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Evaluation of Powdered Golden Apple Snail Shells as a Stabilizing Agent to Sandy Clay Loam Soils

FRANCINE Z. MIRANDA[1], FRANCEZ RICA C. HERRERA[2], ROEL V. MANIAGO[3], ANDREL D. PINEDA[4], JAYSON B. RAMOS[5], ALYNNA MHAY S. SIMON[6], MIRIAM B. VILANUEVA[7], JOHN VINCENT G. TONGOL[8]

[1, 2, 3, 4, 5, 6] *Student, Department of Civil Engineering, Don Honorio Ventura State University*

[7] *Associate Professor V, Department of Civil Engineering, Don Honorio Ventura State University*

[8] *Instructor, Department of Civil Engineering, Don Honorio Ventura State University*

Abstract— The purpose of this research is to evaluate Golden Apple Snail (GAS) shells as an alternative source of stabilizing agent for sandy clay loam soils. However, testing revealed that the acquired soil had a higher plasticity index, indicating that it contains a high percentage of clay. This type of soil can be classified as an A–7–6 type clayey soil according to the American Association of State Highway Transportation Officials (AASHTO) classification. Highly plastic soil tends to be expansive when saturated and shrinks when dry which can lead to the destruction of pavement structures. These conditions can be enhanced to varying degrees depending on the type and amount of stabilizing agent used, the type of soil, and the curing conditions, including temperature and time. The Golden Apple Snail (Pomacea Canaliculata), also known as "Golden Kuhol" in many parts of the Philippines, continuously poses a threat to the livelihood of the farmers where it is considered as a pest due to its rapid growth, high reproduction rate, and great adaptability to a broad range of environments. The material, GAS shells, is found to mostly contain calcium carbonate (CaCO3), which, in the process of calcination, is projected to have approximately 90% calcium oxide (CaO), or quicklime. This paper described the effects of calcined GAS shells to the collected clay soil as a stabilizer. The soil was thoroughly mixed with varying proportions that was 5%, 10%, 15%, and 20% of CaO and tested for the Atterberg Limit test, the Standard Proctor test, and the California Bearing Ratio (CBR) test. The Atterberg Limit test showed an improvement with the decrease of Plasticity Index of the soil when calcined shells are introduced. The Standard Proctor test was used to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of each soil-GAS shell mixture. The MDD was increased from 1515 kg/m3 to 1584 kg/m3 at 20% calcined shells. The CBR tests were carried out using the specific OMC from each percentage of calcined GAS Shells. Following that, the effects of the calcined GAS shell content on CBR and swelling potential were assessed. The results showed that mixing the stabilizer into the soil increased the CBR values from 3% to 7% while increasing the soil's swelling potential from 2.90% to 5.21%.

Indexed Terms— Golden Apple Snail, Soil Stabilizer.

I. INTRODUCTION

Soil is a mixture of weathered rocks, minerals, humus, and organic and inorganic materials. It takes a long time to form due to the natural processes of rock disintegration and weathering caused by natural agencies and changes in climatic conditions. Soil is the integral part of the structure which is the very foundation or structural support needed for both vertical and horizontal structures. However, not all soils are a suitable foundation of structure, which presents a significant challenge to civil engineers. The surface soils of Pampanga are slightly acidic and contain 54% sand, 21% silt, and 25% clay [1]. These soils are classified as sandy clay loam using the United States Department of Agriculture (USDA) Soil Texture Triangle and is categorized as silty-clay material under the group classification of A – 6 type clayey soil according to American Association of State Highway Transportation Officials (AASHTO) classification and its general rating as a subgrade range from "fair" to "poor," indicating that it cannot withstand high stresses.

The stabilization of these soils is considered to be a major problem in the field of civil engineering, especially in the context of projects involving road pavement [2]. This is due to the fact that some soils, such as peat and soft clays, have poor geotechnical and physical properties, which must be managed for applications using pavement subgrade. Weak soils have a high compressibility and low shear strength, which results in unwanted settlements and an unnecessarily high level of risk while building structures. When used as the subgrade for pavements, clayey soils are particularly susceptible to swelling and shrinkage, which are often brought on by moisture changes and can result in the destruction of pavement structures.

Soil stabilization is a technique for enhancing the qualities of soil [3]. Soil stabilization is a process known for improving the characteristics of the soil, such as shear strength and bearing capacity through various components that are introduced and combined with the soil. This process is necessary when the construction soil is unfit to support structural loads. Furthermore, soil stabilization does not only increase the shear strength of the soil mass in earthen structures but also decreases its permeability and compressibility and is often used to lessen the settlement of buildings. In order to increase the geotechnical attributes of poor soils, such as compressibility, strength, permeability, and durability, stabilizing agents (binder materials) are used.

- *Methods of Soil Stabilization*

Soil stabilization methods are broadly classified into two categories: chemical stabilization and mechanical stabilization. Mechanical stabilization changes only the physical properties of soil through compaction, soil blending, interlocking of soil-aggregate particles, or placing a barrier on the soil [4]. The soil-aggregate combination must be graded, and when it is compacted, a dense mass is created. By uniformly combining the material and subsequently compacting the mixture, mechanical stabilization can be achieved. On the other hand, a new approach known as chemical stabilization emerged in recent decades due to the previous mechanical method of stabilization's higher cost and longer implementation time due to the removal and replacement of unstable soil. Using this method, stabilizers are mixed with soils that have poor engineering qualities to start a number of chemical processes such as cation exchange, flocculation, carbonation, and pozzolanic activity.

The soil's mineral composition, water content, amount and kind of additives, curing period, and temperature are only a few of the variables that affect how the soil's qualities are improved [5].

Lime has been used as a stabilizing agent since Roman times [6]. It was used to reduce settlement and increase the bearing capacity of a structure. There are two types of lime stabilizers: hydrated lime and quicklime. The quick lime is said to be more efficient than the other in terms of changing and improving soil strength. It was also mentioned in their study that cement stabilization is the most common method of soil stabilization adopted for soil treatment. The addition of cement decreases the soil's liquid limit when the pore water of the soil encounters cement.

- *Tests for Stabilization*

Testing for soil stabilization entails treating a soil in a manner that protects, enhances, or raises the performance of the soil as a building material. This performance includes the soil's strength and durability [7].

Laboratory testing followed by field tests may be necessary for an effective stabilization agent to establish the properties of engineering and the environment [8]. Although laboratory studies may provide materials with more strength than similar materials from the field, they will still be useful in determining how well stabilized materials perform in the field. Laboratory test results will improve understanding of the selection of binders and quantities. The effectiveness of the stabilizing chemical as an additive in soil stabilization can be evaluated using a variety of tests, including the Atterberg Limit Test, the Standard Proctor test, and the California Bearing Ratio (CBR) Test.

- *Golden Apple Snail Shells*

The Pomacea Canaliculata (Lamarck), often known as the Golden Apple Snail, is a notorious agricultural pest that has gained widespread notice in recent decades [9]. It was first introduced in the Philippines between 1982 and 1984 from South America (Brazil and Argentina) via Taiwan and was locally known as "Golden Kuhol" for food consumption, however, people quickly became disinterested and the GAS has since then polluted the irrigated rice fields in the Philippines. Over the years, GAS has the potential to damage up to 85% of rice crops in irrigated fields without any proper measure of control. It is also one of the world's 100 most notorious invasive alien species as it possesses high adaptability to harsh environments and exhibits rapid reproduction [10]. Female snails can lay oval-shaped egg clusters, producing up to 300 eggs per week with an 80% hatchery in 7-14 days. These adaptations, combined with high population densities, have made these snails a major pest in many farmed fields throughout Asia, especially the Philippines. Pampanga is predominantly an agricultural province since rice cultivation and other high-value commercial commodities are grown extensively on its fertile soil. According to the Provincial Government of Pampanga (2013), rice farming takes up 70,758.60 hectares of the province of Pampanga's crop-producing area. Rats, insects, bacteria, viruses, or fungus, birds, nematodes, and the golden apple snail are among the pests and illnesses that farmers must contend with, according to the International Rice Research Institute (IRRI). The farmers' annual income is lessened by 37% as a result of these issues.

Although GAS is considered a pest, its shells have the characteristics of a binding material, making it usable and attainable: it is abundant enough to provide enough material (shell) for production; it is easy to handle, collect, and culture; it is sedentary; it can survive for a long time without food; and it can be found in almost any rice fields in the Philippines [11]. Several studies have been conducted in order to use alternate sources of $CaCO3$ and CaO from a variety of shells. The calcium extracted is widely utilized in a variety of applications. It is worth noting that this approach utilizes shell byproducts in a commercially viable manner while also providing environmental benefits through waste recycling [12]. In line with this, this study evaluated Golden Apple Snail (GAS) shells that were already proven to have the property found in lime – the Calcium Carbonate ($CaCO3$), as a potential stabilizer to sandy clay loam soils.

II. METHODOLOGY

The materials were gathered within the province of Pampanga. The sandy clay loam soil and the Golden Apple Snails were retrieved from different municipalities with abundant resources. Primarily, soil samples were gathered from Barangay. Colgante, Apalit, Pampanga.

- *Soil Sample*

The sandy clay loam soils in standard were collected at a place where the soil was recently piled up, therefore the top soil is from the deepest part of the recent excavation. The soil was then air-dried into a large pan for 48 hours and was disintegrated into smaller pieces, and larger particles are separated passing through a No. 4 mesh with a size of 4.75 mm nominal sieve opening with a typical wire diameter 0f 1.6 mm and a No. 40 mesh with a size of 0.475 mm nominal sieve opening.

- *Calcined GAS Shells*

The binding material used in this study was the calcined Golden Apple Snail shell powder, obtained from the local farm fields of Pampanga, particularly in the Barangay of San Jose Matulid and San Lorenzo. The gathered snails were boiled for 20 minutes to eliminate any impurities before the meat was removed from its shells and dried in the sun for 3 to 5 days. The material (GAS shell) is high in calcium carbonate ($CaCO3$), which, in the process of calcination, can turn into calcium oxide (CaO) or quicklime under 900°C for one hour. The calcined GAS shells were manually crushed to a fine powder to pass through Sieve No. 200. The material in this study was projected to have approximately 90% CaO; however, the effects of the addition were only evaluated in the short term. Nonetheless, calcium oxide or quicklime could still cause pozzolanic reactions in the long term.

- *Test Procedures*

The evaluation of the effectiveness of calcined Golden Apple Snail Shells as an alternative source of calcium oxide (CaO) for soil stabilization was observed through the following series of tests: Atterberg Limits test, Standard Proctor test, and California Bearing Ratio Test. These following tests were conducted according to the American Society for Testing and Material (ASTM) Standard Test Methods, namely, ASTM D 4318, ASTM D 698, and ASTM D 1883, respectively. All the laboratory tests were conducted at the Department of Public Works and Highways (DPWH) in San Fernando, Pampanga.

- *Design Mixtures*

The design mixture structure for calcined Golden Apple Snail shells or calcium oxide (CaO) as a stabilizer was established from previous studies. In the study of Mounika et al. (2014), they used 0%–45% limestone additives, and the CBR value increased rapidly from 10% to 20%. The maximum CBR value was obtained at 20%, and beyond that, it gradually decreases. Additionally, the study by Pastor et al. (2019) established the 20% threshold UCS and CBR rate for the beneficial effect of the addition of limestone powdered waste. Therefore, for this study, the researchers had designed the samples to consist of 5, 10, 15, and 20% calcined GAS shells by total soil weight.

The soil was first tested without any added components and served as the baseline for comparison with the subsequent specimens. After that, the calcined GAS shells were thoroughly incorporated into the other four soil specimens. It was added with an increment of 5% to the succeeding specimens. The soil specimens had the following mixture: mixture:

Table 1. Design Mixture for Atterberg Limit Test

Materials	Percentages of Materials Per Specimen (%)				
	1	2	3	4	5
Soil	100g	95g	90g	85g	80g
Calcium Oxide	0g	5g	10g	15g	20g

Table 2. Design Mixture for Standard Proctor Test

Materials	Percentages of Materials Per Specimen (%)				
	1	2	3	4	5
Soil	5000g	5000g	5000g	5000g	5000g
Calcium Oxide	0g	250g	500g	750g	1000g

Table 3. Design Mixture for California Bearing Ratio (Soaked)

Materials	Percentages of Materials Per Specimen (%)				
	1	2	3	4	5
Soil	8000g	7600g	7200g	6800g	6400g
Calcium Oxide	0g	400g	800g	1200g	1600g

III. MATHEMATICAL FORMULAS

- *Atterberg Limits Test*

To calculate the liquid and plastic limit, the following formula for the determination of moisture content (%) was used:

$$Moisture\ Content = \omega(\%) = \frac{M_2 - M_3}{M_3 - M_1} = \frac{M_w}{M_s} \times 100$$

Where:
M_w = Mass of Water, g
M_s = Mass of Dry Soil, g
M_1 = Mass of the Moisture Can, g
M_2 = Mass of the Moisture Can + Moist Soil, g
M_3 = Mass of the Moisture Can + Dry Soil, g

The Plasticity Index can be calculated using the formula, and;

$$PI = LL - PL$$

Where:
LL = Liquid Limit
PL = Plastic Limit

The Group Index can be solve using the formula;

$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

Where:
F = Percentage Passing of the Soil at Sieve No. 200
LL = Liquid Limit

PI = Plasticity Index

The Group Index can also be determined using the ASTM D 3282–15 Standard Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.

Standard Proctor Test

The soil's moisture content and dry density are determined by the following equations:

$$Moisture\ Content = \omega(\%) = \frac{M_2 - M_3}{M_3 - M_1} = \frac{M_w}{M_s} \times 100$$

Where:

M_w = Mass of Water, g

M_s = Mass of Dry Soil, g

M_1 = Mass of the Moisture Can, g

M_2 = Mass of the Moisture Can + Moist Soil, g

M_3 = Mass of the Moisture Can + Dry Soil, g

$$\text{Dry Density} = \rho = \frac{[(W_2 - W_1) \times 10^{-3}] \times [9.80665 \times 10^{-3}]}{V} = \frac{m_s}{V}$$

Where:

W_1 = Weight of the Mold, kg

W_2 = Weight of the Mold + Soil, kg

m_s = Mass of Soil, kg

V = Volume of the Mold

California Bearing Ratio Test

The CBR Value was generally selected at 2.54mm and 5.08 mm penetration. The CBR Value was determined by:

$$CBR\ Value = \frac{Test\ Load}{Standard\ Load} \times 100\%$$

The load-bearing capacity was also determined using the following equation:

$$Load\ Bearing\ Capacity\ (kPa) = \frac{Test\ Load}{Area\ of\ the\ Mold} \times \frac{0.00981kN}{1kg}$$

The CBR Swell was determined by:

$$Percent\ Swell\ (\%) = \frac{Final\ height - Initial\ height}{4.584\ in} \times 100$$

IV. RESULTS AND DISCUSSION

In this study, the results from the Atterberg Limits test, Standard Proctor test, and California Bearing Tests are summarized and established the following findings:

Table 4. Atterberg Limit, Compaction, CBR Swell and CBR Test Results

Sample	LL%	PL%	PI%	AASHTO Soil Clas.	Soil Type	MDD kg/cu.m.	OMC %	CBR Swell%	CBR%
Spec. 1	64	28	36	A-7-6 (40)	Clayey	1515	28.0	2.90	3
Spec. 2	64	29	35	A-7-6 (40)	Clayey	1530	27.0	2.25	3
Spec. 3	63	32	31	A-7-6 (36)	Clayey	1545	29.5	2.27	3
Spec. 4	56	31	25	A-7-6 (29)	Clayey	1478	19.5	2.27	5
Spec. 5	53	26	26	A-7-6 (26)	Clayey	1584	14.0	5.21	7

In the Atterberg Limit Test, the improvement of the liquid limit and plastic limit was significant with the 15% and 20% additional Calcium Oxide (CaO). The plasticity index of the 4th and 5th samples was closer to having a low potential swell compared to the first three samples. It was observed based on the LL and PI values that the Spec. 1,2, and 3 shows minimal improvement to be used for subgrade soil stabilizer, while the Spec. 4 and 5 were classified to have a medium swell potential but are close to having a low swelling potential. The 4th specimen with 15% added CaO had the lowest plasticity index of them all having a PI of 25, but still fell under the medium potential swell range. According to the AASHTO system, a group index value that was close to 0 indicated good soils, while value of 20 or more indicates poor soils [13]. Based on the group index of the specimens, it showed an improvement to the soil, lowering its group index value from 40 to 26; however, the current added percentages of CaO were insufficient to show a significant improvement.

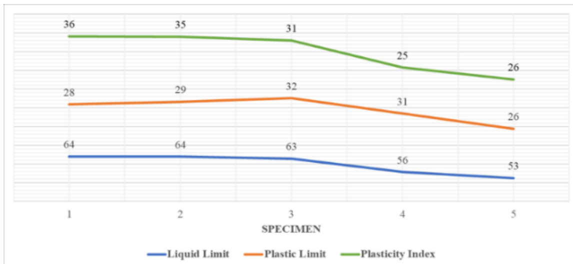

Fig. 1. Atterberg Limit Test Summary

The Standard Proctor Test shows that the addition of Calcium Oxide (CaO) results in an increase in the Maximum Dry Density (MDD) from 1511 kg/m3 to 1574 kg/m3, leading to a decrease in the Optimum Moisture Content (OMC) from 27.7% to 12.2%. The 4th specimen, which had a 15% CaO mixture, showed a significant decrease in the MDD, indicating a deviation from the trend observed in the previous specimens. Although, if the results were assessed from the control and the 5th specimen, the data gathered displayed a constant improvement from both the OMC and MDD. Overall, the 5th specimen achieved the highest MDD and the lowest OMC, indicating a potential for improving soil compaction, resulting in denser and more stable soil. These findings highlight the importance of considering both MDD and OMC in soil compaction. Achieving higher MDD values generally indicates denser and more compacted soil, while lower OMC values imply the soil requires less water for optimal compaction.

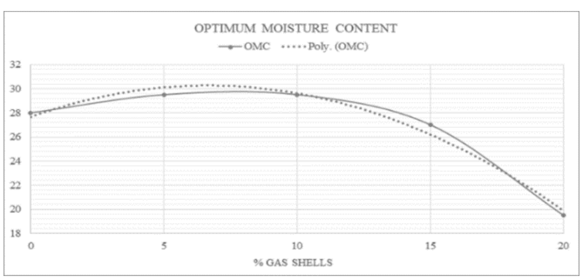

Fig. 2. Optimum Moisture Content Summary

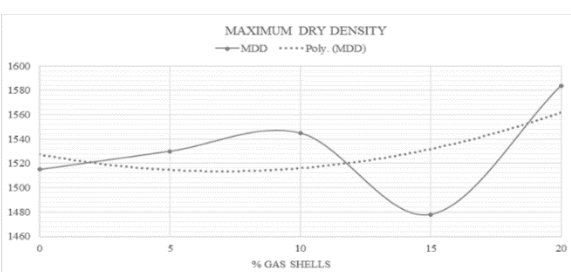

Fig. 3. Maximum Dry Density Summary

In the California Bearing Ratio Test where specimens were soaked for 24 hours, the CBR value of the soil sample increased from 3% to 7% when 20% of CaO was added. It showed that there was an improvement to the soil when a high percentage of CaO is introduced in the soil. The increase of the CBR value was plotted below for better visualization.

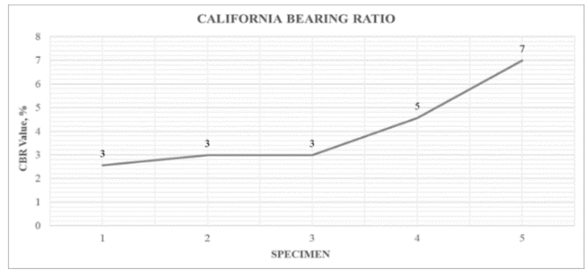

Fig. 4. California Bearing Ratio Summary

The CBR swell lowered after 5% of CaO was added to the soil sample. However, after the 2nd specimen, the swelling slowly increased and rose significantly high at 20%. This may be due to its low OMC at which point it had reached its MDD. Immediately after its soaking, the dial gauge rotated which indicated that it already absorbed moisture. The figure below shows the difference of CBR swell of the 5 specimens.

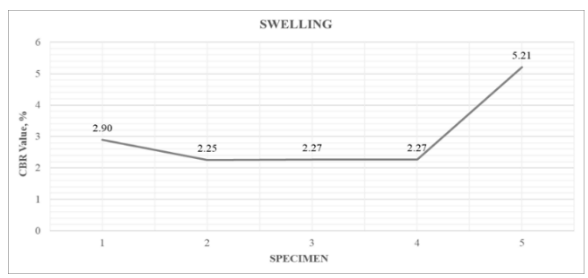

Fig. 5. California Bearing Ratio Swelling Summary

CONCLUSION

The sandy clay loam soil that is prevalent in the province of Pampanga, generally classified to have a fair to poor subgrade rating. However, upon testing, the acquired soil sample was deemed to be only a clayey type of soil which is still unsuitable for construction unless mechanically or chemically enhanced.

In this study, a clayey soil sample was stabilized utilizing calcined Golden Apple Snail Shells as a stabilizer. Different laboratory tests showed improvements in the characteristics of the soil samples. As the percentages of the calcined GAS shells were introduced, the liquid limit and plasticity index of the soil decreased thus leading to an increased MDD and a decreased OMC. An increase of the said compound also makes the soil compact however it still lacks and does not manage to achieve even the lowest CBR value needed for the soil to be a suitable subgrade. It can be concluded that the current percentages of the calcined GAS shells were insufficient to stabilize the said clayey type of soils.

REFERENCES

[1] Google. (2022). Natural Resources. Pampanga.gov.ph. Retrieved from https://www.pampanga.gov.ph/index.php/ general-information/natural-resources.html.

[2] Jahandari, S., Tao, Z., Saberian, M., Shariati, M., Li, J., Abolhasani, M., … Rashidi, M. (2021). Geotechnical properties of lime-geogrid improved clayey subgrade under various moisture conditions. Road Materials and Pavement Design, 1–19. doi:10.1080/14680629.2021.1950816

[3] Afrin, H. (2017). A Review on Different Types Soil Stabilization Techniques. International Journal of Transportation Engineering and Technology. 3. 19. 10.11648/j.ijtet.20170302.12

[4] Adams, T. (2022, June 8). Methods of Soil Stabilization - Global Road Technology. GRT. Retrieved from https://globalroadtechnology.com/methods-of-soilstabilization/

[5] Sharma, L. K., Sirdesai, N. N., Sharma, K. M., & Singh, T. N. (2018). Experimental study to examine the independent roles of lime and cement on the stabilization of a mountain soil: A comparative study. Applied Clay Science, 152, 183–195. doi10.1016/j.clay.2017.11.012

[6] Mohd Zambri, N., & Md. Ghazaly, Z. (2018). Peat Soil Stabilization using Lime and Cement. E3S Web of Conferences, 34, 01034. doi:10.1051/e3sconf/20183401034

[7] Happe, N. (2022, June 17). Stabilisation Testing | CBR Testing | Plate Load Testing. I2 Analytical. Retrieved fromvhttps://www.i2analytical.com/services/geotechnical-testing/stabilisationtesting/

[8] Makusa, G. P. (2013). Soil stabilization methods and materials in engineering practice: State of the art review. Retrieved from https://www.divaportal.org/smash/get/diva2%3A997144/FULLTEXT01.pdf

[9] Wang, Zhigao & Tan, Jicai & Tan, Lin & Liu, Jun & Zhong, Lang. (2012). Control the egg hatchling process of Pomacea canaliculata (Lamarck) by water spraying and submersion. Acta Ecologica Sinica. 32. 184–188.10.1016/j.chnaes.2012.04.008.

[10] Joshi R.C., Cowie R.H., & Sebastian L.S. (eds). (2017). Biology and management of invasive apple snails. Philippine Rice Research Institute (PhilRice), Maligaya Science City of Muñoz, Nueva Ecija 3119. 406 pp.

[11] Peña, S.C., Pocsidio, G.N., & Co. E.l. (2017). Histological Responses of Golden Apple Snail (Pomacea canaliculata) to Copper. Retrieved from https://www.semanticscholar.org/paper/Histological-Responses-of-Golden-Apple-Snail-(-)-to-Pe% C3%B1a-Pocsidio/337b80722ef5be30aa67ccfec 09d-ac6998932079

[12] Laonapakul, T., Sutthi, R., Chaikool, P., Mutoh, Y., & Chindaprasirtd, P. (2019). Optimum conditions for preparation of bio-calcium from blood cockle and golden apple snail shells and characterization. ScienceAsia, 45(1),10. Retrieved from https://doi.org/10.2306/scienceasia15131874.2019.45.010

[13] Deloney, M. L. (2021). What Is the AASHTO Classification System | AASHTO Classification System Procedures. CivilJungle. Retrieved from https://civiljungle.com/what-is-the-aashto-classificationsystem-aashto-classification-system-procedures/