Stabilization of Silty Soil using Cement as Primary Binder and Epoxy Resin as Admixture

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Abstract

This research aims for the assessment of the influence of cement and epoxy resin on the stabilization of silty soil. Cement is used as a primary binder and epoxy as an admixture to stabilize the soil by increasing its compressive strength. Disturbed soil samples near the bank of Bagmati river, Chyasal were sampled through excavation. Laboratory tests show that the soil is silt with low plasticity. A Standard Proctor test is done to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) is done so that the quantity of cement and epoxy required for mixing with the dry soil can be calculated. Cement of proportions (5%,10%,15%) by total weight of dry soil have been used as a primary binder and epoxy resin of proportions (1.25%,2.5%,5%) by total weight of soil as an admixture to prepare soil samples for stabilization for a curing period of 7, 14, 28, 56 and 90 days and the unconfined compressive strength of those samples were determined accordingly. In this paper, the unconfined compressive strength of soil before and after stabilization have been compared. In this research, it is seen that the compressive strength of the stabilized soil drastically improves with the increase in proportions of combination of both cement and epoxy resin. Also, the research shows that the compressive strength increases with increase in curing period.

Keywords

Stabilization, Cement, Epoxy Resin, UCS test

1. INTRODUCTION

The damaged road condition of the valley, shrinkage and swelling potential of silt and clay beneath the Kathmandu valley, earthquake seismic zone V and other such geo-hazards have made Kathmandu valley more susceptible for inducing the deformation and various failures in the soil. Due to these reasons, it is necessary to apply technique to improve bearing capacity, in-situ and engineering properties of soil. Also, fine grained soil possesses high swelling potential and low strength [1]. Hence, one of the techniques for solving such geo-technical problems is soil stabilization. Soil stabilization is a ground improvement technique to improvise the weak geotechnical properties of soil. Soil stabilization removes cost of excavation and backfilling [2]. One of the methods of soil stabilization is chemical stabilization [3]. Normally, chemical stabilization is preferred for fine grained soil. Chemical stabilization uses chemical additives with soil to improvise soil strength properties and remove moisture [2]. We used cement as primary binder due to its high binding capacity and epoxy resin as admixture due to strength gaining capacity by polymerization.

There are many researches done on fine-grained soil and epoxy resin. In the research by [4], it is shown that epoxy resin is very effective for ML (silt of low plasticity), MH (Silt of High Plasticity) and CH (clay of high plasticity) soils. [5]showed the soil samples with mixture of soil-cement and soil-cement-resin mixed increased with increasing the contents of cement and resin as well. According to research done by [6], type of soil was one of the important factors for compressive strength increase. The research had been conducted with cement contents of 3%, 5% and 7% by weight where the compressive strength was increased on increasing the cement content as well as with increase in curing period from 7 days to 28 days by two times for ML soil which can be presented by power curve. The paper [7]supports the theory that hydrolysis and hydration are the primary reactions in a clay-cement interaction where lime could initiate attack of clay particles and cause breakdown of amorphous silica and alumina. [8]suggested that the combination of highly plastic Kaolin clay and Ordinary Portland Cement requires lower pH at higher temperatures to produce secondary cementing material CSH (Calcium Silicate Hydrate). [9], [10]showed that epoxy resin is an organic polymer consisting of carbon and oxygen atoms that improves the strength of fine-grained soil drastically. [11]suggests that blends with higher percent of bio-epoxy leads to conversion of other ether groups which results in process of co-polymerization which weakens strength of materials though. [12] used CH and ML soil with 3,7,28 days of curing period with 0%, 0.5%, 1.0%, 1.5% and 3% polymer.

Polymer stabilizer reduces soil erosion drastically and increases strength significantly [13]. Also, with addition of polymer MDD increases and OMC decreases [12].

This research determines the effectiveness of the combination of cement with epoxy resin on various proportions according to water-cement ratio and epoxy-water ratio for optimum strength for silty soil.

2. MATERIALS

2.1 Natural Soil

The soil was extracted from Himalaya College of Engineering, which lies at the riverside of Bagmati River. The extracted soil was classified as Silt of Low Plasticity (ML) on the basis of Unified Soil Classification System (USCS). Particle size distribution was done by IS-2720 code. Similarly, Liquid limit, Plastic limit and Plasticity Index of soil were found out in accordance with AASTHO T89-90 and T90-96 testing procedures.

Gravel	% Retained on 4.75 mm	11.09%
Sand	%passing 4.75 mm and retained on 75 micron	82.50%
Fines	% passing 75 micron	6.40%
% passing 425 micron		38.32%

Table 1 Particle size distribution

In-situ Moisture Content	17.92%
Bulk Density	1,793.826 kg/m^3
Specific Gravity	2.61
Liquid Limit	28.25%
Plastic Limit	25%
Plasticity Index	3.25%
Maximum Dry Density	1725.5 kg/m^3
Optimum Moisture Content	18.375%
Soil Classification	Silt of Low plasticity (ML) USCS Classification

Table 2 Index properties of soil

2.2 Cement

Cement is a binding material which on mixing with water gets hydrated and the main cementitious property is exhibited by the calcium silicates: C_3S and C_2S. The calcium hydroxide obtained from hydration of cement further reacts with pozzolanic materials to form further cementitious materials. Cement Stabilization helps to remove fatigue failures caused due to repeated deflection of asphalt surface [14].

2.3 Epoxy Resin

Epoxy resin are organic compounds in which a single oxygen atom is bonded with two carbon atoms [15]. Epoxy resin used contained of 1:1 Hardener and Epoxy resin respectively which was stirred and mixed thoroughly. Epoxy Resin being an organic polymer, starts to polymerize when mixed with hardener due to which the soil gains high strength under compression loading by the formation of a strong epoxy structure. Epoxy resin forms 3-dimensional cross-linked network forming cross-linked structure which enhances strength and mechanical properties [15]. Polymers improves soil properties by increasing adhesion between soil grains [16].

3. SOIL SAMPLE PREPARATION AND EXPERIMENT

Mixing of soil with different cement and epoxy resin contents was done according to the BS 1924- 1274 standards (British Standards Institution 1924). At first, the parent soil was oven dried and passed through a 425 micron sieve. Water equal to the OMC was added whereas, cement was added in proportion of either 5, 10 and 15% of the total mass of soil. Similarly, epoxy resin was added in either proportion of 1.25, 2.5 and 5% of the total mass of soil and mixed thoroughly. This makes altogether of 10 combinations of cement and epoxy resin which are shown in Table 3. Two samples were prepared for each combination to obtain average data, which makes it 20 samples for a single curing period. So, a total for 100 samples were prepared for all curing periods of 7, 14, 28, 56 and 90 days. The homogeneous mixture was then compacted by a constant force of 20kg in the cylindrical mold of Harvard Miniature Compaction Apparatus in three layers by blowing 25 times in each layer. Then it was wrapped in plastic to prevent exposure to moisture. Before 3 days of testing, the samples were unwrapped and cured in natural surrounding for the allotted period. As for cement stabilization of silt, for better testing and low cost, unconfined compressive strength test is carried out [17]. Unconfined Compressive Strength tests were carried out on the samples according to the ASTM D1633 (ASTM 1983) standard on their respective time schedule and results were noted.

Figure 1: Brittle failure after testing of sample of high cement and epoxy resin content

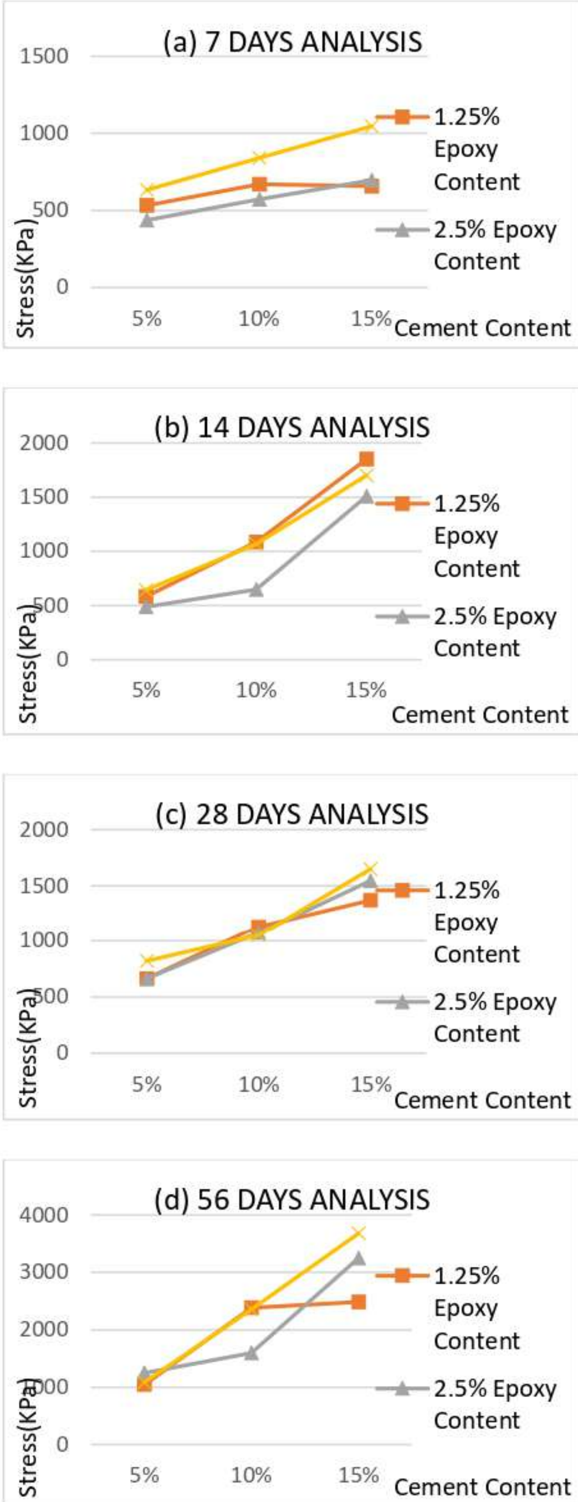
Figure 2: Unconfined Compressive Strength test of Samples

Table 3: Percentage of constituents in soil samples for each curing periods

Samples	Total % of soil	% of dry soil	% of water	% of epoxy resin	% of cement
A	100	84.475	15.522	0.00	0.00
B	93.75	79.195	14.552	1.25	5.00
C	92.5	78.139	14.358	2.50	5.00
D	90	76.028	13.970	5.00	5.00
E	88.75	74.972	13.776	1.25	10.00
F	87.5	73.916	13.582	2.50	10.00
G	85	71.804	13.194	5.00	10.00
H	83.75	70.748	13.000	1.25	15.00
I	82.5	69.692	12.806	2.50	15.00
J	80	67.580	12.418	5.00	15.00

4. RESULTS AND DISCUSSIONS

4.1 Comparison of strength of stabilized samples at 7 days, 14 days, 28 days, 56 days and 90 days



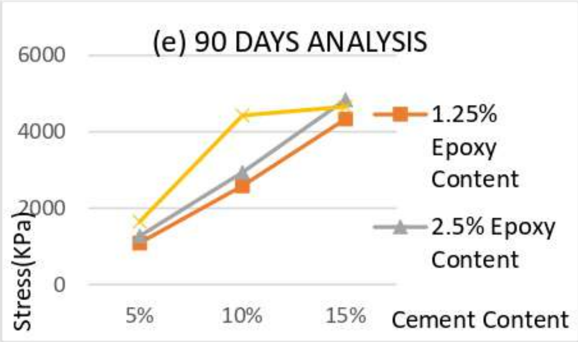
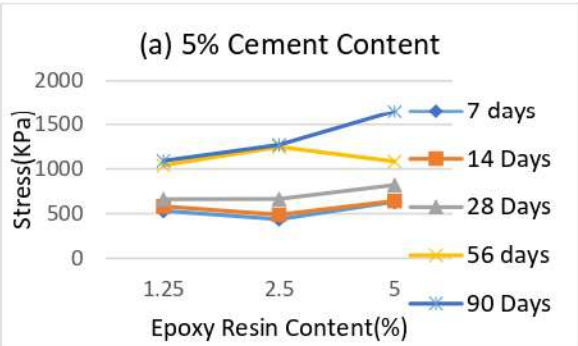
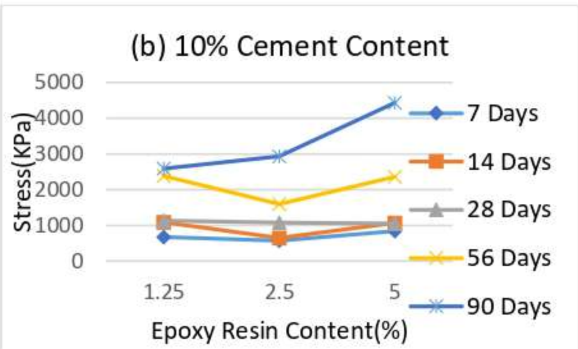


Figure 3: Plot of Unconfined compressive strength Vs Cement content for soil samples (a) 7 Days Analysis of varying epoxy content with varying cement contents; (b) 14 Days Analysis of varying epoxy content with varying cement contents; (c) 28 Days Analysis of varying epoxy content with varying cement contents;
(d) 56 Days Analysis of varying epoxy content with varying cement contents; (e) 90 Days Analysis of varying epoxy content with varying cement contents

4.2 Comparison of stress for various content of epoxy resin with at various cement contents





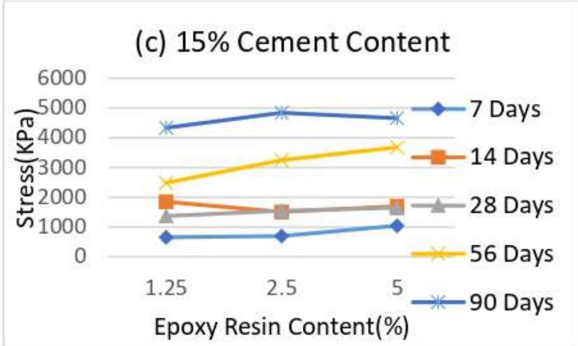


Figure 4: Plot of Unconfined Compressive Strength Vs Epoxy resin content for soil samples prepared with (a) 5% cement; (b) 10% cement; (c) 15% cement for five different curing periods

From these graphs of Figure 3 and Figure 4, it is noticed for 7 days period, the samples with only 5% epoxy resin content for all proportions of cement show drastically increase in strength. Also, till 14 days curing period, the strength increased with high level of epoxy resin and samples with low level of epoxy resin do not vary largely. On 28 days curing period, it can be distinctively seen, for any cement content, the samples of any epoxy resin content show similar increase in strength. For, 7 days, 14 days and 28 days, in all these curing period, cement content have been major factor for drastically increase in strength. Primary binder is more responsible for increase in strength due to properties such as hydration, formation of secondary products etc.

However, the status of strength changes in 56 days and 90 days. In 56 days and 90 days. In 56 days and 90 days, for 5% cement contents, the strength is similar with any proportion of epoxy content. However, the strength rises with increasing epoxy resin content for 10% and 15% cement content. The ultimate strength is acquired with highest epoxy resin and cement contents. The samples used to undergo brittle failure at higher curing periods for higher Cement content and ERC (Figure 5). This concludes, till 28 days of curing period, cement (primary binder) is more responsible for increase in strength and then after, the polymerization property of epoxy resin (admixture) increases strength of the samples. Improvement in strength also relate to improvement in strength means change in engineering properties of soil such as settlement characteristics, shear structure, permeability, swell potential in fine grained soil [18].

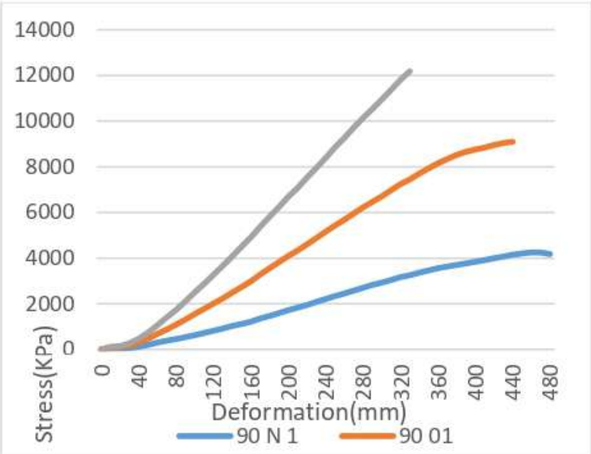


Figure 5: Brittle failure of samples at 90 days curing period after reaching a peak point.

4.3 Comparison of stress of stabilized soil sample for various percentages of cement and epoxy resin for 7, 14, 28, 56 and 90 days

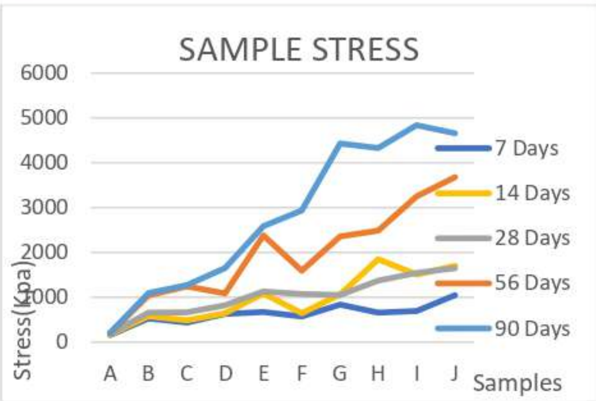


Figure 6: Sample stress variation

Samples are named according to the mixing proportions which is mentioned in table 3. The above graph shows that the maximum strength for the stabilized soil sample is observed frequently near the 9th and 10th samples (samples I and J). The maximum strength is obtained at 90 days of curing. This graph shows that the strength of the soil sample increases with the increase in the number of days of curing and proportions of cement – epoxy content.

4.4 Comparison of stress for unstabilized soil, minimum stabilization proportion and maximum stabilization proportion

As compared to the soil without cement and epoxy content, there is an increase in stress for both minimum proportions (5% cement and 1.25% epoxy resin) which is sample E and maximum proportions (15% cement and 5% epoxy resin) of cement and epoxy resin which is sample P. Also, there is a significant increase in stress for the sample containing any content of either or both cement and epoxy resin for all curing periods.

Hence, it can be concluded that the addition of cement and epoxy resin has successfully stabilized the soil.

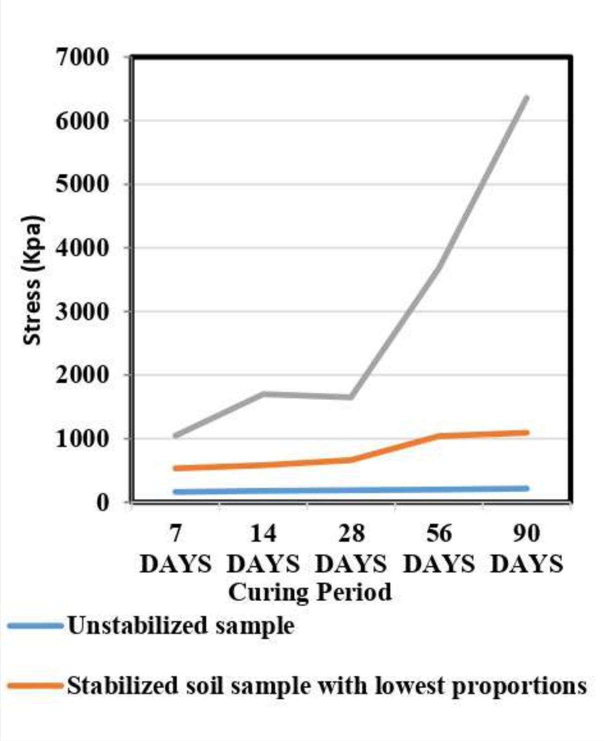


Figure 7: Comparison of stress for un stabilized and stabilized soil samples with minimum and maximum proportions

5. CONCLUSION

1. The compressive strength increased on 5%, 10% and 15% cement proportions with varying proportions of epoxy resin of 1.25%, 2.5% and 5% on all cement proportions.

2. The optimum unconfined compressive strength was obtained at 5% epoxy and 15% cement proportion by weight at highest curing period which is 4658.58% increase in strength compared to strength of wet sample.

3. The strength of stabilized soil was increased on increasing the curing period. The highest Unconfined Compressive Strength was recorded at 90 days followed by 56 days, 28 days, 14 days and 7 days respectively similar as results from [7], [8].

4. The compressive strength increased with increasing cement-epoxy resin content which has similar results with [8], [10].

5. At higher curing periods, the cement-epoxy stabilized sample has a brittle failure nature.

In this research, the stabilization of silty soil with cement and epoxy resin is investigated and the effects of stabilization are measured by the Unconfined Compressive Strength (UCS) test. It is found the addition of epoxy resin to primary binder cement increases the strength by a considerable magnitude. The effect of curing period is also dominant as the strength of a soil sample cured for 90 days is much higher than a soil sample cured for 7 days. The addition of cement causes the pozzolanic reactions to occur and consume a large quantity of water, which if existed as a free solution, would prohibit to some extent the chemical reactions of epoxy resin with hardener. The cement performed better till 28 days of curing period meanwhile epoxy performed better after 28 days of curing period. These results showed that cement and epoxy resin can be effectively used in many fields including pavement layers (road construction), retaining walls, deep soil mixing, earthquake engineering, soil foundation engineering etc. However, further research on this can be carried out to study its economic aspect before application.

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7. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Shishir Dhakal, Sandesh K.C. and Utsav Chimariya, Saurav Shrestha and Suvarna Singh Raut. The draft of the manuscript is written by Shishir Dhakal and all authors commented on the draft of the manuscript, hence revising the draft to final manuscript. All authors read and approved the final manuscript.

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