Biaxial Compression Tests on Soil Micro-Reinforced by Mesh-Elements

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ABSTRACT: The present study concerns the mechanical behaviour of a sand reinforced by mesh-elements. The main originality of the study consists in the use of a biaxial compression apparatus in plane strain, permitting particularly to monitor the strains distribution in the sample.

1 THE BIAXIAL COMPRESSION APPARATUS

The IRIGM has developed a prototype apparatus (figure 1) which differs from the classical triaxial (or axisymmetric biaxial) apparatus used in soil mechanics: The sample is subjected to lateral pressure by membranes filled with pressurised water in the horizontal direction (3). Strains remain equal to zero in the perpendicular direction (2). A transparent plate placed vertically and being perpendicularly to (2) allows the monitoring of the sample deformation.

The sample is subjected vertically (direction 1) to compressive stresses between two symmetric jacks. The loading can generate complex stresses-strains paths but the present tests are realised under constant vertical displacement rate and lateral stress 3. The main compressive stress 1 is measured on the central plate fixed on the loading hydraulic jack (figure 2) to not take into account the boundary effects.

As far as we know, very few biaxial tests in plane strain with reinforced soils have been presented (Mc Gown, 77 and Ling, 93).

2 SAND-MESH ELEMENTS COMPOSITE

First tests using this innovative apparatus were realised both on a sand-geotextile sheets (macro reinforcement) as well as on a sand-mesh elements (micro reinforcement) composites ; the last tests are the topic of the present paper.

The mesh-elements are grid elements (100 x 50 mm^2) made from polypropylene (Mercer, 84) with 10 x 12 mm^2 mesh size and 0.5 mm filament diameter. The tensile resistance expressed as strength per filament is presented on figure 3. Distributed randomly within sand, this material enters in many applications in so far as a quite isotropic reinforcement effect is obtained without permeability reduction and with increasing ductility, what differentiates this technique from other soils improvement techniques.

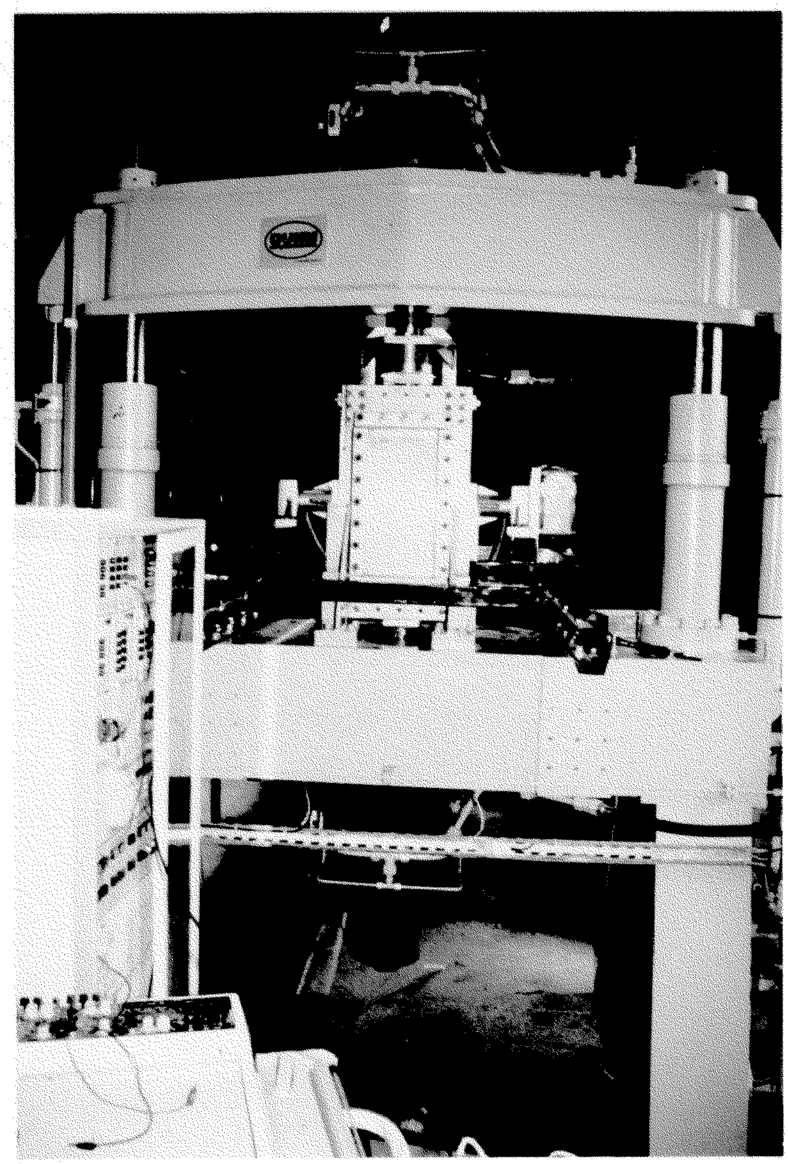

Figure 1: The Biaxial compression apparatus (IRIGM)

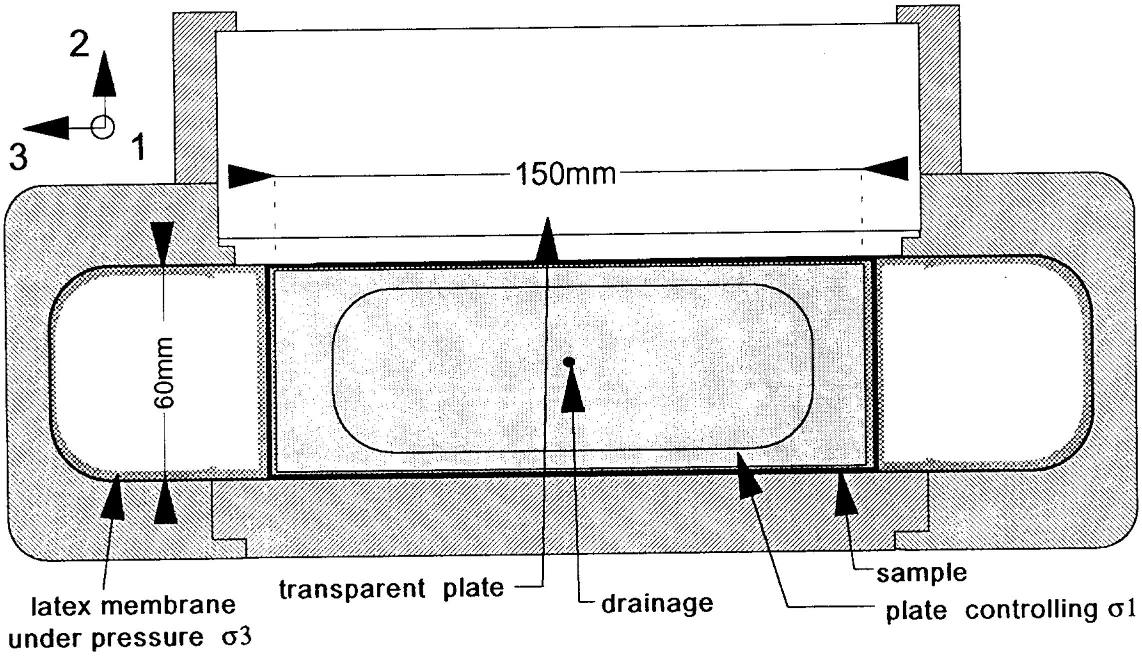

Figure 2: Cross Section of the cell containing the reinforced soil sample

At the IRIGM, a preliminary study was realised in a big shear box (Billet, 92) either with a random orientation, or with mesh-elements layed out only in a vertical plane.

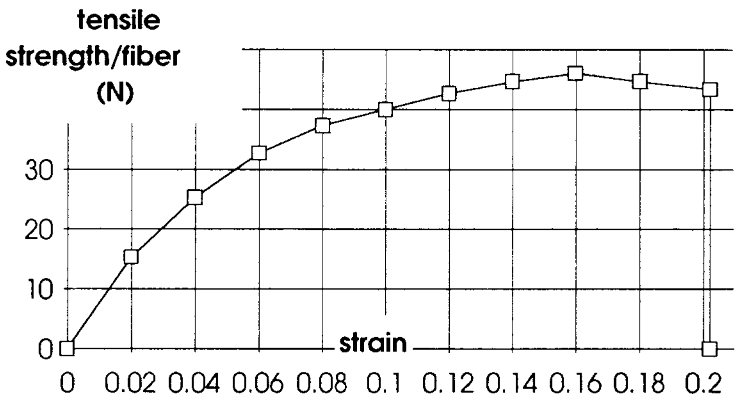

Figure 3: Tensile strength of one fiber of a mesh-element

3 DEFINITION OF A BIAXIAL TESTS PROGRAMME ON MICRO-REINFORCED SAND

The dimensions of the reinforced sand sample are 340 mm in the vertical direction 1, 150 mm in the direction 3 and 60 mm thickness in direction 2. To reduce the boundary effects, the mesh-elements were cutted into four equal parts.

The sand is the Hostun RF sand, a reference sand for the Grenoble University : D_{50}=0.35 mm, CU=1.6, e_{min}=0.64, e_{max}=1.01.

A first interesting investigation consists to study the influence of the reinforcement density on the sand arrangement. Let d_m be the ratio of the mesh-elements weight to the dry sand weight. The sand is deposited from the same fall height (1m). The variation of the void ratio e for the sand alone and e^r for the sand + mesh-elements are studied in relationship with d_m (figure 4). Basically, the composite resistance decreases with an increasing e (disarrangement of sand) and increases with an increasing d_m: it can be supposed, since e changes only slightly for $0.20 < d_m < 0.45$, the reinforced sand resistance increases with d_m in this area. From d_m=0.45 it is not possible to predict which effect will take advantage, either the increasing of e or the increasing of d_m. This permits to set up the type of biaxial tests to be done (range of d_m).

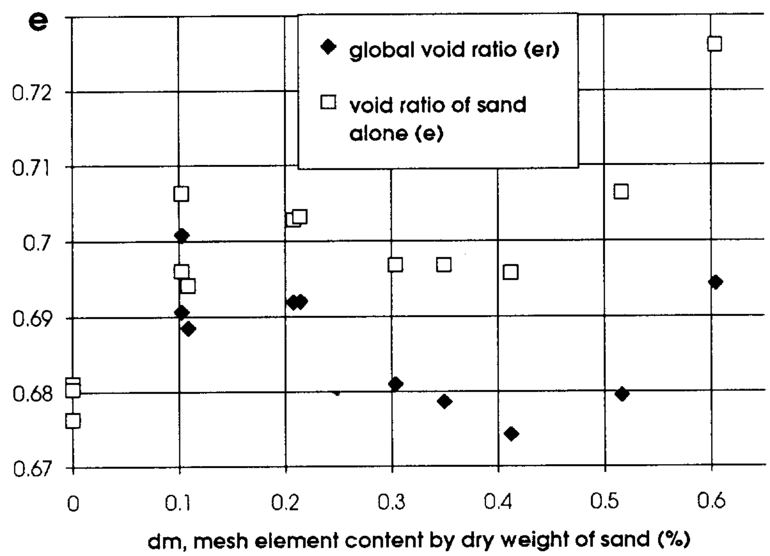

Figure 4: Variation of the void ratio with the density of mesh-elements

4 THE RESULTS OF BIAXIAL COMPRESSION

We present the results (average from 2 or 3 tests) obtained at $\sigma 3$=100 kPa for the same unit weight γ_d=15.0 kN/m^3 and for different d_m (figure 5). These results are consistent with those of figure 4: The ratio σ_1/σ_3 at the same ε_1 increases with d_m up to d_m=0.5, and then stabilizes (d_m=0.57). Concerning the general behaviour, the most outstanding situation remains the increasing of the reinforced sand ductility with d_m.

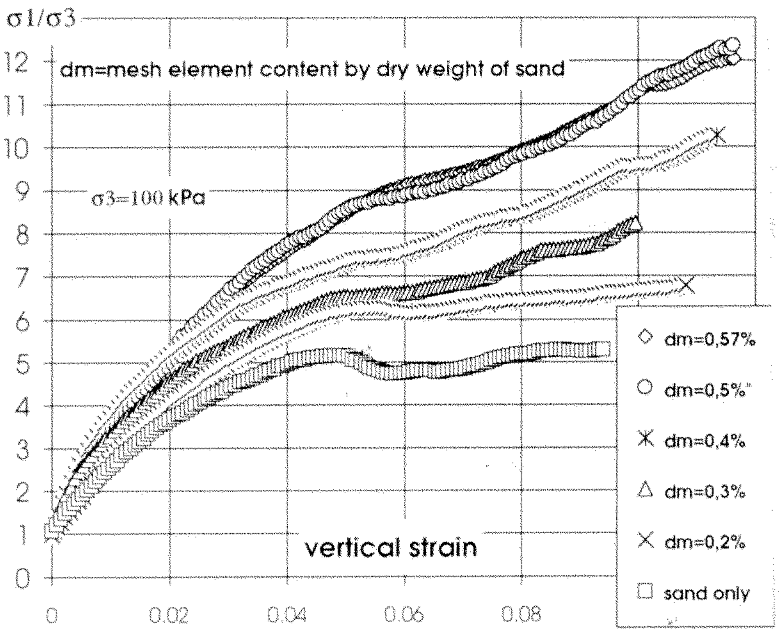

Figure 5: Influence of the mesh element density

5 THE CONTRIBUTION OF THE STEREO-PHOTOGRAMMETRY

The equipment of the 3S laboratory (Grenoble university) could be used, permitting the cartographic strains monitoring of a sample with stereo-photogrammetry (Desrues, 85): the principle consists to register the displacements of several points, here about 200 from pictures corresponding to two successive strain steps of ε_1.

On figure 6, a test result is presented (σ_3=100 kPa, d_m=0.5%), each couple of steps corresponsing to an analysed picture. The picture on figure 8 represents the sample for step 12. A localization of the failure along a shear band can be observed. The shear band is oriented at 25° to 35° with respect to the vertical for this type of test.

The figure 7 shows mesh-elements trial extracted from the shear strip after the test. The figure 9 presents values of distorsion rates obtained between two successive steps : the deformation remains homogenous up to step 5. From step 5-7 a localization appears on a shear strip and remains active up to the end. From step 10 a second shear strip synchronized with a significant increasing of σ_1 appears.

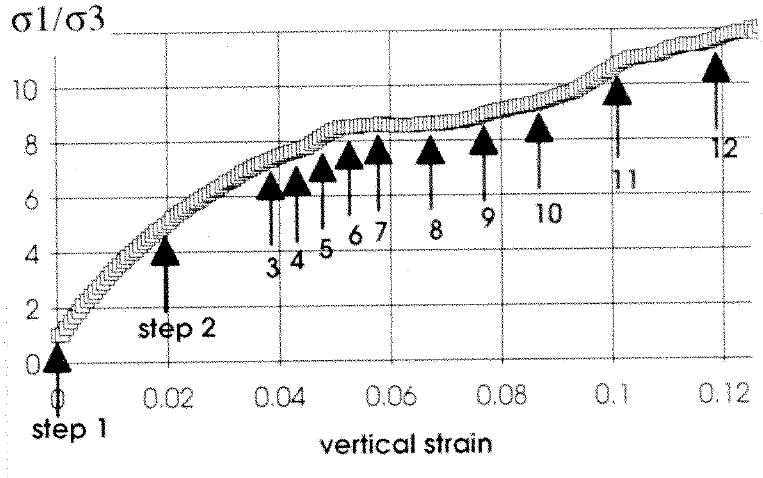

Figure 6: Position of all the steps of the compression test analysed in stereo-photogrammetry

6 CONCLUSION

The apparatus for biaxial compression tests should represent an interesting tool for the understanding of reinforcement mechanisms, partly due to the plane strain state, partly due to the visualization of the strain mode. The results obtained on micro-reinforcement will be shortly extended to study on reinforcement by geotextile sheets.

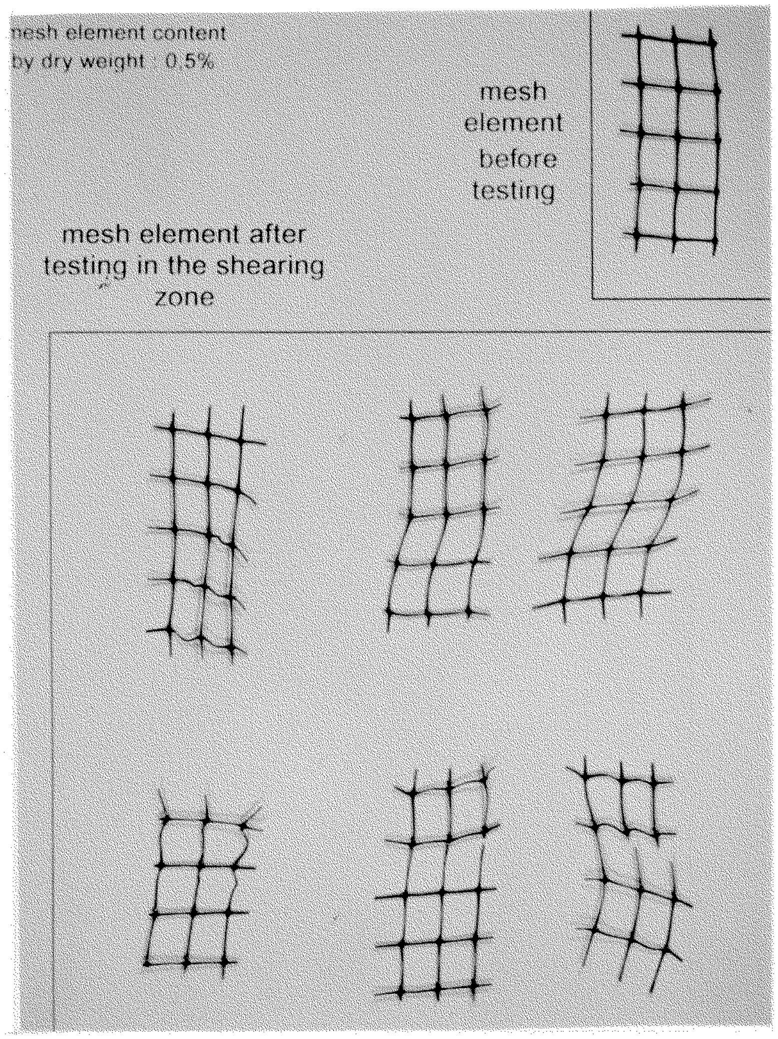

Figure 7: Shape of the mesh-elements after testing, in the area of the shear band

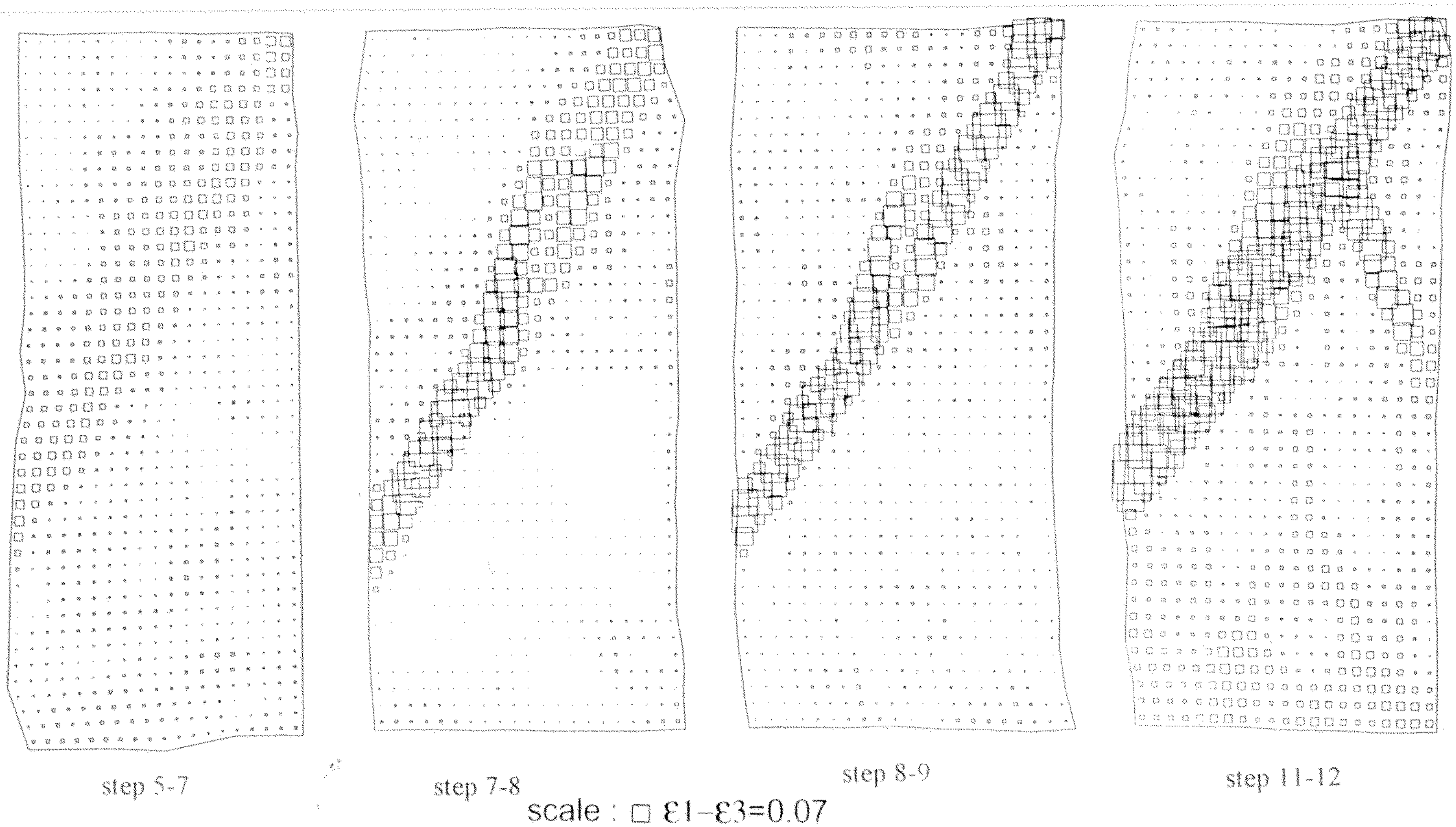

Figure 9: Measure of the distribution of the distorsion in the sample during the test, using the stereo-photogrammetry technics

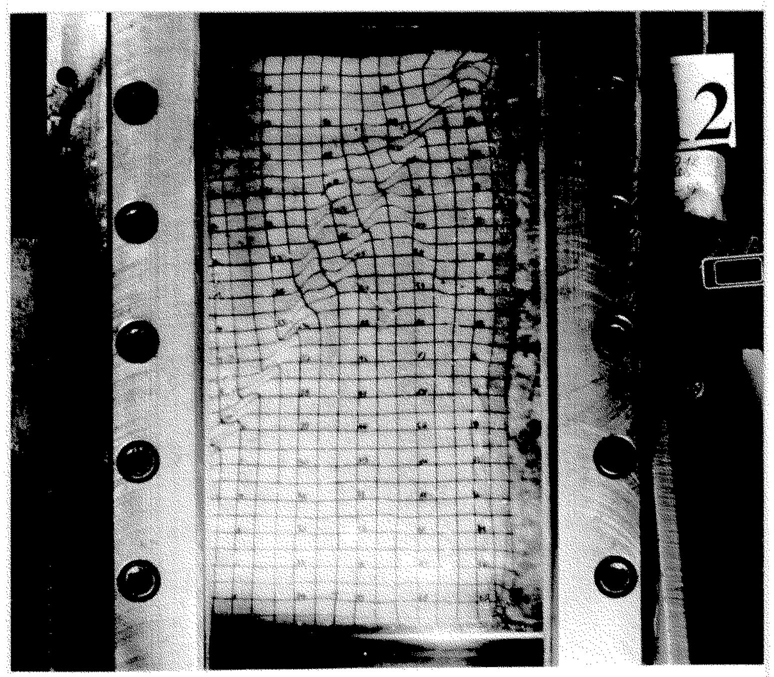

Figure 8: The sample for the step 12 (σ_3 = 100 kPa)

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