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Nanotechnology in construction

Nanotechnology is possibly the next big thing, but what does it have to do with construction? Michael Smith, National Building Specification (NBS) Information Specialist, investigates.

1 nanometre (nm) is a billionth of a metre; the smallest things visible to the naked human eye are around 10,000nm. Industry proponents say that nanotechnology will have a giant effect on building, gaining better performance from existing products at lower cost and creating new and novel applications, from self cleaning roads and fabrics to electricity generating coatings and other even more exotic products.

Market consumption of nanomaterials is accelerating. According to the Freedonia Group, there was $1 billion in worldwide demand for nanomaterials in 2006, with 3% of it in construction. Freedonia expects demand to grow to $4.2 billion by 2011 and $100 billion by 2025: of this, construction is expected to claim around 7%.

Seeing nanoparticles

Until scientists were able to view matter at the nanoscale it was impossible to effectively manipulate materials at that level, view the results of experiments, and measure their properties. Optical tools, along with tools for working with matter at the nanoscale such as electron-beam lithography, were only really developed during the 1980s and 1990s.

Carbon nanotubes (CNT), possibly the first application of nanomaterials, look like a fine black powder to the human eye. Viewed through a microscope it's apparent that the tubes are hollow fibres that can be over a million times as long as they are thick. Their structure gives them a massive strength-to-weight ratio, which when blended with polymers can add strength to anything from car tyres to golf clubs. They are also good conductors, and are used at a much finer level in electronics.

However, it would seem nanotubes are not a new substance; Damascus swords apparently contain carbon nanotubes, which might contribute to the legendary sharpness and strength of this medieval steel.

Unique properties

As a large particle is divided into smaller and smaller pieces, the proportion of its surface area to its mass increases. This happens at an exponential rate when the particle size is 100nm or less. Since the magnitude of many chemical reactions is limited by the available surface area of the chemicals involved, nanotechnology can make far more efficient use of chemicals. This characteristic can have fairly predictable effects as well as explosive ones; nanoparticles of aluminium, which is usually relatively inert, are explosive.

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Controlled production of nanoparticles and the ability to shape materials at the nanoscale have opened up horizons that were hitherto unimagined. Instead of trying to create nanoscale machines, most nanotechnology in commercial use today simply uses the benefits of nanoparticles. For example, nanosilver has become a common antimicrobial treatment in everything from bandages to washing machines; while silver is antimicrobial in larger particles, using nanoparticles makes for more efficient use.

Nanotechnology in building materials

Nanomaterials still have a high cost relative to conventional materials, meaning that they are not likely to feature in high-volume building materials. The day when this technology slashes the consumption of structural steel has not yet been contemplated. Nonetheless, the ‘nano' tag is showing up more often in building products.

Two nanoparticles that stand out in their application to construction materials are titanium dioxide (TiO_2) and carbon nanotubes. The former is being used for its ability to break down dirt or pollution and then allow it to be washed off by rain water on everything from concrete to glass and the latter is being used to strengthen and monitor concrete. The following areas are those where nano-enhanced products are likely to be more widely available soon:

Surfaces and coatings

A number of companies are using nanotechnology to add special characteristics to product surfaces, which can be anything from stain-resistance and colour durability to self-cleaning, improved hardness and scratch-resistance, corrosion and UV resistance, and improved thermal performance.

Nanotechnology also has the potential to bring antimicrobial properties to surfaces. In 2007, research from Yale University found that carbon nanotubes were effective at killing E. coli bacteria.

Thermal performance

By tweaking molecular properties affecting thermal performance, manufacturers have been able to significantly improve this quality in some materials, offering potential energy-efficiency benefits to buildings. Aerogels, very lightweight solids made from silica and carbon, are a high-performing thermal product benefiting from nanotechnology.

Structural materials

With the strength and lightness offered by materials like carbon nanotubes, structural materials would seem to offer a natural fit for nanotechnology in buildings. So far, however, improvement of major building materials is still at the research phase.

Recent nanotechnology research in forest products, focusing on the nanoscale properties of wood, hopes to develop advanced nanomaterials. Wood densification, chemical modification, or impregnation by resins could improve hardness, wear and decay resistance.

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An outline research agenda for nanotechnology in cement and concrete covering the next two decades has been enacted; however, practical applications have not yet emerged. Goals include improving mechanical and shrinkage properties, reducing energy consumption during cement production, developing self-powered sensors to monitor the performance of installations and developing innovative concrete materials.

Health and environmental risks

Nanotechnology's unique benefits come with unique hazards. The large surface area to mass ratio that makes nanoparticles more effective in chemical reactions could also increase the level of exposure to an organism. While this could improve the effectiveness of medications using nanoparticles, it could also increase toxicity. Also, because they can pass through biological barriers, nanoparticle drugs could pose a potent threat if unwanted particles migrate through the body.

Inhalation of nanoparticles is particularly worrisome. Several studies during the last decade have shown that exposure to airborne nanoparticles can result in significant deposition of those particles in the respiratory system. Respiratory problems have followed, as well as cardiovascular ones, including coagulation and inflammation. Given the uncertainties, some groups have advocated for a moratorium on nanotechnology research and development, but that call has not been widely taken up.

One exposure route that doesn't get a lot of attention is disposal of used or waste products. If little is known about the safety of nanotechnology manufacturing, even less is known about the safety after disposal. Unpredictable hazards could occur from burning, biodegradation and leaching in landfills, and exposure to water. Researchers have described plausible scenarios in which bacteria absorb nanoparticles, bringing them into the food chain, or where absorbent nanoparticles bond with more toxic pollutants, making those pollutants more mobile.

The industry generally lacks enough data to make fully informed risk assessments and the inherent danger is that instead of acknowledging this lack of information, it will use it to argue that special attention to risk factors and regulation is not needed. The known risks seem to recommend a prudent approach to limiting exposures as nano-enhanced building materials and other products enter the market.

Regulation

The industry hasn't yet faced any highly publicised health or environmental problems of the kind that might have brought significant regulation or litigation. Asbestos, which bears some resemblance to nanotubes, became costly for the construction industry well after it had been believed to be safe and entered widespread use.

In this unregulated environment, many companies using nanoparticles are choosing not to mention them. In July 2007, Consumer Reports found that out of eight sunscreens it tested, all contained nanoparticles of zinc oxide or titanium dioxide, yet only one of those products disclosed its use on the bottle.

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What's ahead?

While nanotechnology has not yet become as pervasive as past materials revolutions, like plastics, it could already be on that path. Researchers suggest that nanotechnology will increasingly help the building industry to improve the performance of its buildings.

For the time being, cost and the relatively small number of practical applications hold back much of the prospects for nanotechnology in the construction industry.

However, materials are the core business of construction, and the prospects for change are significant in the not too distant future. The sheer size and scope of the construction industry means that the accompanying economic impact will be huge.

Further information

Nanotechnology in construction
Freedonia Group's US industry study with forecasts for 2011, 2016 and 2025 - Summary of the report
http://www.bharatbook.com/upload/NanotechnologyinConstruction.pdf

European Nanotechnology Trade Alliance (ENTA)
Aims to promote the benefits of nanotechnology via a trade body that interfaces with the public, the media, Government and political bodies actively involved in determining regulatory framework
http://www.euronanotrade.com/