Global Scientific JOURNALS

GSJ: Volume 11, Issue 11 November 2023, Online: ISSN 2320-9186

www.globalscientificjournal.com

EFFECT OF CURING TIME ON THE STRENGTH DEVELOPMENT OF CEMENT-STABILIZED LATERITIC SOIL

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ABSTRACT

This study investigates the influence of curing time (T) on the strength evolution of cement-stabilized lateritic soil. Initial experiments were conducted to classify the untreated lateritic soil, followed by cement stabilization at varying levels of 0%, 2%, 4%, 6%, 8%, and 10% cement content (CC). Unconfined compressive strength (UCS) properties were determined using appropriate procedures after 3, 7, 14, 21, and 28 days of membrane curing. Analysis revealed the untreated lateritic soil as an A4 silty soil with a fine material content. Investigating the effect of cement content on UCS gain, a clear linear strength increase was observed for cement content up to 4%, beyond which strength gain became minimal and plateaued, declining at 10% cement addition. This indicates that the impact of cement on strength gain is significant up to around 8% cement content, beyond which diminishing returns are observed. The impact of curing duration on UCS gain indicated increasing strength from the 3rd to the 14th day of curing, followed by a reduction. Notably, interactions between modifiers and water, as well as between soil and water, significantly affected strength properties, with modifier-acid interactions exerting the least influence. This suggests that early-stage curing promotes more substantial strength gains compared to later stages. ANOVA analysis highlighted that curing duration's effect on strength increase exceeded that of percent cement addition, as evidenced by the p-values (1.12E-10 and 0.959639, respectively). A multiple regression model demonstrated a strong fit with an $R^2 = 0.766$. Hypothesis testing using a t-statistic at a 5% significance level yielded a computed t-value (0.000191) lower than the critical t-value ($t_{0.975,29} = 2.045$). Consequently, the null hypothesis was accepted, indicating no significant difference between experimental and predicted UCS values. This study provides insights into the dynamic relationship between curing time, cement content, and strength development in cement-stabilized lateritic soils, paving the way for optimizing stabilization procedures.

Keywords: Curing time, Strength development, Cement-stabilized, Lateritic soils, Experimental investigations, Untreated lateritic soil, Unconfined compressive strength (UCS), Membrane curing, Modifier-acid interaction, ANOVA analysis, Multiple regression model, Hypothesis testing, Significance, Optimize stabilization procedures.

1. INTRODUCTION

Soil stabilization is a critical facet of geotechnical engineering that has garnered significant attention for its capacity to enhance the mechanical attributes of weak soils. The manipulation of soil characteristics through the incorporation of stabilizing agents has enabled the construction of structurally sound foundations, embankments, retaining walls, and slopes. By bolstering the inherent deficiencies of natural soils, stabilization methods facilitate the development of resilient infrastructures capable of withstanding varying loads and environmental challenges (Netterberg et al., 1984; Sherwood, 1993; Maher et al., 2003).

The realm of soil stabilization has matured over time, drawing insights from diverse disciplines including soil mechanics, material science, and chemistry. A foundational element of this process is the comprehension of shear strength properties of soils, which govern their stability and load-bearing capacity. Shear strength tests are pivotal in the assessment of cohesion and angle of internal friction, parameters that dictate the behavior of soils under different stress conditions. The intricate interplay of valence forces, ionic forces, dipole forces, and molecular attraction underscores the complex nature of soil cohesion, which undergoes variations due to particle size, shape, and spacing (Netterberg & Green, 1984; Sherwood, 1993; Maher et al., 2003; Gidigasu, 1976).

Furthermore, the angle of internal friction, indicative of interlocking effects, underscores the importance of particle shape, grain-size distribution, and soil density. The cohesive properties of lateritic soils, contingent on parent materials and the degree of weathering, have found utility across multiple geotechnical applications. In agricultural contexts, they prove invaluable in fish pond construction, while in engineering, they serve roles in clay puddling, tile production, and mortar manufacturing, highlighting their versatility (Arora, 2011; Netterberg & Green, 1984; Sherwood, 1993).

Stabilization of soils constitutes an indispensable endeavor, necessitating thorough site feasibility studies to assess the suitability of subsoil for construction endeavors. The recognition that insitu conditions often fall short of meeting design specifications underscores the importance of soil modification through stabilization techniques. These techniques encompass mechanical and chemical approaches, both offering distinct avenues to enhance soil strength and durability. Mechanical stabilization includes methods like compaction and barrier incorporation, whereas chemical stabilization leverages the interaction between stabilizers, such as cementitious materials, and soil minerals (Sherwood, 1993; FM 5-410).

The category of chemical stabilizers comprises cement, lime, fly ash, and blast furnace slag, each conferring unique attributes to the stabilized soil matrix. Cement, the oldest binding agent, triggers a hydration process upon contact with water, culminating in augmented cohesion, diminished volume expansion, and heightened strength. Lime, in contrast, presents an economical alternative by augmenting soil strength through cation exchange capacity and pozzolanic reactions. Fly ash, a byproduct of coal-fired power generation, harbors latent hydraulic properties when activated, whereas blast furnace slag contributes to latent hydraulic reactions upon interaction with lime (Sherwood, 1993; Roger et al., 1993; Bhuvaneshwari et al., 2005).

Strength development in stabilized soil emerges as a composite result of various interacting factors. Organic matter, sulphates, sulphides, and compaction intricacies can hinder strength enhancement. Optimal moisture content, temperature considerations, and safeguards against freeze-thaw and dry-wet cycles are imperative. Moreover, the curing duration profoundly influences strength gain, with protracted curing periods fostering pozzolanic reactions and subsequent strengthening (Sherwood, 1993; Roger et al., 1993; Maher et al., 2003; Prasanna Kumar, 2011).

Drawing upon the intricate interplay of these multifaceted factors, this study aims to delve into the progression of strength in cement-stabilized soil across varying curing periods. Given the dynamic interactions between stabilizing agents, soil attributes, and environmental circumstances, a comprehensive exploration of the determinants of strength will contribute to an enriched understanding of soil stabilization methods and their application in geotechnical engineering.

2. METHODOLOGY

This section outlines the comprehensive methodology employed to systematically investigate the strength development of cement-stabilized lateritic soils, emphasizing the influence of curing time, cement content, and modifier-acid interaction. The experimental investigations were conducted following a structured approach to achieve the optimization of stabilization procedures.

2.1 Materials

1. Cement: The experimental study utilized Dangote Brand of Portland cement (R. 425, CB 4227), sourced in accordance with BS 12 (1996) standards. This cement type was selected for its suitability in the stabilization process.
2. Lateritic Soil*:* Undisturbed lateritic soil samples were sourced from a burrow pit in Choba. The soil was meticulously prepared to ensure accuracy in testing. A portion of the soil was modified using cement as the stabilizing agent, following prescribed procedures. The laterite underwent the following preparation steps:

i. The lateritic soil was sundried for 48 hours to achieve moisture-free samples.
ii. The dried soil was divided into two portions: one remained unmodified for classification, and the other was modified with cement as a stabilizer.

3. Water: Portable water with a pH value of approximately 6.9, devoid of dirt and organic matter, was utilized for experimental purposes.

2.2 Methods

1. Specific Gravity Test: The specific gravities of the natural soil and cement were determined using a density bottle/pycnometer method as outlined in BS 1377 (2016) standards. The procedure involved weighing the empty pycnometer bottle and stopper (m1), measuring the weight of soil and bottle with cover (m2), and subsequently measuring the weight of the bottle with water (m3) and the bottle with water and soil (m4). Specific gravities were calculated using the formula

$$\mathrm{Gs} = \frac{\mathrm{m_2 - m_1}}{\mathrm{(m_4 - m_1) - (m_3 - m_2)}} \qquad (2.1)$$

Where m_1, m_2, m_3, and m_4 are the weights of component.

2. Atterberg Limits Test $m_{2:}$ The liquid limit and plastic limit of untreated lateritic soil were determined according to ASTM D4318 (2017) to assess its plasticity characteristics. The liquid limit was established as the moisture content corresponding to 25 blows, while the plastic limit was determined using the crumble method. Plasticity index (PI) was calculated as the difference between liquid limit and plastic limit.
3. Liquid Limit: Liquid limit, the moisture content at which the soil starts flowing under its weight, was determined using Casagrande's method.
4. Plastic Limit: Plastic limit, the minimum water content at which soil crumbles when rolled into a thread, was determined through rolling and crumbling experiments.
5. Hydrometer Test: The particle size distribution of untreated lateritic soil was determined using the sedimentation analysis (hydrometer test) following ASTM D7928 (2021) standards. The procedure involved wet sieving, soaking, and drying of the soil sample, followed by sedimentation analysis to obtain particle gradation.
6. Standard Proctor Compaction Test: Standard Proctor compaction tests were conducted on air-dried lateritic soil samples according to BS 1377 (2016). Bulk density (ρ) and dry density (ρd) were calculated using appropriate equations.
7. Oxide Composition Analysis: The oxide composition of the lateritic soil was determined in a physio-chemical laboratory within the Port Harcourt Metropolis.

2.3 Experimental Procedures

1. Batching, Mixing, Curing, and Compaction: Batching of modified soil samples was conducted by weight using manual mixing. Compaction tests were performed on the samples at optimum moisture content, cured using the membrane curing procedure in the laboratory.
2. Unconfined Compressive Strength Test: Unconfined compressive strength (UCS) tests were conducted in accordance with BS 1924: part 2: 1990. Samples were subjected to axial loading, and readings of force and deformation were recorded. The stress applied and the equivalent area were calculated to determine the unconfined compressive strength.
3. Unconfined Compressive Strength (UCS) Gain: The gain in UCS of cement-stabilized lateritic soil due to different curing periods was calculated using the formula;

$$\Delta UCS = \frac{UCS_{cf} - UCS_{ci}}{UCS_{ci}} X\, 100 \qquad (2.2)$$

Where; ΔUCS = increase or change in UCS of cement stabilized soil

UCS_{cf} = UCS of stabilized soil at end curing period

UCS_{ci} = UCS of stabilized soil at initial curing period

3. RESULTS AND DISCUSSION

This chapter presents in details the results of experimental investigation in the forms of tables and figures where necessary. Concrete discussions on the effects of the curing time on the strength development of cement stabilized lateritic soil was also done.

1. Unconfined Compressive Strength (UCS) of Cement Stabilized Lateritic Soil Results

Table 2.1 presents the results of the UCS of lateritic soil stabilized using cement additive at different curing period. Stabilized lateritic soil was produced using the optimum moisture content (OMC) as derived from the compaction test of untreated lateritic soil. This is further represented pictorially in Figure 2.1.

Table 2.1. Unconfined Compressive Strength Result of cement stabilized soil

Curing period / % cement	3	7	14	21	28
0	95.28	119.09	173.56	200.16	211.34
2	175.93	243.24	371.17	434.36	465.65
4	252.55	378.59	597.96	713.66	771.33
6	299.48	460.69	735.78	883.93	955.58
8	342.82	527.74	848.65	1020.71	1103.92
10	308.94	451.41	669.43	781.68	829.46

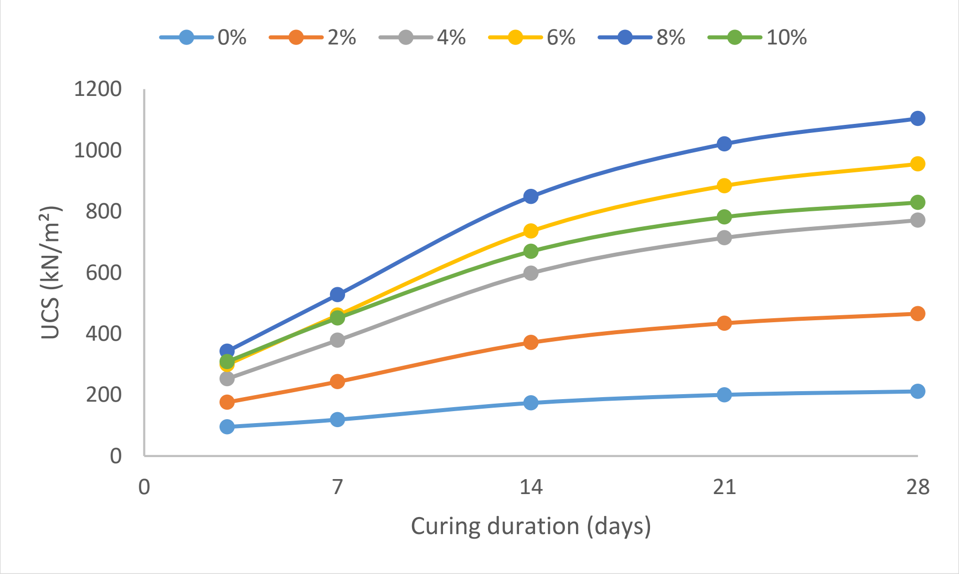


Figure 2.1: UCS Vs Curing duration of Cement stabilized lateritic soil

In the investigation of the impact of cement additive on the strength enhancement of cement-stabilized lateritic soil, a noteworthy trend emerged. As the percentage of added cement increased up to 8%, the unconfined compressive strength (UCS) of the cement-stabilized lateritic soil exhibited a consistent rise. However, beyond this threshold, a decrease in the strength gain was observed with a cement content of 10%. This trend highlights the significance of the cement content in influencing the strength development of the stabilized soil.

For cement contents within the range of 0-4%, the relationship between cement content and strength gain was linear and evident. The strength enhancement was substantial and progressively increased with higher cement proportions. This initial linear behavior can be attributed to the chemical reaction between cement and water, resulting in hydration and improved mechanical properties. This finding aligns with the findings of Kasama et al. (2007), which demonstrated that cement addition to expansive soil increased its strength due to enhanced interaction between cement and soil particles through hydration.

Upon surpassing the 4% cement content, the incremental effect on strength gain started diminishing, approaching a point of saturation. This behavior implies that the relationship between cement content and strength gain becomes more complex beyond this threshold, possibly due to intricate hydration processes that become less pronounced. The subsequent decrease in strength gain at 10% cement content suggests that there is an optimal cement dosage for achieving the highest strength enhancement.

2. UCS gain of Cement Stabilized Lateritic Soil Results

Table 2.2 presents the UCS gain of cement stabilized lateritic soil at different curing period. These values were obtained with the aid of Equation (2.2)

Table 2.2. UCS gain Result of cement stabilized soil

Curing period % cement	3-7	7-14	14-21	21-28
0	24.990	45.739	15.326	5.586
2	38.260	52.594	17.025	7.204
4	49.907	57.944	19.349	8.081
6	53.830	59.713	20.135	8.106
8	53.941	60.808	20.275	8.152
10	46.116	48.298	16.768	6.112

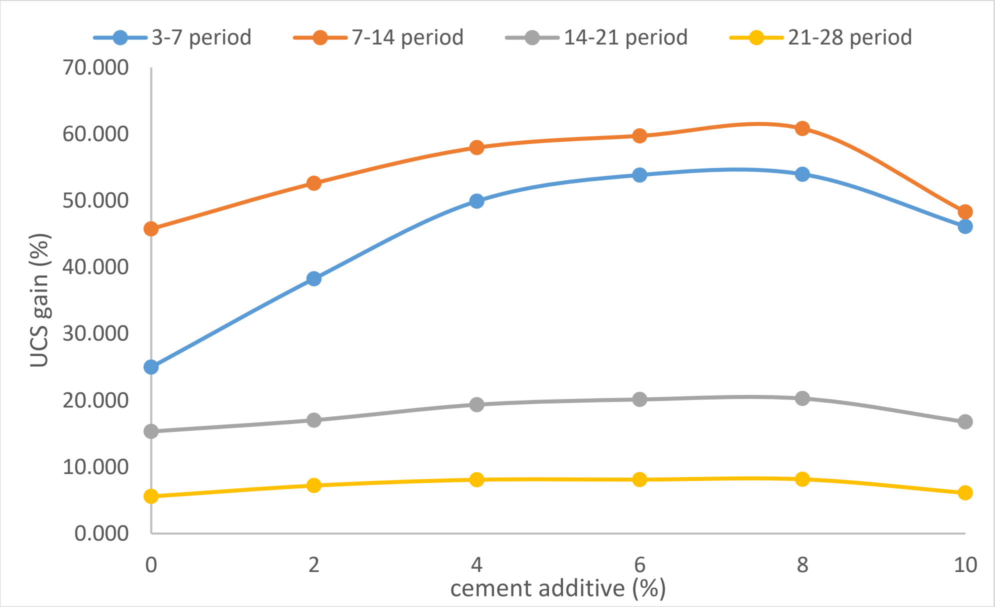


Figure 2.2. UCS Gain Vs % Cement Addition

Figure 2.2 illustrates the impact of cement additive on the unconfined compressive strength (UCS) gain of cement-stabilized lateritic soil. The graphical representation in Figure 2.2 and the corresponding data in Table 2.2 reveal a significant trend regarding the UCS gain as the percentage of cement addition varies.

The findings indicate that the UCS gain of cement-stabilized lateritic soil displays a clear pattern with respect to cement content. When the cement content is increased up to 8%, the UCS gain shows a noticeable increase. However, a diminishing trend is observed after reaching 8% cement content, leading to a decline in strength gain at a 10% cement addition.

For cement additions within the range of 0-4%, the increase in strength gain follows a perfectly linear progression. This outcome underscores the direct correlation between cement content and strength enhancement. Notably, once the cement content exceeds 4%, the rate of strength gain starts to decrease, ultimately reaching a relatively constant value until it declines at a 10% cement addition.

Further analysis of the curing duration also provides insights into the UCS gain. Within the 3-7 days curing period, the strength gain consistently increases from 24.99% (0% cement) to 53.83% (6% cement), accounting for a remarkable 115.41% increase. Similarly, for the 7-14 days curing period, the strength gain rises from 45.739% (0% cement) to 59.713% (6% cement), indicating a 30.55% increase. The subsequent curing periods (14-21 days and 21-28 days) also exhibit notable strength gain increases.

It is worth noting that the effect of cement on strength gain becomes most pronounced between 6% and 8% cement addition. For example, the increase in strength gain during this interval is minimal, with a gain of just 0.21% (3-7 days curing), 1.83% (7-14 days curing), 0.70% (14-21 days curing), and 0.57% (21-28 days curing). This observation highlights that the influence of cement on strength enhancement is most prominent up to around 8% cement content, after which the effect diminishes.

Bar chart showing the relationship between curing duration and UCS gain for the different percent cement addition is presented in Figure 2.3

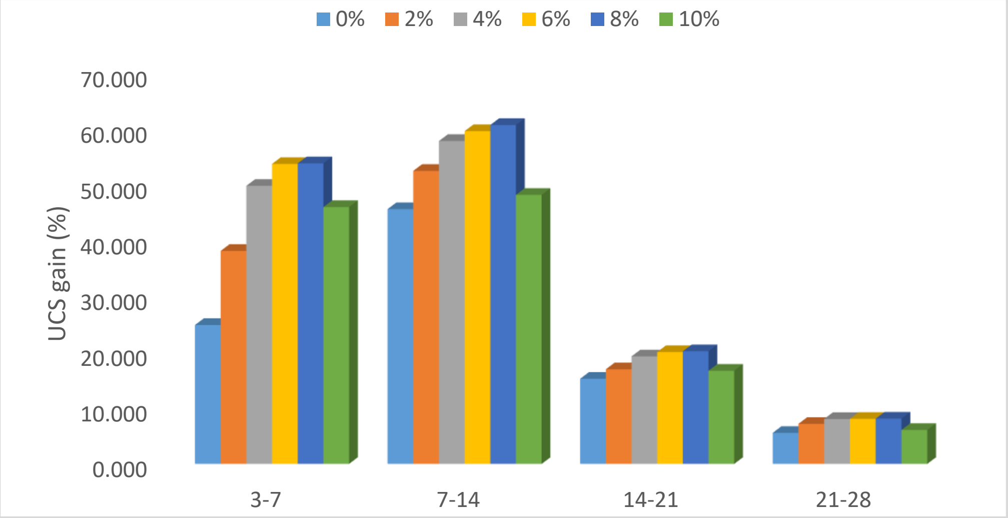


Figure 2.3: Bar charts of UCS Gain (%) Against Curing Period

A bar chart, depicted in Figure 2.3, illustrates the connection between curing duration and unconfined compressive strength (UCS) gain for various percentages of cement addition. Figure 2.3 visually conveys that the strength gain within the curing duration experiences a pattern: an increase from the 3rd day of curing to the 14th day, followed by a subsequent reduction.

For 0% Cement Content:

- Between the 3rd and 7th day of curing, UCS exhibited a gain of 24.99%.
- A notable strength gain of 45.739% occurred during the 7-14 day curing period.
- Between the 14th and 21st day of curing, the strength gain reduced to 15.33%, further decreasing to 5.59% between the 21st and 28th day of curing.

For 2% Cement Content:

- Similarly, at 2% cement addition, there was an increase of 38.26% in strength from the 3rd to 7th day of curing.
- The strength gain further increased to 52.59% between the 7-14 day curing period.
- However, a decline of 17.03% in strength gain was observed between the 21st and 28th day of curing.

For 4% Cement Content:

- At 4% cement addition, the strength gain increased by 49.907% between the 3rd and 7th day of curing.
- A similar strength gain of 52.59% was observed during the 7-14 day curing period.
- Yet, akin to the previous scenarios, the strength gain dropped by 17.03% between the 21st and 28th day of curing, reaching 7.204%.

Similar patterns were also evident for other cement addition percentages, including 6%, 8%, and 10%.

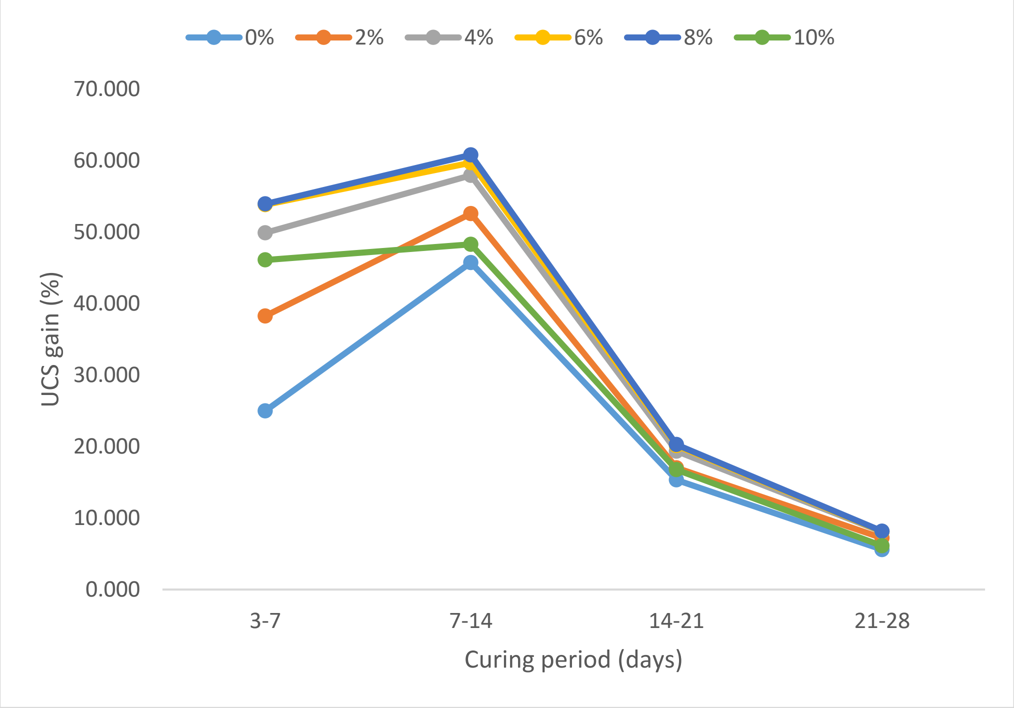


Figure 2.4 UCS Gain Vs Curing Period

The investigation into the effect of curing duration on UCS gain for different percentages of cement addition reveals a noteworthy trend. Specifically, the strength gain experiences an initial rise from the 3rd day of curing, reaching its peak between the 7th and 14th days of curing. Subsequently, the strength gain begins to decline. This pattern holds true across all levels of cement content.

The most significant increase in strength occurs during the 7th to 14th day interval, followed by the 3rd to 7th day interval. Conversely, the increase in strength observed between the 21st and 28th day is relatively minimal. This consistent pattern indicates that the early days of curing yield a considerably greater strength increase compared to the later stages of curing. The heightened strength gain observed during the 7th to 14th day period can be attributed to the maximized hydration process during this phase. In contrast, the latter stages of curing, characterized by completed hydration, contribute only marginally to strength enhancement.

3. Comparative Analysis of the Effect of Curing Period and Cement Additive on the UCS Gain of Cement Stabilized Lateritic Soil

This analysis was conducted using ANOVA statistics. Firstly, the effect of curing duration was checked against the increase in UCS and then, the effect of cement additive checked on UCS strength gain.

Table 2.3: ANOVA Statistics for Curing Duration on UCS Increase

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
3-7 duration	6	267.0426	44.50709	125.5252
7-14 duration	6	325.0951	54.18252	39.41775
14-21 duration	6	108.8774	18.14624	4.208612
21-28 duration	6	43.2406	7.206767	1.258417

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8707.245	3	2902.415	68.1278	1.12E-10	3.098391
Within Groups	852.0501	20	42.6025			
Total	9559.295	23				

From the ANOVA statistics conducted to compare the curing duration and cement addition effect on the strength gain of cement stabilized soil, it was deduced that there is a significant difference in the strength increase of cement stabilized soils due to curing duration margin. This is a consolidation of the fact that the increase in strength recorded in the early days of curing is much greater than that recorded in the later days

It was also revealed that in terms of cement addition, there is a no significant difference in the strength increase or gain of cement stabilized soils. This is a pointer to suggest that the difference in average increase in strength recorded is not statistically significant for the different percent cement used for stabilization.

From this analysis, it can be reached that the curing duration margin had greater influence on the strength increase as compared to the percent cement addition because the p-value (1.12E-10) obtained from curing duration effect analysis is less than the p-value (0.959639) obtained from cement addition effect analysis.

Table 2.4: ANOVA Statistics for Cement Addition on UCS Increase

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
0%	4	91.63967	22.90992	294.3727
2%	4	115.0819	28.77048	420.234
4%	4	135.2809	33.82022	570.8879
6%	4	141.7835	35.44588	636.2488
8%	4	143.1759	35.79398	653.3166
10%	4	117.2938	29.32344	446.1289

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	495.7284	5	99.14569	0.196901	0.959639	2.772853
Within Groups	9063.567	18	503.5315			
Total	9559.295	23				

Table 2.4 shows the effect of cement addition on the UCS gain or increase of cement stabilized lateritic soil. From Table 2.4 and in terms of F- values, the F-statistic (0.1969) is less than the F-critical (2.7728), signifying that there is a no significant difference in the strength increase of cement stabilized soils due to cement addition. In addition, from the p-value and significance level comparison, because the p-value (0.959) is greater than the significance level (0.05), there is no significance difference in the strength gain across the different percent cement addition. This is a

pointer to suggest that the increase in strength recorded is not statistically significant for the different percent cement used for stabilization.

From this analysis, it can be reached that the curing duration margin had greater influence on the strength increase as compared to the percent cement addition because the p-value obtained from Table 2.3 (1.12E-10) is less than that obtained from Table 2.4 (0.959639).

4.3 Analysis of Multiple Regression Model and Test of Hypotheses and Significance

From experimental data, the results for soil-cement mixing are presented in Table 2.5.

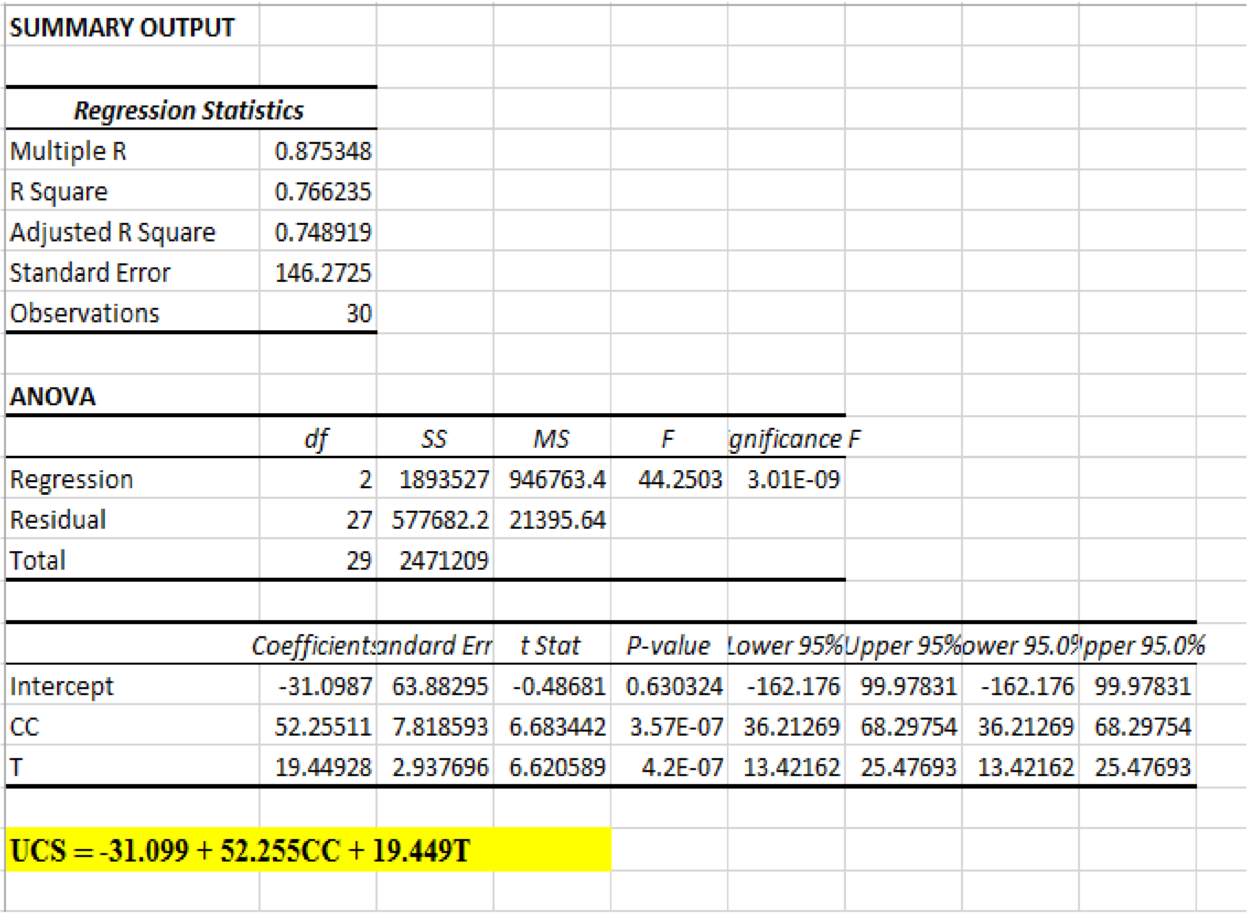
Table 2.5. Unconfined Compressive Strength Result of cement stabilized soil

Curing period (T) **% Cement (cc)**	**3**	**7**	**14**	**21**	**28**
0	95.28	119.09	173.56	200.16	211.34
2	175.93	243.24	371.17	434.36	465.65
4	252.55	378.59	597.96	713.66	771.33
6	299.48	460.69	735.78	883.93	955.58
8	342.82	527.74	848.65	1020.71	1103.92
10	308.94	451.41	669.43	781.68	829.46

Where CC = the cement content (%), T = the curing period (days), and UCS = unconfined compressive strength (kN/m^2).

The experimental results with 30 tests represent the unconfined compressive strength during the 3, 7, 14 and 28 days after addition of water. The cement content (CC) and curing period (T) are linearly predictors of the cement content and the curing period of the soil. Response variable (UCS) is the unconfined compressive strength.

Table 2.6: Multiple Regression Model of Response Variable (UCS) and Predictor Variables (CC) and (T)



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.875348
R Square	0.766235
Adjusted R Square	0.748919
Standard Error	146.2725
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	2	1893527	946763.4	44.2503	3.01E-09
Residual	27	577682.2	21395.64		
Total	29	2471209			

	Coefficient	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-31.0987	63.88295	-0.48681	0.630324	-162.176	99.97831	-162.176	99.97831
CC	52.25511	7.818593	6.683442	3.57E-07	36.21269	68.29754	36.21269	68.29754
T	19.44928	2.937696	6.620589	4.2E-07	13.42162	25.47693	13.42162	25.47693

UCS = -31.099 + 52.255CC + 19.449T

4. Multiple Regression Model

The multiple regression model was proven to have a good fit with inclusion of the response variable (UCS) and predictive variables (CC) and (T) presented as given in Eq. (4.1).

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3}\ ,\ i = 1, 2, \ldots, n \qquad (2.3)$$

where, y_i is the response variable (UCS), β_i is numerical constants and x_i` are the predictive variable cement content (CC), and curing period (T). In this model, multiple regression analysis is applied to all data. The resulting regression is as follows:

For unconfined compressive strength:

$$\text{UCS} = -31.099 + 52.255\mathbf{CC} + 19.449\mathbf{T} \qquad [R^2 = 0.766\,] \qquad (2.4)$$

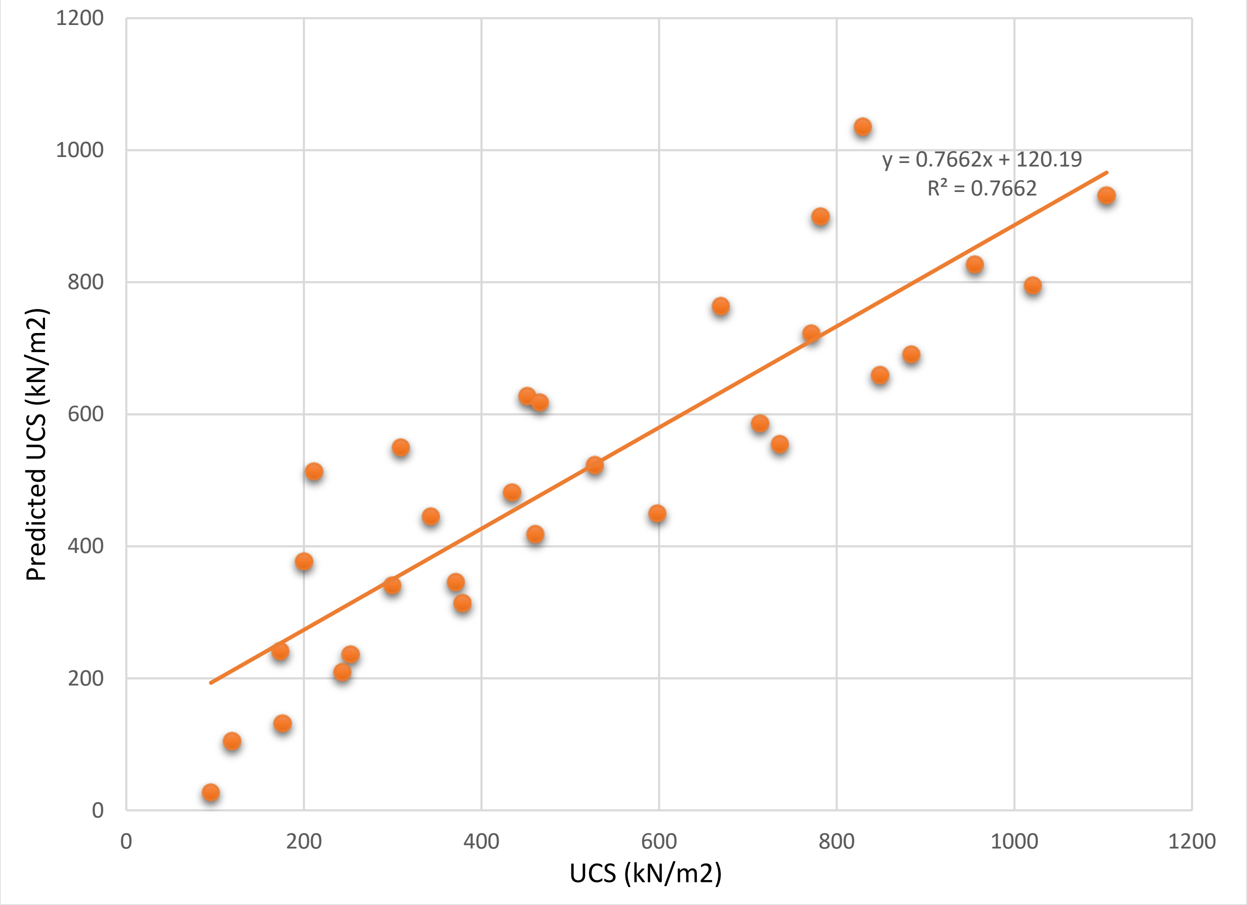


Figure 2.7: Unconfined Compressive Strength Predicted UCS vs Experimented UCS.

where, unconfined compressive strength (UCS) unit: kN/m^2 , cement content (CC) unit: % by weight, curing period (T) unit: days.

Table 2.7: Experimental Data and Predicted Values of UCS for t-Statistic

S/No	CC	T	UCS (Exp)	UCS (Pre)	d=(UCSe-UCSp)	(d-dmean)^2
1	0	3	95.28	27.248	68.032	4627.681799
2	2	3	175.93	131.758	44.172	1951.165584
3	4	3	252.55	236.268	16.282	265.103524
4	6	3	299.48	340.778	-41.298	1705.524804
5	8	3	342.82	445.288	-102.468	10499.69102
6	10	3	308.94	549.798	-240.858	58012.57616
7	0	7	119.09	105.044	14.046	197.290116
8	2	7	243.24	209.554	33.686	1134.746596
9	4	7	378.59	314.064	64.526	4163.604676
10	6	7	460.69	418.574	42.116	1773.757456
11	8	7	527.74	523.084	4.656	21.678336
12	10	7	451.41	627.594	-176.184	31040.80186
13	0	14	173.56	241.187	-67.627	4573.411129
14	2	14	371.17	345.697	25.473	648.873729
15	4	14	597.96	450.207	147.753	21830.94901
16	6	14	735.78	554.717	181.063	32783.80997
17	8	14	848.65	659.227	189.423	35881.07293
18	10	14	669.43	763.737	-94.307	8893.810249
19	0	21	200.16	377.33	-177.17	31389.2089
20	2	21	434.36	481.84	-47.48	2254.3504
21	4	21	713.66	586.35	127.31	16207.8361
22	6	21	883.93	690.86	193.07	37276.0249
23	8	21	1020.71	795.37	225.34	50778.1156
24	10	21	781.68	899.88	-118.2	13971.24
25	0	28	211.34	513.473	-302.133	91284.34969
26	2	28	465.65	617.983	-152.333	23205.34289
27	4	28	771.33	722.493	48.837	2385.052569
28	6	28	955.58	827.003	128.577	16532.04493
29	8	28	1103.92	931.513	172.407	29724.17365
30	10	28	829.46	1036.023	-206.563	42668.27297
				Total	0.148	577681.5615

The comparison between the experimental data and predicted values obtained is further checked for significant difference using the t-test. The degrees of freedom (df) indicate the number of independent values that can vary in an analysis without breaking any constraints. The degree of freedom, df=(N-1), where N is the sample size. Therefore the DOF=29.

Compute the following parametersis done:

The average difference, d= $\frac{\sum d_i}{N} = \frac{0.148}{30} = 0.004933333$

Variance, $S_d^2 = \frac{\sum(d_i - d)^2}{N-1} = \frac{577681.8}{29} = 19920.05$

Standard Deviation, $S_d = \sqrt{19920.05} = 141.1384$

t-statistic, $t = \frac{d}{S_d / \sqrt{N}} = \frac{0.00493333}{(\frac{19920.05}{\sqrt{30}})}$ = 0.000191

Next, the null and alternative hypotheses is stated as follows.

H_0: all d_i=0; there is no difference between the experimental data and predicted values obtained for the Unconfined Compressive Strength (UCS).

H_1: all di≠0; there is a difference between the experimental data and predicted values obtained for the Unconfined Compressive Strength (UCS).

For 5% level of significance (95% confidence level) and 29 degree of freedom, the critical value $t_{0.975,29}$= 2.045 was obtained from the t-Student Distribution Table. The computed t-value was 0.000191, since the t-computed is less than the t-critical, we say there is no significance between the experimental data and predicted values obtained for the Unconfined Compressive Strength (UCS), therefore, the null hypotheses is accepted, “there is no difference between the experimental data and predicted values obtained for the Unconfined Compressive Strength (UCS).”

4. CONCLUSION

In the pursuit of understanding the "Effect of Curing Time on the Strength Development of Cement-Stabilized Lateritic Soil," this study has yielded significant insights that contribute to the realm of geotechnical engineering and soil stabilization. The following essential conclusions have been drawn from the research findings:

1. Soil Classification and Initial Characterization: Employing the AASHTO classification method, the lateritic soil under scrutiny was identified as an A-4 fine-silty material. This classification underscores its marginal suitability as a subgrade material, underscoring the vital role of efficient soil stabilization techniques.
2. Impact of Cement Content on Strength Enhancement: The investigation into the effect of varying cement content on the enhancement of unconfined compressive strength (UCS) has brought forth a coherent pattern. Notably, a linear relationship between cement content and strength gain was observed within the range of 0% to 4%. Beyond this threshold, the rate of strength enhancement diminished, stabilizing at a near-constant value. This observation underscores the pivotal influence of cement content, particularly up to an optimal threshold of around 8%, beyond which diminishing returns are encountered.
3. Curing Duration's Role in Strength Development: A careful analysis of curing duration unveiled a noteworthy trend in strength development. The period from the 3rd day to the 14th day of curing marked a phase of substantial strength gain. Beyond this juncture, the rate of strength improvement tapered, signifying the prominence of early curing stages in maximizing strength development. The dynamics of this trend highlight the need for a balanced approach to curing duration.
4. Interaction Effects and Statistical Significance: The intricate interplay between modifier-acid interactions, curing duration, and cement content demonstrated varied degrees of influence on strength properties. Strikingly, statistical analysis via ANOVA revealed that curing duration exercised a more pronounced impact on strength enhancement compared to cement content. This emphasizes the criticality of optimal curing periods in harnessing the full potential of cement stabilization.
5. Multiple Regression Model and Hypothesis Testing: Introducing a robust multiple regression model, $UCS = -31.099 + 52.255CC + 19.449T$, empowered us to predict unconfined compressive strength based on the interrelation between curing duration and cement content. With an impressive R^2 value of 0.766, the model's effectiveness in predicting strength has been substantiated. Rigorous hypothesis testing further corroborated the congruence between experimental and predicted values, lending credibility to the predictive model.

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