Ontario's Transportation Technology Transfer Digest
MINISTRY OF TRANSPORTATION

Road Talk

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Glass! Crash! Bang!

Bridge Traffic Barriers Reinforced with Glass Fibre Reinforced Polymer Rebar

In November 2010, Ryerson University, a research partner of the Ontario Ministry of Transportation (MTO), conducted the first North American crash test of a Performance Level Three (PL-3) concrete traffic barrier reinforced with Glass Fibre Reinforced Polymer (GFRP). Conducted in Texas, at the Texas Transportation Institute facility, results from the crash test showed that the PL-3 traffic barrier reinforced with Combar (a German GFRP product) satisfies the *Canadian Highway Bridge Design Code* requirements and may now be used on Ontario's highway bridges.

The Canadian Highway Bridge Design Code, CSA S6-06, already includes provisions for use of GFRP in other applications, including PL-2 barriers. Until now, MTO has only used PL-3 barriers reinforced with steel on provincial bridges. While the Code specifies that bridge barriers can be designed using yield line theory, they must also be crash tested to meet the requirements of NCHRP Report 350 before they can be used on Canadian bridges.

Until recently, designs for GFRP bars in barriers required custom bar bends performed when manufacturing. Given bent GFRP bars are much weaker than straight bars due to the redirection and associated rearrangement of the fibres in the bend, the number of bent GFRP bars used for a project must be increased, sometimes doubled. For the Texas crash test, GFRP bars with specially designed anchor heads, developed by Shock in Germany, were used.

GFRP bars with anchored heads.

The Schock anchor heads eliminate the need for custom made bars and reduce their development length in the deck slab. The heads are made of a thermo-setting polymeric resin with a compressive strength far greater than normal grade concrete. The maximum outer diameter of the end heads is 2.5 times the diameter of the bar. The head of the 16 mm bar is approximately 100 mm long, beginning with a wide disk which transfers a large portion of the load from the bar into the concrete. Beyond this disk, the head tapers in five steps to the outer diameter of the bar. This geometry ensures optimal anchorage forces and minimal transverse splitting in the vicinity of the head.

PL-3 barrier tests require impact by a tractor trailer.

For the crash test, 16 mm nominal diameter GFRP bars were used both for the vertical reinforcement of the barrier face as well as for the horizontal reinforcement.

The Ryerson crash test followed the testing protocol of NCHRP Report 350, for evaluating the strength of a PL-3 barrier during impact. The test requires a 36000 kg gross weight tractor trailer travelling at a constant speed of 80 km/hr to impact the barrier at a prescribed angle of 15 degrees. A successful crash test will contain and redirect the vehicle, which must not penetrate or jump over the barrier.

At impact during the crash test, the tractor trailer began to tip toward the barrier, but resolved once its speed was naturally reduced and redirected as required. The test vehicle remained upright during and after the collision, and did not penetrate, under-ride or override the barrier. There were no detached elements, fragments, or other debris from the barrier that showed potential for penetrating the occupant compartment, or cause undue hazard to others in the area. Occupant compartment deformation did not occur.

After the crash test, only minor cracks on both sides of the barrier were observed. Damage to the barrier was acceptable indicating that the test was successful and the barrier met the required capacity. Cracks, such as those exhibited on the crash tested barrier, would require field repair to avoid possible crack propagation.

In the past, MTO has used black steel and epoxy coated steel in concrete barriers. These forms of steel are susceptible to corrosion, and can result in premature barrier maintenance or replacement. The Ministry's earlier corrosion protection >

Glass Fibre Reinforced Polymer Rebar, *continued*

policy has required the use of stainless steel reinforcement for PL-3 barriers. Use of stainless steel – and now advanced composite materials such as GFRP – in barriers, eliminates the possibility of corrosion and ensures a 75-year maintenance-free design life. As barrier walls with black and epoxy coated steel reinforcements need replacement, MTO will now allow the use of both stainless steel and GFRP reinforcement.

GFRP is competitively priced, making it a viable alternative for reinforcing all types of concrete barriers currently used on MTO highway bridges.

MTO is currently developing a Standard Drawing for PL-3 barriers reinforced with Combar GFRP, for use in future Ontario construction contracts. •

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Video courtesy of Ryerson University, 2011.

GFRP bars set up for barrier construction.

Barrier cracking as a result of tractor trailer impact during testing.

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Smog: A Nice, Light Snack?

Photocatalytic Concrete Field Trials along Ontario's Freeways

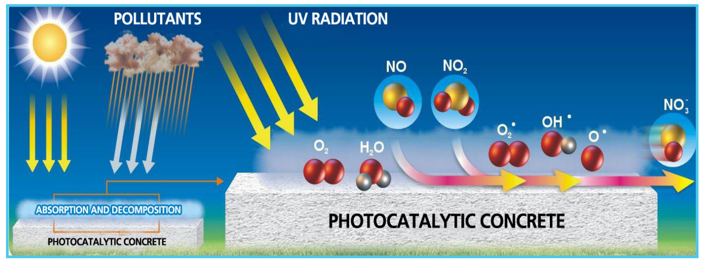
Air pollution is a major global issue affecting our social, economic, and environmental sustainability. The Ontario Ministry of Transportation (MTO) is partnering with the Ministry of Environment, the University of Toronto, Armtec (a noise barrier manufacturer), and Essroc Italcementi Group (the North American division of an international supplier of photocatalytic cement) to conduct photocatalytic concrete field trials. A new "smog-eating" technology, photocatalyic concrete will be applied to a section of noise barriers along Highway 401, near the Highway 404 Interchange in Toronto, starting in the summer of 2011.

Photocatalytic concrete is an emerging green technology which incorporates titanium dioxide particles into Portland cement used to make concrete. Studies have shown that photocatalytic concrete can significantly reduce air pollution and keep concrete surfaces clean. When activated by ultra-violet rays from sunlight, titanium dioxide acts as a catalyst to accelerate the oxidation process that converts nitrogen oxides and other smog components such as fine particulate material, carbon monoxide and sulphur dioxide, to less harmful compounds. Photocatalytic concrete has the potential to significantly reduce smog-forming air pollutants in its vicinity, thus acquiring the moniker "smog-eating concrete".

Italcementi, an international cement producer, has been the industry leader in research and development of photocatalytic cement over the last decade. This technology is being examined by industry and researchers around the world in European, Asian, and North American countries. Positive test results have been generally consistent among industry and researchers. PICADA, a European consortium of manufacturers and research laboratories, has also confirmed industry claims. Prominent technical conferences and workshops have been held, such as the Rilem Symposium on Photocatalysis, Environment, and Construction Materials (Italy, October 2007), and a workshop on Passive Photocatalytic Oxidation of Air Pollution, held at the Lawrence Berkeley National Laboratory (California, June 2007).

Over the last decade, several successful demonstration projects have been completed that involved the application of photocatalytic concrete to the surfaces of buildings, roads, tunnels, and noise barriers. Results show air pollutant improvement ranging from 20 to 70 percent in the vicinity of photocatalytic concrete, depending on sunlight, wind, and other factors. Project costs are minimized since only a thin surface layer of photocatalytic concrete is placed over a conventional concrete base.

Results reported from European trials suggest photocatalytic concrete placed in an area the size of a soccer field can remove emissions equivalent to approximately 190,000 car-km per year. Testing indicates that 1 square metre of photocatalytic concrete removes up to 60 mg of NOx per day. Demonstration projects show that the best pollution reduction occurs when photocatalytic concrete is used in urban areas closest to the source of pollution. The photocatalytic effect is more significant in partially confined spaces such as "canyon" streets. During the photocatalytic concrete demonstrations, the following factors made air pollution abatement more efficient:



Mechanism of decomposition of air pollutants, in presence of photocatalytic cement-based surfaces.
(Image used with permission from Essroc Italcementi Group, 2011).

- Light intensity above 5 W/m2
- Temperatures above 10°C
- Less than 65 percent relative humidity
- Higher pollution concentration
- Concrete surface close to pollution source
- Wind direction blowing perpendicular to concrete's surface
- Porous surface characteristics.

In addition to reducing pollution, the photocatalytic concrete reaction has an established self-cleaning quality found to be most effective on organic stains, in dry conditions and smooth surfaces with minimum porosity. The Ministry plans to evaluate the self cleaning capabilities of the photocatalytic sound barrier Hwy 401 test site.

Through collaboration between government agencies, industry, and academia, using concrete to "clean" outdoor air could become a reality in Ontario. Many potential applications have been identified, although more project demonstrations and research are required. Certainly, the properties of photocatalytic concrete align well with the Ministry's goal of having the greenest roads in North America, but it remains to be seen whether significant benefits are accrued on site. Over the course of a year, the Ministry of Environment plans to conduct air quality monitoring at MTO's test site to confirm the smog reducing capabilities previously obtained in laboratories elsewhere. The final results of MTO's field trial will be used to determine if smog-reduction is significant enough to warrant further, large-scale applications in Ontario. •

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