Final Report
on
Stabilroad Stabilizer Study on Compressive Strength and Durability of Soil

Submitted to
Vishwa Samudra Engineering Private Limited
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DISCLAIMER

All the data and technical information furnished in this report are based on the laboratory investigations as per Vishwa Samudra Engineering Pvt Ltd protocol. The responsibility of the CSIR - Central Road Research Institute (CRRI), New Delhi is limited to the technical and scientific matters contained in this report.

Any use of the findings of the report without consulting CSIR - CRRI by any other agency or person other than the client will be solely at their own risk and responsibility.

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STABILROAD STABILIZER STUDY ON COMPRESSIVE STRENGTH AND DURABILITY OF SOIL

1. Introduction and Background of Product

Stabilroad stabilizer is available in powder form for the purpose of soil stabilisation. To evaluate the effectiveness of the Stabilroad stabilizer for Indian soils, M/s Vishwa Samudra Engineering Pvt Ltd (VSEPL), Hyderabad vide email dated: 20th June 2018 requested CSIR-Central Road Research Institute (CRRI) to investigate the strength and durability characteristics of its when mixed with soil and cement at dosages recommended by the manufacturer". VSEPL has done their first pilot road project using stabilroad stabilizer in August 2017 at Krishnapatnam Port, AP.

2. Objective of Study

To carry out the studies, soil sample from Krishnapatnam Port, Andhra Pradesh was collected by the client and supplied to CSIR -CRRI. The physical and engineering properties such as grain size analysis, Atterberg limits, Free swell index (FSI), modified Proctor's density and California Bearing Ratio (CBR) of native (unstabilised / untreated) soil samples were determined as per Bureau of Indian Standard (BIS) code/specifications.

To assess the geotechnical characteristics of stabilised soil, the collected native soil was mixed with cement and Stabilroad Stabilizer and its strength was evaluated in terms of unconfined compressive strength (UCS) and California bearing ratio (CBR).

The stabilised soil samples were also tested to assess their durability characteristics as per methods recommended by Bureau of Indian standard (BIS) and Indian Roads Congress (IRC). This report presents the test results of the studies carried out in Geotechnical Engineering (GTE) Division, CSIR - CRRI, New Delhi.

3. Scope of Work

The scope of work is given below:

- Geotechnical Characterization of selected soil (Sieve Analysis, Free Swell Index Atterberg limits, Proctor compaction test and CBR)

- Determination of CBR, Unconfined compressive strength (UCS) and Durability of soil stabilized with cement and stabilroad stabilizer(dosages of cement, stabilroad stabilizer and water content as per Vishwa Samudra Engineering Pvt Ltd Protocol)
- Analysis of laboratory test results
- Report Submission

4. Materials

4.1 Soils

Soil collected from Krishnapatnam Port (KP), Andhra Pradesh was used in the present study. The pictorial view of soil sample is shown in the Fig.1.

Fig. 1 Pictorial view of soil sample

4.2 Cement

Ordinary Portland Cement (OPC) of grade 53 conforming to IS 12269: 2013 was used for the stabilisation of selected soil.

4.3 Stabilroad stabilizer

Stabilroad stabilizer is available in a powder form. The pictorial view of stabilizer is shown in the Fig. 2.

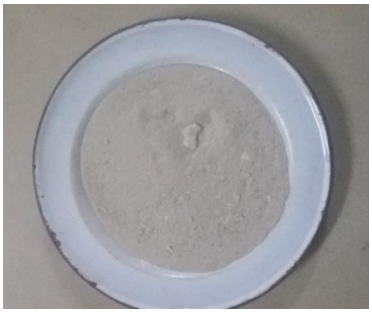

Fig. 2 Pictorial view of Stabilroad stabilizer

5. Geotechnical Characterisation of Native Soil

To study the geotechnical characteristics of selected soil, different laboratory experiments were carried out as per Bureau of Indian Standards (BIS) codes of practice, which included grain size analysis, Atterberg limits, free swell index, modified Proctor compaction test and California bearing ratio test. The results of the same are discussed below.

5.1 Grain Size Analysis

The grain size analysis of Krishnapatnam Port (KP) soil was carried out as per IS 2720 (Part 4)[1]. The Grain size distribution curve is shown in the Fig.3. As per ASTM D 2487 - 17 Unified soil classification system [3] the soil sample can be classified as clayey sand with gravel (SC).

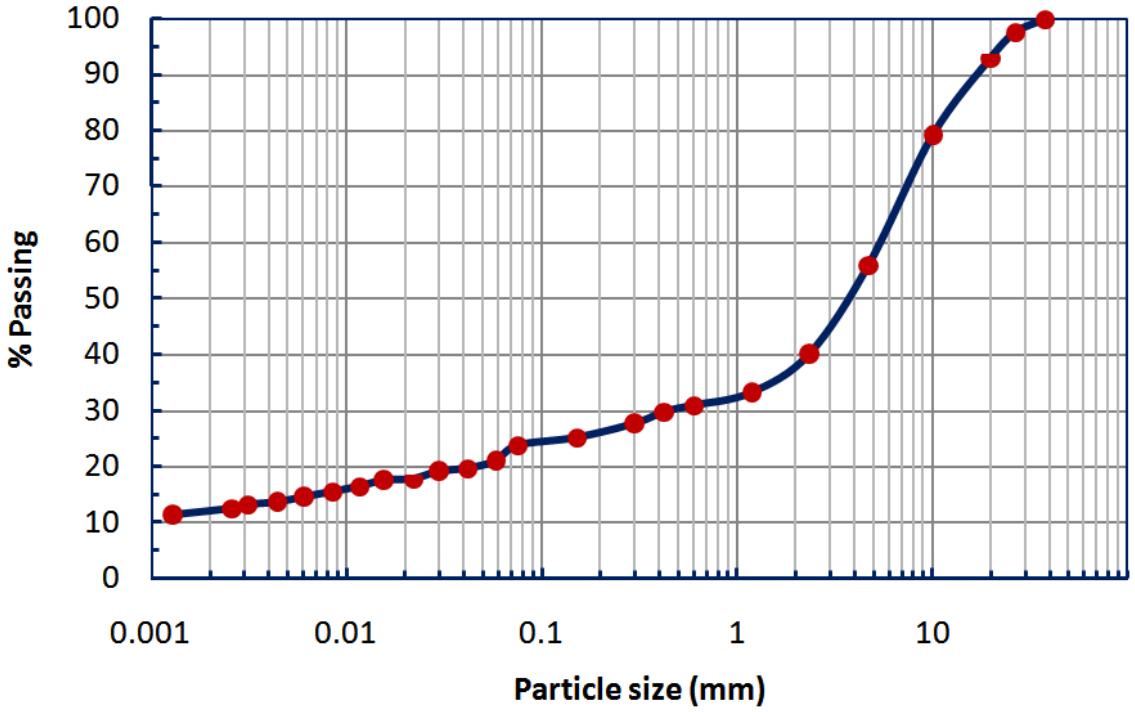

Fig. 3 Grain Size distribution curve of KP soil

5.2 Atterberg Limits

The liquid limit and plasticity index of soil samples were determined as per IS 2720 (Part 5) [2]. The results of liquid limit, plasticity index and soil classification are presented in Table 1. The liquid limit and plasticity index of KP soil satisfied the criteria of MoRTH specification (Section 403.2.1) for cement treated soil.

5.3 Free Swell Index

The Free swell index test of soil sample was carried out as per IS 2720 (part 40) [5]. The results are presented in Table 1. The KP soil is less expansive in nature.

5.4 Proctor Compaction Test

Modified Proctor compaction test on KP soil was carried out as per IN 2720 (Part 8) [6] and the compaction curve is shown in Fig. 4. The test results of maximum dry density (MDD) and optimum moisture content (OMC) are shown in Table 1.

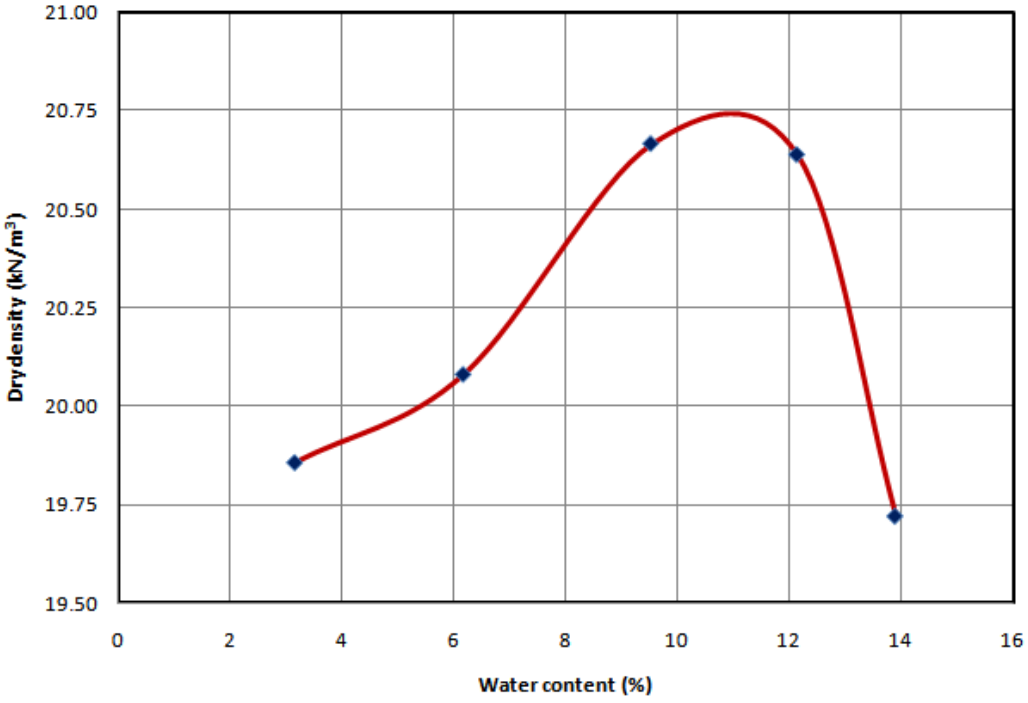

Fig. 4 Proctor compaction curve of KP soil used in the present study

5.5 California Bearing Ratio (CBR) test

California Bearing Ratio test on soil sample was carried out as per IS 2720 (Part 16) [7]. Three specimens were prepared by compacting the sample at 97% of maximum dry density (MDD) at corresponding optimum moisture content. The specimens were soaked for 4 days in potable water and then tested at the strain rate of 1.25 mm/min. The average value of CBR is presented in Table 1.

Table 1 Physical properties of KP soil

Properties	KP soil
Liquid limit	33 %
Plastic Limit	19 %
Plasticity Index	14 %
Unified Soil Classification System	SC
Free swell Index	10 %
γ_{dmax}	20.7 kN/m^3
OMC	11 %
CBR	6 %

6.0 Geotechnical Characterisation of Stabilised Soil

To assess the geotechnical characteristics of stabilised soil, the native soil sample was mixed with cement and stabilroad stabilizer (*Table 2: optimum dosages used as per Vishwa Samudra Engineering Pvt Ltd (VSEPL protocol*). These stabilized soil samples were tested to investigate the efficacy of stabilroad stabilizer with cement for improving the strength and durability characteristics of soils.

Table 2 Optimum dosages used for the KP soil (*as per VSEPL Protocol)*

KP soil	Binder (12%)		Water
	Cement	Stabilroad Stabilzer	
100%	11.7%	0.3%	12.4%

6.1 California Bearing Ratio (CBR) Test

To assess the gain in strength of stabilized soil in terms of CBR value, six specimens were prepared of dried native soil mixed with cement + Stabilroad Stabilzer (dosage as per Table 2) by compacting the sample at 97% of MDD at 12.4 % moisture content. Three stabilized CBR specimens were cured under moist conditions in wet sand for 7 days and then soaked for 4 days (i.e. 96 Hours) in potable water for saturation as per *ASTM D 7762* and another set of three stabilized CBR specimens were soaked for 4 days (i.e. 96 Hours) in potable water for saturation *as per IS 2720 - Part 16*. The testing was carried out at the strain rate of 1.25 mm/min (Penetration rate of plunger) to determine its CBR value. The values of CBR as per *ASTM D 7762*

and IS 2720 - Part 16 are given in Table 3. All the stabilized soil samples have CBR value greater than 100%. The CBR value of stabilized soil improves significantly (>100 %) as compared to native soil (6%)

(For determining CBR value of stabilised soils as per ASTM D 7762 - 18, CBR samples are moist cured for 7 days after which they can be directly kept in water for soaking. The period of soaking is 4 days (96 hours). Hence, total duration from preparation of samples until testing would be only 11 days as per ASTM D 7762-18. There is no Indian standard procedure for determination of CBR of stabilised soils. However the CBR test procedure for normal soil as per IS 2720-Part 16 is used for stabilized soil also i.e. total duration from preparation of samples until testing would be only 4 days.)

Table 3 CBR value of KP stabilized soil

Stabilized soil sample	CBR Value (%)	
	As per *ASTM D 7762*	*IS 2720-Part 16*
Sample 1	>100	>100
Sample 2	>100	>100
Sample 3	>100	>100

6.2 Unconfined compressive strength (UCS) test

The unconfined compressive strength (UCS) test on stabilized soil samples were carried out as per IRC:SP: 89 [10]. To assess the gain in compressive strength characteristic of soils due to stabilisation, three cube specimens of size 150 mm (length) x 150 mm (width) x 150 mm (height) were prepared of KP soil mixed with cement + stabilroad stabilizer (Fig. 5) by compacting the sample at 97% of MDD at 12.4% moisture content with the help of a vibratory hammer (Fig. 6). The test specimens were cured under moist conditions covered with wet gunny bags (Fig. 7) for 7 days and 28 days. After the curing period, the specimens were tested for their unconfined compressive strength (Fig 8). The results of the same are presented in Table 4. The failure patterns of UCS specimens are shown in Fig.9. The stabilized soil samples are achieved 80% of its maximum compressive strength in 3 days of curing period. The UCS of KP stabilized soil satisfied the criteria as per IRC: SP: 89 (Part II) - 2018 (section 7.3.2). The UCS value of KP soil (5.33 - 5.88 MPa) satisfy the IRC specified range for UCS (4.5 to 7 MPa in 7/28 days curing period) in the case of cementitious bases.

Figure 5 Mixing of stabilized soil sample

Figure 6 Compaction and preparation of UCS and Durability cubes

Figure 7 Curing of stabilized soil samples

Figure 8 Unconfined compressive strength test of cubes

Figure 9 Failure pattern of UCS test cubes

Table 4 Unconfined compressive strength (UCS) of stabilised KP soil

Sample designation	Curing period (days)	Density of Cube (kN/m^3)	UCS (MPa)	Ave. UCS (MPa)
Sample 1	3	22.9	5.36	**4.75**
Sample 2		23.3	3.96	
Sample 3		22.2	5.42	
Sample 4		22.6	4.25	
Sample 5	7	22.8	4.61	**5.33**
Sample 6		22.9	5.60	
Sample 7		22.6	6.68	
Sample 8		22.9	4.45	
Sample 9	28	23.2	7.67	**5.88**
Sample 10		23.1	4.85	
Sample 11		22.9	6.61	
Sample 12		22.9	4.39	

6.3 Durability test

The dimension and procedure for durability test specimen preparation is same as for the specimens prepared for UCS tests (section 6.2) for stabilised soils. The test specimens (cubes) were cured under moist conditions covered with wet gunny bags for 7 days. Durability test was carried out as per IS 4332 Part 4. This test is also known as “Wetting and Drying” test. Two different procedures are given in this code - Wetting and Drying tests and Freezing and Thawing tests. Keeping in view climate of Krishnapatnam Port region, Andhra Pradesh, 'Wetting and Drying tests' were adopted. This test broadly determines the weight loss produced by brushing, after repeated number of cycles of the wetting and drying of hardened stabilised soil specimens. In this test specimens are subjected to 12 cycles of wetting and drying, consisting of immersion in water for 5 hours followed by drying at 71^0C for 42 hours. After each such cycle, the specimens are brushed in a standardised manner using a wire-scratch brush (18 to 20 strokes on the sides and 4 strokes at each end). The loss in weight of brushed specimen, after each cycle is determined. After 12 cycles of test, all the specimens are dried to constant weight at 110^0C. The oven dry weight at the end of the test is required for determination of soil-cement loss after specified number of cycles. The percentage loss of different stabilised soil samples were estimated and compared with the permissible soil + cement +stabilroad stabilizer loss as per Indian Roads Congress specifications [10]. The durability test results are presented in Table 5. As per IRC SP 89-2018 the stabilized soil loss for clayey sand with gravel (SC) type of soil is up to 14 per cent of the original weight of test specimen. The condition of KP stabilized soil specimens after durability test is shown in figure 10. KP stabilized soil satisfied the durability test (brushing loss after wetting and drying) criteria as per IRC: SP: 89 (Part II) - 2018. The weight loss of treated soil (soil + cement + stabilroad stabilzer) is less than 1% and it is very within IRC specified limit of <14%. After durability test, as per IRC: SP: 89 (Part II)-2018 residual strength test (UCS test after 12 cycles of wet/dry) were carried out on stabilized soil samples (Fig 11). The residual strength test results are presented in Table 6. The average residual UCS strength is 2.4 times more than the 28days UCS strength of stabilized soil samples. The residual strength of KP stabilized soil satisfying the IRC SP 89 criteria.

Table 5 Results of Durability Test of KP Stabilised Soil

Sample designation	Bulk Density (kN/m^3) *(at the time of casting)*	Weight loss of stabilised samples (%) *(After 12 cycles)*	Maximum Permissible weight loss (%) *(IRC : SP: 89 (Part II) - 2018)*
Sample 1	22.9	0.35	14
Sample 2	22.8	0.63	14
Sample 3	22.8	0.42	14

Table 6 Residual strength of KP Stabilised Soil after Durability Test

Sample designation	Residual UCS (MPa) *(After 12 cycles)*	Ave. 28 days of UCS strength (MPa)	Maximum Permissible weight loss (%) *(IRC : SP: 89 (Part II) - 2018)*
Sample 1	12.9	5.88	Residual UCS strength shall not be less that of 20% of 28 days UCS Strength
Sample 2	16.6		
Sample 3	13.2		

Fig. 10 Condition of stabilised soil specimen after durability test

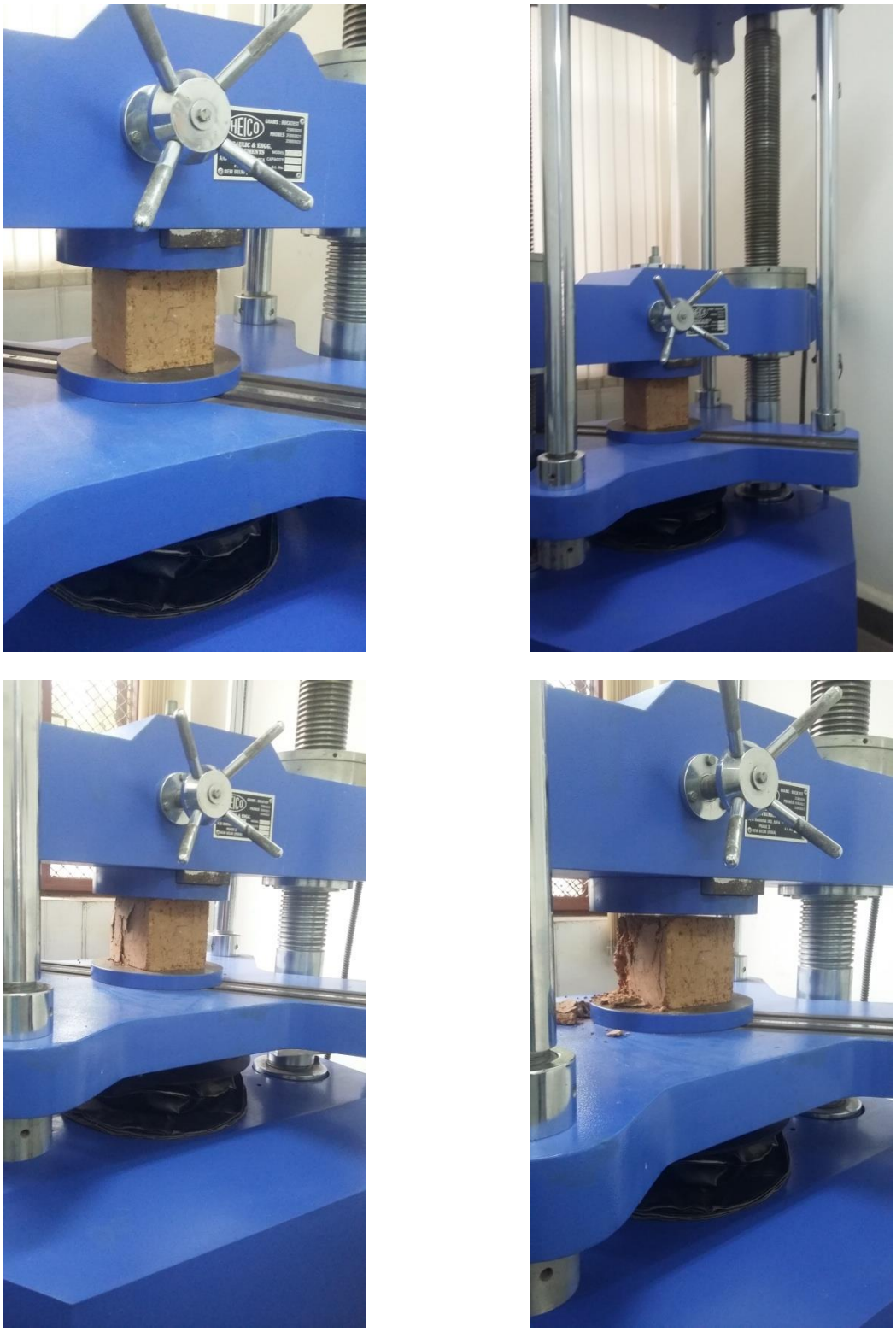

Figure 11 Residual UCS test (after durability cycles) on KP stabilized soil cubes

7. CONCLUSIONS

The major conclusions based on laboratory tests carried out on soil sample collected from Krishnapatnam Port, Andhra Pradesh and stabilised with Stabilroad stabilizer (0.3%)+ cement (11.7%) are given below. *The dosage and test procedure followed were exactly as per Vishwa Samudra Engineering Pvt Ltd protocol*

- The soil selected for this study had FSI within permissible limit of 50%
- The liquid limit and plasticity index (PI) of soil satisfying the MoRTH criteria for cement treated soil (MoRTH specifications for road and bridge works (2013)).
- Soil stabilized with stabilroad stabilizer (0.3%)+ cement (11.7%) showed significant improvement in the CBR value that is more than 100% as compared to untreated soil (6%).
- The UCS of KP stabilized soil satisfied the criteria as per IRC : SP: 89 (Part II) - 2018 (section 7.3.2). The UCS value of KP stabilized soil (5.3 - 5.9 MPa) is well within the IRC specified range (4.5 to 7 MPa in 7/28 days) for cementitious bases.
- KP stabilized soil satisfied the durability test (brushing loss after wetting and drying) criteria as per IRC : SP: 89 (Part II) - 2018. The weight loss of treated soil (soil + cement + stabilroad stabilzer) was less than 1% that is very below the IRC specified limit of <14%.
- The average residual UCS strength (after durability test) of KP stabilized soil is about 14 MPa and that is 2.4 times more than the 28days UCS strength of stabilized soil samples. The residual strength of KP stabilized soil satisfying the IRC SP 89 criteria (not less than 20% of 28 days UCS strength).

The above conclusions are valid for soil samples supplied at CRRI laboratory by M/s *Vishwa Samudra Engineering Pvt Ltd*. Although laboratory tests indicate improvement in the engineering properties of soils after treatment with Stabilroad stabilizer and cement, it is suggested to evaluate the performance of these stabilization materials in field also by constructing a test track and observing performance of the test track for at least for two monsoon seasons for validating the laboratory findings.

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