INNOVATIVE METHODS FOR SOIL STABILIZATIONS: AN OVERVIEW

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Abstract - *From last two decades, we have seen significant infrastructure development in India, leading to rapid pavement construction, often on soft and unfavorable ground. This necessitates thicker pavement layers due to low California Bearing Ratio (CBR) values, resulting in the depletion of natural resources. Soil stabilization offers an economical solution by modifying existing soil properties to meet design requirements. Cement-based stabilization is common, but new commercial stabilizers like Zycobond and Terrasil have emerged. Evaluating their effectiveness compared to traditional cement is crucial. Various studies have investigated the use of additives like Silica fume, Recron 3-S fiber, and Terrasil to enhance soil strength and reduce pavement thickness, focusing on increasing CBR values for economic benefits. Expansive soils pose challenges, expanding during monsoon and shrinking in summer, necessitating soil stabilization. Utilizing industrial by-products like Ground Granulated Blast Furnace Slag (GGBS) and Rice Husk Ash (RHA), along with additives such as Terrasil and Zycobond, offers promising solutions for improving soil properties and sustainable construction practices.*

Key Words: Soil Stabilization, Terrasil, Zycobond, Lime, Expansive soil

1. INTRODUCTION

In civil engineering and building projects, soil stabilization is essential, particularly in regions with difficult soil composition. Conventional techniques such as using cement, lime, or asphalt are expensive and harmful to the environment. On the other hand, alternative, economical, and eco-friendly soil stabilization methods like Terrasil and Zycobond are gaining popularity. A soil stabilizer called Terrasil binds soil particles together to give them more strength and endurance. It works well on a variety of soil types, such as gravelly, clayey, and sandy soils. In contrast, Zycobond creates strong molecular bonds between soil particles, increasing the soil's resistance to load-bearing stresses and deformation. It works especially well in wide soils, high groundwater table regions, and harsh soil environments. Zycobond and Terrasil together can have synergistic effects on soil stability. In this paper, we will explore the principles behind the stabilization of soil using Terrasil and Zycobond, examining their mechanisms of action, benefits, applications, and potential challenges. Additionally, case studies and real-world examples will be presented to illustrate the effectiveness of these innovative soil stabilization solutions in various construction scenarios.

2. LITERATURE REVIEW

Dr. R. S. Kumar *et al.* (2018) studied the effect of stabilizers (Zycobond and Terrasil) on strength of subgrade on BC soil. In order to carry out experimental investigation, clayey soil was collected from the Karimnagar District, Telangana, India. The chemical stabilizers used in the study were Zycobond and Terrasil. Zycobond and Terrasil were commercially manufactured by Zydex Industries. These stabilizers were used to investigate their effectiveness in improving the strength of subgrade on BC soil. The tests performed on the soil for its classification included the California Bearing Ratio (CBR) test, which measures the strength of the soil, and the moisture-density curve test, which determines the compaction characteristics of the soil. Additionally, the specific gravity, free swell percentage, liquid limit, plastic limit, plasticity index, and particle size distribution curve tests were conducted to further classify the soil. The results of the experiment showed that the addition of Zycobond and Terrasil to the clayey soil led to improvements in the un-soaked CBR value in the range of 2.7% to 6.31%. Additionally, the soaked CBR value showed improvement in the range of 2.17% to 3.72% for a dosage of 0.6kg Terrasil and Zycobond. Test results pertaining to Clay stabilized with Terrasil and Zycobond are given in Table 1.

Table 1: Test Results Pertaining to Clay Stabilized with TS and ZB (R. S. Kumar et al., 2018)

Terrasil & Zycobond	CBR Test Results			
	Unsoaked	Soaked 7 days	Soaked 14 days	Soaked 28 days
0.6 kg	6.31	3.2	3.4	3.72
0.75 kg	6.13	2.31	2.57	2.83
1 kg	5.51	1.42	1.68	1.94

It was also observed that as the curing period increased, the ability to react the chemical with the soil increased, especially for the 0.6kg chemical dosage, and gradually decreased as the chemical dosage increased. These results indicate the effectiveness of Zycobond and Terrasil in improving the strength of the subgrade on BC soil.

Dr. B. L. Swami *et al.* (2016) experimentally examined the suitability of nano-chemical stabilizer in black cotton soil. The study was conducted on black cotton soil which was classified as intermediate compressible clay (CI) found in Jhalawar Kota region of India. The chemicals used as soil stabilizers in experimental investigations were Terrasil and Zycobond. To stabilize given soils with Terrasil, initially, it was mixed with water in the required proportion to prepare the Terrasil solution. Similarly, Terrasil was mixed first, and then Zycobond was added. For combinations that consisted of cement, initially, a predetermined quantity of cement was added to oven-dry soils, then the Terrasil solution was mixed with the soil-cement blend. The trail mix program for various soil tests are given in Table 2.

Table 2: Trial Mix Program for Various Soil Test (B. L. Swami et al., 2016)

S. No.	Treatment	Trial Mix (kg/m³) Chemical Added)		
		Dosage-1	Dosage-2	Dosage-3
1	Untreated	NA	NA	NA
2	T	0.5	0.75	1.5
3	T + Z	0.5 + 0.25	0.75 + 0.37	1.5 + 0.75
4	T + C	0.5 + 3%	0.75 + 3%	1.5 + 3%

All the test specimens were prepared using the static compaction method at the optimum moisture content determined by the standard Proctor test. Terrasil and Zycobond were found to improve soil engineering properties, including decreased plasticity index, optimal moisture content, and increased maximum dry density. The treatment also enhanced strength, with the California Bearing Ratio and Unconfined Compressive Strength values increasing significantly. Terrasil also reduced soil permeability, indicating enhanced water resistance. The optimal dosage rate for soil stabilization was Dosage-2, which included specific proportions of Terrasil and Zycobond. Combinations of Terrasil and Zycobond with cement showed improved mechanical characteristics.

D. S. Ray and P. Tripathi (2020) performed a test on Evaluation and Analysis of Soil Stabilization with Non - Conventional Additives. The researchers selected three stabilizers for the study: Silica fume, Recron 3-S fibre, and Terrasil. These materials were chosen based on their properties and availability. Soil samples were collected from Krishna Nagar, Lucknow, for use in the experiments. The test plan included Grain size distribution, Liquid limit test, Plastic limit test, Standard Proctor Test and California Bearing Ratio (CBR) Test. The soil was blended with various percentages of the stabilizers to determine the optimum percentage of each additive. CBR tests were conducted on samples with different stabilizer percentages. The tests were performed according to relevant IS (Indian Standard) codes and guidelines. CBR values were recorded for different combinations of stabilizers . Crust thickness of the pavement was calculated based on the CBR values obtained. Cost analysis was performed to evaluate the economic feasibility of using stabilizers. The study concluded that the combination of Silica fume, Recron 3-S fibre, and Terrasil (SF+RF+T) was the most effective and economical for soil stabilization. Recommendations for future research and areas for further investigation were provided.

T. Raghavendra *et al.* (2018) conducted a study that aimed to address the expansiveness and cracking issues in black cotton soil, which contain montmorillonite clay mineral, by stabilizing it with nano chemicals. The Soil sample collected was Black cotton soil near RGM College, Nandyal. The tests conducted were Specific gravity, liquid limit, plastic limit, sieve analysis, hydrometer analysis, compaction test, unconfined compressive strength test, direct shear test, CBR test, and free swell index test. The study used stabilizing agents like Cement (3% of soil amount), Terrasil, and Zycobond at different proportions (0.6 kg/m3, 0.8 kg/m3, 1 kg/m3, 1.2 kg/m3). Fig 1 shows Variation of Free Swell Index on Addition of Chemicals (Terrasil and Zycobond).

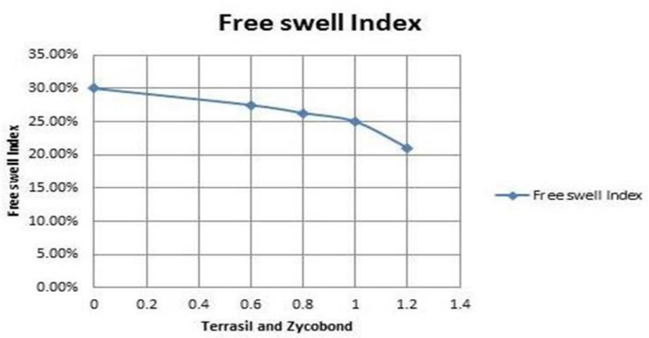

Fig 1: Variation of Free Swell Index on Addition of Terrasil and Zycobond (T. Raghavendra et al., 2018)

The addition of Terrasil and Zycobond resulted in a decrease in the free swell index of the soil. This indicates an improvement in soil behavior, particularly in terms of reducing volume changes associated with moisture variations. Table 3 shows the UCS of all samples varying with curing period.

Table 3. UCS of All Samples Varying with Curing Period

PROPERTY	UCS kg/cm² (7Days)	UCS kg/cm² (21 Days)	UCS kg/cm² (28Days)
SOIL+CEMENT	2.56	3.49	2.82
SOIL+CEMENT+0.6 kg/m³	2.77	3.57	2.64
SOIL+CEMENT+0.8 kg/m³	3.56	2.81	2.81
SOIL+CEMENT+1 kg/m³	3.9	2.8	2.55
SOIL+CEMENT+1.2 kg/m³	3.93	2.76	2.08

The study found that the unconfined compressive strength decreased as the dosage of nano chemicals (Terrasil and Zycobond) increased. This outcome contrasts with the expectation that adding stabilizing agents like cement and nano chemicals would enhance the strength of the soil. Given the unexpected decrease in unconfined compressive strength with the addition of nano chemicals, the study concluded that further investigation is necessary to understand the underlying reasons for this phenomenon.

M. P. Kumar *et al.* (2022) carried out the experimental investigation, treating expansive soil with varying proportions of Rice Husk Ash (RHA) and Zycobond. The type of soil used in the study was natural expansive soil which was extracted from the agricultural fields of turupulanka near Amalapuram, East Godavari district, Andhra Pradesh. The preliminary tests were performed on untreated soil and soil was classified as CH according to IS standards. The soil was further tested with RHA and Zycobond to carry out tests like UCS, CBR, Compaction test, Differential free swell and Atterberg's limit. The results of treating expansive soil with 15% RHA and 1.5% Zycobond were compared with untreated soil. The treated soil had shown a significant decrease in plasticity index, a decrease in optimal moisture content, and an increase in maximum dry density. The California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) values had also improved, with the CBR value increasing by 24.66% and the UCS value by 27.40% after 28 days of curing, respectively. Overall, it was concluded that soil stabilization with 15% RHA and 1.5% Zycobond considerably improved the strength characteristics of expansive clay beds.

Prof. N. B. Parmar *et al.* (2016) carried out Laboratory Investigation of Soil Stabilized using Terrasil. Black Cotton (BC) soil samples were collected for laboratory testing which represented the natural soil condition without any stabilization. The collected soil samples were prepared according to standard procedures for testing. Two types of stabilizers were selected for the study, Terrasil was chosen as a chemical stabilizer, while cement served as a traditional stabilizer for comparison purposes. For cement stabilization, dosages of 0.5% and 1% were used. For Terrasil stabilization, dosages of 0.02% and 0.04% were employed. Various laboratory tests were conducted to evaluate the engineering properties of the stabilized soil samples. Fig 2 shows soaked CBR value of natural soil. Fig 3 shows soaked CBR value of Soil + Cement. Fig 4 shows soaked CBR value of Soil + Terrasil. Fig 5 shows soaked CBR value of Soil + Cement + Terrasil.

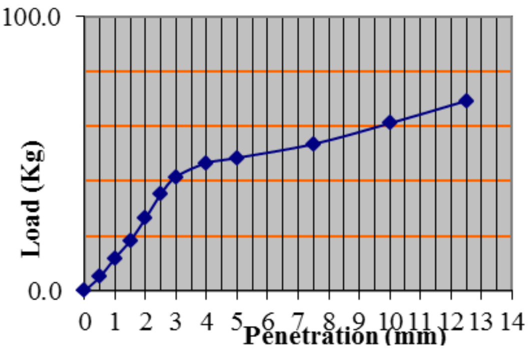

Fig. 2: Soaked CBR Value of Natural soil (N. B. Parmar *et al.*, 2016)

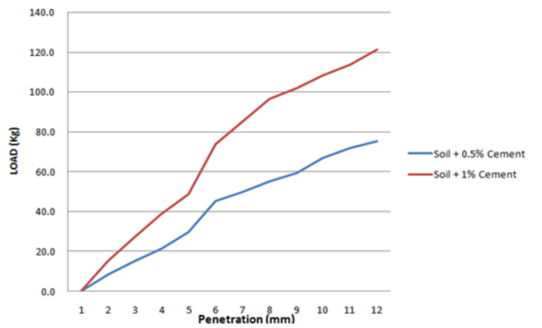

Fig. 3: Soaked CBR Value of Soil + Cement (N. B. Parmar et al., 2016)

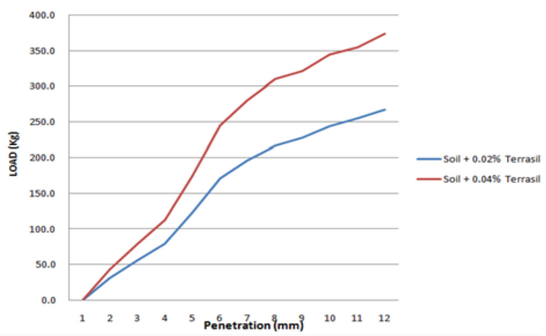

Fig. 4: Soaked CBR Value of Soil + Terrasil (N. B. Parmar et al., 2016)

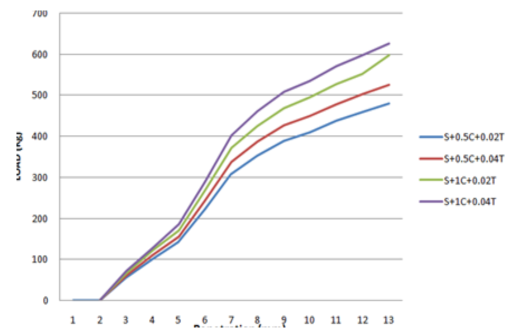

Fig. 5: Soaked CBR Value of Soil + Cement + Terrasil (N. B. Parmar *et al.*, 2016)

Addition of stabilizers like cement and Terrasil led to an increase in the California Bearing Ratio (CBR) values of the soil from 2.58 to 5.38 on addition of 1% cement, from 2.58 to 12.49 on addition of 0.02% Terrasil, and from 2.58 to 17.89 on addition of 0.04% Terrasil. This indicated that Terrasil had a notable effect on improving the soil's bearing capacity. The study found that a dosage of 0.04% Terrasil provided the best CBR values compared to other dosages tested. Stabilizing the soil with cement and Terrasil affected the Granular Sub Base (GSB) and Dense Bituminous Macadam (DBM) layers of the pavement, resulting in a reduction in their thickness. This reduction ranged from approximately 35-80%, indicating potential cost savings in pavement construction. The study concluded that Terrasil could effectively improve the strength of the subgrade soil, enhance load-carrying capacity, reduce permeability, erosion, and construction costs, making it a promising stabilizer for road construction.

K. Italiya *et al.* (2020) carried out an experimental investigation on improvement of soil properties using zycobond + terrasil with GGBS. The aim of the investigation was to determine the physical and chemical behaviour of unsterilized black cotton soil and evaluate the strength and the effectiveness of the stabilizers mixed with black cotton soil. The study focuses on black cotton soil, chosen for its expansive properties. Stabilizers like Ground Granulated Blast Furnace Slag (GGBS), Zycobond, and Terrasil are selected based on their properties and suitability for soil stabilization. Baseline soil properties of the black cotton soil are established through tests including Liquid limit test, Plastic limit test, Standard Proctor test for Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), California Bearing Ratio (CBR) test for soil strength assessment. Initially, these tests are performed on untreated black cotton soil (0% stabilizer content) to determine baseline values. Stabilizers (GGBS, Zycobond, and Terrasil) are added to the black cotton soil in varying percentages, ranging from 0% to 15% by dry weight. The percentage of stabilizers is gradually increased, and tests are repeated at each increment to observe the effects on soil properties. As the percentage of stabilizers increased, there was an increase in the CBR value for unsoaked conditions in both samples. Table 4 shows the result of P.L, L.L and P.I with 0% to 15% using GGBS, ZB and TS. Table 5 shows the result of OMC and MDD with 0% to 15% GGBS. Table 6 shows the result of Unsoaked CBR with 0% to 15% GGBS, ZB and TS. Table 7 shows the result of Soaked CBR with 0% to 15% GGBS, ZB and TS.

Table 4: Result of P.L, L.L and P.I with 0% to 15% using GGBS, ZB and TS (K. Italiya et al., 2020)

Sr. No.	GGBS (%)	Liquid limit	Plastic limit	Plasticity index
1	0%	59.79%	36.05%	23.74%
2	5%	57.05%	33.90%	23.15%
3	10%	54.80%	32.07%	22.73%
4	15%	51.01%	29.20%	20.81%

Table 5: Result of OMC and MDD with 0% to 15% GGBS (K. Italiya et al., 2020)

Sr. No.	GGBS (%)	OMC%	MDD
1	0%	17.8	1.95
2	5%	17.5	1.98
3	10%	17.1	2.01
4	15%	17.2	2.04

Table 6: Result of Unsoaked CBR with 0% to 15% GGBS, ZB and TS (K. Italiya et al., 2020)

Sr. No.	GGBS, ZB & TS (%)	2.5 mm Penetration (%)	5 mm Penetration (%)
1	0%	4.28	4.10
2	5%	4.84	4.42
3	10%	5.63	4.88
4	15%	4.96	5.01

Table 7: Result of Soaked CBR with 0% to 15% GGBS, ZB and TS (K. Italiya et al., 2020)

Sr. No.	GGBS, ZB & TS (%)	2.5 mm Penetration (%)	5mm Penetration (%)
1	0	2.84	2.69
2	5	3.41	3.10
3	10	3.93	3.57
4	15	3.80	3.60

This suggests an improvement in soil strength. However, when the stabilizer percentage reached 15%, the CBR values for both unsoaked and soaked conditions decreased in both samples. This indicates a decrease in soil strength at higher stabilizer percentages. With the increase in GGBS, Zycobond, and Terrasil percentages, the OMC decreased while the MDD increased. This suggests that the soil became denser and harder with higher percentages of stabilizers. The specific gravity of the soil increased with higher percentages of stabilizers, indicating increased soil density. The percentage of finer particles decreased with the increase in stabilizer percentages, which strengthened the soil. The study found that a 10% addition of GGBS, Zycobond, and Terrasil provided significant improvement in CBR values. Increasing stabilizer percentages led to improvements in soil properties, but excessively high percentages might lead to decreased soil strength.

N. A. Patel *et al.* (2015) carried out subgrade soil stabilization using chemical additives. In this experimental investigation, the soil under scrutiny was gathered near Nadiad, Gujarat, where the road was slated to pass, connecting Ahmedabad to Vadodara via NH8. In the study, two chemical additives were used as stabilizers: Terrasil and Zycobond and they were sourced from Zydex Industries, Vadodara. The study conducted several laboratory tests on the untreated soil to evaluate its physical and engineering properties according to Indian Standard (IS) specifications which included Liquid Limit Test, Plastic Limit Test, Free Swell Index Test and California Bearing Ratio (CBR) Test. From these preliminary tests the soil was classified as clayey soil. The soil was treated with the chemical stabilizers and underwent a series of laboratory tests similar to those performed on the untreated soil. The study found that the use of Terrasil and Zycobond stabilizers improved soil engineering properties, making it more suitable for road construction. The liquid limit decreased, indicating improved stability and reduced moisture-induced volume changes. The plastic limit also changed, affecting workability and compaction characteristics. The free swell index decreased, minimizing potential for soil expansion. The maximum dry density increased, indicating better compaction and load-bearing capacity. The California Bearing Ratio (CBR) value also improved, indicating greater resistance to penetration and improved load-bearing capacity. These findings support the effectiveness of chemical soil stabilization techniques in enhancing soil performance and ensuring long-term road infrastructure stability.

O. S. Aderinola and E. S. Nnochiri (2017) carried out the stabilization of Lateritic soil using Terrasil solution. In order to carry out this experimental investigation, six different lateritic samples were sourced from three borrow pits located within Akure, Nigeria. These samples were chosen to represent a variety of soil conditions and were collected in accordance with standard sampling procedures. Before stabilization, preliminary tests were conducted on the soil samples to determine their basic properties.

Table 8: Summary of Preliminary Results of Lateritic Soil Sample from Borrow Pit 1 (E. S. Nnochiri et al., 2017)

Property	Sample 1	Sample 2
Specific gravity	2.67	2.62
Natural Moisture Content (%)	23.9	14.4
% passing through Sieve No 200	21	31
Liquid Limit (%)	31.6	39.0
Plastic Limit (%)	25.8	29.4
Plastic Index (%)	5.8	9.6
Maximum Dry Density (Kg/m^3)	2198	1864
Optimum Moisture Content (%)	15.61	11.20
AASHTO Classification	A-1-b	A-2-4

Table 9: Summary of Preliminary Results of Lateritic Soil Sample from Borrow Pit 2 (E. S. Nnochiri et al., 2017)

Property	Sample 1	Sample 2
Specific gravity	2.67	2.53
Natural Moisture Content (%)	18.8	18.2
% passing through Sieve No 200	8.5	7.9
% passing through Sieve No 40	55	59
Liquid Limit (%)	31.0	35.3
Plastic Limit (%)	21.8	26.5
Plastic Index (%)	9.2	8.8
Maximum Dry Density (Kg/m^3)	1952	2139
Optimum Moisture Content (%)	10.4	13.8
AASHTO Classification	A-3	A-3

Table 10: Summary of Preliminary Result of Lateritic Soil Sample from Borrow Pit 3 (E. S. Nnochiri et al., 2017)

Property	Sample 1	Sample 2
Specific gravity	2.69	2.64
Natural Moisture Content (%)	20.8	21.4
% passing through Sieve No 200	47.0	53.4
Liquid Limit (%)	46.0	49.0

Plastic Limit (%)	16.3	20.3
Plasticity Index (%)	29.7	28.7
Maximum Dry Density (Kg/m³)	1267	1420
Optimum Moisture Content (%)	19.92	22.70
AASHTO Classification	A-7-6	A-7-6
Unsoaked CBR (%)	8.4	6.2

Tables 8 and 9 show that the soil samples from borrow pits 1 and 2 were good enough and therefore needed no stabilization, while soil samples 1 and 2 from borrow pit 3 are poor in strength, thus, necessitating the need for stabilization. Table 10 shows the summary of preliminary result of lateritic soil sample from borrow pit 3

Terrasil, a commercially available chemical stabilizer, was prepared by mixing it with distilled water in a specified ratio. Compaction tests were performed on the soil samples with varying percentages of Terrasil solution. The soil samples were compacted using standard compaction procedures, and the MDD and OMC were determined for each Terrasil content level.

Table 11: Compaction Tests Results for Borrow Pit 3, Sample 1 (E. S. Nnochiri et al., 2017)

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	MDD (Kg/m³)	OMC (%)
100	0	1267	19.92
98	2	1590	19.05
96	4	1668	17.50
94	6	1697	17.20
92	8	1707	17.00
90	10	1769	16.43
88	12	1785	15.97
86	14	1717	18.95
84	16	1608	19.24

Tables 11 and 12 show the relationship between the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) with variations of water – terrasil ratio contents. The result indicated that between 0% and 12% terrasil solution, the MDD values for both samples increased and the OMC reduced.

Table 12: Compaction Tests Results for Borrow Pit 3, Sample 2 (E. S. Nnochiri et al., 2017)

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	MDD (Kg/m³)	OMC (%)
100	0	1420	22.70
98	2	1559	20.22
96	4	1608	19.84
94	6	1678	19.06
92	8	1760	18.41
90	10	1793	18.10
88	12	1942	17.92
86	14	1766	19.35
84	16	1633	20.90

CBR tests were conducted to evaluate the strength characteristics of the stabilized soil samples. The unsoaked CBR values were determined for each soil sample with different percentages of Terrasil solution.

Table 13: CBR Tests Results for Borrow Pit 3, Sample 1 (E. S. Nnochiri et al., 2017)

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	Unsoaked CBR (%)
100	0	8.4
98	2	11.1
96	4	14.4
94	6	16.3
92	8	20.3
90	10	25.4
88	12	30.3
86	14	26.1
84	16	24.8

Table 14: CBR Tests Results for Borrow Pit 3, Sample 2 (E. S. Nnochiri et al., 2017)

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	Unsoaked CBR (%)
100	0	6.2
98	2	13.5
96	4	17.3
94	6	18.7

92	8	21.7
90	10	26.3
88	12	32.0
86	14	27.9
84	16	25.5

Tables 13 and 14 show that for the increasing addition of terrasil solution, CBR value rose from 8.4% to optimum value of 30.3%, for sample 1. For sample 2, the CBR rose from 6.2% to 32.0%.

From the study, it was concluded that Terrasil was found to reduce the plasticity indices of the soil, improving its strength properties. CBR values increased with the addition of Terrasil, indicating enhanced soil strength. Terrasil was considered an effective and economical stabilizing agent for poor soil.

M. V. Reddy *et al.* (2023) investigated the improvement of strength characteristics of expansive soils using terrasil, fly ash and cement. The study aimed to evaluate the impact of stabilizer mix proportions on soil properties, determine optimal additive combinations for improved strength, evaluate stabilizer effectiveness in supporting structures, and explore cost-effective soil stabilization methods in challenging soil conditions. Soil samples were obtained from Mahabub Nagar, and various stabilizers were chosen for the study. The materials included 43-grade Ordinary Portland Cement, terrasil from ZYDEX INDUSTRY, and fly ash obtained from a thermal power plant. Standard laboratory experiments were conducted to evaluate different mix proportions of stabilizers added to the soil. The experiments aimed to determine the optimal combination and proportion of additives that improved soil strength and other relevant properties. Three sets of additive mixtures were used in the experiment, varying in the proportions of cement, terrasil, and fly ash. Various soil properties, including specific gravity, grain size distribution, Atterberg limits, CBR values, and UCC strength, were measured and recorded for untreated soil and soil with different stabilizer mixtures. The experimental results were analyzed and discussed in terms of the effectiveness of different stabilizer combinations in improving soil properties. Conclusions were drawn based on the findings, highlighting the most effective mixtures and their economic viability.

3. CONCLUSIONS

From the above-mentioned published research work based on use of terrasil and zycobond as chemical stabilizers in geotechnical engineering to modify the stability of soil, following concluding remarks can be done:

- The findings suggest adding Terrasil and Zycobond to improve natural use, reducing liquid limit and plasticity, but increasing pavement load capacity, offering economic benefits for road development.
- Terrasil-treated soil can replace clay in landfill liners and capping materials due to their strong bonds, increased strength, and imperviousness.
- Study found that soil stabilization with GGBS, zycobond, and terrasil improved CBR values, but increased stabilizer percentages led to decreased optimal moisture content, increased dry density, and specific gravity.
- The CBR value of parent soil increases with the addition of Recron fiber, and Terrasil with varying percentages, with Silica fume increasing it more effectively at 15%. The best combination for soil stabilization is (SF+RF+T), which is most economical and reduces crust thickness with higher CBR values.
- Terrasil stabilized roads improve subgrade strength, reduce erosion, and enhance soil quality. Construction costs are lower than un-stabilized pavements, reducing 60-80%.
- CBR values increases with the increase in percentage of terrasil solution. Terrasil serve as a cheap stabilizing agent for poor soil.
- Soil type significantly influences performance, with nano-chemical soil stabilizers improving clay soil's properties. However, increased dosage rates result in stiffer soil and impermeability.
- Using RHA and Zycobond stabilized soil significantly improves the strength characteristics of expansive clay beds, reducing liquid limit, plastic limit, OMC, MDD, CBR, UCS, and strength over 28 days.

4. REFERENCE

[1] P. Tripathi, D. S. Ray (2020), "Evaluation and Analysis of Soil Stabilization with Some Non-Conventional Additives", *International Journal of Engineering Research & Technology (IJERT)*, Volume 09, Issue 07, pp. 2-7

[2] K. Italiyal, S. Chauhan, P. Lakhani, K. Umrao, V. Vaghela, S. Nayak (2020), "Improvement of Soil Properties using Zycobond+Terrasil with GGBS", *International Journal of Innovative Research in Technology*, Volume 07, Issue 01, pp. 1-3

[3] N. A. Patel, C. B. Mishra, D. K. Parmar, S. B. Gautam (2015), "Subgrade Soil Stabilization using Chemical Additives", *International Research Journal of Engineering and Technology (IRJET)*, Volume 02, Issue 04, pp. 3-5

[4] U. V. Mrudul, Prof. S. M. Damodariya, Prof. N. B. Parmar (2016), "Laboratory Investigation of Soil Stabilized

using Terrasil", *International Journal for Scientific Research & Development*, Volume 04, Issue 03, pp. 2-4

[5] O. S. Aderinola, E. S. Nnochiri (2017), "Stabilizing Lateritic Soil Using Terrasil Solution", *Journal of Civil Engineering*, Volume 12, Issue 01, pp. 4-8

[6] A. Thomas, R. K. Tripathi, "Soil Stabilisation Using Terrasil", *International Journal of earth sciences and engineering*, Volume 09, Issue 03

[7] S. Subbarayudu, S. Rozwana (2017), "Study of soil stabilization by using recron-3s, fly-ash & lime", *International Journal for Technological Research in Engineering*, Volume 04, Issue 09

[8] N. A. Patel, Prof. C. B. Mishra, Mr. V. V. Pancholi (2015), "Scientifically Surveying the Usage of Terrasil Chemical for Soil Stabilization", *International Journal of Research in Advent Technology*, Volume 03, Issue 6

[9] J. B. Ozaa, Dr. P. J. Gundaliya (2012), "Study of black cotton soil characteristics with cement waste dust and lime", *International Journal of Advanced Structures and Geotechnical Engineering*, Volume 01, Issue 02.

[10] R. Srivastava, P. Kushwaha, Dr. B. L. Swami (2016), "Suitability of Nano-Chemical Stabilizer in Black Cotton Soil", *Indian Geotechnical Conference*, pp. 1-7

[11] Dr. R. S. Kumar, S. R. Rohith, W. Paul, N. K. Swamy (2018), "A Study on the effect of Stabilizers (Zycobond & Terrasil) on Strength of Subgrade on BC Soil", *Indian Journal of Scientific Research*

[12] T. Raghavendra, B. Rohini, G. Divya, S. A. Sharooq, B. Kalyanbabu (2018), "Stabilization of Black Cotton Soil using Terrasil and Zycobond", *International Journal of Creative Research Thoughts*

[13] M. P. Kumar, R. D. Babu, K. Ramu (2022), "Use of Zycobond in Enhancing The Strength of Expansive Soil Modified With Rice Husk Ash (RHA)"

[14] G. Sneha, M. V. Reddy, M. Prashanth, S. Talari (2023), "Improvement of Strength Characteristics of Expansive Soils Using Terrasil, Fly Ash and Cement by Forming Zyco Bond"