Effect of nano materials in rigid pavement

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1-Introduction

Nano materials are defined as engineered materials with a least one dimension in the range of 1-100nm [1].Concrete pavements are used in highways, airports, ports, stacking container yards, and industrial floors. Therefore, it is necessary to improve sustainability throughout their life cycle. One of the strategies applied is the use of industrial by-products and waste materials such as blast furnace slag, fly ash, and glass cullet [2]., which result in more energy efficiency. There are also new instruments and construction technologies that increase construction quality, e.g., laser screening[3]. Such improved construction methods and quality control results in more efficient services to vehicular traffic in the utility phase. Consequently, leading to less maintenance and rehabilitation. Following that, recycling of concrete has provided a new source of material for construction. However, there is an increasing need to develop a new generation of construction materials, which are more compatible with the environment, with higher strength and more potential for use in multi-role infrastructure assets. Under such circumstances, the materials of miniature size, which is the cornerstone of nanotechnology, have been developed for concrete pavements. Because there are various types of nanomaterials, with a wide range of applications, it is necessary to know the performance of such materials in detail. Therefore, the performance of different nanomaterials used in concrete pavements is discussed[4].

2-Purpose of this report

The aim of this report explains the importance of using nano materials in rigid pavement. Nano materials have a significant impacton the performance and durability of rigid pavements. Rigid pavements are commonly used in roads and highways, and they consist of a thick layer of concrete. By incorporating nano materials into the concrete mix, several beneficial effects can be achieved.

3-Beneficial effects of nanomaterials in rigid pavement

The beneficial effects of nanomaterials and some useful applications in concrete are summarized as following:

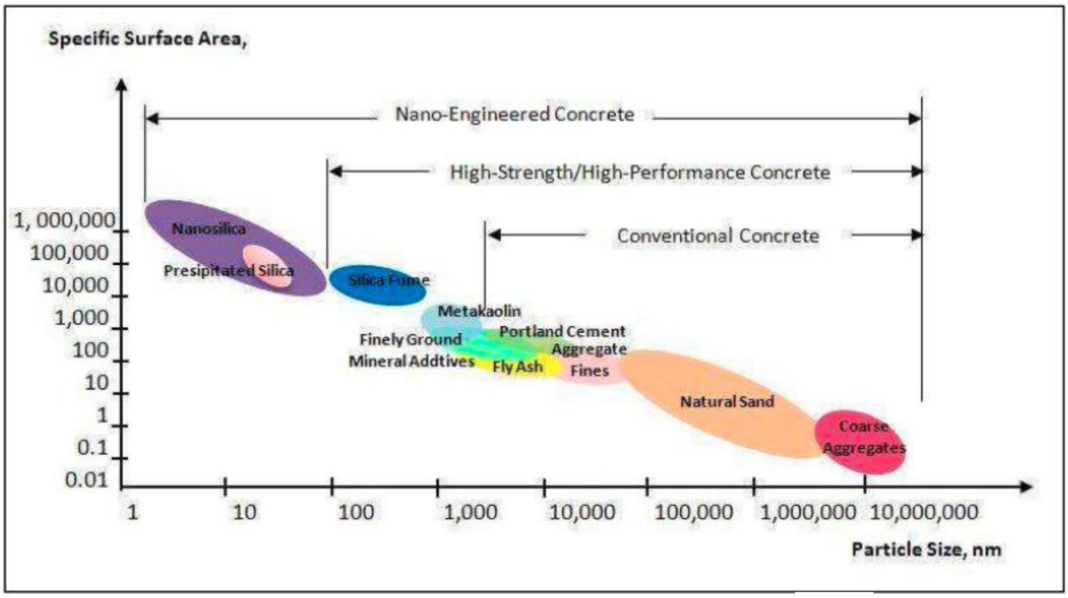
-They can enhance the resistance of the concrete to traffic and environmental loads, such as high temperature, moisture, aging, and fatigue

-They can increase the strength and durability of the concrete by filling the pores and cracks, and reinforcing the matrix.

-Producing a concrete having appropriate strength at a lower cost.

-Producing high-performance concrete materials, by the means of enhancing their mechanical, durability, and shrinkage properties[5].

-Adding novel properties to concrete[6].



Examples of particle size related to concrete material [8]

4-Litreature review (Nano materials used in rigid pavement and their application)

Nano-silica

Nano-clay

Nano titanium dioxide

4-1 Nano-silica

Nano-silica (NS) or silicon dioxide is a product of micro-based silica. NS has the same advantages of silica fume and micro-silica based on strength and durability. However, the advantage of NS is rapid early strength-gain in comparison to micro-silica[9]. The reason is that the higher surface area in NS increases the rate of reaction. Therefore, the curing time of concrete pavement decreases, which results in less construction time. It should be noted that lower construction time decreases delays during construction. Furthermore, the delay decreases sustainability and efficiency, because delay increases energy wasted proportionally in the paving projects[10]. The early strength-gain of concrete plays a crucial role in the maintenance and rehabilitation of airport pavements because it is often necessary to repair runway and taxiway pavements in a relatively short time[11]. Another advantage of the use of NS in concrete pavements is that the workability increases. The higher workability is an important factor to reinforce concrete pavements constructed with NS. There are two reasons behind the higher workability of such concrete. The first reason is that the NS acts as ultra-fine filler in the mix due to its tiny size. Another reason is that the ball-shape of NS decreases friction and interlocking among the granules. Therefore, the granules can slide with less energy, which results in lower viscosity Another study showed that cement consumption decreases by 20%e30%, which decreases raw material demand[12]. As a result, incorporation of NS in the concrete pavement results in high strength and cost-effective concrete pavements.

4-2 Nano-clay (NCL)

NCL has attracted attention for use in concrete products. It should be noted that small amounts of NCL can considerably improve engineering properties of concrete materials due to their natural structure and chemical properties. In addition, NCL can be categorized into different classes such as montmorillonite, bentonite, kaolinite, hectorite, and halloysite, depending on the chemical characteristics and nanoparticle morphology[13]. Generally, clay is categorized as a mineral material, simply called hydrous silicate[14]. In addition, clay can be referred to as hydrous aluminum phyllosilicate with various amounts of other mineral materials such as iron, magnesium, and alkali metals. Clay has high surface area due to its fine grained structure, micron, and sub-micron size. Fig. 1-A shows compressive and flexural strength of samples containing various percentages of NCL. It can be seen that NCL increases the compressive strength of samples[15]. NCL also improves strength of the concrete. The reason is the ultrafine size of the nanomaterials and their high surface area. The maximum compressive strength is for samples containing 3% NCL (Fig. 1-A), which can be considered as ONC. In addition, the strength reaches maximum after 21 days of conditioning, which points to rapid curing compared with the control samples. Furthermore, the compressive strength of control samples and samples containing 1% NCL, was almost identical. However, incorporation of 5% and 7% NCL decreases the compressive strength significantly. The possible reason is that the higher percentages of NCL cannot react very well and acted as excess filler in the mix. Therefore, interlocking in the mix structure decreases. In addition, the higher percentage can result in agglomeration in the mix[16].

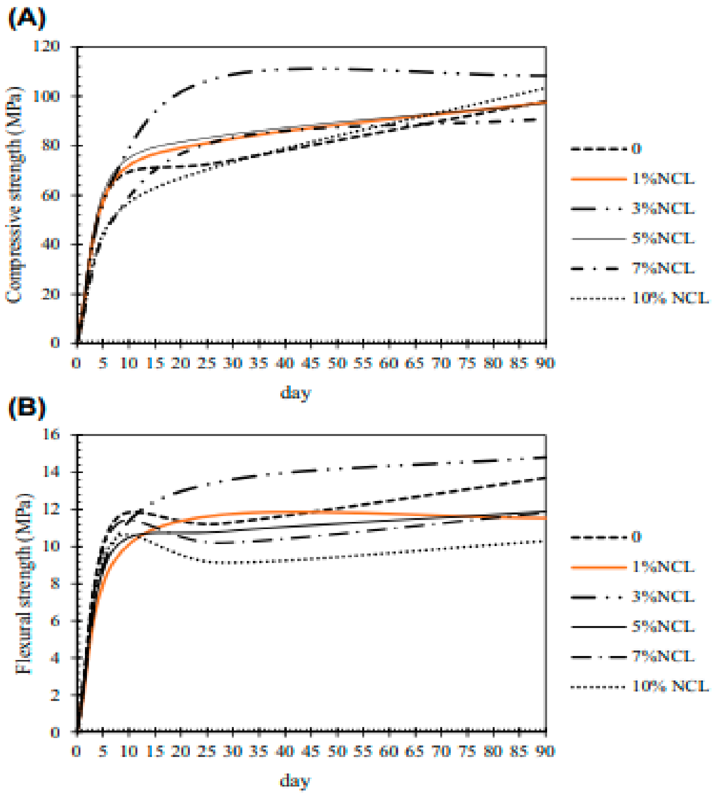


Fig. 1-A Strength of NCL samples: (A) Effects of NCL content on the compressive strength; (B) Effects of NCL content on the flexural strength.
Plotted based on the data reported by Mohamed, A.M., 2016. Influence of nano materials on flexural behavior and compressive strength of concrete. HBRC Journal 12(2), 212–225.

Fig. 1-B shows that the maximum flexural strength is for the samples containing 3% NCL.

4-3 Titanium oxide

(TiO_2) TiO_2 or titania is a product derived from oxidation of titanium. There are two important advantages that make TiO_2 attractive to use in concrete pavements. The main application of TiO_2 is to enhance the self-cleaning performance of such materials[17]: (1) early strength gaining; (2) self-cleaning property. The early strength gain results in opening the pavement to traffic earlier, thus resulting in less delay in the construction phase of the concrete pavement. It is a very important advantage as the pavements require rapid maintenance and rehabilitation. For example, the time span for maintenance of an airport pavement is relatively short. Therefore, the paving crew has to work quickly. The performance mechanism of TiO2 as a photocatalyst agent, involves the transfer of electrons from the valence band to the conduction band by photons for ultraviolet (UV) radiation in the UV array range. Therefore, the absorbed UV array results in electron holes, which are responsible for the formation of hydroxyl radicals in the microstructure of the pavement. In fact, titanium dioxide becomes a semiconductor element when exposed to UV rays. The formation of hydroxyl radicals is due to humidity at the surface of the photocatalyst. The humidity or water is also degraded into two ions and produces hydroxyl radicals[18].

5-Hazardous effects of nanotechnology and nanomaterials

The growth of nanotechnology brings with itself some hazardous effects. Some of these hazards are in direct contact with human health and some others are time related hazards, which adversely affect the environment. Among the nanomaterials nano silica, carbon nano tubes and nano Titania are the most widely used materials in the construction sector. In spite of many beneficial applications for these materials, the exposure to high concentration of these materials may cause serious human health hazards and defects including death. Furthermore, the release of these materials into the environment may adversely affect the environment and cause serious problems[19]. summarized four scenarios for environmental release and exposure to nanomaterials. The first scenario is the release of nanomaterial in to environment through the manufacture of building materials. The occupational exposure to workers can occur through inhalation, which could cause health problems. So it is essential for the workers in these plants to use inhalation protection equipments such as air filters to protect them against asbestos or ultra fine particles. The second scenario is happens during the demolition process which results in the environmental release of construction materials. It is essential that trained specialists dispose of hazardous materials like asbestos, cement, lead based paint and some persistent residues. The other scenario occurs during repair, renovation and construction activities. In this aspect, landfill disposal and dumping of construction wastes might be common methods of discharging nanomaterials to environment. The last scenario is the long-term release, which takes place during the lifetime of buildings, damage, wear, and abrasion of infrastructures. Either artificial effects or natural may cause these[20].

6-Conclusion

The incorporation of nano materials in rigid pavements offers numerous advantages. They improve the mechanical properties, enhance durability, strengthen bond with reinforcing materials, and enhance thermal performance. These effects ultimately lead to longer-lasting and more resilient pavements, reducing maintenance costs and improving overall road quality.

7-Recommendation

The adequate knowledge of the effect of nano materials during production or application on human health is still not sufficient so the safety must be seriously considered. The use of nanomaterials in rigid pavement has the potential to significantly improve its mechanical properties, durability, and sustainability. However, careful consideration, testing, and collaboration with experts are essential to effectively leverage the benefits of nanotechnology in pavement construction. The cost of most equipment and materials in nanotechnology is presently quite expensive, partly because it is an emerging technology but also because of the intricacy of the technology. In the case of nanomaterials, however, over time, prices have proven to drop the assumption is that the cost of materials will drop as production methods improve.

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