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Review Article

Carbon Nanotube and Civil Engineering

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Abstract: The construction of roads on soft clay soils is a challenging task and therefore considered as one of the biggest concerns in geotechnical engineering. The utilization of soft soils in tropical regions is currently low, although construction on them has become increasingly necessary due to economic reasons. Recent developments in nanoscience and nanotechnology opened fundamental and applied new frontiers in science and materials engineering. Advanced materials are being developed with enhanced chemical and physical properties with unique characteristics. The properties of these materials are determined not only by their composition and chemical bonds, but also by size and morphology. However, the traditional cementitious stabilizers like cement are under discussion, not only for their negative environmental effects during manufacture but also for their cost.
Keywords: Green Environmental; Nanomaterials; Cementitious Stabilization; Carbon Nanotube.

Introduction

The use of stabilization techniques has increased significantly in recent decades owing to new construction sites, increasingly being located in areas of poor quality ground. It is suggested that ground improvement will be critically important in future geotechnical practices to adopt cost-effective solutions, to achieve reductions in quantities of material used and etc. [1–3]. One of the extensively used techniques for the improvement of problematic soils in relatively tropical countries is soil treatment with customary cementitous additives such as cement, lime and fly ash [4-7].

In recent years, nanoparticles have attracted considerable scientific interest for many civil engineering applications. The types of nanoparticles that are most commonly used in cementitous composites are SiO_2, TiO_2, Al_2O_3, and carbon nanotubes [8-11]. Of all the introduced nanoparticles plays the most significant role. Furthermore, nanoparticles accelerate hydration of cement due to its high surface energy [9,12,15]. Also, nanomaterials causes physical alterations such as improvement in the packing density which corresponds to filling effect of its particles [14-17]. The emerging field of nanotechnology is mostly focused on carbon and inorganic based nanomaterials, such as carbon nanotubes, graphene, transition metal nanotubes and nanowires [17-20].

This study addresses a review of role stabilization soft soils by nanomaterials. Inclusion of carbon nanotube may reduce the cement consumption in the soil and accelerate the stabilization process and causes reduce air and soil pollution by adding a big amounts of chemical additive like cement and lime.

Carbon Nanotube

Carbon Nanotube (CNT) can now be considered as the “king” of nanomaterials. Its exceptional strength have made it as one of the candidates for stiff and robust structures. In-line with this, as the prices of the CNT continue to drop (this is important since geotechnical engineering use materials in bulk), its applications in geotechnical engineering is envisaged [17].

A Carbon Nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nanometer scale. The graphite layer appears somewhat like a rolled-up chicken wire with a continuous unbroken hexagonal mesh and carbon molecules at the apexes of the hexagons. Carbon Nanotubes have many structures, differing in length, thickness, and in the type of helicity and number of layers. Although they are formed from essentially the same graphite sheet, their electrical characteristics differ depending on these variations, acting either as metals or as semiconductors. As a group, Carbon Nanotubes typically have diameters ranging from <1 nm up to 50 nm. Carbon Nanotubes can be categorized by their structures:

Single-wall Nanotubes (SWNT), Multi-wall Nanotubes (MWNT), and Double-wall Nanotubes (DWNT)

Single-wall Nanotubes (SWNT)

Single-wall nanotubes (SWNT) are tubes of graphite that are normally capped at the ends. They have a single cylindrical wall. The structure of a SWNT can be visualized as a layer of graphite, a single atom thick, called graphene, which is rolled into a seamless cylinder. Most SWNT typically have a diameter of close to 1 nm. The tube length, however, can be many thousands of times longer. SWNT are more pliable yet harder to make than MWNT. They can be twisted, flattened, and bent into small circles or around sharp bends without breaking.

Multi-wall Nanotubes (MWNT)

Multi-wall nanotubes can appear either in the form of a coaxial assembly of SWNT similar to a coaxial cable, or as a single sheet of graphite rolled into the shape of a scroll. The diameters of MWNT are typically in the range of 5 nm to 50 nm. The interlayer distance in MWNT is close to the distance between graphene layers in graphite. MWNT are easier to produce in high volume quantities than SWNT. However, the structure of MWNT is less well understood because of its greater complexity and variety.

Double-wall Nanotubes (DWNT)

Double-wall nanotubes (DWNT) are an important sub-segment of MWNT. These materials combine similar morphology and other properties of SWNT, while significantly improving their resistance to chemicals. This property is especially important when functionality is required to add new properties to the nanotube. Since DWNT are a synthetic blend of both SWNT and MWNT, they exhibit the electrical and thermal stability of the latter and the flexibility of the former.

Mechanical and Transport Properties of Carbon Nanotubes

The intrinsic mechanical and transport properties of Carbon Nanotubes make them the ultimate carbon fibers. Table 1 and Table 2 compare these properties to other engineering materials. Overall, Carbon Nanotubes show a unique combination of stiffness, strength, and tenacity compared to other fiber materials which usually lack one or more of these properties. Thermal and electrical conductivity are also very high, and comparable to other conductive materials.

Table 1: Mechanical Properties of Engineering Fibers

Fiber Material	Specific Density	Strength (GPa)	Strain at Break (%)
Carbon Nanotube	1.3 - 2	10 – 60	10
HS Steel	7.8	4.1	< 10
Carbon Fiber-PAN	1.7 - 2	1.7 - 5	0.3 – 2.4
Carbon Fiber - Pitch	2 – 2.2	2.2 – 3.3	0.27 – 0.6
E/S - glass	2.5	2.4 – 4.5	4.8

Table 2. Transport Properties of Conductive Materials

Material	Thermal conductivity (w/m.k)	Electrical Conductivity
Carbon Nanotube	> 3000	106 - 107
Copper	400	6 × 107
Carbon Fiber-Pitch	1000	$2 – 8.5 \times 10^6$
Carbon Fiber - PAN	8 - 105	$6.5 – 14 \times 10^6$

Stabilization Using CNT

Effects of adding CNT to kaolinite causes the liquid limit, plastic limit, and of the mixtures increases in the mixture. This indicate that the mixture will have a lower soil strength, higher compressibility and reduced hydraulic conductivity. Consolidation tests results showed that the observation on compressibility to be true [18].

The presence of carbon nanotube (CNT) in a soil cement matrix has the ability to reduce the interparticles, spacing, which will promote the construction of a stronger and stiffer soil skeleton matrix together with the cementitious materials, therefore improving the mechanical properties of the material [21].

Additional CNT can lead to increased durability, decreased brittleness and increased tensile strength, and routine use of large volumes of non-traditional materials like fly ash [24].

Soil cement is extremely weak in tensile and flexural strength due to its brittleness. Thus, cracks tend to propagate quickly as the soil cement is put through undue stress in tension and by using a few amount of CNT which they have very unique specific (Table 1 &2) the problem will be solved [22-24].

The use of carbon nanotubes (CNT) in material science have already been documented to providing 117 times more tensile strength than steel and 30 times more strength than Kevlar. The use of CNT also provides an increase in Yong's modulus and elastic potential, which means that the soil cement and concrete can take greater loads without any potential permanent damage [24].

Conclusion

In view of the importance of achieving the status of green environmental policy and cleaner technology approach, the innovation of using carbon nanotube in tropical soft soil stabilization was investigated. The positive findings of this research work proved the existence of a combined action among the pozzolanic reaction between cement/lime by nanomaterials in clayey soil stabilization. These findings can help attacking two aspects: First, under adequate technical and environmental conditions, massive amounts of this residue would be partially reduced, converted to useful, value-added adsorbents, and second, can result in more economic projects. Although the use of nanomaterials in ground improvement applications is still in its infancy stage, the widespread and significant progress in the application of this environment-friendly stabilizer in tropical soil stabilization can be expected in the future.

References

1. Galende M.A. Becerril J. M. Gómez-Sagasti M. T., Barrutia O. Epelde L. Garbisu C. Hernández A. (2014). *Chemical stabilization of metal-contaminated mine soil: early short-term soil-amendment interactions and their effects on biological and chemical parameters*. Water Air, & Soil, 1825-1836.
2. Murali Krishna T. Shekun Beebi Sd. (2015). *Soil Stabilization by Groundnut Shell Ash and Waste Fiber Material*. International Journal of Innovations in Engineering and Technology, 52-57.
3. Manzoor Q.M. Mateo-Sagasta J. Jiménez B. Siebe C. Siemens J. Hanjra M. A. (2015). *Environmental Risks and Cost-Effective Risk Management in Wastewater Use Systems*. Wastewater springer, 55-72.
4. Horpibulsuk, S. Phetchuay C. Chinkulkijniwat A. (2012). *Soil Stabilization by Calcium Carbide Residue and Fly Ash*. J. Mater. Civ. Eng., 24(2): 184–193.
5. Du Y.J. Jiang N.J. Liu S.Y. Jin F. Singh D.N. Puppala A.J. (2014). *Engineering Properties and Microstructural Characteristics of Cement Stabilized Zinc Contaminated Kaolin*. Canadian Geotechnical Journal, 51(3): 289-302.
6. Horpibulsk S. Rachan R. Suddeepong A. Chinkulkijniwat A. (2011). *Strength Development In Cement Admixed Bangkok Clay: Laboratory And Field Investigations*. Soils and Foundations, 51(2):239-251.
7. Liang Y. Bradford S.A. Simunek J. Heggen M. Vereecken H. Klumpp E. (2013). *Retention and Remobilization of Stabilized Silver Nanoparticles in an Undisturbed Loamy Sand Soil. Environ*. Sci. Technol., 47 (21): 12229–12237.
8. Lowry G.V. Gregory K.B. Apte S.C. Lead J.R. (2012). *Transformations of Nanomaterials in the Environment*. Environ. Sci. Technol., 46 (13): 6893–6899.
9. Majeed Z.H. Taha M.R. (2012). *Effect of Nanomaterial Treatment on Geotechnical Properties of a Penang Soft Soil*. Journal of Asian Scientific Research 2(11):587-592.
10. Firoozi A.A, Taha M.R. Firoozi A.A. A. Khan T. (2015). *Effect of Ultrasonic Treatment on Clay Microfabric Evaluation by Atomic Force Microscopy*. Journal of Measurement. 66: 244-252.
11. Peralta-Videaa J.R. Zhaoa L. Lopez-Morenoc M.L. Rosad G. Hongb J., Jorge L. Gardea-Torresdey J. (2011). *Nanomaterials and the environment: A review for the biennium 2008–2010*. Journal of Hazardous Materials. 186(1):1–15.
12. Westerhoff P.k. Kiser M.A. Hristovski K. (2013). *Nanomaterial Removal and Transformation during Biological Wastewater Treatment*. Environmental Engineering Science. 30(3): 109-117.
13. Kendra L. Garner, Arturo A. Keller. (2014). *Emerging patterns for engineered nanomaterials in the environment: a review of fate and toxicity studies*. Journal of Nanoparticle Research. 16:2503.
14. Bahmania S.H. Huata B.K. Asadib A. Farzadnia N. (2014). *Stabilization of residual soil using* SiO_2 *nanoparticles and cement*. Construction and Building Materials. 64(14): 350–359.
15. Taha M.R. Taha O.M. (2012). *Influence of nano-material on the expansive and shrinkage soil behavior*. Journal of Nanoparticle Research. 14:1190.
16. Firoozi A.A, Taha M.R. Firoozi A.A. A. Khan T. (2014). *Assessment of Nano-Zeolite on Soil Properties*. Australian Journal of Basic and Applied Sciences. 292-295.
17. Firoozi A.A, Taha M.R. Firoozi A.A. A. Khan T. (2014). *Nanotechnology in Civil Engineering*. EJGE journal. 19:4673-4682.
18. Taha M.R. Ying T. (2012). *Effects of Carbon Nanotube on Kaolinite: Basic Geotechnical Behavior*. Journal of Nanoparticle Research. 23-27.
19. Belin T. Epron F. (2005). *Characterization methods of carbon nanotubes: a review*. Mat. Sci. Engineer. B. 119: 105–118.
20. Burghaus U. Bye D. Cosert K. Goering J. Guerard A. Kadossov E. Lee E. Nadoyama Y. Richter N. Schaefer E. Smith J. Ulness D. Wymore B. (2007). *Methanol adsorption in*

carbon nanotubes. Chem. Phys. Lett. 442: 344–347.

21. Chappell M.A. (2008). *Solid-phase characteristics of engineered nanoparticles: a multi-dimensional approach*. Nanomaterials: Environmental Risks and Benefits and Emerging Consumer Products, Springer. 1–14.
22. Chen C. Wang X. (2006) *Adsorption of Ni(II) from aqueous solutions using oxidized multiwall carbon nanotubes*. Ind. Eng. Chem. Res., 45: 9144–9149.
23. Chappella M.A. Georgeb A.J. Dontsovab K.M. Porterb B.E. Pricea C.L. Zhouc P. Morikawac E. Kennedya A.J. Steevensa J.A. (2009). *Surfactive stabilization of multi-walled carbon nanotube dispersions with dissolved humic substances*. Journal Environmental Pollution 157(4): 1081–1087.
24. Garboczi E. (2009). *Concrete Nanoscience and Nanotechnology*: Definitions and Applications. Nanotechnology in Construction 3: Proceedings of the NICOM3. 81-88.