixes for specialty pavements that...
include porous pavements, stress relief layers and high performance thin overlays (thinlays).

RAP Technologies hired B&W Constructors in Boyertown, Pa., to build a portable “proof of concept” plant in 1999 from an assortment of new and used components. The decision proved fortuitous when the New York City DOT issued a request for proposals to rent a 75 ton per hour 100 percent RAP plant in 2001. Those first streets paved in November 2001 with 100 percent recycled mix are still in service and look no different than conventional mix placed in echelon. One hundred percent recycled mix is still being placed daily in New York City with a larger All-RAP Plant operated under license by Michael Capasso’s Green Asphalt LLC. The original pilot plant is headed to northern Canada where it will move from town to town producing mix for mill-and-fill projects. Future projects include marketing a winter mix plant and launching All-RAP Plants in major cities across the United States.

GOVE, ALEXANDER
CARGO BOX PLANT
In 2004, Rick Gove and Don Alexander built a second Cargo Box Plant to produce 100 percent RAP mixes. This plant also has an outer, ceramic-insulated, heat containment chamber similar to the Alex-Sin plant. Inside the chamber as a U-shaped horizontal trough. Two burners are mounted at opposing ends of the containment chamber and heat the U-tube by direct radiation. Burners are adjusted to create a pencil flame 15 feet in length that distributes radiant energy over the entire length of the U-tube.

Inside the U-tube are double lifting flights connected to a rotating steel pipe that moves RAP along the U-tube. Every revolution of the lifting flights dumps RAP onto the center steel pipe that is also heated.

Hot air from the combustion chamber on the bottom moves through ducts from the middle of the Cargo Box up to the top of the U-shaped tube. Hot air at 900 degrees is drawn with suction into both the upstream and downstream ends of the center space in the U-trough. RAP
going into the U-tube is heated initially in counterflow. A second 900 degree air stream moves in parallel with material to the downstream end. At the discharge end, the RAP exits through a drop chute that passes through the combustion zone. “We were putting RAP through it at 50 tons per hour and it discharged 268-degree mix with just three minute retention time,” Alexander said.

**BROOKS CONSTRUCTION HYRAP**

On June 11, 2011, Brooks Construction Company held a grand opening for a new asphalt plant and introduced HyRAP—100 percent recycled RAP. Located in Fort Wayne, Ind., Brooks’ HyRAP has multiple recycle collars to introduce fractionated RAP progressively along the length of the parallel flow dryer. A continuous mixer is used at dryer discharge to blend in a proprietary recycling agent supplied by Crowley Chemical.

Coarse particulate is removed from dryer exhaust gases with a high efficiency primary cyclone followed by a conventional baghouse to remove fine particulates. Similar to the Cycle plant on which it is modeled, the HyRAP plant uses a thermal oxidizer to destroy hydrocarbon emissions from the RAP. Hot exhaust gases from the oxidizer (1800 degrees F) are re-introduced at the four RAP collars to supplement heat from the Hauck EcoStar II burner.

A one-mile demonstration project with HyRAP mix was completed along Eggeman Road in Fort Wayne. A technical analysis of mix properties was presented during the 2014 Transportation Research Board meeting of AFH60 subcommittee on Flexible Pavement Construction and Rehabilitation that confirmed equal performance of high RAP mixes to conventional pavements. North Central Superpave Center at Purdue University assisted with the mix testing.

Having a plant capable of producing 100 percent recycled mix is just one step. As Gove said, “Equally problematic is to develop mix designs and find a binder that reliably rejuvenates aged RAP binder. In sum, the basic concept is proven—the gamble now is whether to spend enough extra money to put the machine to work and develop workable mix designs.” It has been a long road for many innovators due to the challenges of both plant design and knowing how to make a quality mix.