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Stress Strain Characteristics of Cement Stabilised Kerawa Upland Soils as a Potential Subgrade Material

KEYWORDS: Cement-stabilisation, stress-strain curve, Unconfined compressive strength, Lacustrine deposit.

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ABSTRACT *In view of upland lacustrine deposits, most of them are relatively dry and considerably consolidated nature. The soil available at such upland locations has been successfully used as a potential borrow material for road sub-grades in filling. However, generally, the remolded strength of such soils is relatively low because of soil sensitivity issues. Efforts are aimed at identifying some potential borrow soil sites from various areas of Kashmir Valley and evolving a methodology for significant stabilisation of same, so that performance of soil as a sub-grade can be practically improved. This paper shows the experimental study which is principally focused on cement based stabilisation of different borrow soils and their critical characterization based on stress strain performance, relative to each other. Based on comparative analysis of experimental and analytical results of stress-strain based characterization results, some rational technical suitability is expected to be recommended for stabilisation.*

Introduction

In upland kerawas of Kashmir, the chances to have good quality pavement construction sites become rarer and it is necessary to choose sites that include compressible soils, especially for transportation projects. Soils are mostly alluvial, hence are weak and have low shear strength. Therefore, the tasks to do road constructions on these problematic soils have become a challenge for geotechnical engineers. The ground or soil condition is one of the important factors in pavement design. Before starting to design a pavement, a civil engineer must first obtain the required soil, information from soil investigation carried out at the proposed site. Therefore, a civil engineer must have an adequate knowledge on the properties of soil and the soil testing. Soils with characteristics of low strength and compressible exist all over the world. One of the most significant problems arises because of its characteristics that are difficulties in supporting wheel loads on such pavements. The problem arises with low strength is that it leads to difficulties in guaranteeing the stability of the pavement on this type of soil. Therefore, the stabilisation of soil is important to be done in the pavement construction.

The main purposes of soil stabilisation are to modify the soil, expedite construction, and improve the strength and durability of the soil. Besides that, soil stabilisation also can be defined as the modification or improvement of the characteristics of soil in order to enhance the engineering performance of the soil

The term modification implies a minor change in the properties of a soil, while stabilisation means that the engineering properties of the soil have been changed enough to allow field construction to take place. There are two primary methods of soil stabilisation used today, mechanical and additives. The method of soil stabilisation is determined by the amount of stabilizing required and the conditions encountered on the project. An accurate soil description and classification is essential to the selection of the correct materials and procedures. The most common improvements achieved through stabilisation include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and strength.

Mechanical stabilisation is the process of altering soil properties by changing the gradation through mixing with other soils, densifying the soils using compaction efforts, or undercutting the existing soils and replacing them with granular material. The examples of mechanical method are soil replacement, vibroflotation, compaction and others.

In additive method, stabilisation of soils to improve strength and durability properties often relies on cement, lime, fly ash, and asphalt emulsion. These materials are inexpensive, relatively easy to apply, and provide benefits to many different soil types. However, there are varieties of non-traditional soil stabilisation/modification additives available from the commercial sector such as polymer emulsions, acids, lignin derivatives, enzymes, tree resin emulsions, and silicates. These additives may be in liquid or solid form and are often touted to be applicable for most soil.

Soil stabilisation with cement has been successfully applied in engineering Construction. Applications of this method have recently been further expanded. The more Common uses today are for improving sub grade of roads. Soil cement has been proven in all of these uses to be cost effective, aesthetically pleasing, performance and time tested. Other uses for soil cement are retaining walls, streets, shoulders, airports, parking and storage areas. As the soil cement is placed and compacted, the cement hydrates and the mix becomes a structural slab-like material. After construction and curing, soil cement is not affected by water or the freeze thaw cycle to a great extent, therefore it does not pump under construction traffic or rut during spring thaws, and can bridge over soft sub grade.

Experimentation

The projected work shall encompass following course of action.

- Identification of at least three potential dry-upland sites, which may be successfully used as borrow source for sub grade soil material.
- Laboratory investigations for determining engineering properties of natural soil and evolving a methodology for subsequent cement based stabilization.
- Laboratory characterization of cement stabilized soils and natural soils in terms of Stress-Strain characteristics.
- Analysis of results and discussions for sub-sequent recommendations.

Field Sampling

Soil sampling is an essential and basic work that has to be done for soil testing.

In present study, three sites have been identified which are potentially dry upland sites and can be a good borrow source for sub grade soil material. The details of these sites are given in the following table:

Table 1

Sr. No.	Name of site	GPS marking	Elevation
1	Village Amlar Tral	N 33°53′10.7″ E 075°04′10.7″	1626 m
2	SSM college Pattan	N 34°09′18.9″ E 074°38′49.8″	1623 m
3	Village Kroham Budgam	N 33°59′18.7″ E 074°43′09.1″	1753 m

Sampling Procedure
The procedure followed on each sampling site is given as below:

- Sampling spots were randomly selected.
- The top soil consisting of roots and debris was cleared until the natural soil got exposed.
- Thick slices of natural soil was taken and placed in a gunny bags.
- The bags were labeled with name of the site and sample number.
- Simultaneously the GPS marking and elevations of the sites were noted down.

Laboratory investigations
The samples retrieved from the field were thoroughly sealed/tagged and subsequently transferred to Road Research and Material Testing Laboratory for further laboratory investigations.

- Moisture Content
- Specific Gravity.
- Wet sieve Analysis.
- Atterberg's Limits.
- Standard proctor test.
- Unconfined compressive strength test.

Table 2

Depth below Ref/NSL (m)	Visual Soil Identification (Color, Texture, Consistency)	BIS- Classification	Specific Gravity	Grain Size Analysis (Fraction)			Consistency Limits		Representative In-situ Properties			Site*
				Gravel/ Organic Matter %	Sand %	Fines (Silt-clay) %	Liquid Limit **	Plastic Limit	Dry Density (g/cc)	Natural Moisture Content (%)	Optimum Moisture Content (%)	
0.1	Brown clay soil of soft consistency.	CL	2.67	-	9.5	90.50	29	16.91	1.74	14.36	16.20	T
0.1	Brown silty/ silt-clay soil of soft to medium consistency.	CL	2.64	-	5.04	94.96	32	17.49	1.68	9.54	19.91	P
0.1	Brown silty/silt-clay Soil of medium consistency	CL	2.55	-	0.47	99.53	33	16.69	1.68	17.18	22.46	B

*** Designation of soil sample for laboratory testing.**
**** Consistency tests performed for fine content in soils only (passing 425)**

T Tral Site

P Pattan Site

B Budgam Site

CL Clay of low plasticity

Soil Cement Mix – Stabilisation Methodology
Soil-Cement is an intimate mixture of pulverized soil, cement and water compacted and cured for the desired period producing a hardened and stable mass. Soil-cement has been mainly used as sub-base and base course material for highway and airfield pavements. For all soils the strength of soil cement increases with cement content. It has been a controversial matter to decide the basis for the design of a soil-cement mix; the points generally considered are;

- Desired strength
- Resistance to adverse weather conditions including alternate wet dry or freeze-thaw cycles.
- Volume and moisture changes during the above weathering cycle

Methodology adopted in present study:
a) Specimens Preparation
Following relatively different testing methodology has been adopted for preparation of natural and cement stabilized samples from assorted locations

Sieve 10.5 kg soil passing 425μ from each site sample and oven dry the sieved soil sample for 24 hours and then divide the 10.5 kg sample into three equal parts of 3.5 kg each. Now add cement 5%, 10% and 15% by weight of soil to these three parts and add water equal to optimum moisture content of original soil samples as calculated in the previous experiment to each cement soil sample and perform wet mixing, the wet soil is mixed and is stored inside an air tight polythene for 24 hours to enable the moisture to get uniformly distributed throughout the soil. After 24 hours remove the polythene and take the cement soil sample into the mould for compaction process, then place the mould in hydraulic sample extracting machine and obtain three cylindrical specimens each of diameter 3.5 cm and length 10cm. Repeat the same procedure to other cement soil moulds and place these specimens for a curing period of 7 days in a desiccators. Similar procedure as reported above is adopted to prepare the sample of natural soil without stabilisation, wherein no cement is added to the soil.

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Fig 1: Soil in tube sampler

Fig 2 Samples for unconfined compression test
(b) Testing

After curing, the specimens are tested in unconfined compression machine at a rate of 1.22 mm/min. and the maximum load is determined where the specimen fails by shear. Simultaneously readings of the proving ring and dial gauge are noted down. The primary purpose of this test is to determine the unconfined compressive Strength. According to the ASTM standard, the unconfined compressive strength is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test.

Fig 3. Soil sample placed in compression device

Fig 4. Soil sample failure

Results And Discussions

In order to have better representation and technical evaluation of these upland soils, different potential borrow locations have been evaluated in this study, namely, Tral, Budgam & Pattan, for stabilisation scheme.

Stress strain results of Tral samples (7 days curing)

While testing the samples from Tral area, the observations which were recorded are as shown graphically.

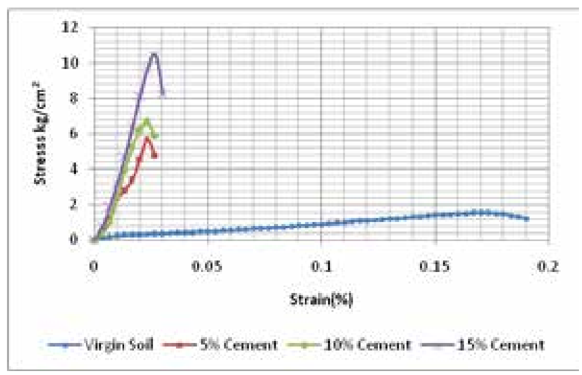

Fig 5

It can be observed from Fig 5 that the unconfined compressive strength for virgin soil increases from 1.55kg/cm^2 to 5.66kg/cm^2 with 5% cement, when the cement percentage is increased from 5% to10% the strength increases to 6.68 kg/cm^2.Futher an increase in percentage of cement from 10% to 15 % the strength increased to 10.43kg/cm^2 .There is increase in U.C.S. with increase in percentage of cement.

Stress strain results of Pattan samples (7 days curing)

While testing the samples from Pattan area, the observations which were recorded are as shown graphically.

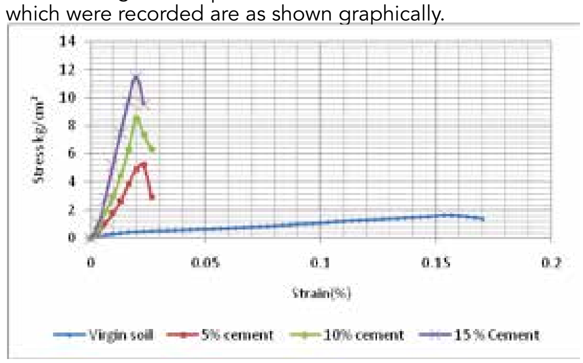

Fig 6

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From Fig 6 that the unconfined compressive strength for virgin soil increases from 1.61kg/cm² to 5.23kg/cm² with 5% cement, when the cement percentage is increased from 5%to10% the strength increases to 8.46 kg/cm².Futher an increase in percentage of cement from 10% to 15 % the strength increased to 11.52kg/cm² . Thus increase in U.C.S. with increase in percentage of cement.

Stress strain results of Budgam samples (7 days curing)
While testing the samples from budgam area, the observations which were recorded are as shown graphically.

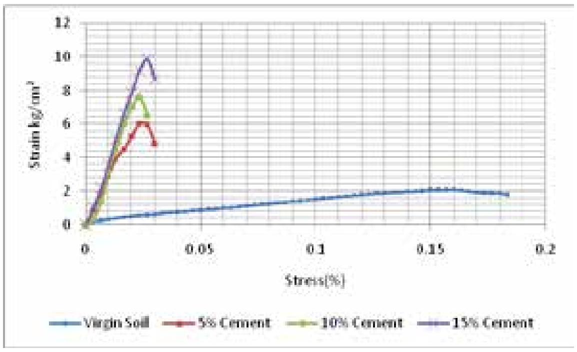

Fig 7

From Fig 7 that the unconfined compressive strength for virgin soil increases from 2.10kg/cm² to 6.01kg/cm² with 5% cement, when the cement percentage is increased from 5%to10% the strength increases to 7.65kg/cm².Futher an increase in percentage of cement from 10% to 15 % the strength increased to 9.85kg/cm². Thus increase in U.C.S. with increase in percentage of cement.

In this study, curing period for all samples was restricted to 7-Days and all soils have shown significant gain in stress-strain characteristics. This was evaluated by plotting peak Unconfined Compressive Strength of all soil samples verses Cement Content.

Relation Between Average Peak Strength Of Soil And Cement Content
Table 3

Cement (%)	Average peak strength(Kg/cm²)		
	Tral	Pattan	Budgam
0	1.56	1.79	1.90
5	5.95	5.06	6.66
10	8.43	9.05	8.82
15	10.68	10.90	9.72

Plot between average peak strength vs cement content percentage

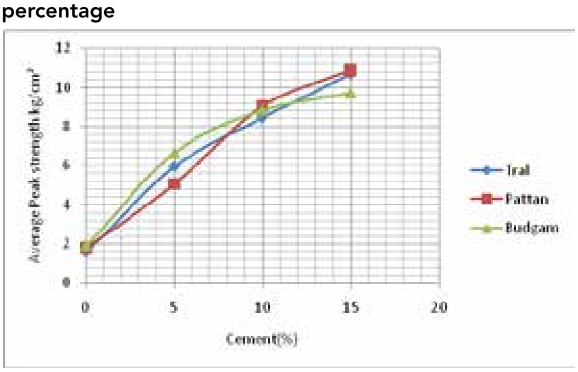

Fig 8

Determination Of Secant Modulus And Its Relation With Cement Content
Table 4

Samples	Cement (%)	50% of Ultimate Strength	Accumulated Strain	Seq-modulus (E50) Kg/cm²
Tral	0	0.77	0.086	8.95
	5	2.83	0.011	257.27
	10	3.34	0.011	303.63
	15	5.21	0.013	400.76
Pattan	0	0.80	0.070	11.42
	5	2.62	0.011	228.18
	10	4.23	0.010	423.00
	15	5.76	0.010	576.00
Budgam	0	1.05	0.088	11.93
	5	3.01	0.011	273.63
	10	3.82	0.011	347.27
	15	4.92	0.013	378.46

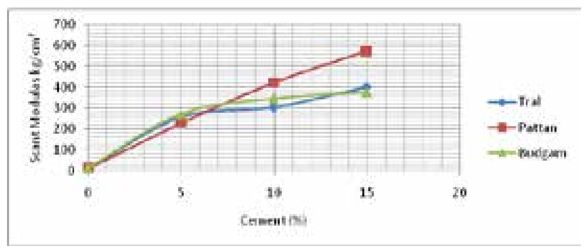

Fig 9

Conclusions

- • Based on detailed field/laboratory investigations and subsequent analysis of results, following inferences are drawn.
- Kerawa Upland soils, which are geologically classified under Lacustrine formations of recent origin, are invariably used as a potential option as fill sub-grade material in Kashmir Valley, particularly in those areas, where natural sub-grades are having low shear strength & high compressibility.
- In view of consistent sensitivity related issues in such upland soils, sometimes, it has been observed that the disturbed strength of soil during its placement as fill material, is significantly reduced. As such additional efforts, in terms of time and money are spent for excessive compaction of such soils.
- In present study, all the soils from above stated locations, have shown good response to cement based stabilisation. Response has been critically evaluated in terms of Stress-Strain Characteristics of soils at variable cement percentages, when compacted to standard proctor density Light Compaction. Effect on strength at cement stabilization at 5%, 10% and 15% has been evaluated in particular.
- It has been observed that beyond minimum cement content of 5%, the soil samples from Pattan location have shown relatively increased strength response to cement content.
- For better understanding of effect of stabilisation, strength of given soil has been evaluated in terms of Secant Modulus at 50% of peak strength obtained for each sample (E_{50}). With this, the cement content has been optimized to as low as 10% for soils of Tral & Budgam locations. However, due to better response of Pattan

soils even at lower cement content, the optimization of cement content is possible only beyond 15% of cement content.

- In general it has been observed that keeping stabilization cement content constant at 10% value and with light compactive effort (Standard Proctor Compaction), the Secant Modulus(E_{50}) has shown approximately 33-fold increase from its natural unstabilised state
- From above experimental and analytic observations, it is quite evident that even at very low cement content; substantial strength gain could be achieved in Lacustrine upland soils. This surely reinforces the economic viability aspect of such soils as prospective road sub grade material.

Future Scope

However, nevertheless, it is very imperative to emphasize here that in order to better understand the stabilised nature of such soils, more experimental investigations are required, which shall yield more data for relatively rational evaluation of Stress-Strain based evaluation of strength of soils. Extensive studies in this direction shall also facilitate relative technical evaluation and feasibility of prospective borrow sites for stabilisation and their subsequent economical use as source for soil-sub grade material.

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