

Study Added of Waste Chicken Egg Shell in Soils

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Abstract—Soil is the foundation of structure or construction that will receive the load transfer through to foundation. If the soil has a carrying capacity of small and cannot withstand the load transfer can result in the failure of construction. If the soil has a carrying capacity of small ground it is necessary to stabilize or improve the soil so that an increase in the carrying capacity of the land so that it can be used for construction. One material is commonly used for soil stabilization with the addition of lime. Waste chicken egg shell is waste that is still rarely used, the results of research is states that composition egg shell broadly consists of water (1,6%) and dry material (98,4%). The total dry ingredients are there, in shell eggs contained mineral elements (95,1%) and protein (3,3%). Based on the existing mineral composition, then the egg shells are composed of crystalline CaCO_3 (98,43%), MgCO_3 (0,84%) and $\text{Ca}_3(\text{PO}_4)_2$ (0,75%). This research was done by adding powdered chicken egg shell waste in clay with a composition of 5%, 7,5%, 10% and 14% with physical properties test and soil compaction test. This research is an experimental study dan the results showed classification of soil with system USCS (*Unified Soil Classification System*) shows the percentage of grains of soil sieve No. 200 amounted to 60,24% (> 50%), then USCS ground based system can be classified as fine-grained soil, liquid limit is 31,92% and plasticity index is 5,44 so that the soil is classified as silt organic and clay organic with low plasticity (OL). Unit weight dry (γ_{dry}) value in the addition of 10% waste chicken egg shell has increased a maximum of 1,58 gr/cm^3 into 1,630 gr/cm^3 at 14 days of aging (increase occurred at 3,164%). Water Content Optimum (w_{opt}) in the addition of 10% waste chicken egg shell has decreased a maximum of 22,18% into 20,33% at 21 days of aging (decrease occurred at 1,85%).

Index Terms—soils, waste chicken egg shell, liquid limit, plasticity index

I. INTRODUCTION

Land is an essential element in the development of the construction as a beachhead foundation that bears the entire burden of the construction that was built on it. If bearing capacity of soil is low and soil properties are sensitive to water maybe cause damage to the construction, examples of the damage that may occur landslip, cracks in the pavement (cracking), the structure of plates uplifted, the soil expands, etc.

Soil stabilization can be done to increase the carrying capacity of the land The first method is the mechanical

stabilization for example, mixing several types of soils with the aim of producing well graded soil, the installation of other materials as reinforcement on the ground, use of geotextiles as well as the improvement of the soil surface with a drainage system. The second method is soil improvement with the addition of chemical stabilization of added materials (additive) to the soil to improve soil physical properties, such as strength, texture, workability and plasticity. Materials that can be used as an added ingredient in the improvement of the soil include lime, portland cement, asphalt (bitumen), fly ash, etc.

Soil stability is mixing the soil with certain materials to improve the engineering properties of soil stabilization. Process covering soil mixing with other soil or added material to obtain the desired gradation so that the engineering properties of the soil such as: strong support, compressibility, permeability, potential for development and sensitivity becomes better [1].

II. CHIKEN EGGSHELL

Egg shell is the outermost part of the egg that serves to give protection to the component of the egg content from damage, either physically, chemically and micro-biologically, the rest of the hatchery is meant here is everything waste generated from industries such hatching eggs that did not hatch (sterile), eggshell of chicks that have hatched and eggshells in it still contains the embryo dead. When observed through a microscope, it can be seen that the eggshell is composed of four layers, namely:

A. Cuticle Layer

Cuticle is a transparent layer of proteins that coat the surface of the eggshell. This layer lining the pores in the eggshell but nature can still be passed gas so that the discharge of water vapor and CO_2 gas can still occur.

B. Foam Layer

This layer is the biggest part of the skin layer of the egg. This layer consist of protein and limestone layers consisting of calcium carbonat, calcium phosphate, magnesium carbonat and magnesium phosphate.

C. Mammillary Layer

This layer is the third layer of the egg shell consists of a cone-shaped layers with a round or oval cross-section. This layer is very thin and consists of woven protein and minerals.

D. Membrane Layer

This is part of the deepest layer of the egg shell. Composed of two layers of the membrane that envelops the entire contents of the egg.

Based on this research, chicken egg shell powder contains calcium of 401 ± 7.2 grams or about 39% of calcium, in the form of calcium carbonate. There is also a strontium at $372 \pm 161\mu\text{g}$, toxic substances such as Pb, Al, Cd, and Hg in small quantities, as well as V, B, Fe, Zn, P, Mg, N, F, Se, Cu, and Cr. [2].

The composition of egg shell broadly consists of water (1,6%) and dry matter (98,4%). The total dry ingredients are there, in shell eggs contained mineral elements (95,1%) and protein (3,3%).[3], the existing mineral composition, then the egg shells are composed of crystal CaCO_3 (98,43%), MgCO_3 (0,84%) and $\text{Ca}_3(\text{PO}_4)_2$ (0,75%).

III. CALCIUM CARBONATE (CaCO_3)

Calcium carbonate is the calcium salts contained in chalk, limestone, marble and is a major component contained in egg shells [4]. Calcium carbonate powder form, white, odorless, tasteless, stable in air. Partially insoluble in water, solubility in water increases with little ammonium salts or carbon dioxide. Insoluble in nitric acid to form gas bubbles [5].

One of the chemical properties of calcium carbonate that can neutralized the acid. The use of calcium carbonate in the pharmaceutical field is as an antacid because of its ability to neutralize the acid but calcium carbonate can cause constipation.

If calcium carbonate is heated to a temperature of 900°C , the calcium carbonate will form calcium oxide (CaO) due to release of carbon dioxide (CO_2), The reaction can be written as follow:



CO_2 is an exhaust gas which can have a negative impact on human health, therefore living soil stabilization with lime (quicklime) or calcium oxide (CaO) which is generally obtained from the above reaction can have a negative impact on the environment.

IV. SOIL PHYSICAL PROPERTIES TEST

A. Water Content (w)

Water content (Moisture content) is the ratio between weight of water to weight of the soil grains. The water content is percentage of water a material that can be expressed by wet weight (wet basis) or based on the dry weight (dry basis). The water content of the wet weight has a theoretical maximum limit of 100 percent, while the water content by dry weight can be more than 100 percent [6].

B. Specific Gravity (G)

Specific gravity is the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to

the mass of a reference substance for the same given volume. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance [7].

C. Atterberg Limit

Atterberg limits introduced by Albert Atterberg in 1911 with the aim of fine-grained soil to classify and determine the nature of the soil property index. Atterberg limits comprise the liquid limit, plastic limit, and shrinkage limit [8].

Fine grained soils usually have plastic properties. The plastic properties of the soil's ability to adjust the shape change of the ground after mixed with water at a fixed volume. The land will be a liquid, plastic, semi-solid or solid depending on the amount of water that is mixed in the soil. Atterberg limits show the shape of the solid ground to become viscous fluids according to their water content. Atterberg limits of test parameters will be obtained liquid limit, plastic limit, sticky limit and limit cohesion which is the state of the soil consistency. Atterberg boundaries can be seen in the following Table I below:

TABLE I. PLASTICITY LIMIT OF SOILS

PL(%)	Character	Type of soils	Cohesif
0	Non plastic	Sand	Non cohesif
< 7	Low plasticity	Silt	Cohesion partly
7 - 17	Medium plasticity	Clayed silt	Cohesif
> 17	High plasticity	Clay	Cohesif

1) Liquid Limit (LL)

Liquid limit (LL) is the water content of soil for the values above, the soil will behave as a viscous liquid (the boundary between the liquid state and a plastic state), which is the upper limit of the plastic area.

2) Plastic Limit (PL)

Plastic limit (PL) is the water content to values below, the ground is no longer influential as the plastic material. Soil will be a plastic material in a water content ranging between LL and PL. This range is called the plasticity index.

3) Plasticity Index (PI)

Plasticity index is an interval of water content, the soil still is plastic. Therefore, the plastic index indicates the nature of the soil keplastisitas. If the soil has a water content interval small plastic area, then this state is called invitation thin soil. In contrast, jika soil water content interval area has a large plastic called peat. Plasticity index value can be calculated with the following equation:

$$IP = LL - PL \quad (2)$$

Restrictions on plastic index, the nature, kinds of soil and cohesion provided by Atterberg contained in the following Fig. 1.

D. Shrinkage Limit (SL)

Condition water content at the position between the semi-solid and solid areas, namely the percentage of moisture content where further reduction of water content does not lead to changes in the volume of soil is called Limit Losses.

$$SL = (V_0 / (W_0 - 1/G_s)) \times 100\% \quad (3)$$

where:

- SL = Shrinkage limit
- V_0 = Volume of specimen dry
- W_0 = Weight of specimen dry
- G_s = Specific gravity

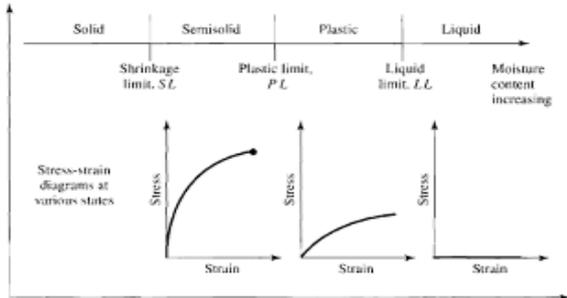


Figure 1. Atterberg limits

V. MECHANICAL ANALYSIS OF SOIL

A. Gradation of Soils

Mechanical analysis is the determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight. Two methods are generally used to find the particle size distribution of soil:

- a. Sieve analysis – for particle sizes larger than 0,075 mm in diameter.
- b. Hydrometer analysis – for particle sizes smaller than 0,075 mm in diameter.

The basic principle of sieve analysis and hydrometer analysis are briefly described in the following two section.

B. Modified Proctor Test

Modified Proctor compaction test is a laboratory method to determine the optimal experimental moisture content where in a particular type of soil will be the most solid and achieve maximum dry density. The term proctor is to honor RR Proctor, who in 1933 showed that the dry density for a given compaction effort depends on the amount of groundwater during soil compaction and the original tests often referred to as a standard proctor compaction test [9]. Laboratory tests generally consist of soil compaction on water levels known to the cylinder mold dimensions using the standard amount of compaction effort is controlled. The soil is usually compacted into molds with a certain amount of the same layer, each received a blow from a hammer-weighted standard at a certain height. The process is then repeated for a range of water content and dry density determined for each. Graphic relationship of the dry density of the water content is then plotted to form a curve compaction. Finally maximum dry density obtained from the cusp of the curve compaction and moisture content are appropriate, also known as the optimum moisture content. The formula used in the calculation modified proctor compaction as follows:

$$ZAV = G_s / (1 + (G_s + w) / 80) \quad (4)$$

$$\gamma = (\text{weight of wet soil} / (\text{volume mold})) \quad (5)$$

$$\gamma_d = \gamma / (1 + w) \quad (6)$$

where;

- Z.A.V = zero void water
- w = moisture content
- G_s = specific gravity
- γ_d = Unit weight dry (g/cm^3)
- γ = Unit weight (g/cm^3)

VI. SOIL SAMPLING TEST

Soils sampling sites taken in district Gowa, Sungguminasa, Subdistrict Pallangga, Poros Limbung.street in South Sulawesi Province, country Indonesia.

Testing was conducted in laboratory test soils mechanics Universitas Atmajaya Makassar.

VII. FLOW DIAGRAM

Flow diagram is shown in the following Fig. 2:

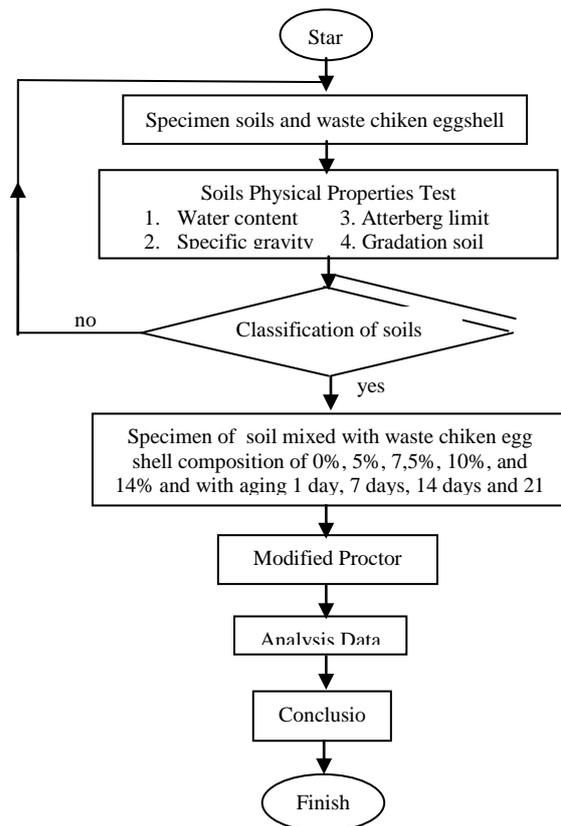


Figure 2. Flow diagram

VIII. METHODOLOGY

A. Types of Research

Research was an experimental study, to make trial samples and then test in soil mechanics laboratory. Samples for testing are made as many as 85 samples, consisting of soil samples no mixture is 5 sample, sample soils with the addition of 5%, 7.5%, 10% and 14% respectively of 20 samples consisting of 5 samples for soaked 1 day, 5 samples for soaked 7 days, 5 samples for soaked of 14 days and 5 samples for soaked of 21 days.

B. Standard of Reference

Table II. Shows the reference laboratory test.

TABLE II. STANDARD OF REFERENCE

Test	Reference
Water Content	ASTM D-2216-98
Unit Weight	ASTM D-854-02
Sieve Analysis	ASTM D 1140
Liquit Limit	ASTM D-4318-00
Plastis Limit	ASTM D-4318-00
Modified Proctor	ASTM D-698

IX. ANALYSIS DATA

A. Soil Physical Mechanical Properties

Soil Physical Properties Test results are shown in Table III:

TABLE III. TESTING PHYSICAL AND MECHANICAL PROPERTIES OF SOILS

No	Soils test	Value
1	Water content (w)	27,61%
2	Unit weight (γ)	2,475
3	Liquid Limit (LL)	31,92%
4	Plastic Limit (PL)	26,48%
5	Index Plasticity (IP)	5,44%
6	Shrinkage Limit (SL)	19,44%
7	Percent sieve 200	60,24%
8	Unit weight dry (γ_d)	1,58 gr/cm ³
9	Water content optimum (w_{opt})	20,33%

According to the Unified Soil Classification System (USCS), including fine-grained soil, this is expressed by percent through sieve 200 more than 50%. Liquid limit values obtained less than 50% causes the soil has a low plasticity. From the results of soil classification by USCS then district Gowa, Sunggu-minasa, Subdistrict Pallangga, Poros Limbung.street in South Sulawesi Province belonging to the types of silt organic and clay organic with low plasticity (OL).

B. Testing Chemical Properties of Waste Chicken Eggs Shell

Testing chemical properties of waste chicken eggs shell results are shown in Table IV.

Chemical test results show that waste chicken eggs shell contains Calcium (Ca) is 37,30% and Carbonate (CO₃) is 58,0% which is large around 95,30%.

TABLE IV. THE ABSOLUTE AND RELATIVE WEIGHT OF THE MINERAL CONSTITUENT OF EGG SHELL

Mineral	% of the total weight	g / total weight
Calcium (Ca)	37,30	2,30
Magnesium (Mg)	0,38	0,02
Phosphorus (P)	0,35	0,02
Carbonate (CO ₃)	58,00	3,50
Manganese (Mn)	7,00	ppm

Source [3]

C. Modified Proctor Test

Modified Proctor test with the original soil, water content optimum (w_{opt}) is 20,33% and unit weight of dry is 1,58 gr/cm³. Result modified proctor test in the addition of a waste chicken egg shell with aging 1 day, 7

days, 14 days and 21 days are shown in Table V to Table VIII below:

TABLE V. RESULT MODIFIED PROCTOR TEST WITH AGING 1 DAY

No	Waste chicken eggs shell	Unit weight dry (gr/cm ³)	Optimum Moistuire Content (%)
1.	5 %	1,599	16,46
2.	7,5%	1,605	17,29
3.	10 %	1,612	17,36
4.	14 %	1,610	17,31

TABLE VI. RESULT MODIFIED PROCTOR TEST WITH AGING 7 DAY

No	Waste chicken eggs shell	Unit weight dry (gr/cm ³)	Optimum Moistuire Content (%)
1.	5 %	1,602	17,54
2.	7,5%	1,609	18,96
3.	10 %	1,618	21,46
4.	14 %	1,615	19,61

TABLE VII. RESULT MODIFIED PROCTOR TEST WITH AGING 14 DAY

No	Waste chicken eggs shell	Unit weight dry (gr/cm ³)	Optimum Moistuire Content (%)
1.	5 %	1,622	19,55
2.	7,5%	1,625	20,48
3.	10 %	1,630	22,08
4.	14 %	1,628	20,13

TABLE VIII. RESULT MODIFIED PROCTOR TEST WITH AGING 21 DAY

No	Waste chicken eggs shell	Unit weight dry (gr/cm ³)	Optimum Moistuire Content (%)
1.	5 %	1,618	19,10
2.	7,5%	1,620	20,20
3.	10 %	1,625	22,18
4.	14 %	1,619	20,10

The test results of modified proctor test showed the addition of waste chicken eggs as much as 10% obtained value unit weight dry maximum where the aging 1 day obtained is 1,612 gr/cm³, aging 7 days obtained is 1,618 gr/cm³, aging 14 days was obtained 1,630 gr/cm³ and 21 days of aging was obtained 1,625 gr/cm³. Unit weight dry value in the addition of 10% waste chicken egg shell has increased a maximum of 1.58 gr/cm³ into 1,630 gr/cm³ at 14 days of aging (increase occurred at 3,164%).

Graph addition of waste chicken egg shell to the value of the unit weight dry shown in Fig. 3 below.

Fig. 3 shows the maximum value of unit weight dry of 10% occurred on the addition of waste chicken egg shell on curing 14 days and the addition of up to 14% showed a decline of 1,630 gr/cm³ be 1,628 gr/cm³.

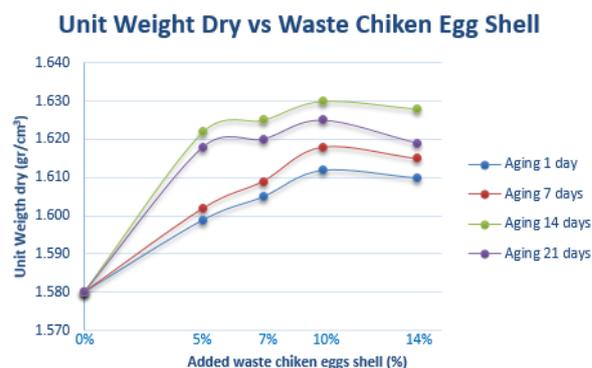


Figure 3. Unit weight dry vs waste chicken egg shell

Graph addition of waste chicken egg shell to the value of the water content optimum shown in Fig. 4 below

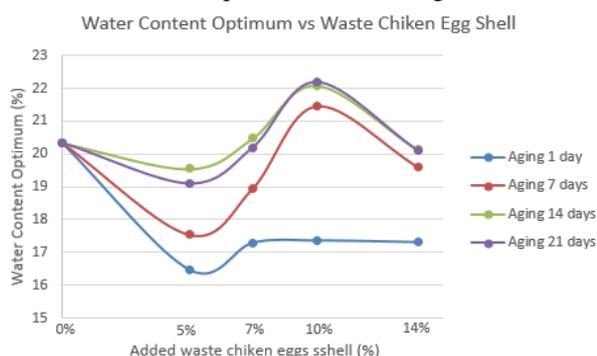


Figure 4. Water content optimum vs waste chicken egg shell

Fig. 4 shows the maximum value of water content optimum of 10% occurred on the addition of waste chicken egg shell on curing 21 days and the addition of up to 14% showed a decline of 22,18% be 20,10%.

V. CONCLUSION

Results of research on soils is added to the waste chicken eggs shell as follows:

- 1) Soil sample from district Gowa, Sungguminasa, Subdistrict Pallangga, Poros Limbung street in South Sulawesi Province is classification by USCS is the types of silt organic and clay organic with low plasticity (OL).
- 2) Unit weight dry value in the addition of 10% waste chicken egg shell has increased a maximum of 1.58 gr/cm³ into 1,630 gr/cm³ at 14 days of aging (increase occurred at 3,164%)
- 3) Water Content Optimum in the addition of 10% waste chicken egg shell has increased a maximum of 22,18% into 20,33% at 21 days of aging (decrease occurred at 1,85%)

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