Materials and infrastructure

Materials are an important aspect of infrastructure, be they structural materials in physical structures, or the functional materials that underpin the devices used in information technology, for example. New lighter and 'smart' materials will be important in the development of sustainable and safe intelligent infrastructure.

From the development of steel track for railways, materials technology has always underpinned the development of new infrastructure. Materials, and their shortcomings, can also present challenges of safety and environmental performance. Even something as well established as steel rails can throw up new problems, as was the case when a poorly understood form of metal fatigue caused a major train crash at Hatfield.

Innovation in materials is likely to follow, rather than to lead, the development of infrastructure systems. The introduction of new materials is limited by our ability to accommodate them rather than by unmet demands for materials with particular characteristics.

We will need new materials technologies to keep up with demands for sustainability and for increasing environmental performance, during manufacture, operation and disposal. Demands for ever higher safety standards also mean that materials must not only operate safely, they must also fail 'gracefully,' reducing the risk of serious accidents or of catastrophic failures due to sabotage or similar malicious interventions.

Materials technology can do much to reduce the energy consumption of transport through weight reductions in cars and other vehicles. Each 10 percent reduction in the weight of a car or truck increases fuel efficiency by seven percent. For example, plastics offer high performance and durability, as well as lighter weight compared to steel, aluminium and glass.

Structural materials

The materials most visible in our infrastructure include the traditional structural materials – steel, concrete, asphalt and combinations of them.

Any future construction of infrastructure may have to cope with challenges to the supply of structural materials. Limitations on land use and waste disposal could put pressure on the continued extraction and use of aggregate as a virgin material. Here we can expect to see greater use of recycled and secondary materials from the construction industry.

For cement production, the constraint in future is more likely to be its energy intensive manufacturing processes. New materials and processing techniques can support the development of cement that is more durable and has better performance.

Cement structures may also benefit from incorporating 'smart materials'. For example, 'smart concrete' could contain short carbon fibres which to give the concrete the ability to detect stress and tiny deformations.

Another option could be to embed into concrete materials that can act as sensors to monitor hydration, curing, shrinkage and creep, and strain in operation. Such sensors would add a degree of 'intelligence' to structures. In this way smart materials could lead to smart structures – buildings in which materials provide structural safety and serviceability while providing longer service life and cheaper maintenance.

Any new composite including smart materials should match the performance of traditional materials. For example, if the embedded components have a lifetime of just 10 or 20 years, this should not compromise the residual lifetime of the concrete, which might well be a further 80 to 100 years.

Smart materials

As well as their potential in structural materials, there are numerous possibilities for other applications of 'smartness' in functional materials. In many cases, the materials could also have uses far beyond transport. For example, some materials can remember their shape in such a way that raising their temperature after they have been mechanically deformed will return them to their original shape.

Other smart materials could include electrostrictive and magnetostrictive materials that respond to an applied electric or magnetic field, creating a mechanical effect. Such materials could operate as actuators, shock absorbers or active tags, for example.

This Research Brief is based on the Research Review written by Professor Peter Guthrie, of the Department of Engineering, University of Cambridge, for the Foresight Project on Intelligent Infrastructure Systems. Series editors Professors Phil Blythe, Glenn Lyons, Will Stewart and John Urry. Editor Michael Kenward.

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