Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 7 Issue 10, October - 2021

Numerical Study Of Foundation Beaviour On Reinforced Soil With Waste Tire Shreds

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***Abstract*— Waste production is one of the greatest problems of the modern world. One of the most difficult and growing in amounts waste is scrap tires. The most common method of utilization of end-of-life tyres is by their incineration, which raises much concern in terms of air pollution. These problems produced the need to reuse the tire waste in beneficial ways in geotechnical applications. The aim of this research is to investigate numerically the effect of using tire shred–sand mixtures on bearing capacity and settlement of shallow foundations using finite element software Plaxis ver. 8.6. The Rubber-Sand layer was placed beneath the foundation in thicknesses of 0.5 up to 1.5 times the foundation width B. It was found that the ultimate bearing capacity of foundations constructed on reinforced soil was increased considerably up to 42% with a decreased settlement.**

Keywords— Scrap tires, Rubber-Sand layer, bearing capacity, Settlement, finite element, Plaxis

I. INTRODUCTION

In recent decades, the volume of scrap tire rubber in the world has increased significantly because of the globally developing vehicle industry and due to growing population. Consequently, their disposal has become a major environmental problem worldwide where hundreds of millions of waste tires are dumped in landfills or stockpiled, despoiling the environment. To address the environmental concerns, using waste tires combined with soil is becoming popular. In addition, when the chipped, shredded and granulated tire rubbers are mixed with soil, the mixture might behave as reinforced soil, similar to geosynthetic-reinforced soil, which can be advantageously employed to increase soil strength, depending on the rubber content and the size of rubber particles ([1] 2005; [2] 2006, [3] 2012, [4] 2013, [5] 2016 and [6] 2012).

[6], using a small-scale test, found that the optimal thickness of a single layer of rubber-soil mixture was approximately 0.5 times the width of the footing to achieve the maximum improvement in bearing capacity of the foundation bed. They reported that an increase in the thickness of rubber-soil mixture beyond its optimum value increases the soil's compressibility because of an increase in the total void space between the soil particles of the mixture and increases the settlement of the foundation bed.

[7], Studied experimentally the effect of using shredded tires as lightweight inclusion to improve the physical and mechanical properties of soil. It was found that using fine, medium and coarse tire shreds improves the shear strength of soil–tire mixture significantly where the maximum increase in angle of internal friction (ϕ) increased by up to 13%. The optimum percentage of shredded tires content was 9%.

II. MATERIALS USED

The materials used in this study are sand and fine shredded tires having the following properties

A. Sand

A fine to medium sand was used. Sand is classified as SP-SM according to Unified Classification System. The properties of sand sample are given in table (1).

TABLE 1. Summary of the Sand properties

Parameter	Value
Specific gravity Gs	2.65
Maximum dry density (kN/m^3)	17.8
Effective diameter D_{10} (mm)	0.07
Uniformity Coefficient (Cu)	3.429
Coefficient of curvature (Cc)	1.234
Modulus of elasticity Es (Mpa)	58
Poisson's ratio υ	0.3
Angle of internal friction (ϕ)	33°

B. Fine shredded tire

The shredded tire used is fine (< 0.425mm) having the following properties

TABLE 2. Summary of the fine shredded tire properties

Parameter	**Value**
Effective diameter D_{10} (mm)	**0.169**
Uniformity Coefficient (Cu)	**2.123**
Coefficient of curvature (Cc)	**1.062**

C. Shreded tire-Sand mixture

Fine shredded tire was used as a percentage which was selected as of 9% of dry weight of sand (according to [7]). The properties of shredded tire – Sand mixture are presented in table (3).

TABLE 3. Summary of the shredded tire- Sand mixture properties

Parameter	Value
Maximum dry density (kN/m^3)	15.14
Effective diameter D_{10} (mm)	0.11
Uniformity Coefficient (Cu)	2.278
Coefficient of curvature (Cc)	0.848
Modulus of elasticity Es (Mpa)	140
Poisson's ratio υ	0.35
Angle of internal friction (ϕ)	36°

III. NUMERICAL ANALYSIS

Numerical analysis using the finite element method (FEM) was carried out using plane strain elasto-plastic finite element method program (PLAXIS 8.6) to study the effect of using tire shred–sand mixtures on the behavior of centrally loaded footing on the top of rubber reinforced soil. Full modeling of soil, footing and loading are performed using commercial FEM package PLAXIS Version 8.6.

A. Numerical Model Setup

The soil was modeled using well-known Mohr-coulomb model which has been considered as a first order approximation of real soil behavior. A strip footing of width equal to 1m was placed on the soil surface exactly at the center of the soil model as shown in fig.1. The FE model has been configured with 15-noded triangular elements.

The boundaries are laterally fixed on both sides, and fixed horizontally and vertically at the bottom boundary as shown in fig. 2. The footing was modeled as a rigid plate element. Varied rubber reinforced soil layer thickness (h_{rs}/B) = 0.5, 0.75, 1, 1.25 and 1.5 were used to investigate the effect of shredded tire-soil mixture thickness on the bearing capacity and settlement of footing.

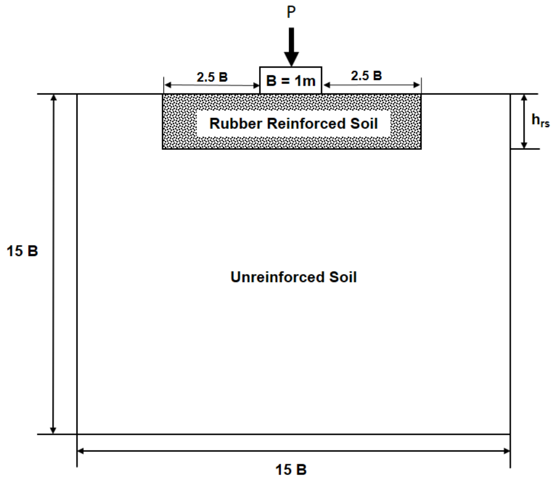

Fig.1 Geometry of finite element model

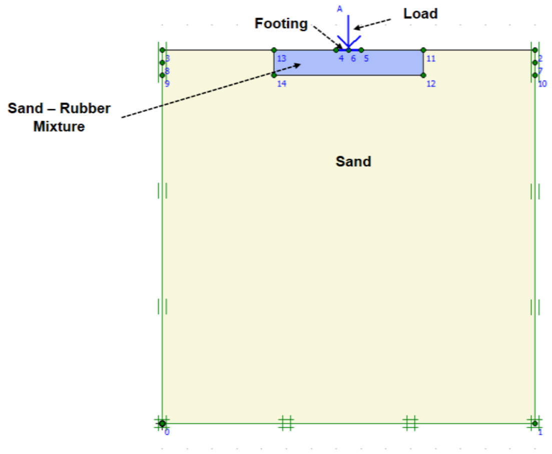

Fig.2 Finite element model showing the load and boundary conditions

Figs. 3-4 show the deformed mesh of the model and vertical displacement after application of footing load in case of rubber reinforced soil of thickness equal to one time the footing width (h_{rs}/B = 1**)**.

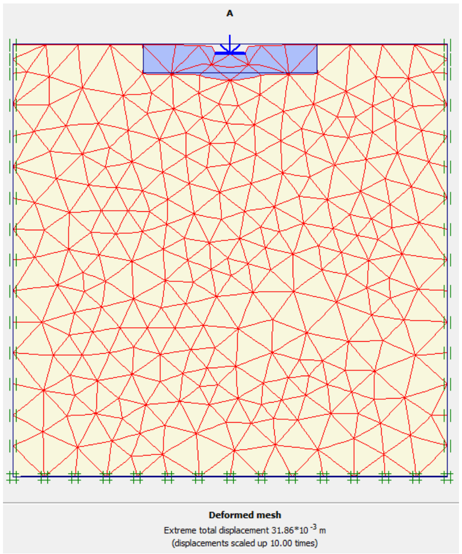

Fig.3 Deformed mesh

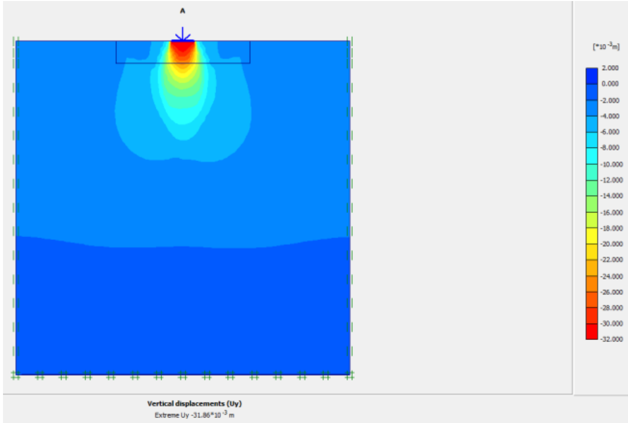

Fig. 4 Vertical Displacement (Uy)

IV. RESULTS AND DISCUSSION

The results were presented as the relation between the stresses under the footing in (KN/m2) versus its associated settlement in (cm). fig. 5 shows the relationship between the footing stress versus settlement in case of unreinforced soil and rubber reinforced soil with thicknesses ranges from 0.5 up to 1.5 times the footing width B. From fig. 5 it was observed that rubber-soil layer improves the ultimate bearing capacity of footing. The improvement reaches an increase in bearing capacity by a maximum percentage of 42% in case of using rubber-soil layer of thickness equal to 1.5 times the footing width B. Also, it was noted that the increase in bearing capacity is associated with a decrease in settlement for the same stress value.

The increase in bearing capacity could be attributed to the internal confinement provided by rubber - soil layers in the active zone beneath the footing, which restricts lateral displacement of soil layer as shown in figs. (6-7) and, hence, tends to increase the bearing capacity. It was observed that when the thickness of rubber-reinforced soil layer reaches around 1.0 times of the footing width, the reinforcing efficiency of mixture decreased considerably.

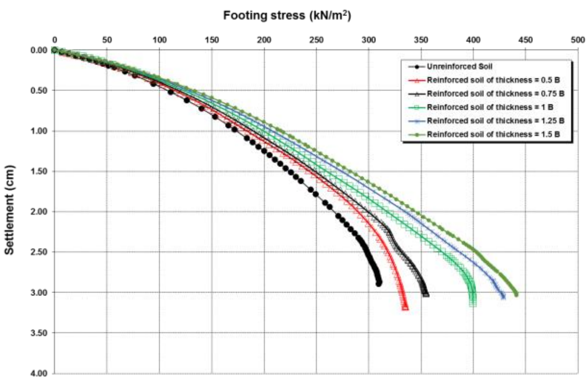

Fig. 5 The relationship between the footing stress versus settlement in case of unreinforced soil And Rubber reinforced soil

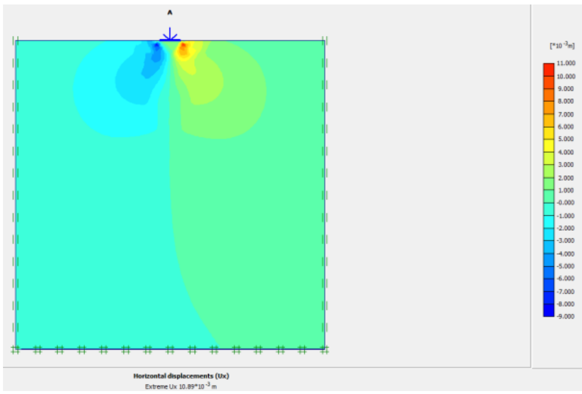

Fig. (6) lateral displacement (Ux) in case of unreinforced soil

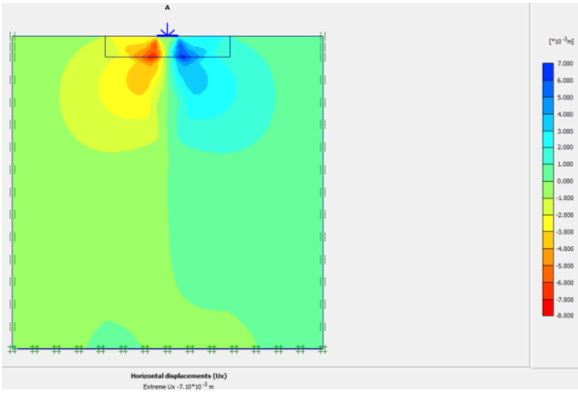

Fig. (7) lateral displacement (Ux) in case rubber reinforced soil of thickness ($h_{rs}/B = 1$)

V. CONCLUSIONS

Based on the results obtained, the following conclusions are derived:

1. The results prove the usefulness in recycling of tires waste to be used in geotechnical aspects hence, leads to beneficial effects on environmental considerations.
2. The results strongly suggest the re-use of tire waste in the form of shredded rubber mixed with soil beneath the footing. The improvement in ultimate bearing capacity reaches a maximum increase of 42% in case of using rubber-soil layer of thickness equal to 1.5 times the footing width B.
3. From the results of tests, it was concluded that the bearing capacity of footing increases with the increase in the thickness of rubber-reinforced soil layer up to an optimum value of about one times the width of footing.

4. It was noted that the increase in bearing

   capacity is associated with a decrease in settlement for the same stress value.

5. It can be concluded that the use of shredded

   tire-soil mixtures as reinforcement layer in foundation bed beneath the footing is very promising.

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