International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I7P233

Volume 69 Issue 7, 263-269, July, 2021
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Model Test of Bearing Capacity of WasteTire Assembly Foundation on Soft Soil Layer

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Abstract - *In the planning of the foundation on the building, the selection of the model of the foundation is determined based on the function of the building.The purpose of this study was to analyze the behavior of waste tirse by filling granular material (coarse aggregate), as a concept capable of reducing foundation settlement on soft soil. Planning of three foundation models, Three gradations of coarse aggregate in the CBR (unsoaked) tests, and the highest CBR (unsoaked) value is used as the gradation of the waste tire filling for the foundation model test. Next test the ASTM D-2166 based compressive foundation model. Each foundation model applied to the soft soil layer, The results showed that in the model 1 soil without foundation there was a settlement by 100 mm with a maximum load of 26,55 kN, the model 2 vertically arranged tire foundation, there was a settlement by 10 mm with a maximum load of 45 kN, the model 3 horizontally arranged tire foundation, there was a settlement by 14 mm with a maximum load of 32, 43 kN.*

Keywords - *California Bearing Capacity (CBR), Coarse aggregate, Compressive Strength, Soft soil, Waste tire foundation.*

I. INTRODUCTION

In the planning of the foundation on the building, the selection of the model of the foundation is determined based on the function of the building. In general, foundation construction is built on basic land. The ability of the soil to shouldering this load is expressed as the bearing capacity of the soil, including the strong sliding of the soil. The land has always had an important role in every construction worksite. This is because the land is a load structure of the building to be erected on it [13][6].

Mixture of aggregate as a foundation construction material is influenced by the quality of the foundation, one of the factors is the nature of the aggregate gradation, density and bearing capacity expressed by CBR. The CBR value depends on the aggregate grain composition, density and bearing capacity [7].

The annual volume of the waste tire is estimated to be 800 million tires globally. It is subjected to a 2% increase each year [1][2]. The annual production of tires globally is reported to be around 1.4 million tires, equivalent to 17 tons of waste rubber [1][3]. Landfilling is the most common method for dumping tires today. Landfilling method is considered the worst way of disposal as it creates environmental problems[1]. Research on the strengthening of soft soil on shallow foundation with waste tires has been conducted by Gunawan S and Tjusanto T (2012) [4]. The results of soft soil research on shallow foundations before experiencing strengthening with waste tires have decreased considerably due to the load of the point he carried. The addition of a layer of tire to soft soil as a strengthening material minimizes the decrease that occurs by the load it carries compared to soft soil before the strengthening [4].

Shallow foundation models in the form of waste tire assemblies filled with coarse aggregate have ease of installation with a large enough bearing capacity. This study was conducted to analyze the behavior of waste tires filled with granular material (coarse aggregate), as a concept capable of reducing foundation settlement on soft soil.

II. MATERIALS AND METHODS

A. Materials

The coarse aggregate used in the study was obtained from the production of stone crushers, on Malino Road km. 7 [7]. Soft Soil taken from the quarry of Pattalassang Village, The land is transported by a dump truck to the laboratory and then put into the foundation tub soil [6].

Soft soils and coarse aggregates are tested to find out the characteristics of physical. California Bearing Capacity (CBR) performed as a parameter to evaluate the nature of the technique follows ASTM D-1833, CBR (unsoaked) testing standard, while the foundation model compressive test refers to ASTM D-2166. Three variations of coarse aggregate gradation in CBR (unsoaked) test, the highest CBR value in aggregate variation, which is used as waste tire stuffing gradation, namely 1"<(15%)<1.5", 3/4"<(25%)<1", no.4<(60%)<3/4". A high CBR (unsoaked) value in the gradation of coarse aggregate means that the gradation of coarse aggregate is dense and hard so that it is able to bearing the load.

The waste tires used are R.16 tires, have a wire on the tire, the thickness of the tire ring was 1,2 cm, tread was 13 cm, the diameter of 66 cm, and the thickness of 32 cm. The Installation of geogrid on the underside of tires, the installation of the geogrid is intended to hold the coarse aggregate from entering the soil, as shown in Figure 1.

Fig 1: The bottom of the waste tire was installed geogrid

B. Research Plan Model

This study continues the experimental research was conducted by Meti et al.(2021)[6], this research was conducted in The Geotechnical Laboratory of the Environment, Faculty of Engineering, Hasanuddin University, South Sulawesi, Indonesia.

This study tested the shallow foundation model, there are three shallow foundation models, namely model 1 soil without foundation, model 2 vertically arranged tire foundation, and model 3 horizontally arranged tire foundation., testing the compressive foundation model based on ASTM D-2166.

a) Foundation Model 1 Sketches Applied on Soft Soil

Model 1 soil without foundation is applied on soft soil for compressive strength test. The soft soil AASHTO A-7-5 method, which has been compacted, has a CBR value was 5.70 %. The length of the foundation tub was 266,67 cm, the thickness of the right left tub wall was 25 cm, the width of the tub was 250 cm, the thickness of the right left tub wall was 25 cm, the height of the foundation tub was 170 cm, thickness soil was 140 cm, diameter plate of 24 cm, as shown in Figure 2.

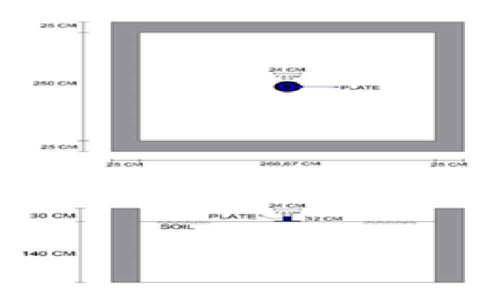

Fig 2: Foundation model 1 sketch

b) Model 2 sketches applied on Soft Soil

Model 2 vertically arranged tire foundation is applied on soft soil for compressive strength test. The soft soil AASHTO A-7-5 method, which has been compacted, has a CBR value of 5.70%. The length of the foundation tub of 266.67 cm, the thickness of the right left tub wall is 25 cm, the width of the tub is 250 cm, the thickness of the right left tub wall of 25 cm, the height of the foundation tub is 170 cm, thickness soil of 140 cm, diameter plate of 24 cm ,as shown in Figure 3.

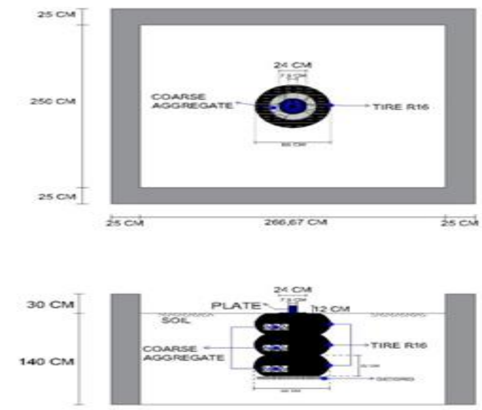

Fig 3: Foundation model 2 sketch

c) Model 3 Sketches Applied on Soft Soil

Model 3 horizontally arranged tire foundation is applied on soft soil for compressive strength test. The soft soil AASHTO A-7-5 method, which has been compacted, has a CBR value of 5.70 %. The length of the foundation tub was 266.67 cm, the thickness of the right left tub wall was 25 cm, the width of the tub was 250 cm, the thickness of the right left tub wall was 25 cm, the height of the foundation tub was 170 cm, thickness soil was 140 cm. diameter plate of 24 cm, as shown in Figure 4.

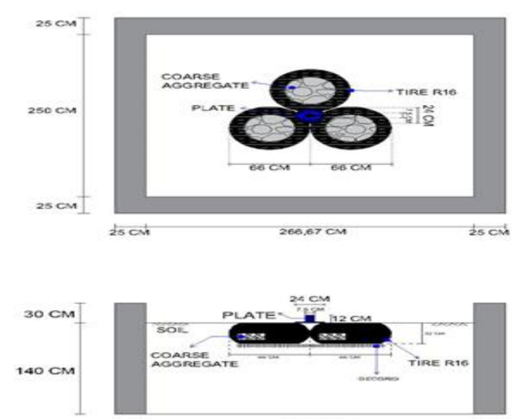

Fig 4: Foundation model 3 sketch

C. Research Procedural

Preparation of how to install the foundation tires of each model of the foundation, model 1 soil without foundation, model 2 vertically arranged tire foundation, and model 3 horizontally arranged tire foundation.

a) How to Install Foundation Model 1

How to install model 1 soil without foundation, namely soft soil AASHTO A-7-5 method, which has been compacted, has a CBR (unsoaked) value of 5.70 %, evenly filled in the tub with a height of 140 cm as shown in Figure 5.

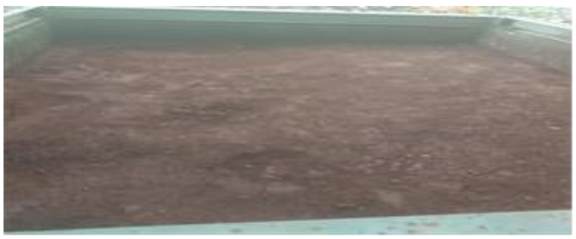

Fig 5: Finished installation of foundation model 1

b) How to Install Foundation Model 2

How to install model 2 vertically arranged tire foundation, namely soft soil AASHTO A-7-5 method, which has been compacted, CBR (unsoaked) value of 5,70%, ground height of 140 cm, then digging the soil as deep as 3 stacking tires, namely 96 cm, and installing the first tire into the ground, the first tire has been installed a geogrid, a geogrid that serves to hold the coarse aggregate, so as not to enter the ground, and put coarse aggregate gradation 1"<(15 %)<1.5", 3/4"<(25%)<1", no.4<(60%)<3/4", into the tire until full and compacted by pounding until solid, then installation the second tire, on top of the first tire and filled with coarse aggregate to the brim and pounded until solid and the installation of the third tire on top of the second tire, and filled with coarse aggregate until full and pounded until solid and even as shown in Figure 6.

Fig 6: : Finished installation of foundation model 2

c) How to Install Foundation Model 3

How to install model 3 horizontally arranged tire foundation, namely soft soil AASHTO A-7-5 method, which has been compacted, CBR (unsoaked) value of 5,70 %, ground height of 140 cm, Then dig the soil as deep as the tire, which is 32 cm, and install the three tires horizontally with the geogrid installed on the bottom three tires, as shown in Figure 7a. Geogrid serves to hold coarse aggregate from entering the soil, coarse aggregate gradation 1"<(15%)<1.5", 3/4"<(25%)<1", no.4<(60%)<3/ 4", is inserted into the three tires, until they are full which have been compacted or ground, as shown in Figure 7 b.

(a) (b)

Fig 7: Model 3 foundation mounting, (a) Installation of tires into geogrid-mounted soil, (b) Finished installation of foundation model 3

D. Research Stage Framework

Figure 8 shows the framework of the research stage. This study used waste tire waste material, coarse aggregate as gradation of used tire stuffing for foundation model test. The planned foundation model is three. The foundation model is applied to the soft soil layer, then the compressive strength test is carried out to analyze the behavior of each foundation model on the soft soil layer.

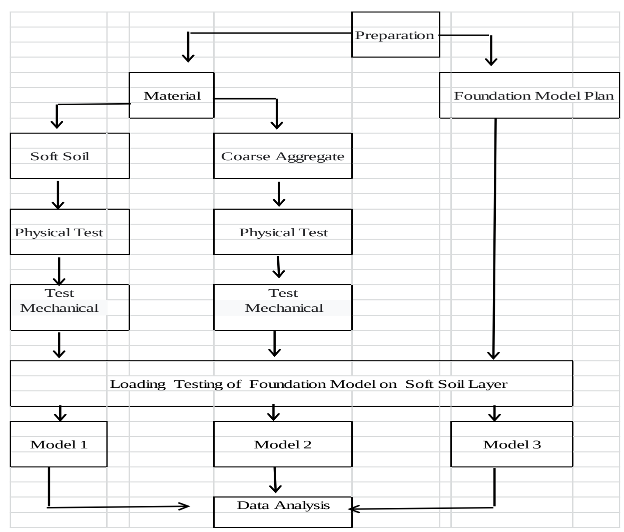

Fig 8: Research stage framework

III. RESULTS AND DISCUSSION

A. Physical Characteristics of Soil and Mechanical Characteristics

Based on the sieve and hydrometer analysis test on the soil

used, the filter no.200 or 0.075 mm is more than 50%. Based on the sieve and hydrometer analysis test on the soil used, the filter no.200 or 0.075 mm is more than 50%. The results of testing the physical characteristics of the soil are summarized Table 1. The results of the sieve analysis percentage of soil that passes the # 200 sieve is more than 50%. To produce a value between clay and silt, a hydrometer analysis was performed. The results of the hydrometer analysis showed that the percentage of silt and clay, namely silt, respectively, was obtained as a percentage of 57,4%. While the clay fraction was 12.8% [6].

Table 1. Recapitulation of soil physical characteristics examination[6].

Parameter	Symbol	Value	Unit
Voumetric Soil			
Specific Gravity	GS	2,68	-
Limit of Land Consistency			
1.Liquid Limits	LL	65,46	%
2. Plastic Limits	PL	44,03	%
3. Plastic Index	PI	21,43	%
Sieve Analysis and Hidrometer			
1.Sand		29,8	%
2. Silt		57,4	%
3. Clay		12,8	%
Sand Cone Test			
Soil without foundatioan	ɣdry	1,36	gr/cm^3
Vertically arranged tire foundatioan	ɣdry	1,36	gr/cm^3
Horizontally arranged tire foundatioan	ɣdry	1,36	gr/cm^3
Proctor Test			
Optimum moisture content	OMC	32,26	%
Maximum density	ɣdry	1,33	gr/cm^3

The purpose of direct shear testing is to determine the shear strength of the soil, which is obtained ϕ was 13^o and c was 0.17 kg/cm², and unconfined compressive testing strength, the compressive strength given until the soil is separated from the grains also measures the soil strain due to the pressure, qu was 0.14 kg/cm², the value of the bearing capacity of the soil in holding/supporting the load working on it, the CBR (unsoaked) value was 5.70 %.. The results of testing the mechanical characteristics of the soil, as shown in Table 2.

Table 2. Mechanical characteristics of the soil

Parameter	Symbol	Value	Unit
Direct Shear			
	ϕ	13	^{o}
	c	0,17	kg/cm²
Unconfined Compressive Strength	qu	0,14	kg/cm²
California Bearing Ratio- Unsoaked	CBR	5,70	%

The coarse aggregate used in the study was obtained from
the production of stone crushers, on Malino Road km. 7 and aggregate (as filler material) of waste tire assemblies. The requirements of aggregate physical in this study were those established by AASHTO (1990). In this study examination of aggregate physical examination results [7]. The results of the inspection, the aggregate meets the requirements and can be used, as shown in Table 3.

Table 3. Aggregate of physical examination [7].

No	Physical of aggregate	Terms	Test Results
1	Specific gravity	> 2,5	2,65
2	Saturated surface dry density	> 2,5	2,69
3	Apparent density	> 2,5	2,76
4	Absorption	< 3%.weight	1,63% weight
5	Wear	<40%.weight	23,52% weight

Figure 9, and Table 4, showing the test results of Califonia Bearing Capacity (CBR) unsoaked third variation of roughaggregate aggregate composition of 1.5", 1" and 3/4:" with gradations of 1 : 1"<(15%)<1.5", 3/4" <(25%)<1", and no.4<(60%)<3/4" ; gradation 2 : 1"< (20%)< 1.5", 3/4" <(30%)< 1" and no.4 <(50%)< 3/4"; gradation 3 : 1"<(25%)<1.5", 3/4"<(35%)<1" and no.4<(40%)< 3/4". Gradation 1 indicates CBR (unsoaked) value was 38.41 %, gradation 2 indicates CBR (unsoaked) value was 30.97 %, gradation 3 indicates CBR (unsoaked) value was 30.08 %.. Of the three gradations, gradation 1 with CBR (unsoaked) value the highest was gradation : 1"<(15%)<1.5", 3/4" <(25%)<1", and no.4<(60%)<3/4", CBR (unsoaked) value was 38,41% and chosen to be used as a gradation of waste tire stuffing foundation model, considered aggregate grains to fill and bind each other. The CBR (unsoaked) value is high, because the aggregate grains are distributed with a composition where the finer grains fill the voids between the coarser grains, so that the aggregate is dense.

Table 4. CBR (unsoaked) value of coarse aggregates

No	Gradation of coarse aggregates	CBR (%)
01	1"<(15%)<1.5", 3/4" <(25%)<1", and no.4<(60%)<3/4"	38,41
02	1"<(20%)<1.5", 3/4" <(30%)<1", and no.4<(50%)<3/4"	30,97
03	1"<(25%)<1.5", 3/4" <(35%)<1", and no.4<(40%)<3/4"	30,08

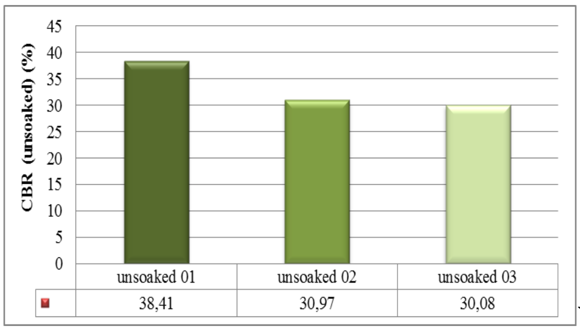

Fig 9: CBR (unsoaked) value of coarse aggregat

B. Foundation Model Test Behavior

In the performance model test model 1 soil without foundation. on top of a soft soil layer with a thickness of 140 cm. Furthermore, for compressive strength test, soil without foundation is burdened using bearing plate diameter of 24 cm until the collapse. The collapse occurred when the decline continued, but the load showed no increase. Figure 9 shows soil without foundation there is a deep settlement on soft soil during compressive strength test.

Fig 10: Soil without foundation model test

Based on the load-settlement behavior diagram, and the deformation pattern is shown in Figure 11, settlement occurring by 100 mm at a load of 26.55 kN. In the loading phase 6.55 kN the coating settlement by 10 mm, the loading phase was 11.55 kN, settlement by 20 mm, the loading phase was 16.5 mm, settlement by 40 mm, the loading phase was 21.55 kN, settlement by 80 mm and the peak load of 26.55 kN a settlement by 100 mm.

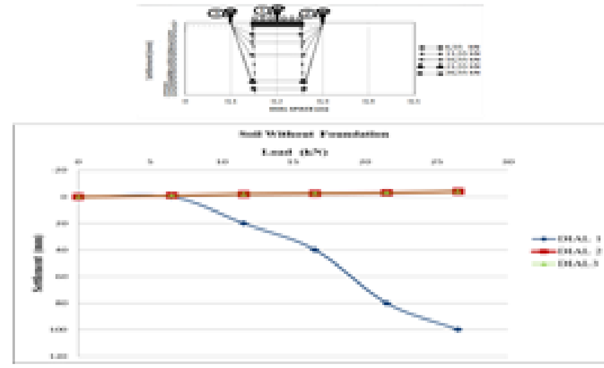

Fig 11: Graph of the relationship between load and settlement of foundation model 1

In the test the soft soil performance model with the horizontally arranged tire foundation model, . on top of a soft soil layer with a thickness of 140 cm, furthermore for loading test, the soil with vertically arranged tire foundation model is burdened using bearing plate diameter of 24 cm until the collapse. The collapse occurred when the decline continued, but the load showed no increase. The performance of the soil as a foundation soil layer and graph of the relationship between load and settlement as well as the collapse diagram at each phase of loading on the vertically arranged tire foundation model test.

Based on the load-settlement behavior diagram, and the deformation pattern is shown in Figure 13, settlement occurring by 10 mm at a load of 45 kN. In the 5 kN loading phase the layer settlement by 1 mm, the 15 kN loading phase settlement by 2 mm, the 25 kN loading phase settlement by 4 mm, the 35 kN loading phase settlement by 8 mm and the peak load of 45 kN, settlement by 10 mm.

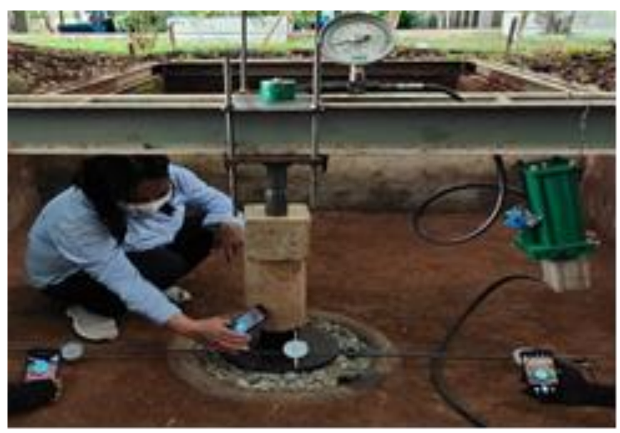

Fig 12 : Vertically arranged tire foundation model Test

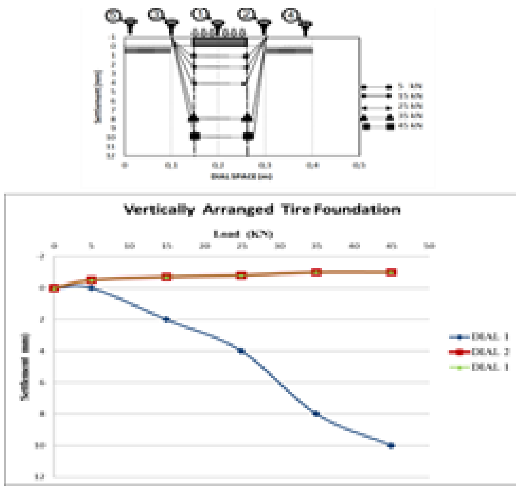

Fig 13: Graph of the relationship between load and settlement of foundation model 2

In the test the soft soil performance model with the horizontally arranged tire foundation model, . on top of a soft soil layer with a thickness of 140 cm. furthermore for loading test, the soil with vertically arranged tire foundation model is burdened using bearing plate diameter of 24 cm until the collapse. The collapse occurred when the decline continued, but the load showed no increase. The performance of the soil as a foundation soil layer and graph of the relationship between load and settlement as well as the collapse diagram at each phase of loading on the tire foundation model test are arranged vertically.

Based on the load-settlement behavior diagram and deformation pattern, the settlement occurred by 14 mm at a load of 32.43 kN. In the loading phase of 6.43 kN the layer settlement by 2 mm, the layer's 16.43 kN loading phase decreased by 6 mm, the 26.43 kN loading phase settlement by 10 mm, the 31.43 kN loading phase settlement by 13 mm and the peak load of 32.43 kN settlement by 14 mm, as shown in Figure 15.

Fig 14 : Horizontally arranged tire foundation model test

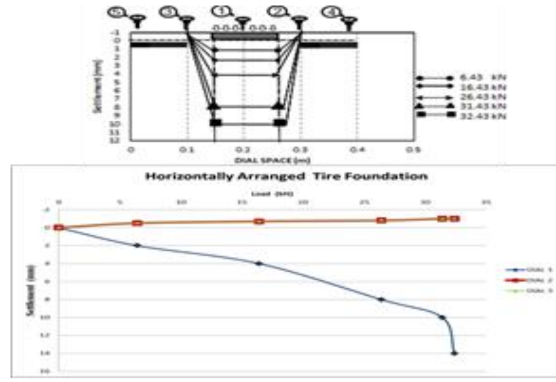

Fig 15: Graph of the relationship between load and settlement of foundation model 3

Based on the load-settlement behavior diagrams aimed at Figure 16, the 1st model soil without foundation showed the largest settlement of 100 mm with a maximum load achieved of 26,55 kN, model 2 vertically arranged tire foundation showed a settlement of 10 mm with a maximum load achieved of 45 kN, model 3 horizontally arranged tire foundation a settlement of 14 mm achieved a maximum load achieved of 32.43 kN, at the same observation point as the bearing plate position. At this stage, model 2 of vertically arranged foundations and model 3 of horizontally arranged foundations showed better performance compared to model 1 of soil without foundation. Peak loads increased by 18.55 kN on model 2 and 5.88 kN on model 3 compared to model 1. Vertical deformation decreased by 90 mm on model 2 and vertical deformation decreased by 86 mm on model 3 compared to model 1, as shown in Figure 16.

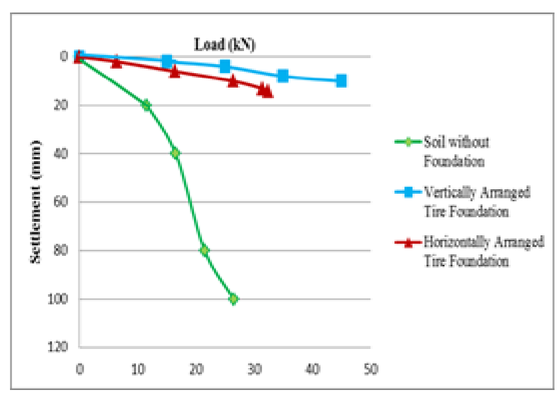

Fig 16: Comparison of subsoil performance with the three foundation models

IV. CONCLUSION

The conclusion from the research results that load-settlement behavior model 1 soil without foundation showed the largest settlement by 100 mm with a maximum load achieved of 26,55 kN, model 2 vertically arranged tire foundation showed a settlement by 10 mm, with a maximum load achieved of 45 kN, model 3 of horizontally arranged tire foundation a settlement by 14 mm achieved a maximum load achieved of 32,43 kN. Model 2 of vertically arranged foundation, and model 3 of horizontally arranged foundation showed better performance compared to model 1 of soil without foundation. Peak loads increased of 18,55 kN on model 2 and 5,88 kN on model 3 compared to model 1. Vertical deformation decreased of 90 mm on model 2, and vertical deformation decreased of 86 mm on model 3 compared to model 1. The shallow foundation model using waste tires filled with granular material (coarse aggregate) is able to significantly reduce the settlement of the foundation on soft soil compared to soil without foundation

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