CBR Characteristics of Cementitious Graded Gravel Soils by Curing Methods

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Abstract: The service life and performance of pavements mainly depends on the quality of materials used in the construction. Majority of local soils in their natural form lack in desired strength and durability required for the intended constructions, they are to be improved through the standard process of stabilization to make them suitable as one of the construction material. The cement treated soils are widely used in granular base and sub-base courses of pavements as construction material due to batter strength and durability. The current study there are three different locally available gravel soils has been selected and tested for their physical properties, compaction and strength characteristics, as per the test results the soils were classified as GM-GC, GC-1 and GC-2 and CBR% values were 28, 26 and 25 respectively, as per MORTH specifications CBR%>35 to use as base course material, hence the selected soils could not be used as base course material due to its low CBR values, so that cement stabilization has been used to improve the CBR% values. The different percentages of cement 0%, 1 %, 2%…..15% were added to GM-GC, GC-1 and GC-2 soils with gradation of G-50%(26.5 mm to 4.75mm IS-Sieves) and G - 50% (4.75mm to 0.002mm IS-Sieves) and tests were conducted to assess the compaction and strength characteristics by varying curing methods as 7days moisture, 7days water and 7days partial curing (3days moisture+4days water). As per the experimental results , it observed that among selected soils GM-GC soil has achieved CBR% of 85-101 with addition of 6-7% of cement under the partial curing (3M-4W) for 7days, it is more than appropriate to use this soil as base course material in road construction as per the MORTH (CBR %> 35)specifications.

Keywords: California Bearing Ratio (CBR) Value, Ministry of Road Transport and Highway (MORTH), Gradation, Stabilization, M-moisture is curing and W-water curing.

1. Introduction

Soil is a naturally occurring material above the ground surface, while physical verification of these soils it is observed that there are verity of soils are available in nature and these soils are classified into different groups based on its nature. It is very much needed to determine the index and engineering properties of locally available soils to construct the civil engineering structures like buildings, roads, dams etc. majority of local soils in their natural form lack in desired strength and durability required for the intended constructions, they are to be improved through the standard process of stabilization to make them suitable as one of the construction material. Among all available stabilization techniques cement stabilization is one of the best options as suits to all types of soils. Cement treated soils are widely used in granular base and sub-base courses of pavements as construction material due to batter strength and durability. Soils are classified into two types based on the grain size the grain size of the particles from 80mm to 4.75mm as course grained soils and the grain size of the particles from 4.75 mm to0.002mm as fine grained soils.
Compressive strengths in the samples under standard test increased with the increase of cement content up to some percentage of cement. But when cement content is increased above, the compressive strength increased at a slower rate, the percentage at which there is no more increment in strength, it is considered as optimal dosage of cement content [13].

The soil stabilized mechanism mainly depends on type of stabilizer applied. It’s very from formation of new compounds, binding the finer particles of the soils, particle surface coating with stabilizer to limit the moisture sensitivity. In the presence of water the overall stabilization process can be divided into four different procedures cation exchange, flocculation and amalgamation, pozzolanic reaction and cementitious hydration. Cement hydration is the most important contributor to the improvement of the engineering properties of soil. Cement hydration is relatively fast and causes an immediate gain in the strength of the soils [17].

The soil gradation and curing method is very much influencing the compaction and strength characteristics of mix.

2. Materials and Experimental Study

2.1. Gravel Soils

The gravel soils are naturally available in huge quantity across the world, approximately 30 to 40% of gravel soils are available Eastern & Western Ghats and central plateau. Three locally available gravel soils, are taken for the current investigation from Vishakhapatnam City-Andhra Pradesh at 17°43’47.3880”N latitude and 83°19’17.3820”E longitude. The physical, compaction and strength properties of gravel soils were determined from the experimental study, the data reported in Table-[1],[2] and references are [1], [2], [3] & [4] respectively.

| S.no | Property of Gravel Soil | Sample-1 | Sample-2 | Sample-3 |
|------|-------------------------|----------|----------|----------|
| 1.   | Grain Size Distribution |          |          |          |
| a.   | Gravel Size%            | 50       | 50       | 50       |
| b.   | Sand Size%              | 35       | 30       | 25       |
| c.   | Fines%                  | 15       | 20       | 25       |
| 2.   | Liquid Limit%           | 24       | 27       | 30       |
| b.   | Plastic Limit%          | 18       | 19       | 20       |
| c.   | Plasticity Index%       | 06       | 08       | 10       |
| 3.   | Soil Classification     | GM-GC    | GC-1     | GC-2     |
| 4.   | Compaction Characteristics |      |          |          |
| a.   | OMC%                    | 7.20     | 8.60     | 9.00     |
| b.   | MDD g/cc                | 2.08     | 2.06     | 2.05     |
| 5.   | CBR %                   | 28       | 26       | 25       |
2.2. Physical Properties of Cement

The ordinary Portland cement of Ultra-Tech 53 grade cement is used in this study. The properties of cement determined by the laboratory tests are reported in the Table-[2] and references are [5] respectively.

| S.No | Cement Property               | Value |
|------|-------------------------------|-------|
| 1.   | Specific Gravity              | 3.15  |
| 2.   | Initial Setting Time(Minutes) | 150   |
| 3.   | Final Setting Time(Minutes)   | 350   |
| 4.   | Consistency %                 | 31    |
5. Compressive Strength(Mpa)
   a. 7Days            34.46
   b. 28Days           45.24

2.3. Gradation of Gravel Soils
The gravel soils which are chosen for the investigation is graded into two categories for batter compaction characteristics and strength; one is G-50% the grain size of the gravel soil vary from 26.5 mm to 4.75mm as per IS sieve and second one is G-50% the grain size of gravel soil vary from 4.75 to 0.002 mm as per IS-sieves.

2.4. Compaction Characteristics of Cement Treated Graded Gravel Soils
The modified proctor test was carried out as per IS-4332 Part-3-1995 on cementitious graded gravel mix with 0%, 1%,2%......up to 15% of cement content by weight of the total mix, to determine the optimum moisture content and maximum dry density of the mix. The test results are reported in the figure [3], [4] and references are [3] respectively.

Figure-3: Optimum Moisture Content of Soils

Figure-4: Maximum Dry Density of Soils
As per the rest results reported on figure no: [3], It is observed that with increase of cement content 0%, 1%, 2%......15% to the graded gravel soils, the optimum moisture content (OMC) also increases respectively. In case of GM-GC soil has lowest OMC % 10.60 and GC-1:12.00 & GC-2:12.60 respectively.

As per the rest results reported on figure no: [4], It is observed that with increase of cement content 0%, 1%, 2%......15% to the graded gravel soils, the maximum dry density (MDD) also increases respectively. In case of GM-GC soil has more MDD value 2.38 g/cc and GC-1:2.36 & GC-2:2.34 respectively.

2.5. CBR % Values of Cement Treated Graded Gravel Soils with Different Curing Methods

The selected OPC-53 grade ultra-tech cement is added to the graded gravel soils from 0%, 1%, 2%, 3%......15% in weight of the total mix. To determine the optimum dosage of cement with respective compaction characteristics, CBR values, its improvement ratio and different curing methods for 7 days (Partial Curing Method (3M+4W), Moisture Curing Method and Water Curing Method)

Improvement Ratio = CBR Treated / CBR Untreated

Percentage increase = CBR T – CBR UT / CBR UT

Figure-5: 7 Days Partial Curing (3M+4W)

In partial curing method (3M+4W) the water content in the gravel soil due to presence of fine particles (slit and clay) and their corresponding plasticity characteristics slowdown and development of strong bonding between soil and cement particles in moist curing and it is continued in water curing also. Therefore, high CBR values are achieved at high percentages of cement. This behaviour is more pronounced further at high cement dosages also. In case of selected cement treated graded gravel soils the CBR% values are GM-MC: 182, GC-1:170, GC-2:153 respectively.
In case of moist curing (7M) development of strong bonding between soil particles and cement particles has been taken place during its initial curing period and not continued that effectively due to form requirement of some more water contain to form cementitious compounds under hydration process therefore relatively less and marginal reduction CBR values are reported w.r.t partially curing method. In case of selected cement treated graded gravel soils the CBR% values are GM-MC: 176, GC-1:163, GC-2:140 respectively.

In case of water curing method (7W) the interaction between soil solids and cement particles is taking place at high water contents. Development of effective bonding is less at its initial curing period and continued with times it helps in formation of work bonds. Therefore, less CBR values are obtained compared is moist curing and partial curing methods this phenomenon is well observed at low dosages of cement and at high dosages of cement 10-15% strong bonds are to be formed due to availability of more percentage of cement and its hydration process due to high percentage of fine particle. In case of selected cement treated graded gravel soils the CBR% values are GM-MC: 168, GC-1:156, GC-2:128 respectively.

3. Conclusions

By conducting laboratory tests on physical properties of selected soil samples, as per the test
results, the selected soils are classified as GM-MC, GC-1, and GC-2.

- Individually the selected soils have attained CBR% values GM-MC: 28, GC-1: 26, GC-2: 25 with their plasticity index (Ip) values 6, 8, 10 respectively. As per MORTH specifications CBR %> 35 to use as base course material. These soils could not be used as base course due to its low CBR% values, so that cement stabilization has used to improve the CBR% values.
- The different percentages of cement 0%, 1%, 2% ....... 15% were added to GM-MC, GC-1 and GC-2 soils with gradation of G-50% (26.5 mm to 4.75 mm IS-Sieves) and G-50% (4.75 mm to 0.002 mm IS-Sieves), with reference of modified proctor test results it is observed that with increase of cement content in graded gravel soils, the optimum moisture content (OMC) also increases respectively. In case of GM-MC soil has lowest increment in the OMC than remaining GC-1 & GC-2 soils.
- It is observed that with increase of cement content 0%, 1%, 2% ....... 15% to the graded gravel soils, the maximum dry density (MDD) also increases respectively. In case of GM-GC soil has more increment in the MDD than remaining GC-1 & GC-2 soils.
- Cement treated graded gravel soil GC-1 has achieved CBR% 93-102 with addition of 10-11% of cement under the 7 days water curing. In case of Moisture curing for 7 days the CBR% is 93-103 with addition of 9-10% of cement. But in case of partial curing (3M-4W) for 7 days the CBR% is 93-103 with addition of 8-9% of cement only.
- Cement treated graded gravel soil GC-2 has achieved CBR% 92-102 with addition of 8-9% of cement under the 7 days water curing. In case of Moisture curing for 7 days the CBR% is 97-107 with addition of 8-9% of cement. But in case of partial curing (3M-4W) for 7 days the CBR% is 91-102 with addition of 7-8% of cement only.
- Cement treated graded gravel soil GM-GC has achieved CBR% 98-110 with addition of 8-9% of cement under the 7 days water curing. In case of Moisture curing for 7 days the CBR% is 93-104 with addition of 7-8% of cement. But in case of partial curing (3M-4W) for 7 days the CBR% is 85-101 with addition of 6-7% of cement only.
- As per the experimental results, it is observed that among selected soils GM-GC soil has achieved CBR% of 85-101 with addition of 6-7% of cement under the partial curing (3M-4W) for 7 days. It is more than appropriate to use this soil as base course material in road construction as per the MORTH (CBR %> 35) specifications.

4. References

[1] IS: 2720 (Part-IV) 1985, First Revision Methods of test for soils, part-4 and determination of grain size analysis, Bureau of Indian standards, New Delhi.
[2] IS 2720-5 (1985): Methods of test for soils, Part 5 Determination of liquid and plastic limit, Bureau of Indian standards, New Delhi.
[3] Determination optimum moisture content and Maximum Dry Density by Modified Proctor Test as per IS 2720(Part-08)-1987.
[4] Determination of California Bearing Ratio Value by CBR Test as per IS 2720(Part-16)-1987.
[5] Determine the chemical and physical requirements of 53 grade ordinary Portland cement as per IS: 269:2015 (Part-2, 3, 4, 5 & 6).
[6] IRC-37(2001), the general guidelines for the design of flexible pavements, Indian road congress, New Delhi.
[7] IRC-37(2012), the general guidelines for the design of flexible pavements, Third Revision, Indian road congress, New Delhi-2012.
[8] IRC: SP: 89 -2018 (Part-II) “Guidelines for the design of stabilized pavements”. Published by Indian Roads Congress, New Delhi, India.
[9] MORTH - Specifications for Road & Bridge Works (5th Revision)
[10] Hamed Ahmadi Chenarboni and Seyad Hamid Lajevardi “The Effect of Ziolite and Cement Stabilization on the Mechanical Behavior of the Expansive Soils” Construction and Building Materials, Elsevier, November-2020.
[11] Omid Amini and Mojtaba Ghasemi “Laboratory study of the effects of using magnesium slag on the geotechnical properties of cement stabilized soils” Construction and Building Materials, Elsevier, July-2019.

[12] Basha and Abd al-redhghani “Study of Cement Treated Base Aggregate Properties for Pavement Structure” International Journal of Information Research and Review, January 2018.

[13] Md Ali Ashraf, S. M. Shazeebur Rahman, Md Omar Faruk, Md Abul Bashar. “Determination of Optimum Cement Content for Treatment of Soft Soil and Durability Analysis of Soil Treated with Cement” American Journal of Civil Engineering, Vol. 6, No. 1, 2018.

[14] Ekwulo E.O and Eme D.B “Effect of aggregate gradation on compressive strength and elastic modulus of cement treated aggregate base material for highway pavement” IOSR Journal of Engineering Vol-07-Issue 10-2017.

[15] Yuanjie Xiao and Liuxin Chen “Laboratory validation of a gradation design concept for sustainable applications of unbound granular materials in pavement construction” Construction and Building Materials, Elsevier, October-2016.

[16] A.A Amadi and A.S.Osu “Effect of curing time and strength development in black cotton soil-Quarry fines composite stabilized with cement kiln dust(CKD)”, Journal of King Saud University-Engineering Sciences-April 2016.

[17] Murad Abu-Farsakha, and Sanjay Dhakalb, Qiming Chen, “Laboratory characterization of cementitiously treated poor sub grade soil under cyclic loadin”, Published in Soil and Foundation, Elsevier-2014.

[18] Manasseh Joel and Isaac O. Agbede. “Mechanical-Cement Treatment of Laterite for Use as Flexible Pavement Materials” Journal of Materials in Civil Engineering, Vol. 23, No. 2, February 1, 2011. ©ASCE, ISSN 0899-1561/2011/2-146–152/$25.00.