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STABILITY STUDIES OF COHESIVE SOIL WITH NANO MAGNESIUM AND ZINC OXIDE

ŠTUDIJ STABILNOSTI KOHEZIVNE ZEMLJINE Z DODATKOM NANO-MAGNEZJA IN CINKOVEGA OKSIDA

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Cohesive soils are found all over the world and can cause significant harm to infrastructure and structures. Many innovative ways to improve the strength of cohesive soils are being explored to decrease the negative qualities and make them appropriate for construction applications. The availability of novel materials, in addition to traditional procedures, has boosted the area of soil reinforcement. In the realm of soil stabilisation, the inclusion of nanomaterials is one of the newest creative ideas. In geotechnical engineering, nanotechnology could be viewed as dual methods: the composition of the soil can be found at the nanoscale, and soil modification can be accomplished at the atomic and molecular levels. The goal of this research is to see if it is possible to stabilise cohesive soil using two distinct nanomaterials and to look at the changes in geotechnical parameters. Nanocrystalline magnesium oxide and nano zinc oxide is included in the soil with (0.25, 0.5, 0.75 and 1) *w*/% and trials were executed to evaluate the optimal percent and strength properties of the mixtures.

Keywords: ground development, nano crystallie, magnesium oxide, zinc oxide, kaolinite clay

Kohezivne (plazovite) zemljine najdemo povsod po svetu in le-te lahko povzročijo pomembne poškodbe na zgradbah in infrastrukturi. Različni raziskovalci in projektanti so na področju gradbeništva našli že številne inovativne rešitve, kako izboljšati njihovo trdnost in s tem zmanjšati negativne vplive na načrtovane konstrukcije. Danes je na razpolago že vrsta novih ali izboljšanih materialov, kot dodatek k tradicionalnim postopkom, ki lahko ojačijo (utrdijo) zemljino. Na področju novejših načinov oziroma kreativnih idej stabilizacije zemljin je vgrajevanje nanomaterialov v zemljino. To je tudi eden od najučinkovitejših pristopov. V geotehničnem inženiringu in nanotehnologijah si lahko na zemljino kot tako ustvarimo dva pogleda: njeno sestavo lahko definiramo na nano nivoju in jo modificiramo z združitvijo atomskega in molekularnega nivoja. Cilj pričujoče raziskave, opisane v tem članku, je bil ugotoviti možnosti stabilizacije izbrane kohezivne zemljine z uporabo dveh različnih materialov in ovrednotiti spremembe geotehničnih parametrov. Avtorji so dodajali različne količine (0,25, 0,5, 0,75 in 1) *w*/% nano-kristalinične magnezije oziroma magnezijevega oksida in nano-cinkovega oksida v izbrano zemljino. Nato so izvajali preizkuse s katerimi so določili trdnost vzorcev in optimalni delež dodatka MgO oziroma ZnO v mešanicah.

Ključne besede: priprava podlage, nano kristali, magnezijev oksid, cinkov oksid, kaolinitna glina

1 INTRODUCTION

Structures built on cohesive soil were invariably plagued by subsidence and stability issues. Many civil-engineering projects that involve soft soils have resulted in the adoption of a variety of soil-improvement techniques, including stabilization. Engineers identify the modification or stabilization of soil-engineering features as a significant procedure for boosting the effectiveness of problematic soils and enhancing the effectiveness of marginal soils as a building material. This area has discovered a variety of different alteration approaches. Traditional soil additions include straw, bitumen, and salts, but cement, petrochemicals, and other materials are rapidly being utilized to stabilize the soil mechanically and chemically. New technologies have indeed been extensively applied in the field of stabilization, in addition to established methods. The use of biopolymers with nanomaterials (NMs), for example, is a recently designed method for soil enhancement (of the order of 10^9). Nanotechnology (NT) is a fast-developing field with enormous promise for developing new materials with distinctive features as well as new and enhanced products for a variety of uses. In geotechnical engineering, NT can be viewed in two methods: the composition of the soil was shown at the nanoscale, and soil modification can be prepared at the atomic as well as the molecular level.

Many studies have demonstrated that even a modest amount of NM can significantly alter the soil's physical and chemical qualities.[1] This is owing to the NMs large specific surface area, which allows them to interact more effectively with other particles in the soil structure. NT is an important technique in geotechnical engineering which was to increase soil engineering qualities.[2] Since the 1940s, agricultural engineers have been considering the use of biological polymers in soil as a stabilization and hardening substance for collections. Since it was created from farmed non-food crops, biopolymer has a long-term carbon neutrality and also regarded as a renewable substance. As a result, using biopolymers in geotechnical engineering would result in a long-term

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business. Experiments with extensively treated soil with varying percent of guar gum gel for varied water levels resulted in expanded soil with better strength. The inclusion of biopolymers increases the intercept and CBR (California bearing ratio) scores of extensive soils.[3]

In a talk given in 1959, Feynman established the notion of NT for the first time. Even if present in modest amounts, such as a few percent, nano particles can have a significant impact on soil qualities investigated.[4] The impact of adding different NMs to soft soil, such as nano CuO, nano MgO, and nano clay, on the geotechnical parameters. The liquid and plastic edge, plasticity index of the soil was all reduced when each NM was introduced. With a rise in NM %, the dry density and optimal humidity content rose. With the use of nanomaterials, the compressive strength improved.[5] Experiments were undertaken to investigate the characteristics of nano kaolin combined with kaolin. Even when only a little amount of nano kaolin was applied, the qualities of the kaolin were improved.[6]

The influence of sodium altered montmorillonite nano clay on the engineering qualities of clay was investigated. According to the findings of Atterberg's limits test, introducing nano clay to the soil can enhance the plastic and liquid limit.[7] On the findings of the study of nano-SiO_2 to clay soil based of a sequences of compaction, direct shear, and released compressive strength experiments, the impacts of nano-SiO_2 on clayey soil were investigated.[8,12] The impacts of NMs on the geotechnical parameters of clayey soils in an experimental study. The impact of NMs (nano-silica and -zeolite) on differential free swell, Atterberg's confines, compacted properties, and unconfined compressive strength were studied. The analysis indicates that as the percentages of NMs grew, the expanding nature of the soil reduced and Atterberg's constraints and shear strength properties of soils improved.[8] A combustion approach was used to make nanocrystalline (NC) MgO particles utilizing magnesium nitrate as an oxidant and hexamine as a fuel. To increase crystallinity and phase purity, the materials generated by combustion technique were annealed at 800 °C for 3 h. The current findings show that materials with higher crystallinity can be produced utilizing the hexamine combustion process.[9]

This paper deals with the effect of nano magnesium oxide (MgO) and nano aluminium oxide (Al_2O_3) with different contents (0.5, 1, 1.5 and 2) *w*/% on the properties of expansive soils.[10] The results indicate that the swelling potential is reduced with the addition of nano materials, thus making soil suitable for construction purposes. The maximum dry density (MDD) increases and the optimum moisture content (OMC) increases initially and then decreases with the addition of nano materials. A study of the effect of the combination of nano materials on the performance of black cotton soil. The study includes the effect on geotechnical properties of soil, mainly on the Atterberg's limits, compaction characteristics, unconfined compressive strength, CBR value and swelling pressure. nano copper (1, 1.5 and 2.5) *w*/% and nano silica[11,12] (0.3, 0.6 and 0.9) *w*/% is mixed with soil at three different percentages.[11]

The objectives of this research are the study of engineering characteristics of cohesive soil before as well as after the inclusion of two diverse NMs.

2 EXPERIMENTAL PART

2.1 Kaolinite clay

The majority of prevalent clay is kaolinite, which has a soft viscosity and an earthy texture. They do not have a lot of bearing capacity. The study used kaolinite clay from the Mangalapuram region of Thiruvananthapuram district. The soil samples were collected, dried, and ground into a powder. It was examined in accordance with IS 2720-1985, and the basic soil characteristics were discovered. The clay's characteristics are listed in **Table 1**.

Table 1: Characteristics of kaolinite clay

Properties	Values
specific gravity	2.64
liquid limit, W_L (%)	75
plastic limit, W_p (%)	40
shrinkage limit, W_s (%)	25
plasticity index, I_p (%)	36
percentage of clay (%)	70
percentage of silt (%)	30
optimum moisture content (%)	30
maximum dry density (kg/m^3)	1440
Unconfined Compressive Strength (UCS), q_u (kN/m^2)	12.75
California bearing ratio (%)	1.89
unified soil classification system	CH

2.2 Nanocrystalline magnesium oxide (NC MgO)

The NC MgO materials were processed by a solution-combustion technique. The NC MgO materials were

Figure 1: Kaolinite clay

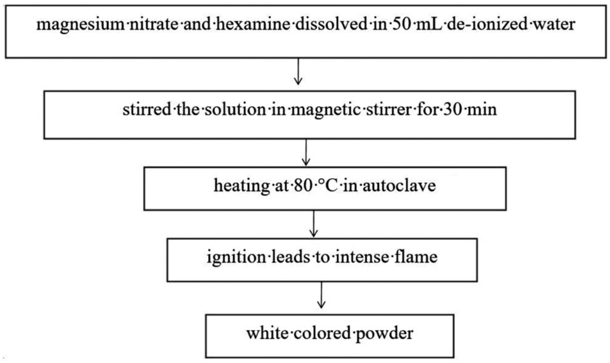

Figure 2: Flowchart for the synthesis of NC MgO

Table 2: Properties of NC MgO

Content	NC MgO
physical state	dry, white coloured powder, odourless, non-toxic
size (nm)	30–50
magnesium (*w*/%)	55.32
oxygen (*w*/%)	44.68
density (kg/m^3)	3580
molar mass (g/mol)	40.3
melting point (°C)	2852
boiling point (°C)	3600

obtained through a redox reaction between magnesium nitrate, $Mg(NO_3)_2{\cdot}6H_2O$ and hexamine. A flowchart for the synthesis of NC MgO is shown in **Figure 2**. The properties of NC MgO are exemplified in **Table 2**.

A scanning electron microscope (SEM) microstructure study of MgO SEM photos were collected in the SEM to understand the shape of the nanoparticles size of the NC MgO (SEM; FEI Quanta 200 instrument) (**Figures 3a** and **3b**). The SEM results were captured at various magnifications. The annealing MgO NMs seem porous and heavily aggregated with the nano entities, according to the SEM data. As a consequence, the size of the NP of MgO could not be precisely determined using the current SEM observations.

2.3 Nano zinc oxide (ZnO)

Nano-sized nano ZnO powder was prepared by the ball milling method. Commercially available ZnO powder purity 99.5 % (Himedia Laboratories) was crushed in steel cells (250 mL) by employing the hardened steel balls (diameter 10 mm and 20 mm) in ambient atmosphere for diverse times varying from 2 h to 10 h. The synthesized powders were examined by employing a field-emission SEM (FESEM, FEINova Nano SEM

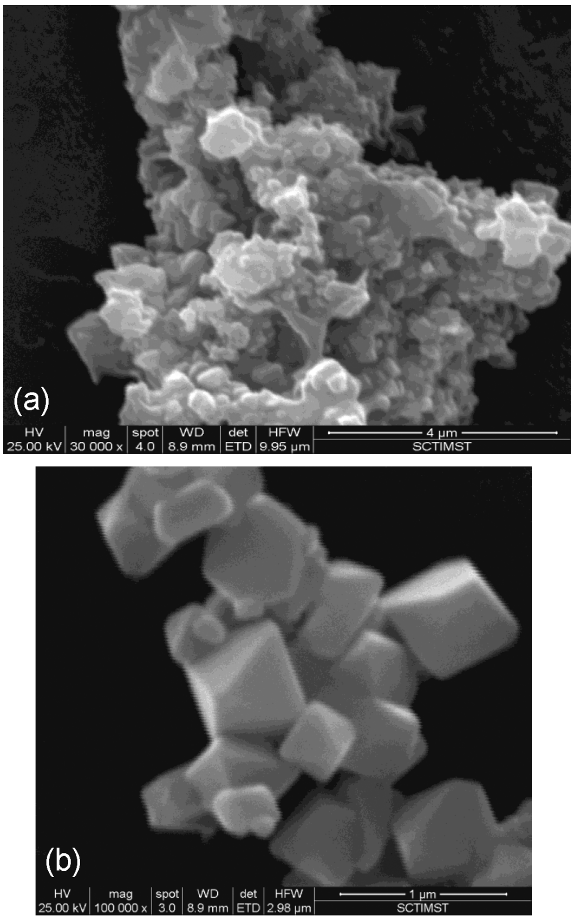

Figure 3: SEM images of annealed NC MgO attained by combustion technique: a) mag. 30 000 ×, b) mag. 100 000 ×

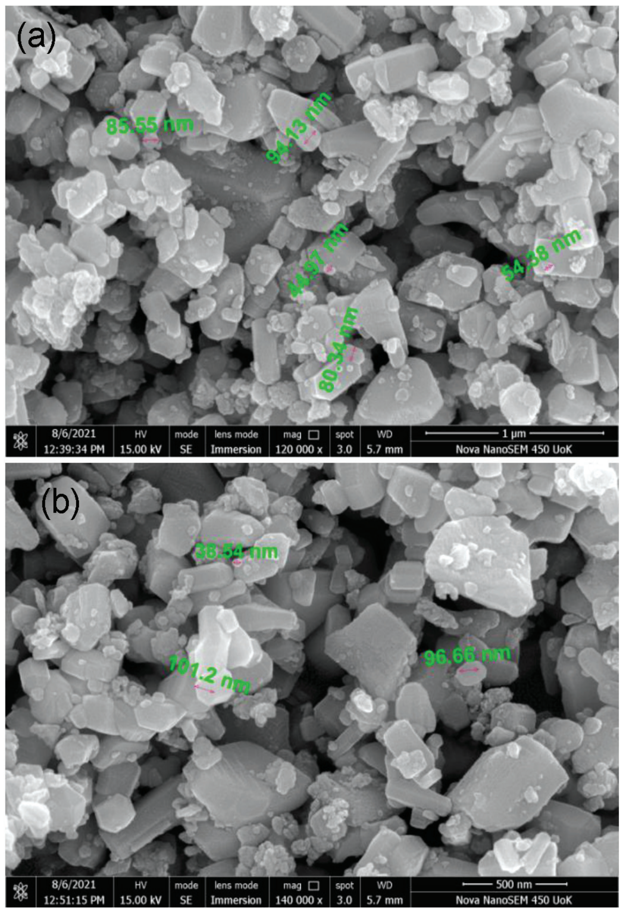

Figure 4: FE SEM images of nano ZnO powders: a) mag. 120 000 ×, b) mag. 140 000 ×

450), see **Figures 4a** and **4b**. **Table 3** shows the characteristics of the nano zinc oxide powders.

Table 3: Characteristics of mano zinc oxide

Content	Sample
physical state	dry, light gray coloured powder, odourless, non toxic
average size (nm)	50–100
shape	roughly round
solubility	high
zinc (%)	84.07
oxygen (%)	15.93
density (kg/m^3)	5600
molar mass (g/mol)	81.4
nummelting point (°C)	1975
boiling point (°C))	2360

2.4 Specimen Preparation

The wet mixing procedure is used to prepare the sample. After dissolving the nano magnesium powder in freshwater, it is incorporated into the soil matrices. NC MgO and nano ZnO was added at varying percentages of (0.25, 0.5, 0.75 and 1) *w*/%.

2.5 Experimental study

The soil specimen combined with two different NPs with concentration of (0.25, 0.5, 0.75 and 1) *w*/%. Atterberg limits, compaction test, California bearing ratio (CBR) test, unconfined compressive strength (UCC) test, etc are completed on the specimen processed with diverse concentration. Water was then introduced at the appropriate liquid boundary for specimen processing when conducting UCC tests. OMC is obtained through a compaction test and used to generate the CBR test samples.

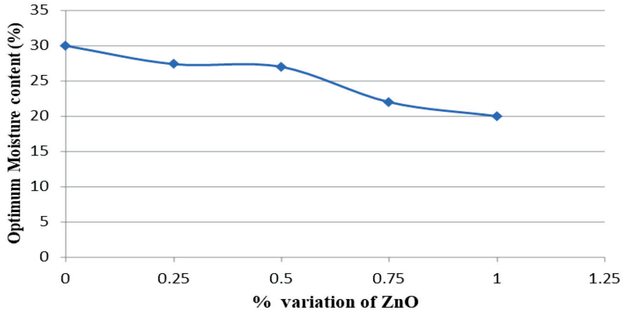

Figure 6: Difference of CBR value with addition of NC MgO

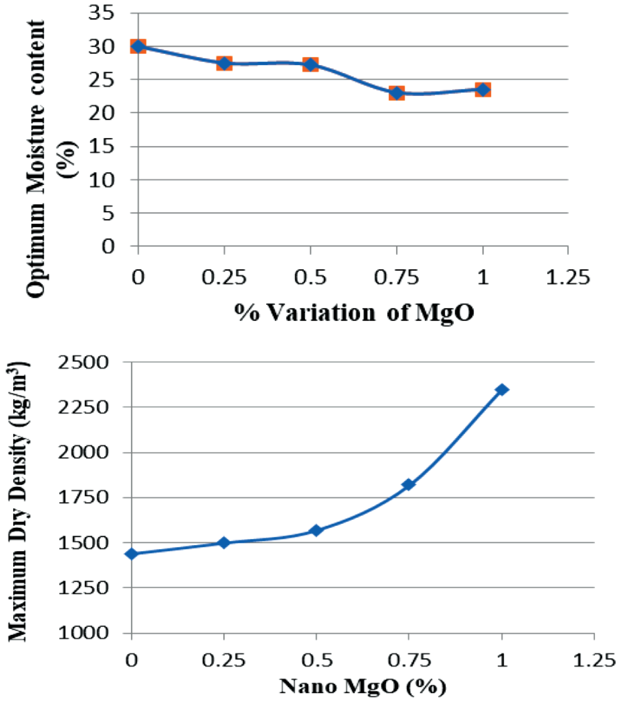

Figure 5: Outcomes of compaction study: a) OMC vs MgO, b) MDD vs MgO

3 RESULTS AND DISCUSSION

The benefits of nano materials on soft clay and some of its influencing factors were investigated in this study. For that, a sequence of tests was made. The details of test results and related discussions are explained below. The difference of the CBR values of soft clay mixed with diverse percentage of nano MgO and nano ZnO was also discussed. The liquid restrict of the specimen appears to be reducing as the NC MgO concentration rises with the inclusion of various doses.

The outcomes of the compaction study were identified as, enhanced maximum dry density as well as the resultant OMC content growing. The MDD was attained at 1 *w*/%. NC MgO as an additive. The outcomes of compaction study are shown in **Figures 5a** and **5b**.

Unconfined compressive strength (UCC) enhances with the rise in percentage addition of NC MgO up to 1 *w*/% and decreases on further addition, as shown in **Figure 6**. The stress-strain reaction of the samples was calculated and it shows that the maximum stress-strain variation is obtained for 1 *w*/%. addition of NC MgO in clay.

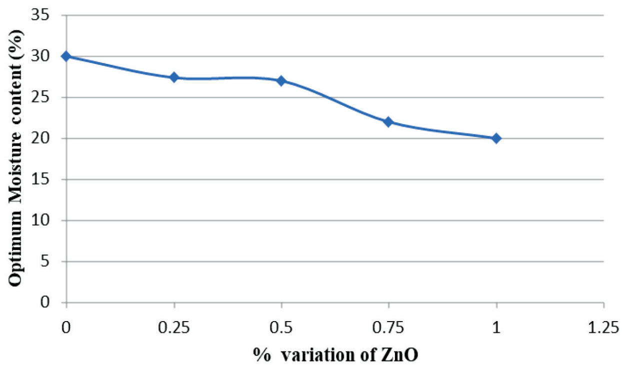

Figure 7: Variation in OMC with nano ZnO

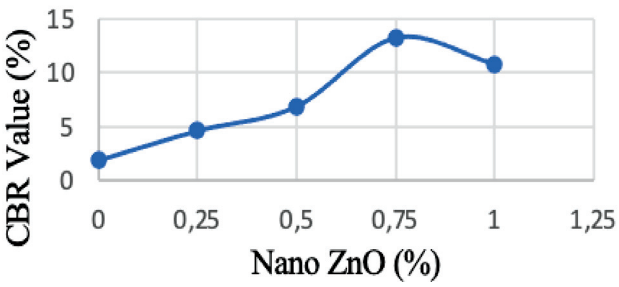

Figure 8: Variation in CBR value with nano ZnO

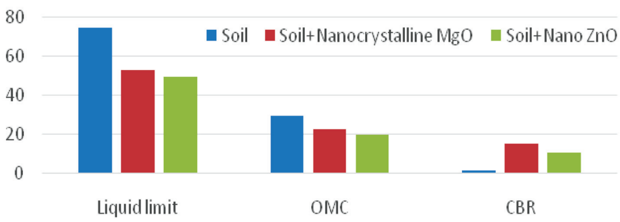

Figure 9: Variation of result at optimum nano content

With the inclusion of diverse doses of nano zinc oxide, the liquid boundary of the clay specimen was found to be reducing with the rise in nano concentration. The liquid constraint of the clay specimen varies from 75 % to 49.52 % with the rise of nano ZnO from zero to one percentage. The variations are plotted in **Figure 7**.

CBR value rises with the upsurge in nano Mg content. The outcomes of CBR test shows that CBR value increases up to 0.75 *w*/% inclusion of nano ZnO, and after that it declines with rise in nano content, shown in **Figure 8.**

Kaolinite clay is mixed with two different nano materials with different concentrations (0.25, 0.5, 0.75 and 1) *w*/% and laboratory test were performed. The variation of liquid limits, OMC, MDD, UCC and CBR values were tabulated for optimum percentage of nano content. The result shows that clay with one percentage NC MgO is the best combination for soil stabilization than clay with nano ZnO. **Figure 9** shows the variation of the results.

4 CONCLUSIONS

NMs were added to selected clay to improve its characteristics. With the inclusion of NMs, the CBR and UCC values improved, while the clay's liquid limit fell.

The optimal value of NC MgO content was identified as 1 *w*/%.

The liquid boundary of the clay was decreased to 53 % from 75 % with the optimal NC MgO content.

The MDD of clay rises to 2.35 g/cm^3 when preserved with 1 per cent of NC MgO.

The CBR value of the clay rises to 15.67 % from 1.89 % with the inclusion of NC MgO. Hence, the clay became appropriate for concrete construction.

The CBR value of the clay was rises to 10.78 % from 1.89 % with the inclusion of nano ZnO.

Hence, it can be determined that NC MgO and nano ZnO inclusion enhanced the engineering and index characteristics of clay and made it more appropriate for diverse determinations. As per this experimental research, NC MgO gave a greater improvement than the nano ZnO in clay.

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