Influence of Nano Copper Slag in Strength Behaviour of Lime Stabilized Soil

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ABSTRACT: Nanotechnology has been widely used in many applications such as medical, electronics, and robotics also in geotechnical engineering area through stabilization of bore holes, grouting etc. In this paper, an attempt is made for understand the influence of nano copper slag (1%, 2% & 3%) on the index, compaction and Unconfined Compressive Strength (UCS) properties of natural soil (CH type) with and without lime stabilization for immediate and 7 days curing period. Results indicated that upto 1% of nano copper slag, there is an increment in UC strength of virgin soil and lime stabilised soil. Beyond 1% nano copper slag, there is a steep reduction in UC strength and increase of plasticity both in lime stabilised soil and virgin soil. The effect of lime is found to show more influence on large surface area of nano copper slag in natural soil. In lime stabilised soil, for both immediate and curing effect, with 1% of nano copper slag the maximum unconfined compressive strength was 38% and 106% higher than that of the virgin soil strength.

KEYWORDS: Lime, Nano copper slag, SEM, Unconfined Compression Strength, XRD

1. INTRODUCTION

Nanotechnology is the understanding, control and restructuring of matter on the order of nanometers, i.e. less than 100nm, to create materials with fundamentally new properties and functions. At scales of nanometer range, materials can exhibit unique properties different from their bulk state.

Norazlan Khalid and Mazidah Mukri (2014) studied the influence of nano-soil particles in soft soil stabilization. Addition of 2% and 4% nanoclay has increased the compressive strength of soft soil to about 3% to 22% and also the internal friction was improved. Taipodia J et al (2011) studied the effect of different concentrations of nano size chemicals on the properties of soil. Addition of nano particles increased the maximum dry density of the soil.

Zaid Hameed Majeed et al (2014) studied the influence of nanomaterials such as nano-copper, nano-clay and nano-magnesium on the geotechnical properties of soft soil. Taha M.R. and Taha O.M.E (2012) conducted an experimental study on the performance of four types of soils mixed with three types of nano-material of different percentages. Prabu (2015) studied the influence of nanosized cemented particles on the behavior of soil. The nano particles admixed soil yielded the co-efficient of permeability ten times lower than that of non-nano sized additives of flyash-cement and silica-lime.

Wahith (2014) studied the influence of nano particles on the effectiveness on soil grouting and found that the settlement decreases and the load carrying capacity of the soil increases when the soil is grouted with cement solution along with small percentages of nano lime. In this paper, effect of nano copper slag on the index, compaction and UC strength of soil was attempted.

2. MATERIALS

2.1 Soil

The soil used for this study was collected at shallow depth of 0.5m from Perumbakkam, Chennai, India. The soil was made air dry to room temperature for conducting index tests.

Specific gravity test on soil was conducted using specific gravity bottle as per IS: 2720 (Part 3/sec-1)–1980. Liquid limit test of soils was determined by using Casagrande apparatus as per IS: 2720 (Part 5) – 1985. As per IS: 2720 (Part 5) - 1985, the soil samples have to be sieved through 425 micron IS sieve and tested. Plastic limit test was conducted by standard method (IS: 2720 (Part 5) - 1985) for all the soils.

The shrinkage limit of the soil was determined according to the bureau of Indian standard procedure IS: 2720 (Part 6) – 1972. All the test result values reported are the average of three tests. The index properties results are shown in Table 1 and the soil is classified as 'CH' type. The free swell index test was determined as per IS: 2720 (Part 40) – 1972 expressed in percentage.

Table 1 Index Properties of Natural Soil

Properties	Values
Specific gravity	2.61
Clay (%)	68%
Silt (%)	13%
Sand (%)	19%
Liquid Limit (%)	76
Plastic Limit (%)	34
Plasticity Index (%)	42
Shrinkage Limit (%)	10
Free Swell Index (%)	64
Classification	CH

2.2 Lime

Chemical composition of lime which was taken to stabilize the soil was obtained by Energy Dispersive X-ray Analysis (EDAX) test. This shows that lime consist of 31% calcium and 17% of magnesium as its major contributed chemicals.

2.3 Nanomaterials preparation

Generally nano particles are prepared by bottom up method and top down method. Bottom up method begin with atoms and molecules, which react under chemical and physical circumstances to form nano-structure. Top down method, used in this paper, begins with bulk materials that are subsequently reduced into nano-structures. This is archived by the way of physical, chemical and mechanical processes such as mechanical ball-milling, grinding, etc.

2.4 Nano Copper Slag

Copper slag which has a specific gravity of 3.57 was subjected to mechanical ball milling process for 8 hours in order to produce nano copper slag. To find the size of the particle and the crystallite size of the ball milled copper slag, SEM analysis and XRD test were carried out. From Figure 1 and Figure 2, most of the nano copper slag particles with rounded edge. It was also found that, after ball milling process, the uniformity of particles was achieved.

From Figure 3, for Nano Copper Slag the d spacing values,

$d1 = 7.2489A^{o}$, $d2 = 7.4937A^{o}$, $d3 = 6.8677A^{o}$.

Thus, the corresponding mineral for the above d-spacing is Nenadkevichite and its chemical constituent is (NaCaK) (NbTi) Si2O6 (O.OH) 2(H2O). From XPowder software, the crystal size of the particles as per Scherrer's equation was found to be 53.5nm.

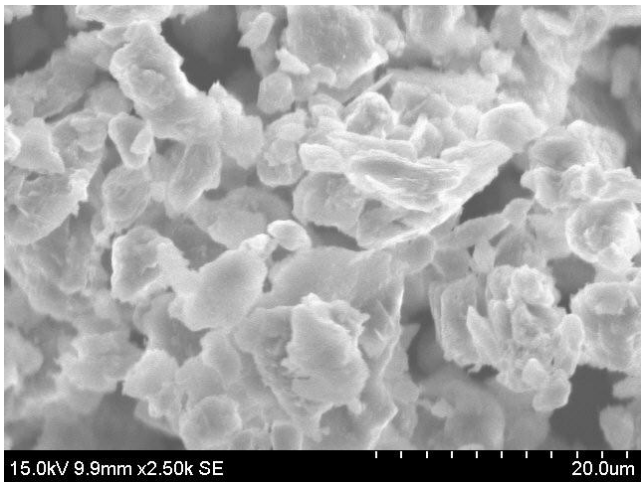

Figure 1 SEM Image of Nano Copper Slag at 20 µm

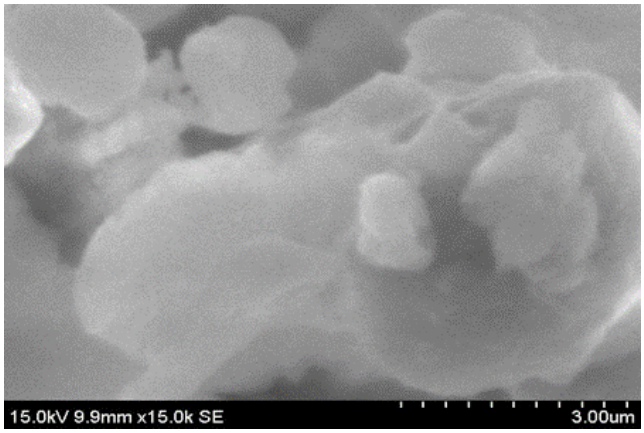

Figure 2 SEM Image of Nano Copper Slag 3 µm

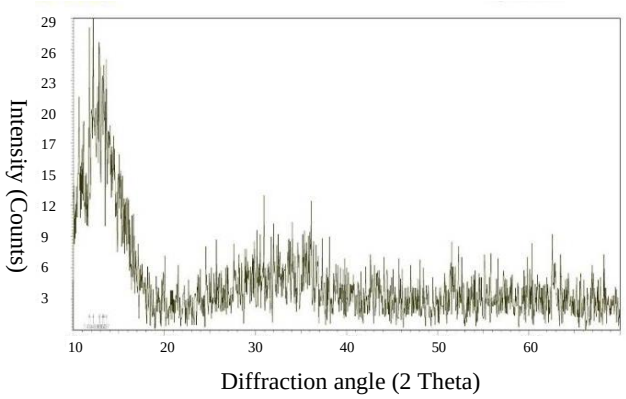

Figure 3 XRD graph of Nano Copper Slag

2.5 Process

The strength and compaction characteristics of the soil is found for different percentage of lime such as 3, 5, 7 and 9%. Table 2 shows the UCS and plasticity Index values for different percentage of lime. From the table it is clear that the maximum strength was attained for 5% lime at 0 days (uncured) and 7% lime for 7 days curing. For uncured soil (0 days) UCS value is 30.4% higher than virgin soil, whereas for 7 days cured soil, the UCS value is 165.8% higher. For further studies on the effect of nano copper slag, 5% lime content was used.

Table 2 Effect of Lime content on the properties of soil

Description		Plasticity Index in %		UCS in kN/m^2	
Curing Period (days)		0	7	0	7
virgin soil	0%	42		124.45	
soil with different percentage of lime	3%	36	21	140	195
	5%	28	3.3	162	230
	7%	23	2.7	102	330
	9%	19	0.4	98	257
Percentage of increase with 5% lime				30	84

Having 5% percentage of lime as constant, variation in the percentage of 1, 2 and 3% for nano copper slag was studied in virgin soil and lime stabilised soil. The samples are tested for immediate and for 7 days curing. All the samples prepared as per IS standards and were labeled according to the trial combination chosen. Samples were cured by sand bath method and covered with jute bag on top of the tank to maintain 100% humidity. The effect of addition of nano materials to the lime stabilized soil on unconfined compressive strength of soil samples was examined.

3. INFLUENCE OF NANO COPPER SLAG ON VIRGIN SOIL

3.1 Influence of nano copper slag on the index properties of virgin soil

As shown in Table 3. addition of nano copper slag decreased the liquid limit by about 22% for sample without curing and 20% for sample with 7 days curing. Thus, it is seen that the curing period has only less influence on the liquid limit values of soil.

Table 3 Effect of nano copper slag in liquid limit and plastic limit

Description	Liquid Limit, %		Plastic Limit, %	
Percentage of Nano copper slag	Curing Period (days)		Curing Period (days)	
	0	7	0	7
0%	76		34	
1%	62	64	18.12	22.23
2%	60	62.5	18.28	23.65
3%	59	61	40.32	37.79

The variation in the plastic limit infers that on addition of nano copper slag plastic limit decreased from 34% to 18.12% for uncured sample and 22.23% for cured sample. Plasticity index values for different percentage of nano copper slag is plotted in Figure 4. It is seen that for both 0th day and 7th day cured sample, plasticity index increased upto 1% of nano copper slag and on further increase, the plasticity index value decreased.

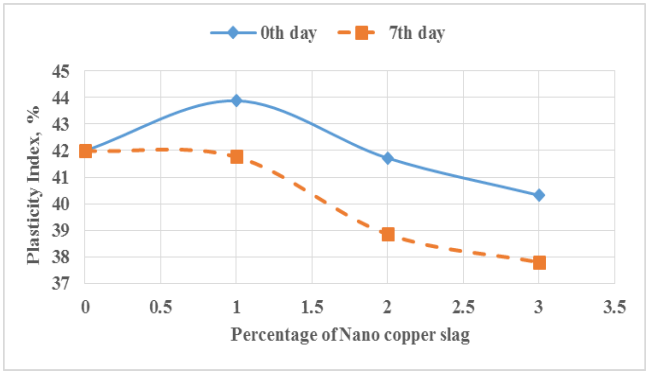

Figure 4 Variation of Plasticity Index with different percentage of nano copper slag for 0th day and 7th day

3.2 Influence of Nano Copper Slag on the Compaction Characteristics of Virgin Soil

Table 4 shows the OMC and γd max for 1%, 2% and 3% nano copper slag. It is seen that with the increase in the percentage of nano copper slag, optimum moisture content increased and maximum dry density decreased which is because of higher surface area of nano particles in soil. The increase in the dry density subsequently leads to decrease in the soil shrinkage and expansive strains. Moreover, the increase in the content of agglomerated particles leads to decrease in the dry density and increase in voids which increase the water content. Therefore, the shrinkage and swell strain also increases. (Zaid Hameed Majeed et al-2014).

Table 4 Variation of γd,max & OMC of Soil with % of Nano Copper Slag

% of Nano Copper Slag	OMC (%)	γd,max(g/cc)
1	28	1.35
2	31	1.32
3	32	1.28

3.3 Influence of Nano Copper Slag on the Unconfined Compression Strength of Virgin Soil

Unconfined compressive test was conducted for different percentages of nano copper slag for 0th day and 7th day curing period. The variation in the unconfined compressive strength is plotted in Figure 5, which shows that for both 0th day and 7th day cured samples the maximum strength is attained for 1% of nano copper slag and beyond which the same is decreasing. For uncured soil, the maximum strength is 154.3kN/m^2 and 229.3kN/m^2 for cured soil specimen.

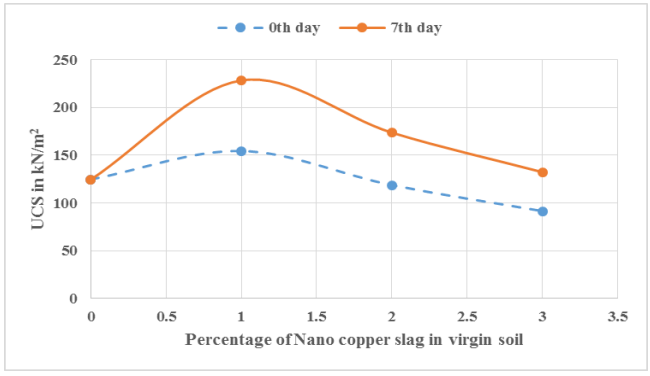

Figure 5 Effect of Nano Copper Slag on the UCS value of virgin Stabilized Soil

4. INFLUENCE OF NANO COPPER SLAG ON LIME STABILIZED SOIL

4.1 Influence of Nano Copper Slag on the Index Properties of Lime Stabilized Soil

On addition of nano copper slag of different percentage, it is seen that the liquid limit remained around 62%. It can also be inferred that curing effect is nil for soil mixed with nano copper and lime for these percentages. Plastic limit increased negligibly over different percentages of nano copper slag. It is also clear that the effect of lime is dominant compared to the nano copper slag's influence on the plastic limit. Lime contains 31% of calcium which contributes considerably in the formation of flocculant fabric and suppresses double layer thickness and thus results in reduction in the liquid limit value. The addition of nanomaterials further contributes to the interparticle growth and leading to reduction in liquid limit behavior (Mitchel and Soga, 2005).

From Figure 6, it is noted that the plasticity index remain almost constant around 25% for uncured sample and around 20% for 7 days cured sample. Thus for uncured sample it remained close to the plastic index of soil with only lime. Whereas, for 7 days cured sample, it is 5 times higher than the plasticity index of soil with lime alone.

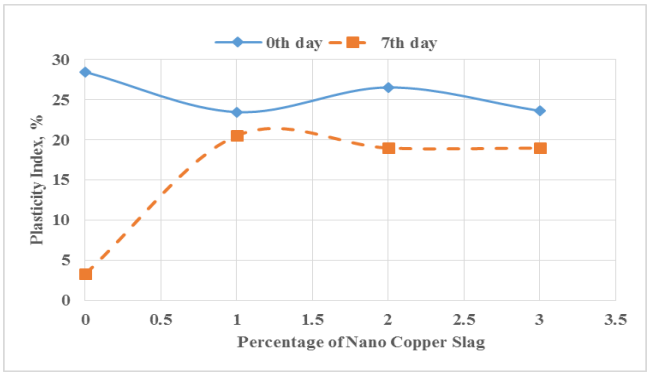

Figure 6 Variation in Plasticity Index for Soil + Lime + Nano Copper Slag

4.2 Influence of Nano Copper Slag on the Compaction Characteristics of Lime Stabilized Soil

The compaction tests results are shown in Table 5 and it is seen that the optimum moisture content increased and the maximum dry density decreased and, compared to virgin soil the γd max and OMC values are still lower for any percentage of nano copper slag. The increase of nano-material more than the optimum limit may possibly result from agglomeration in nanomaterial particles which in turn causes an increase in the void ratio then decrease in density and increase in water content. According to Ferkel and Hellmig (1999), the agglomeration of nanoscaled powders increase the amount of necks between particles and therefore decreases the density of green bodies.

Table 5 Variation of γd, max & OMC of Lime Stabilized Soil with different % of Nano Copper Slag

% of Nano Copper Slag	OMC (%)	γd,max(g/cc)
1	33	1.311
2	35	1.281
3	37	1.22

4.3 Influence of Nano Copper Slag on Unconfined Compressive Strength of Lime Stabilized Soil

The results of UCC tests conducted for 1, 2 and 3% of nano copper slag with 5% of lime is shown in Figure 7 and Figure 8 for uncured and cured samples respectively. Figure 9 represented the Stress-Strain curve of virgin soil and lime stabilised soil with 1%, 2% & 3% nano copper slag for 0th day and 7th day. Figure 10 shows the effect of nano copper slag on the UCS value of Lime Stabilized Soil. In both 0th and 7th day curing, the unconfined compressive strength increased for 1% of nano copper slag and after which the strength value decreased.

For uncured soil, the maximum strength is 171.7kN/m^2 and was 255.9kN/m^2 for cured soil. Increasing the amounts of nanomaterials leads to an increase in the unconfined compressive strength. The increase of nanomaterial more than the optimum limit may possibly result from agglomeration in nanomaterial particles which in turn cause an increase in the void ratio then decrease in density and increase in water content. (Taha M.R. and Taha O.M.E - 2012). Soil to which nano copper slag had been added showed hardening and improved strength compared with soil specimens without nano material additives.

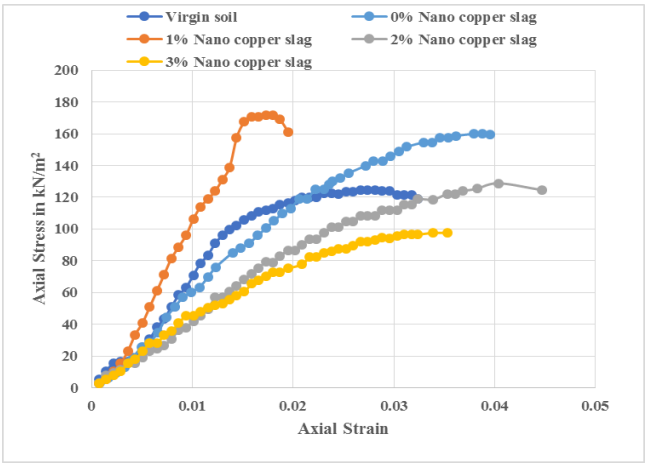

Figure 7 Stress-Strain curve of lime stabilised soil with Nano copper slag for 0 days curing

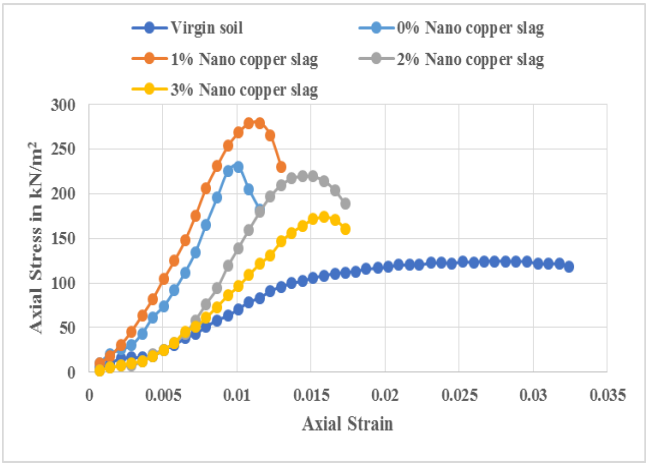

Figure 8 Stress-Strain curve of lime stabilised soil with Nano copper slag for 7 days curing

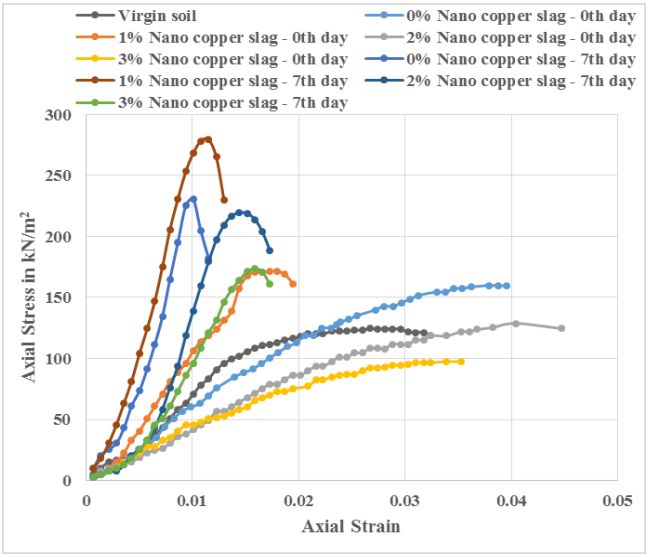

Figure 9 Stress-Strain curve of lime stabilised soil with 1%, 2% & 3% Nano copper slag for 0th day and 7th day

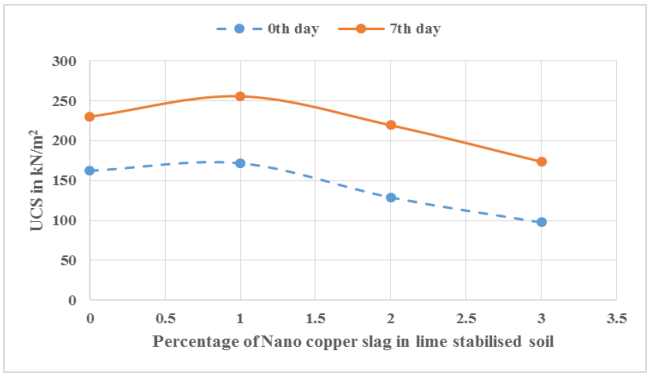

Figure 10 Effect of Nano copper slag on the UCS value of lime stabilised soil

5. CONCLUSIONS

The following conclusions may be drawn from the index, compaction and UCS tests conducted on soil admixed nano copper slag with and without lime for 0 and 7 day curing period.

A. Immediate Effect:

Addition of nano copper slag upto 1% in virgin soil, the liquid limit decreased and plastic limit increased. According to Meisam Bahari et al. (2013), increasing the limits of liquid and plasticity, increase attributes to coherency of nanomaterials when surrounded by water. This leads to growth of interlock forces between nanoparticles in the vicinity of moisture which can cause soil stabilization by fastening the particles together and filling pores. Results shown that nanomaterial because of absorbing water has a considerable influence on, and increase in adhesion and internal friction angle.

However, it is found that for 3% of nano copper slag, plasticity index was found to decrease from 42% to 18% and 23% for virgin soil and lime stabilized soil respectively. For both the virgin and lime stabilized soil, the maximum value of unconfined compressive strength is achieved for 1% of nano copper slag as 154.3kN/m^2 and 171.7kN/m^2. The addition of nano-materials more than the optimum value causes agglomeration of particles that produce negative side effects on the mechanical properties of the soil. Taha M.R. and Taha O.M.E., (2012). Thus, compared to the actual strength of the virgin soil (124.4kN/m^2), the increase in the strength is upto 24% and 38% for virgin and lime stabilized soil respectively.

B. Curing Effect:

The addition of nano copper slag upto 1%, decreased the liquid limit value from 76% to 61% with and without the addition of lime. With the increase in the percentage of nano copper slag plastic limit value is found to increase for both virgin and lime stabilized soil. Thus it is found that for 3% of nano copper slag, plasticity index decreased from 42% to 23% and 19% for virgin and lime stabilized soil respectively. For virgin soil and lime stabilized soil, the maximum unconfined compressive strength is achieved for 1% of nano copper slag. From actual strength of soil it increased by 84% and 106% for virgin soil and lime stabilized soil respectively.

It is hence concluded that addition of nano copper slag upto 1% in virgin and lime stabilised soil, is beneficial on the improvement of soil and beyond which, there found a considerable reduction on the strength of soil. At any percentage of nano copper slag, the lime stabilised soil show a better performance compared to virgin soil. Apart from nano size particles, resulting to higher surface area and more reactivity of clay, the pozzalanic materials present on the nano material seems to be primary influential factor for a better reaction in soil. Based on the study it shown, by using small amount percentage of nano-copper slag were giving significant in soil stabilization to improve the geotechnical properties of soil.

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