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Compaction and Strength Properties (after 28 days of curing) of Soil Stabilized by Stone Sust and Cement

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Abstract
The weak soil of Kathmandu valley is not applicable for heavy loads from structures. In such a case, cement-soil stabilization can be an option to enhance the strength and stability of the soil and by chemical bonding properties of the cement. Another cheaper option can be the stabilization of the soil with stone dust from crushers. So, this study involves the laboratory investigation for the use of stone dust and cement to stabilize the weak soil, hauled from Kupondole, Kathmandu valley. Hauled soil was air dried, crushed, powdered, and then sieved through 425 microns. The sieved soil powder was mixed with sieved stonedust (0%, 30% and 40%) and cement (0%, 2%, 4%, 6%, 8% and 10%) to study compaction properties and strength properties. The strength properties were compared after28 days of curing in the Unconfined Compressive Strength (UCS) test. As the result of the stabilization, the UCS values for weak soil showed improvement in strength properties after cement and stone dust mixing. Also, the stone dust increased the density and reduced the optimum moisture content in the compaction test whereas the cement showed a mixed type of behavior in the compaction test.

Keywords
Cement, Stone Dust, Weak soil, Compaction, Unconfined Compressive Strength

1. Introduction

Soil stabilization, a modification method of soil properties and structure by addition of stabilizing agents, is generally used in engineering for the improvement of the strength and bearing capacity of weak soils[1]. The lacustrine and fluvial-deltaic deposits of Kathmandu valley make its soil soft, weak, and highly compressible[2] [3]. So, it is important to prepare a standard and norms of the valley for a wide range of cement-soil stabilization. Some of the commonly used stabilizing agents are cement, fly ash, lime, a combination of any of these, etc. This study deals with the addition of cement and stone dust in the weak soil to study the soil properties of Kupondole soil. The general objectives of this study are to compare the compaction and strength behavior of the soil with and without various content of stabilizing agents (cement and/ or stone dust). For this, Optimum Moisture Content (OMC), and Maximum Dry Density (MDD) are compared for different samples of the soil. And then, the Unconfined Compressive Strength (UCS) is related after 28 days of curing period. So, the geotechnical parameters of the Kupondole soil before and after modification will be studied to find the effective content of the stabilizing agent.

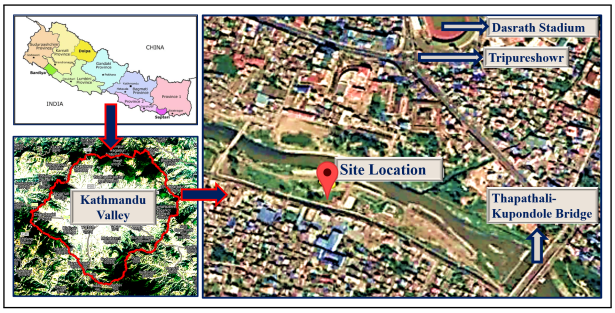

Figure 1: Location map of the study area, Kupondole. (Source: Google)

For a road, from a geotechnical point of view, the subgrade in weak soil results in a negative consequence on the strength of a road surface. So, to strengthen the subgrade, the soil can either be modified or can be substituted by another dense material. But the substitution method may get costlier and this primes to exploration for stabilization methods to counter the weak soil [4]. Generally, the stabilization of soil is separated into mechanical stabilization and chemical stabilization. Out of these, cement stabilization falls under chemical stabilization which refers to the improvement of soil properties by altering its natural composition and intensifying the strength and stiffness through the act of reaction in the soil.[3] [5]. Chemicals, such as cement, decrease the moisture and plasticity of the soil. The pozzolanic reaction generated by calcium hydroxide with silica and alumina results in the development of Calcium Silicate Hydrate (CSH) and Calcium Aluminate Hydrate (CAH) gels. Then, the covering of weak soil surfaces with such gel outcomes in the bonding between the particles. And further, the crystallization of the bond results in the formation of an interlocking of the entire soil structure, resulting in the strength increment.[6]

Out of many methods, the compressive strength of a soil sample can be measured from the UCS test and the UCS tests performed by several researchers have shown that the calcium generated by the cement has a major role in cement-soil stabilization.[?] After the addition of cement to the soil, the strength of the soil has been found to be multiplied by 4.4 to 14.8 times [7]. So, the UCS and residual strength of weak soil can be increased with the help of cement as well as the curing time [3]. In the case of stone dust, it is found that the liquid limit, plastic limit, and OMC of soil decrease when the amount of the quarry dust is increased. On the other hand, the maximum dry density increases with the increment of the dust [8]. Another study has shown that the strength of soil stabilized with stone dust and lime in combined form shows better performance when compared with the strength of soil stabilized with stone dust and lime in individuals [9] Likewise, the Maximum Dry density was found to be increased and there was a reduction of Optimum Moisture Content when stone dust was added to the weak soil up to 40% by weight[10]. The gap in the research mentioned above is that the test for the strength of the soil was conducted either for natural soil only, for cement-stabilized soil only, or for stone dust stabilized soil only. So, this study deals with the study of the combined effect of stone dust and cement in weak soil.

2. Research Methodology

A disturbed soil sample was hauled from Kupondole, Kathmandu valley. Hauled soil was collected at the Central Material Testing Lab of Pulchowk Campus, where it was left to be air dried at 27 degrees Celsius. Then, a wooden mallet was used to crush the chunks of the soil it crushes it in the form of powder, Then the powdered soil was sieved through 425 microns and was stored in a moisture-proof bag. Similarly, stone dust was procured from the Jadibuti site. The dust was also air dried in a similar manner and was sieved through 425 microns. The cement used in this test was Riddhisiddhi OPC Cement. The soil, cement, and stone dust were mixed in varying proportions to study the compaction and strength properties by using Indian Standard laboratory tests.

2.1 Nomenclature of samples for UCS test

2.1.1 Soil sample with no stone dust

0-0: Sample with 0% Stone Dust and 0 % Cement.
0-2: Sample with 0% Stone Dust and 2 % Cement.
0-4: Sample with 0% Stone Dust and 4 % Cement.
0-6: Sample with 0% Stone Dust and 6 % Cement.
0-8: Sample with 0% Stone Dust and 8 % Cement.
0-10: Sample with 0% Stone Dust and 10 % Cement.

2.1.2 Soil sample with 30% stone dust

30-0: Sample with 30% Stone Dust and 0 % Cement.
30-2: Sample with 30% Stone Dust and 2 % Cement.
30-4: Sample with 30% Stone Dust and 4 % Cement.
30-6: Sample with 30% Stone Dust and 6 % Cement.
30-8: Sample with 30% Stone Dust and 8 % Cement.
30-10: Sample with 30% Stone Dust and 10% Cement.

2.1.3 Soil sample with 40% stone dust

40-0: Sample with 40% Stone Dust and 0 % Cement.
40-2: Sample with 40% Stone Dust and 2 % Cement.
40-4: Sample with 40% Stone Dust and 4 % Cement.
40-6: Sample with 40% Stone Dust and 6 % Cement.
40-8: Sample with 40% Stone Dust and 8 % Cement.
40-10:Sample with 40% Stone Dust and 10 % Cement.

2.2 Material Properties

The natural soil after Atterberg's test had a liquid limit of 83%, a plastic limit of 43.44%, and hence, a plasticity index of 39.697%. So, following the plasticity chart of Unified Soil Classification System, the soil was found to be weak soil (MH or OH) because the plot was below A-line in the chart.
The specific gravity of the soil, stone dust, and cement was found to be 2.32, 2.67, and 2.98 respectively. The initial and final setting time of the cement was 41 and 205 minutes. The compressive strength of the cement after 3, 7, and 28 days was found to be 32.59, 41, and

50.43 N/mm2 respectively. The cement properties were checked and verified by the Central Material Testing Lab (CMTL).

2.3 Results

2.3.1 Plasticity Properties of natural and modified soil sample

The summary of Atterberg's limit test on the natural soil sample and modified soil sample with mixed proportions of stone dust is represented in the table below. It is observed from the figure below that the Liquid Limit(LL), Plastic Limit(PL), and Plasticity Index(PI) reduces after the addition of stone dust because a non-plastic material (stone dust), definitely decreases the plasticity index when it is added to a soil with high plasticity.

Table 1: Test results on Plasticity properties of natural and modified soil.

Stone Dust	LL (%)	PL (%)	PI (%)
0%	83.137	43.440	39.697
30%	70.521	36.412	34.109
40%	64.099	34.117	29.982

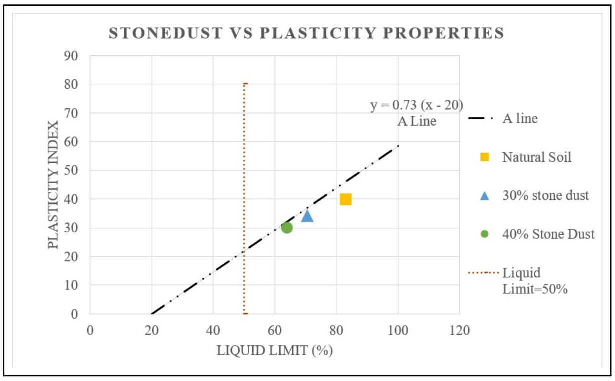

Figure 2: Plasticity Chart for the natural soil and modified soil.

2.3.2 Compaction Characteristics of the soil modified by stone dust only

The compaction test results show that the optimum moisture content of Natural soil is 38.6% and the maximum dry density (MDD) is 12kN/m3. The curve of compaction test for the soil after the addition of stone dust has lifted towards the higher side than the natural soil. So, the stone dust addition increases the MDD from 12.00 kN/m3 to 13.84 kN/m3 which is 15.33% higher. The OMC has decreased slightly from 38.46 percent to 27.5%.

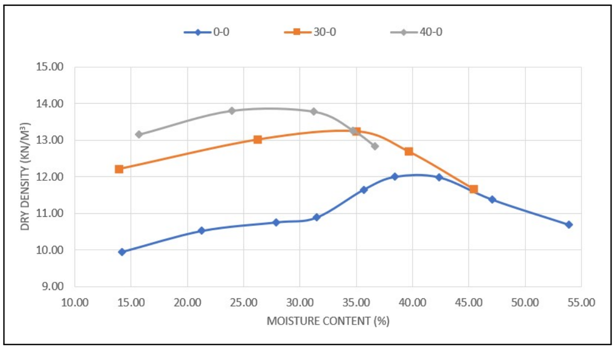

Figure 3: Compaction curve of soil with and without stone dust.

2.3.3 Compaction Characteristicts of the soil modified by both stone dust and Cement

The compaction curves for soil modified with cement only i.e., 0-(0, 2, 4, 6, 8 10) depicts that for growth in cement content, the dry unit weight increases up to 8% of cement and it decreases after that. The results for the soil modified with 30% stone dust show that for growth in cement content, the dry unit weight increases up to 6% of cement and it decreases after that. The decrease in maximum dry density even for the higher cement content might have been caused either due to the improper mixing of cement or the possibility of the presence of organic matters in the soil. However, the results for the soil modified with 40% stone dust show that for growth in cement content, the dry unit weight shows undulations up to 6% of the cement and it increases up to 10% of the cement content. The reason for this might be because of the formation of the coarse particle after cementing agents coat and binds the weak soil surface.

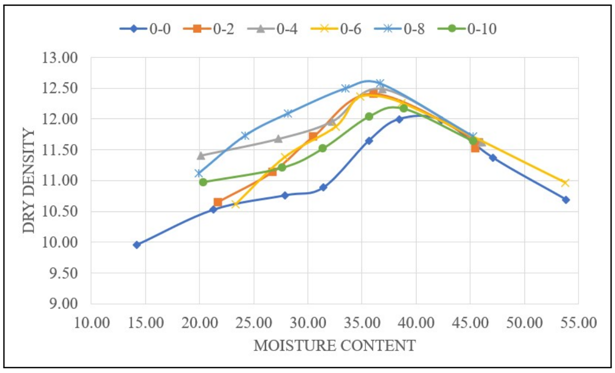

Figure 4: Compaction curves for natural sample modified with cement)

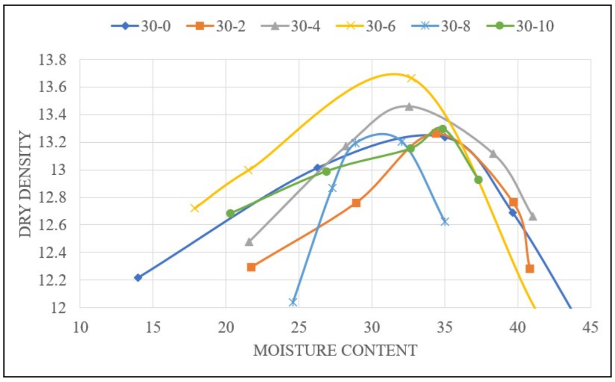

Figure 5: Compaction curves for soil modified with 30% stone dust and cement

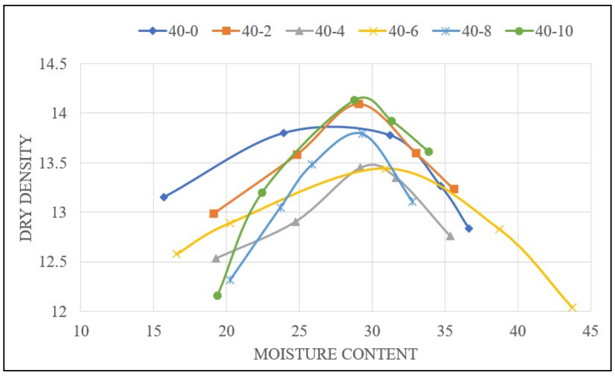

Figure 6: Compaction curves for soil modified with 40% stone dust and cement

2.3.4 Strength Characteristics of the soil modified by stone dust only

Unconfined compression tests of the compacted samples, 0-0, 30-0, and 40-0 are 270.73 kPa, 292.45 kPa, and 423.073 kPa respectively. The result indicated that there is slightly improved soil strength from 0% to 30% stone dust but the strength improvement has noticeably increased when 40% of stone dust is added in soil. This is because the UCS is the function of cohesion before friction in the natural soil sample, and the increase in stone dust decreases the cohesion and increases the friction of the modified soil.

2.3.5 Strength Characteristics of the soil modified by both stone dust and Cement

The chart for the Unconfined Compressive Strength values after 28 days of curing, depicts that the addition of stone dust and cement in the natural weak soil increases the strength. For natural soil and the soil with 40% stone dust, the strength increased gradually for cement content from 0% to 4%, and then the UCS had a sudden growth for cement increment of 4% to 8%. The trend of the UCS curve has changed after 8% cement content. However, in the case of the soil with 30% stone dust, the UCS showed a gradual increment for cement content from 0% to 4%, and then the strength had a sudden surge for an increase in cement content from 4% to 8%. When Stone dust is added (from 0% to 40%) in a soil, the addition of stone dust by 40% shows better strength imrovement. However, a natural soil with 0% stone dust- 6% of cement shows the same strength as shown by the soil stabilized with 30% stone dust- 6% cement and 40% stone dust- 6% cement. As it is observed that all the curves come to a junction at 6% of cement content, it suggests that the efficient cement content for Kupondole soil. Yet, the soil with 30% stone dust and higher cement content (8%-10%) shows improvement of UCS by 230% to 340%. So, soil stabilization with 30% stone dust and higher cement content could perform better in terms of strength improvement.

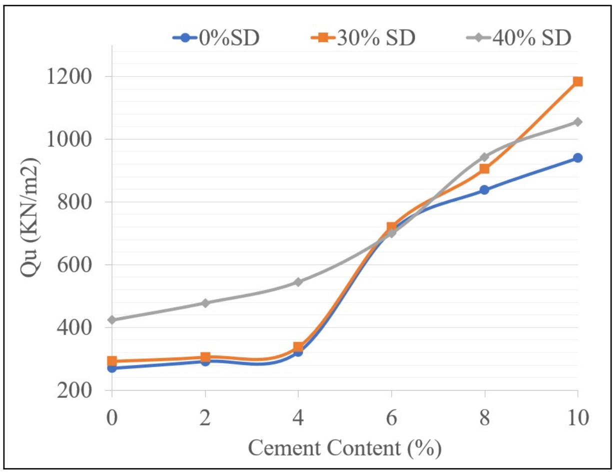

Figure 7: UCS values at different cement content for natural soil and soil with 30% stone dust.

3. Conclusion

- The optimum moisture content decreases by 28.49% when stone dust is increased from 0% to 40%.
- The maximum dry density increases by 15.33% when stone dust is added from 0% to 40%.
- It is found that adding more cement increases the unconfined compressive strength of soil in both cases(with and without stone) dust.
- For 28 days of curing, the stabilization of soil with 30% stone dust and higher cement content (8-10%) shows better performance in terms of strength improvement.

- However, the optimum cement content for Kupondole soil is observed to be the 6% of cement by weight.
- As the 40% stone dust in the soil gives high strength, when compared to the other dust content,the optimum stone dust for the soil in Kupondole is observed to be 40% of stone dust by weight.

4. Future Areas of Research

- Pozzolanic reactions last for a longer time and could last for years. This study's curing period was taken as 28 days, which does not adequately evaluate the effect of the pozzolanic reaction on strength. It is possible to undertake additional studies with a longer curing period.
- Similar study of stabilization by addition of stone dust up to 50% can be performed to understand the trend of the strength curve.
- The chemical and mineralogical composition test, triaxial test and organic matter test of the materials are also recommended for future research.

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