Effect of Tire Layer on Bearing Capacity of Foundation

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Abstract Growth of economic, demographic and building activities in Iraq has necessitated carrying out geotechnical investigations for soft soils to study behavior of foundation resting on these soils. The laboratory test has been carried out to analyze the effect of tire as reinforcement to decrease the excessive settlement of soft soil. The influence of depth and area of tire layer is examined on the settlement of shallow foundation. For this purpose, a square foundation (60 \* 60) mm is used for the model test. All tests are conducted on the surface of homogeneous soil layer 250 mm; in a box steel (600 x 300 x 300) mm. The undrained shear strength of soil is 12 kPa. The reinforcement layer (tire layer) has been placed at depth 0.5B, B and 2B (B is the width of the square foundation) in the soft soil under foundation. The area of tire layer (B x B), (1.5B x 1.5B) and (2B x 2B) are investigated too. The analysis of the test results indicated that using tire layer under foundation has a significant effect on the settlement improvement (St/Su). It is worth noting, that the settlement improvement (St/Su) is decreased with the increase of the depth of tire layer. The results shows that the maximum increase in bearing capacity reaches approximately to 130\% at area of tire layer (B x B) and depth equal to 0.5B.

Keywords: Soil reinforcement, Tire layer, Soft clay, Shallow foundation.

1. Introduction

Soft soils require improvement of their properties if they have to be utilized as foundation (Abdulrasool, 2015). For this purpose, many soil improvement techniques such as preloading with sand drains, dynamic compaction, stone column, soil reinforcement, and skirted foundation by sand-lime wall (this method is new technique proposed by Abdulrasool, 2017). The soil reinforcement is an economical method and alternative to deep foundations. The big amounts of waste produced in the last year. These materials such as waste tires, rubbers, plastic and steel materials enter the environment and many countries around the world spend much more money than they did 15 years ago to remove the waste. The beneficial effect of slice stabilizes soils through reinforcement of soil in nature against erosion and slopes failure. In effect, the reinforcement of soil is a good and reliable technique for increasing stability and strength of soil. The good thing about this work is using the waste tire to bolster the soft clay, reduce settlement and increase the bearing capacity of soil. The foundation load transmits its weight to the underlying soil. The soil is sliding under applied load. When slippage of soil occurs a waste tire layer working to resist moving of soil, then, decrease the foundation shipwright inside the soil. Therefore, the tire reinforcement at effective depth is necessary to decrease settlement and increase bearing capacity. However, researchers have undertaken many studies in recent years to investigate best material to reinforce the soil and the best location to reinforce the soil such as (Pokharel, et al, 2010); (Sitharam, et al, 2007); (Garga, et al, 2000); (Kumar, et al, 2012);
(Zhang et al., 2010); (Al-Neami, 2010) is investigated the settlement behavior of soft clay by using reed layer under foundation and asphalt coating with reed. He recommends achieve the durability of the reed in the soil, asphalt coating must be used to prevent the reed decay).

2. Experimental Work

2.1 Material Used and Testing Program

2.1.1 Tire layer. The dimensions of tire layer are chosen to be (B x B) mm, (1.5B x 1.5B) mm, and (2B x 2B) mm (B is width of foundation 60mm). The thickness of the tire layer is equal to 3 mm.

2.1.2 Soil used. A clayey soil from the east of Baghdad is brought. The physical and chemical properties of the clay are shown in Table 1. The grain size distribution of clay used showed 3.3% sand, 31.7% silt and 65% clay as shown in figure 1. According to USCS, the soil is classified as CL.

| Index properties            | Index value | Units |
|-----------------------------|-------------|-------|
| Specific gravity (Gs)       | 2.69        | -     |
| Liquid limit (LL)           | 42          | %     |
| Plastic limit (PL)          | 19.5        | %     |
| Shrinkage limit (SL)        | 14.2        | %     |
| Plasticity index (PI)       | 22.5        | %     |
| Activity (At)               | 0.60        | -     |
| Gravel                      | 0           | %     |
| Sand                        | 3.3         | %     |
| Silt                        | 31.7        | %     |
| Clay                        | 65          | %     |
| Gypsum content              | 2.92        | %     |
| Total dissolved salt        | 3.7         | %     |
| SO₂ content                 | 1.8         | %     |
| Organic matter O.M          | 0.73        | %     |
| Ph. value                   | 9.32        | -     |
| Classification (USCS)       | CL          | -     |

Table 1. Physical and Chemical properties of Soil.

Figure 1. Grain size distribution of clayey soil used.
2.1.3 Arrangement of Soft Clay Bed. Many experiences of natural soil drying and mixing with water to obtain soil of undrained shear strength equal 12 kPa. These Attempts are used before preparing the bed of clay. Figure 2 as shown the fully saturated clay beds are prepared at undrained shear strength between 5 to 15 kPa.

![Figure 2](image_url) Variation of undrained shear strength versus water content.

After that, five layers of soil is placed in a steel box 600 x 300 x 300 mm. a steel hammer of 9.87 kg and dimension of 150x 150 mm is used to remove any entrapped air for each layer. This process persists for the five layers till 250 mm thickness of soil in the steel box. Top layer (final layer) of soil is scraped to get a flat surface, and polythen sheet is placed in top layer to prevent loss of moisture. A wooden board 600 x 300 mm (it is similar area to that of the surface area of bed soil) is placed on the top layer. After that, a seating load equal 5 kPa is placed for one day as cited by (Abdulrasool, 2017)

![Figure 3](image_url) Preparation steps of the bed of soil.

2.2 Testing Program
A series of tests are performed to study the reinforcing effect of clay with variation of width of tire layer and depth of tire layer. The first test investigated on the dimensions of the tire layer (60 x 60) mm, (90 x 90) mm, and (120 x 120) mm with thickness of 3 mm while depth is constant 30 mm. Second test investigated on three different types of tire layer depth i.e. 0.5B, B and 2B mm (B is width of foundation). The depth dimension of the tire layer for all cases is constant, (60 x 60) mm. The foundation (60 x 60 x 10) mm are placed on the surface of the soil in the steel box and subjected to
vertical static loading using. Two dial gauges were used and the vertical settlement of the foundation for each increment of load applied is recorder. The average of two dial gauges is taken. The dial gauges are located on each side of the Centre line of the foundation. Details of the main features of the loading assembly are shown in figure 4.

![Figure 4. Steel container and loading assembly](image)

3. Results and Discussion

The load-settlement relation is devoted for evaluating the settlement by using tire layer with different depth and different dimensions of layer too. The first group tests, effect of tire depth on the settlement of foundation, where the depth of tire to width of foundation ratio (d/B) (0.5, 1 and 2) and the dimension of tire layer is constant for all tests (B x B) (B is the width of the square foundation equal to 60 mm). Several criteria used to determine the bearing capacity. One of these criteria is (Terzaghi, 1947). (Brand, 1981), who considered the failure condition at a settlement equal to 10% of the width of foundation, use the same criterion. Figure 5 shows the bearing ratio (q/cu) versus settlement ratio (S/B Foundation) where S is settlement. Improvement ratio St/Su versus q/cu is shown in Figure 6. From these Figures, it can be seen that using tire layer at d= 0.5B showed clear decrease in the settlement of foundation and the maximum increase in the bearing capacity using tire approximately reach to 130 % in same depth because the foundation submergence is decreased in the soil. The Second group tests, the width of tire layer is gradually increased (B x B), (1.5B x 1.5B), (2B x 2B) while the depth of layer 0.5B. Figure 7 and 8; from these Figures the settlement ratio of foundation on different reinforcement area are determined. When increase the dimension of tire layer is not leading to significant settlement ratio and it is not considered an economical basis. The best of settlement ratio can be considered at area of tire equal (B x B) due to tire layer is working to resistant the soil wedge under foundation. This in turn caused an increase the bearing capacity of soft soil and decreases in settlement of foundation.
Figure 5. Bearing ratio \( (q/c_u) \) versus settlement ratio \( (S/B \text{ Foundation}) \) at different depth of tire layer.

Figure 6. Settlement reduction ratio versus bearing ratio at different depth of tire layer.

Figure 7. Bearing ratio versus settlement ratio at different dimensions of tire layer.
4. Conclusions
The following conclusions may be drawn from this study:
1. The load carrying capacity of the clayey soil increased by using tire layer due to the occurrence of resistance to sliding soil.
2. The tire layer will lead to reducing settlement and, depending on the depth of layer under foundation and the maximum improvement can be occurred in the depth approximately equal to 0.5B.
3. The Improvement settlement ratio $S_t/S_u$ is decreased for all cases because the foundation submergence is decreased in the soil.
4. The area of tire layer ($B \times B$) is considered economical to reducing settlement.

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