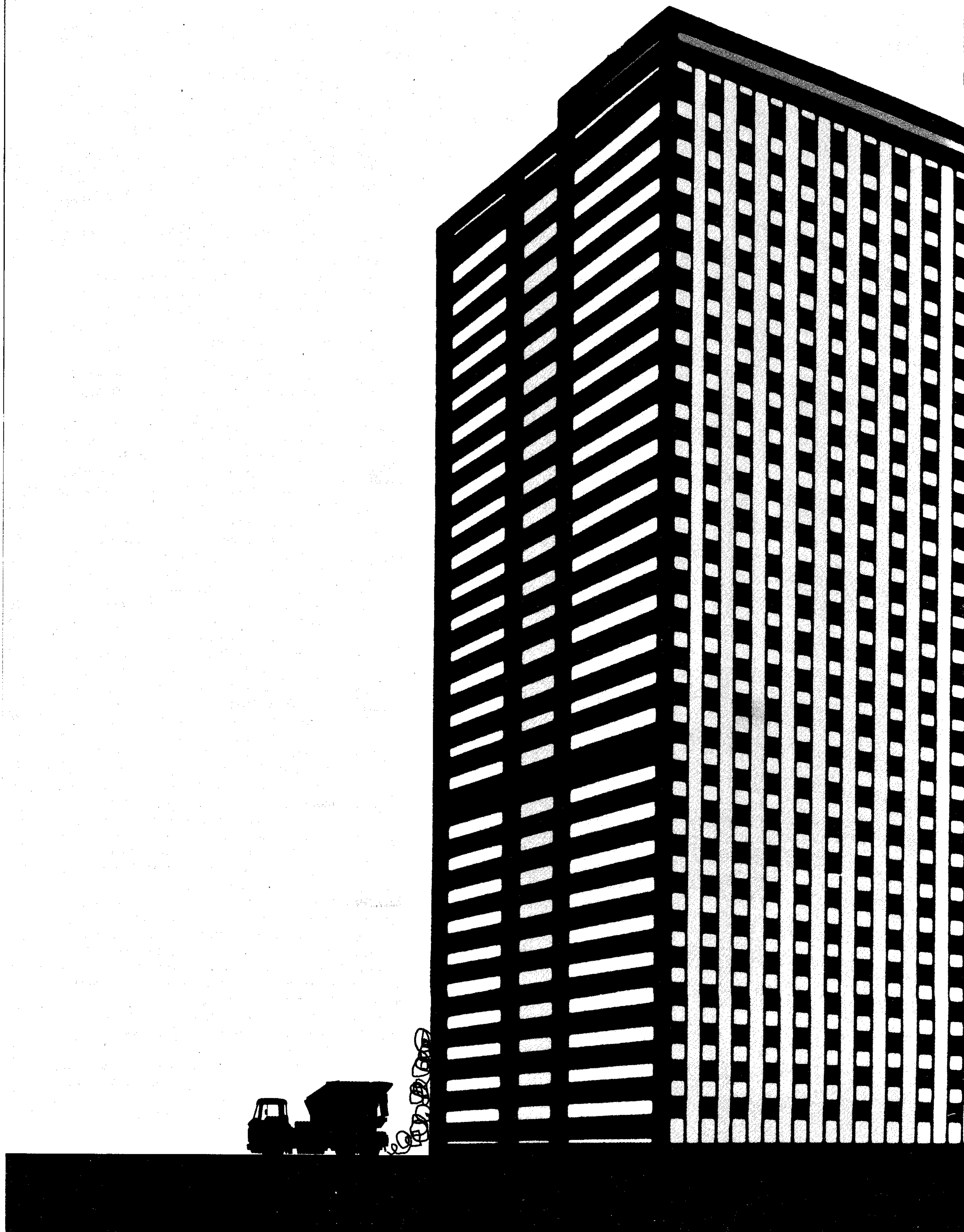
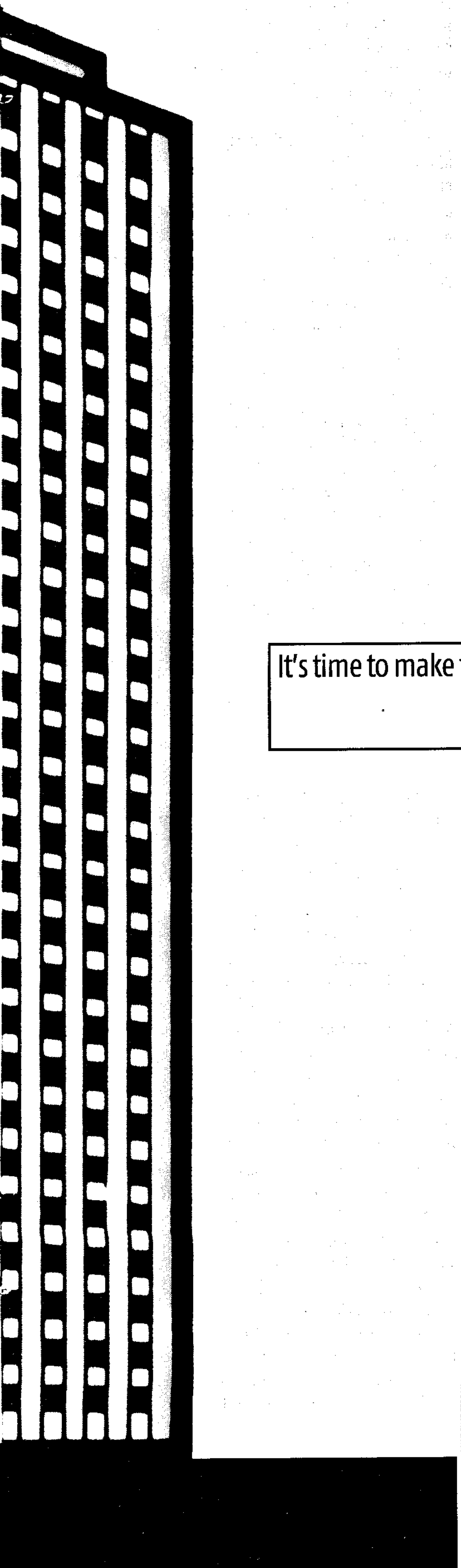




LAWRENCE ZEEGAN

Green Foundations

It's time to make the concrete jungle emulate the real thing, says Fred Pearce

THERE is a way to make our city streets as green as the Amazon rainforest. Almost every aspect of the built environment, from bridges to factories to tower blocks, and from roads to sea walls, could be turned into structures that soak up carbon dioxide – the main greenhouse gas behind global warming. All we need to do is change the way we make cement.

John Harrison, a technologist from Hobart, Tasmania, reckons his alternative cement, based on magnesium carbonate rather than calcium carbonate, could reduce climate change without sacrificing modern living. It's a big claim, and Harrison has set about trying to convince the building industry to adopt his ideas.

"The Kyoto Protocol was a good effort," says Harrison. "But it got things wrong when it assumed that trees were the only things that could absorb carbon from the air." Instead, he wants to replace the ubiquitous Portland cement with a substance that he calls "eco-cement". This magnesium-based material, he says, "could be cheaper to manufacture than Portland cement, more durable and soaks up CO_2 as well." And, claims Harrison, if the building industry listens, cities and their suburbs could turn into sinks for CO_2 as effective as, for example, the natural grass and woodland they replaced.

Our modern world is largely built of Portland cement, invented almost 180 years ago by a Yorkshire stonemason called Joseph Aspdin. In 1824, he obtained a patent for "an improvement in the modes of producing artificial stone" that involved roasting chalk and clay in a kiln, grinding the resulting "clinker" into a fine power containing mainly calcium silicates and mixing it with water. This starts a complex chemical reaction that forms crystals of calcium silicate hydrate, for example, which hardens the mix (see Diagram p 40).

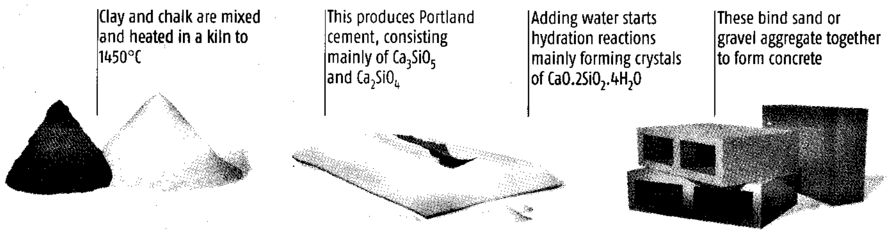
The 19th century was a time when the great cities of Britain were under construction, and many other inventors were working on artificial stone. But Aspdin cracked the problem by subjecting the ingredients to the ultra-high temperatures of a glassmaker's kiln in his home town of Hunslet. He called the product Portland cement because of its resemblance to the most popular natural stone of the day, from the Isle of Portland in Dorset.

Portland cement proved cheap to make and immensely versatile, and soon became the basic ingredient of both concrete and mortar, the building blocks of every city on the planet. Every year, some 1.7 billion tonnes of Portland cement are now produced worldwide, a staggering quarter of a tonne for every person on Earth.

But there's a problem. The manufacture of Portland cement produces massive amounts of ▶

CONCRETE CHEMISTRY

Making concrete the old-fashioned way



CO_2. This is partly because of the huge amounts of energy required to raise temperatures inside cement kilns to the 1450 °C needed to roast the calcium carbonate (from chalk or limestone). And it's also because the process of conversion itself creates CO_2.

For every tonne of Portland cement emerging from the kilns, roughly a tonne of CO_2 gas escapes into the atmosphere. Cement manufacture is responsible for around 7 per cent of total man-made CO_2 emissions worldwide, a figure that rises above 10 per cent in fast-developing countries such as China, which currently manufactures one in every three tonnes of cement made around the world (*New Scientist*, 19 July 1997, p 14).

If we mean to control global warming this situation can't go on. And, says Harrison, it need not. His solution, being brought onto the market by his small company TecEco, is to replace the calcium carbonate in the kilns with magnesium carbonate – a rock that occurs widely on its own, as the mineral magnesite, or in mixtures with calcium carbonate, such as dolomite.

Magnesium-based cements aren't new. They were first developed in 1867, by Frenchman Stanislas Sorel, who made cement from a combination of magnesium oxide and magnesium chloride. However, his mixtures couldn't stand long exposure to water without losing their strength. Put a tower block of the stuff in a Manchester or Seattle drizzle and it would eventually crumble away.

Harrison's magnesium carbonate-based "eco-cements", on the other hand, are chemically quite similar to calcium carbonate-based Portland cement, and are far more robust than Sorel's material. And according to Harrison, his material has a number of major environmental advantages. For a start, the kilns don't need to be run so hot. Magnesium carbonate converts readily to magnesium oxide at around 650 °C. This means that emissions of CO_2 from the energy used to fire kilns are roughly halved.

The roasting process for the manufacture of eco-cements produces more CO_2. But during setting and hardening, a process called carbonation reabsorbs most of this from the air.

When conventional concrete made from Portland cement is fresh, water in the mix also slowly absorbs CO_2 from the atmosphere. This solution then reacts with the alkaline calcium-containing components in the concrete matrix to deposit calcium carbonate crystals, which reduce the strength of the concrete.

But carbonation is quicker and more efficient in Harrison's eco-cement. Magnesium carbonate crystals are stronger than those of calcium carbonate, so they add to the material's strength.

If eco-cement is used to make porous materials like masonry blocks, virtually all the material will eventually carbonate, says Harrison. So a tonne of concrete can end up absorbing up to 0.4 tonnes of CO_2, he says, equalling about 100 kilograms of carbon. "The opportunities to use carbonation processes to sequester carbon from the air are just huge," says Harrison. "It can take conventional cements centuries or even millennia to absorb as much as eco-cements can absorb in just a few months."

This means that eco-cements quietly carbonating in a tower block could be performing much the same atmospheric function as a growing tree. And if eco-cements gained a foothold in our cities, they could immediately reduce the cement industry's contribution to global warming, reabsorbing much of what was emitted in their creation. By directly replacing Portland cement with his eco-cement, Harrison estimates that we could eliminate over a billion tonnes of CO_2 each year.

The idea is "a world first", says Fred Glasser of the University of Aberdeen's chemistry department, one of the leading authorities on cement technologies. And eco-concrete has another way of proving its greenhouse-friendly status. The material has huge potential for incorporating all sorts of waste matter, including carbon-based organic wastes that would otherwise rot or burn and release CO_2 into the air.

Adding inert waste such as fly ash to cement is routine in the industry. But for Portland cement there are strict limits. Because the cement is alkaline, mixtures can react with aggregate to crack the concrete or make it brittle, sometimes causing failure. "Magnesium cements are much less alkaline, and the potential problems are far less," says Glasser, who believes this could be one key to their eventual widespread use.

Organic waste from rice husks to sawdust, plastics and rubbers can all be incorporated as a bulking material in magnesium cement without it losing significant strength, says Harrison, thus turning the cement in buildings, bridges and so on, into permanent stores of carbon. "We have made bricks that are over 90 per cent ash," he says. "We can probably get three to four times more waste into our cement than Portland cement." This would also massively reduce the amount of cement needed in the first place.

His magnesium-based cements may not meet every requirement, he admits. You might not want to replace Partland cement entirely for bridge beams, say. But Harrison reckons magnesium cements could eventually replace 80 per cent of cement. This move wouldn't come cheap. Prime sources of magnesium carbonate, such as magnesite and dolomite,cost more to mine than calcium carbonate. But the price should fall with economies of scale, says Glasser.

Harrison has already gone into manufacture. He sold his first eco-cement bricks for a commercial building project in May this year. But he fears the costs of maintaining his patents could force him out of business before it really gets going. Industry associations contacted by *New Scientist* had not heard of Harrison's new eco-cement, and they still believe that magnesium-based formulations are unreliable.

The main problem, says Glasser, is that "the building materials industry is intensely conservative". It prefers what it knows – Portland cement. Engineers are familiar with its mechanical properties. And of course, Portland cement is cheap. It may guzzle energy like there is no tomorrow, but a couple of dollars will buy you as much of the stuff as you can carry away from a hardware store. "The market for Portland cement is so vast that it is difficult to see magnesium cements making much of an inroad in the next 10 years," says Glasser. But perhaps, as the world tries to think up new ways of cutting back on its emissions of CO_2, eco-cement may have its day.

Our burning of fossil fuels is force-feeding Earth's atmosphere with CO_2 at a rate that vegetation can no longer absorb. The logical way out is to accelerate the formation of carbonate with our own man-made rocks. What better way, says Harrison, than in cement? ●

CLEAN AIR ACTS

There are other ways for cities to soak up pollution, such as incorporating nature into the built-up environment. Trees and grass at the roadside soak up not just carbon, but also many of the ingredients of smog. And now traffic queues could help too: car manufacturers Volvo and Nissan have started to equip their vehicles with radiators coated in a catalyst that converts ozone in the air to oxygen. Better still, scientists at Mitsubishi in Japan have come up with the pollution-eating paving stone. The idea is to coat titanium dioxide onto paving stones, roads and even the walls of buildings.

This chemical, normally manufactured for use as a whitener in paint and toothpaste, is a photocatalyst. Spread at nanometre thickness, it can speed up the breakdown of water vapour by ultraviolet light. This in turn produces hydroxyl radicals, reactive molecules that can oxidise a range of common pollutants. Hydroxyls can convert smog-causing nitrogen oxides from vehicle exhausts into harmless nitrogen and oxygen, for instance.

Two years ago, Westminster City Council in London tested Mitsubishi's paving slabs on the streets of the capital. Things haven't gone beyond that. But in Japan, the paving slabs are already in use in 50 towns. And in parts of Hong Kong, they are estimated to remove up to 90 per cent of the nitrogen oxides that trigger smogs.

Titanium dioxide removes most pollutants from the air except CO_2. But by spreading it onto concrete slabs made from Harrison's cement, even that could be addressed in the ultimate eco-city of the future.