

# Interaction between Geogrid and Tire Chips-Sand Mixture: Pullout Test Simulation

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## ABSTRACT

The aims of the study were to measure and calculate the interaction coefficient between geogrid and sand and between geogrid and a tire chips-sand mixture using a laboratory test and numerical simulations. Numerical simulation was imperative for the sensitivity analyses of the laboratory test results to find the important parameters. Two types of material were used as backfill, namely sand and a tire chips-sand mixture. The sand and tire chips in the mixture were in the proportion by weight of 70 and 30%, respectively. Polyfelt geogrid was used as geosynthetic reinforcement with a tensile strength of 97.48 kN/m from the in-air tensile test. Pullout tests were carried out on a large-scale pullout machine. The shear strength parameters of Ayutthaya sand and the tire chips-sand mixture were a 29.8° friction angle with cohesion of 15.6 kPa for sand and a 24.4° friction angle with 14.3 kPa cohesion for the tire chips-sand mixture. The results revealed that the interaction coefficient obtained from the pullout test was 0.7 and 0.6 for the sand and tire chips-sand mix, respectively. Numerical analyses were also performed using finite element software. The results of the numerical simulation agreed reasonably with the laboratory results. Sensitivity analyses were carried out for the pullout test by varying the interaction coefficient and axial stiffness of the geogrid. These two important parameters were found to affect the efficiency of the geogrid reinforcement.

**Key words:** lightweight, geogrid, pullout, numerical, tire chip

## INTRODUCTION

In this study, construction of mechanically stabilized earth (MSE), a form of reinforced soil structure, has been proposed by reinforcing backfill soil with geosynthetic reinforcement. An MSE structure does not reduce the subsoil settlement owing to the embankment load. However, the presence of reinforcements can reduce the lateral movement. Subsequently, the settlement, especially the differential settlement, at the top of the embankment is reduced. The use

of lightweight geomaterials, like rubber tire chips and sand mixture, is becoming popular nowadays (Aydilek *et al.*, 2006). The lightweight tire chips-sand mixture is a recycled-waste geomaterial. When considering the reinforcing materials to use in field applications, the trend towards the use of typical geosynthetic reinforcements has been increasing markedly, especially with the use of geogrids. Many researchers are currently studying the basic properties and the stress-strain characteristics of lightweight geomaterials, like a tire chips-sand mixture, including the interaction

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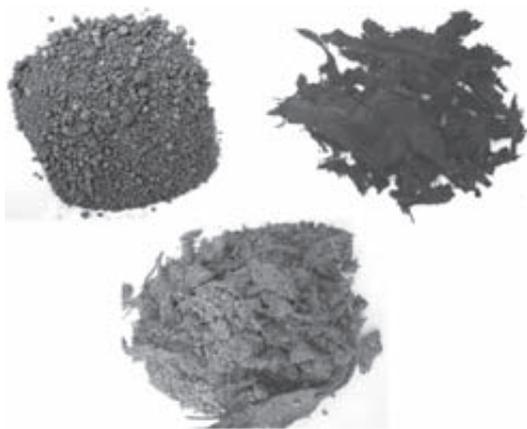
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between geogrid reinforcement and lightweight mixtures, by conducting large-scale direct shear tests and pullout tests (Tatliso $\acute{z}$  *et al.*, 1998; Prempramote, 2005; Tanchaisawat *et al.*, 2007).

This study applied several tests. The study started with sieve analyses and specific gravity tests for Ayutthaya sand and tire chips-sand mixtures. Then, compaction tests were carried out on the sand and tire chips-sand mixtures to determine the maximum dry unit weight and optimum moisture content of the materials. Subsequently, in-air tensile and pullout tests were used to study the interaction between grid reinforcement and backfill materials consisting of silty sand with- and without tire chips. Polyfelt geogrid (GX 100/30) was selected as the reinforcing material. Finally, the pullout tests were simulated using computer software.

## MATERIALS AND METHODS

The materials used in this study were sand and tire chips. Sand was obtained from a local source and the tire chips were sourced from a shredding process having had the steel belts removed (Figure 1). Backfill materials were of two kinds: 1) sand; and 2) a tire chips-sand mix with the ratio of 30:70 by weight. A standard test method



**Figure 1** Sand, tire-chips and tire chips-sand mixture.

for specific gravity was used for the sand and tire chips. This test was proposed because the results of the test were necessary for the calculation of other properties of sand and rubber tire chips. The standard procedure of sieve analysis was adopted to investigate the particle-size distribution of the sand and tire chips. A standard Proctor compaction test was used for both filling materials to obtain the optimum moisture content and maximum dry unit weight. The compaction parameters were used to determine the degree of compaction effort applied for each fill material throughout the pullout tests.

As sand with- and without tire chips was used as filling material, it needed curing to the optimum moisture based on the results of standard Proctor compaction test. For the comparison with the sand, the tire chip-sand mixture sample was also cured depending upon the optimum moisture content of the compaction test, based on the proportion % by weight of 30:70 for tire chips and sand, respectively, as recommended by Prempramote (2005). Polyfelt geogrid (GX 100/30) was chosen as the reinforcing material for this study, as it consisted of high-molecular, high-strength polyester yarns. The yarns were knitted to a stable network and equipped with a polymeric coating protection, in order to achieve a product with high knot stiffness and low material reduction factors. The product was suitable for both short-term and long-term soil reinforcement applications. A summary of geogrid properties by the manufacturer is shown in Table 1.

### In-soil pullout tests

Pullout tests conducted in this study were in-soil pullout tests i.e., the clamp was installed in the pullout box confined by the soil. This pullout test program was mainly used to investigate the interaction between the geogrid reinforcement and sand, with- and without tire chips, and the relationship between pullout resistance and pullout displacement. Both types of filling material were

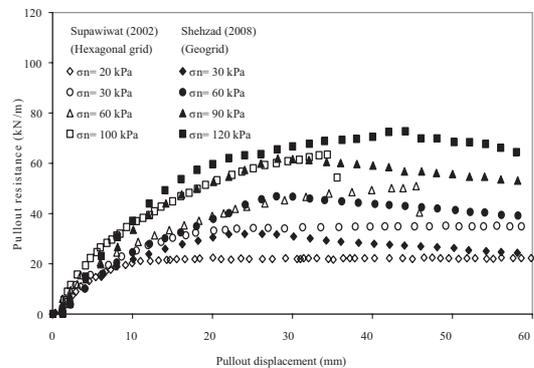
subjected to four normal stresses of 30, 60, 90 and 120 kPa, in order to cover the range of possible reinforcement failures (i.e., slippage and breakage). Since there were four applied normal stresses on the geogrid and sand, with- and without tire chips, the number of pullout tests on the geogrids was eight. Furthermore, as the results obtained from these eight tests included the results from the clamp with reinforcement, another eight pullout tests for the clamp only (without reinforcements) had to be added from those eight tests. Consequently, the total number of pullout tests was sixteen.

**In-soil pullout tests results**

The results of the in-soil pullout test with sand only (Figure 2) and with the tire-chips sand mixture showed pullout resistances that increased as the normal stress increased because with higher normal stress, the confinement on the grid increased. The peak values occurred between 20 and 50 mm pullout displacements for different normal pressures. With additional pullout displacement, the peak pullout resistances started

to decrease because the geogrid was torn at different places at different normal pressures. The maximum pullout resistances are shown in Figure 3.

On the other hand, the results of the tire chips-sand mixture were quite similar to previous research. After reaching the maximum pullout resistance, the subsequent values were nearly constant in registering the residual strength. Depending upon the magnitude of the applied normal stress, the failure mode of the geogrid could



**Figure 2** Pullout test results (sand backfill).

**Table 1** GX 100/30 properties.

Property (Test standard)		GX 100/30
Type of product		Knitted Polyester Geogrid
Material		High tenacity Polyester yarns with polymer coating
Characteristic short-term	MD (kN/m)	100
Tensile strength (ISO 10319)	CD (kN/m)	30
Elongation at characteristic short-term tensile strength	MD (%)	11
Creep limited strength 120 years (kN/m)		68
Long term design strength for 120 yrs (kN/m)		58
Aperture size (+5 mm)	MD (mm)	25
	CD (mm)	30
Forms of supply	Width (m)	2.5
	Length (m)	100
	Weight of roll (kg)	108

be divided in two modes, namely slippage failure and tensile failure. Figure 5 shows that at low normal stresses of 30 and 60 kPa, slippage failures occurred for both the sand and tire chips-sand mixture as shown by no tension failure conditions of the geogrid after the test. Moreover, the failure mode was confirmed to be tensile failure at normal stresses of 90 and 120 kPa (Figure 4). The tensile failure breakage was observed more with sand than with the tire chip-sand mixture.

### RESULTS AND DISCUSSION

In this study, the PLAXIS 8.2 software was used for the numerical simulation of the pullout test. An elastic model was used for the geogrid element simulation, while for the sand and tire chips-sand mixture, a Mohr-Coulomb elastic, perfectly-plastic model was used. The modulus of

elasticity (E) and poison ratio ( $\nu$ ) for both the sand and tire chips-sand backfill material were taken from Tanchaisawat *et al.* (2007). The generated model mesh is shown in Figure 4.

A comparison between the laboratory tests and the predicted results is shown in Figures 5 and 6 for the sand only and tire chips-sand mixture, respectively. The sand backfill (Figure 5) produced simulation results that had similar overall behavior to the pullout test. The interaction coefficient increased with increasing normal stresses. The predictions for the tire chips-sand mixture (Figure 6), were quite close to the measured results, including the residual strength

### CONCLUSION

The shear strength parameters of the sand and tire chips-sand mixture were determined as a friction angle of  $29.8^\circ$  and cohesion of 15.6 kPa. The tire chips-sand mixture was found to have a

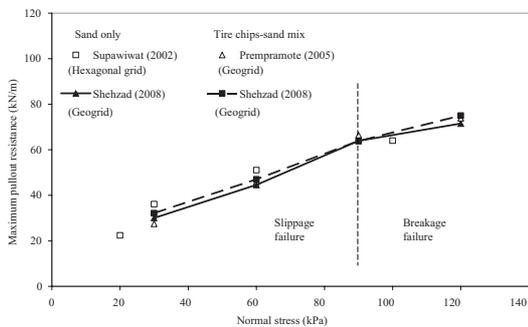


Figure 3 Maximum pullout resistance.

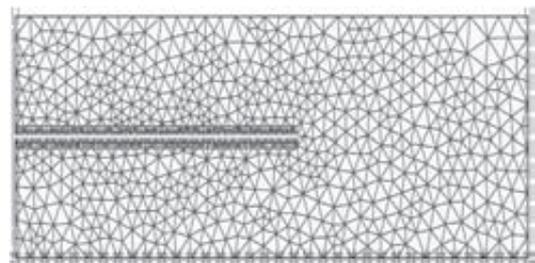


Figure 4 Pullout simulation mesh.

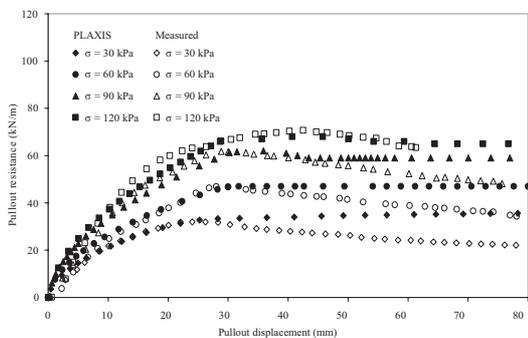


Figure 5 Pullout simulation of sand backfill.

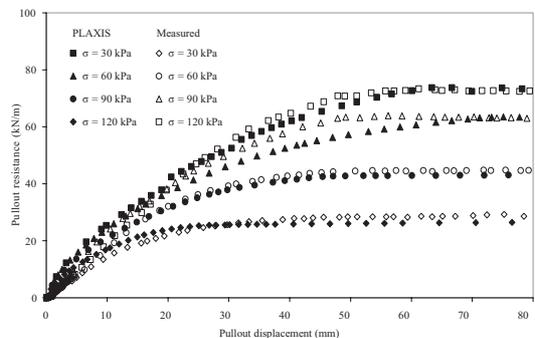


Figure 6 Pullout simulation of tire chips-sand backfill.

friction angle of  $24.4^\circ$  and cohesion of 14.3 kPa. The failure envelopes of the pullout resistance showed bilinear behaviour. Slippage failure occurred at low normal stresses of 30 to 60 kPa and tensile failure at higher normal stresses of 90 to 120 kPa. The interaction coefficients for the pullout test were found to be 0.72 and 0.69 for the sand and the tire chips-sand mixture, respectively. The results of the numerical simulation agreed reasonably with the laboratory results. The simulations from the finite element software produced similar predicted results in the pullout tests. The average values of interaction coefficients that were back-calculated from numerical simulations were found to be similar to the measured results. The tire chips-sand mixture could be used as a lightweight backfill material, as the shear strength parameters of the tire chips-sand mixture were only slightly less than the sand, and 30% weight reduction could be achieved by replacing the sand with the tire chips-mixture.

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