The Effects Of Rice Husk Ash Substitution On Physical And Mechanical Properties Of Clay

by Saloma Hasyim

The Effects Of Rice Husk Ash Substitution On Physical And Mechanical Properties Of Clay

Dina Levika Oktavia, Ratna Dewi, Saloma, Febrian Hadinata, Yulindasari

Abstract: Clay is a soil with poor characteristics, which include low weight bearing capacity hence it needs to be fixed. Stabilization is a soil improvement technique, involving the use of cement for increase bearing capacity. However the high cost of cement, led to the investigation of other alternatives, e.g. Rice husk ash (RHA), a pozzolanic agricultural waste, which contains a lot of silica, processed by burning husk ash. This study therefore analyses the effect of substituting RHA on the physical and mechanical property of clay, in an attempt to increase the value of its carrying capacity. Laboratory scale testing was based on ASTM standards, which include California Bearing Ratio (CBR) and Unconfined Compression Test (UCT). The variation of RHA applied to the sample were 3%, 6%, 9%, 12% and 15% of the soil (dry density), at a curing period of 0, 3 and 7 days. The results further showed that the optimum value of UCT (1.05 kg / cm^2), was obtained at 6% RHA, within a 7-day curing period. The optimum CBR value (13.12%) was obtained with the unsoaked mixture at 9%, with a 7-day curing period.

Index Terms: CBR, clay, rush husk ash (RHA), specific gravity, standard proctor compaction test, UCT.

◆

1 INTRODUCTION

Clay is a soil, which is very difficult to use, as a construction material because it has a low weight bearing capacity and it also undergoes high shrinkage and water content, which is responsible for its structural failure [1], many techniques to improve soil have been carried out on clay, including stabilization, using materials, including acrylic polymers, tin, aluminum, cement, etc. Furthermore, the application of acrylic polymer material, led to the selection of an optimum percentage (6%) and further increase the CBR value by 102%, at a curing period of 14 days [2]. A research on the use of tin and aluminum resulted in an optimum mixture of 6% [3]. Wood ash has also been used as a material to achieve stability of clay, by reducing its maximum dry density value [4]. However, cement is the most commonly used agent, which increases the UCT value by 395.8% [5], however, its use proffers negative effects on the environment and it is also expensive. This study therefore analyzes the use of RHA, which contains 90% silica and some metal impurities (iron, manganese, calcium, sodium, potassium, and magnesium [6]), as a substitute for cement (pozzolan) because of its cost effectiveness and environmental friendliness [7]. Tests were conducted on on the dry density of the soil, with various variations of RHA content. Furthermore, research by Sheeba and Sasikumar [8], regarding clay stabilization in Bolgatty, Ernakulam India involved the addition of 5%-20% RHA, which showed an increase in the value of Unconfined Compression Test (UCT) of 10% on the dry density of soil or an elevation by 21.174 kN/m^3. Roy [9] showed that adding 10% RHA to clay, taken from a depth of 1.5 m - 2.5 m in West Bengal, India resulted in an increase in CBR value by 106%.

2 MATERIALS AND METHODS

2.1 MATERIALS AND PREPARATION

Clay used in this study was quarry soil, taken from Pedamaran Village, OKI, using disturbed sampling technique. The specimen was excavated at a depth of 2.5 meters, to obtain a layer that is not contaminated with other materials, often present on the surface level. Furthermore, water content analysis was carried out at the time of collection and the sample was then forwarded to the laboratory for testing. The RHA was obtained from Lahat, South Sumatra, using a sack to maintain its condition. This sample was further cleaned and sapped, using a number-60 strainer. Furthermore, the RHA mixture ratio used (3%, 6%, 9%, 12% and 15%) of the dry density of soil, was obtained from previous research journals.

2.2 METHODS

The experimental method involved the addition of RHA to clay, adjusted to the predetermined variations. The tests were conducted based on ASTM requirements, in the form of Standard Proctor Compaction Test (SPCT), Specific Gravity Test (Gs), soaked and unsoaked Capacity Bearing and Unconfined Compression Test (UCT) as shown in Table 1.

Table 1. *Testing of Mixed Variations*

Mix Design	Specific Gravity Test	Standard Proctor Compaction Test	Capacity Bearing Ratio (soaked)	Capacity Bearing Ratio (unsoaked)	Unconfined Compression Test
Original soil (TA)	◆	◆	◆	◆	◆
RHA	◆	-	-	-	-
TA + 3% RHA	◆	◆	◆	◆	◆
TA + 6% RHA	◆	◆	◆	◆	◆
TA + 9% RHA	◆	◆	◆	◆	◆
TA + 12% RHA	◆	◆	◆	◆	◆
TA + 15% RHA	◆	◆	◆	◆	◆

- *Dina Levika Oktavia is master student in Civil Engineering, Faculty of Engineering, Sriwijaya University, Indonesia.*
- *Ratna Dewi (Corresponding author) is Lecture in Civil Engineering Department, Faculty of Engineering, Sriwijaya University, Indonesia. Email: ratnadewi@unsri.ac.id*
- *Saloma, Febrian Hadinata, Yulindasari is Lecture in Civil Engineering Department, Faculty of Engineering, Sriwijaya University, Indonesia*

3 RESULTS AND DISCUSSION

3.1 PROPERTIES OF SOIL SAMPLE AND RHA

The properties of the soil sample, categorized as CH clay (USCS classification) and A-7-5 (AASHTO classification) were observed in Table 2. The composition of the RHA can be seen in Table 3.

***Table 2.** Properties of Soil*

Characteristics	Value
Pass 200 strainer No.200 (%)	94.713
Specific Gravity (Gs)	2.637
Liquid limit (%)	97.00
Plastic limit (%)	41.88
California bearing ratio, soaked (%)	3,94
California bearing ratio, unsoaked (%)	4.86
Unconfined compression strength (kg/cm♠)	0.55

Table 3. Oxide composition of RHA

Elements	Name of elements	Value (%)
Si	Silica	39.16
Al	Aluminum	0.58
Fe	Iron	0.11
Ca	Calcium	0.38
Mg	Magnesium	0.36
C	Carbon	3.61
O	Oxygen	53.90
Na	Sodium	0.05
P	Phosphor	0.25
K	Potassium	1.61

The largest content in RHA was oxygen at 53.90%, however, it also contains silica (39.16%), a pozzolanic binder substitute to cement, as shown in Table 3.

3.2 MIXTURE OF SOIL AND RHA

3.2.1 SPECIFIC GRAVITY TEST (GS)

The test was carried out to determine the specific gravity value of the original soil and soil/RHA mixtures (3%, 6%, 9%, 12%, and 15%), as seen in Table 4 and Fig.1.

***Table 4.** Specific Gravity test results*

Mix Design	Specific Gravity
Original soil (TA)	2.637
RHA	1.915
TA + 3% RHA	2.599
TA + 6% RHA	2.555
TA + 9% RHA	2.547
TA + 12% RHA	2.469
TA + 15% RHA	2.449

Based on Table 4 and Fig. 1, it can be observed that the decrease in the value of specific gravity was concurrent with the elevated percentage of RHA in clay. Research conducted by Ghutke, et al. [1] showed a decrease in the value of Gs, alongside the addition of RHA, up to 16%. The same results were also observed by Shahiri and Ghasemi's research [5] on the use of cement as a clay stabilization agent. The reduction in specific gravity of mixed soils occurred due to the mixture of two types of materials, which possess lower value than the specimen.

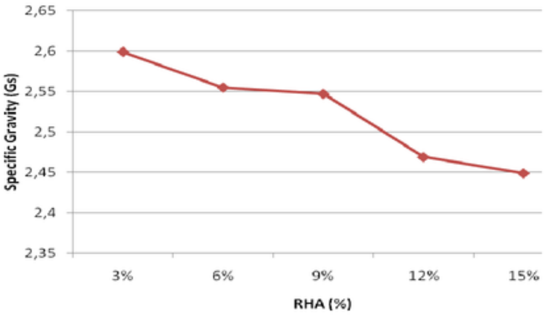

***Fig. 1.** Graph indicating the decrease in specific gravity values (Gs)*

3.2.2 ATTERBERG LIMITS

The Atterberg limits test results, shows a decrease in the liquid limit value (LL) from 97.00% to 89.50% and plastic index (PI) from 55.12% to 32.72%, with the elevation in the level of RHA in the soil, corresponding with the results of the Specific Gravity (Gs) test as shown in Table 5 and Fig. 2. In contrast, the plastic limit value (PL) increased with the addition of RHA levels of 41.88% to 56.78%.

***Table 5.** Atterberg limits test results*

No.	Mix Design	Value of atterberg limits		
		LL (%)	PL (%)	PI (%)
1	Original soil (TA)	97.00	41.88	55.12
2	TA + 3% RHA	96.70	51.86	44.84
3	TA + 6% RHA	94.50	52.12	42.38
4	TA + 9% RHA	93.60	55.67	37.93
5	TA + 12% RHA	93.00	58.57	34.43
6	TA + 15% RHA	89.50	56.78	32.72

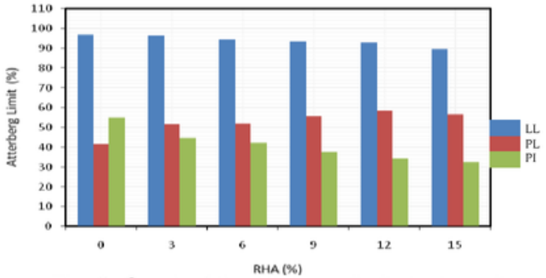

***Fig. 2.** Graph of the atterberg limits test results*

3.2.3 STANDARD PROCTOR COMPACTION TEST (SPCT)

SPCT was carried out to determine the optimum water content as well as the dry density of soil and soil/RHA samples with different percentage variations, as seen in Table 6 and Fig. 5.

***Table 6.** Standard Proctor Compaction test results*

Mix Design	Optimum water content (%)	Optimum dry density (gr/cm^3)
Original soil (TA)	35.00	1.333
TA + 3% RHA	36.50	1.290
TA + 6% RHA	37.10	1.286
TA + 9% RHA	37.70	1.256
TA + 12% RHA	40.00	1.209
TA + 15% RHA	41.00	1.159

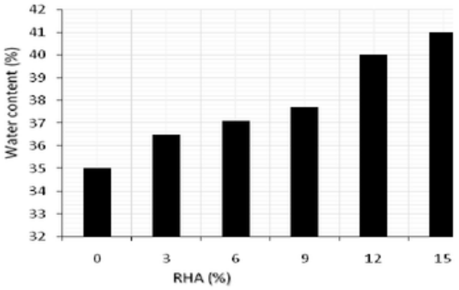

Fig. 3. *Graph of the increase in optimum water content variation of the mixture of original soil and RHA*

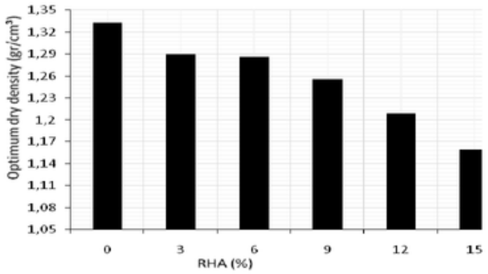

Fig. 4. *Graph of the decrease in dry density variation of the mixture of original soil and RHA*

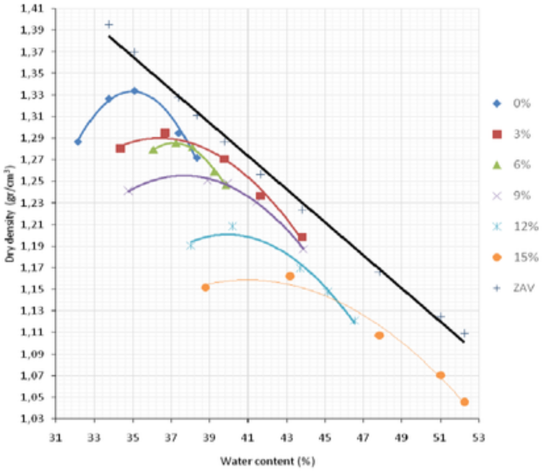

Fig. 5. *Graph of the correlation between optimum water content and optimum dry density*

Table 6 and Fig. 3 Indicates that elevating RHA content in soil, increases its optimum water content, due to its silica content and the optimum dry density of the sample further decreased (Fig. 4) because it possesses smaller specific density. Similar results were observed in previous research, where it was stated that the addition of cement at 2%, 4% and 6%, optimally increased the water content and reduced the dry density [5].

3.2.4 CALIFORNIA BEARING RATIO

California Bearing Ratio (CBR) test is commonly used as an indicator for the evaluation of soil carrying capacity, which can be carried out in soaked and unsoaked conditions.

Table 7. *The percentage of soaked and unsoaked CBR test results*

Mix design	Curing (day)	CBR soaked	Increase percentage (%)	CBR unsoaked	Increase percentage (%)
Original soil (TA)		3.67	-	4,86	-
TA + 3% RHA	0	4.86	32.43	5.51	13.37
	3	4.99	35.97	8.40	72.84
	7	5.64	53.68	11.15	129.42
TA + 6% RHA	0	5.12	39.51	9.05	86.21
	3	5.12	39.51	9.19	89.09
	7	6.30	71.66	12.99	167.28
TA + 9% RHA	0	5.25	43.05	10.50	116.05
	3	5.51	50.14	13.12	169.96
	7	6.69	82.29	13.12	169.96
TA + 12% RHA	0	5.38	46.59	7.87	61.93
	3	6.30	71.66	8.53	75.51
	7	7.09	93.19	9.97	105.14
TA + 15% RHA	0	4.59	25.07	7.74	59.26
	3	5.12	39.51	8.27	70.16
	7	6.15	67.57	9.71	99.79

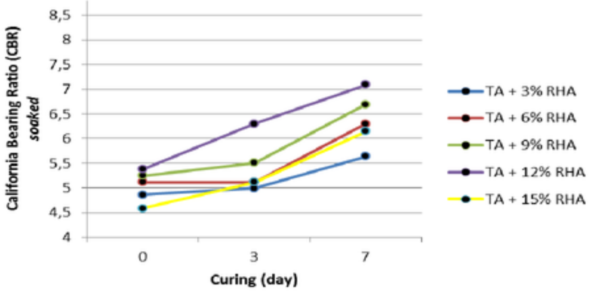

Fig. 6. *Graph of CBR soaked test result*

Fig. 6, Fig. 7 and Table 7 show an increase in the value of the soaked CBR test from the variation of 3% to 12% RHA and the optimum value 12% was selected, which indicated an increase of 93.19% during the 7-day curing period. Conversely, in unsoaked conditions, the CBR values increased from variations of 3% to 9% RHA and the latter was selected as the optimum, indicating an elevation by 169.96% during the 7-day curing period. Soaked and unsoaked CBR values elevated with increased curing time, at each variable, which is caused by the occurrence of longer reactions taking place between the components, therefore enabling the reaction bonds to grow stronger hence the CBR value increases.

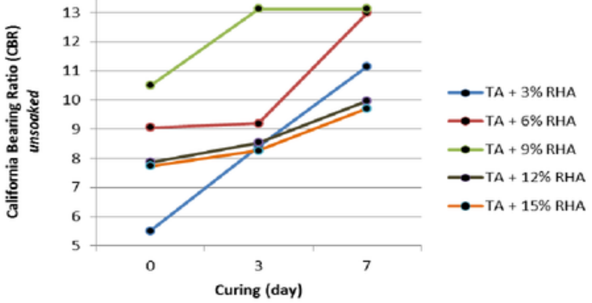

Fig. 7. *Graph of CBR unsoaked test result*

3.2.5 UNCONFINED COMPRESSION TEST

UCT is an evaluation carried out on soil, to obtain shear strength values from cohesive variety. The qu value obtained from the test results is attributed as the maximum axial stress that the soil sample can hold before shear failure is recorded. Variations with different percentages of RHA are illustrated in Table 8.

Table 8. *Percentage of UCT results*

Mix design	Curing (day)	qu	Increase percentage (%)
Original soil (TA)	-	0.55	-
TA + 3% RHA	0	0.81	47.27
	3	0.91	65.45
	7	1.03	87.27
TA + 6% RHA	0	0.86	56.36
	3	0.98	78.18
	7	1.05	90.91
TA + 9% RHA	0	0.79	43.64
	3	0.87	58.18
	7	0.92	67.27
TA + 12% RHA	0	0.70	27.27
	3	0.71	29.09
	7	0.82	49.09
TA + 15% RHA	0	0.61	10.91
	3	0.71	29.09
	7	0.79	43.64

Fig. 8 and Table 8 indicates the effect of RHA on UCT value for each variation. The qu data obtained increased with variables of 3% to 6%, which is in contrast with the results of CBR testing, which increased by up to 9%. Furthermore, the qu value decreased after 6% to 15% variation, which may be due to excess RHA, as the Standard Proctor Compaction test results, showed the dry density reduction alongside the addition of RHA, which filled the ground space and further lessened the soil cohesion value. From the UCT test, the optimum qu value was 6% RHA, at a 7 day curing period of 1.05 kg/cm^2 (up to 90.91%). The research conducted by Shahiri and Ghasemi [5], using cement as a stabilizing material, also showed the optimum value at 6% cement mixture, with an elevation of about 395.8%. Fig. 8 and Table 8. shows the effect of curing period on soil samples during UCT testing as a longer curing time, indicates greater qu value, which was shown by the results, testing each variation. Furthermore, this was caused by the occurrence of a longer reaction between the stabilization material and the soil, thereby increasing its strength.

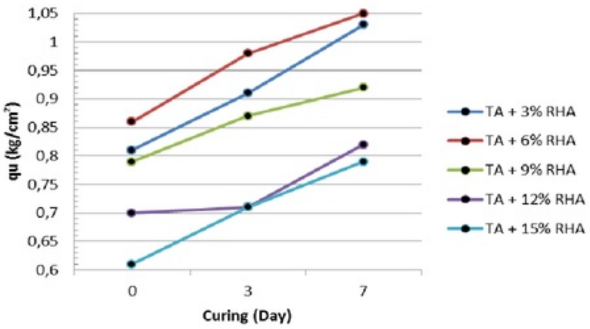

Fig. 8. *Graph of UCT results for each variation*

3.2.6 SEM AND EDS ANALYSIS

Fig. 9 to Fig. 16 indicates the results of studies, using Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS), on original soil and the varieties stabilized with RHA, at levels of 6%, 9%, and 15%. The results of the SEM analysis indicated that the original soil was stabilized with RHA, through the formation of floccules, hence creating a soil that is denser at higher concentration ratios. Furthermore, flocculation is a process which alters particles thereby increasing soil strength in this case.

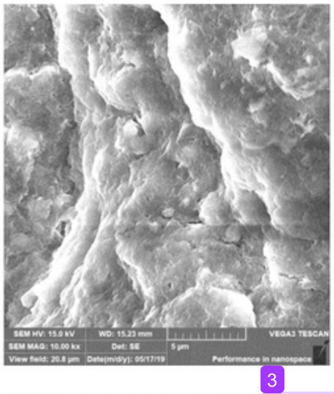

Fig. 9. *SEM analysis results of Original soil*

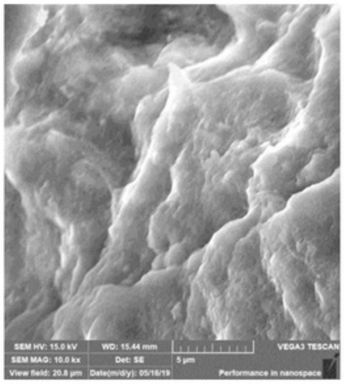

Fig. 10. *SEM analysis of Original soil + 6% RHA*

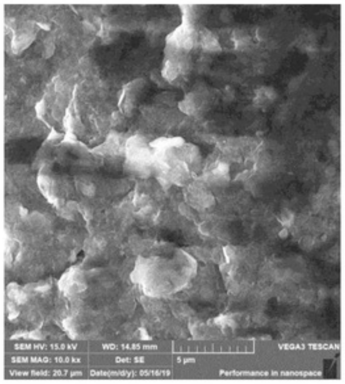

Fig. 11. *SEM analysis of Original soil + 9% RHA*

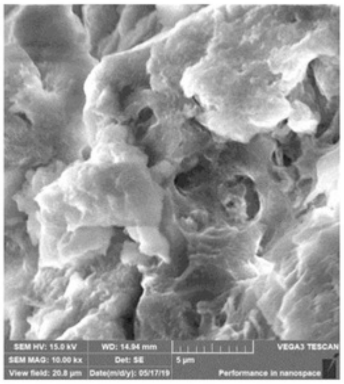

Fig. 12. *SEM analysis of Original soil + 15% RHA*

EDS is used for quantitative analysis of certain material elements. Fig. 13 to Fig. 16 shows an increase of the number of soil contents, including Silica, Oxygen, Calcium and other elements in clay, due to subsequent addition of RHA. Furthermore, the highest elevation was observed in the 15% variable, where the soil experienced maximum density, as seen in the results of SEM analysis.

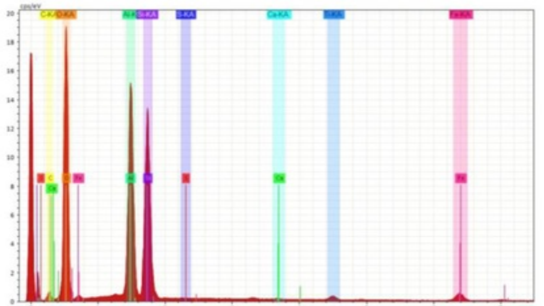

Fig. 13. *EDS analysis of Original soil*

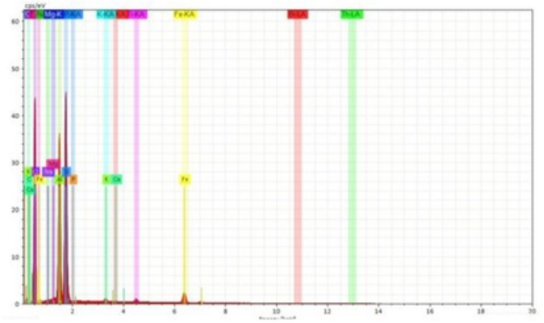

Fig. 14. *EDS analysis of Original soil + 6% RHA*

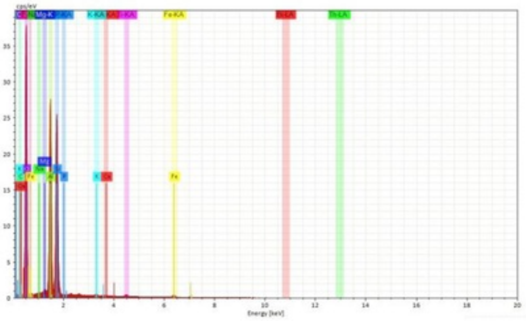

Fig. 15. *EDS analysis of Original soil + 9% RHA*

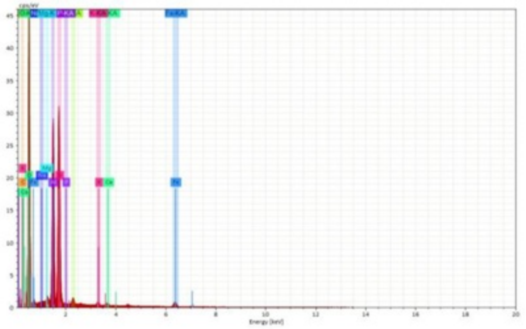

Fig. 16. *EDS analysis of Original soil + 15% RHA*

4 CONCLUSION

Based on theresearch and subsequent discussions, the conclusions are as follows:

(i) The substitution of RHA in clay, increases the value of soil carrying capacity as seen from the results of CBR and UCT testing.
(ii) RHA also increases the plastic limit value (PL), by elevating its level in the soil and further reducing the liquid limit (LL) and plastic index value (PI).
(iii) This substitution leads to an increase the soil density, as observed in the results of SEM and EDS analysis.
(iv) The optimum level observed in CBR testing was obtained in the unsoaked condition, with 9% RHA variety, at a 7 days curing period, which indicated 13.12 from 4.86, with an increase of 169.96%.
(v) The optimum level in UCT testing was obtained on the addition of 6% RHA and at a 7 days curing period, which was equal to 1.05 from 0.55, with a percentage increase of 90.91%.

ACKNOWLEDGMENTS

The research presented in this paper was supported by a grant from Unggulan Kompetitif Universitas Sriwijaya.

REFERENCES

[1] Ghutke, V., Bhandari, P., Agrawal, V., (2018): Stabilization of Soil by Using Rice Husk Ash. The International Journal of Engineering and Science: 92-95.
[2] Sohaib, N., Sarfraz, M., Sana, G., (2018): Use of Acrylic Polymer for Stabilization of Clayey Soil. International Journal of Scientific & Engineering Research, 9: 433-438.

[3] Canakci, H., Celik, F., Bizne, M., O., A., (2016): Stabilization of Clay with Using WasteBeverage Can. Procedia Engineering, 161: 595-599.
[4] Ikra, B., A., Kabir, T., Mowrin, A., N., Habib, A., (2018): Stabilization of Clay Soil Mixed with Wood Ash. International Jurnal of Scientific & Engineering Research 9 (10): 820-823.
[5] Shahiri, J., and Ghasemi, M., (2017): Utilization of Soil Stabilization with Cement and Copper Slag as Subgrade Materials in Road Embankment Construction. International Journal of Transportation Engineering, 5 (1): 45-58.
[6] Bakar, R., A., Yahya, R., Gan, S., N., (2016): Production of High Purity Amorphous Silica from Rice Husk. Prosedia Chemistry, 19: 189-195.
[7] Behak, L., (2017): Soil Stabilization with Rice Husk Ash. INTECH, 3: 29-45.
[8] Sheeba, B., S., and Sasikumar, A., (2017): Utilization of Rice Husk Ash as a Soil Stabilizer. International Research Journal of Engineering and Technology, 04:1799-1801.
[9] Roy, A., (2014): Soil Stabilization using Rice Husk Ash and Cement. Research India Publications, 5:49-54.

The Effects Of Rice Husk Ash Substitution On Physical And Mechanical Properties Of Clay

ORIGINALITY REPORT

4%	%	4%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Alvin L. Valor, Mary Regina B. Apsay, James Russell M. Acebo, Arfel Aguilar, Christine Joy B. Onquit, Marissa G. Chua. "HeartSaver: A heart rate monitoring system with SMS notification", 2016 IEEE Conference on Systems, Process and Control (ICSPC), 2016 Publication	2%
2	Saggaff, Anis, Talal Alhajri, M. Ismail, Khaled Alenezi, and Mohamad Ragae. "Finite Element Modelling of Innovative Precast Cold-Formed Steel Ferrocement as Composite Beam", Applied Mechanics and Materials, 2015. Publication	1%
3	Chang-sheng Yue, Ben Peng, Wei Tian, Guang-hua Lu, Gui-bo Qiu, Mei Zhang. "Complete stabilization of severely As-contaminated soil by a simple H_2O_2 pre-oxidation method combined with non-toxic TMT-15 and $FeCl_3·6H_2O$", International Journal of Minerals, Metallurgy, and Materials, 2019	1%

Publication

4 Saloma, Maulid Muhammad Iqbal, Ibnu Aqil. "Sulfate resistance of fly ash-based geopolymer mortar", AIP Publishing, 2017 1%

Publication

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		