EFFECT OF GEOCELLS ON THE LIQUEFACTION RESISTANCE OF SAND UNDER CYCLIC LOADING

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RESUME :
This paper presents a study on the dynamic behavior and liquefaction resistance of geocell-reinforced sandy soils. This study uses undrained cyclic triaxial tests to evaluate the effectiveness of geocells in reducing liquefaction vulnerability. The results show that geocells, especially those with a height of 50 mm, significantly reduce strain accumulation and excess pore pressure, thereby increasing liquefaction resistance. Higher-height geocells provide better stability by reducing the number of cycles required to reach the liquefaction threshold. This study contributes to a better understanding of the use of geocells in seismically active areas.

MOTS CLES :
Geosynthetics, Liquefaction, Geocells, Earthquakes, Triaxial tests.

1. INTRODUCTION

Earthquakes have historically posed a significant threat to human life and infrastructure, with liquefaction being a primary cause of damage to soil-structure systems such as dams, embankments, and foundations[1, 2]. Liquefaction occurs when saturated granular soils lose their shear strength under cyclic or monotonic undrained loading, leading to a liquefied state[3]. This phenomenon has been extensively studied using triaxial testing, which has helped identify key factors influencing liquefaction susceptibility. Recent research has highlighted the effectiveness of geosynthetics, including geogrids, geotextiles, and geocells, in mitigating liquefaction-induced damage[4]. A review of the literature confirms that geosynthetics significantly improve soil resistance to liquefaction by providing efficient three-dimensional confinement. Previous studies on pond ash, calcareous sand, and coastal sand have shown that geocells enhance shear strength, delay pore pressure generation, and reduce permanent deformations[5-7]. In this context, an experimental campaign was carried out on Zemmouri sand under undrained cyclic triaxial loading, with and without reinforcement. Geocells of various heights (12.5 mm, 25 mm, 50 mm) were tested under different cyclic stress ratios (CSR = 0.30; 0.35; 0.40)..

2. MATÉRIELS ET MÉTHODES

2.1 Materials used

The sand used in this study comes from the region of Zemmouri (Boumerdes), located about 50 km east of Algiers, an area affected by numerous liquefaction phenomena during the 2003 earthquake. To ensure the homogeneity of the samples, the sand was washed using an 80 µm sieve, then calibrated by a 2 mm sieve. The granulometric curve and index properties of the sand are presented respectively in Figure 1 and Table 1. This sand, essentially siliceous, was used to study its mechanical behavior under controlled dynamic loading[8].

The geocells used were made from non-stretch geotextile strips (type ALVEOTER AT30, AFITEX-Algeria) made of high-permeability polyester. They were manually sewn into a cylindrical cell adapted to the mold and positioned in the middle of the sand specimen. Three geocell heights (12.5; 25; 50 mm) were tested to analyze the effect of confinement on liquefaction resistance. Their technical characteristics are shown in Table 2.

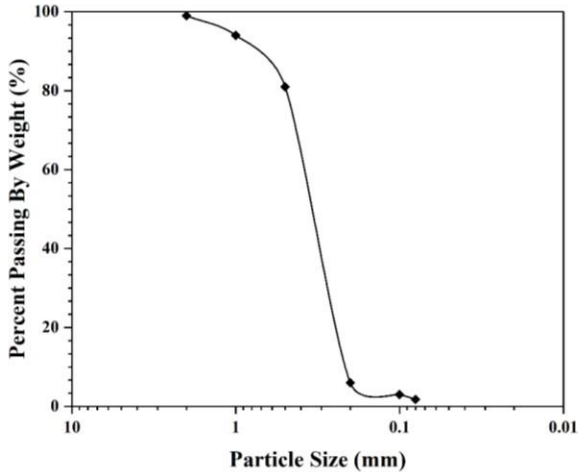

Figure 1. *Grain size distribution curve of sand.*

Table 1. *Properties of the sand.*

Composition	**Sand**
D_{50} (mm)	0.376
C_u	1.925
C_c	0,975
Gs (-)	2.65
ρ_{dmin}	1.15
ρ_{max}	1.70
e_{min}	0.57
e_{max}	0.95

Table 2. *Characteristics of the used geotextile.*

Characteristics	**Normes**	**Units**	**Value**
Physical characteristics			
Surface mass	ISO 9864	g/m²	272
Thickness	EN ISO 9863-1	mm	2.20
Mechanical characteristics			
Tensile strength of geotextile MD*	ISO10319	kN/m	15
Shear resistance of connections	ISO10319	kN/m	15
Bond peel resistance	ISO10319	kN/m	15

2.2 Device and test procedure

Undrained cyclic triaxial tests on Zemmouri-Boumerdes sand (50 mm diameter × 100 mm height specimens prepared at 30% relative density using moist tamping) evaluated seismic performance under ASTM D5311 (2013). Specimens were saturated via CO_2 purging (20 min) and deaired water infusion, achieving Skempton's B-value > 0.96, followed by isotropic consolidation at 50 kPa effective stress. Testing applied undrained cyclic axial loading at 0.33 Hz (simulating low-moderate seismic frequencies) with three cyclic stress ratios (CSR = 0.30, 0.35, 0.40) to both unreinforced and geocell-reinforced samples (geocell heights: 12.5, 25, 50 mm). Liquefaction was defined as the point where the excess pore pressure ratio ($\Delta r_u = \Delta u/\sigma'_c$) reached 1, terminating the test and recording the number of cycles to liquefaction (NL). The experimental matrix comprised twelve test series (4 reinforcement configurations * 3 CSR levels), measuring axial strain accumulation, pore pressure development, stiffness degradation, and NL to assess geocell height effects on liquefaction resistance.

3. RESULTS AND DISCUSSIONS

3.1. Effective stress behavior

The cyclic stress–strain behavior and effective stress paths of Zemmouri sand, tested under cyclic stress ratios (CSR = 0.30), demonstrate the effectiveness of geocell reinforcement in improving soil stability. In unreinforced samples, axial strain accumulated progressively, especially at higher CSRs, indicating shear failure and onset of liquefaction.
Unreinforced sand paths shifted toward the origin, indicating rising pore pressure, while reinforced samples, especially with 25 mm and 50 mm geocells, maintained higher effect.

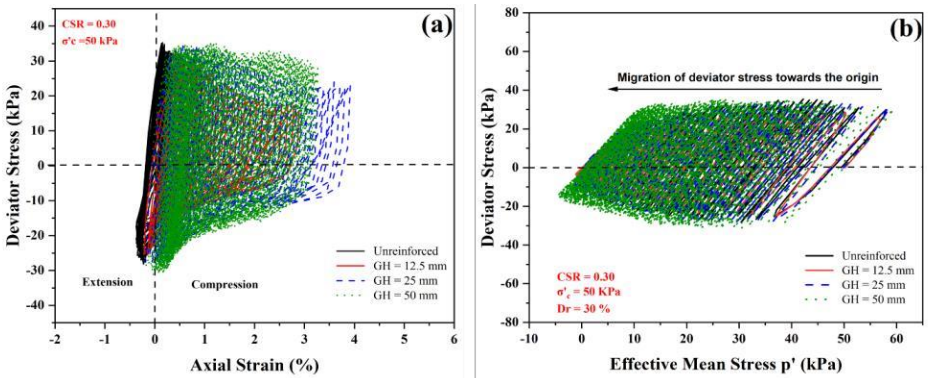

Figure 2. Undrained Cyclic Response of Sand under CSR of 0.30: (a) Stress–Strain Behavior (b) Effective Stress path.

3.2 Effective stress behavior

Figure 05 highlights the significant impact of geocell reinforcement in controlling excess pore pressure buildup during undrained cyclic loading. In unreinforced sand, the pore pressure ratio (ru) quickly reached 1, signaling liquefaction. Introducing geocell reinforcement delayed this onset in a height-dependent manner. A 12.5 mm geocell reduced ru buildup by up to 32%, extending the number of cycles to liquefaction by 1.3 times These results confirm that increasing geocell height enhances soil confinement, redistributes stresses, and substantially improves resistance to liquefaction

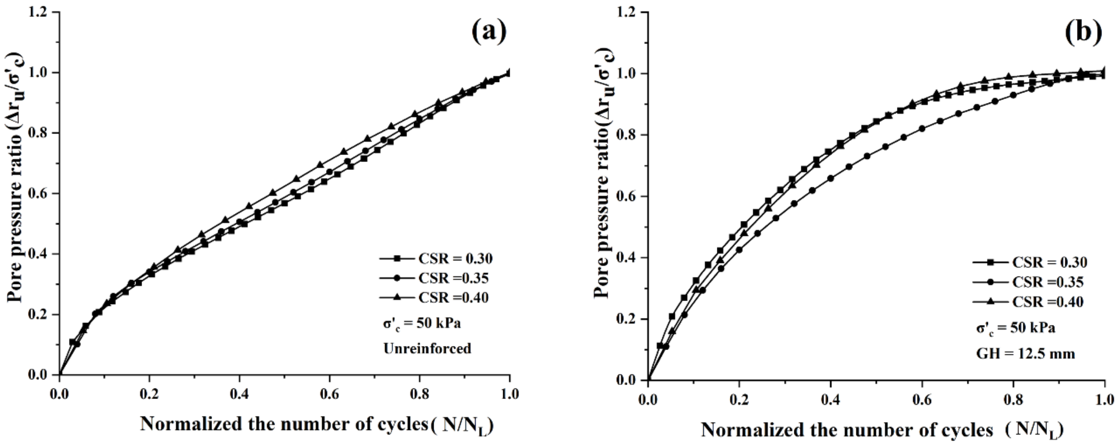

Figure 3. Pore pressure ratio versus normalized number of cycles for unreinforced and geocell-reinforced: (a) unreinforced sand, (b) GH = 12.5 mm, (c) 25 mm, (d) 50 mm.

4. CONCLUSION

The study investigates the impact of geocells on the liquefaction resistance of sand under cyclic loading using undrained cyclic triaxial tests. The results demonstrate that geocells significantly enhance the liquefaction resistance of sandy soils. Specifically, geocells reduce strain accumulation and excess pore pressure, thereby delaying the onset of liquefaction. The effectiveness of geocells increases with their height, with the 50 mm geocell providing the most substantial improvements. This study highlights the potential of geocells as a viable solution for improving soil stability in seismically active areas.

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