Laboratory Study of Full Depth Reclamation Mixes

Ambrish Pandey[1], R.K. Yadav[2]

[1]*M.E. Scholar, Geotechnical Engineering, Department of Civil Engineering, Jabalpur Engineering College (JEC), Jabalpur, India*

[2]*Associate Professor, Department of Civil Engineering, Jabalpur Engineering College (JEC), Jabalpur, India*

Abstract - ***The objective of this research was to develop a mix design for Full Depth Reclamation and to evaluate the performance of reclaimed pavement material. For this purpose an experimental program was undertaken to observe the effect of binder material and additives on reclaimed pavement material (RPM). The gradation of the reclaimed pavement material was done. For determining the MDD & OMC, the sample was subjected to Modified Proctor Compaction test as per IS 2720 (Part 8), the result of which, in turn, is used for determining the adequate amount of water for UCS test. Samples of mixes were prepared in the laboratory with RPM, water, cement (3%, 5%, and 7%) + Terrasil + Zycobond, cured for 7 days and were tested for Unconfined Compressive Strength {as per IRC: SP: 89: 2018 (Part II) & IS 4332 (Part V)-1970} and its result was used to select the optimum cement content for the reclaimed pavement material (which came out to be 5%). The existing crust pavement material stabilized with Terrasil + Zycobond and optimum cement content produced the 7 day & 28 day Unconfined Compressive Strength value which is well within the specified range of IRC (i.e. 4.5 to 7 MPa in 7 days). Using optimum cement content along with additive (Terrasil + Zycobond), Modified Proctor Compaction test was again carried out to observe its effect on MDD and OMC of FDR mix.***

Key Words: *Full depth reclamation, Reclaimed Asphalt Pavement material, Terrasil, Zycobond.*

I. INTRODUCTION

Full Depth Reclamation is a technique in which the deteriorated pavement, including the existing surface, base, and/or sub-base layers, is pulverized and mixed with a stabilizing agent. The stabilizing agent such as cementitious material, chemical stabilizers etc is added to enhance the strength of the reclaimed material. This mixture is then uniformly graded and compacted so that a solid and homogeneous layer is obtained. Full Depth Reclamation techniques involve recycle and reuse of existing pavement materials, minimizing the need for new aggregates and reducing the demand for new construction materials. This approach not only reduces waste generation but also conserves valuable natural resources. Additionally, FDR eliminates the necessity for extensive

excavation and disposal of old pavement, resulting in substantial cost savings and reduced environmental impact. Flexibility is one of the advantages of Full Depth Reclamation as it can be applied to various pavement types, including asphalt and rigid pavements making it a suitable solution for a wide range of road rehabilitation projects. FDR can be a solution for a variety of pavement distresses, thereby increasing the lifespan of the roadway and enhancing its overall performance.

Hence, Full Depth Reclamation is an innovative and sustainable approach to pavement rehabilitation that combines recycling, reclamation, and stabilization techniques. By utilizing existing pavement materials, FDR minimizes waste, reduces costs, and found to be environmental friendly. With its versatility and ability to improve pavement performance, Full Depth Reclamation has become an increasingly popular choice in modern road construction, offering long-lasting and sustainable infrastructure solutions.

Objectives of the Study

- To assess the gradation of the existing crust material and to prepare gradation envelope.
- To evaluate the compaction characteristics of untreated reclaimed pavement material with different percentages of water (i.e. 3%, 5%, and 7%).
- To assess the Maximum Dry Density and Optimum Moisture Content of untreated reclaimed pavement material, in order to establish a proper FDR mix for unconfined compressive strength.
- To determine the UCS value of reclaimed pavement material at various doses of cement (i.e. 3%, 5%, and 7%) + Terrasil + Zycobond stabilizer at MDD and its corresponding OMC.
- To find out the cement content (in %) from graphical analysis of UCS values vs. cement content so as to establish most economical combination of cement and stabilizer for Full Depth Reclamation mix.

II. LITERATURE REVIEW

Literature reviews on full-depth reclamation cover various aspects of the technique, including its effectiveness, environmental impact, design considerations, and case studies. Here are summaries of some key literature reviews on full-depth reclamation:

Nandan Patel et al. (2015) made their study on stabilization of sub-grade soil using Terrasil and found that the treated soil produced improved density values by reducing the void ratios. The addition of Terrasil to the soil resulted in the reduction of liquid limit, plastic limit and permeability of the soil and the UCS value of the soil also got improved.

D.E. Ewa et.al. (2016) presented a study which gave details about effects of Nano-Chemical on Geotechnical Properties of sub-grade. They examined that the geotechnical characteristics of sub-grade which was inorganic silty clay of high plasticity, was affected by Terrasil being used as a stabilizing agent.

Zhang et. al. (2018) reviewed "Full Depth Reclamation as a Sustainable Pavement Rehabilitation Technique". To enhance the performance of the recycled materials, it featured the use of additives including cement, lime, and foamed asphalt. In addition to energy efficiency and economic factors, this study concentrated on the advantages of full-depth reclamation for the environment and sustainability.

S R Rohith Mane et. al. (2018) concentrated on the effects of stabilizer (Zycobond & Terrasil) on strength of sub-grade on Black Cotton Soil and evaluated the effectiveness of the stabilizers. Their study focused just on the stabilizing process's mechanism. The primary goal of this investigation was to enhance the CBR characteristics of soft clayey soil and it has been found that the CBR value lowers as the dosage of Terrasil and Zycobond was increased.

Banerjee et al. (2019) in their study, "The Rehabilitation of Flexible Pavement Using Full-Depth Reclamation Techniques," which looked at various pulverization, additive selection and dosage, compaction methods, and curing techniques, they gave an overview of full-depth reclamation techniques used for repairing flexible pavements. The review also emphasizes how crucial it is to take into account site-specific factors for successful implementation.

Sandeep Yadav, Er. Ajay K Duggal et al. (2023) established their study on use of Nanotechnology Materials for Designing of Rural Roads. Zycobond and Terrasil was used as additives and found that its use helps in utilization of in-situ soils that may be weak and substantial reduction in aggregate consumption. The results of OMC, MDD, and Plasticity limit and UCS test was observed.

III. MATERIAL AND METHODOLOGY

A. Materials used

- Existing crust materials collected from from deteriorated carriageway near JNKVV Campus (23.2072° N, 79.9540° E), Adhartal, Jabalpur (M.P.).
- Ordinary Portland Cement (OPC) of grade 43.
- Terrasil and Zycobond stabilizer from Zydex Industries, Vadodara, Gujarat.

B. Testing Programme

- The gradation test of the in-situ pulverized materials was done as per IRC: SP: 89 AND MoRTH.
- Modified Proctor Compaction test on existing crust materials was carried out in accordance with IS 2720 (Part 8) with three different water content i.e. 3%, 5%, & 7% to get OMC and MDD.
- Based on the Modified Proctor Compaction test results, specimens was prepared at different proportion as shown in table below, for finding out unconfined compressive strength values for 7 days and 28 days, in accordance with IRC: SP: 89:2018 (Part II).

S.NO.	SAMPLE	CEMENT	TERRASIL	ZYCOBOND
1.	RPM	3%	2.86 gms	2.86 gms
2.	RPM	5%	2.86 gms	2.86 gms
3.	RPM	7%	2.86 gms	2.86 gms

Table 1: Sample preparation for Unconfined Compressive Strength (UCS) Test

- The optimum cement is determined corresponding to the target UCS value from the graph between UCS values and cement content (%).
- Using optimum cement content along with additive (Terrasil + Zycobond), Modified Proctor Compaction test was again carried out to observe its effect on MDD and OMC of FDR mix.

IV. RESULT AND DISCUSSION

A. Gradation Test of the Sample

The gradation of the pulverized materials was done keeping in mind that it should meet the criteria given in MoRTH specification.

Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Retained Cumulative (%)	Percentage Passing (%)	Specified limit of Percentage Passing as per IRC & MoRTH
53	0	0	0	100	100
37.5	3510	3510	10.03	89.97	95-100
19	3640	7150	20.43	79.57	45-100
9.5	5260	12410	35.46	64.54	35-100
4.75	2210	14620	41.77	58.23	25-100
0.6	5167	19787	56.53	43.47	8-65
0.3	2784	22571	64.49	35.51	5-40
0.075	8490	31061	88.75	11.25	0-10

Table 2: Combined Gradation of the existing crust material

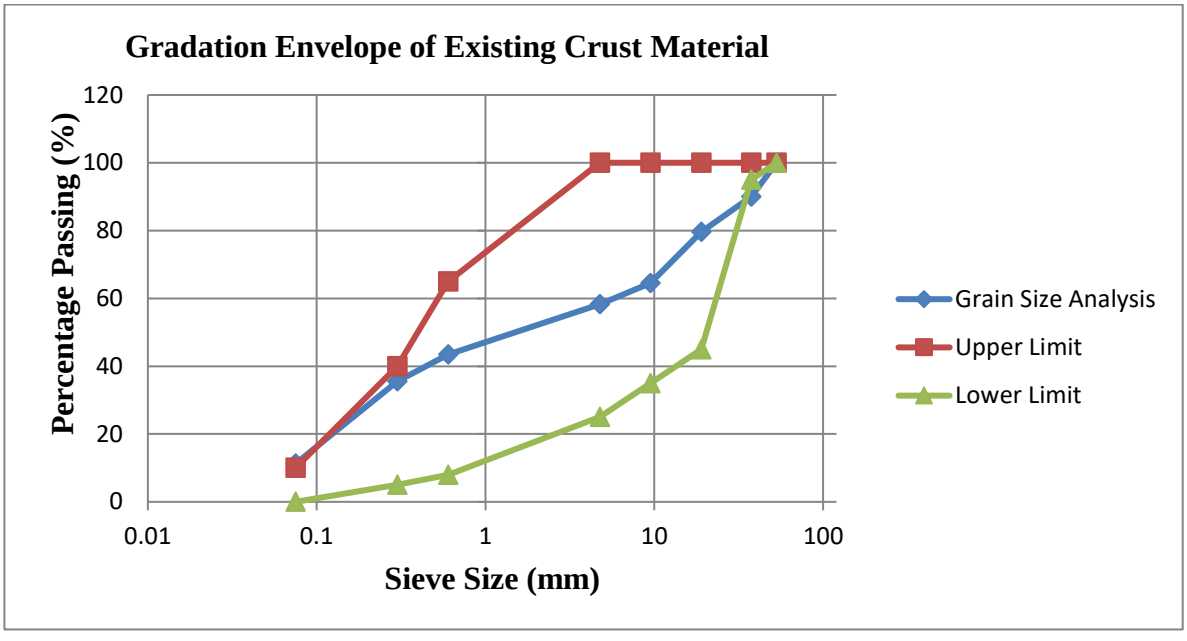

Figure 1: Gradation Envelope of Existing Crust Material

B. Modified Proctor Compaction Test on untreated existing crust material

Modified Proctor Compaction Test was performed on untreated existing crust material as per IS: 2720 (Part 8). The result obtained is represented in tabular form below. The Optimum Moisture Content obtained is 6.2 % and corresponding Maximum Dry Density is 2.062 gm/cc.

S.No.	Dry Density (gm/cc)	Moisture Content (%)
1.	1.97	5.56
2.	2.062	6.2
3.	1.969	8.88

Table 3: Compaction Characteristics of Untreated RPM

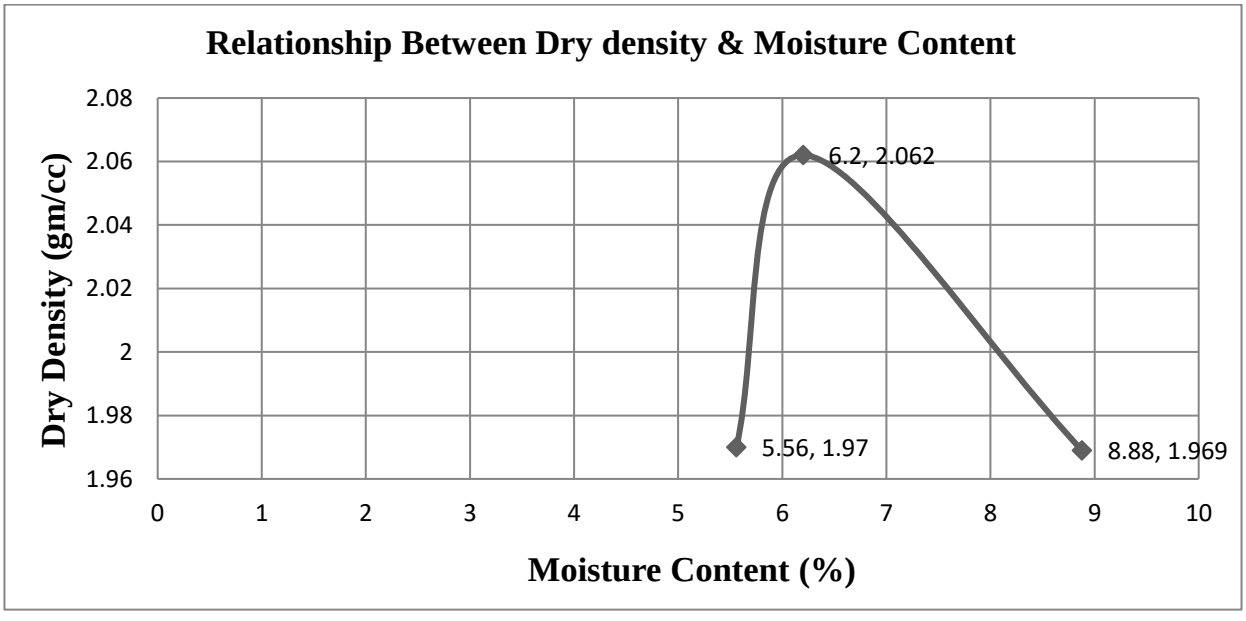

Figure 2: Compaction Curve of Existing Crust Material

C. Unconfined Compressive Strength (UCS) Test

The unconfined compressive strength test on treated sample was performed as per IRC: SP: 89 (Part II)-2018 and IS: 4332 (Part V)-1970. The average UCS value for stabilized existing crust material obtained after 7 days and 28 days is represented in tabular form below.

Specimen No.	Rap + Additives + Cement	Date of Casting	Cube Size (mm)	Plan Area (mm^2)	Date Of Testing	Maximum Load at Failure (kN)	UCS (MPa) 7 DAYS
1.	3% Cement	13-07-2023	150	22500	21-07-2023	55	2.44
2.	5% Cement	13-07-2023	150	22500	21-07-2023	105	4.66
3.	7% Cement	13-07-2023	150	22500	21-07-2023	130	5.77

Table 4: Determination of Cube Strength after 7 days

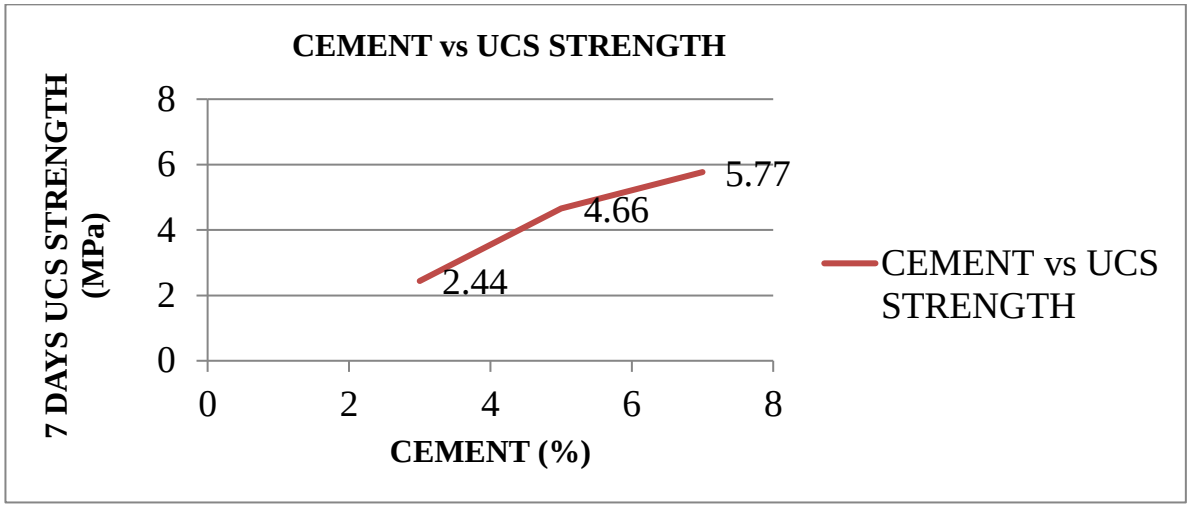

Figure 3: UCS after 7 days at varying cement content

Specimen No.	Rap + Additives + Cement	Date of Casting	Cube Size (mm)	Plan Area (mm^2)	Date Of Testing	Maximum Load at Failure (kN)	UCS (MPa) 28 DAYS
1.	3% Cement	13-07-2023	150	22500	11-08-2023	70	3.11
2.	5% Cement	13-07-2023	150	22500	11-08-2023	132	5.86
3.	7% Cement	13-07-2023	150	22500	11-08-2023	150	6.67

Table 5: Determination of Cube Strength after 28 days

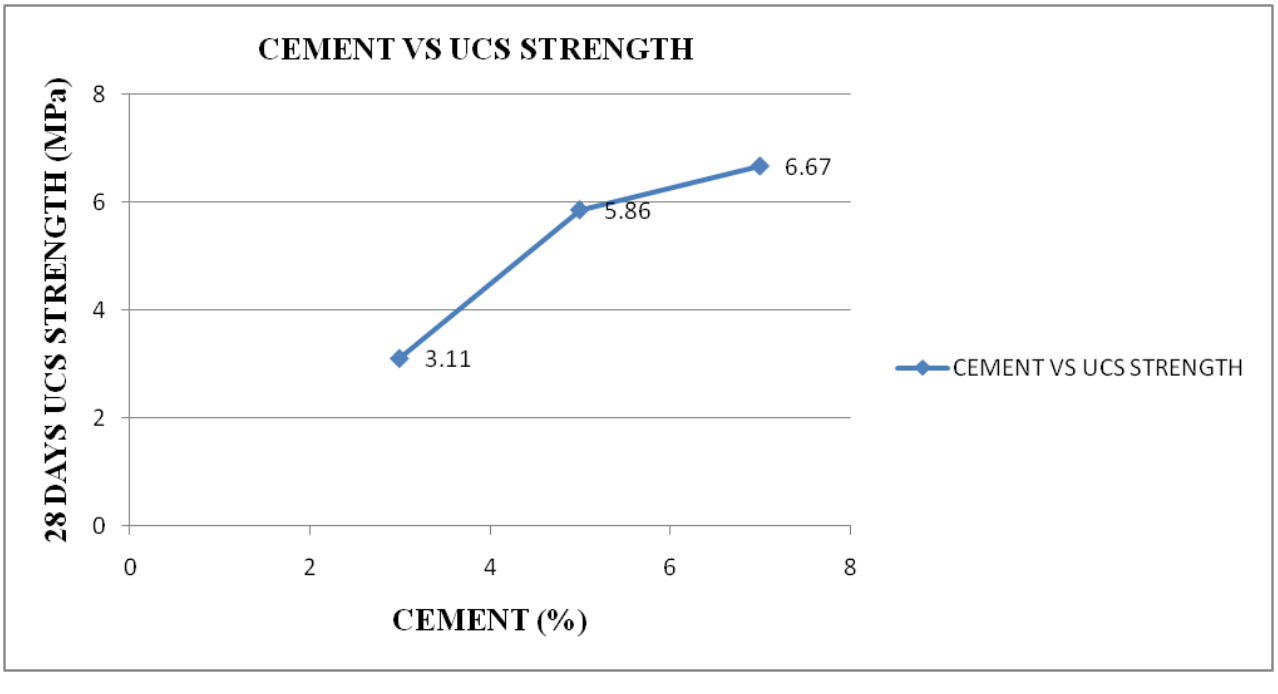

Figure 4: UCS after 28 days at varying cement content

D. Modified Proctor Compaction Test for FDR Mix

Using optimum cement content along with additive (Terrasil + Zycobond), Modified Proctor Compaction test was again carried out to observe its effect on MDD and OMC of FDR mix. The result obtained is shown below:

S.No.	Dry Density (gm/cc)	Moisture Content (%)
1.	1.988	4.2
2.	2.127	5.3
3.	2.015	6.51

Table 6: Compaction Characteristics of FDR mix

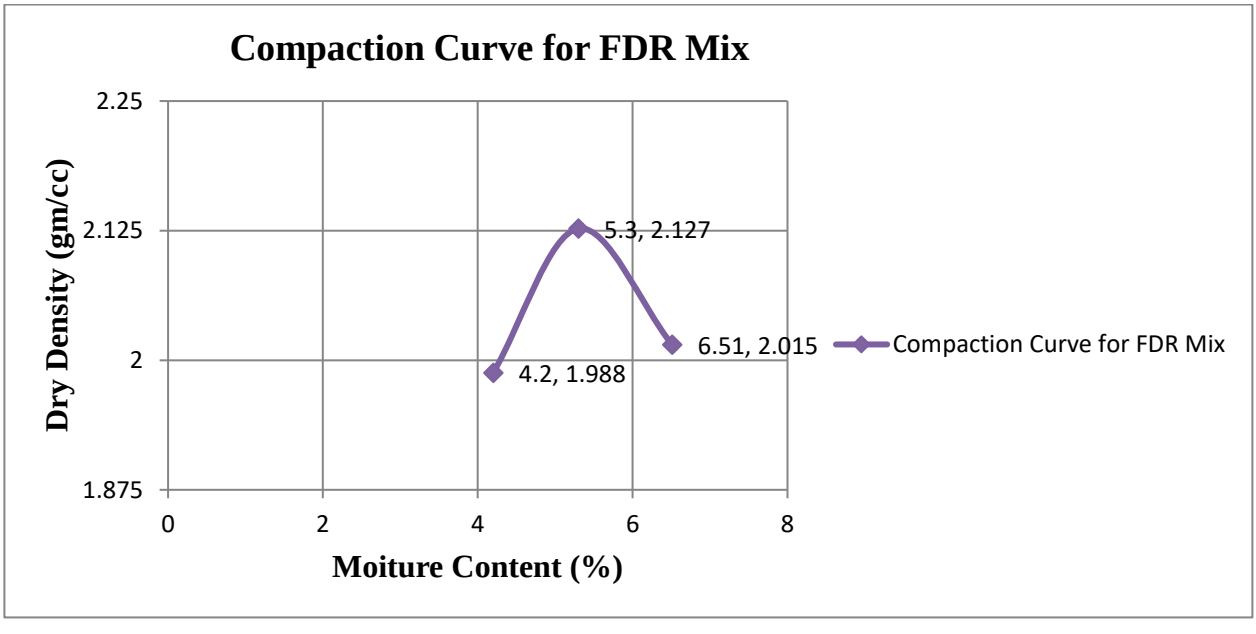

Figure 5: Compaction Curve for FDR mix

V. CONCLUSION

- Existing crust material collected from site is found to conform to the specified gradation limits as per IRC and MoRTH.
- Maximum dry density (MDD) for the untreated sample obtained is 2.062 gm/cc before falling to 1.969 gm/cc, and corresponding optimum moisture content (OMC) obtained at maximum dry density is 6.2 %.
- Modified Proctor Compaction test conducted on FDR mix with optimum cement content (5%) + Terrasil & Zycobond (1.37 % each by weight of cement) shows that the treated sample attained a Maximum dry density (MDD) of 2.127 gm/cc, and the corresponding optimum moisture content (OMC) obtained at maximum dry density is 5.3 %.

- The conclusion drawn is that, by using optimum cement content (5%) + Terrasil + Zycobond (0.7 % by weight of cement) resulted in 3.15 % increase Maximum Dry Density and reduction in Optimum Moisture Content 14.51%, as compared to untreated RPM, making the mix more compact and less susceptible to moisture.
- From the UCS values for the FDR mix, it is observed that the UCS value after 7 days of curing kept on increasing on increasing the cement content. On increasing 2% cement content (from 3% to 5%), there is 90.9% increase in strength of FDR mix whereas same amount of increase in percentage of cement (from 5% to 7%) resulted in only 23.82 % increase in strength of FDR mix.
- Similarly, from the 28 days UCS values it can be concluded that, on increasing 2% cement content (from 3% to 5%), there is 88.42% increase in strength of FDR mix whereas same amount of increase in percentage of cement (from 5% to 7%) resulted in only 13.82 % increase in strength of FDR mix.
- The concluding remark based on the laboratory studies is that, the existing crust materials collected from deteriorated carriageway near JNKVV Campus requires the optimum cement content of 5 % along with Terrasil & Zycobond (0.85kg/cum each) for the purpose of rehabilitation using Full Depth Reclamation.

REFERENCES

1. IS 2720-Part 4 “Methods of test for soils: Grain size analysis”. Published by Bureau of Indian standard, New Delhi, India.
2. IS 4332-Part 5 “Methods of test for stabilized soils: Determination of Unconfined Compressive Strength of Stabilized Soils”. Published by Bureau of Indian standard, New Delhi, India.
3. IRC: SP: 89-2010 “Guidelines for soil and granular material stabilization using cement lime and fly ash”. Published by Indian Roads Congress, New Delhi, India.
4. IRC: SP: 89-2018 “Guidelines for the Design of Stabilized Pavements”. Published by Indian Roads Congress, New Delhi, India.
5. Guide to Full-Depth Reclamation (FDR) for Rehabilitation of Low Volume Roads, PMGSY, Ministry of Rural Development, Government of India, 2019.
6. Design and construction guidelines for full depth reclamation of asphalt pavement, Geotechnical Engineering Manual GEM-27, Department of Transportation, New York, 2015.