



Two years after MTO finished building its perpetual pavement tests section on Highway 401, the results of the testing program are starting to come in.

Does a perpetual pavement resist bottom up cracking better than a conventional pavement? According to the preliminary findings from the Centre for Pavement and Transportation Technology, the answer is “yes”.

LESS STRAIN LONGER LIFE

Testing the Perpetual Pavement on Highway 401

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Backgrounder

Perpetual Pavement Testing

Testing Agency: Centre for Pavement and Transportation Technology

Testing Stations:

- Standard design section
- Perpetual pavement (with rich bottom mix)
- Perpetual pavement (without rich bottom mix)

Testing Equipment per Station:

- Strain gauges (12)
- Pressure cell
- Moisture probe
- Thermistor string

Testing Equipment Cost: approx. \$100,000

Data Collection: weekly

Supporting Organizations:

- MTO
- OHMPA
- Stantec Consulting
- Natural Science and Engineering Research Council
- McAsphalt Industries

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The Test Program

In 2009, MTO completed the construction of perpetual pavement test sections on Highway 401 near Woodstock. The 15-kilometre long pavement has three sections, an 11-kilometre long 300-millimetre thick conventional pavement with two 2-kilometre long perpetual pavements at the west end. The two perpetual pavements, each one 420-millimetres thick, are identical except for the bottom layer of 100 mm SP 25, which in one of the sections has 0.8% more asphalt cement. Known as a 'rich bottom mix', the additional asphalt cement increases the flexibility of the pavement and is designed to resist fatigue bottom-up cracking at low temperatures. (See page 37 for a detailed backgrounder on the design of the perpetual pavement).

A perpetual pavement is designed to last at least 50 years, which means that it could be decades before there is any indication if the design is adequate or not. That's too long to wait, says Susan Tighe, a professor of civil engineering at the University of Waterloo and the director of the Centre for Pavement and Transportation Technology.

"The only way we're going to know what's going on inside the pavement structure is to monitor it and see how different pavement structures react and perform under various traffic loadings and environmental conditions," Tighe says.

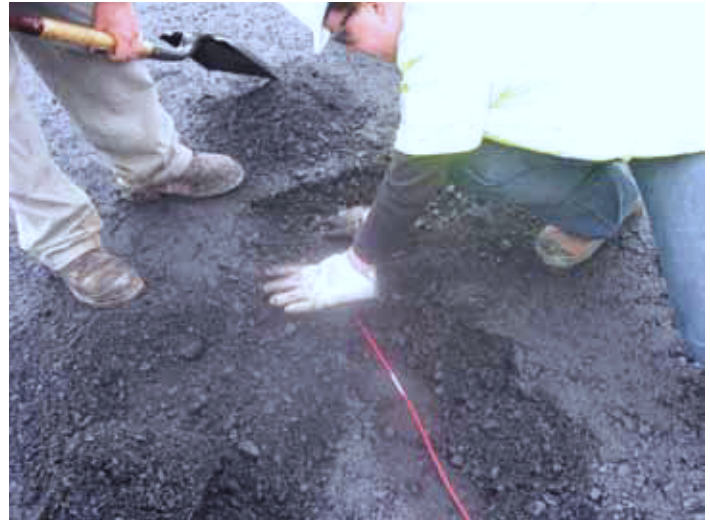
With the support of the Ministry of Transportation of Ontario and the Ontario Hot Mix Producers Association, CPATT installed three testing stations on Highway 401 at a cost of approximately \$100,000. One station is in the standard section of the highway, one in the perpetual pavement with the rich bottom mix and one in the perpetual pavement without a rich bottom mix. Since there are no exits along this particular stretch of the 401, the traffic loading, an estimated Average Annual Daily Traffic of 48,000, on all three pavements is identical.

Strain gauges capture the dynamic strain in the pavement in locations where crack initiation is anticipated, the most critical of which is the bottom of the asphalt concrete layer under the wheel path where the tensile stress is the greatest. Strain gauges were also installed near the top of the bottom layer about 90 millimetres above the granular base.

An earth pressure cell was installed under the wheel path on the top of subgrade material so that the research team can measure vertical stresses and monitor subgrade rutting. A moisture probe in the subgrade tracks water penetration while a thermistor string, with 10 temperature sensors spaced 10 centimetres apart, measures frost penetration.

The instrumentation, powered by solar cells, is connected to a data logger that collects the information and transmits it to the CPATT laboratory in Waterloo once a week.

"The strain gauges are the key element in the testing program," says Tighe. "They tell us first of all if the strains in the bottom layer of the perpetual pavement are less than those in the standard section and second if the strains in the bottom layers are excessive. The other sensors give us important information about the environmental conditions, especially freeze thaw progression, and whether factors other than loading are in play."

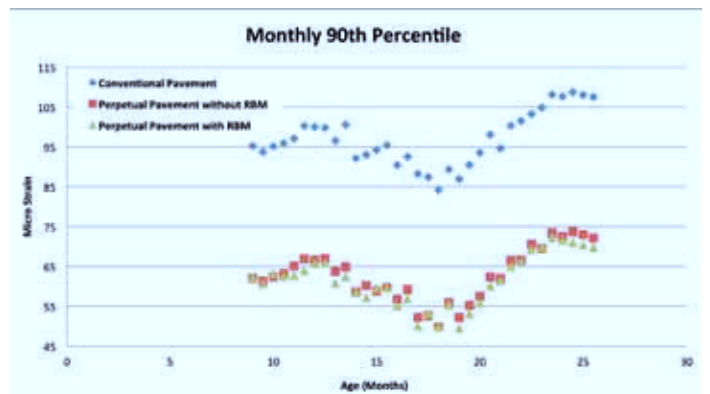


Test Results

For Mohab El-Hakim, the perpetual pavement project has been a unique opportunity to combine his academic studies with one of the most important pavement projects in the province's history. As a master's student in civil engineering at the University of Waterloo, he covered the construction of the project, helped install the microsensors for the testing program and ran simulations to predict the structural performance of the pavement. Today El-Hakim, under the direction of Professor Susan Tighe, is collecting and analyzing the test data as he completes his Ph.D.

The most important consideration in designing a perpetual pavement is the tensile strain at the bottom of the asphalt layers, El-Hakim explains. "If the tensile strain at the bottom layer of the pavement is kept below the fatigue endurance limit (typically for most asphalt pavements around 70 microstrains) you can eliminate bottom up cracking, which is the most significant cause of pavement failure. The problem, of course, is that bottom up cracking is virtually undetectable. The surface looks good until suddenly all the cracks start to propagate and then you have to do a full reconstruction. Measuring the tensile strain at the bottom of the pavement is the only way we can determine if there is a potential for bottom up cracking."

So far, he adds, after analyzing two years of data the results seem to indicate that the perpetual pavement is performing significantly better than the conventional pavement.



The first analysis, a plot of the bi-weekly 90th percentile strain data (90 percent of the strain values measured are at or

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less than the 90th percentile, the other 10 percent are higher but are disregarded as anomalies), clearly shows that the bottom of the perpetual pavements, with and without the rich bottom mix, are showing considerably less strain than the conventional pavement.

You can also see, El-Hakim notes, the similarity in the plots for all three types of pavement, with the strain decreasing from the 15th to the 18th month and then increasing again, a period of time that coincides with winter. "It is a typical pattern," he says. "When the temperature goes down, the pavement becomes less elastic and that means less strain."

At the same time, he continues, you can also see that the strain in all three pavements is greater at its peak at the end of 24 months than it was 12 months earlier.

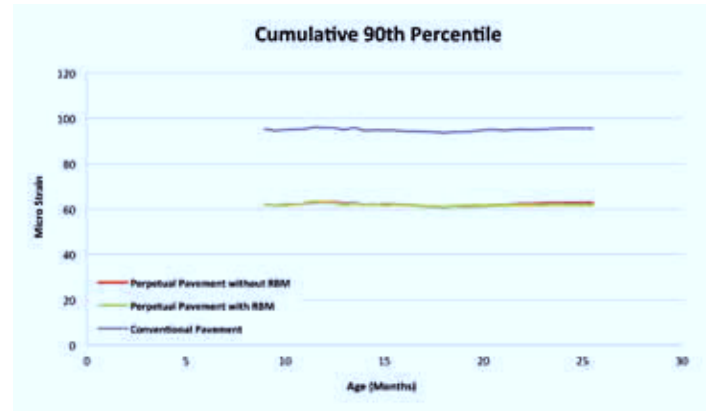
"Even with constant traffic conditions, you would expect to see more strain in the pavement as it ages so that sort of pattern is to be expected. On the other hand, you have to be a bit careful because the way that we have plotted the data is giving a bit of a distorted picture.

"Not all the strain that we are measuring stays in the asphalt. Once the vehicle has passed, it relaxes and some of the strain dissipates. In a way, the asphalt heals itself. So plotting the monthly figures tends to distort the trend. To get around that we look at the cumulative strain, the 90th percentile of all

the data that we have collected before a given point in time."

The second analysis, which shows the cumulative 90th percentile for each of the three types of pavements, confirms that the perpetual pavements are showing less strain than the conventional pavement. It also shows that the strain value, rather than increasing after the second year, is actually starting to flatten out.

"This is the key to sustaining the structural integrity of the perpetual pavement – keeping the cumulative strain below that critical 70 micro strain threshold," El-Hakim notes.



While the perpetual pavement is clearly outperforming the conventional pavement, the difference between the perpetual pavement with the rich bottom mix and the one without it is virtually imperceptible. Whether or not adding additional asphalt cement for more flexibility contributes to better long-term per-

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formance remains to be seen, which, according to El-Hakim, may not show up for the next 10 years or so.

“Given that a perpetual pavement should last for 50 years, you wouldn’t expect to see major differences in the first couple of years. But over the long term even a small difference can have a big impact. Since the cost of additional binder is negligible compared to the construction cost of the whole pavement section, even a slight improvement can have a significant economic benefit.”

CPATT continues to collect and analyze the data from the test stations and will publish reports as the information becomes

available. It has also prepared a structural analysis based on the Mechanistic-Empirical Pavement Design Guide using the physical and mechanical properties of the pavement mixes. The predictions of the mechanistic model are showing a good correlation to the field tensile strain collected to-date.

CPATT has used the MEPDG results to design a maintenance and rehabilitation program for the different pavement designs and will be using all the results in a Life Cycle Cost Analysis to determine whether the additional construction costs of a perpetual pavement (roughly about 30 percent more than a conventional pavement) are justified. ■

Backgrounder

The Highway 401 Perpetual Pavement Project

Designed to withstand 400 million ESALs over its 50-year life, the Ministry of Transportation of Ontario’s first large-scale perpetual pavement trial was completed in 2009 on Highway 401 near Woodstock.

It is a big test - 24 lane-kilometres long - but its potential is far bigger. If the test section validates the promise of perpetual pavements, it will influence the design of major highways throughout the province for decades to come.

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Perpetual Pavement Design

Location: Hwy 401 near Woodstock

Size:

- Length - 2 sections of 2 kilometres each
- Width - 6 lanes

Traffic:

- Traffic Category E
- 400 million ESALs over 50 years
- AADT - 48,000

Standard Design (11 kilometres)

Granular B - 550 mm
Granular A - 200 mm
Pavement structure - 300 mm

Perpetual Pavement Design (4 kilometres)

Granular B - 550 mm
Granular A - 200 mm
Pavement structure - 420 mm

Asphalt Cement

- 4 upper layers - PGAC 64-28
- 2 lower layers - PGAC 58-28

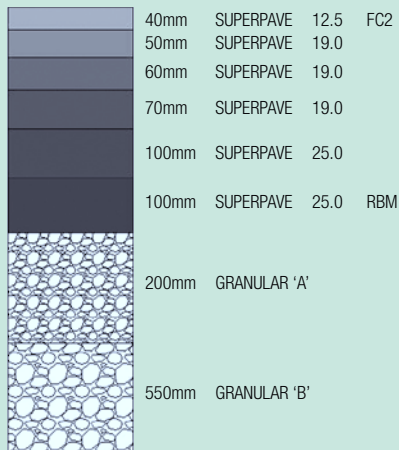
Overall Project:

Size: 15.3 kilometres / 6 lanes wide
Timing: July 2008 - October 2010
Contract value: \$105 million

General Contractor: Aecon

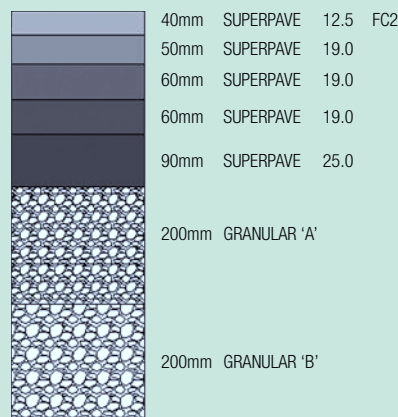
Subgrade Construction: Aecon

Paving Contractor: Capital Paving



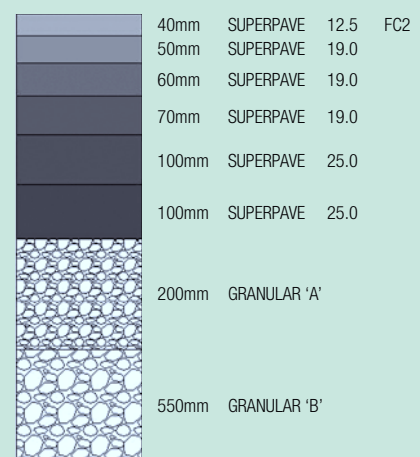
PERPETUAL PAVEMENT WITH RBM CROSS SECTION

STATION 12+230



CONVENTIONAL PAVEMENT CROSS SECTION

STATION 13+067



PERPETUAL PAVEMENT WITHOUT RBM CROSS SECTION

STATION 12+350

Backgrounder continued...

Perpetual Pavements

Asphalt pavements are under constant stress but it is the ability to resist fatigue that ultimately determines a pavement's longevity. In engineering terms, fatigue is the progressive failure of a material due to repeated long-term stresses, usually at levels well below the normal stress levels that the material can withstand. In other words, as the name implies, the material simply gets tired.

Fatigue failure creates cracks in the bottom layer, which then work up to the surface and since this compromises the pavement's structural integrity, the entire pavement has to be replaced.

Perpetual pavements are designed not to fail. The base layer is either a "rich bottom" mix - a mix with more asphalt cement and less air voids - or an extra thick section designed to resist fatigue. The intermediate layer resists rutting. Properly designed, the two bearing courses never need to be replaced.

Traffic and exposure to the elements will inevitably wear down the surface course but it can be milled and replaced relatively inexpensively and without too much disruption as and when needed.

The Design

The pavement along the 11-kilometre standard highway reconstruction is more than usually robust. The base is 750 mm of granular A and B. The pavement, 300 mm thick in total, has four bearing courses (a 90 mm SP 25, two 60 mm courses of SP 19, and another 50 mm course of SP 19) and will be finished with a wearing course of 40 mm SP 12.5 FC2.

The perpetual pavements, built across all six lanes at either end of the reconstruction project, are even more substantial. The 750 mm granular base is the same as the conventional design but the perpetual pavements at 420 mm thick is forty percent thicker than the standard pavement.

The two perpetual pavements are identical with the exception of the bottom layer of 100 mm SP 25, which in the rich bottom pavement has 0.8% more asphalt cement. There are two SP 25 bearing courses, each one 100 mm thick, followed by three courses of SP 19 (70, 60 and 50 mm thick respectively) and finished with a 40 mm surface course of SP12.5 FC2. ■

