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THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

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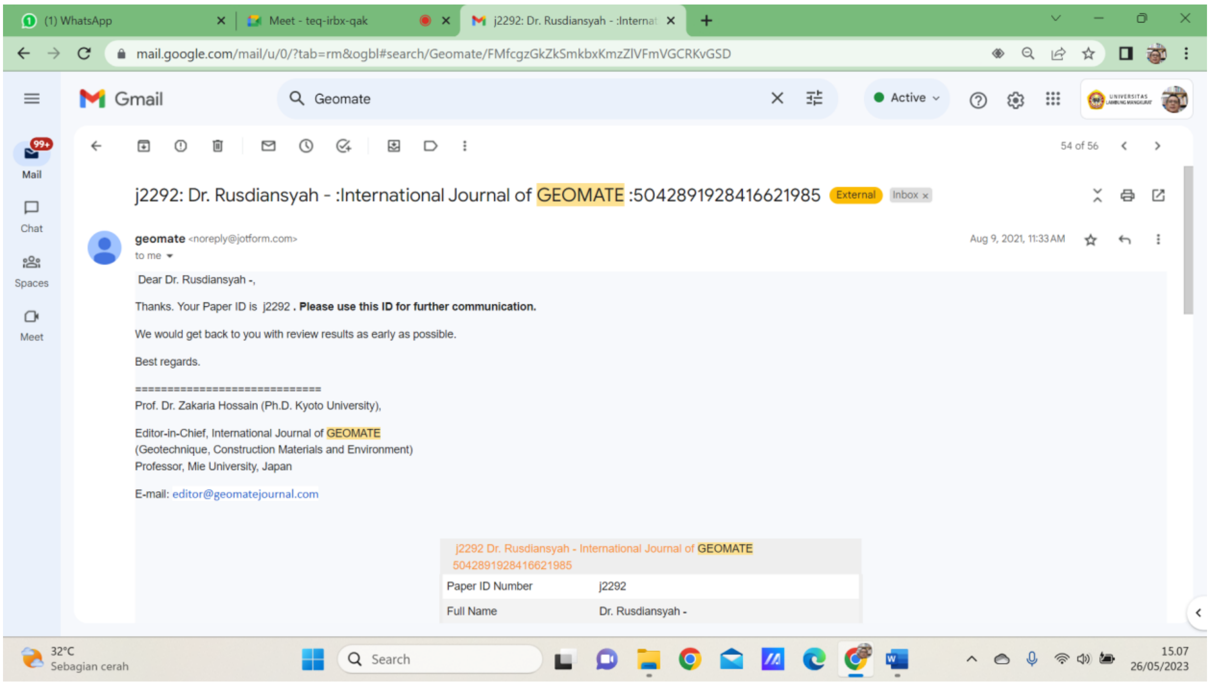

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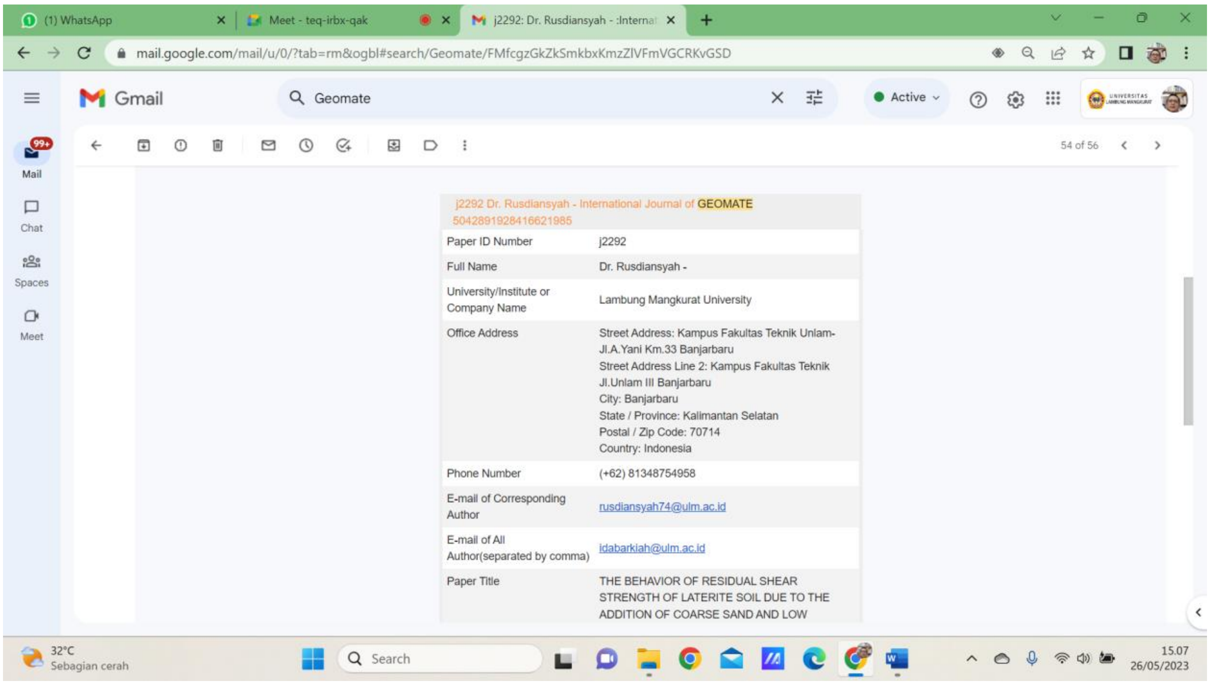

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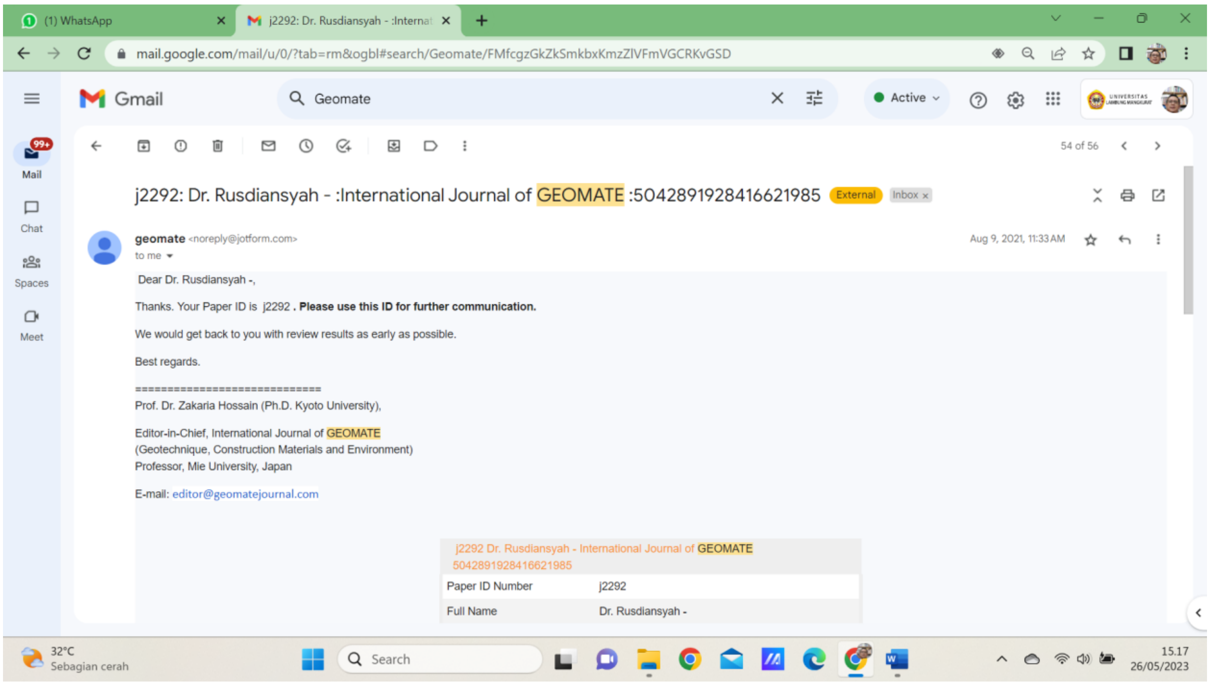

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THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

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ABSTRACT: Residual shear strength plays a very significant role in geotechnical engineering. This concept has contributed extensively to diverse studies on soil behaviors under the influence of shear failure, both in drained and saturated conditions. In terms of landslides, the assessment of the residual shear strength after an occurrence and the progressive failure risk of slope stability has been very useful. However, information on this shear property in laterite soil appears relatively minimal. This soil type is the most frequently applied embankment for road construction in virtually every Kalimantan region. Therefore, the purpose of this research is to determine the behavior of residual shear strength in laterite soils and the effects of adding coarse sand and clay fractions, using direct shear analysis. Subsequently, the specimens were prepared by compaction tests to obtain the optimum moisture content and uniform density, using coarse sand of varying proportions, termed 5, 10, 15, 20 and 25%, while, the shear strength treatment with wetting and drying cycle conditions was conducted under 2, 4, 6, 8 and 10 days, respectively. The results showed that the inclusion of the coarse sand and clay (CL) portions was able to increase the residual shear strength parameters (cohesion and internal friction angle) by 4-6%, compared to the pure state. Therefore, the introduction of clay (CL) materials ranging from 20-25% appears suitable in enhancing the residual shear strength of laterite soil. However, the extensive wetting-drying cycle tends to reduce the peak and residual shear strength.

Keywords:shear strength, residual shear strength, wetting cycle, drying cycle, lateritic soil, coarse sand

1. INTRODUCTION

Laterite soil is a fairly hard and red surface residue originating from tropical deposits. The sample is generally a result of final weathering from disintegration and decomposition activities. This soil type is due to the chemical transfer of silica from the slump, with relatively increasing Fe and Al concentrations. The process is formed in the tropics where the rainfall intensity and temperatures are higher, causing the Si content to easily dissolve and form oxysols, comprised of laterite and latosol.

Laterites occur in the tropical regions, including Indonesia, with an extension over the Sumatra, Java, Kalimantan, Sulawesi, and Papua islands. This soil is commonly employed as an embankment material for road construction and shoulders, as well as expansion. The sample from South Kalimantan province varies in grain size distribution, comprising gravel, sand, silt and clay fractions. Meanwhile, the clay fragment shows a relatively significant percentage above 20%, leading to a high plasticity index. As a result of the superior value, the road embankment stability factor is relatively minimal, with certain limitations, including the easy occurrence of massive compressions on the main road from the embankment materials, as well as simple surface erosion due to the rain, with the tendency to instigate landslides.

Slope slides from embankments are common in Kalimantan, ranging from small to large scale, with the tendency to hinder traffic lanes. As a consequence, studies on residual shear strength in soils appear necessary to determine the possibility of using areas adjacent to the landslide as traffic access or total road closures. These actions are essential to avoid the potential threat to public safety, although the implementations are relatively time-consuming.

Residual shear strength is very significant in geotechnical engineering and has also contributed immensely to the research on the soil behavior of soil under failure events, both in drained and saturated conditions. This concept plays an essential role in landslide properties, particularly in the assessment of the residual shear strength after an occurrence and progressive failure risk of slope stability. Furthermore, the residual shear strength of the over-consolidated (OC) soil was analyzed in two stages. The first attempt was conducted at a peak state, followed by a gradual decrease to a critical condition value due to improved moisture content. Meanwhile, in the second stage, the shear strength declined under an extensive deformation, as a result of the re-orientation of the soil particles parallel to the shift direction. Under this circumstance, the shear strength becomes minimal and is called the residual shear strength.

However, information on residual shear strength of laterite soil after landslide appears relatively insignificant. This is related to the behavior of the residual shear strength of the embankment with laterite soil that shows the most frequently used for road construction in virtually every Kalimantan region in Indonesia.

Several studies on the residual strength of non-laterite clays have also been conducted since the late 1930s, including by [1], [2], and [3]. Furthermore, [4] reported the residual shear strength of the soil using a conceptual model, based on experimental data. This attempt was successively followed by [5], [6], [7], and [8], where the results of [4] were refined over time.

The residual shear strength forms a key parameter required for the analysis and design of slopes, retaining walls and fine-grained soil foundations under relatively massive deformations [9]. This property is mainly applied for two purposes. The first effort involves calculating the extent of slope decrease in an earthquake [10], followed by evaluating the previous slope stability [11].

Residual shear strength is important in comprehending the stability of past landslides, assessment of engineering properties of soil deposits, comprising pre-existing shear surfaces and the progressive failure risk on new and current slopes [12], [13], [11]. The variable also plays a significant role in the design of corrective action [14] and understanding its position under initial failure conditions [15].

Several studies on soil parameters, termed Atterberg limit, clay fraction, and so on, to determine residual strength have also been previously investigated, including [16] and [17]. This research intends to contribute to the development of subsequent slope stability analysis [18]. The residual strength is commonly defined as the minimum and constant drained shear strength needed for the soil to undergoes an extensive shear shift under normal stress [18], as represented in Figure 1.

Figure 1 shows that the residual shear strength of soil is never zero [19]. This factor depends not only on soil type, termed material, particle size and shape, surface roughness, and so, but also on soil situations, in terms of density, moisture content, frame structure, and test conditions, including the selection of shear testing equipment, normal stress, over-consolidation ratio, shear rate, acceleration, and so on [20].

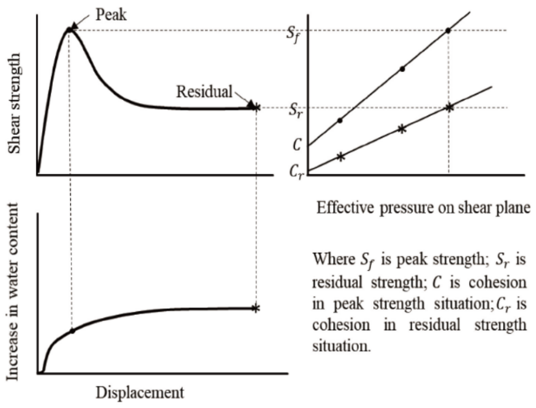

Figure 1 Concept of residual strength in shear characteristics

Several previous attempts have been recorded relating the friction angle of the residual soil and its index properties, including Atterberg limit as well as clay fraction [21] and friction angle in residual clay fraction [4], by performing a series of controlled direct shear tests in certain mixtures of bentonite, kaolin and sand. In the two investigations, the shear rate varied between 0.0001-100 mm/min. This observation concluded that a positive relationship between the shear transfer rate and the clay's residual strength was observed, with higher fractions and displacement above 50% and 1 mm/min, respectively. Additionally, the shear test has also been conducted on a mixture of soil and sodium chloride to examine the salt concentration effects. The results showed that the positive impact becomes more intense with increasing salt concentration. This increment is possibly comprehended by the decrease in the void ratio and the increase in contact solid particles due to the concentration of the mixture, [22], [23].

2. RESEARCH METHODS

Material

The research specimen included laterite soil from a quarry in Cempakasub-district, Banjarbaru city, South Kalimantan province, Indonesia. This soil is commonly applied as an embankment material in road construction across the Kalimantan island. The additional samples were coarse sand from the Barito river, Barito Kuala regency in a similar location, and clay fractions with a characteristic plasticity index (PI) of 6%. This value is classified by the USCS standard as CL (low plasticity clay).

Table 1 shows the physical and mechanical characteristics of laterite soil, with a classification of CH (high plasticity soil) and a relatively high PI of 34.51%.

Based on the grain size distribution test results, the fine-grained soil showed a percentage above 50%. This outcome is also reviewed on the basis of the moderately high liquid limit (LL) and compressibility index (Cc) values. Therefore, the selected laterite soil is plastic in nature, and is easily compressed, but appears less profitable in constructing road embankments.

Table 1. Characteristics of Laterite Soil

Properties	Value

- Volumetric weight, γ (kN/m^3)
- Water content, Wn (%)
- Specific Gravity, Gs
- Liquid limit, LL (%)
- Plastic limit, PL (%)
- Plastic Index, PI (%)
- Cohesion, C (kPa)
- Internal angle, (°)
- Compressibility index, Cc
- Swelling Index, Cs
- Grained of Distributions
  - Gravel (>2mm), %
  - Coarse sand (0.6-2mm), %
  - Medium sand (0.2-0.6mm), %
  - Fine sand (0.05-0.2mm), %
  - Silt-clay (0.002-0.05mm), %
  - Clay (<0.002mm), %
- Sensitivity
- USCS classification
	17.38
	40.636
	2.65
	62.91
	28.40
	34.51
	26
	22.61
	0.51
	0.07
	16.99
	7.85
	7.21

	6.42 24.79 36.74 1.1 CH

Testing Procedure

The laboratory research activities involved evaluating the physical and mechanical properties, including the shear strength, with the addition of sand and clay fractions at 5, 10, 15, 20 and 25% respectively. Soil specimens for the shear strength test were obtained from the standard compaction results, with 80-90% maximum density. This assessment was conducted for each variation, without the addition of mixing material in wetting and drying cycles, but at the peak and residual shear strength for 2, 4, 6, 8, and 10 days.

Figure 2 represents the main direct shear test tool in the present research. This also refers to the test method conducted by [24].

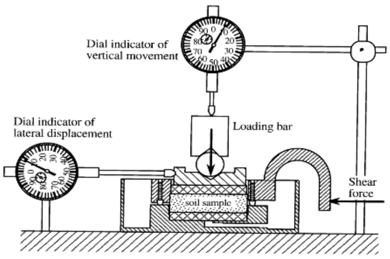

Figure 2: Scheme for the Direct Shear Test Tool.

3. RESULTS AND DISCUSSION

Grain Size Distribution of Laterite Soil Mixture

Figure 3 shows the grain size distribution curve for each mixture. The shape of the curve for laterite soil and clay components rests on the upper side of the laterite soil and coarse sand blend, particularly the curve line on the fine-grained soil fraction, including silt and coarse sand.

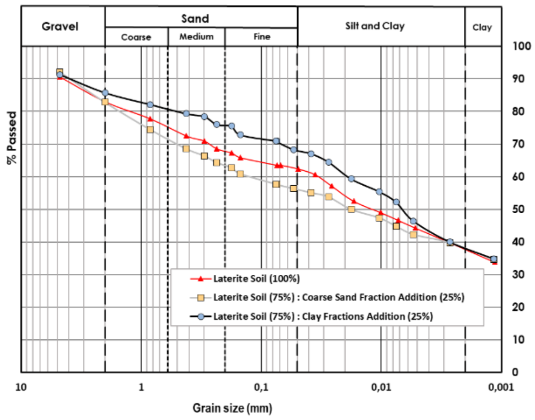

Figure 3: Grain Size Distribution Curve.

Effect of The Addition Sand and Clay Fraction on the Cohesion Value of Laterite Soil at Peak and Residual Conditions

Figure 4 shows the effects of adding sand and clay fractions on the soil cohesion value at peak and residual conditions. Based on the graph, the soil cohesion value at peak state generally appears greater, compared to the residual position. This statement applies to both added soil types, including coarse sand and clay fractions. Also, the residual cohesion values decreased towards the peak condition in the sand and clay materials by an average of 17 and 13%, respectively. This outcome indicates a cohesion value of the residual soil in the coarse sand and clay fractions at 83 and 87%, correspondingly, after the added materials. However, compared to the cohesion of plain laterite soil, the value was 4% lower than the added material of 20-25% clay fraction.

Figure 4, also shows an increase in the residual cohesion along with the percentage of added clay fractions, but contrary to the sand components. Theoretically, the addition of clay fractions was believed to enhance the soil friction, leading to an increased bond between the grains. Also, the cohesion among soil grains contained in the mixture was known to decline, due to additional coarse sand.

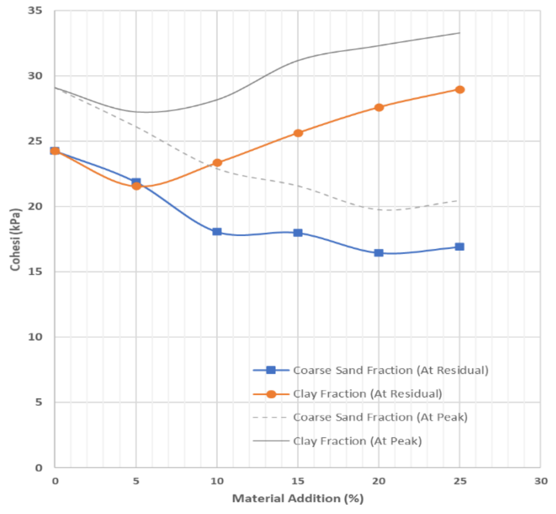

Figure 4: The Relationship between the Added Materials and Soil Cohesion at Peak and Residual Conditions.

Effect of the Addition of Sand and Clay Fractions on Friction Angle in Laterite Soil at Peak and Residual Conditions

Figure 5 shows the effects of adding sand and clay fractions on the friction angle in laterite soil at both peak and residual conditions. Based on the graph, the internal friction angle at peak position was greater, compared to the residual state. This statement applies to the two added materials, termed sand and clay.

The comparison shows that the internal friction angle at the residual conditions decreased by 12 and 23% in the coarse sand and clay fractions, respectively, at peak conditions. In addition, the relationship curve indicates that the residual state of added sand particles generated the maximum friction angle, compared to clay. This outcome also recorded a residual shear strength of 88 and 77% in coarse sand and clay fractions, respectively, after the added soil materials. Consequently, the internal friction angle in the residual condition for the plain sample was 6% lower than the added materials with a 20-25% clay fraction.

Therefore, the addition of coarse sand significantly enhanced the shear angle, compared to the original soil. Increasing the sand in the mixture cause the interconnected grains to strongly attract each other. Under the prevalent circumstance, the voids between the soil particles tend to reduce, although the friction between the sand fraction and the original soil becomes more extensive. This conclusion is also related to the previous studies of [25], where the shear strain instigated a minimal decline in the friction angle, compared to the saturated peak condition (critical value). However, the displacement required to achieve this equilibrium appeared very significant.

This statement also relates to the shape of the particle size distribution curve obtained before and after the shear test. Therefore, most of the soil clusters disintegrated during sample preparation. Direct shear assessments showed that the normal effective stress greatly influenced the particle deformation mechanism. This situation results to the reduction in the friction angle at increasing normal effective stress, under residual conditions [25].

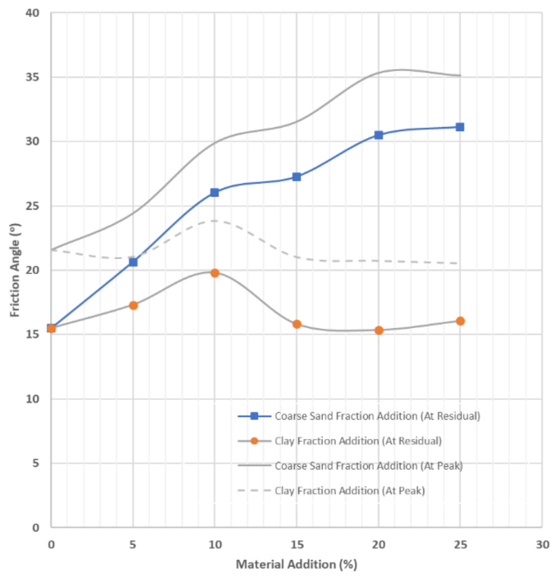

Figure 5: The Relationship of Material Addition and Friction Angle at Peak and Residual Conditions.

Effect of Plastic Index on Shear Strength at Peak and Residual Conditions

Figure 6 shows the effects of plasticity index on shear strength, with added coarse sand, at peak and residual conditions. Based on the graph, the shear strength significantly decreased as plastic index becomes intense. However, with a constant plasticity index, the residual shear strength appeared slightly minimal, compared to the peak positions.

Also, the reduction in plasticity index corresponded to the percentage increment in the added coarse sand that tends to disintegrate the grain adhesion. This inclusion was aimed at declining the soil mineral, cohesion value and plasticity index. However, the friction was due the involvement of the coarse sand fractions that tends to reduce the cavities between soil grains.

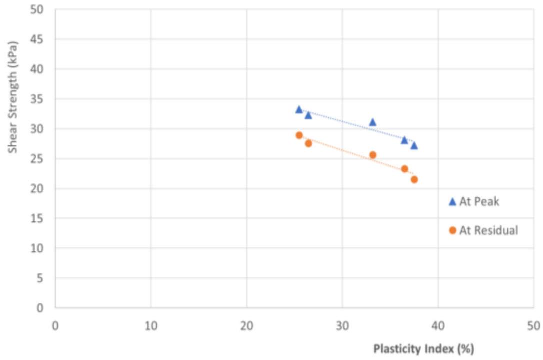

Figure 6: The Relationship between Plasticity Index and Shear Strength at Peak and Residual Conditions.

Effect of the Addition of Sand and Clay Fractions on the Shear Strength of Laterite Soil at Peak and Residual Conditions

Figure 7 represents the relationship between the added material and shear strength at both peak and residual conditions. Under these circumstances, the addition of coarse sand and clay fractions significantly influenced the shear strength. However, the soil retains the minimal residual shear strength after experiencing peak conditions. This observation corresponded to previous research [18], where the soil's residual shear strength was not zero.

Figure 7 also shows that the addition of the clay fractions instigated a higher residual shear strength than the pure sample, based on a constant percentage of added materials. According to the percentage ratio, the resulting graph and the comparison indicated a decline in the residual shear strength by average values of 17.4 and 16.6% in coarse sand and clay components, respectively. This peak outcome also observed the residual shear strength of 82.6 and 83.4% for coarse sand and clay samples after the added materials.

Furthermore, the soil mixture with 20-25% clay fractions tends to generate a minimal residual shear strength, compared to the added sand fractions. However, by comparing previous research [11], the residual strength was mainly influenced by the sand and silt fractions, with clay samples below 25%. Meanwhile, beyond 50%, the residual strength is almost entirely impacted, although further increase in the clay fraction reported insignificant effects. Also, between 25-50%, a 'transition' type of behavior occurred, where the residual strength was influenced by the proportion of clay particles and the properties.

In other research results, the clay content generated very minimal residual shear strength. This condition was due to the alignment of particles parallel to the shear surface and the disintegration of certain soil groups rather than the damage to individual soil particles. Conversely, the existence of various soil types or groupings described the significant difference between peak and residual conditions in direct shear tests [25].

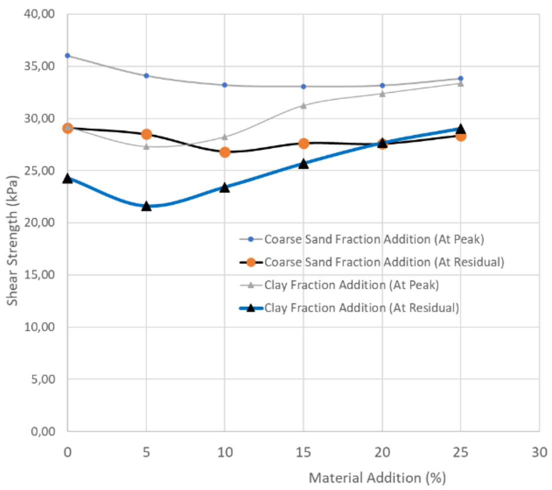

Figure 7: The Relationship of Material Addition and Soil Shear Strength at Peak and Residual Conditions.

Effect of Wet-Dry Conditions on Laterite Soil Shear Strength at Peak and Residual Conditions

Figure 8 shows the relationship between wetting and drying cycles. Extensive periods tend to reduce the shear strength at normal and residual conditions. This decline generated average values of 5.11 and 4.92% for normal and residual conditions, respectively. Consequently, the graph confirmed a decrease in the residual shear strength by an average of 26.42% against the normal conditions, under constant wetting and drying cycles.

Figure 8 also indicates an increased shear strength dues to the changes from wetting to drying phases, although not very significantly. Conversely, the transition from drying to wetting phase decreased the shear strength by an average of 4.5%. Under the 10-day drying interval, the shear strength under normal appeared more substantial, compared to the residual conditions.

In addition, a loss in suction power was known to reduce the shear strength of the residual unsaturated soil [9]. Also, the contribution of matric suction to residual shear strength decreased significantly with increasing matric suction, although the influence was drastically displaced with extensive normal stress. This behavior is caused by a reduction in the area of the water menisci in contact with the aggregate.

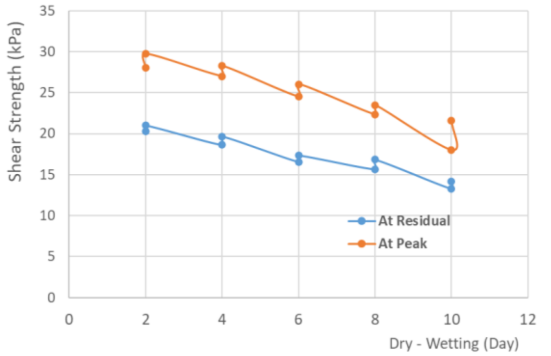

Figure 8: The Relationship between Wet-Dry Laterite Soil Conditions on Shear Strength at Peak and Residual Conditions.

4. CONCLUSION

Based on the analysis results and discussion, certain deductions were generated, including:

1. The addition of the coarse sand and clay (CL) fractions in laterite soil increased the residual shear strength parameters (cohesion and internal friction angle) by 4-6%, compared to previous conditions with pure samples.
2. The clay materials also enhanced the residual shear strength from the previous condition without added materials, compared to the involvement of the coarse sand fractions.
3. The residual shear strength of the laterite soil mixed with the low plasticity clay fraction (CL) was higher than the pure state.
4. Additional clay materials, with a percentage between 20-25%, were

applied to improve the residual shear strength of the laterite soil,.

5. Extensive wetting-drying cycles tend to lower the peak and residual shear strength.
6. During the change from wet to dry phase, the shear strength increased in both peak and residual conditions, although not very significant.
7. Under a similar interval, the residual shear strength appeared minimal in wet conditions, compared to the dry state.

5. ACKNOWLEDGMENT

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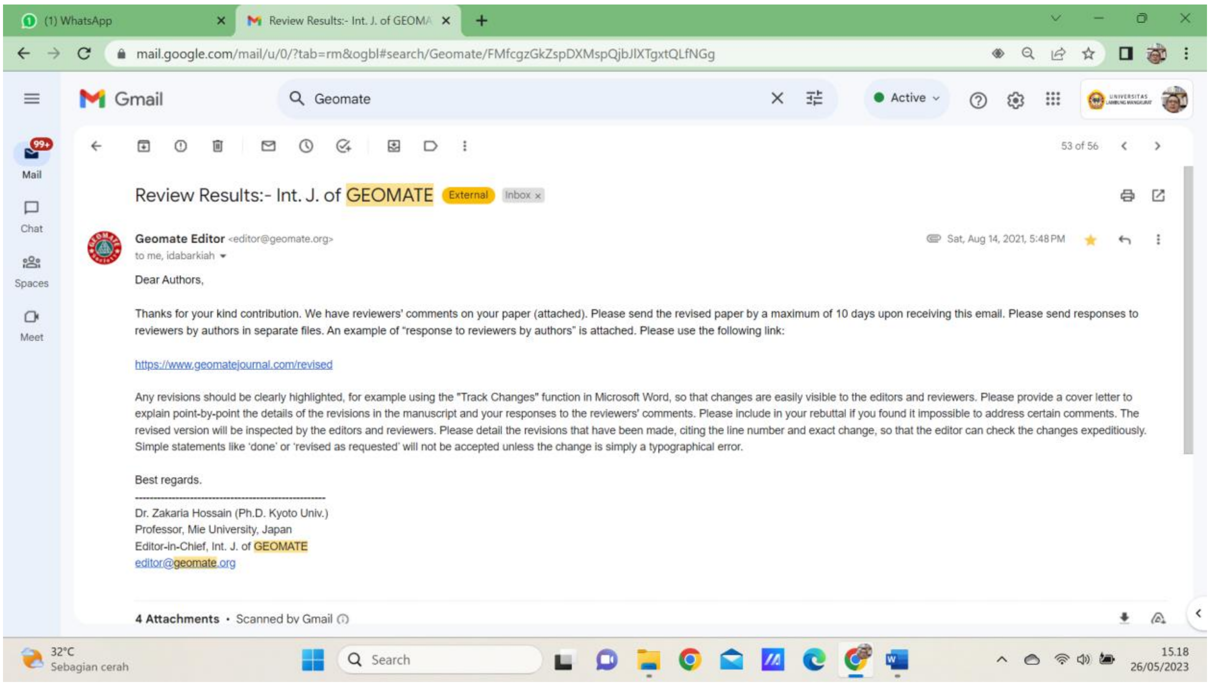

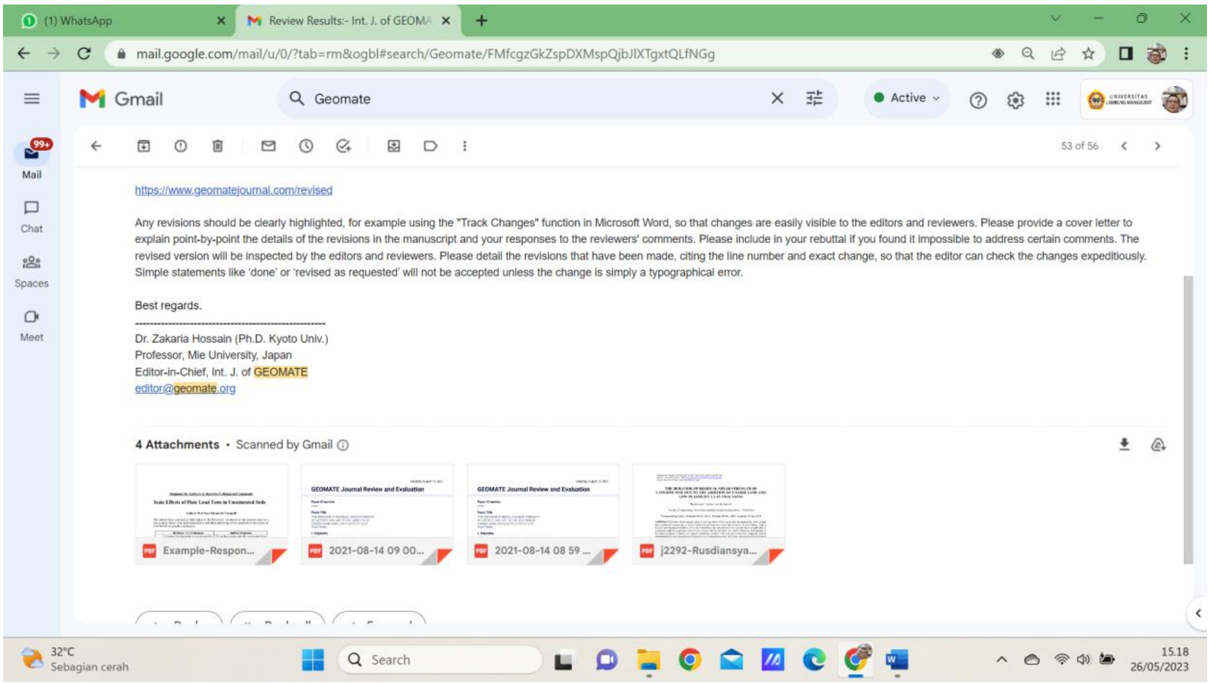

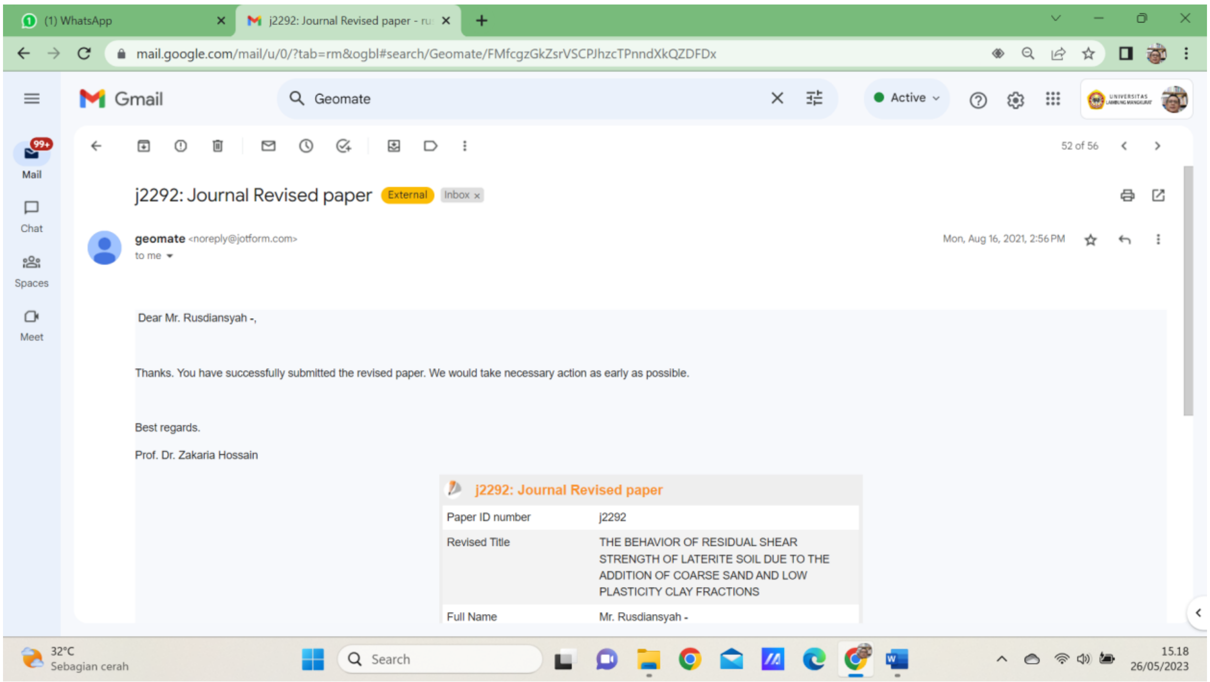
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Thanks. You have successfully submitted the revised paper. We would take necessary action as early as possible.
Best regards.
Prof. Dr. Zakaria Hossain
j2292: Journal Revised paper
Paper ID number
j2292
Revised Title
THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS
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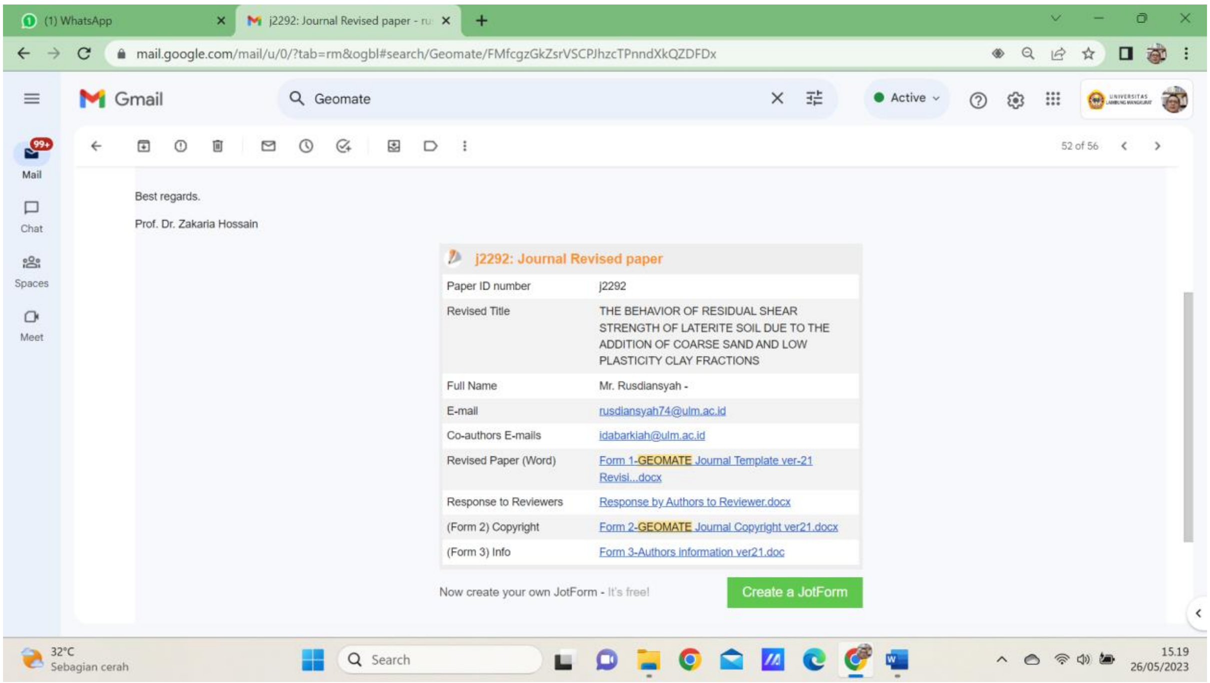
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Best regards.
Prof. Dr. Zakaria Hossain
j2292: Journal Revised paper
Paper ID number
j2292
Revised Title
THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS
Full Name
Mr. Rusdiansyah -
E-mail
rusdiansyah74@ulm.ac.id
Co-authors E-mails
idabarkiah@ulm.ac.id
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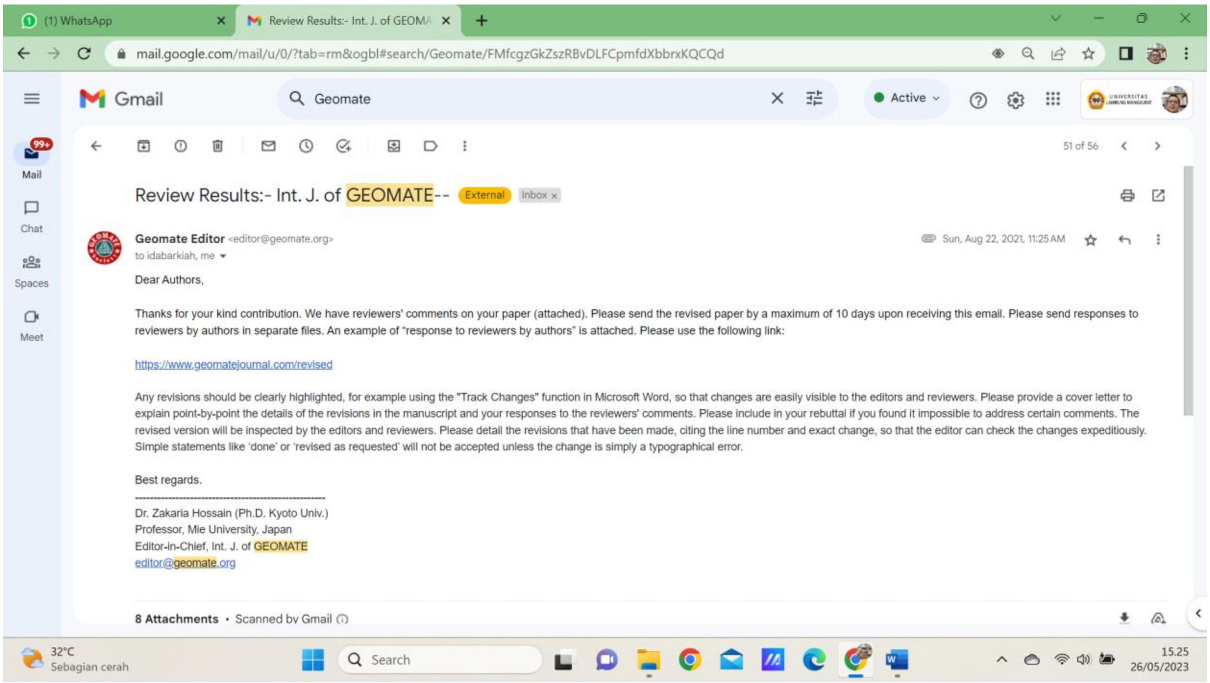
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Sun, Aug 22, 2021, 11:25 AM

Dear Authors,

Thanks for your kind contribution. We have reviewers' comments on your paper (attached). Please send the revised paper by a maximum of 10 days upon receiving this email. Please send responses to reviewers by authors in separate files. An example of "response to reviewers by authors" is attached. Please use the following link:

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Any revisions should be clearly highlighted, for example using the "Track Changes" function in Microsoft Word, so that changes are easily visible to the editors and reviewers. Please provide a cover letter to explain point-by-point the details of the revisions in the manuscript and your responses to the reviewers' comments. Please include in your rebuttal if you found it impossible to address certain comments. The revised version will be inspected by the editors and reviewers. Please detail the revisions that have been made, citing the line number and exact change, so that the editor can check the changes expeditiously. Simple statements like 'done' or 'revised as requested' will not be accepted unless the change is simply a typographical error.

Best regards.

Dr. Zakaria Hossain (Ph.D. Kyoto Univ.)
Professor, Mie University, Japan
Editor-in-Chief, Int. J. of GEOMATE
editor@geomate.org

8 Attachments • Scanned by Gmail

Saturday, August 14, 2021

GEOMATE Journal Review and Evaluation

Paper ID number

j2292

Paper Title

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

i. Originality

4

ii. Quality

5

iii. Relevance

5

iv. Presentation

4

v. Recommendation

5

Total (sum of i to v)

23

General comments

The Figure presentation should use the font size 10 and the graphic lines must be clear.

Mandatory changes

-

Suggested changes

Further research can be developed for variations of other additives

Reviewer's E-mail (Remove before sendiing to author)

GEOMATE Journal Review and Evaluation

Paper ID number

j2292

Paper Title

THE BEHAVIOR OF RESIDUALSHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

i. Originality

4

ii. Quality

4

iii. Relevance

4

iv. Presentation

4

v. Recommendation

4

Total (sum of i to v)

20

General comments

The manuscript is good enough.

Mandatory changes

Please do the revisions of the suggested changes.

Suggested changes

1. There are typo on the use of several words in the manuscript such as: virtually (line 6), soils-soil(line 7), inclusions-addition 9LINE 11), lateritic-laterite (line 16), Cempakasub-Cempaka.
2. Suggestion:
- Part Introduction
Several studies on the residual strength of non laterite clays have also been conducted since the late 1930s, Hvorslev [1], Hvorslev[2], and Haefeli[3]. Furthermore, Skempton[4] reported the residual shear strength of the soil using a conceptual model, based on experimental data. This attempt was succesively followed by Borowicka[5], Chandler[6], Chandler[7], and Kenney[8], where the results of Skempton[4] were refined over time.
- Conclusion no. 4, at the end of sentence: soil,. must be improved as soil.
- Research methods, material:
The sample of laterite soil on this research is taken from a quarry in Cempaka Sub District, Banjarbaru City, South Kalimantan Province, Indonesia.
The samples of coarse sand and clay fraction which have 6% of Placticity Index as the additional material in the mixture is taken from the Barito River, Barito Kuala Regency.

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GEOMATE Journal Review and Evaluation

Paper ID number

j2292

Paper Title

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

i. Originality

3

ii. Quality

4

iii. Relevance

4

iv. Presentation

4

v. Recommendation

4

Total (sum of i to v)

19

General comments

The authors report the results of a research on determining the behavior of residual shear strength in laterite soils and the effects of adding coarse sand and clay fractions, using direct shear analysis. The results of direct shear test showed that the inclusion of the coarse sand and clay portions was able to increase the residual shear strength parameters. An inclusion of clay content from 20-25% was recommended to be effective in increasing the shear strength of the residual soil. Since a low plasticity clay was used, risk of problematic clay behavior is minimized.

Mandatory changes

NA

Suggested changes

More discussion would be needed on the reason of reduction in residual shear strength after extensive wetting/drying condition.

Reviewer's E-mail (Remove before sendiing to author)

Sunday, August 15, 2021

GEOMATE Journal Review and Evaluation

Paper ID number

j2292

Paper Title

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

i. Originality

4

ii. Quality

5

iii. Relevance

4

iv. Presentation

4

v. Recommendation

4

Total (sum of i to v)

21

General comments

This paper presented very interesting results on the behavior of residual shear strength of laterite soil due to the addition of coarse sand and low plasticity clay fractions. Reviewer recommends this paper for acceptance with the following change.

Mandatory changes

1. Author names: Please check again.
2. Author address: Follow template.
3. Keywords: Follow template, four or five keywords (First characters of each key are in capital/uppercase letters), Italic
4. Citation: Multiple references [2,3] are each

numbered within one frame [1-3].
5. The second level heading: First characters of each word are in capital font.
6. All table: Follow template, no vertical lines or borders are needed.
7. All figure: Follow template, number figures consecutively in the order in which reference is first made to them in the text. Locate them after and close to where they are first referenced (Fig.1).
8. All figure: Draw figures clearly and embed text in the image properly and readable after printing. Font size in all figures must be 10 font size times new roman or similar.
9. Results: It should be change to heading "RESULTS AND DISCUSSION"
10. Conclusion: Make it concise form possibly.
11. References: Follow template.

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Reviewer's E-mail (Remove before sendiing to author)

Monday, August 16, 2021

GEOMATE Journal Review and Evaluation

Paper ID number

J2292

Paper Title

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

i. Originality

3

ii. Quality

3

iii. Relevance

3

iv. Presentation

2

v. Recommendation

3

Total (sum of i to v)

14

General comments

REVISED THE FORMAT OF THE PAPER BY FOLLOWING THE GEOMATE FORMAT.
SUB-TOPIC NEED TO BE HIGHLIGHTED.

HIGHLIGHT THE METHODOLOGY

Mandatory changes

REVISED THE FORMAT OF THE PAPER BY FOLLOWING THE GEOMATE FORMAT.
SUB-TOPIC NEED TO BE HIGHLIGHTED.

HIGHLIGHT THE METHODOLOGY

Suggested changes

REVISED THE FORMAT OF THE PAPER BY FOLLOWING THE GEOMATE FORMAT.
SUB-TOPIC NEED TO BE HIGHLIGHTED.

HIGHLIGHT THE METHODOLOGY

Reviewer's E-mail (Remove before sendiing to author)

Paper ID number: j2292

Paper Title: THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

i. Originality (out of 5): 4
ii. Quality (out of 5): 5
iii. Relevance (out of 5): 4
iv. Presentation (out of 5): 4
v. Recommendation (out of 5): 4

Overall (sum of i-v) : 21

General Comments
This paper presented very interesting results on the behavior of residual shear strength of laterite soil due to the addition of coarse sand and low plasticity clay fractions. Reviewer recommends this paper for acceptance with the following change.
Mandatory Changes
1. Author names: Please check again. 2. Author address: Follow template. 3. Keywords: Follow template, four or five keywords (First characters of each key are in capital/uppercase letters), Italic 4. Citation: Multiple references [2,3] are each numbered within one frame [1-3]. 5. The second level heading: First characters of each word are in capital font. 6. All table: Follow template, no vertical lines or borders are needed. 7. All figure: Follow template, number figures consecutively in the order in which reference is first made to them in the text. Locate them after and close to where they are first referenced (Fig.1). 8. All figure: Draw figures clearly and embed text in the image properly and readable after printing. Font size in all figures must be 10 font size times new roman or similar. 9. Results: It should be change to heading "RESULTS AND DISCUSSION" 10. Conclusion: Make it concise form possibly. 11. References: Follow template.
Suggested Changes
None

TAHAP 3 HASIL REVISI Ke-1 OLEH AUTHOR

Response by Authors to Reviewer's Remarks/Comments

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

Authors: Rusdiansyah, Adriani, and Ida Barkiah

No.	***Reviewer_A's Comments***	***Authors Response***
1	The Figure presentation should use the font size 10 and the graphic lines must be clear.	The font size in the figure is replaced in the revised manuscript, and the graphic lines is replaced in the revised manuscript.
2	Further research can be developed for variations of other additives	Thank you for the advice. Further research development will be carried out in the future
	Reviewer_B's Comments	***Authors Response***
1	There are typo on the use of several words in the manuscript such as: virtually (line 6), soilssoil(line 7), inclusions-addition 9LINE 11), lateriticlaterite (line 16), Cempakasub-Cempaka.	The sentence is replaced in the revised manuscript
2	- Part Introduction Several studies on the residual strength of non laterite clays have also been conducted since the late 1930s, Hvorslev [1], Hvorslev[2], and Haefeli[3]. Furthermore, Skempton[4] reported the residual shear strength of the soil using a conceptual model, based on experimental data. This attempt was succesively followed by Borowicka[5], Chandler[6], Chandler[7], and Kenney[8], where the results of Skempton[4] were refined over time.	The author has followed the Writing Guidelines, Form 1 Paper Template and Instruction in Geomate Journal, about citation and reference list. The author cannot carry out Reviewer_B's Comments because it is contrary to the Geomate journal writing guidelines.
3	Conclusion no. 4, at the end of sentence: soil,.must be improved as soil.	The sentence is revised in the manuscript
4	-Research methods, material: The sample of laterite soil on this research is taken from a quarry in Cempaka Sub District, Banjarbaru City, South Kalimantan Province, Indonesia. The samples of coarse sand and clay fraction which have 6% of Placticity Index as the additional material in the mixture is taken from the Barito River, Barito Kuala Regency.	The sentence is replaced in the revised manuscript

The authors appreciate the valuable comments from the Reviewers

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

*Rusdiansyah[1], Adriani[2] and Ida Barkiah[3]

[1]Faculty of Engineering, Universitas Lambung Mangkurat, Banjarbaru ; [2,3]Indonesia

*Corresponding Author, Received: 00 Oct. 2018, Revised: 00 Nov. 2018, Accepted: 00 Dec. 2018

ABSTRACT: Residual shear strength plays a very significant role in geotechnical engineering. This concept has contributed extensively to diverse studies on soil behaviors under the influence of shear failure, both in drained and saturated conditions. In terms of landslides, the assessment of the residual shear strength after an occurrence and the progressive failure risk of slope stability has been very useful. However, information on this shear property in laterite soil appears relatively minimal. This soil type is the most frequently applied embankment for road construction in every Kalimantan region. Therefore, the purpose of this research is to determine the behavior of residual shear strength in laterite soil and the effects of adding coarse sand and clay fractions, using direct shear analysis. Subsequently, the specimens were prepared by compaction tests to obtain the optimum moisture content and uniform density, using coarse sand of varying proportions, termed 5, 10, 15, 20 and 25%, while, the shear strength treatment with wetting and drying cycle conditions was conducted under 2, 4, 6, 8 and 10 days, respectively. The results showed that the addition of the coarse sand and clay (CL) portions was able to increase the residual shear strength parameters (cohesion and internal friction angle) by 4-6%, compared to the pure state. Therefore, the introduction of clay (CL) materials ranging from 20-25% appears suitable in enhancing the residual shear strength of laterite soil. However, the extensive wetting-drying cycle tends to reduce the peak and residual shear strength.

failure conditions [15].

Several studies on soil parameters, termed Atterberg limit, clay fraction, and so on, to determine residual strength have also been previously investigated, including [16] and [17]. This research intends to contribute to the development of subsequent slope stability analysis [18]. The residual strength is commonly defined as the minimum and constant drained shear strength needed for the soil to undergoes an extensive shear shift under normal stress [18], as represented in Figure 1.

Figure 1 shows that the residual shear strength of soil is never zero [19]. This factor depends not only on soil type, termed material, particle size and shape, surface roughness, and so, but also on soil situations, in terms of density, moisture content, frame structure, and test conditions, including the selection of shear testing equipment, normal stress, over-consolidation ratio, shear rate, acceleration, and so on [20].

ratio and the increase in contact solid particles due to the concentration of the mixture, [22], [23].

2. RESEARCH METHODS

Material

The sample of laterite soil on this research is taken from a quarry in Cempaka, Banjarbaru city, South Kalimantan province, Indonesia. This soil is commonly applied as an embankment material in road construction across the Kalimantan island. The samples of coarse sand and clay fraction which have 6% of Plasticity Index as the additional material in the mixture is taken from the Barito River, Barito Kuala Regency. This value is classified by the USCS standard as CL (low plasticity clay).

Table 1 shows the physical and mechanical characteristics of laterite soil, with a classification of CH (high plasticity soil) and a relatively high PI of 34.51%.

Based on the grain size distribution test results, the fine-grained soil showed a percentage above 50%. This outcome is also reviewed on the basis of

Editors-in-Chief

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1. Authors' Confirmation (Please answer the followings)

- Q1. Does the abstract contain "background, methodology, results, and conclusions" within 150 words to 250 words? Answer (Yes or No): Yes

- Q2. Have you filled in the gap in all pages (no blank space at all)? Answer (Yes or No): Yes

- Q3. Are the references inside the text according to the template? Answer (Yes or No): Yes

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- Q6. Does the paper length at least 6 to 8 pages or more)? Answer (Yes or No): Yes

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- Q15. Have you understood the guidelines given on the web page? Answer (Yes or No): Yes https://www.geomatejournal.com/guidelines

2. Authors' Biography (Please write all authors' full name and biodata here)

Example: Ms. Siti Hanggita is currently a Ph.D. student in the Department of Environmental Science and Technology, Graduate School of Bioresources, Mie University, Japan. Her email is email2@example.com

3. Authors' Contributions (Please write all authors' contribution here)

Please state the contributions made by each author in the preparation, development, and publication of this manuscript.

Example: Siti Hanggita Rachmawati: Conception, design, acquisition, analysis, and interpretation of data and drafting the article. Prof. Zakaria Hossain: Critical reviewing and final approval of the version to be submitted.

4. Ethics (Please provide ethical issues that may arise after the publication of your paper)

Example This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues.

5. Authors' Confirmation (Please answer the followings)

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- Q2. Have you filled in the gap in all pages (no blank space at all)? Answer (Yes or No): Yes
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- Q5. Are all Tables and Figures with the same font size ten and symbol etc.? Answer (Yes or No):Yes
- Q6. Does the paper length at least 6 to 8 pages or more)? Answer (Yes or No): Yes
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- Q9. Does the copyright signed by all authors? (Yes or No)? Answer (Yes or No): Yes
- Q10. Are all equations explicit and font size 10? (Yes or No)? Answer (Yes or No): Yes
- Q11. Does your paper contain at least ten recent references? Answer (Yes or No): Yes
- Q12. Have you proofread English grammar by a native? Answer (Yes or No): Yes
- Q13. Do you know the following free version of grammar correction? Answer (Yes or No): Yes
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- Q14. Does your paper contain at least 8 (eight) tables and figures? Answer (Yes or No): Yes

- Q15. Have you understood the guidelines given on the web page? Answer (Yes or No): Yes
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6. Authors' Biography (Please write all authors' full name and biodata here)

Example: Ms. Siti Hanggita is currently a Ph.D. student in the Department of Environmental Science and Technology, Graduate School of Bioresources, Mie University, Japan. Her email is email2@example.com

7. Authors' Contributions (Please write all authors' contribution here)

Please state the contributions made by each author in the preparation, development, and publication of this manuscript.

Example: Siti Hanggita Rachmawati: Conception, design, acquisition, analysis, and interpretation of data and drafting the article. Prof. Zakaria Hossain: Critical reviewing and final approval of the version to be submitted.

8. Ethics (Please provide ethical issues that may arise after the publication of your paper)

Example This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues.

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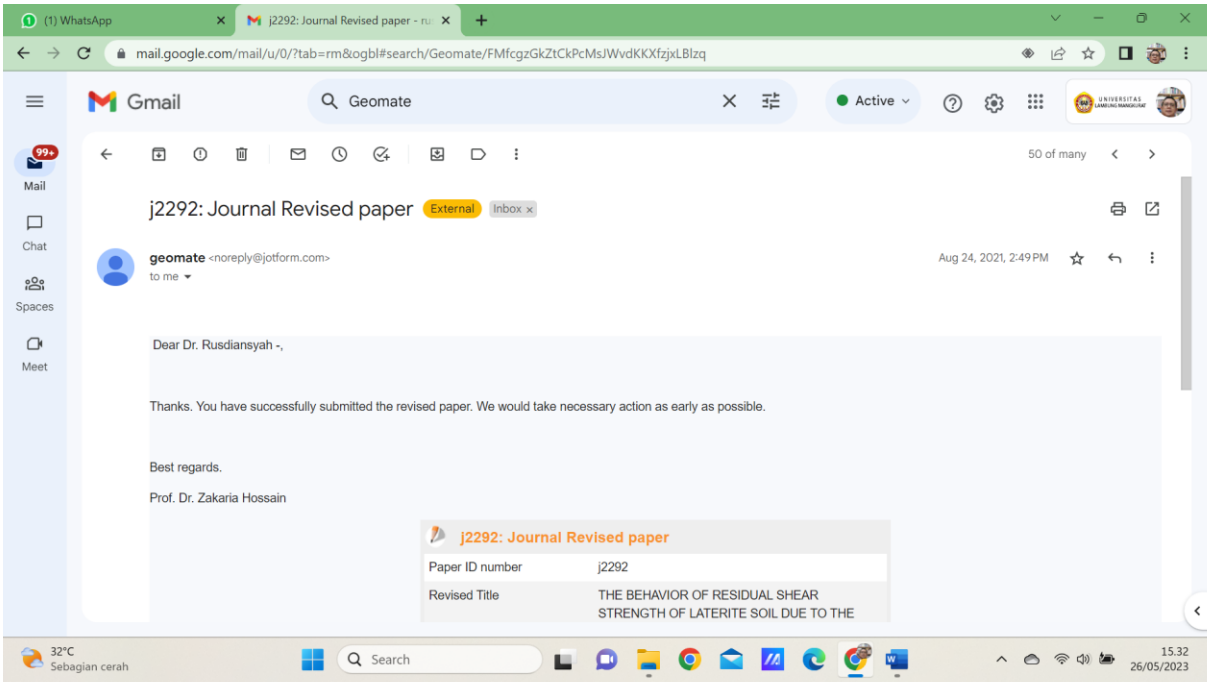

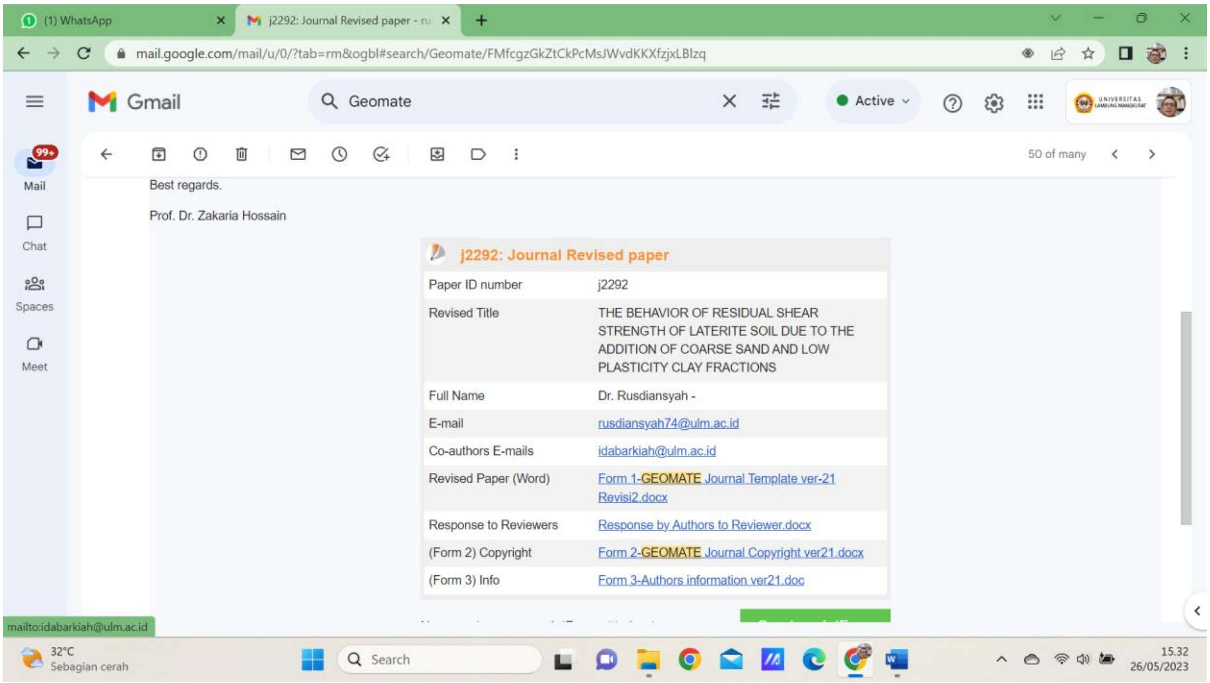

TAHAP 5 HASIL REVISI Ke-2 OLEH AUTHOR

Response by Authors to Reviewer's Remarks/Comments

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

Authors: Rusdiansyah, Adriani, and Ida Barkiah

No.	***Reviewer_A's Comments***	***Authors Response***
1	The Figure presentation should use the font size 10 and the graphic lines must be clear.	The font size in the figure is replaced in the revised manuscript, and the graphic lines is replaced in the revised manuscript.
2	Further research can be developed for variations of other additives	Thank you for the advice. Further research development will be carried out in the future.
	Reviewer_B's Comments	***Authors Response***
1	There are typo on the use of several words in the manuscript such as: virtually (line 6), soilssoil(line 7), inclusions-addition 9LINE 11), lateriticlaterite (line 16), Cempakasub-Cempaka.	The sentence is replaced in the revised manuscript.
2	- Part Introduction Several studies on the residual strength of non laterite clays have also been conducted since the late 1930s, Hvorslev [1], Hvorslev[2], and Haefeli[3]. Furthermore, Skempton[4] reported the residual shear strength of the soil using a conceptual model, based on experimental data. This attempt was succesively followed by Borowicka[5], Chandler[6], Chandler[7], and Kenney[8], where the results of Skempton[4] were refined over time.	The author has followed the Writing Guidelines, Form 1 Paper Template and Instruction in Geomate Journal, about citation and reference list. The author cannot carry out Reviewer_B's Comments because it is contrary to the Geomate journal writing guidelines.
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	Reviewer_C's Comments	***Authors Response***
1	The authors report the results of a research on determining the behavior of residual shear strength in laterite soils and the effects of adding coarse sand and clay fractions, using direct shear analysis. The results of direct shear test showed that the inclusion of the coarse sand and clay portions was able to increase the residual shear strength parameters. An inclusion of clay content from 20-25% was recommended to be effective in increasing the shear strength of the residual soil. Since a low plasticity clay was used, risk of problematic clay behavior is minimized.	Yes, that's true, The authors appreciate the comments from the reviewer C. Thank you very much.
2	More discussion would be needed on the reason of reduction in residual shear strength after extensive wetting/drying condition.	More discussion about the reason of reduction in residual shear strength after extensive wetting/drying condition added in the revised manuscript.
	Reviewer_D's Comments	***Authors Response***
1	This paper presented very interesting results on the behavior of residual shear strength of laterite soil due to the addition of coarse sand and low plasticity clay fractions. Reviewer recommends this paper for acceptance with the following change.	The authors appreciate the comments from the reviewer D. Thank you very much.
2	1. Author names: Please check again. 2. Author address: Follow template. 3. Keywords: Follow template, four or five keywords (First characters of each key are in capital/uppercase letters), Italic 4. Citation: Multiple references [2,3] are each numbered within one frame [1-3]. 5. The second level heading: First characters of each word are in capital font. 6. All table: Follow template, no vertical lines or borders are needed. 7. All figure: Follow template, number figures consecutively in the order in which reference is first made to them in the text. Locate them after and close to where they are first referenced (Fig.1). 8. All figure: Draw figures clearly and embed text in the image properly and readable after printing. Font size in all figures must be 10 font size times new roman or similar.	1. Author names is checked in the revised manuscript. 2. Author address is followed template in the revised manuscript. 3. Keywords is followed template in the revised manuscript. 4. Citation is followed template in the revised manuscript. 5. The second level heading is followed template in the revised manuscript. 6. All table is followed template in the revised manuscript. 7, 8. All figure is followed template in the revised manuscript. Fig.1 is relocated in the revised manuscript 9. "RESULTS AND DISCUSSION" is replaced with Results in the revised manuscript.

	9. Results: It should be change to heading "RESULTS AND DISCUSSION" 10. Conclusion: Make it concise form possibly. 11. References: Follow template.	10. Conclusion is made it concise form possibly in the revised manuscript. 11. References followed template in the revised manuscript.
	Reviewer_E's Comments	***Authors Response***
1	REVISED THE FORMAT OF THE PAPER BY FOLLOWING THE GEOMATE FORMAT. SUB-TOPIC NEED TO BE HIGHLIGHTED. HIGHLIGHT THE METHODOLOGY	Same as Reviewer_D's Comments Manuscript is revised and followed the format of the paper by following the geomate format. Sub-topic needed to be highlighted. the methodology was highlight

The authors appreciate the valuable comments from the Reviewers

KUTIPAN NASKAH REVISI Ke-2 OLEH AUTHOR

International Journal of GEOMATE, Month, Year Vol.00, Issue 00, pp.000-000
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/Year.Issue.PaperID
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

*Rusdiansyah[1], Adriani[2] and Ida Barkiah[3]

[1,2,3]Faculty of Engineering, University of Lambung Mangkurat, Banjarbaru, Indonesia

*Corresponding Author, Received: 00 Oct. 2018, Revised: 00 Nov. 2018, Accepted: 00 Dec. 2018

ABSTRACT: Residual shear strength plays a very significant role in geotechnical engineering. This concept has contributed extensively to diverse studies on soil behaviors under the influence of shear failure, both in drained and saturated conditions. In terms of landslides, the assessment of the residual shear strength after an occurrence and the progressive failure risk of slope stability has been very useful. However, information on this shear property in laterite soil appears relatively minimal. This soil type is the most frequently applied embankment for road construction in every Kalimantan region. Therefore, the purpose of this research is to determine the behavior of residual shear strength in laterite soil and the effects of adding coarse sand and clay fractions, using direct shear analysis. Subsequently, the specimens were prepared by compaction tests to obtain the optimum moisture content and uniform density, using coarse sand of varying proportions, termed 5, 10, 15, 20 and 25%, while, the shear strength treatment with wetting and drying cycle conditions was conducted under 2, 4, 6, 8 and 10 days, respectively. The results showed that the addition of the coarse sand and clay (CL) portions was able to increase the residual shear strength parameters (cohesion and internal friction angle) by 4-6%, compared to the pure state. Therefore, the introduction of clay (CL) materials ranging from 20-25% appears suitable in enhancing the residual shear strength of laterite soil. However, the extensive wetting-drying cycle tends to reduce the peak and residual shear strength.

Keywords: Shear strength, Residual shear strength, Laterite soil, Coarse sand, Low plasticity clay

of laterite soil after landslide appears relatively insignificant. This is related to the behavior of the residual shear strength of the embankment with laterite soil that shows the most frequently used for road construction in virtually every Kalimantan region in Indonesia.

Several studies on the residual strength of non-laterite clays have also been conducted since the late 1930s, including by scientists [1-3]. Furthermore, Skempton [4] reported the residual shear strength of the soil using a conceptual model, based on experimental data. This attempt was successively followed by scientists [5-8], where the results of Skempton [4] were refined over time.

The residual shear strength forms a key parameter required for the analysis and design of slopes, retaining walls and fine-grained soil foundations under relatively massive deformations [9]. This property is mainly applied for two purposes. The first effort involves calculating the extent of slope decrease in an earthquake [10], followed by evaluating the previous slope stability [11].

Residual shear strength is important in comprehending the stability of past landslides, assessment of engineering properties of soil deposits, comprising pre-existing shear surfaces and the progressive failure risk on new and current slopes [11-13]. The variable also plays a significant role in the design of corrective action [14] and understanding its position under initial failure conditions [15].

Several studies on soil parameters, termed Atterberg limit, clay fraction, and so on, to determine residual strength have also been previously investigated, including scientists [16, 17]. This research intends to contribute to the development of subsequent slope stability analysis [18]. The residual strength is commonly defined as

investigations, the shear rate varied between 0.0001-100 mm/min. This observation concluded that a positive relationship between the shear transfer rate and the clay's residual strength was observed, with higher fractions and displacement above 50% and 1 mm/min, respectively. Additionally, the shear test has also been conducted on a mixture of soil and sodium chloride to examine the salt concentration effects. The results showed that the positive impact becomes more intense with increasing salt concentration. This increment is possibly comprehended by the decrease in the void ratio and the increase in contact solid particles due to the concentration of the mixture [22, 23].

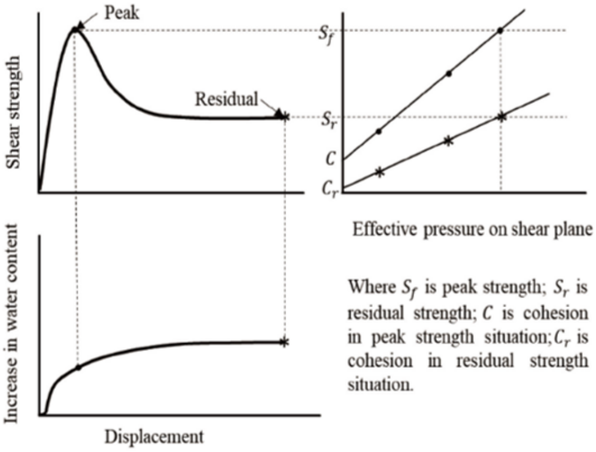

Fig. 1 Consept of residual strength in shear characteristics

2. RESEARCH METHODS

2.1 Material

The sample of laterite soil on this research is cohesion among soil grains contained in the mixture was known to decline, due to additional coarse sand.

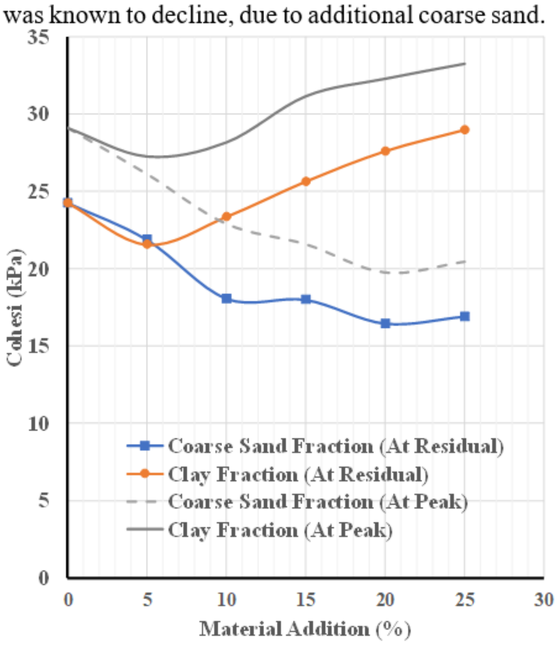

Fig. 4 The Relationship between the Added Materials and Soil Cohesion at Peak and Residual Conditions.

3.3 Effect of the addition of sand and clay fractions on friction angle in laterite soil at peak and residual conditions

Figure 5 shows the effects of adding sand and clay fractions on the friction angle in laterite soil at both peak and residual conditions. Based on the graph, the internal friction angle at peak position was greater, compared to the residual state. This statement applies to the two added materials, termed sand and clay.

The comparison shows that the internal friction angle at the residual conditions decreased by 12 and 23% in the coarse sand and clay fractions, respectively, at peak conditions. In addition, the although the friction between the sand fraction and the original soil becomes more extensive. This conclusion is also related to the previous studies of Heidemann *et al.* [25], where the shear strain instigated a minimal decline in the friction angle, compared to the saturated peak condition (critical value). However, the displacement required to achieve this equilibrium appeared very significant.

This statement also relates to the shape of the particle size distribution curve obtained before and after the shear test. Therefore, most of the soil clusters disintegrated during sample preparation. Direct shear assessments showed that the normal effective stress greatly influenced the particle deformation mechanism. This situation results to the reduction in the friction angle at increasing normal effective stress, under residual conditions [25].

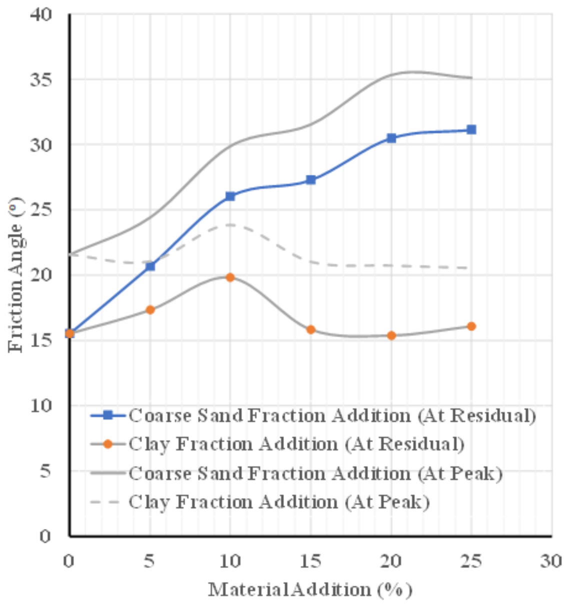

Fig. 5 The Relationship of Material Addition and Friction Angle at Peak and Residual Conditions.

compressibility index (Cc) values. Therefore, the selected laterite soil is plastic in nature, and is easily compressed, but appears less profitable in constructing road embankments.

Table 1. Characteristics of Laterite Soil

Properties	Value
- Volumetric weight, γ (kN/m³)	17.38
- Water content, Wn (%)	40.636
- Specific Gravity, Gs	2.65
- Liquid limit, LL (%)	62.91
- Plastic limit, PL (%)	28.40
- Plastic Index, PI (%)	34.51
- Cohesion, C (kPa)	26
- Internal angle, (°)	22.61
- Compressibility index, Cc	0.51
- Swelling Index, Cs	0.07
- Grained of Distributions	
- Gravel (>2mm), %	16.99
- Coarse sand (0.6-2mm), %	7.85
- Medium sand (0.2-0.6mm), %	7.21
- Fine sand (0.05-0.2mm), %	6.42
- Silt-clay (0.002-0.05mm), %	24.79
- Clay (<0.002mm), %	36.74
- Sensitivity	1.1
- USCS classification	CH

2.2 Testing procedure

The laboratory research activities involved evaluating the physical and mechanical properties, including the shear strength, with the addition of sand and clay fractions at 5, 10, 15, 20 and 25%

3. RESULTS

3.1 Grain size distribution of Laterite soil mixture

Figure 3 shows the grain size distribution curve for each mixture. The shape of the curve for laterite soil and clay components rests on the upper side of the laterite soil and coarse sand blend, particularly the curve line on the fine-grained soil fraction, including silt and coarse sand.

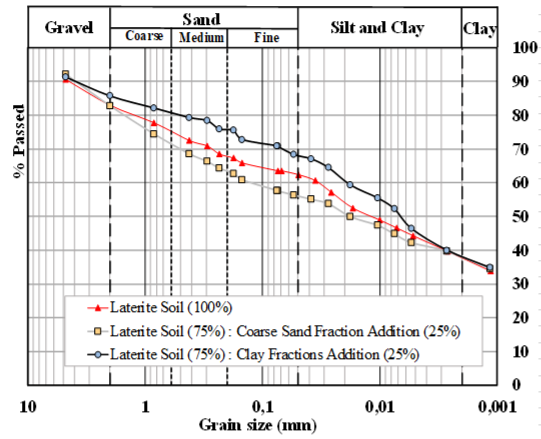

Fig. 3 Grain Size Distribution Curve

3.2 Effect of the addition sand and clay fraction on the cohesion value of Laterite soil at peak and residual conditions

strength value on the condition of the wetting and drying cycle on day 10 was 17% greater than on the previous days, which was only 5.8%. In addition, the comparison of the peak shear strength and residual shear strength on the 8th to the 10th day is relatively small, namely 27% compared to the 2nd day to the 6th day which is 34.4%.

In addition, a loss in suction power was known to reduce the shear strength of the residual unsaturated soil [9]. Also, the contribution of matric suction to residual shear strength decreased significantly with increasing matric suction, although the influence was drastically displaced with extensive normal stress. This behavior is caused by a reduction in the area of the water menisci in contact with the aggregate.

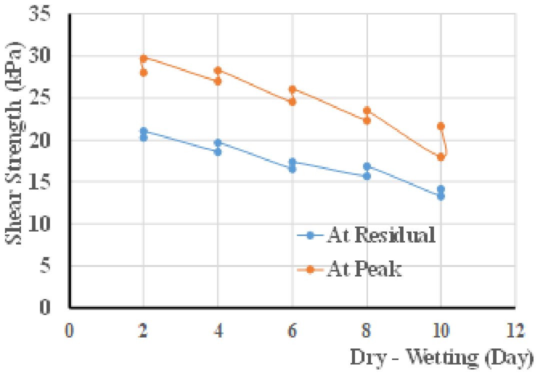

Fig. 8 The Relationship between Wet-Dry Laterite Soil Conditions on Shear Strength at Peak and Residual Conditions.

4. CONCLUSION

Based on the analysis results and discussion, certain deductions were generated, including:

1. The addition of the coarse sand and clay (CL) fractions in laterite soil increased the residual shear strength parameters.
2. The residual shear strength of the laterite soil mixed with the low plasticity clay fraction (CL) was higher than the pure state.
3. Additional clay materials, with a percentage between 20-25%, were applied to improve the residual shear strength of the laterite soil, must be improved as soil.
4. Extensive wetting-drying cycles tend to lower the peak and residual shear strength.
5. During the change from wet to dry phase, the shear strength increased in both peak and residual conditions, although not very significant.
6. Under a similar interval, the residual shear strength appeared minimal in wet conditions, compared to the dry state.

5. ACKNOWLEDGMENT

The author is grateful to the Universitas Lambung Mangkurat, for funding this research for the 2021 fiscal year through the Research and Service Institute.

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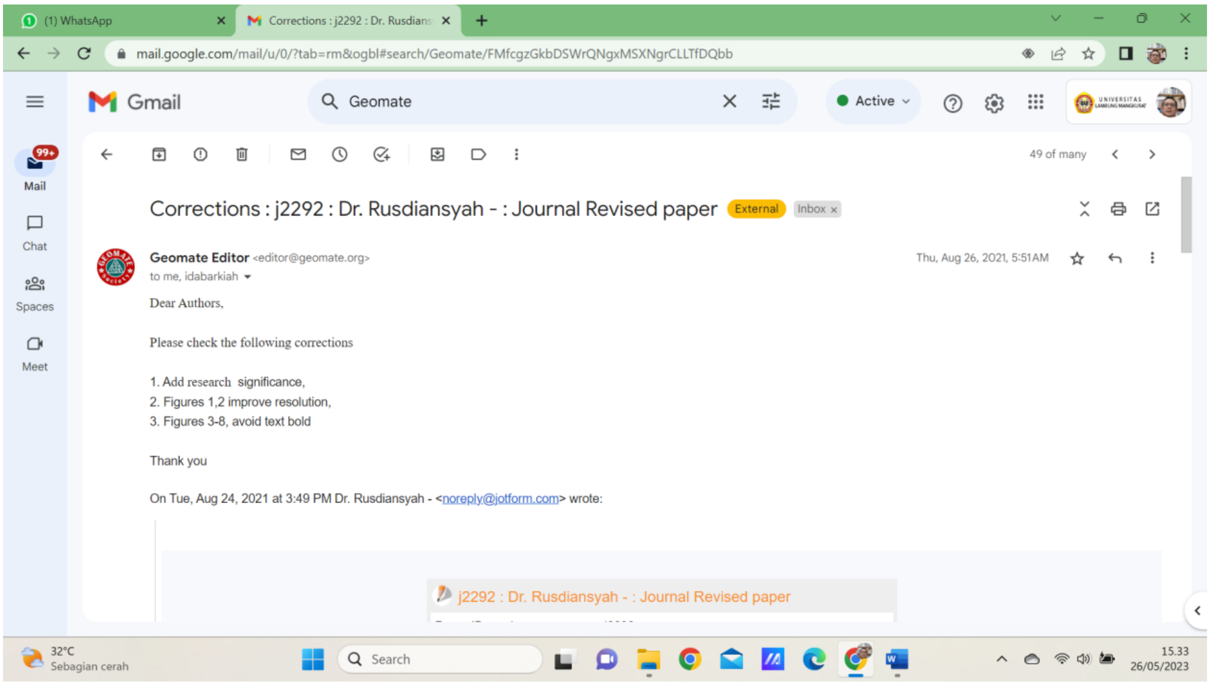
TAHAP 6 HASIL REVIEW : PERMINTAAN REVISI Ke-3



Corrections : j2292 : Dr. Rusdiansyah - : Journal Revised paper

Geomate Editor <editor@geomate.org>
to me, idabarkiah

Thu, Aug 26, 2021, 5:51 AM

Dear Authors,

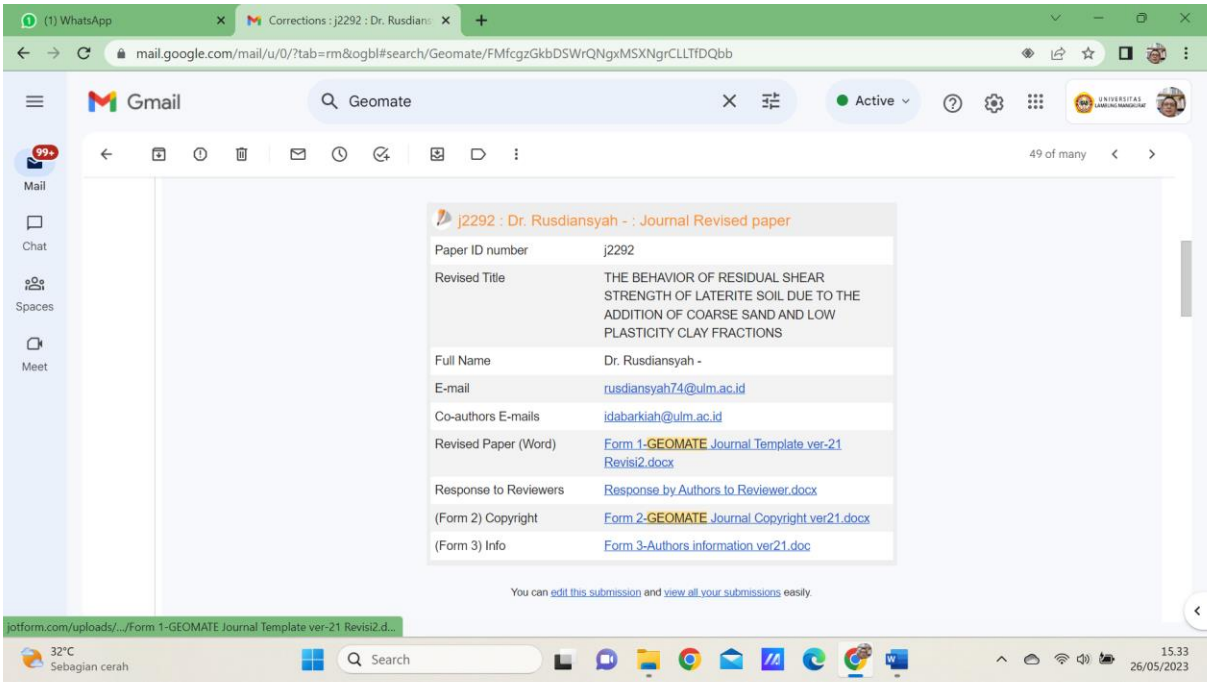
Please check the following corrections

1. Add research significance,
2. Figures 1,2 improve resolution,
3. Figures 3-8, avoid text bold

Thank you

On Tue, Aug 24, 2021 at 3:49 PM Dr. Rusdiansyah - <noreply@jotform.com> wrote:

j2292 : Dr. Rusdiansyah - : Journal Revised paper



j2292 : Dr. Rusdiansyah - : Journal Revised paper

Paper ID number	j2292
Revised Title	THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS
Full Name	Dr. Rusdiansyah -
E-mail	rusdiansyah74@ulm.ac.id
Co-authors E-mails	idabarkiah@ulm.ac.id
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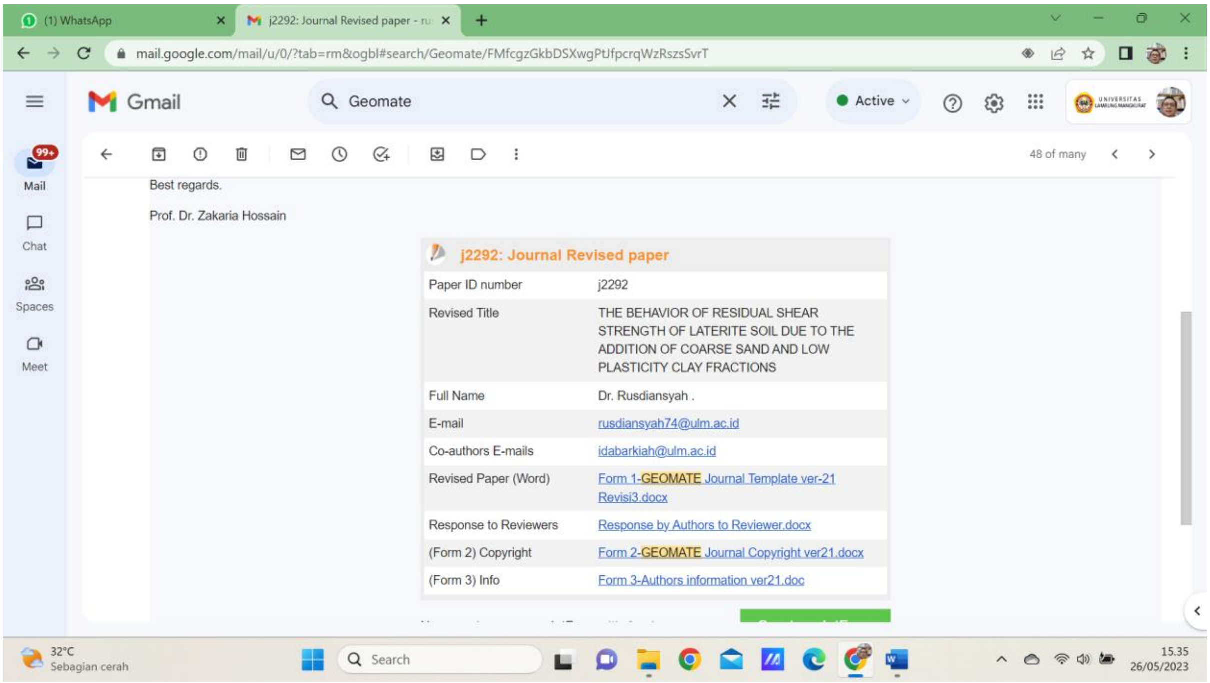
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Prof. Dr. Zakaria Hossain
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Revised Title
THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS
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Co-authors E-mails
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Revised Paper (Word)
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Response by Authors to Reviewer's Remarks/Comments

THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

Authors: Rusdiansyah, Adriani, and Ida Barkiah

No.	***Reviewer_A's Comments***	***Authors Response***
1	The Figure presentation should use the font size 10 and the graphic lines must be clear.	The font size in the figure is replaced in the revised manuscript, and the graphic lines is replaced in the revised manuscript.
2	Further research can be developed for variations of other additives	Thank you for the advice. Further research development will be carried out in the future.
	Reviewer_B's Comments	***Authors Response***
1	There are typo on the use of several words in the manuscript such as: virtually (line 6), soilssoil(line 7), inclusions-addition 9LINE 11), lateriticlaterite (line 16), Cempakasub-Cempaka.	The sentence is replaced in the revised manuscript.
2	- Part Introduction Several studies on the residual strength of non laterite clays have also been conducted since the late 1930s, Hvorslev [1], Hvorslev[2], and Haefeli[3]. Furthermore, Skempton[4] reported the residual shear strength of the soil using a conceptual model, based on experimental data. This attempt was succesively followed by Borowicka[5], Chandler[6], Chandler[7], and Kenney[8], where the results of Skempton[4] were refined over time.	The author has followed the Writing Guidelines, Form 1 Paper Template and Instruction in Geomate Journal, about citation and reference list. The author cannot carry out Reviewer_B's Comments because it is contrary to the Geomate journal writing guidelines.
3	Conclusion no. 4, at the end of sentence: soil,.must be improved as soil.	The sentence is revised in the revised manuscript.
4	-Research methods, material: The sample of laterite soil on this research is taken from a quarry in Cempaka Sub District, Banjarbaru City, South Kalimantan Province, Indonesia. The samples of coarse sand and clay fraction which have 6% of Placticity Index as the additional material in the mixture is taken from the Barito River, Barito Kuala Regency.	The sentence is replaced in the revised manuscript.

	Reviewer_C's Comments	***Authors Response***
1	The authors report the results of a research on determining the behavior of residual shear strength in laterite soils and the effects of adding coarse sand and clay fractions, using direct shear analysis. The results of direct shear test showed that the inclusion of the coarse sand and clay portions was able to increase the residual shear strength parameters. An inclusion of clay content from 20-25% was recommended to be effective in increasing the shear strength of the residual soil. Since a low plasticity clay was used, risk of problematic clay behavior is minimized.	Yes, that's true, The authors appreciate the comments from the reviewer C. Thank you very much.
2	More discussion would be needed on the reason of reduction in residual shear strength after extensive wetting/drying condition.	More discussion about the reason of reduction in residual shear strength after extensive wetting/drying condition added in the revised manuscript.
	Reviewer_D's Comments	***Authors Response***
1	This paper presented very interesting results on the behavior of residual shear strength of laterite soil due to the addition of coarse sand and low plasticity clay fractions. Reviewer recommends this paper for acceptance with the following change.	The authors appreciate the comments from the reviewer D. Thank you very much.
2	1. Author names: Please check again. 2. Author address: Follow template. 3. Keywords: Follow template, four or five keywords (First characters of each key are in capital/uppercase letters), Italic 4. Citation: Multiple references [2,3] are each numbered within one frame [1-3]. 5. The second level heading: First characters of each word are in capital font. 6. All table: Follow template, no vertical lines or borders are needed. 7. All figure: Follow template, number figures consecutively in the order in which reference is first made to them in the text. Locate them after and close to where they are first referenced (Fig.1). 8. All figure: Draw figures clearly and embed text in the image properly and readable after printing. Font size in all figures must be 10 font size times new roman or similar.	1. Author names is checked in the revised manuscript. 2. Author address is followed template in the revised manuscript. 3. Keywords is followed template in the revised manuscript. 4. Citation is followed template in the revised manuscript. 5. The second level heading is followed template in the revised manuscript. 6. All table is followed template in the revised manuscript. 7, 8. All figure is followed template in the revised manuscript. Fig.1 is relocated in the revised manuscript 9. "RESULTS AND DISCUSSION" is replaced with Results in the revised manuscript.

	9. Results: It should be change to heading "RESULTS AND DISCUSSION" 10. Conclusion: Make it concise form possibly. 11. References: Follow template.	10. Conclusion is made it concise form possibly in the revised manuscript. 11. References followed template in the revised manuscript.
	Reviewer_E's Comments	***Authors Response***
1	REVISED THE FORMAT OF THE PAPER BY FOLLOWING THE GEOMATE FORMAT. SUB-TOPIC NEED TO BE HIGHLIGHTED. HIGHLIGHT THE METHODOLOGY	Same as Reviewer_D's Comments Manuscript is revised and followed the format of the paper by following the geomate format. Sub-topic needed to be highlighted. the methodology was highlight
	Editor_E's Comments	***Authors Response***
1	Please check the following corrections 1. Add research significance, 2. Figures 1,2 improve resolution, 3. Figures 3-8, avoid text bold	Thank you for the correction 1. Research significance is added : 18th reference, 19th reference, 20th reference 2. Figures 1,2 is improved resolution, 3. Figures 3-8 has avoid text bold

The authors appreciate the valuable comments from the Reviewers and Editor.

Thank you very much

KUTIPAN NASKAH REVISI Ke-3 OLEH AUTHOR

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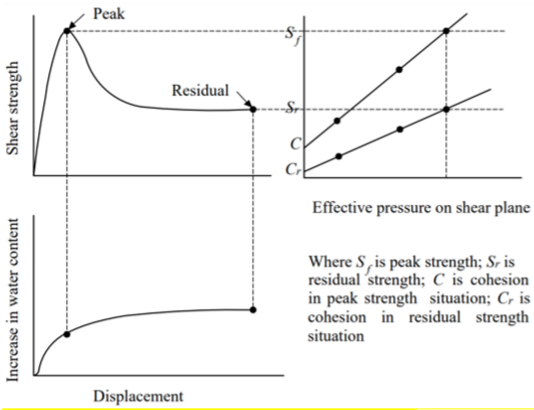

Fig. 1 Consept of residual strength in shear characteristics

2. RESEARCH METHODS

2.1 Material

The sample of laterite soil on this research is taken from a quarry in Cempaka, Banjarbaru city,

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- Cohesion, C (kPa)	26
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- Clay (<0.002mm), %	36.74
- Sensitivity	1.1
- USCS classification	CH

2.2 Testing procedure

The laboratory research activities involved evaluating the physical and mechanical properties, including the shear strength, with the addition of sand and clay fractions at 5, 10, 15, 20 and 25% respectively. Soil specimens for the shear strength test were obtained from the standard compaction results, with 80-90% maximum density. This assessment was conducted for each variation, without the addition of mixing material in wetting and drying cycles, but at the peak and residual shear strength for 2, 4, 6, 8, and 10 days.

Figure 2 represents the main direct shear test tool in the present research. This also refers to the test method conducted by So and Okada [27].

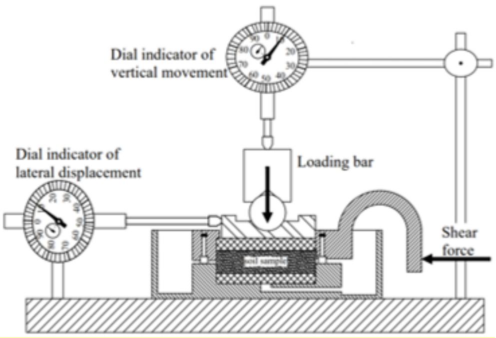

Fig. 2 Scheme for the Direct Shear Test Tool

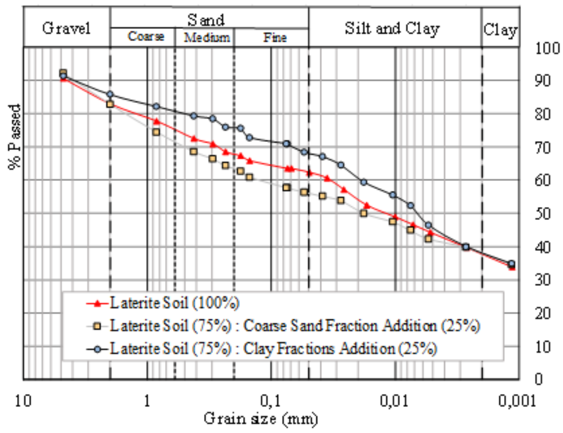

Fig. 3 Grain Size Distribution Curve

3.2 Effect of the addition sand and clay fraction on the cohesion value of Laterite soil at peak and residual conditions

Figure 4 shows the effects of adding sand and clay fractions on the soil cohesion value at peak and residual conditions. Based on the graph, the soil cohesion value at peak state generally appears greater, compared to the residual position. This statement applies to both added soil types, including coarse sand and clay fractions. Also, the residual cohesion values decreased towards the peak condition in the sand and clay materials by an average of 17 and 13%, respectively. This outcome indicates a cohesion value of the residual soil in the coarse sand and clay fractions at 83 and 87%, correspondingly, after the added materials. However, compared to the cohesion of plain laterite soil, the value was 4% lower than the added material of 20-25% clay fraction.

Figure 4, also shows an increase in the residual cohesion along with the percentage of added clay fractions, but contrary to the sand components. Theoretically, the addition of clay fractions was believed to enhance the soil friction, leading to an increased bond between the grains. Also, the cohesion among soil grains contained in the mixture was known to decline, due to additional coarse sand.

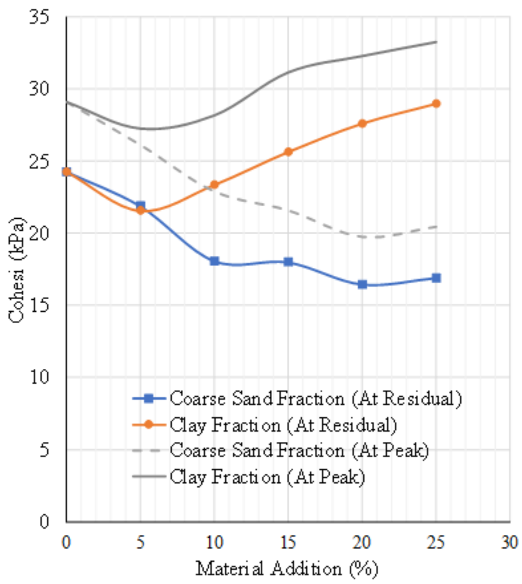

Fig. 4 The Relationship between the Added Materials and Soil Cohesion at Peak and Residual Conditions.

3.3 Effect of the addition of sand and clay fractions on friction angle in laterite soil at peak and residual conditions

Figure 5 shows the effects of adding sand and clay fractions on the friction angle in laterite soil at both peak and residual conditions. Based on the graph, the internal friction angle at peak position was greater, compared to the residual state. This statement applies to the two added materials, termed sand and clay.

The comparison shows that the internal friction angle at the residual conditions decreased by 12 and 23% in the coarse sand and clay fractions, respectively, at peak conditions. In addition, the relationship curve indicates that the residual state of added sand particles generated the maximum friction angle, compared to clay. This outcome also recorded a residual shear strength of 88 and 77% in Heidemann *et al*. [28], where the shear strain instigated a minimal decline in the friction angle, compared to the saturated peak condition (critical value). However, the displacement required to achieve this equilibrium appeared very significant.

This statement also relates to the shape of the particle size distribution curve obtained before and after the shear test. Therefore, most of the soil clusters disintegrated during sample preparation. Direct shear assessments showed that the normal effective stress greatly influenced the particle deformation mechanism. This situation results to the reduction in the friction angle at increasing normal effective stress, under residual conditions [28].

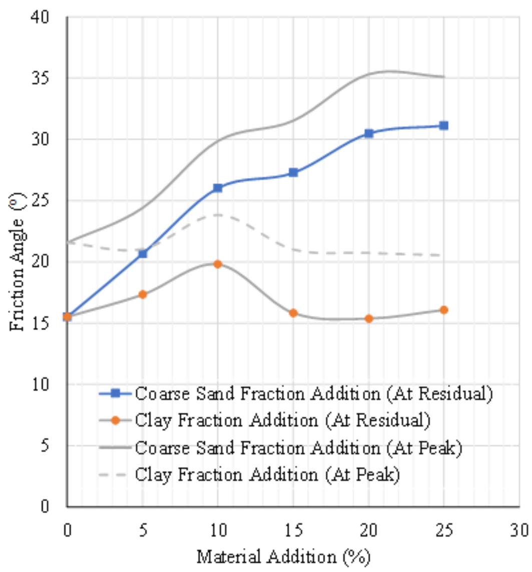

Fig. 5 The Relationship of Material Addition and Friction Angle at Peak and Residual Conditions.

3.4 Effect of plastic index on shear strength at peak and residual conditions

involvement of the coarse sand fractions that tends to reduce the cavities between soil grains.

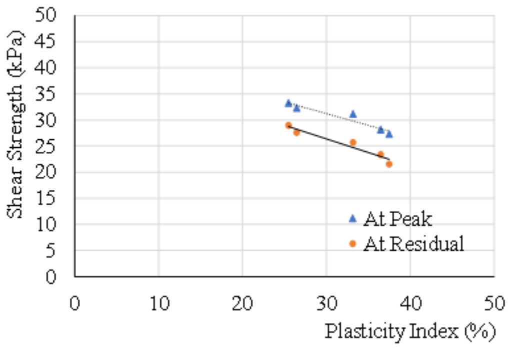

Fig. 6 The Relationship between Plasticity Index and Shear Strength at Peak and Residual Conditions.

3.5 Effect of the addition of sand and clay fractions on the shear strength of laterite soil at peak and residual conditions

Figure 7 represents the relationship between the added material and shear strength at both peak and residual conditions. Under these circumstances, the addition of coarse sand and clay fractions significantly influenced the shear strength. However, the soil retains the minimal residual shear strength after experiencing peak conditions. This observation corresponded to previous research [21], where the soil's residual shear strength was not zero.

Figure 7 also shows that the addition of the clay fractions instigated a higher residual shear strength than the pure sample, based on a constant percentage of added materials. According to the percentage ratio, the resulting graph and the comparison indicated a decline in the residual shear strength by average values of 17.4 and 16.6% in coarse sand and clay components, respectively. This peak outcome also observed the residual shear strength of 82.6 and 83.4% for coarse sand and clay samples after the added materials.

Furthermore, the soil mixture with 20-25% clay fractions tends to generate a minimal residual shear strength, compared to the added sand fractions.

In other research results, the clay content generated very minimal residual shear strength. This condition was due to the alignment of particles parallel to the shear surface and the disintegration of certain soil groups rather than the damage to individual soil particles. Conversely, the existence of various soil types or groupings described the significant difference between peak and residual conditions in direct shear tests [28].

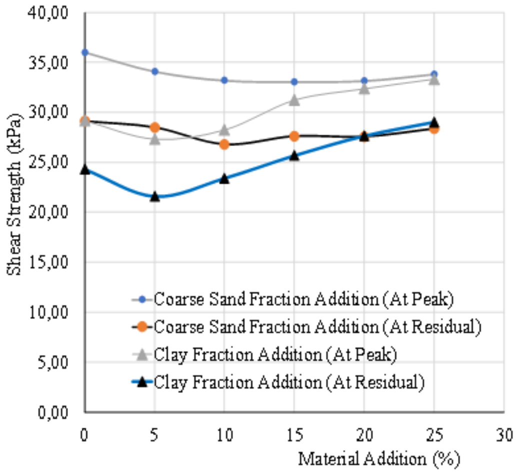

Fig. 7 The Relationship of Material Addition and Soil Shear Strength at Peak and Residual Conditions.

3.6 Effect of wet-dry conditions on laterite soil shear strength at peak and residual conditions

Figure 8 shows the relationship between wetting and drying cycles. Extensive periods tend to reduce the shear strength at normal and residual conditions. This decline generated average values of 5.11 and 4.92% for normal and residual conditions, respectively. Consequently, the graph confirmed a decrease in the residual shear strength by an average of 26.42% against the normal conditions, under constant wetting and drying cycles.

Figure 8 also indicates an increased shear strength dues to the changes from wetting to drying phases, although not very significantly. Conversely, the transition from drying to wetting phase

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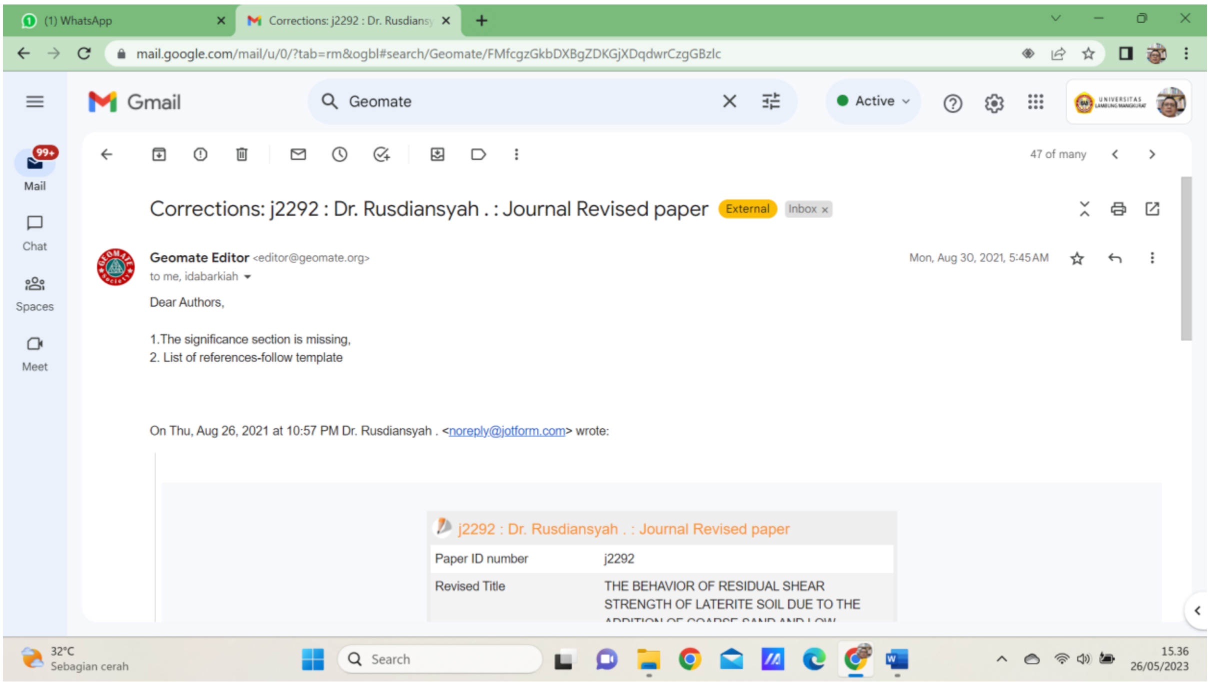

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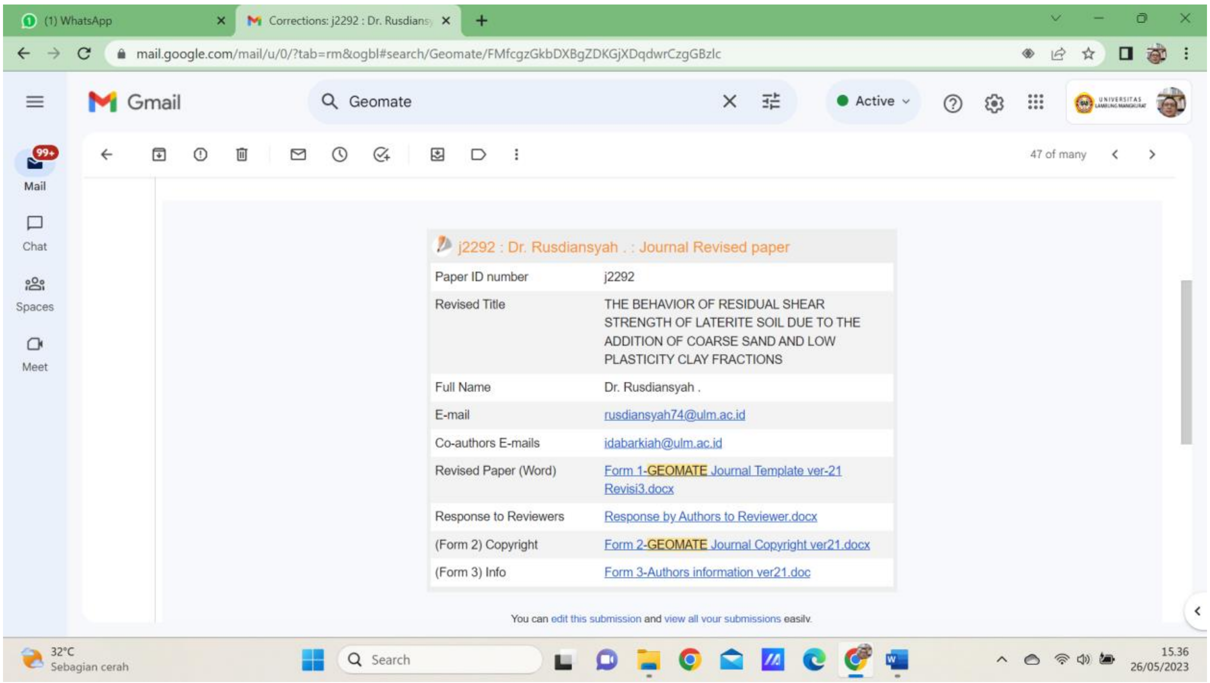

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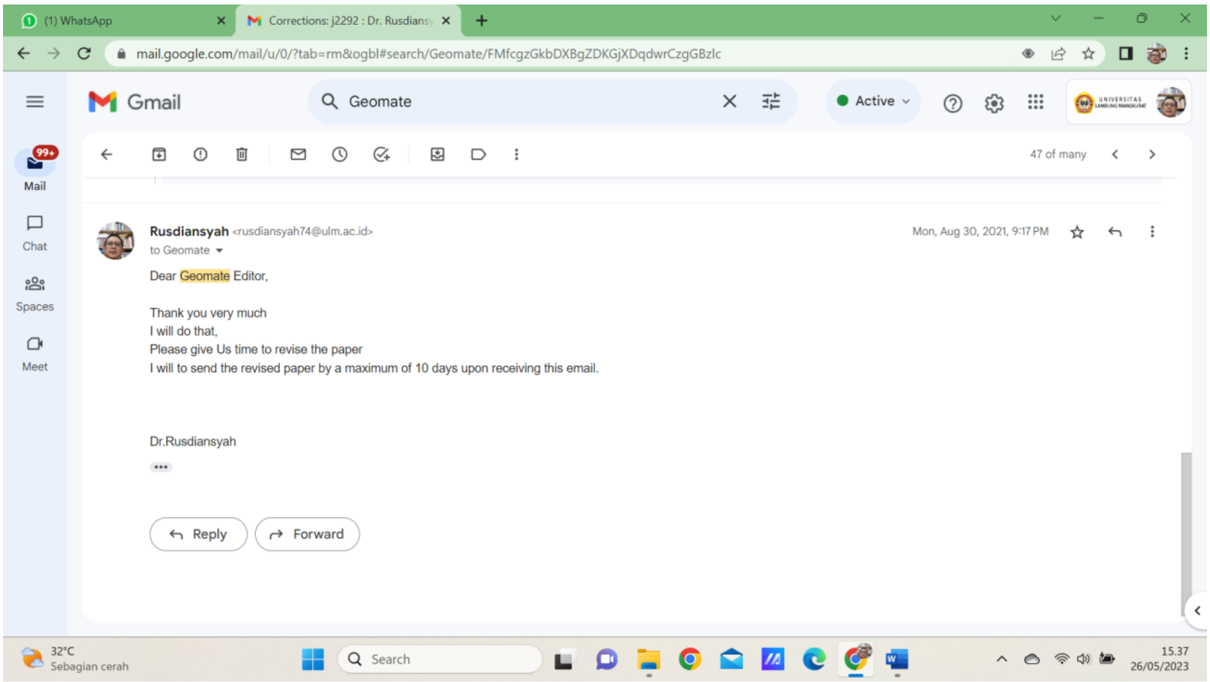
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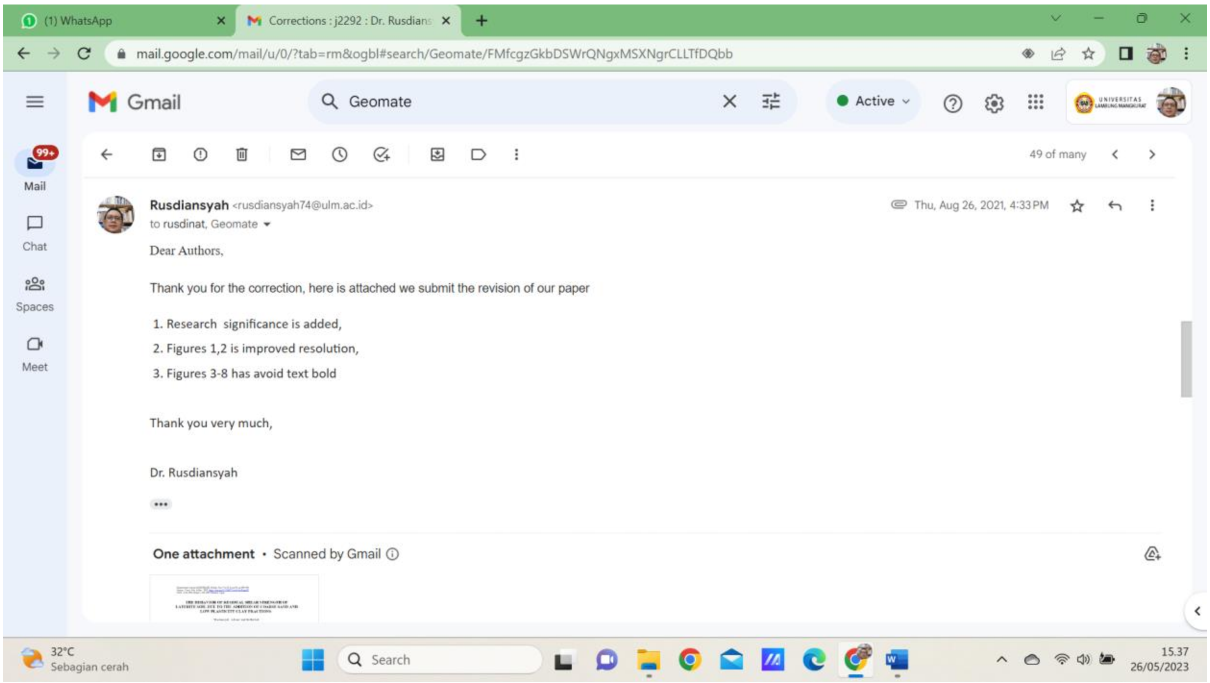
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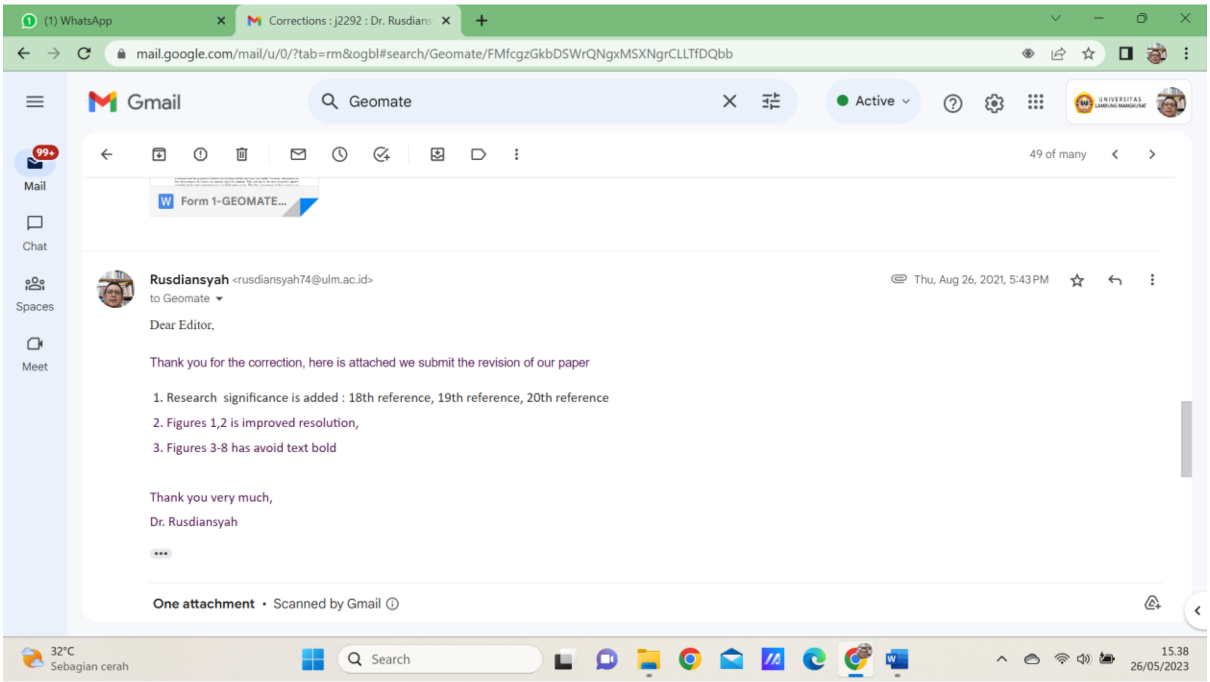

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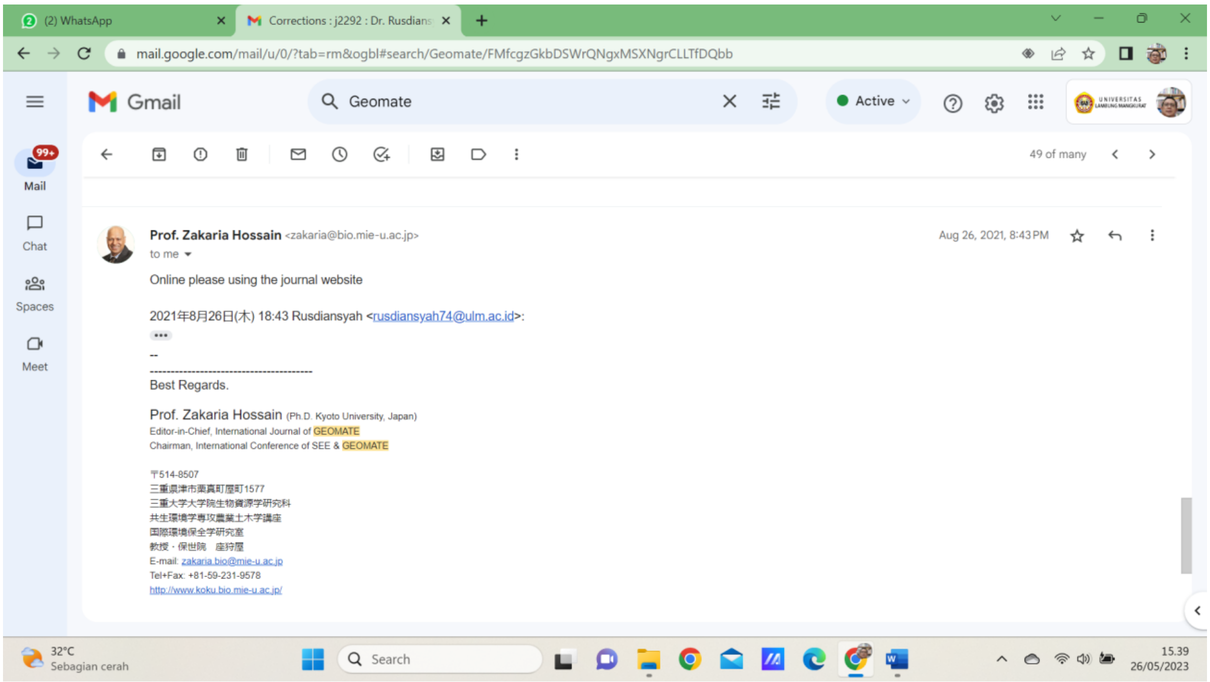

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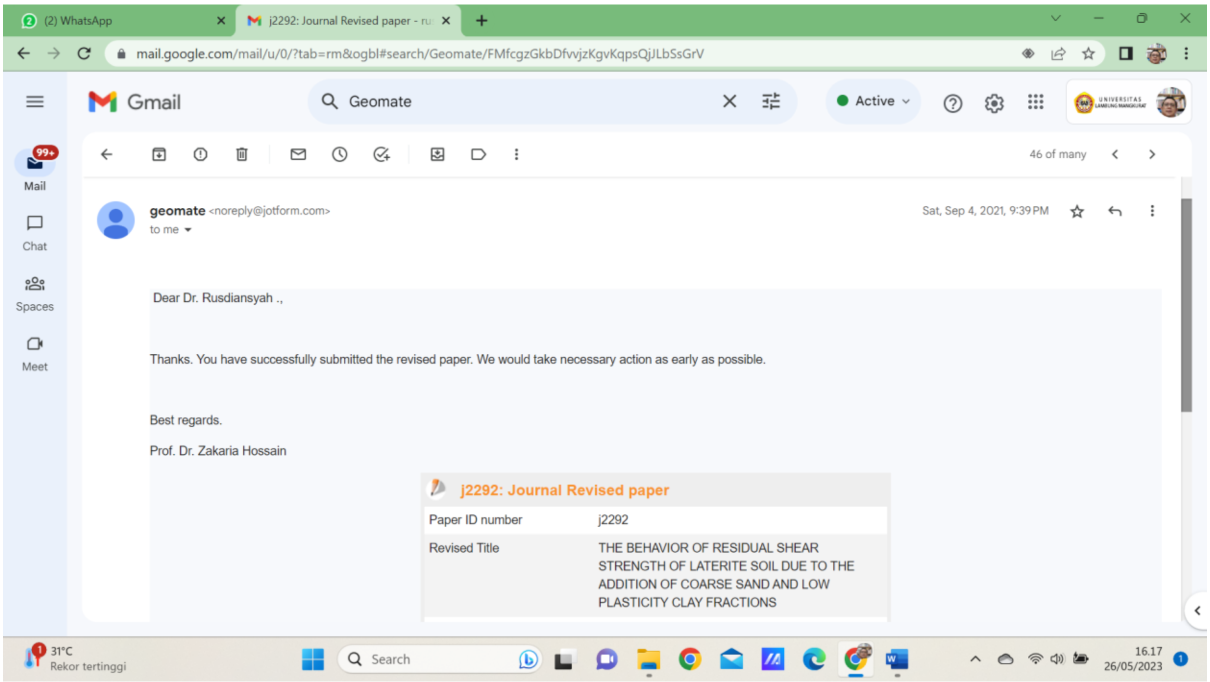

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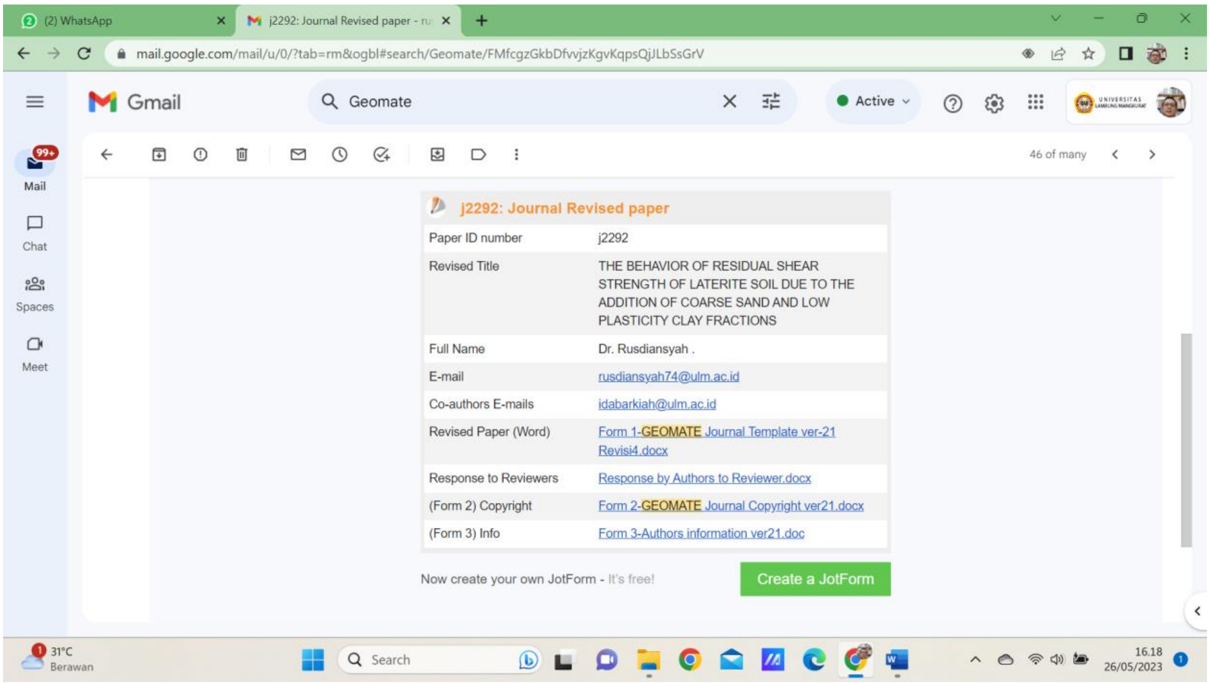

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THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

Authors: Rusdiansyah, Adriani, and Ida Barkiah

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parallel to the shift direction. Under this circumstance, the shear strength becomes minimal and is called the residual shear strength.

However, information on residual shear strength of laterite soil after landslide appears relatively insignificant. This is related to the behavior of the residual shear strength of the embankment with laterite soil that shows the most frequently used for road construction in virtually every Kalimantan region in Indonesia.

Several studies on the residual strength of non-laterite clays have also been conducted since the late 1930s, including by scientists [1-3]. Furthermore, Skempton [4] reported the residual shear strength of the soil using a conceptual model, based on experimental data. This attempt was successively followed by scientists [5-8], where the results of Skempton [4] were refined over time.

The residual shear strength forms a key parameter required for the analysis and design of slopes, retaining walls and fine-grained soil foundations under relatively massive deformations [9]. This property is mainly applied for two purposes. The first effort involves calculating the extent of slope decrease in an earthquake [10], followed by evaluating the previous slope stability [11].

Residual shear strength is important in comprehending the stability of past landslides, assessment of engineering properties of soil deposits, comprising pre-existing shear surfaces and the progressive failure risk on new and current slopes [11-13]. The variable also plays a significant role in the design of corrective action [14] and understanding its position under initial failure conditions [15].

Several studies on soil parameters, termed Atterberg limit, clay fraction, friction angle, and so on, to determine residual strength have also been previously investigated, including scientists [16-20]. This research intends to contribute to the development of subsequent slope stability analysis [21]. The residual strength is commonly defined as the minimum and constant drained shear strength needed for the soil to undergoes an extensive shear shift under normal stress [21], as represented in Fig. 1.

Fig. 1 shows that the residual shear strength of soil is never zero [22]. This factor depends not only on soil type, termed material, particle size and shape, surface roughness, and so, but also on soil situations, in terms of density, moisture content, frame structure, and test conditions, including the selection of shear testing equipment, normal stress, over-consolidation ratio, shear rate, acceleration, and so on [23].

Several previous attempts have been recorded relating the friction angle of the residual soil and its index properties, including Atterberg limit as well as clay fraction [24] and friction angle in residual clay fraction [4], by performing a series of controlled direct shear tests in certain mixtures of bentonite, kaolin and sand. In the two investigations, the shear rate varied between 0.0001-100 mm/min. This observation concluded that a positive relationship between the shear transfer rate and the clay's residual strength was observed, with higher fractions and displacement above 50% and 1 mm/min, respectively. Additionally, the shear test has also been conducted on a mixture of soil and sodium chloride to examine the salt concentration effects. The results showed that the positive impact becomes more intense with increasing salt concentration. This increment is possibly comprehended by the decrease in the void ratio and the increase in contact solid particles due to the concentration of the mixture [25, 26].

Based on the description above, there are no known reports on the behavior of the residual shear strength of laterite soil due to the addition of coarse sand fraction and low plasticity clay fraction. Previous studies were limited to the residual shear strength behavior of pure clay, bentonite mixed clay, kaolinite mixed clay, and sand mixed clay. Furthermore, these studies examined the relationship between the residual shear strength of clays besides laterite soil types, and Atterberg limit parameters, clay fraction parameters, internal friction angle parameters, soil particle behavior, as well as porosity.

Therefore, studies on the residual shear strength behavior of laterite soil are required because the theory of laterite soils, especially regarding residual shear strength, has not been widely developed. This research is a suitable preliminary for further theory development on this topic, and the findings from this study are bound to provide more insight. Furthermore, it examines the shear strength behavior of the residual laterite soil after a mixture of coarse sand and low plasticity clay (CL) fractions have been added, as well as the effect of wetting and drying cycle conditions as in the rainy and dry season conditions in Indonesia, as these tend to reduce the peak shear strength and residual shear strength of laterite soils. In Indonesia, laterite soil is often used as embankment material for road bodies under the road foundation layer material, and the conditions of these soils exhibits weaknesses in several properties, while commonly causing problems, including low peak and residual shear strengths, due to the dominant plastic nature. This has the potential to easily cause landslides on the laterite soil slopes of the road embankment.

This research's findings are also a suitable material for the development of laterite soil theory, particularly the theory of residual shear strength behavior, and bound to play a significant role in the stability of laterite soil embankment slopes.

Furthermore, the findings also provide the groundwork for further explorations, for instance, studies on how the behavior of soil particles and porosity influence the residual shear strength of laterite soils, as well as how the magnitude and velocity of residual shear strength affect the slope stability behavior of laterite soils. This research is also useful for local government policymakers and engineering consultants in considering the use of laterite soil mixed with coarse sand and low plasticity clay fractions as a road embankment material, as this is technically better, compared to laterite soil alone.

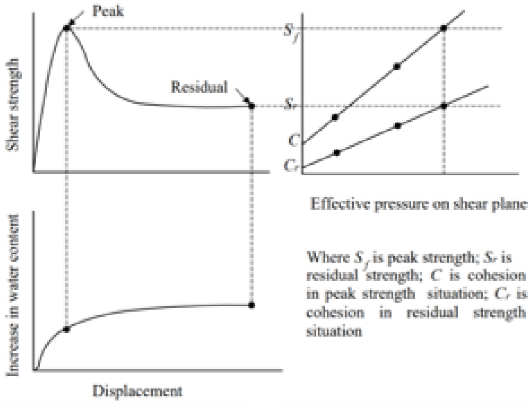

Fig. 1 Consept of residual strength in shear characteristics

2. RESEARCH METHODS

2.1 Material

The sample of laterite soil on this research is taken from a quarry in Cempaka, Banjarbaru city, South Kalimantan province, Indonesia. This soil is commonly applied as an embankment material in road construction across the Kalimantan island. The samples of coarse sand and clay fraction which have 6% of Plasticity Index as the additional material in the mixture is taken from the Barito River, Barito Kuala Regency. This value is classified by the USCS standard as CL (low plasticity clay).

Table 1 shows the physical and mechanical characteristics of laterite soil, with a classification of CH (high plasticity soil) and a relatively high PI of 34.51%.

Based on the grain size distribution test results, the fine-grained soil showed a percentage above 50%. This outcome is also reviewed on the basis of the moderately high liquid limit (LL) and compressibility index (Cc) values. Therefore, the selected laterite soil is plastic in nature, and is easily compressed, but appears less profitable in constructing road embankments.

Table 1. Characteristics of Laterite Soil

Properties	Value
- Volumetric weight, γ (kN/m^3)	17.38
- Water content, Wn (%)	40.636
- Specific Gravity, Gs	2.65
- Liquid limit, LL (%)	62.91
- Plastic limit, PL (%)	28.40
- Plastic Index, PI (%)	34.51
- Cohesion, C (kPa)	26
- Internal angle, (°)	22.61
- Compressibility index, Cc	0.51
- Swelling Index, Cs	0.07
- Grained of Distributions	
- Gravel (>2mm), %	16.99
- Coarse sand (0.6-2mm), %	7.85
- Medium sand (0.2-0.6mm), %	7.21
- Fine sand (0.05-0.2mm), %	6.42
- Silt-clay (0.002-0.05mm), %	24.79
- Clay (<0.002mm), %	36.74
- Sensitivity	1.1
- USCS classification	CH

2.2 Testing procedure

The laboratory research activities involved evaluating the physical and mechanical properties, including the shear strength, with the addition of sand and clay fractions at 5, 10, 15, 20 and 25% respectively. Soil specimens for the shear strength test were obtained from the standard compaction results, with 80-90% maximum density. This assessment was conducted for each variation, without the addition of mixing material in wetting and drying cycles, but at the peak and residual shear strength for 2, 4, 6, 8, and 10 days.

Figure 2 represents the main direct shear test tool in the present research. This also refers to the test method conducted by So and Okada [27].

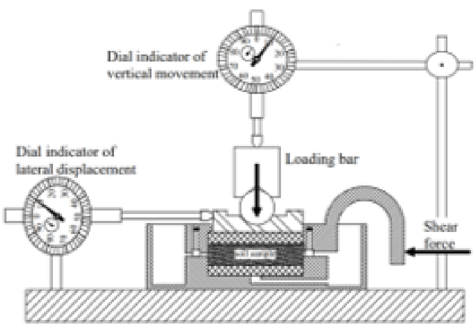

Fig. 2 Scheme for the Direct Shear Test Tool

The author is grateful to the Universitas Lambung Mangkurat, for funding this research for the 2021 fiscal year through the Research and Service Institute.

6. REFERENCES

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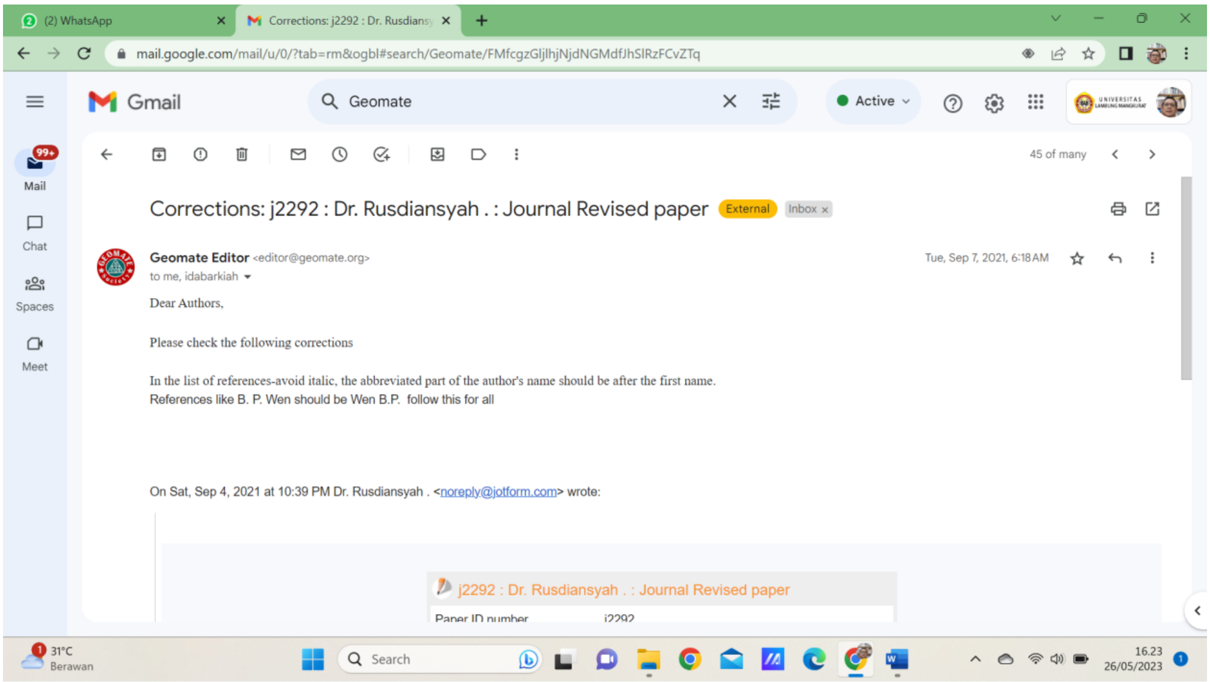

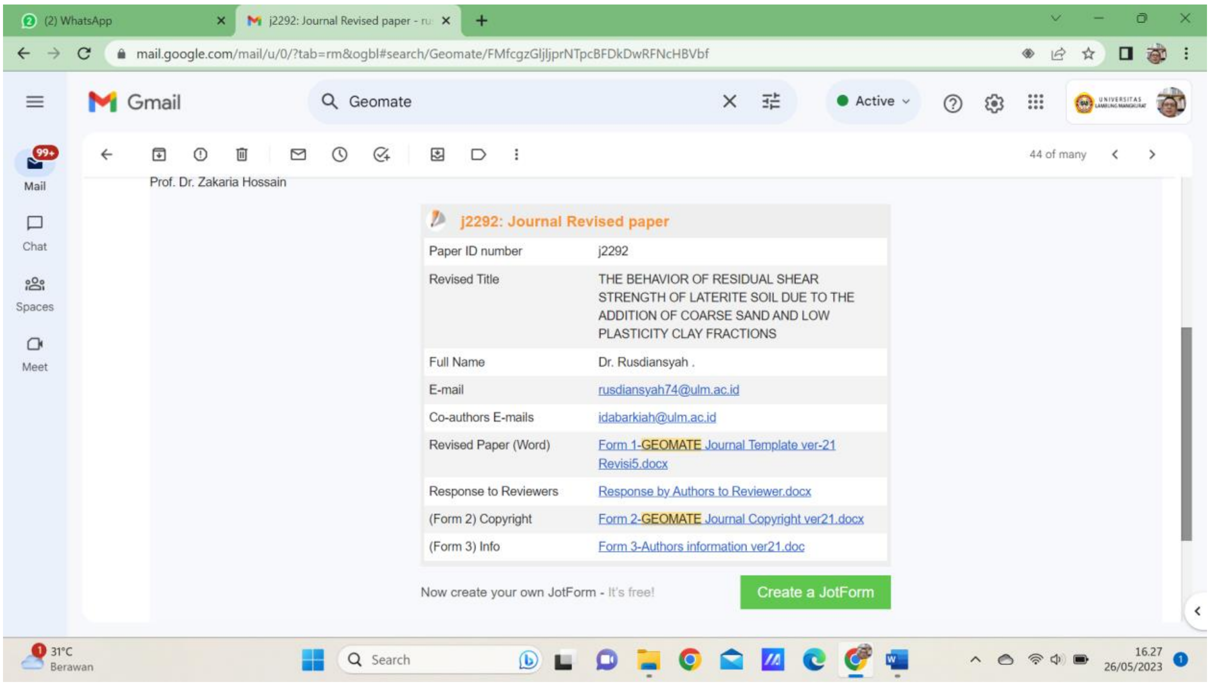

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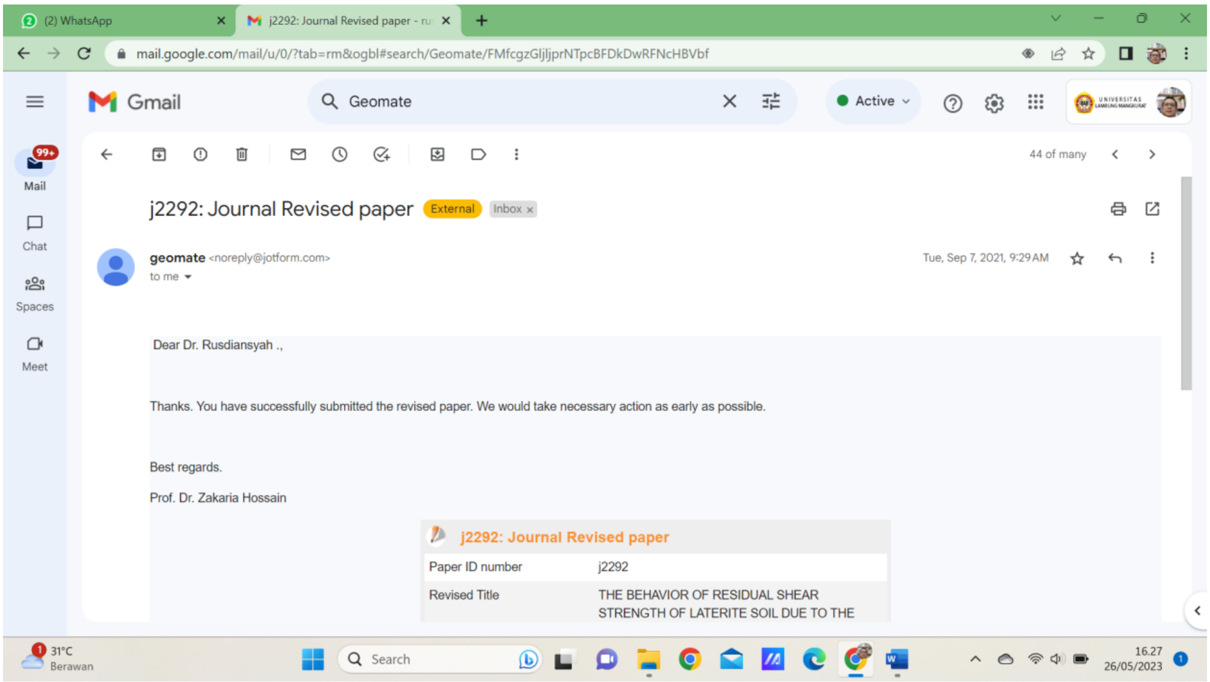

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THE BEHAVIOR OF RESIDUAL SHEAR STRENGTH OF LATERITE SOIL DUE TO THE ADDITION OF COARSE SAND AND LOW PLASTICITY CLAY FRACTIONS

Authors: Rusdiansyah, Adriani, and Ida Barkiah

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5. ACKNOWLEDGMENT

The author is grateful to the Universitas Lambung Mangkurat, for funding this research for the 2021 fiscal year through the Research and Service Institute.

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[1] Hvorslev M.J., Conditions of Failure for Remoulded Cohesive Soil, Proceedings of the 1st International Conference on Soil Mechanics and Foundation Engineering, Cambridge, 22-26 June 1936, pp. 51-53.

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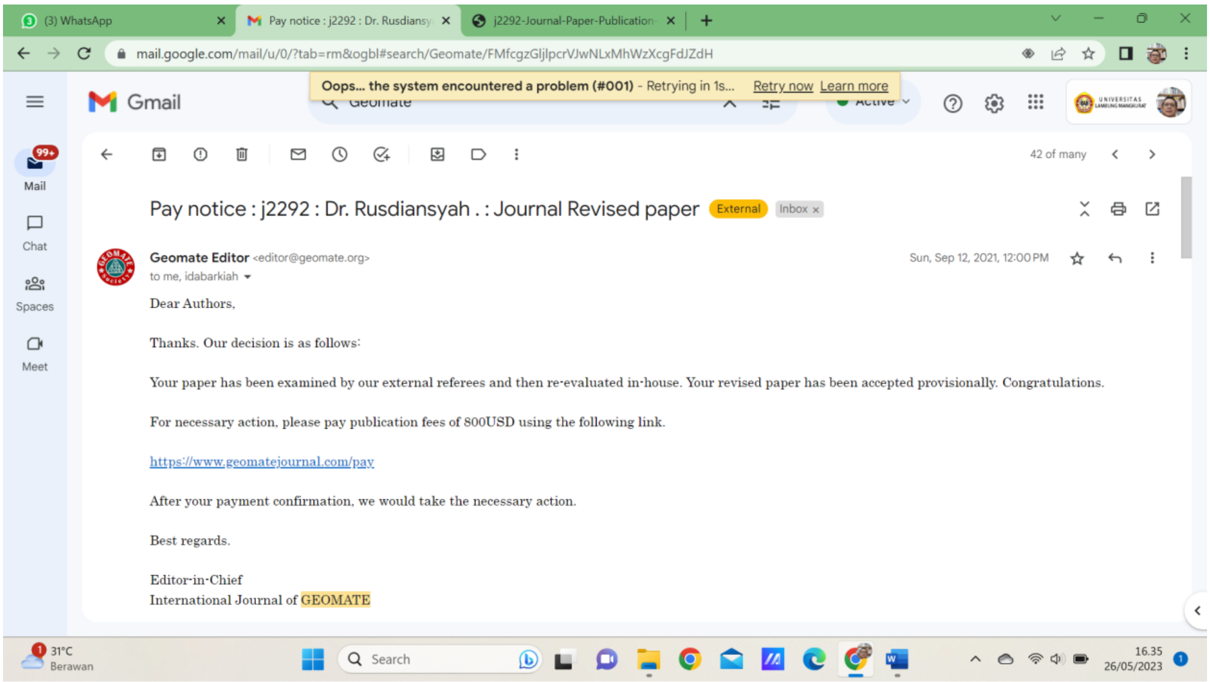

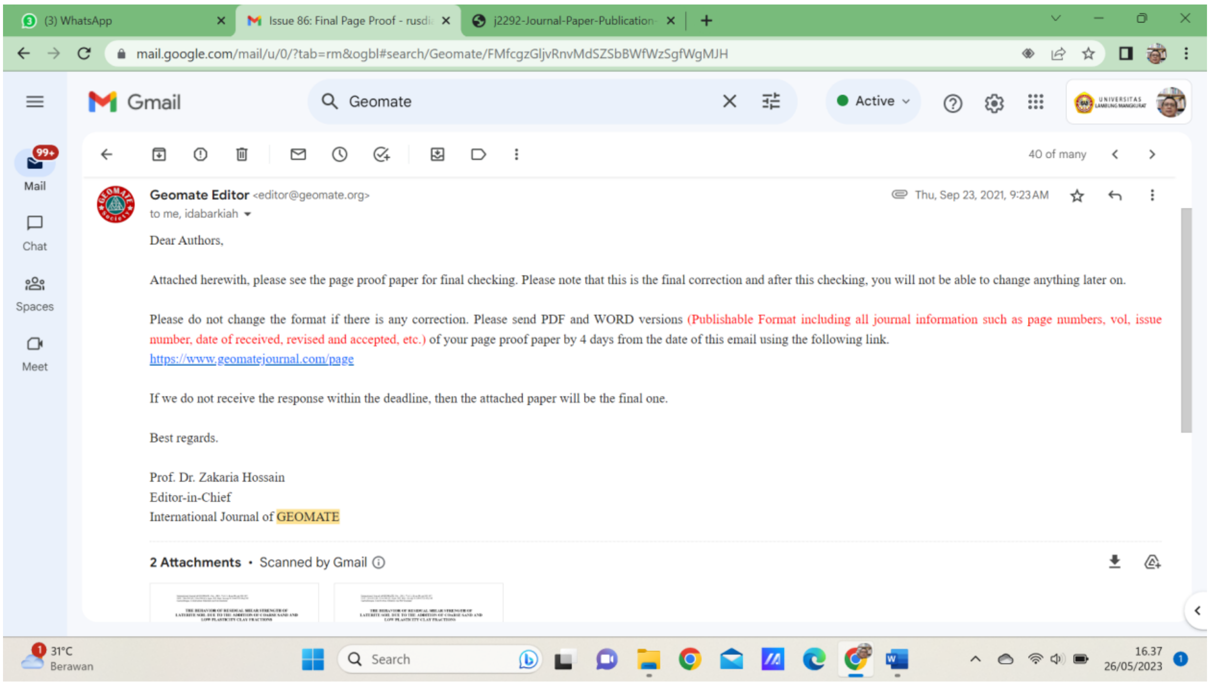

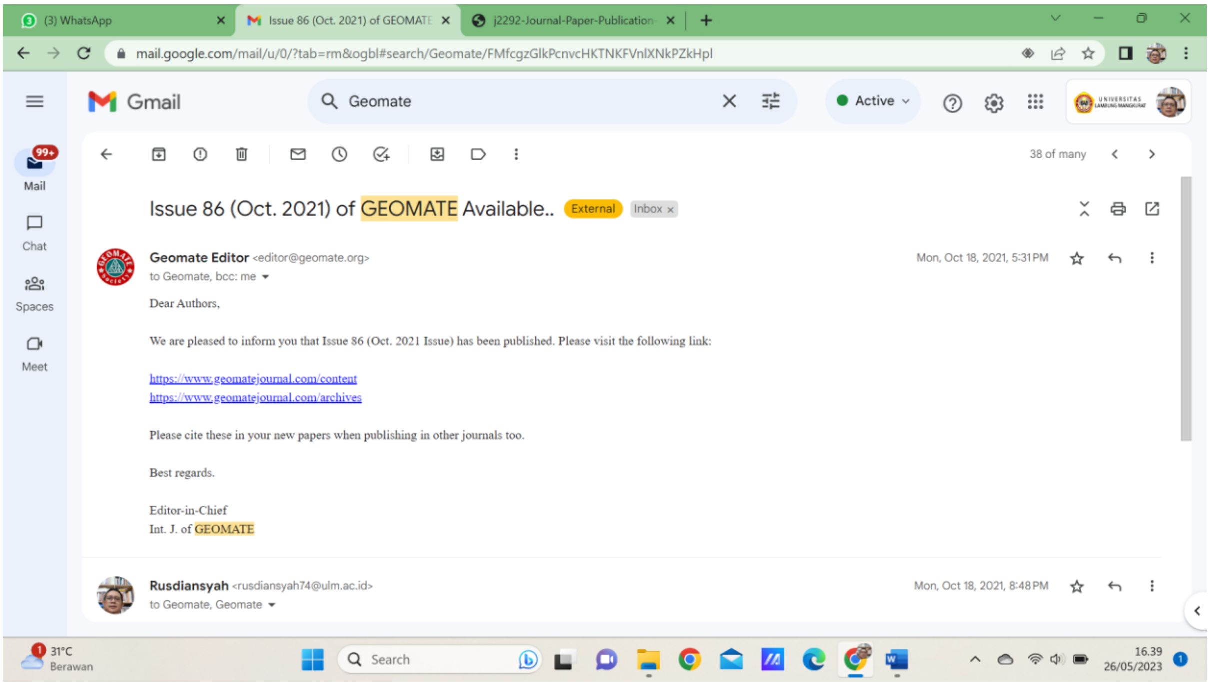
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Best regards.

Editor-in-Chief
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