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Effective Method of Curing Improving the CBR

[1] PABBISETTY V S P S P RAO, [2] Mr. Krishna Naik, M.Tech.

[1]M. Tech Student, Department of Civil Engineering, MVR College of Engineering and Technology (autonomous) paritala, India.
[2]Assistant Professor , Department of Civil Engineering, MVR College of Engineering and Technology, paritala, India.

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Abstract - Flexible pavements are commonly constructed using locally available natural soils, but many of these soils fail to meet standard specifications, necessitating the use of alternative materials. Soil stabilization involves modifying the properties of soil through chemical or physical means to improve its engineering performance. One common method is to stabilize subgrade soils with stronger materials, such as cement. In this study, cement is used as a stabilizer to enhance the properties of graded gravel soil, making it suitable for use in road construction. The present investigation focuses on mixing graded gravel residue with varying percentages of cement and evaluating the compaction and California Bearing Ratio (CBR) characteristics of the mixes. These mixes were tested for their CBR values after different curing periods, including 3 days of moisture curing followed by 4 days of water curing. The results showed that the gravel residue-cement mixes achieved high dry densities and significant improvements in CBR values, demonstrating their potential for use in sub-base and base course layers of flexible pavements.

Key Words: Flexible Pavement, Soil Stabilization, Gravel Residue, Cement Stabilization, CBR, Compaction, Sub-base, Base Course, Curing, Road

1.INTRODUCTION

Infrastructure development is crucial for economic growth, and road networks play a pivotal role in this process. Flexible pavements, a widely used road construction method, transmit vertical compressive stresses to underlying layers through grain-to-grain contact. These layers' performance depends on the material's properties, including grain size distribution, density, and plasticity (Murthy et al., 2003). Gravel soils, due to their particle size distribution, are highly regarded in civil engineering for their ability to form dense, strong configurations under loading (Prakash et al., 1993). However, fine-grained particles like silt and clay can absorb excess moisture, leading to deformation and reduced strength (Thom et al., 1988).To improve such soils, stabilization techniques like cement addition are widely used. Cement, a hydraulic binder, increases strength by filling voids and reacting with water to form a hardened structure. It has been extensively studied as an effective stabilizer for various soils in road construction (Gourley et al., 1990). This research explores the potential of stabilizing locally sourced gravel residue soil with cement to enhance its properties for use in road construction (Jain et al., 2010).

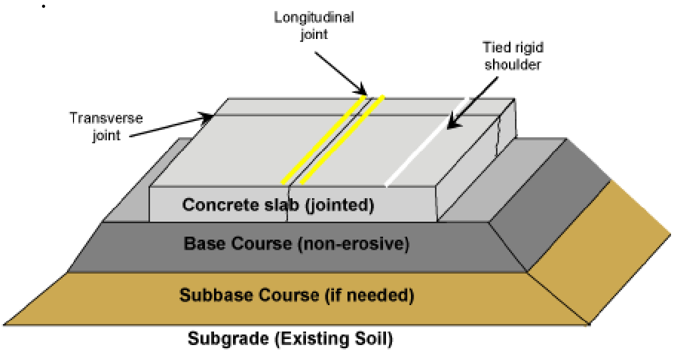

Fig.1 Materials and Functions of Pavement Component layers:

2. Objectives

The main objective of the present study is gravel soils with cement and their mixes can be used in road construction.
1.To determine the geotechnical characterization of gravel residue soils such as gradation, compaction, strength etc.,
2.To determine the compaction and strength characteristics of gravel residue soil- cement mixes at various percentages of cement.
3.To determine the suitability of stabilized gravel residue soils in road construction.
4.To determine the compaction characteristics w.r.t different methods of curing at various percentages of cement

2.1 SCOPE OF THE PRESENT STUDY:

In the present study local available gravel soils were collected from Visakhapatnam quarries of Andhra Pradesh. These soils were tested for geotechnical characteristics such as gradation, compaction and CBR characteristics. To study the performance of cement at various percentages cement were added to these soils and studied plasticity and strength characteristics. Based on CBR values of stabilized soils are checked as pavement materials in accordance with MORTH specifications.

3. Materials and Methodology

This chapter outlines the materials used and the methodology adopted for conducting laboratory tests in this investigation. The experiments were aimed at evaluating the properties of soil and their suitability for construction applications. The following sections describe the materials used and the laboratory procedures followed for various tests conducted as per Indian Standards (IS).

3.1 Materials Used

The primary materials used in this investigation are gravel residue and cement. These materials were selected for their properties and suitability for enhancing the strength of soil in road construction and pavement applications. Gravel residue, a by-product of quarrying operations, was used as a base material for soil stabilization, while cement was employed as a stabilizing agent to improve the strength and durability of the soil.

3.2 Laboratory Testing

To determine the properties of the soil and its suitability for construction purposes, a series of tests were conducted according to IS standards. The tests included:

1. Grain size analysis (IS 2720-part 4, 1985): This test helps classify the soil based on particle size distribution.
2.Specific Gravity (IS 2720-part V, 1985): This test determines the density of soil solids.
3. **Modified Proctor's compaction test (IS 2720 part VII, 1983): This test evaluates the optimal moisture content and maximum dry density of the soil.
4. California Bearing Ratio (CBR) (IS 2720-part 16, 1997): This test assesses the strength of the subgrade soil and its suitability for road construction.

3.2.2 Grain Size Analysis

Grain size analysis was conducted using a standard set of IS sieves. The soil sample was oven-dried and placed on the sieves, and the retained weights were recorded after shaking for 10-15 minutes. The fine fraction passing through the 75-micron sieve underwent hydrometer analysis. The results were used to calculate parameters such as D10, D30, D60, and the coefficients of uniformity and curvature, providing insights into soil gradation.

3.2.3 California Bearing Ratio (CBR)

The CBR test evaluates the penetration resistance of the soil to determine its subgrade strength. Soil samples were compacted at optimum moisture content and cured for different durations. A cylindrical plunger was used to apply pressure, and the loads for different penetration depths were recorded. CBR values were calculated based on the ratio of measured load to standard load, providing insights into the soil's bearing capacity.

Fig.2 CBR

3.2.4 Modified Proctor Test

The Modified Proctor test was conducted to determine the maximum dry density and optimum moisture content of the soil. A heavier rammer and higher compactive effort were used compared to the standard Proctor test. This method simulates field conditions with heavy rollers. The dry density values were plotted against moisture content to derive the compaction curve.

3.2.5 Specific Gravity Test

The specific gravity of the soil was determined using a pycnometer. This test helps assess the density of soil particles by comparing their weight to the weight of an equal volume of water. The specific gravity was calculated using the weights of the pycnometer with and without soil and water.

Gradation properties	
Gravel%	0
Sand%	62
fines%	38
Compaction Characteristics	
optimum moisture content (%)	12
Maximum dry density(g\cc)	2
Strength characteristics	
California bearing ratio(%)	8

TABLE: 1.Geotechnical Characteristics of Gravel Soil

Table.2 Physical properties of ordinary Portland cement of 53 grade cement

s.no	property	value
1	specific gravity	3.1
2	initial setting time (min)	95
3	final setting time(min)	240
4	Compressive strength(n\mm2)	
5	at 3daya	31
6	at7days	45

The materials used in this study include locally available gravel residue and cement. Gravel soils were sourced from quarries in VIJAYWADA Andhra Pradesh, and subjected to geotechnical testing to determine grain size distribution, compaction, and California Bearing Ratio (CBR) (IS: 2720, 1985). Cement, primarily Ordinary Portland Cement (OPC) of 53 grade, was added in varying percentages (1–15%) to improve soil properties (Bureau of Indian Standards, 1987). Grain size analysis was performed using IS sieves, and hydrometer analysis was conducted to classify soil particles smaller than 75 microns (IS 2720-Part 4, 1985). The samples were subjected to Modified Proctor tests to determine the optimum moisture content (OMC) and maximum dry density (MDD) as per IS 2720 Part 8 (1993). Compaction was carried out by compacting the soil-cement mixtures into five layers, each subjected to 25 blows with a 4.89 kg rammer

4.Results and Discussion

The results indicate a clear correlation between the percentage of cement added and the geotechnical properties of the gravel residue soils. The addition of cement significantly improved the OMC and MDD of the soils, with maximum values observed at 12-16% OMC and 2.12 g/cm³ MDD for cement proportions ranging from 1% to 15% (Satyanarayana et al., 2013). The results from Modified Proctor tests showed an increase in compaction with cement addition, leading to higher MDD and lower OMC values. This indicates that cement enhances the soil's load-bearing capacity by reducing the void spaces between soil particles (Omar, 2003).

The test results also demonstrated that adding cement stabilizes gravel residue soils, making them suitable for sub-base and base layers in road construction (Jain et al., 2010).

The CBR tests confirmed that cement-stabilized soils meet the strength requirements for road construction. Samples cured under moisture conditions exhibited higher CBR values compared to those cured in water alone. The highest CBR values (135%) were achieved with 15% cement after 3-day moisture curing and 4-day water curing, suggesting that this method is optimal for enhancing soil strength (Endalcokca, 2001).

The study confirms that cement stabilization effectively enhances the strength and compaction characteristics of gravel residue soils.

Further increases in cement content resulted in even higher CBR values. At 10% cement, the CBR value was 88% after 7 days of moisture curing, qualifying the mixture for use as base material for low-traffic roads. The highest CBR value of 135% was recorded for mixtures containing 15% cement after 3 days of moisture curing followed by 4 days of water curing. This curing method allowed for better hydration of the cement, leading to the formation of stronger cementitious bonds and, consequently, a more durable material (Endalcokca, 2001).

The results from the different curing methods suggest that moisture curing followed by water curing provides the most effective method for developing strength in cement-stabilized soils. Moisture curing allows the cement to absorb sufficient water for hydration, while subsequent water curing prevents the soil from drying out, ensuring continuous hydration and strength gain.

The study also compared the effectiveness of the three curing methods on the CBR values of the stabilized soils. Moisture curing alone produced CBR values ranging from 25% to 130% for cement contents between 4% and 15%. Water curing yielded similar results, with CBR values ranging from 22% to 126%. However, the combination of moisture curing and water curing produced significantly higher CBR values, ranging from 30% to 135% for cement contents between 4% and 15%.

This comparison highlights the importance of curing conditions in achieving optimal strength in cement-stabilized soils. The higher CBR values observed with combined curing can be attributed to the more efficient hydration process, which leads to better cementation of soil particles and greater strength development.

The improvement ratio, defined as the ratio of CBR values for stabilized soil to untreated soil, increased with higher cement contents. For mixtures containing 4% cement, the improvement ratio was 3.12, indicating a 212.5% increase in CBR value compared to untreated soil. For mixtures containing 15% cement, the improvement ratio reached 16.87, representing a 1587.5% increase in CBR value (Satyanarayana et al., 2013).

These results demonstrate that even small amounts of cement can significantly improve the strength and compaction characteristics of gravel soils, with the improvements becoming more pronounced at higher cement contents.

Table.3 CBR Value for 100% reside

CBR VALUE FOR 100% RESIDUE			
%OF	7DAYS MO	7DAYS	3DAYS MOISTURE
CEMENT	MOISTURE	WATER	CURING+4DAYS
ADDED	CURING	CURING	WATER CURING
0	8	8	8
1	10	10	11
2	13	12	16
3	18	16	23
4	25	22	30

5	33	30	39
6	42	39	47
7	52	48	57
8	63	58	68
9	75	70	78
10	80	81	89
11	96	91	100
12	105	100	110
13	112	110	119
14	120	118	128
15	130	126	135

The CBR test results are gravel cement soils at various percentages of cement shows the following observations values of gravel soil which are greater than 30, can be used as sub base material as per MORTH specifications. In the test results of gravel residue soil - cement mixers it is identified that high plastic gravel residue soils with 4% cement exhibited CBR values as25 In case of moisture curing condition it exhibits 44 which is lesser than moisture control sub-base course material in construct.

4.2 Method of curing.

Among natural soils gravel soils showed high bearing values and less deformation under different types of loading patterns. Gravel soils immediately under loading require high bearing values in terms of compressive strength and CBR values. In the present study gravel soil of well graded nature is tested for CBR values at various percentages of cement ie 1 to 15% and verified their CBR values w.r.t 7 Days Moisture curing. The test results are compared with MORTH specification requirements to suit as base course material in pavement.To know the CBR characteristics of gravel cement mix, various gradation i.e. 95-5 is mixed with different percentages of cement and CBR samples are prepared at their OMC& MDD values using Modified Proctor test. These samples are cured for 7 days in two methods of curing. In the first method of curing prepared CBR samples are kept in wet gunny bags for 7 days known as moist curing and in the second method of curing CBR samples are kept in water for 7 days known as water curing(soaking). After completion of required curing periods these sample are tested for CBR values as per IS-2720-part-16. The test results are shown.

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6. conclusion

Gravel soils are prominent construction material in road construction works. The present study of these graded gravel residue is stabilized with cement and tested for compaction, CBR characteristics. This gravel residue - cement mixes are prepared at (0-100) by adding various percentages of cement and tested for CBR characteristics at different curing periods. these stabilized graded gravel residue conclusions have drawn. cement mixes are compared and the followingGraded gravel residue - cement at (0-100) mixes have attained maximum dry densities in the range of 2.00 g/ce to 2.12g/ce and their corresponding OMC values in the range of 12%-15.7%.Mixes of gravel residue - cement at grade (0-100) of 3 days moisture curing +4 days water curing have attained maximum CBR value ie 135 at 15% of cement dosage. From 4% dosage of cement, these materials can be used as sub-base course materials. From 8% dosage of cement, these materials can be used as base course materials at low traffic. From 10% dosage of cement, these materials can be effectively used as base course materials at high traffic. Mixes of gravel residue cement at grade (0-100) of 7 days moisture curing have attained maximum CBR value i.e 130 at 15% of cement dosage. From 5% dosage of cement, these materials can be used as sub-base course materials. From 8% dosage of cement, these materials can be used as base course materials at low traffic. From 10% dosage of cement, these materials can be effectively used as base course materials at high traffic. Mixes of gravel residue cement at grade (0-100) of 7 days water curing have attained maximum CBR value i.e 126 at 15% of cement dosage. From 5% dosage of cement, these materials can be used as sub-base course materials. From 9% dosage of cement, these materials can be used as base course materials at low traffic. From 10% dosage of cement, these materials can be effectively used as base course materials at high traffic.

Improvement ratio and percentage of increase for gravel cement mixes at (0-100) grade at 7 days moisture curing in the range of 1.25 to 16.25% at 1 to 15% of cement dosage and percentage of increase in the range of 25 to 1525%.

Improvement ratio and percentage of increase for gravel cement mixes at (0-100) grade at 7 days water curing in the range of 1.25 to 15.75% at 1 to 15% of cement dosage and percentage of increase in the range of 25 to 1475%.

Improvement ratio and percentage of increase for gravel cement mixes at (0-100) grade at 3 days moisture curing + 4 days water curing in the range of 1.37 to 16.87% at 1 to 15% of cement dosage and percentage of increase in the range of 37.5 to 1587%.

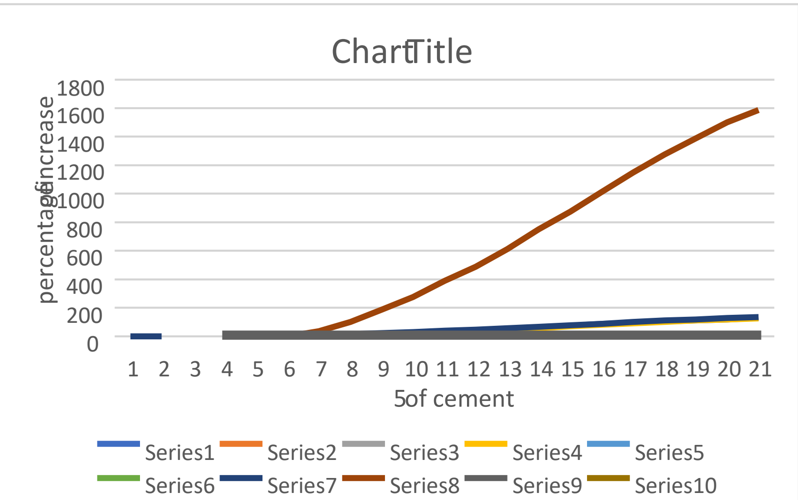
SCOPE OFFURTHER STUDY

In this study gravel (residue) soils is stabilized with cement and experiments were conducted for CBR values of various percentages of cement curing periods, it is also studied the use of cement as admixture with gravel (residue) soils and compared with cement.

			G(0-100)							
S.NO	% OF CEMENT ADDED	7 DAYS CURING		MOISTURE	7 DAYS WATER CURING			3 DAYS MOISTURE CURING + 4 DAYS WATER CURING		
		CBR value	% of increase	improvement ratio	CBR VALUE	%of increase	Improvement ratio	CBR value	% of increase	improvement ratio
1	0	8	0	1	8	0	0	8	0	1
2	1	10	25	1.25	10	25	1.25	11	37.5	1.375
3	2	13	62.5	1.62	12	50	1.5	16	100	2
4	3	18	125	2.25	16	100	2.0	23	187.5	2.875
5	4	25	212.5	3.12	22	175	2.75	30	275	3.75
6	5	33	312.5	4.12	30	275	3.75	39	387.5	4.875
7	6	42	425	5.25	39	387.5	4.87	47	487.5	5.875
8	7	52	552	6.5	48	500	6.0	57	612.5	7.125
9	8	63	687.5	7.8	58	625	7.25	68	750	8.5
10	9	75	837.5	9.37	70	775	8.75	78	875	9.75
11	10	88	900	10	81	912.5	10.12	89	1012	11.12
12	11	96	1100	12	91	1037.5	11.37	100	1150	12.5
13	12	105	1212	13.12	100	1150	12.5	110	1275	13.75
14	13	112	1300	14	110	1275	13.75	119	1387	14.87
15	14	120	1400	15	118	1375	14.47	128	1500	16
16	15	130	1525	16.25	126	1475	15.75	135	1587	16.87

Table.4 CBR comparrsion value

SHAPE * MERGEFORMAT



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