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BEHAVIOR OF MODIFIED COASTAL SOIL USING COREX SLAG AND HYDRATED LIME: A LABORATORY INVESTIGATION

Mohammed ISLAMUDDIN FARAZ[1*], Rakesh KUMAR[1]

Abstract

The current study aims to determine the impact of lime and Corex slag on the strength, durability, and compaction properties of coastal soil from Gujarat, India. Twelve mixes of soil with Corex slag (0%, 10%, 20%, 30%, 40%, and 50%) and lime (2% and 4%) were added to determine their suitability as admixtures for stabilizing the subgrade layer. The Atterberg limits, free swelling index (FSI), compaction characteristics, California bearing ratio (CBR), durability, and unconfine compressive strength (UCS) of the stabilized soil with diffe ent curing days (0, 7, and 28) using standard Indian procedures were determined for the flexible pavement's subgrade layer. The test results show that Corex slag positively affe ts the maximum dry density (MDD), optimum moisture content (OMC), and soil plasticity. Furthermore, the findings demonstrated that the strength properties and durability were effe tively improved after stabilization. The strength of the stabilized coastal soil signifi antly improved as a result of the binding gel formation, according to examinations using scanning electron microscopy (SEM) and X-ray diff action (XRD).

Address

[1] Dept. of Civil Engineering, Sardar Vallabhbhai National Institute of Technology, Surat, India

[*] ***Corresponding author:*** ds19ce011@ced.svnit.ac.in, mifaraz019@gmail.com

Key words

- Corex Slag,
- Durability,
- Scanning Electron Microscopy,
- Soil Stabilization,
- Unconfined Compressive Strength,
- X-ray diffraction.

1 INTRODUCTION

The subgrade is the lowermost layer of a pavement and is compacted to sustain the load above it (Adlinge & Gupta, 2013). It has the highest plasticity index (PI) and lowest California Bearing Ratio (CBR) and Maximum Dry Density (MDD) of all the layers in the pavement. The subgrade characteristics directly influence the pavement's performance and condition and affect the pavement's service life (Luo et al., 2017). Due to rapid urbanization, some roads must be constructed on poor subgrade soils. Oceanic and coastal area reclamation and development are examples of pavement construction over coastal soils. Although coastal soil is widely known and commonly found on coastlines, it is generally considered difficult to work with, primarily when used as the foundation for various overhead construction projects. Due to the brittle nature of clayey soils in these regions, road construction work on coastal sites is traditionally tricky for pavement engineers. These clays have poor engineering properties such as low strength, low permeability, and high compressibility (Sumayya et al., 2016; Zainuddin et al., 2019). As a result, much research has been done to enhance the properties of weak subgrade soil using different techniques, including soil stabilization, which is a method frequently used to improve soil properties for different construction purposes. The process involves adding a stabilizer to the soil to enhance its strength and durability, reduce plasticity, and increase the load-bearing capacity (Islam et al., 2018; Singh & Sharma, 2014).

Enhancing soil properties generally involves the routine practice of stabilizing problematic soils using binders like lime or cement. Previous research has emphasized the effect of lime and cement on fine-grained soil and its percentage of clay (Bahar et al., 2004; Baker, 2000; Beetham et al., 2015; Rajasekaran & Narsimha Rao, 1997). Some researchers have also confirmed their effects on the plasticity and swelling characteristics of various soil types (Al-Mukhtar et al., 2010;

Al-Rawas & Goosen, 2006). The impact of the composition of clay minerals on lime stabilization has also been successfully studied (Bell, 1996; Cherian & Arnepalli, 2015). The long-term structural performance of lime-clay mixes has also been evaluated (Rogers et al., 1996). In order to stabilize such problematic soils, additional byproducts such as stone dust, fly ash, rice husk ash, basalt fiber, waste ceramic dust, etc., have also been used (Bagus et al., 2023; Brooks, 2009; Ghanbari et al., 2022; Islamuddin Faraz et al., 2019; Nguyen & Phan, 2021; Saber & Iravanian, 2022; Salahudeen & Ochepo, 2015; Turkane & Chouksey, 2022). Moreover, the benefits of the use of lime and other byproducts as stabilizers on coastal soil have also been widely presented by previous researchers (Al-Bared & Marto, 2019; Anggraini et al., 2016; Marto et al., 2016; Rajasekaran & Rao, 2001; Saleh et al., 2018; Zainuddin et al., 2019). The use of lime and Corex slag to stabilize clayey soil has also been highlighted (Gonawala et al., 2019). The various test findings indicate improvement in the geotechnical characteristics of the soils investigated. Still, the efficiency of the above-mentioned materials as stabilizers in actual practice is still unclear.

The Corex process is a recognized method used to create refined metal of a quality comparable to the metal produced in a blast furnace. It is a direct smelting reduction technique for producing metal at a cheaper cost with a negligible environmental impact. The conventional blast furnace process involves the use of coke sourced from coking coal in a totally different and energy-intensive coking facility. Blast furnaces have a severe effect on the environment as they emit large amounts of carbon dioxide, sulfur dioxide, and other gases (Li et al., 2016). However, the Corex process is comparatively newer and is more eco-friendly in nature. It is a two-stage process that does not require the use of coke. In the first stage, iron ore is reduced in a reduction shaft by using a gas that is derived from the partial burning of the coal in a melter-gasifier. The reduced iron is then converted to the molten iron in the melter-gasifier. Compared to the blast furnace process, the Corex process yields smaller amounts of carbon dioxide and other polluting compounds. In comparison to the blast furnace method for producing hot metal, the Corex process generates at least 15% less CO_2 (Satyendra, 2017). Besides, it can use lower-quality coal, which is cheaper and more available in the market as compared to coking coal. Thus, it has received significant attention in the steel industry. However, like any other reduction process, the Corex process also generates a primary by-product called Corex slag, with a production rate of 265 kg per ton of hot metal produced (Pan et al., 2019). Dumping is the most general practice adopted for slag disposal (Alanyali et al., 2006). But this is not an effective method as it requires large amounts of land and makes them unfit for other uses. Therefore, a suitable method should be investigated for the disposal of Corex slag.

The findings of the laboratory investigation on coastal soil taken from the Dumas coastal area near the Arbian Sea, Surat City, Gujarat, India, are presented in the paper. The purpose of the study is to determine the physical and geotechnical characteristics of coastal soil treated with lime and Corex slag. Lime is added to the Corex slag because it acts as an activator that improves the pozzolanic characteristics of the slag and can assist in a rapid gain of higher strength (Beetham et al., 2015; James & Pandian, 2016; Kang et al., 2019; Majhi & Nayak, 2020). The pozzolanic reaction continues until there is sufficient residual calcium in a highly alkaline environment; it can positively contribute to the stress-strain relationship of the stabilized soil (Little, 1987, 1999). The impact of the stabilization of the mixture is then experimentally investigated. This paper aims to promote and valorize Corex slag as a useful stabilizer of subgrade layer applications in flexible pavements.

2 MATERIALS AND METHOD

2.1 Coastal Soil

As per the soil classification criteria, the soil at isssue is classified as clay of intermediate plasticity (CI). It was sampled from the Dumas area of Surat in Gujarat, India. Table 1 displays the physical and geotechnical characteristics of the coastal soil.

Tab. 1 *Physical and geotechnical properties of coastal soil*

Soil Properties	Values	Test Procedure
[NMC] (%)	74%	IS:2720 (Part 2)
[Gs]	2.60	IS:2720 (Part 3)
Grain Size Analysis Gravel Sand Silt & Clay Soil Classification	 - 32% 68% Cl	IS:2720 (Part 4) IS:1498
Consistency limit [LL] (%) [LL] (%) [PI] (%)	 47.3 23.1 24.2	IS:2720 (Part 5)
[FSI] (%)	72.9	IS:2720 (Part 40)
[MDD] (g/cm3)	1.78	IS:2720 (Part 8)
[OMC] (%)	12.21	IS:2720 (Part 8)
[UCS] (KPa)	60.12	IS:2720 (Part 10)
[CBR] (%)	2.42	IS:2720 (Part 16)

2.2 Corex Slag

Corex slag contains a large amount of amorphous material, i.e., SiO_2, Al_2O_3,CaO, and other oxides, as shown in Table 2. For the current study, the Corex slag sample was collected from ESSAR Industries in the Hazira area of the city of Surat, Gujarat. The G_s of the slag was determined as 2.70

and was classified as poorly-graded sand (SP) as per the soil classification criteria. Furthermore, the slag was non-plastic (NP) in nature, having an FSI value of zero.

Tab. 2 *Chemical composition of Corex slag* (Gonawala et al., 2019)

Oxide	Composition (%)
SiO_2	3.91
Al_2O_3	55.31
Fe_2O_3	3.15
CaO	32.69
MgO	0.74
SO_3	1.01
Residue	1.06
LOI	3.4

2.3 Lime

Calcium hydroxide [Ca $(OH)_2$] was used as an activator for the Corex slag in the coastal soil. It was purchased in a powder form from a local vendor. It was sealed and stored inside airtight containers to protect the integrity of the content.

2.4 Method

In this study, soil stabilization was accomplished using Corex slag according to the dry weight of the soil; it was incorporated into the soil at 0, 10, 20, 30, 40, and 50%. A high percentage of Corex slag was added in order to comprehensively assess its performance over a broader range of concentrations. Lime was used as a slag activator for the initial activation of the pozzolanic reaction (Baghabra Al-Amoudi et al., 2022). It was mixed in at 2% and 4% by the dry weight of the mixture. The samples were created by carefully mixing the required amount of coastal soil with an appropriate amount of lime and Corex slag. Then, the mixture was hydrated with water.

The Atterberg limits, swelling, compaction, strength, and durability characteristics of the coastal soil-lime-Corex slag mixes were then investigated. Each experiment was carried out at room temperature. The UCS test was carried out for different curing days (0, 7, and 28). The durability test was performed as per the standard Indian procedure mentioned in IRC: SP:89-2010 by making two identical sets of cylindrical samples and curing one set of samples under normal conditions and the other first cured and then soaked for a total of fourteen days. After the curing, the samples were tested for their UCS values, and the ratio of the UCS soaked to the UCS-controlled samples was denoted by its R-value, indicating the loss in strength.

$$\text{R-value} = \frac{\text{UCS soaked}}{\text{UCS controlled}} \tag{1}$$

A micro-level investigation of the stabilized mix was performed on the optimum mix using scanning electron microscopy (SEM) and X-ray diffraction (XRD). The interpretation of the test data was influenced by prior research on soils around the globe (Gonawala et al., 2019; Harichane et al., 2011; Ma & Chen, 2021; Okagbue & Yakubu, 2000; Parvathy et al., 2022; Zainuddin et al., 2019).

To assess the environmental risks of the use of Corex slag in the soil stabilization, Corex slag and optimum mix samples were tested for the metals chromium, nickel, lead, copper, and zinc in accordance with the USEPA's Toxicity Characteristics Leaching Procedure (TCLP) (1311 of July 1992), as per IRC: SP: 89 (Part II)-2018. A summarized overview of the methodology adopted in the study is presented as a flowchart in Figure 1.

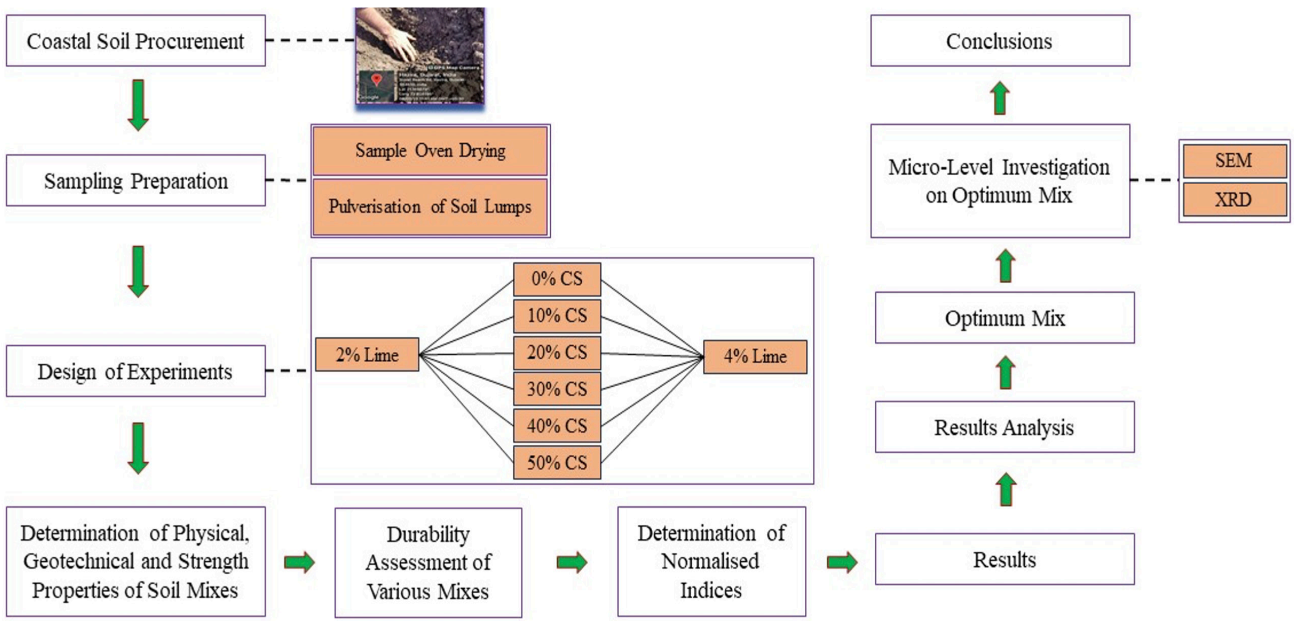

Fig. 1 *Methodology of the current study*

3 RESULTS AND DISCUSSION

The main findings that are significant to the topic of this paper, including the impact of the Corex slag and hydrated lime mixture treatment on the strength, durability, and compaction characteristics of the coastal soil, are presented below.

3.1 Impact of Additives on the Index Properties of Coastal Soil

Using the Casagrande plasticity chart with the Indian Standard soil classification system (ISSCS), the behavior of the soil after treatment can be assessed. The LL and PI for the treated soil decreased significantly, according to the findings of the Atterberg limit test. The addition of lime and Corex slag led to the production of flocs. The LL and PI drop as the floc size becomes larger as compared to the clay particle sizes, and less water is needed for the mixture to flow and behave like a liquid (Phanikumar & Ramanjaneya Raju, 2020). A continuous reduction in LL and PI with the increasing Corex slag content was observed. The incorporation of lime and Corex slag resulted in enhanced soil stability and reduced plasticity. The reduction was found to be higher for a 4% lime content, indicating better flocculation at a higher lime content. Figure 2 shows the impact of adding Corex slag on the PI of the coastal soil.

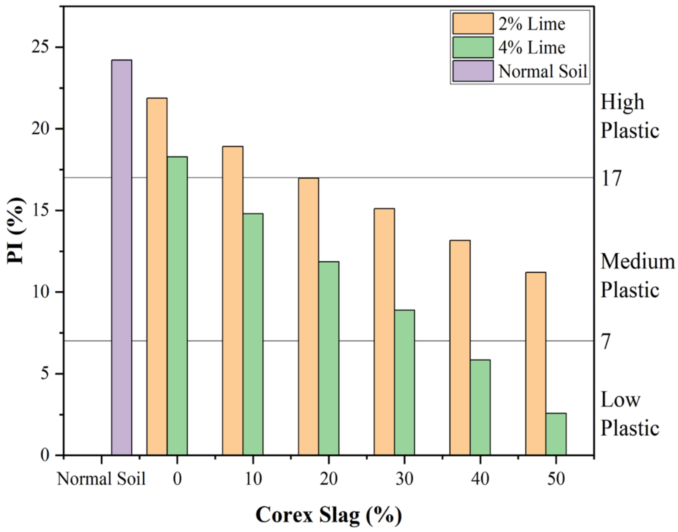

Fig. 2 *Impact of additives on PI of coastal soil*

PI is a reliable indication of the swelling potential (Saadeldin & Siddiqua, 2013). A strong correlation between the swelling potential and PI was developed by (Seed et al., 1963), indicating a direct relation between them. The inclusion of Corex slag and lime decreases the plasticity of the coastal soil considerably. This implies a decrease in the swelling potential. Also, FSI was used as a direct method to determine the swelling in the soil. In comparison to the indirect methods, this is more useful. Figure 3 displays the findings of the FSI of the soil samples following the treatment. A significant reduction in swelling was observed with an increase in the percentage of the Corex slag. However, a mix treatment, including 4% lime - 50% Corex slag, achieved a minimum amount of swelling. This behavior could be explained by a decrease in the percentage of the clay and the possibility that tiny clay particles filled the gaps between the Corex slag particles, thus limiting the swelling of the mixes. The reduction in FSI also indicates that the inclusion of Corex slag enhances the durability of the soil due to a reduction in its swelling and cracking potential. This can be particularly beneficial for coastal soils, where high water content and a saline environment can cause significant damage to the environment.

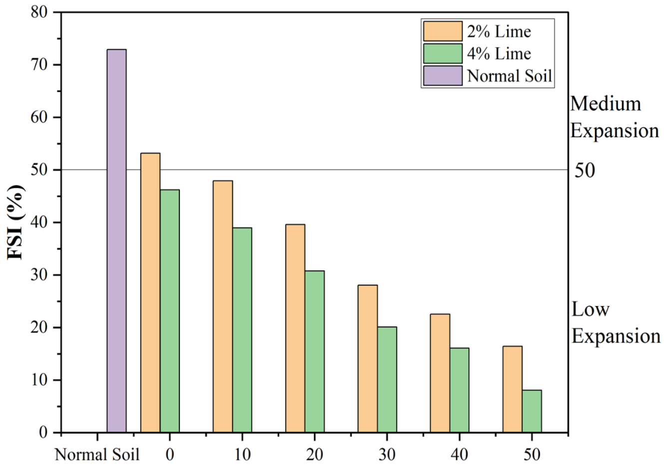

Fig. 3 *Impact of additives on FSI of coastal soil*

3.2 Impact of Additives on the Compaction Properties of Coastal Soil

A series of Proctor compaction tests were conducted on the lime and lime-Corex slag-treated soils to analyze the impact of additives on the compaction characterization and obtain the compacted dry unit weight for the unconfined compressive strength studies. Figure 4 illustrates how varying levels of the lime content (2% and 4%) and Corex slag concentration (0%, 10%, 20%, 30%, 40%, and 50%) affect the compaction characteristics of coastal soil. According to the findings, the unblended coastal soil had a lower MDD than the lime-coastal soil mixes at 2% and 4% lime levels. This is consistent with the results of previously published works (Athanasopoulou, 2014; Moayed et al., 2012). Also, as the Corex slag and lime were added, the MDD values of the resultant mixes steadily increased along with the rise in the Corex slag percentage. This is because Corex slag has a high specific gravity (Patel & Shahu, 2015). Moreover, because Corex slag absorbs less water, it decreases the diffused double layer and draws the particles nearer to one another; thus, the density rises (Abdalqadir et al., 2022). The improvement in the density indicates that the mixes are denser and more compact as compared to normal soil. At 2% and 4% lime percentages, the OMC of the lime-coastal soil mixes was more than that of the unblended coastal soil. This may be attributed to the ability of lime to absorb water (Phanikumar & Ramanjaneya Raju, 2020). However, the OMC values of the mixes begin to fall after adding Corex slag. This results from the addition of Corex slag reducing the water-holding ability of coastal soil (Al-Bared & Marto, 2019). This suggests that adding lime and Corex slag reduces the quantity of water needed for compaction, which can decrease the impact of construction operations on the environment.

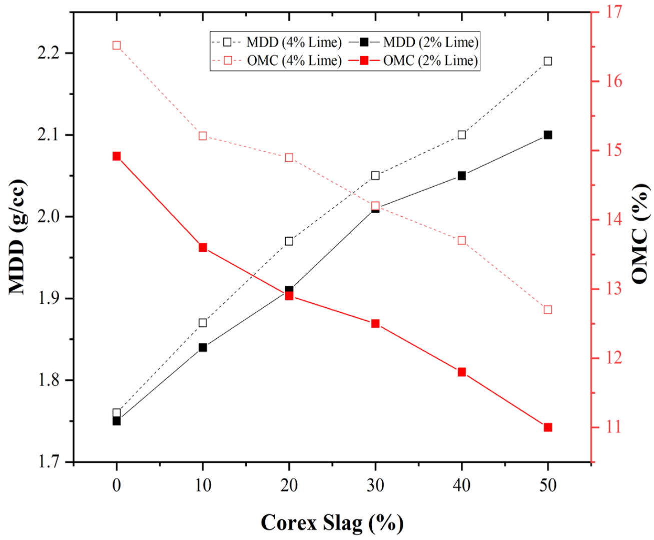

Fig. 4 *Impact of additives on MDD and OMC of coastal soil*

3.3 Impact of Additives on the UCS and CBR of Coastal Soil

The stress-strain characteristics of the cylindrical specimens were used to calculate the UCS values for the soil, soil-lime, and soil-Corex slag-lime mixes. For the specific percentage strain with the increasing Corex slag content, the samples needed to be subjected to an increasing amount of stress. Therefore, the peak stress also increased as the percentage of Corex slag increased, reaching its peak at 50% Corex slag and 4% lime. This might be because when lime and Corex slag are added to coastal soil, a denser and better flocculant structure is attained. Also, after seven days of curing, the samples achieved higher strength due to better cementation; curing the samples for 28 days led to even higher strength. However, the percent value increment after 28 days was comparatively less than after seven days of curing, illustrating that the rate of cementation decreases over time. This cementing effect results in an increase in soil strength and deformation resistance. Figures 5 (a) and 5 (b) show the changes in the UCS values of the different mixes with 2% and 4% lime, respectively.

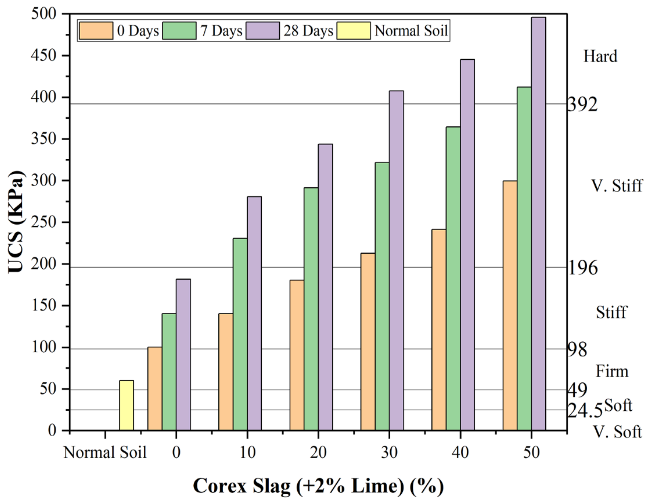

Fig. 5a *Impact of additives on UCS of coastal soil*

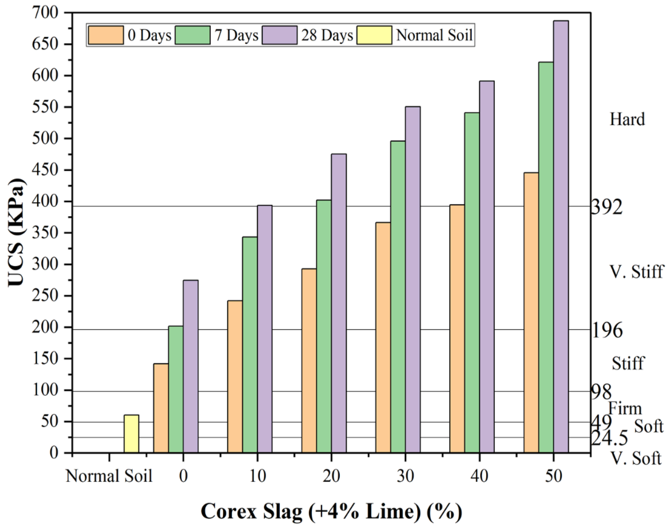

Fig. 5b *Impact of additives on UCS of coastal soil*

The difference in the soaked CBR for the mixes of Corex slag and lime at various mix percentages is illustrated in Figure 6. For both mixes, the bearing strength improved as the amount of Corex slag increased. The rise was more remarkable in mixes of 4% lime in the coastal soil and Corex slag. This is explained by the rise in cementation caused by adding 4% lime to the mixes. For example, at a 30% Corex slag content, the CBR improved from 2.42% to 26.70% and 41.20% when 2% and 4% lime were added to the mixes, respectively. This increase indicates that adding Corex slag and lime can enhance the load-bearing support of the soil, making it more suitable as a subgrade layer.

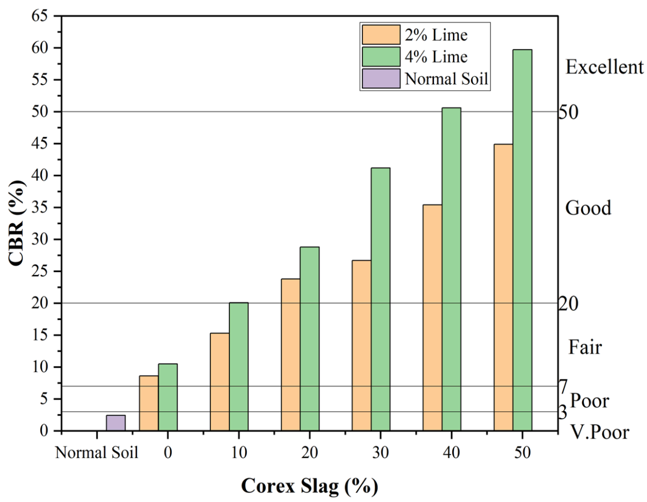

Fig. 6 *Impact of additives on the CBR of coastal soil*

3.4 Impact of Additives on the Durability of Coastal Soil

The results of the tests indicate a general pattern of improvement in durability as the Corex slag content is increased. Upon saturation, specimens containing 30% or more of Corex slag achieved an R-value of more than 0.8. However, specimens with a Corex slag of less than 30% could not sustain the minimum required value. The results indicate that Corex slag contributes to the pozzolanic reaction stabilizing the soil to resist deterioration. Based on the current findings, it can be stated that 30% Corex slag can be considered an adequate quantity that could provide the required rigidity to the soil when used with lime. The impact of Corex slag on durability is shown in Figure 7.

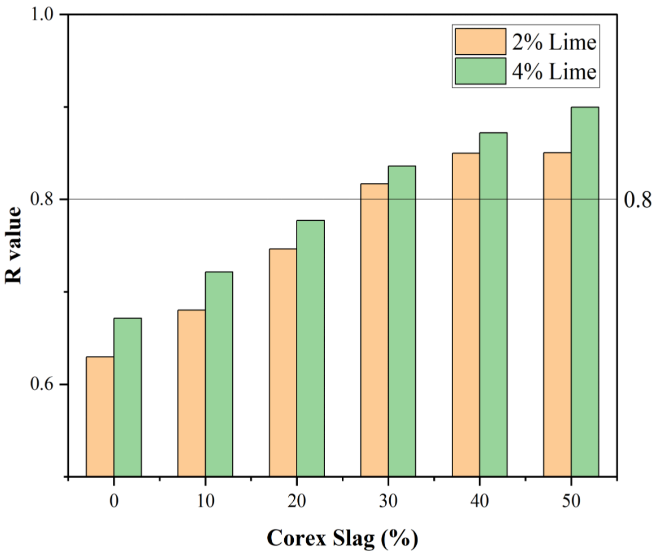

Fig. 7 *Impact of additives on the durability of coastal soil*

3.5 Normalizing of Test Results

In order to investigate the impact of admixtures on the different attributes of the virgin soil in more detail, the OMC, MDD, FSI, UCS, and CBR values were standardized in the following manner (Basack et al., 2021):

α_o = OMC of stabilized soil/OMC of untreated soil,

α_d = MDD of stabilized soil/MDD of untreated soil,

α_f = FSI of stabilized soil/ FSI of untreated soil,

α_{PI} = PI of stabilized soil/PI of untreated soil,

α_{ucs} = UCS of stabilized soil/UCS of untreated soil,

$\alpha_{ucs(7)}$ = UCS of stabilized soil cured for seven days/UCS of untreated soil,

$\alpha_{ucs(28)}$ = UCS of stabilized soil cured for 28 days/UCS of untreated soil,

α_{CBR} = CBR of stabilized soil/CBR of untreated soil

Correlation of normalized indices with the stabilizer's content and durability

The statistical indicators, root mean square error (RMSE), and the coefficient of determination (R^2) were used to demonstrate the effectiveness of the model. A perfect model should have zero RMSE, as well as an R^2 as a unity. This suggests that the more closely the R^2 approaches 1, the better the model fits the data, and the more closely the RMSE values approach 0, the less variable is the data around the regression line. The correlations were found using single and multiple regression analysis, and the results are tabulated below in Table 3.

Tab. 3 *Regression Equations for Various Indices*

Index	Type of regression	Lime content	Regression equation (x is Corex slag content)	R^2	RMSE
α_o	Linear	2%	y = -0.0057x + 1.333	0.971	0.0069
α_o	Linear	4%	y = -0.0059x + 1.1958	0.973	0.0068
α_d	Linear	2%	y = 0.0047x + 1.0065	0.987	0.0038
α_d	Linear	4%	y = 0.004x + 0.9992	0.980	0.0040
α_f	Linear	2%	y = -0.012x + 0.8363	0.987	0.0094
α_f	Linear	4%	y = -0.0119x + 0.7119	0.991	0.0079
α_{PI}	Linear	2%	y = -0.0086x + 0.8834	0.993	0.005
α_{PI}	Linear	4%	y = -0.0128x + 0.7482	0.999	0.0021
R-value	Multiple Linear	2%	$y = 9.6022\alpha_o + 4.8323\alpha_d + 2.5431\alpha_f -8.1710\alpha_{PI} -10.6165$	0.993	0.0029
R-value	Multiple Linear	4%	$y = 0.2513\alpha_o + 1.0398\alpha_d + 0.0322\alpha_f -0.1863\alpha_{PI} -0.579$	0.998	0.0005
α_{ucs}	Linear	2%	y = 0.0633x + 1.6734	0.991	0.0419
α_{ucs}	Linear	4%	y = 0.0974x + 2.7859	0.971	0.1177
$\alpha_{ucs(7)}$	Linear	2%	y = 0.0851x + 2.7521	0.968	0.1078
$\alpha_{ucs(7)}$	Linear	4%	y = 0.1323x + 3.9153	0.975	0.1461
$\alpha_{ucs(28)}$	Linear	2%	y = 0.1012x + 3.4444	0.976	0.1116
$\alpha_{ucs(28)}$	Linear	4%	y = 0.1298x + 4.9937	0.982	0.1233
α_{CBR}	Linear	2%	y = 0.2889x + 3.4317	0.986	0.2432
α_{CBR}	Linear	4%	y = 0.4131x + 4.1972	0.998	0.1280
R-value	Multiple Linear	2%	$y = -0.1026\alpha_{ucs} -0.1225\alpha_{ucs(7)} + 0.1559\alpha_{ucs(28)} + 0.0216\alpha_{CBR} + 0.5358$	0.995	0.0025
R-value	Multiple Linear	4%	$y = 0.1004\alpha_{ucs} -0.0671\alpha_{ucs(7)} + 0.0040\alpha_{ucs(28)} + 0.0080\alpha_{CBR} + 0.6081$	0.999	0.0009

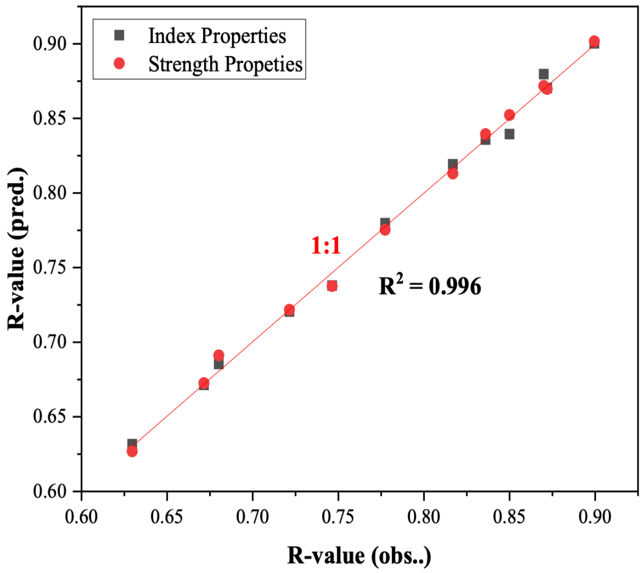

Fig. 8 *Observed vs. predicted R-values from regression models*

The statistical analysis results show that the R^2 is more than 0.95 for each case, indicating that the models can explain more than 95% of the data's variability. Additionally, the findings show that the corresponding RMSE values range from 0.2432 to 0.0005. The basic rule of thumb states that the model can reasonably predict the data reliably when the RMSE values are between 0.2 and 0.5. Also, R^2 values over 0.75 are highly recommended for their accuracy. The variation in the observed and predicted R-values has been shown in Figure 8. The R^2 value obtained is 0.996, indicating the predicted values to be extremely close to the observed values.

3.6 Micro-level Investigation (SEM and XRD)

Since Corex slag has a high concentration of aluminum oxide (Al_2O_3) and calcium oxide (CaO), it has unique qualities that make its application promising for soil stabilization. These oxides have a major role in enhancing the properties of coastal soil. The initial phases of this transformation process are shown in Figure 9.

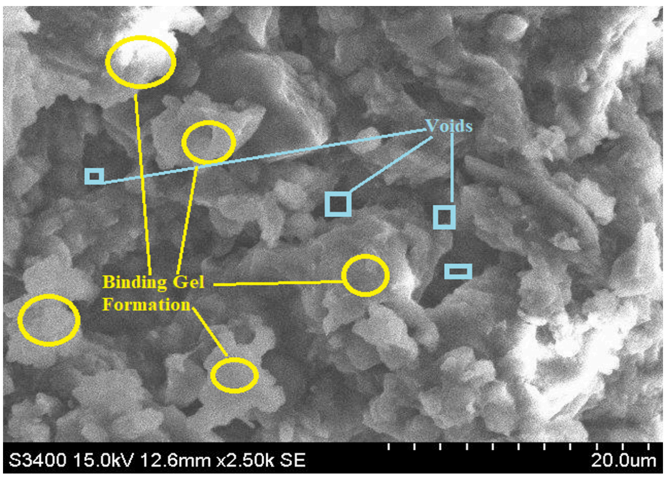

Fig. 9 *SEM image of stabilized soil sample after seven days*

It clearly illustrates the formation of the binding gel in the sample with 50% Corex slag and 4% lime after seven days of curing. The formation of the binding gel is a critical indicator that the pozzolanic process in the mixture is continuing and producing cementitious chemicals. The formation of these cementitious compounds is essential as it promotes the development of a dense matrix in the soil, which modifies its structural characteristics. The process of densification causes the soil to become noticeably more compact, resulting in the formation of a solid structure.

The diffraction peak values of the reaction products found in the coastal soil are depicted in Figure 10. These observations were made after adding 4% lime and 50% Corex slag to the soil, followed by a curing period of seven days. The JCPD database was used to collect the data from the X-ray diffraction examination, and the map overlay approach was used to evaluate and identify the reaction products that were detected. The diffraction peak values for the binding gel are highlighted. The main hydration products of the pozzolanic process are Calcium Silicate Hydrate (C-S-H) and Aluminium Modified Calcium Silicate Hydrate (C-A-S-H) gel (C Sekhar & Nayak, 2019; Ramesh & Manjunatha, 2020; S. Singh & Patel, 2023). The diffraction peaks of the C-S-H gel and C-A-S-H were found to differ significantly, as seen in the image below. Binding gel products are formed in soil treated with slag and lime after curing.

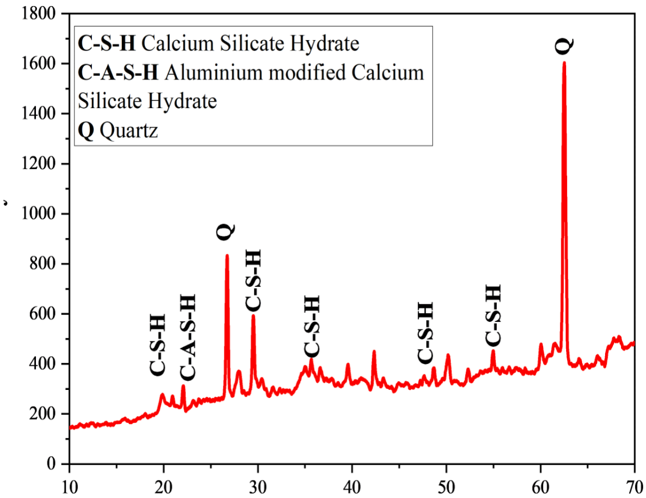

Fig. 10 *XRD pattern of the stabilized soil sample after seven days*

3.7 Leaching of Toxicity Characteristics

The S+50CS+4L and Corex slag were used for the test. After the samples were crushed, they were examined for leaching of the metals; we specifically looked for chromium, nickel, lead, copper, and zinc. First, the crushed material was combined with distilled water. A pH meter was used to evaluate the pH of the sample after 24 hours. Then, the sample was extracted in a closed vessel using the same solution for 18 ± 2 hours at 23 ± 2 °C and pH 2.88 ± 0.05 at 30 ± 2 rpm. The final leachates were filtered, treated, and examined for various metals using the Atomic Absorption Spectrometer (AAS) in accordance with APHA, 2005. The acceptable levels for chromium, nickel, lead, copper, and zinc are 0.05, 0.02, 0.01, 1.5, and 15 mg/l, respectively, as per the regulatory limits provided by IS: 10500-2012. All of the heavy metals in the samples tested were found to be below the threshold indicated in Table 4, indicating that the mixes posed no environmental risk.

Tab. 4 *Results for toxicity analysis*

Oxide	Corex Slag	S+50CS+4L
Chromium (mg/L)	0.00	0.00
Nickel (mg/L)	0.00	0.00
Lead (mg/L)	0.00	0.00
Copper (mg/L)	0.362	0.199
Zinc (mg/L)	8.098	5.872

4 CONCLUSIONS

Samples of coastal soil were mixed with different percentages of industrial waste (Corex slag) and commercially available lime (2% and 4%). For both the regular and stabilized soil samples, a number of attributes, including FSI, plasticity, compaction, and strength characteristics, were identified. The results obtained for the different properties were further normalized for better prediction of the results.

From the current study, the following conclusions can be drawn:

- With the rise in the percentage of Corex slag content, the PI of the coastal soil was reduced. Also, when compared to a lime content of 2%, the drop was more for the 4% lime, which results from the substitution of non-plastic Corex slag and lime replacing the coastal soil.
- The FSI value likewise dropped as the amount of lime and Corex slag increased. In comparison to the 2% lime content, a notable decrease at the 4% lime content was revealed. This is due to the replacement of the coastal soil with Corex slag, which has little swelling potential, and the binding of clayey particles due to the addition of lime.
- The laboratory compaction parameters were significantly affected by the percentage of lime and Corex slag. It significantly reduced the OMC and increased the MDD. The increment in density is attributed to the higher specific gravity of the Corex slag, and the lower moisture content value is because of the better cementing reaction due to an increase in the overall calcium oxide content in the mixes.
- An effective improvement in the strength characteristics was also achieved by using Corex slag and lime. With the addition of the Corex slag, the UCS and CBR significantly increased. The values continuously improved with the rise in the Corex slag content and were found to be more for the 4% lime. Also, with the increased number of curing days, a considerable increase in the UCS values was observed with more dominance in the increment for seven days than for 28 days. On the basis of the test results, the highest strength value was obtained for the S+50CS+4L mix, indicating it to be the optimal mix for the current set of mix proportions.
- The normalized indices suggest a noticeable improvement in the characteristics of the stabilized soil with both lime contents. However, the improvement in the strength parameter is comparatively greater compared to the other properties. Also, the strength and index property indices were found to have a significant effect on the durability of the soil mixes.
- A microstructural analysis was used to determine the effect of the addition of the lime and Corex slag. The microstructural changes observed through the SEM examinations have been used to explain the increase in the mix strength. With the help of the XRD analysis, the formation of bonding gels (C-A-H and C-A-S-H) was confirmed.
- The result of the leaching test carried out on the Corex slag and the optimum mix to determine the ecotoxicity of the waste products revealed that the leaching concentrations of the heavy metals in both the Corex slag and the mix are all within the regulatory limits.

Based on the current study, it can be concluded that Corex slag and lime can be successfully used for stabilization of coastal soil. Corex slag is not only useful for the improvement of soil strength but can be a viable alternative for its disposal (being an industrial waste). Also, using Corex slag for the stabilization of coastal soil promotes sustainable waste management practices, making waste material a valuable resource. This would also reduce the burden on landfills and contribute to the circular economy.

FUTURE SCOPE

The current study is limited to using Corex slag in combination with hydrated lime as a soil stabilizer. Based on the current results, a minimum of 30% Corex slag is required for significant improvement in the soil. Using such high percentages of any material for soil stabilization in most field applications may not be very economical. Therefore, further research can be performed using other hydraulic binders combined with Corex slag to achieve desirable results by incorporating lower percentages of Corex slag.

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