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FEATURE SERVICE

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New Polymers for Water-Permeable Concrete Tracks: The Bebenroth Tunnel Project

A concrete track that allows thousands of liters of water to drain away in just a few minutes? Roads that swallow up tire noise? Both are possible thanks to new ETONIS® 260 polymer binder. While construction work was underway on the new tunnel for the railroad line from Göttingen to Bebra, Deutsche Bahn AG came across concrete which possessed these amazing properties, and took immediate action. It modified its plans for the accessibility of the ballastless track inside the tunnel which is designed to afford quick and safe access for rescue vehicles and fire trucks hurrying to the scene of an accident. The Bebenroth Tunnel was put into commission several weeks ago – and, with it, the polymer-modified, open-pored concrete.

Drainage concrete steals the show at the Hockenheimring

The Hockenheimring race track in mid-September 2012. As the cameras roll, water gushes from a concrete mixer truck onto the track. Instead of spreading out or running off the surface, it drains away into it – "just like magic," as television presenter Aiman Abdallah will later report in the investigative program "Galileo." While researching one of its "Fake Checks" programs aimed at establishing the truth behind unbelievable internet videos, the television crew has encountered Siegfried Riffel from HeidelbergCement AG and the test section on the celebrated race track in Hockenheim. The test road link had been constructed back in 2002 from open-pored concrete, also known as drainage concrete. The Galileo team actually discovers that this

A road swallowing water

open-pored surface coating swallows up more than 6,000 liters of water, without forming a film of water on top. But then the surface coating is unable to absorb any more for a while. When asked why by the reporter, Siegfried Riffel explains by saying that the comparatively thin surface coating, just eight centimeters, has been laid on a dense concrete underlay.

Research project for quiet traffic

Further open-pored concrete applications would follow starting in 2002 along the B56 state road near Düren, Germany, as part of the research project “Quiet Road Traffic – Less Road Traffic Noise”. However, there were problems with durability after several years of use along the project stretch: “The concrete composite underlay dislodged at numerous locations such that cracks emerged which led to road damage”, Riffel explains. A further weakness would involve the open-pored joints’ and bonding course’s resistance to frost and road salt. “This is why it was necessary to develop a new and more long-lasting generation of open-pored concrete”, he adds.

A new generation of materials in the railroad tunnel

Change of scene and time. About 25 kilometers from Göttingen, right beside the former inner-German border on December 16, 2012, Deutsche Bahn Netz AG has organized a modest opening ceremony, mainly for representatives from the companies involved in the construction of the New Bebenroth Tunnel, which is 1,030 meters long. Between and alongside the rails of the ballastless tracks of the design type “Rheda 2000” – this means the rails are fixed in concrete or asphalt instead of supported ballast – the roughly 16-centimeter-thick surface coating inside the tunnel consists of flat, continuous, drainage concrete

which works on the same principle as its counterpart at the Hockenheimring, minus the flaws. In close cooperation with HeidelbergCement, WACKER experts have eliminated the resistance-related deficits – to the delight of Björn Kunisch, who is representing the developer, Deutsche Bahn Netz AG. "This drainage concrete not only passed our water-permeability and fire-resistance tests, but can also carry emergency response vehicles with 10-metric-ton axle loads." According to a European safety regulation, new railway tunnels longer than one kilometer must be easily accessible for rescue vehicles and fire trucks. Kunisch adds: "I am confident that the drainage concrete will prove extremely durable in service and that we have found a very good solution which meets the safety requirements for tunnels as regards accessibility."

Less flaws …

… increased durability

The drainage concrete or open-pored concrete as used in the New Bebenroth Tunnel first saw the light of day in 2008. At that time, Siegfried Riffel from HeidelbergCement AG contacted Wacker Chemie AG with a list of requirements for a new generation of concrete. Just three years later, the developers returned with a message: "Mission accomplished." The magnitude of the task and the speed with which it was completed are best appreciated by delving into the internal structure of the drainage concrete. The water is able to drain away quickly and easily through it because of the pores it contains: they make up some 15 to 20 percent of it. Clearly, then, it is no easy task to render the drainage concrete as strong and as durable as normal concrete composed of a dense matrix of cement and aggregate.

Developed in just three years

The secret behind the pores

Open-pored concrete is made with aggregate stones broken into cubes that measure five to eight millimeters across and are thus roughly the same size. These gap-graded stones, as they are called, are responsible for creating the pores because they cannot be packed together densely. One way to understand this is to imagine the gaps in a jar filled with peas. Dense concrete, in contrast, is made with stones which vary in size, usually from 0.063 to 32 millimeters in diameter. Here, the smaller stones fill the gaps between the larger ones. In the jar of peas, for example, the gaps could be reduced by adding grains of rice.

Size does matter

Binders make the surface more durable

"The individual aggregate stones of the open-pored concrete are completely enveloped by the cement paste and only bond to each other wherever they touch. In other words, they are only connected to each other by their edges, and weakly at that," explains Dr. Klas Sorger. The WACKER expert adds: "Without additional polymer binder, the stones would be plucked out from the surface when a tire rolls over it." Not only that, cracks would form readily in the material, because hardened cement on its own is too brittle without polymer; it is particularly vulnerable to frost and road salts, which can damage the bonds between the stones. Siegfried Riffel from HeidelbergCement adds: "For that very reason, we used a polymer binder for the first-generation drainage concrete. However, it took collaboration with WACKER to create a binder that critically improves the mechanical properties of the drainage concrete."

When they started collaborating, the researchers first had to establish precisely what was wrong with the old recipe. "We sub-

The binder had to be tailor-made

sequently developed ETONIS® 260, a polymer that is tailored in every respect to the application," says Sorger. High-performance polymer fibers were also added to the new drainage concrete to reinforce it.

For Deutsche Bahn Netz AG, this development came at just the right time. In 2009, it decided that the old two-track Bebenroth Tunnel, which was built in 1875, was not up to modern standards on account of its sandstone brick lining. A straightforward renovation was not possible because the safety regulations stipulate that each track must have its own tunnel tube. Deutsche Bahn therefore decided to split the project into two parts. The first would be to build a new tunnel tube – the New Bebenroth Tunnel. Once it was connected to the important North-South freight line between Göttingen and Bebra, the second part would get underway: renovation of the old tunnel for subsequent use in one direction only. This renovation work will now start in September 2013.

Launch of the Bebenroth project

"Originally, precast slabs were to be used to render the New Bebenroth Tunnel accessible to rescue vehicles," explains Ralph Pino, who was commissioned by the Project Construction Department of Deutsche Bahn to oversee construction of the New Bebenroth Tunnel. "But it soon became clear in the course of planning that it is difficult to dewater the tunnel with such precast slabs, especially lengthways." The water gets into the tunnel chiefly via the entrances. Added to which, it is swept in by incoming trains or forms condensation on the tunnel walls.

As construction work on the tunnel continued, Deutsche Bahn Netz AG searched around for alternatives to the precast slabs,

Search for alternatives to precast slabs

and discovered the drainage concrete. In a technical opinion, Prof. Stephan Freudenstein from the Technical University of Munich's "Prüfamt für Verkehrswegebau" (test authority for traffic route engineering) recommended the developer use drainage concrete via the cast-in-place concrete process. That means that concrete is installed in site. The alternative to the cast-in-place concrete process is delivery of precast slabs which, however, have various disadvantages. Following installation, these have joints and can shift due to mechanical stress.

A delighted developer

Kunisch and Pino are united in their delight at how quickly and easily the drainage concrete track can be installed – it took just ten days in the case of the New Bebenroth Tunnel. And they also stress that the open-pored concrete can be very readily adapted to deviations within the construction tolerances. Ultimately, "if the rails and track are ever damaged, such as in a derailment, the drainage concrete can be removed and repaired much faster than precast elements," notes Pino.

A material doubling as whispering concrete

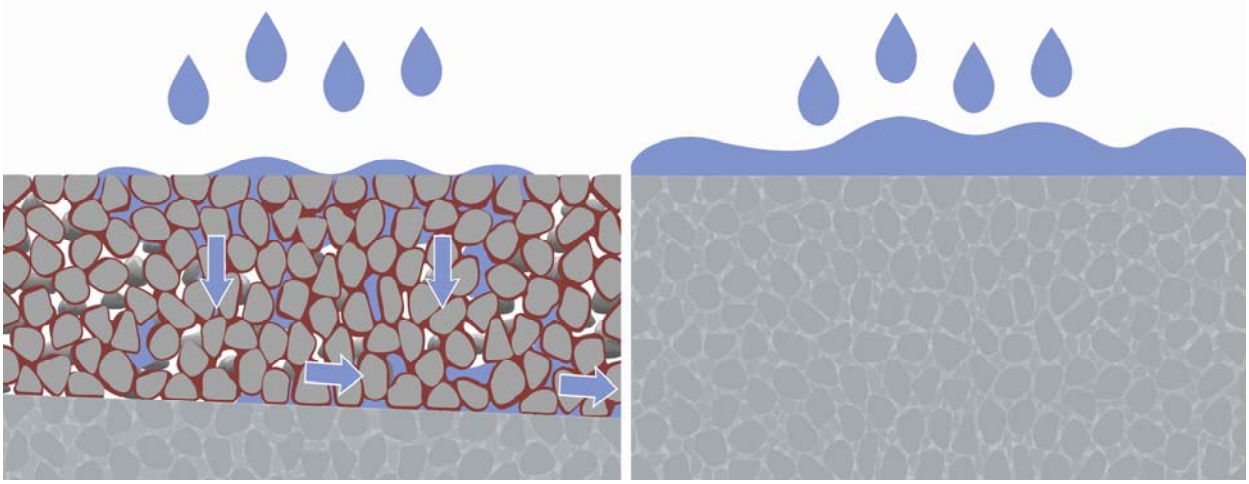
The future of the new polymer-modified drainage concrete looks rosy – not only because it will likely soon be used in the old Bebenroth Tunnel and other railroad tunnels. As the material's compressive strength and tensile strength in bending, resistance to frost and road salt, and thus its longevity have vastly improved over the drainage concrete of the first generation, it can now at last be used in the application for which it was originally conceived. Open-pored concrete was originally designed in the early 1990s as "whispering concrete." "Sound gets lost, as it were, inside the material's pores. Consequently, open-pored concrete

is highly efficient at attenuating the noise of tires rolling over it," explains WACKER expert Sorger. When it comes to noise nuisance, the rolling kind becomes much more annoying than engine noise once a car is traveling faster than 40 kilometers an hour.

Preliminary tests on the highway

The German Federal Highway Research Institute (BASt) intends to start testing the second-generation, open-pored concrete this year. If these tests are successful, test stretches will be installed on German highways from 2014 on. And in its role as a sound absorber for the ballastless track, the open-pored concrete could well be used for rail lines outside of tunnels. The reason is that traditional ballast, which is good at damping noise, is unsuitable for high-speed trains. Intercity express (ICE) routes will therefore be getting their own ballastless track which, though not very sound-absorbent, but rather strongly sound-reflecting when built in the traditional way, would benefit from open-pored concrete. WACKER and HeidelbergCement already tested this back in 2010 in a joint EU research project “Urban Track”. Open-pored concrete was successfully installed as a rail sound absorber at a railroad test section in Brussels, Belgium.

Freshly mixed drainage concrete in laboratory trials: the open-pored structure and pores can be clearly seen. Thanks to the new ETONIS® 260 polymer, the non-slump fresh concrete does not flow or disintegrate at the edges – this is a vital prerequisite for level track surfaces (photo: Wacker Chemie AG).



Water-permeability test: Open-pored concrete modified with ETONIS® 260 facilitates the transport of moisture (left), while on conventional solid concrete, water builds up and runs off slowly (right). This results in far fewer cracks forming in the new concrete and augments its resistance to frost and road salts (picture: Wacker Chemie AG).

Drainage concrete modified with ETONIS® 260 is spread between and beside tracks and thus provides rescue vehicles and fire trucks with fast access to railroad tunnels. The new concrete is quick to put down, extremely durable and stable, and thus ideal for applications in road, tunnel and underground construction (photo: Wacker Chemie AG, courtesy of Deutsche Bahn AG).

Test section of drainage concrete. While the water builds up on normal concrete or asphalt and runs off slowly (right side of photo), it can drain away easily and quickly on the new drainage concrete (left) (photo: Wacker Chemie AG).

Note:
These photos are available for download at:
http://www.wacker.com/pressreleases

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The company in brief:
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