NANOTECHNOLOGY IN ROAD CONSTRUCTION

Nanotechnology is a recently developed, major enabling tool, already well-established in several sectors of applied science, technology and engineering. Development of nanotechnology has lead to advanced characterization, prediction and control of properties of materials at sub-micron level. Nanotechnology has enhanced the understanding of 'origins' of key properties of everyday materials and structures; of manufacturing processes and interactions between materials, structures, external elements and internal components. Experiences in developed countries have proved that the possible benefits of nanotechnology in the transportation sector are manifold. In addition, much more effective uses of basic resources and development of environmentally sustainable production processes are predicted. Its potential for development is such that nanotechnology is often being considered as the Industrial Revolution of the 21st century.

It is being predicted that the application of nanotechnology in construction of highways would lead to safer, simpler and cost effective highways. The science holds great promise for the transportation sector because, scientists potentially could manipulate the molecules of cement and asphalt to optimize certain features and create pavements to give much better performance. They could also manufacture more durable and stronger steel by rearranging and combining alloy particles.

Experiences in the developed world have revealed that there are multiple potential applications of this technology in highway sector. Concrete is a material containing pores on a nanoscale. Repeated exposure of concrete to chemicals causes oxidation, cracks and long-term deterioration in the structures. Utilizing nanotechnology to create smart, self-healing materials could lead to faster construction as well as increased durability and improved performance of structures, thereby helping to prevent catastrophic failures.

The ability of nanotechnology to constantly monitor materials could offer better prediction of service life and life cycle performance of the bridges. During construction, nanotechnology could allow for embedding increasingly small sensors throughout a structure or pavement. These sensors could be used for long-term monitoring of corrosion and could offer an invaluable tool in monitoring deterioration and cracking in concrete without physical intervention. Similarly, these sensors could monitor vibrations and loads on bridges and enable researchers to assess weaknesses and fix them long before they are apparent to human inspectors. It has also been assessed that the road sensor networks could gather and provide data to transportation operators to manage congestion and accidents on roads in a better way.

Experiments in USA have established that through the application of nanotechnology, the potential for improvements in the engineering properties of constituent materials of hot mix asphalt (HMA) is significant particularly, in resistance to moisture damage, strength and longevity. The ability to target material modifications at the nano level promises the optimization of material behavior and significantly improves mechanical properties of pavements like, durability, skid resistance, binding properties, maintenance and sustainability etc. It has also been experimented that nanoscale

research could lead to an increased use of recycled materials in pavements through a better understanding of bonding of different materials to improve the workability and durability of recycled materials, which would help to reduce costs.

Researchers are also developing new construction materials using microfibers and hybrid fiber systems to be used in cementitious materials, which could lead to the next generation of fiber-reinforced concrete. Carbon nanotubes are cylindrical carbon molecules with very high length-to-diameter ratios and novel properties. Carbon nanotubes have the ability to fill cracks in cement concrete. Preliminary research has shown that nanofibers and nano-tubes potentially can make cement super ductile, with more ability to accommodate tension without cracking, which could significantly increase the flexural strength. However, dispersion of nanotubes in cementitious materials remains a major challenge and various processing methods are being explored to optimize the number of nanotubes and their dispersion,which would help to develop cost-effective concrete for the next generation of highways.

As per the reports of FHWA, a self-sensing nanotechnology composite material has been developed, to provide real-time information on traffic flows and to monitor stress applications on highways, like vehicular loadings etc. The monitoring of vehicle weights is more convenient and effective as the weighing is performed while the vehicle is moving on the highway. In this way, traffic is not affected and time is saved. Apart from detecting traffic flow and monitoring loads, the self-sensing capability of the nanocomposite to detect stress levels is also finding applications in monitoring the health of structures. Deformation in the structure is registered as a change in the electrical resistance which is remotely monitored.

Several environmental applications of nanotechnology in highways have also been reported from the developed countries. One example is the ability to monitor mobile source pollutants during construction and operations by using nanoscale devices. Low-cost environmental sensors are being used to monitor the air, water and soil quality and mapping the pollution levels.

While nanomaterials are making in roads into certain construction applications in pavements and highway structures, many obstacles remain in the path of widespread adoption of this technology due to the conservative nature of contractors and high expectations of consumers. In addition, material and manufacturing costs are an issue in cost sensitive, large volume applications while concerns over health and safety are also yet to be proved.

As scientific research shifts focus to smaller scales, new and innovative research methods and partnerships are needed to solve complex problems. As with other areas of science and engineering, highway research, globally, is also moving towards investigating phenomena at smaller scales. Spotlighting nanoscale research could accelerate the ability of researchers to measure, model and manipulate matter at the nanoscale in pursuit of solving highway research needs. Assessing that relevant opportunities would be developed for other industries as well, it could accelerate breakthroughs in highway research also.

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