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A simple method to evaluate the pullout resistance of extruded geogrids embedded in a compacted granular soil

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Abstract

Pullout tests are necessary in order to study the interaction behaviour between soil and geosynthetics in the anchorage zone; hence, the resulting properties have direct implications on the design of reinforced soil structures.

Several experimental studies showed the influence of different parameters (reinforcement stiffness, geometry and length, applied vertical effective stress, and geotechnical properties of soil) on the peak and on residual pullout resistance.

On the basis of the results of the tests carried out by Moraci and Recalcati [2005. Factors affecting the pullout behaviour of extruded geogrids embedded in a compacted granular soil. Geotextiles and Geomembranes, submitted for publication], a new theoretical method was developed to determine the peak and the residual pullout resistance of extruded geogrids embedded in a compacted granular soil. The method is capable of evaluating both the bearing and the frictional components of pullout resistance, taking into account the reinforcement extensibility and geometry as well as the non-linearity of the failure envelope of backfill soil. The comparison between theoretical and experimental results was favourable, thus confirming the suitability of the proposed approach.

Keywords: Soil dilatancy; Reinforcement extensibility; Pullout resistance; Skin friction; Bearing resistance

1. Introduction

The main interaction mechanisms affecting the pullout resistance of extruded geogrids are the skin friction, between soil and reinforcement solid surface, and the bearing resistance, that develops against transversal elements (Fig. 1).

The pullout resistance of a geogrid, assuming that the different interaction mechanisms act at the same time with maximum value and that they are independent of each–other, may be evaluated using the following equation:

$$P_R = P_{RS} + P_{RB}, \tag{1}$$

where P_{RS} is the skin friction component of pullout resistance and P_{RB} the bearing component of pullout resistance.

The frictional component of pullout resistance, for a geogrid of length L_R and unit width W_R (Fig. 2), may be evaluated from the following expression:

$$P_{RS} = 2\alpha_S L_R \tau = 2\alpha_S L_R \sigma'_n \tan\delta, \tag{2}$$

where σ'_n is the normal effective stress, δ the skin friction angle between soil and geogrid, τ the shear stress acting at soil–reinforcement interface and α_S the fraction of geogrid surface area that is solid.

To evaluate the bearing component of pullout resistance, Jewell (1990) proposed the following expression:

$$P_{RB} = \left(\frac{L_R}{S}\right)\alpha_B \sigma'_b B, \tag{3}$$

where S is the spacing between geogrid bearing members, L_R/S the number of geogrid bearing members, α_B the fraction of total frontal area of geogrid available for bearing, B the bearing member thickness and σ'_b the effective bearing stress on the geogrid bearing members.

For granular soils, the bearing stresses σ'_b on geogrid bearing members are linked to the soil shear strength angle,

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Nomenclature

δ	skin friction angle between soil and geogrid (deg.)
α_B	fraction of total frontal area of geogrid available for bearing (dimensionless)
σ'_b	effective bearing stress on the geogrid bearing members (kN/m^2)
σ'_n	normal effective stress (kN/m^2)
α_S	fraction of geogrid surface area that is solid (dimensionless)
A_b	area of each rib element (mm^2)
A_r	node embossment area (mm^2)
A_t	bar portion between two nodes area (mm^2)
B	bearing member thickness (mm)
B_r	node thickness (mm)
B_t	thickness of the bar portion between two nodes (mm)
B_{eq}	strip of uniform thickness
$C_{\alpha S}$	reduction coefficient of geogrid area where skin friction develops (α_S)
d_{50}	average grain size (mm)
f_b	soil–geosynthetic pullout interaction coefficient (dimensionless)
L	reinforcement length in the anchorage zone (m)
L_R	specimen length (m)
n_t	number of geogrid bearing members
n_{tb}	number of nodes in a transversal element
P_R	pullout resistance (kN/m)
P_{RB}	bearing component pullout resistance (kN/m)
P_{RR}	residual pullout resistance (kN/m)
P_{RS}	skin friction component pullout resistance (kN/m)
P_{RRS}	skin friction component pullout resistance under residual conditions (kN/m)
S	spacing between geogrid bearing members (mm)
U	uniformity coefficient (dimensionless)
w_{opt}	optimum water content (%)
W_r	node width (mm)
W_t	width of the bar portion between two nodes (mm)
ϕ'	soil shear strength angle (deg.)
ϕ'_{cv}	soil shear strength angle at constant volume (deg.)
ϕ'_p	peak shear strength angle (deg.)
γ_{dmax}	maximum dry unit weight (kN/m^3)
$\mu^R_{S/GSY}$	soil–geosynthetic residual interface apparent coefficient of friction (dimensionless)
$\mu_{S/GSY}$	soil–geosynthetic peak interface apparent coefficient of friction (dimensionless)

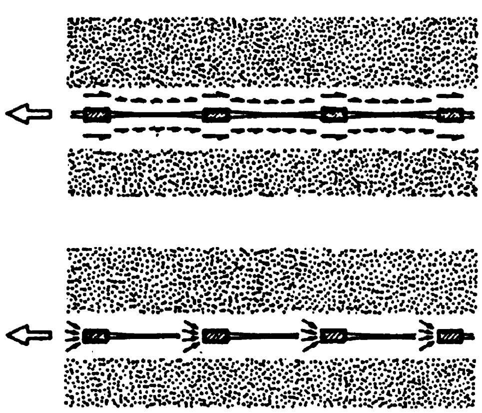

Fig. 1. The two mechanisms for bond between reinforcement and soil (Jewell et al., 1985).

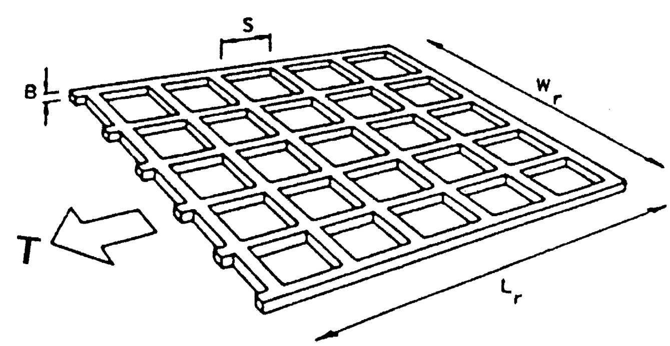

Fig. 2. Definition of terms for a geogrid (Jewell, 1990).

the initial stress state, the interface roughness and the reinforcement depth in relation to the sizes of the bearing members (Rowe and Davis, 1982). For punching failure mechanism, the ratio σ'_b/σ'_n depends only on soil shear strength angle and may be defined as following (Jewell et al., 1985):

$$\frac{\sigma'_b}{\sigma'_n} = e^{[((\pi/2)+\phi')\tan\phi']}\tan\left(\frac{\pi}{4}+\frac{\phi'}{2}\right). \tag{4}$$

For general shear failure mechanism, the ratio σ'_b/σ'_n may be defined as follows:

$$\frac{\sigma'_b}{\sigma'_n} = e^{\pi\tan\phi'}\tan\left(\frac{\pi}{4}+\frac{\phi'}{2}\right). \tag{5}$$

According to Jewell (1996), the Eqs. (4) and (5) represent a lower bound and an upper bound for the bearing component of resistance in pullout conditions.

In order to evaluate the bearing component of pullout resistance, Matsui et al. (1996) and Bergado and Chai (1994) proposed other relationships.