

COMPACTION BEHAVIOR AND CONSISTENCY LIMITS OF LATERITE SOIL MIXED WITH CEMENT DUE TO COMPACTION DELAY

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ABSTRACT

Laterite soil, which is quite common in various places on Kalimantan Island, is generally used for road embankment material. However, laterite soil was often associated with road construction damage and landslides when used as a base embankment (subgrade) in Central Kalimantan. In order to overcome the issue, the handling process should be carried out by stabilizing laterite soil mixed with cement to ensure soil technical properties meet certain requirements. The time lag between soil-cement mixing stage, including the spreading and compaction time in the field caused by a damaged grader, compaction roller, heavy rain, bad weather, worker injuries, or other forms of disturbance, need to be evaluated. Therefore, this research used an experimental method to determine the effect of compaction delay on the behavior and consistency limits of Central Kalimantan laterite soil mixed with cement. The density behavior and cone limits were determined by mixing laterite soil with variations in cement content of 2%, 4%, 6%, 8%, and 10% to obtain an increased dry weight value of 1.39 t/m³ to 1.43 t/m³. Compaction process was postponed for 1, 2.5, and 4 hours, respectively. In conclusion, Liquid Limit (LL) decreased with increase in cement content, while Plasticity Index (PI) reduced with rise in cement content, and increased with a delay in compaction time of 1, 2.5, and 4 hours.

Keywords: laterite soil, cement, stabilization, compaction, consistency limit, time delay.

1. INTRODUCTION

Several road constructions are built on laterite soil in Central Kalimantan, although not all soil materials are used for the base layer or embankment. In locations, characterized by high plasticity clay, using laterite soil as the base layer or embankment tended to be unprofitable. Therefore, to meet the standard usage requirements, laterite soil must be improved or stabilized.

Laterite soil is produced from laterization, a natural process that occurs in the tropical and subtropical areas (Anbazhagan et al., 2018). Yaragal et al. (2019) reported that it is generally formed in places rich in alumina, iron, and silica parent

rocks, with the coloring process influenced by the presence of iron oxide and manganese. The distinctive red color is due to iron oxide, and over time, soil changes to brown or black (Rusdiansyah, 2023).

In this context, laterite soil could be improved by stabilizing or mixing with cement. When mixed with water-logged soil, cement causes a hydration process resulting in soil lumps. However, a gradual compaction process reduced the strength of the mixture.

Following the discussion, ascertaining the duration of compaction process, enabled the strength to be accepted based on the mandated specification limits. This helped in avoiding work quality below standard specification.

2. MATERIALS AND METHODS

Laterite soil samples were collected directly from a quarry situated beside Palangka Raya Sampit national road, precisely in Parit Village, Cempaga Hulu Sub-district, East Kotawaringin Regency, Central Kalimantan Province, using the disturbed method. Additionally, Conch brand of Portland Composite Cement (PCC) was purchased at a building materials shop in Banjarbaru City.

The physical and mechanical properties of natural laterite soil was tested in the laboratory. These included grain size distribution, compaction, and Atterberg limit. Laterite soil mixed with varying cement content of 2%, 4%, 6%, 8%, and 10% were tested for grain size distribution, compaction, Atterberg limit. Simultaneously, each variation of the mixture was applied in respect to a delay of 0, 1, 2.5, and 4 hours to determine compaction behavior and consistency limits.

3. RESULT AND DISCUSSION

Physical Test of Natural Laterite Soil

Table 1. Physical Properties of Natural Laterite Soil (100% Laterite)

Sample Number		Laterite Parit Village
Soil Properties	Specific Gravity (Gs)	2,633
Grain Distribution	Gravel (>2 mm)	% 4,53
	Coarse Sand (0.6 – 2.00 mm)	% 4,72
	Medium Sand (0.2-0.6 mm)	% 2,00
	Fine Sand (0.05-0.2 mm)	% 4,46
	Silt and Clay (0.002-0.05 mm)	% 61,81
	Clay (<0.002 mm)	% 22,48
	No. 10 (2.00 mm)	% 95,47
	No. 40 (0.425 mm)	% 89,79
	No. 200 (0.0075 mm)	% 88,18

Atterberg Limits	Liquid Limit (LL)	%	55,32
	Plastic Limit (PL)	%	27,61
	Plasticity Index (PI)	%	27,71
	USCS Method Classification		CH
Compaction	Optimum Water Content	%	27,14
	Maximum Unit Weight (γ_d max) t/m ³		1,39

Table 1 shows that specific gravity (Gs) examination of laterite soil obtained was 2.633. This value proved that laterite soil sample found in Central Kalimantan belonged to the inorganic silt group.

The results of the sieve and hydrometer tests conducted on the original sample under disturbed conditions showed that laterite soil had a passing sieve No. 200 of 88.18% (greater than 50% of soil passed sieve No. 200). This showed that laterite soil from Central Kalimantan was generally categorized as fine-grained (silt and clay), in line with USCS table.

Based on the laboratory analyses, including the consistency limit tests, it was found that the results of LL and PL examinations conducted on the samples were sequentially 55.32% and 27.61%, respectively, with PI value of 27.71%. Therefore, laterite soil from Central Kalimantan was grouped in Clay-High (CH) classification, referring to inorganic clay with high plasticity (fat clays).

Results of Maximum Dry Density and Optimum Water Content Tests with Variations in Cement Content

Table 2. Results of Maximum Dry Density and Optimum Water Content Tests

Cement content (%)	Maximum dry weight unit (γ_d mak) (t/m ³)	Optimum Water Content (%)
0	1,39	27,14
2	1,40	26,30
4	1,41	24,50
6	1,42	23,12
8	1,42	21,89
10	1,43	21,42

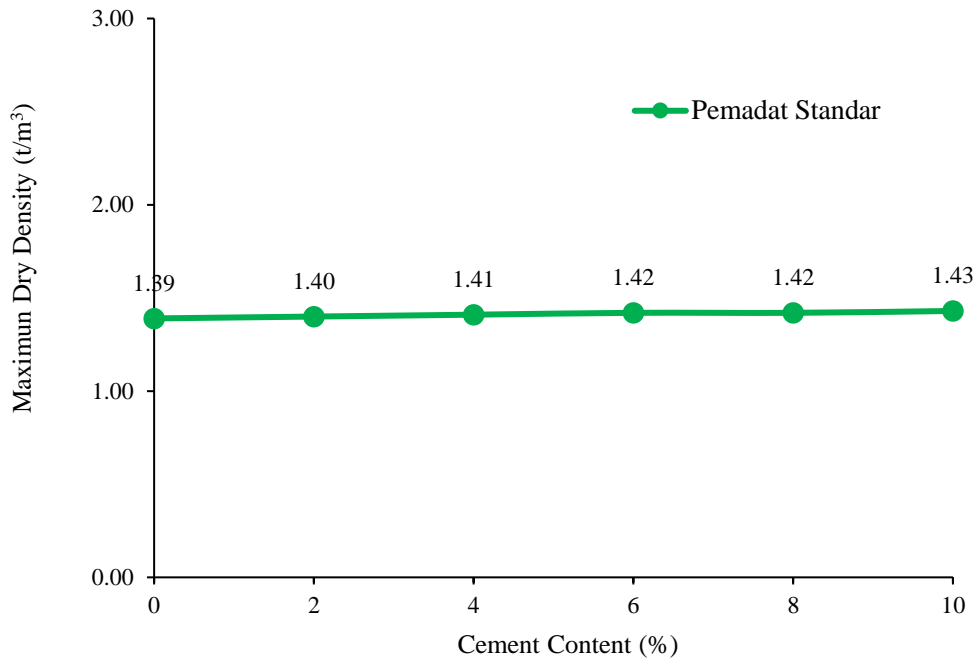


Figure 1. Relationship of Maximum Dry Density to Cement Content

An increase in the maximum dry unit weight ($\gamma_{d\text{ mak}}$) value raised the cement content from 1.39 t/m³ at 0% to 1.43 t/m³ at 10%, equivalent to an increase of 2.88%, as shown in Table 2 and Figure 1. This was consistent with previous research on the effect of delaying compaction time and behavior of CBR and gravel laterite soil mixed with cement (Charles MO Nwaiwu, Obinna U. Ubani, and Charles Mahawayi, 2022). The reason was that cement contained silica elements whose volume weight was greater than laterite soil. Silica causes laterite soil to bound to cement paste, increasing the dry volume weight. However, this behavior was not in accordance with previous research on the properties of soil-cement mixtures (Osuolale, O. M., Olawuyi, O. A., Busari, A. and Adewumi, A. S, 2017).

Consistency Limit Test Results with Cement Content Variations towards Time Delay Variations

Table 3. Consistency Limit Test Results for Laterite + Cement (Direct)

Laterite soil (%)	Cement (%)	LL (%)	PL (%)	PI (%)	USCS Classification
100%	0%	57,12	27,85	29,27	CH
98%	2%	55,78	27,27	28,51	CH

96%	4%	55,26	27,07	28,18	CH
94%	6%	53,04	28,00	25,04	CH
92%	8%	50,08	25,48	24,60	CH
90%	10%	49,12	25,11	24,01	CL

Table 4. Consistency Limit Test Results for Laterite + Cement (1 hour)

Laterite soil (%)	Cement (%)	LL (%)	PL (%)	PI (%)	USCS Classification
100%	0%	59,35	28,86	30,49	CH
98%	2%	57,53	28,54	28,99	CH
96%	4%	56,13	27,96	28,18	CH
94%	6%	56,02	27,91	28,12	CH
92%	8%	55,70	28,27	27,43	CH
90%	10%	56,06	28,36	27,70	CH

Table 5. Consistency Limit Test Results for Laterite + Cement (2,5 hours)

Laterite soil (%)	Cement (%)	LL (%)	PL (%)	PI (%)	USCS Classification
100%	0%	59,95	28,96	30,99	CH
98%	2%	58,63	28,27	30,37	CH
96%	4%	57,78	27,82	29,96	CH
94%	6%	56,67	27,34	29,33	CH
92%	8%	56,55	27,13	29,42	CH
90%	10%	56,23	26,94	29,28	CH

Table 6. Consistency Limit Test Results for Laterite + Cement (4 hours)

Laterite soil (%)	Cement (%)	LL (%)	PL (%)	PI (%)	USCS Classification
100%	0%	63,59	29,95	33,64	CH
98%	2%	59,64	29,15	30,48	CH
96%	4%	58,44	28,17	30,27	CH
94%	6%	58,18	27,95	30,22	CH
92%	8%	57,21	27,38	29,83	CH
90%	10%	56,16	27,87	28,30	CH

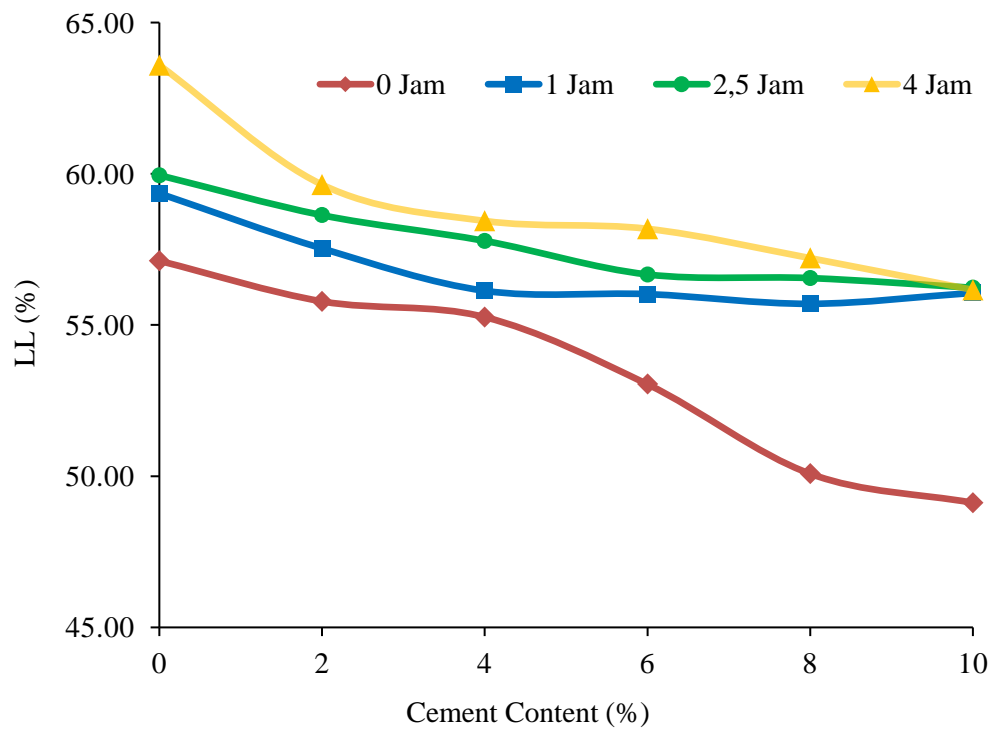


Figure 3. Relationship of LL to Cement Content

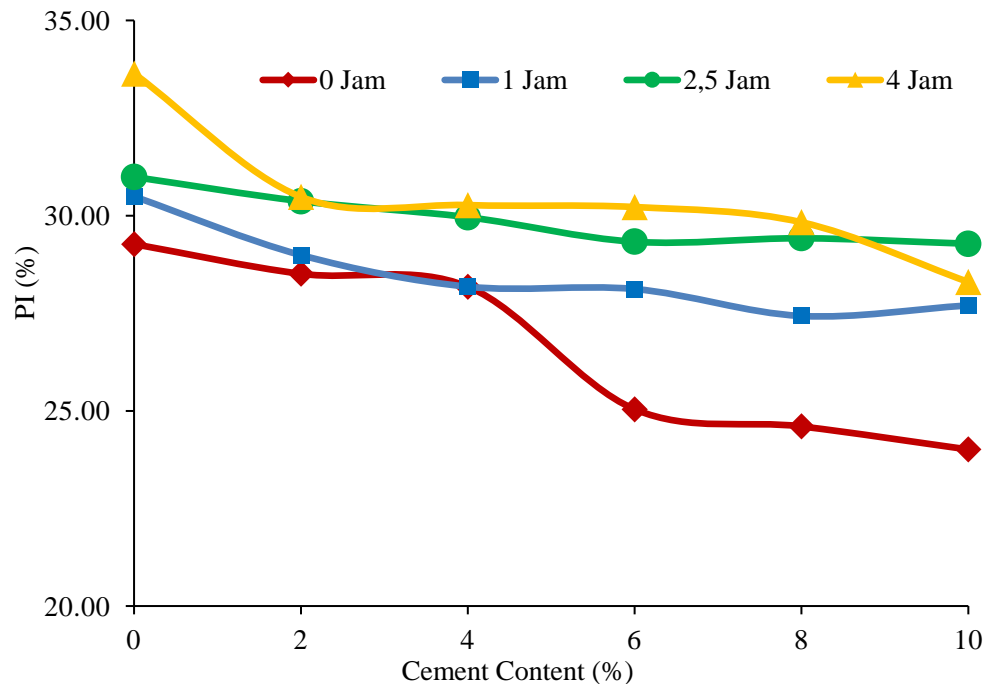


Figure 4. Relationship of PI to Cement Content

In Tables 3 to 6, as well as Figures 3 and 4, LL value experienced a decrease with increasing percentage of cement content. However, under compaction time delay, LL experienced an increase for the varying cement mixture of approximately 8%. At 10% cement content, the LL value has an equivalent value. The PI values also decreased with the addition of cement content, and when subjected to compaction time delay, it experienced an increase in each of the mixtures.

Based on the context, PI value experienced a decrease alongside the addition of cement content, which caused plasticity of soil not to be lower than the original sample. In Figure 4, the PI value experienced a decrease, depicting that soil, originally classified as High Plasticity (CH), was converted to a particular Low Plasticity (CL) for the mix at 10% cement content with no delay time. Therefore, cement was used to control plastic properties of laterite soil.

4. CONCLUSION

- In conclusion, distinct results were obtained from diverse analyses conducted. Additionally, these led to following points
- The maximum dry content weight test ($\gamma_{d \text{ mak}}$) tended to rise with increasing cement content, from 1.39 t/m^3 at 0% cement content to 1.43 t/m^3 at 10% cement content, or 8%. Additionally, 2.8% was also subjected to an equivalent increase.
- LL value decreased as cement content increased, as does PI value. However, it increased by applying compaction time delay to each cement content variation.
- Considering cement-soil mixture without compaction delay time, soil classification according to USCS changed from CH to CL and back to CH with delays of 1, 2.5, and

4 hours, respectively.

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