Granular Soil Reinforced with Geotextile and Randomly Oriented Fibres: A Comparison

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ABSTRACT: A series of triaxial compression tests were performed in order to investigate the strength and deformation characteristics of unreinforced sand, a sand reinforced with oriented geotextiles and a sand reinforced with randomly distributed fibres made in Algeria. The tests, the results and the findings are reported, and behaviour of both types of reinforcements are discussed.

1 INTRODUCTION

Reinforced earth as a construction technique in civil engineering was introduced in civil engineering in 1966 and involves the amalgamation of renforcing elements into a mass of fill. Many reinforced earth structures have been erected worldwide and normally comprise metallic reinforcement in a cohesionless soil. More recently, attention has turned to the development of new materials that improve the performance or economy of such structures. Exemple of this development is:
a) the use of woven and non woven fabrics reinforcing elements (sheets, grids, etc...).
b) the use of fill other than selected granular fills currently specified (Bouazza and Wei, 1992, 1993, Wei and Bouazza, 1992).
c) the use of randomly distributed elements such as polymeric mesh elements (Andrawes et al, 1986), synthetic fibres (Gray and Al Refeai, 1986, Maher and Gray, 1990) or the "Texsol" system (Leflaive, 1982, 1988) in which a single monofilament is spun or injected in a random pattern simultaneously with the deposition of a given sand.

In Algeria, the use of reinforcing elements started in 1987 and consisted mainly on the use of metallic strips for abutments construction, near algiers, on the eastern highway. There is no construction involving geotextiles except in dams construction where they are used as drainage. It is also worth noting that geotextiles are generally imported and thus seem less attractive for the algerian builders. In recent years, fibres manufacturing has seen a drastic increase directed mainly towards the textile industry.

The purpose of the present paper is to present the results of a comparative study between a dry sand reinforced with an oriented non woven fabric (bidim) and a dry sand reinforced with local synthetic fibres (polyamide). A series of triaxial tests on reinforced and unreinforced sand were conducted to investigate the reinforcing effect on the stress strain response and strength of a sand.

2 MATERIALS

2.1 Soil

The sand used in the present study was a medium clean uniform beach sand from Draouch, Annaba, with the following properties: Maximum porosity n_{max}=48%, Minimum porosity n_{min}=28%, specific gravity G_s=2.65, uniformity coefficient Cu= 1.9, shape= subrounded.

2.2 Reinforcements

The reinforcements were of two types: a) Locally made synthetic fibre of polyamide type commercially available. The fibres were supplied by the manufacturer in the form of long filaments. They were cut to a standard length of 20mm. There properties were as follow:

Table n° 1 Fibre properties

Fibre Type	Diametre (mm)	Tensile strength (N/tex)	Elongation at break (%)
Polyamide	0.5	75	21

b) Non woven fabric (Bidim B6) made of polyester filaments and manufactured by Rhone Poulenc (France). Its properties are summarized in table 2.

Table n° 2 Geotextile properties

Fabric	Thickness (mm)	Tensile strength (kPa)	Elongation at break (%)
Bidim B6	2.3	75	41

3 EXPERIMENTAL PROGRAM

Laboratory triaxial compression tests were performed to examine the effect of the reinforcements on the stress strain response and the shear strength of the soil reinforcement system. All tests were carried out on dry cylindrical samples with a diametre of 50 mm and a heigth of 100 mm and at confining pressure varying from 50 to 400 kPa. The strain rate was 0.5 mm/min. Reinforced and unreinforced samples were compacted, by tamping succesive layers, to the same density of soil excluding the volume of reinforcements. Relative density of 50 % was selected because it was easily and efficiently achieved for all inclusions used. The sand alone tested at this relative density yielded the following angle of frictions (φ): φ=39° if $\sigma_3 < 125$ kPa and φ= 29° if $\sigma_3 > 125$ kPa.

In the case of the geotextile, the reinforcements consisted of circular discs of Bidim which were cut from the fabric sheets. The samples were built up layer by layer with the reinforcement placed at predetermined intervals (Δh=50mm and Δh=25mm). The number of reinforcement layer was 1 and 3. The testing on sand reinforced with fibres was carried out on the same size specimens used in the previous cases. The concentration of fibres choosen was 1 % (as a weight percentage of dry sand). The sand fibre was mixed by hand until the fibres were evenly distributed and randomly oriented throughout the sand. The samples were prepared as specified previously.

The friction angles and cohesions, at rupture, were determined using p-q diagrams, the results are summarized in table 3.

4 DISCUSSION

Figures 1 and 2 show the stress strain response of unreinforced sand and sand reinforced with randomly distributed fibre and oriented geotextile layer respectively. It can be observed that both type of reinforcement system increased peak strength. It could also be noted that increasing the confining pressure results in increasing the strength and the deformation of the sand geotextile system. This phenomenon, which was reported by Schlosser et al (1985) and studied by McGown et al (1981), is based on the fact that the confining pressure increases the frictional stresses which develop between the fibres and on the other hand the sand grains come closer and closer contact with the filaments that oppose their sliding and reorientation. It can also be seen that increasing the number of geotextile layers resulted in an increase in peak strength and deformation. However, fibre reinforcements (1% pw) produced a similar behaviour but with larger deformations (10% at 100 kPa and 12% at 400 kPa). It can also be noted that fibre reinforcement give a peak strength value close to the 3 Bidim reinforcement.

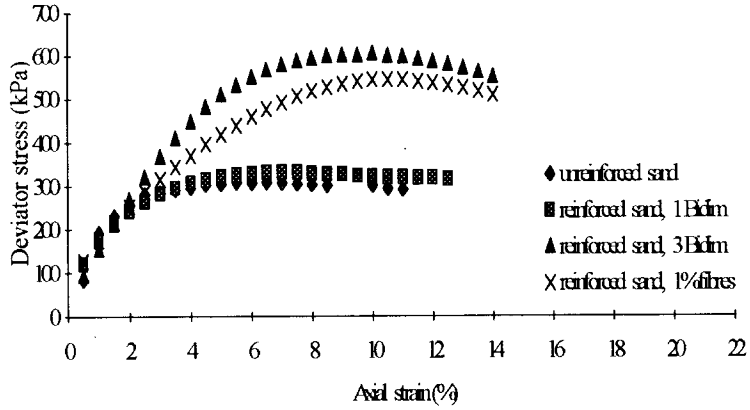

Fig 1. Stress-strain relationship at confining pressure of 100 kPa

Fig. 3 indicates that sand reinforced with both reinforcement system have a curved linear principal stress envelope. the transition from curved to a linear envelope occurs at a confining stress which is referred to as the critical confining stress σ_{crit}. It can be seen that the existence of a critical confining stress is common to both systems (110 kPa < σ_{crit} < 125 kPa). In the case of $\sigma_3 < \sigma_{crit}$, the sand fails before the reinforcement because of the extensibility of the latter (Schlosser et al, 1985). A close examination of the failed sample showed (for both systems) that the reinforcements stayed intact. No damage for either the Bidim or the fibre reinforcement has been observed. However, it can also be observed from table 3 that, with the introduction of the reinforcements, the angle of internal friction increased by up to 12° from an original angle of 39°. The cohesion being zero in all cases. The reinforcement with locally made fibres gives a result close to the 3 Bidim reinforcement. When σ_3 exceeds σ_{crit}, it is observed that the thickness of the Bidim reinforcement

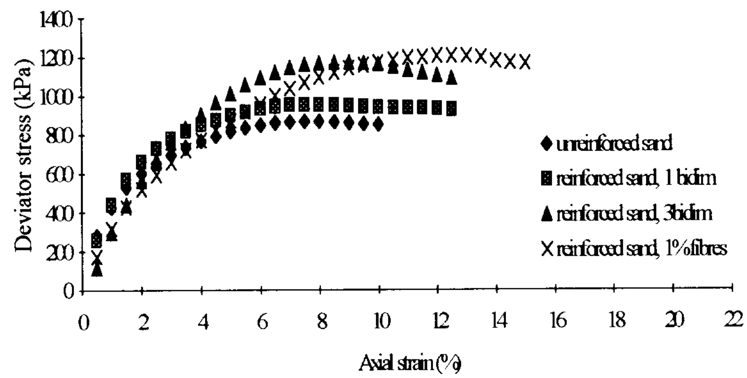

Fig 2. Stress-strain relationship at confining pressure of 400 kPa

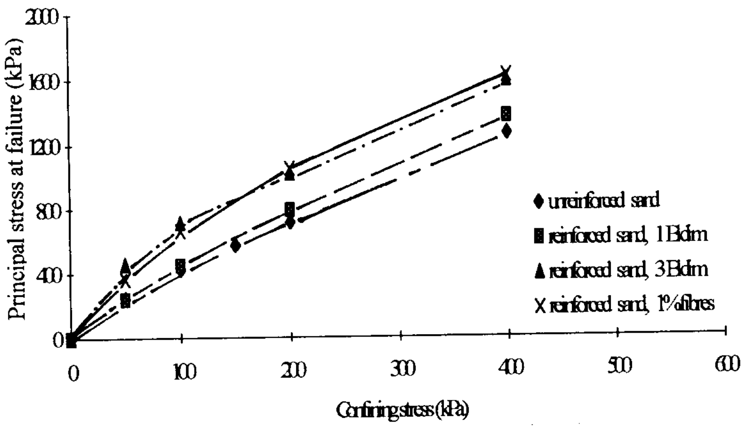

Fig 3. Principal stress at failure vs confining stress

decreases especially at 400 kPa. A large proportion of the fibres had one of the welded end pulled out. A sample of 100 fibres taken randomly from the failed sample showed that 41 fibres had one of the welded end pulled out. For both reinforcement systems breakage has not been observed. Fig. 3 shows also that shear envelopes are parallel to the envelop for sand alone. This suggests that the reinforcement do not affect the frictional properties of the sand (Gray & Ohashi, 1983) but increases the value of cohesion (table 3). One can note that reinforcement with 1% fibres pw gives approximatelly the same cohesion as reinforcement with 3 layers of Bidim.

Table n° 3 triaxial test results as obtained from p-q diagrams

	$\sigma_3 < \sigma_{crit}$		$\sigma_3 > \sigma_{crit}$	
	c_r (kPa)	φ_r(°)	c_r(kPa)	φ_r(°)
sand	0	39	-	28
sand + 1Bidim	0	41	57	29
sand + 3Bidim	0	51	126	29
sand + 1% fibres	0	49	125	28

5 CONCLUSIONS

The salient observations that can be drawn from this study are as follow:

(i) Subrounded uniform sand exhibited a curved linear stress envelop for both types of reinforcement.

(ii) Both types of reinforcement increased the shear strength and altered the sand stress strain response in a significant manner. However, larger axial strains were achieved with fibre reinforcement.

(iii) Locally made fibres show some promise and the present results indicate that they might be a viable alternative in reinforcing soils structures. However, a thourough investigation is needed to allay some of the local builders apprehensions.

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