Review of the Nano-Materials Used for the Soil Stabilization

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Abstract. Soil stabilization is required to make the soil fit for the given project and improve the desired engineering property of in situ soil. Soil modification by including materials like lime, fly ash, slag, cement and chemical based grouting etc., have been used to achieve the same. Nanotechnology has great potential to improve the soil engineering properties. The material particles having size of nanometers are known as nano materials. The soil modified by addition of such nano materials is known as Nano soil. The usage of Nano included substances in the field of soil change has offered an amazing good position in geotechnics. This paper review the major Nanomaterials or Nano Additives used for improving geotechnical qualities of soil. Improvements in the geotechnical properties depend upon the percentage dosage used as well as type of nanomaterial. The aim of this paper is to provide the complete reference for the researchers towards the types of nano materials used, its optimum dosages and type of engineering property improved.

Keywords: Nano materials; Soil Stabilization; Ground Improvement; Nano Soil.

1 Introduction

Soil is one among nature's most abundant construction materials. Almost all construction is made with or upon soil. Once unsuitable construction conditions are encountered, a contractor has four options; finding a new construction site, redesign the structure, remove the poor soil and replace it with suitable soil or improving the engineering properties of the site soils. Improving an on-site (in situ) soil's engineering properties is referred to as soil stabilization. Soil stabilization is seen as a means of enhancing aspects of engineering and other elements, including the conductivity of hydraulics, compressibility, strength, and the density. There are two primary methods of soil stabilization used today: Mechanical and Chemical or Additives.

A proper understanding of the geotechnical properties of soils is a pre-requisite for its use in engineering construction works. Numerous stabilization techniques are available to boost soil properties like addition of materials like cement, lime, bitumen etc. Nanoparticles are one of the newest additives and researches are working on to find its effect in properties of soils.

Nanotechnology is a rapidly emerging technology with vast potential to create new materials with unique properties and to produce new and improved products for numerous applications. In recent years Nanotechnology is also gaining popularity in the field of Civil and Geotechnical Engineering. The applications of Nanotechnology in geotechnical engineering in dealing with soil can be in two ways: 1) in studying soil structure at the Nanoscale and 2) in soil manipulation at the atomic or molecular level through the addition of Nanoparticles as an external factor to soil.

There is an excellent potential of Nanotechnology's application in soil mechanics because of their chemical reaction. Mixture of soil with additive may improve the soil strength parameters and this procedure has been performed in the past for stabilization and improvement of weak soils. The main strategy of Nanotechnology in geotechnical engineering is the improvement of soil parameters with the application of nano materials. The presence of nano material in the soil could influence significantly the physical and chemical behavior of soil due to a very high specific surface area of nano materials, surface charges and their morphologic properties.

2 Review of Literature on Nano Additives in stabilization of soil

In this paper an attempt is made to review the change in engineering properties by the addition of different nano materials. Previously few researchers [1, 14, 35] have demonstrated such review material wise, which has limitation of insight of materials applicability for importance of the particular engineering property. While here it is presented engineering properties wise. In subsequent paragraphs, engineering property wise effects of different nanomaterials with various soil type enlisted.

2.1 Atterberg's Limits

Many researchers have attempted to study the change in Atterberg's limit of CH type of soil. [18, 23, 26, 36, 38, 39, 44]

Jumrik Taipodia, Jagori Dutta & A.K. Dey used $CaCl_2$, CaO, KNO_3 on clayey soil and sandy soil with 10% dry wt. of soil. They have done atterberg's limit test with different proportions and obtained results that with addition of nano particles, compression index increases and plasticity index decreases.

P.Hareesh & R.Vinothkumar used nano silica & nano zeolite on CH & CI soil. Nano silica (0.2, 0.4, 0.6, 0.8, 1 %) & Nano Zeolite (0.4, 0.8, 1.2, 1.6 & 2%) were used and on addition of nano silica atterberg's limit increases and on addition of nano zeolite atterberg's limit decreases.

J.Ranjitha, Supritha D.K, Hitaishi.P & Pratik Kumar used Nano Polymer (SoilTech MK III) with Black Cotton Soil (CH) from 0.2, 0.4, 0.6, 0.8 to 1% proportions. After stabilizing the soil with varying percentages of SoilTech MK III polymer, there is considerable decrease in liquid limit & plasticity index.

Sanjeev Naval, Kanav Chandan, Diksha Sharma used Nano MgO & Nano Al_2O_3 with Kaolinite clay (CH) by 0.5%, 1.0%, 1.5% & 2.0% proportions. As nanomaterial content increased in the soil Liquid limit, plastic limit & plasticity index decreases.

Ajay Kumar Pandagre, Rajesh Jain used Nano-chemical Terrasil with Black Cotton soil (CH) with 2% lime by wt. of dry soil as an additive by 0.03, 0.05, 0.07 and 0.09% by wt. of dry soil. As Terrasil content increased in the soil, liquid limit, plasticity index decreases.
Dr. Sunil Pusadkar, Snehal Bakhade, Dr. Anant Dhatrak used Nano-Silica on Black Cotton soil (CH) with 0.3, 0.6 & 0.9% wt. of soil. Atterberg's limit of soil increases up to 0.6% & after it was decreased.
Nisha S L, Riya Roy used Nano Silica with CI type of soil with Sodium Bentonite (CH) as an additive. Proportions are nS + Bentonite Mixes (10+10, 5+15, 20+20, 15+25, 30+30, 25+35). As percentage addition increases, plasticity index increases.
Sanusha Babu & Shyla Joseph used nano titanium dioxide & nano fly ash on silty clay (CH-MH) with 0.5, 1, 1.5 & 2% proportion. When there is increase in nano TiO_2 & nano flyash, atterberg's limit decreases (around 60%).

Few researchers have attempted to study the change in Atterberg's limit of CL type of soil. [21, 31, 45]
Ansu thomas, R K Tripathi, L K Yadu & Sudeep Roy used Nano chemical terrasil stabilizer with Soil with 0.2, 0.5, & 0.8% by weight of soil. Results showed that upon increment plastic limit increases whereas liquid limit decreases. So, plasticity index decreases.
N. Ghasabkolaei, A. Janalizadeh, M. Jahanshahi, N. Roshan & Seiyed E. Ghasemi used Nano silica on CL type of soil with Cement (9% by dry weight) with 1, 1.5, 2 & 3% proportions. Plasticity Index (PI) decreases with addition of cement to the clayey soil but addition of nanosilica to cement-treated clay slightly increases the PI.
Alireza Tabarsa, Nima Latifi, Christopher L. Meehan & Kalehiwot Nega Manahiloh used montmorillonitr K(10) nano clay with loess soil (CL-ML) by 0.2, 0.5, 1, 2, 3% proportions. As nano clay content increases liquid limit, plastic limit & plasticity index increases.

2.2 Compaction Characteristics

Some of the researchers have attempted to study the change in Compaction Characteristics of CH type of soil. [23, 26, 36, 42, 44]
P. Sachin Prabhu, T. Prabu, P. Eswaramoorthi prepared nano fly ash (10, 20, 30%) using ball-milling with CH type of soil with prepared nano cement (2, 6, 10%) using Ball-milling as an additive. OMC value increases steeply with percentage of cement and MDD value decreases with percentage increment.
Dr. Sunil Pusadkar, Snehal Bakhade, Dr. Anant Dhatrak used nano silica with black cotton soil (CH) by 0.3, 0.6 & 0.9% wt. of soil. Results showed that MDD was increased up to 0.6% and OMC was decreased up to 0.6%.
Sanjeev Naval, Kanav Chandan, Diksha Sharma used nano MgO & Nano Al_2O_3 with Kaolinite clay (CH) by 0.5%, 1.0%, 1.5% & 2.0% proportions. As nanomaterial content increased in the soil MDD increases and OMC firstly increases & then decreases.
Sanusha Babu & Shyla Joseph collected nano titanium dioxide & nano fly ash with silty clay (CH-MH) by 0.5, 1, 1.5 & 2% proportions. Increasing in nano TiO_2 & nano fly ash results in maximum dry density (MDD) increased by 2.94% and optimum moisture content (OMC) decreased by 5.2%.

P. Hareesh & R. Vinothkumar used nano silica & nano zeolite with CH & CI type of soil with different nano silica (0.2, 0.4, 0.6, 0.8, 1 %) & nano zeolite (0.4, 0.8, 1.2, 1.6 & 2%) proportions. On addition of nano silica, OMC increases and MDD decreases.

Some of the researchers have attempted to study the change in Compaction Characteristics of CI type of soil. [31, 32, 38, 43, 45]

Ansu thomas, R K Tripathi, L K Yadu & Sudeep Roy used nano chemical terrasil stabilizer with soil by 0.2, 0.5, & 0.8% by weight of soil. Results showed that MDD increases (limited to 0.5%) and OMC decreases.

Olumuyiwa S. Aderinola, Emeka S. Nnochiri used nano-chemical terrasil with lateritic sample by 0% to 16% at 2% interval. As terrasil content increased in the soil, MDD values increased up to 12% & then decreased & OMC values decreased up to 12% & then increased.

Seyed Esmaeil Mousavi, Aliakbar Karamvand used nano polymer stabilization CBR PLUS (0 to 1%) with Silty Sandy Clay with Silica Sand (0 to 10%) as an additive. In results, highest MDD was found to be at optimum percentage.

Alireza Tabarsa, Nima Latifi, Christopher L. Meehan & Kalehiwot Nega Manahiloh used montmorillonite K (10) nano clay with loess soil (CL-ML) by 0.2, 0.5, 1, 2, 3% proportions. As nano clay content increases OMC decreased at 0.5% & afterwards increases and MDD decreases by increasing nano clay content.

Nisha S L, Riya Roy used nano silica with CI type of soil with sodium bentonite (CH) as an additive. Proportions were nS + Bentonite Mixes (10+10, 5+15, 20+20, 15+25, 30+30, 25+35). As percentage addition increases, OMC increases and MDD decreases.

2.3 Compressive Strength

Some of the researchers have attempted to study the change in Compressive strength of CH type of soil. [18, 20, 30, 36, 38]

J. Ranjitha, Supritha D.K, Hitaishi.P & Pratik Kumar used nano polymer (SoilTech MK III) with black cotton soil (CH) by 0.2, 0.4, 0.6, 0.8, 1% proportions. UCS value increases & was effective at 0.4% of polymer.

Dr. Sunil Pusadkar, Snehal Bakhade, Dr. Anant Dhatrak used nano-silica for stabilization of Black Cotton soil (CH) by 0.3, 0.6 & 0.9% weight of soil. The UCS value increases up to 0.6% dosage of nano-silica and then decreases.

Seyed Esmaeil Mousavi, Aliakbar Karamvand used nano polymer stabilization CBR PLUS (0 to 1%) with silty sandy clay and silica sand from 0 to 10%. The UCS increased by 1.8 times as compared to that of untreated soil.

Antonio Alberto S. Correia & Maria Graca Rasteiro used MWCNTs in coimbra soft soil with two surfactants (Amber 4001 & Glycerox) by MWCNTs of 0.001% (referred to dry weight of cement) & Surfactant concentration of 0.5, 1, 2 & 3% (weight percentage in water). Addition of small quantity of MWCNT leads to further mechanical improvements.

V. Subramani & S. Sridevi used nano clay & nano cement with soft soil (peat) by 0.5 to 2% proportions. Addition of 1% of nano cement & 1% of nano clay gave maximum strength.

Some of the researchers have attempted to study the change in Compressive strength of CI type of soil. [31, 43, 45, 46]

Ansu thomas, R K Tripathi, L K Yadu & Sudeep Roy used nano chemical terrasil stabilizer with soil by 0.2, 0.5, & 0.8% by weight of soil. UCS increases up to 0.5% dosage of terrasil & then decreases.

Alireza Tabarsa, Nima Latifi, Christopher L. Meehan & Kalehiwot Nega Manahiloh used Montmorillonite K(10) and nano-clay with loess soil (CL-ML) of amount 0.2, 0.5, 1, 2, 3%. The UCS test value is increases with increasing the dosage to the soil.

Dhruva Kant Verma, Dr. U. K. Maheshwari used nano titanium dioxide in clayey soil (CI). The amount mixed with soil is 0, 0.25, 0.50, 0.75 & 1%. The UCS test conducted with different amount of TiO_2, results showed that UCS value increased up to 0.75% & then decreases.

Nisha S L, Riya Roy used nano silica with CI type of soil mixed with sodium bentonite as an additive. Proportions were nano silica with bentonite mixes (10+10, 5+15, 20+20, 15+25, 30+30, 25+35). The UCS value increases for last two proportions mixed with soil.

2.4 California Bearing Ratio Value (CBR Value)

Some of the researchers have attempted to study the change in CBR values of CH type of soil. [18, 29, 36, 38]

J. Ranjitha, Supritha D. K, Hitaishi. P & Pratik Kumar used nano polymer (Soil Tech MK III) in Black Cotton Soil (CH) for different proportion (0.2, 0.4, 0.6, 0.8, 1%). The CBR test results shows that addition of nanomaterial responds positively.

Dr. Sunil Pusadkar, Snehal Bakhade, Dr. Anant Dhatrak used nano-silica mixed with black cotton soil (CH) in range of 0.3, 0.6 & 0.9% weight of soil. The samples tested for CBR and its value increases up to 0.6% & then decreases.

Chaudhari Riddhi, Tabiyar Suman, Bholanda Heena, Chaudhari Shivani & C.B. Mishra used nano chemical terrasil stabilizer for MH (from Palsana village of Surat) with 0.04% of optimum dosage, the CBR test value of specimen increases.

Seyed Esmaeil Mousavi, Aliakbar Karamvand used nano polymer stabilization CBR PLUS with different amount from 0 to 1% in silty sandy clay with silica sand (0 to 10%) as an additive. Values of CBR increased 6 times as compared to that of untreated soil.

Some of the researchers have attempted to study the change in CBR values of CL & CI type of soil. [21, 25, 32, 40, 46]

S. Anwar Hussain used Organosilane solution (Terrasil) in expansive soil (CL) with additives Polymer (Zycobond) & cement of quantity 0.6 kg/m^3. The addition of organosilane eliminates capillary rise and water ingress from top and reduces water permeability hence it’s CBR value Increases.

N. Ghasabkolaei, A. Janalizadeh, M. Jahanshahi, N. Roshan & Seiyed E. Ghasemi used nano silica in CL type of soil with cement as an additive of 9% by dry weight of soil. The soil is mixed with cement and nano silica (1, 1.5, 2 & 3%) and samples tested for CBR test. The test results are positive with incremental amount of nano-silica with cement.

Ankit Patel, C. B. Mishraused Nano-chemical Terrasil with Intermediate plastic clayey soil (CI). The soil replaced with 0.021% dosage and CBR test performed. As Terrasil content increased in the soil, CBR value increased.
Dhruva Kant Verma, Dr. U. K. Maheshwari used nano titanium dioxide in clayey soil (CI) with amount 0, 0.25, 0.50, 0.75 & 1%. The specimens performed for CBR test, and results of CBR increases by increasing nano TiO_2.
Olumuyiwa S. Aderinola, Emeka S. Nnochiri used nano-chemical terrasil with lateritic sample by 0% to 16% at 2% interval. As terrasil content increased in the soil, the CBR value increasing from 0 to 12% & after increasing amount of terrasil, it decreases.

2.5 Permeability

Few researchers have attempted to study the change in permeability of different type of soil. [38, 43]
Seyed Esmaeil Mousavi, Aliakbar Karamvand used nano polymer stabilization CBR PLUS of amount from 0 to 1% in silty sandy clay with silica sand (0 to 10%) as an additive. The soil tested for permeability test and it show that, the Coefficient of permeability decreases with increase of CBR PLUS amount.
Nisha S L, Riya Roy used nano silica with CI type of soil mixed with sodium bentonite as an additive. Proportions were nano silica with bentonite mixes (10+10, 5+15, 20+20, 15+25, 30+30, 25+35). The test results show that as percentage addition increases, coefficient of permeability decreases.

3. Discussions

Regarding Atterberg’s limit, when nanomaterials were added, in CH/CI type of soil plasticity index decreases. Also, if some additives were added with nanomaterials, in CI/CL type of soil plasticity index increases. Regarding compaction characteristics, when nanomaterials were added, in CH type of soil, optimum moisture content decreases and maximum dry density increases. Regarding strength characteristics, when nanomaterials were added, unconfined compressive strength increases up to its optimum values and then decreasing for almost all type of soil. Also, CBR values are increasing when nanomaterials were added. Permeability also reduces as nanomaterials were added.

4. Conclusion

Nanotechnology has great potential to alter soil engineering properties which is highly versatile. Only few changes in dosage affects the soil properties to great extent at macro level. Optimum dosage for various nanomaterials ranges from 0.6% to 10% considering additives. From optimum dosage, it is clear that utilization of nanoparticles in a soil blend builds quality compared to regular soil. These nanoparticles have novel properties due to their incredibly little size bringing about very high explicit surface region and surface charges.

From this review it is revealed that most of the scientist have work on strength and plasticity characteristics of soil. However none of them have cover environmental impact study for effects of soil with nano materials.

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