Inner Workings: Paving with plants

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Most thruways are made from rocks and gravel held together with asphalt, a petroleum product. Chemist Ted Slaghek envisions a time when the trucks, cars, and bicycles of his native Netherlands will travel over green roads—literally.

Slaghek has high hopes for a material found in woody plants, called lignin. With the right balance of chemical components, lignin pavings, he says, could prove to be resilient and cost-effective. However, he'll have to make both the scientific and economic case.

Slaghek, a chemist at the Zeist campus of an independent applied research organization in the Netherlands called TNO, started the project in response to a request from the Danish company Icopal that sought sustainable alternatives to asphalt (often called bitumen in Europe). The material is essentially the tarry goo that’s left behind after petroleum is refined. Quality varies from batch to batch, so, at an added cost, companies like Icopal blend in expensive polymer additives (also derived from petroleum) to maintain performance.

Supply is also a problem in some parts of the world, as many refineries have gravitated toward products that have proven to be more profitable than asphalt (1–3).

Although Northern Europe lacks refineries, it’s rich in trees. Hoping to come up with something both less expensive and more sustainable, Slaghek thought of lignin, which makes up about 30% of the biomaterial on Earth.

Usually, after the sugars, cellulose, and other more useful materials have been extracted from plant matter to make biofuels or paper, the leftover lignin is tossed aside and burned. In principle, the economics are therefore promising: Paper companies could profit from what had been a waste product, and biofuel makers could similarly use the proceeds of selling lignin to bring down fuel production costs.

From a chemical perspective, lignin and asphalt have some things in common. Asphalt is a complex stew of organic compounds. Lignin is a large, complex biopolymer consisting of defined subunits, some of which—particularly the carbon-ring-containing compounds, called aromatics—resemble major components of asphalt. A specialist in natural polymers, Slaghek saw the commonality. “My world is the molecular world,” he says.

Simply blending untreated lignin into asphalt doesn’t work. The relatively hydrophobic plant polymer forms unmixable lumps. So Slaghek’s group at TNO performed some chemical modifications to lignin, taken from paper production leftovers, to make it more hydrophobic and get it to blend with asphalt. The TNO researchers use a method called dynamic shear rheology to simulate how the various blends of sustainable asphalt hold up under increasing levels of vibration meant to simulate the flow of traffic at temperatures ranging from −10 °C to 60 °C. The researchers found they can replace as much as half of the asphalt in paving material with modified lignin and the paving won’t crack or dent. TNO has applied for patents on the materials.

One version of TNO’s material is designed to stay sticky on winter days in cold climates to prevent rocks from flying up into the windshield. The other is tailored for hotter climates; in the summer, it will resist forming ruts (they won’t say how the two versions differ chemically, due to the pending patents). Other researchers have upgraded asphalt but use expensive polymers. Slaghek described the lignin project in March 2015 in Denver at a meeting of the American Chemical Society.*

Governments in the provinces of North and South Holland have expressed interest. Later this year, they’ll build short lengths of road from the material to see how it performs under the stresses of cars, trucks, and bikes.

Other groups have similar bioasphalt aspirations. R. Chris Williams, a materials engineer at the Iowa State University Institute for Transportation, has developed a way to turn lignin-rich stover, leftover from biofuel production, into bioasphalt. The Iowa team uses a process called fast pyrolysis that turns plant waste into a charcoal-like fertilizer, natural gas, and an oily mixture that can be made into bioasphalt.

In 2010, the state of Iowa tested the material on a small scale. A bike trail had 3% of its asphalt replaced with bioasphalt derived from corn stover and wore as well as a conventional path—it didn’t crack or wear out any faster. Laboratory tests, Williams says, suggest a blend of 80% bioasphalt and 20% conventional asphalt by weight works better than the pure petroleum version, and he hopes these will be on highways eventually. Williams performs vibration and temperature tests similar to the ones used by Slaghek.

Researchers do high shear mixing of bitumen with lignin, a process they hope to scale up. Image courtesy of Ted Slaghek and Dave van Vliet (TNO, The Netherlands).

*Slaghek T, Vliet D, Haaksman I, Giesen C American Chemical Society National Meeting, March 22, 2015, Denver, CO.

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The process is very efficient: Natural gas produced during pyrolysis fuels the reactor. Startup Avello Bioenergy of Boone, Iowa, has licensed the technology and is currently building a pilot plant. In 2014, says Williams, the price of asphalt was $550 to $600 a ton; bioasphalt costs $385 to $380 a ton. Still, Iowa has been more cautious than the Netherlands provinces about rolling out green test pavings.

For Slaghek, sustainability is a plus, but he’s really keen on economic viability (although he won’t name a price point yet). “It’s a dot on the horizon, but one day, crude oil won’t be so abundant,” he says. “Sustainability is a plus, but the business case prevails.”

1. World Highways (February 17, 2015) Data revealed on Europe’s asphalt bitumen usage. World Highways. Available at www.worldhighways.com/categories/materials-production-supply/news/data-revealed-on-europes-asphalt-and-bitumen-usage/. Accessed August 17, 2015.

2. George L, Bousso R (February 13, 2015) Corrected: European “refining spring” won’t save plants from the axe. Reuters. Available at www.reuters.com/article/2015/02/13/europe-refineries-idUSL6N0VG42L20150213. Accessed August 17, 2015.

3. Oil and Energy Trends (2014) Focus: European refinery closures continue as foreign competition increases. Oil Energy Trends 39(3):3–6.