World of Concrete 2013, a parking lot demonstration of RCC went on for four afternoons and and included test strip placement, curing, saw cutting and testing

Photo courtesy of Tom

The ABCs of RCC

Roller-compacted concrete advances invasion of pavements

As roller-compacted concrete inexorably penetrates existing asphalt pavement markets, research into their composition and performance is ramping up as specifications are being fine-tuned by ASTM.

Up to the past decade, roller-compacted concrete (RCC) mixes principally were used in a variety of heavy-duty applications such as logging yards, loading docks, intermodal port facilities, large parking areas and dams. But as highway agencies and contractors followed in the wake of early adopters, in the last 10 years it has started to move into pavements.

"Roller-compacted concrete (RCC) is gaining popularity as a paving alternative for a number of roadway applications," says Stacy G. Williams, Ph.D., P.E., research associate professor in Department of Civil Engineering at University of Arkansas-Fayetteville.

"RCC is a zero-slump concrete mixture that does not require forms, reinforcing, jointing or finishing," Williams says. "This type of material combines [some] advantages of conventional concrete pavements with the ease of construction of an asphalt pavement, and can be opened to traffic more quickly than conventional concrete pavements."

Simplicity is the essence of RCC, compared to conventional portland cement concrete, and even hot- or cold-mix asphalt. "Roller-compacted concrete is concrete pavement placed a different way," says David R. Luhr, Ph.D., P.E., former program manager, Portland Cement Association, and now with the Washington State Department of Transportation. "RCC has zero slump, uses no forms, dowels or reinforcing steel, and requires no finishing," he says.

Benefits of RCC, Luhr says, include low construction cost and rapid construction sequence, resulting in a tough, strong, durable product with low maintenance demands and a long-time low life-cycle cost.

What it doesn't do, he says, is provide a high-level pavement suitable for arterials or interstate-type highways. "RCC does not provide all the features of conventional concrete pavement," Luhr says. The final product will lack acceptable pavement surface texture and uniformity, smoothness and, for that matter, aesthetics.

Typically, RCC is produced in a pug mill or central batch plant and is transported by dump trucks. It's often placed by a robust, oversized European-style paver, or sometimes by a conventional asphalt paver. It's compacted by smooth-wheeled rollers and cured with water or curing compound, Luhr says.

RCC is placed at a 4-inch minimum and 8-inch maximum depth, but sometimes 10 inches when used with Eurostyle heavy-duty pavers. "Adjacent lanes are placed within 60 minutes to maintain a 'fresh joint' and multiple lifts [are] placed within 60 minutes for bonding," he says. Production should match paver capacity and, like all pavements, a continuous forward motion should be maintained for optimum smoothness.

RCC is seeing use in more than just pavements and industrial parking and storage areas. Recently RCC was used for a Catholic grade school parking lot overlay in New York City.

The Wayne Companies of northwestern Pennsylvania and southwestern New York completed a 50,000-sq.-ft. unbonded overlay of 4 inches of RCC directly on the existing asphalt, which makes it one of the few, if not the only, unbonded overlay projects using RCC in the country, notes the National Ready Mixed Concrete Association (NRMCA). By using a conventional asphalt paver and hauling the RCC in dump trucks, Wayne was able to convince the owners that RCC could solve their situation more economically than tearing up existing asphalt and replacing with either new asphalt or conventional concrete.

Despite RCC's low rate of shrinkage cracking, the decision was made to joint the pavement similarly to a conventional overlay to reduce the risk of reflective cracking from the old asphalt. The new RCC parking lot came in under the asphalt bid and should provide years of service due to the durability of concrete, NRMCA says.

At the 2013 Transportation Research Board meeting in January in Washington, D.C., Korean researchers described use of RCC to build bicycle paths in an environmentally sustainable manner.

Careful selecting mixture proportions

Use of roller-compacted concrete in pavement construction is increasing, say Yoon-moon Chun, Tarun R. Naik and Rudolph N. Kraus of the Department of Civil Engineering and Mechanics, College of Engineering and Applied Science at the University of Wisconsin-Milwaukee, in their paper, Roller-Compacted Concrete Pavements.

"Roller-compacted concrete is a zero-slump, highly compacted concrete that is placed by equipment similar to that used in asphalt pavement construction," Chun, Naik and Kraus say. "RCC pavements may contain fly ash, or other powder materials to increase the fines content and to fill voids between aggregate particles in RCC."

Normally, use of air-entraining admixture provides a proper air-void system to prevent damage to the concrete due to freezing and thawing, they say. "Air-entraining admixtures have been added to RCC mixtures in laboratory tests and such concrete mixtures have performed satisfactorily," they write. "However, due to the nature of RCC, it is very difficult to provide a sufficient amount of entrained air in RCC mixtures."

Instead, Chun, Naik and Kraus say, the most common method of providing sufficient durability for RCC pavement against freezing and thawing is by judicious selection of mixture proportions, including a low water-cementitious materials ratio, a free draining base course material, and achieving a high degree of RCC compaction (96 to 98 percent of maximum density), with the use of fly ash or other supplementary cementitious materials, or other materials which add fines to the RCC mixture.

"Although the rate of strength gain of RCC is lower than that for conventional concrete pavement, the final strength is higher," the authors say. Compressive strength, at the age of 28 days, as high as 40 MPa (6,000 psi) is common, and the 28-day flexural strength can be 5.5 MPa (800 psi) or greater. It's been shown that RCC pavement compacted to 96 percent of maximum density is more than twice as strong as the same mix compacted to 86 percent.

Because RCC pavement is much stronger and durable than asphalt pavement, Chun, Naik and Kraus add, RCC will not rut from high axle loads, or shove or tear from turning or braking of operating equipment. It will not soften from heat generated by hot summer sun or material stored on RCC floors (for example, compost).

"RCC pavement offers a substantial cost savings over conventional portland cement concrete and asphaltic concrete pavements when used in heavy wheel load applications," they say. "A first-cost savings of 15 to 25 percent can be expected, if RCC is specified as a pavement alternative for projects requiring wheel loadings of 50,000 to 120,000 lb."

RCC for energy sector haul roads

These cost benefits are driving use – and research – of RCC in Arkansas, where RCC is proving to be a cost-effective alternate for building energy sector haul roads that will stand up to trucks serving new natural gas wells and infrastructure.

The Fayetteville Shale is an "unconventional" natural gas reservoir which has been producing abundant natural gas in the age of fracking. The Fayetteville Shale "play" stretches across Arkansas from approximately Fort Smith east to beyond Little Rock, and is some 50 miles wide from north to south.

The Fayetteville Shale is important because it has become an important natural gas producer. Shale holds natural gas in a fine-grained rock matrix, but today's technologies of horizontal drilling and fracking has made production on an economic scale feasible. Thousands of wells on millions of acres now are producing, but they require construction of roads and pipelines and other infrastructure to handle hundreds of millions of gallons of fracturing fluids.

This haul traffic is tearing up existing roads. More than 1,000 miles of roadways in Arkansas have been adversely affected by the increased traffic loadings, leading to a sharp acceleration of pavement distress. In response the Arkansas State Highway & Transportation Department is seeing how new RCC pavements are performing in the Fayetteville Shale "play" area.

"The accelerated pavement distress that has become prevalent in the area illustrates the need to examine cost-efficient rehabilitation strategies that can provide a long service life," the agency says. "Roller-compacted concrete pavement is one such potential alternative ... [t]he reduced cement content and ease of construction result in substantial cost savings. RCC is very strong and well-suited for heavy traffic loadings, but the success of any pavement depends on the quality of its foundation."

In this area, two test sections were constructed, each one mile long. Section I had 6 inches of full-depth cement-treated base reclamation, topped by 7 inches of RCC. Section II had an 8-inch RCC overlay of the existing pavement including level-up. Safety edge was used on both sections. Both sections were diamond-ground to improve smoothness, a major criticism of RCC surfaces.

The project took less time and money than reconstructing the existing two-lane rural road. Construction of both miles took nearly one month, where reconstruction would have taken most of a construction season. The cost for the project was $1.9 million for the two miles, compared to the average $3 million per mile the Natural State spends for reconstructing a two-lane rural roadway. Ultimately, this project saved Arkansas nearly $2 million per mile compared to conventional asphalt reconstruction, and the RCC pavement should be able to withstand the increased weight loads from the heavy vehicle traffic.

Gyratory compactor for RCC?

This month, a subcommittee exploring standard specs for roller-compacted concrete was to meet to further develop specs for testing RCC in the lab.

ASTM International's Subcommittee C09.45 on Roller-Compacted Concrete is working on three proposed standards for roller-compacted concrete. They are the following:

- WK33682, Test Method for Preparation, Compaction and Density Determination of Roller-Compacted Concrete Specimens by Means of the Gyratory Compactor. According to subcommittee member Dr. Stacy G. Williams, Ph.D., of the University of Arkansas, because the Superpave gyratory compactor was developed during the 1980s as a means to provide a laboratory simulation of the compactive effort imparted by rollers on a Superpave asphalt mat, it may be applicable to RCC, as it's compacted using the same type of roller. Therefore, preparing RCC specimens in a laboratory can be expected to provide similar results to those experienced in the field.

  Williams further explored the gyratory concept in a 2013 TRB paper, Comparison of the Superpave Gyratory and Proctor Compaction Methods for the Design of Roller-Compacted Concrete Pavements.

  "In general, the gyratory compactor does offer a viable alternative for the design of RCC paving mixtures," Williams says. "Since the performance of RCC is highly dependent upon density as its primary quality measure, the ability of the SGC to generate higher maximum densities may also serve as a mechanism to improve the quality of RCC paving mixtures.

  "However, it should be recognized that the gyratory design method may not produce a mixture design equivalent to that derived by the proctor method," she writes. "While higher densities imply improved quality, the higher design densities will also require that higher in-place densities be achieved in the field, unless current specifications are adjusted. Further research should be performed to verify the compaction method and level that most adequately simulates the

Web Extra: Read "Optimizing Use by Processing" at *www.BetterRoads.com*.

maximum achievable field densities, while also maximizing pavement quality."

Thus WK33682 is being developed to establish a protocol for preparing laboratory specimens of RCC that more adequately represent field mixes. "The most practical application is that you can use the gyratory-compacted specimens for determining density," says Williams. "Strength and density are key performance parameters for RCC, such that increases in these properties lead to increases in performance."

- WK41101, Practice for Molding Roller-Compacted Concrete in Beam Molds Using a Vibrating Hammer. Once approved, WK41101 will be used to consolidate RCC into beam molds with established flexural strengths. This is important because RCC is gaining use as a pavement for roads, shoulders and streets, and all pavements need flexural strength data for design purposes.
- WK42461, Test Method for Density (Unit Weight) and Air Content (Pressure Method) of Freshly Mixed Roller-Compacted Concrete. WK42461 covers the determination of density and air content of freshly mixed concrete. WK42461 will be used in the design of roller-compacted concrete mixtures and to aid in controlling the quality of those mixtures during RCC construction.

Tech transfer via demos [A LOT OF THIS SECTION CAN BE CUT IF NECESSARY.]

Field demonstrations of RCC have become a big part of spreading the "gospel" of roller-compacted concrete. For example, RCC was an attraction in itself during a four-day continuing demonstration of placement at World of Concrete 2013 in February in Las Vegas. There, a Eurostyle heavy paver with compaction at the screed placed RCC, which was compacted by a heavy tandem smooth-drum roller.

The parking lot demo was held four afternoons in a row, and included test strip placement, curing, saw cutting and testing, and drew throngs of individuals. The event was sponsored by the American Concrete Pavement Association and the Portland Cement Association, with support of contractor A.G. Peltz Co., and suppliers Aggregate Industries USA, CalPortland Co., Cemex, and Wirtgen America Inc.

Not quite a year earlier, in January 2012, Cemex held a public demonstration in New Braunfels, Tex., for the construction of a half-mile segment of Solms Road. The demo attracted over 100 public agency personnel from cities, counties and Texas DOT, as well as engineers and construction professionals.

This road is the main truck access road off of I-35 for the Cemex plant, and other industrial facilities nearby. Large numbers of fully loaded 18-wheelers run across the pavement each day, and the existing asphalt road was a veritable "roller-coaster/mine field" for those needing to travel across it, says sponsor Cement Council of Texas.

The pavement section consisted of a cement/lime-modified subgrade layer, with cement-treated base on top, and 9-inCH RCC pavement as the driving course. The RCC was mixed in a pug mill at the Cemex plant, placed with a high-density Eurostyle paver, and compacted with vibratory steel-wheeled rollers.

The RCC pavement was diamond ground, by Penhall Co., the technique allowing RCC to be used for higher speed-limit roads, where ride quality is more sensitive.

According to the council, another recent example of RCC pavement being placed in Texas is a 3/4-mile section of Grape Creek Road in San Angelo, where the RCC placement was so successful that the city is looking at other RCC projects.

"RCC pavement is a great alternative for roads and pavement applications that have traditionally used asphalt," the Cement Council of Texas says. "It can be placed fast, opened to traffic quickly, and can be less expensive than an equivalent asphalt pavement reconstruction. And it lasts a lot longer than an asphalt alternative."❖