International Journal of Civil and Structural Engineering– IJCSE
Volume 2 : Issue 2 [ISSN : 2372-3971]
Publication Date: 19 October, 2015

Study of the confinement contribution on the mechanical behavior of composite structures made with confined ground for use in civil and/or geotechnical engineering.

MENAA L. * – CHERIFI A. – BENOUALI A. – ALLICH M. – ZIRARI M.

***Abstract*— Confining of granular materials remains a very interesting engineering practice to perform civil and / or geotechnical engineering works. In this paper, the analysis of the mechanical behavior of technical fabric- confined sand models in order to design bearing provisional and / or permanent structures is exposed.**

A composite structure, made of local materials (technical fabric and sand) and exposed in previously achieved works, belongs to a context of sustainable development, when a design and an analysis, for the first time, of a monostory building for use in inaccessible areas were carried out (i.e. Sahara).

As a new perspective, many other applications (geotechnical) are considered, such as retaining wall structures, structures for protection against impacts and linear structures applied in rural road traffics.

For this purpose, an experimental analysis was conducted on specimens made of technical fabric-confined sand in order to determine the mechanical properties of studied structure; This is followed by mathematical treatment of experimental results, leading to mathematical regressions development which can be injected into a numerical Finite Element Method analysis (ANSYS Code), analyzing the mechanical behavior of the indicated above structure.

***Keywords*—sustainability, bearing capacity, protection, structure, technical fabric, confined sand.**

I. Introduction

According French standards and definitions of the company "International Geosynthetic Society", **Geocontainers** can describe all alveolar structures obtained by alternative connection of flexible or rigid textile bands.

Early developed Geobags or geocontainers, using confining technics, have been used to achieve many geotechnical and civil engineering structural works. We can cite, as example, Mariotti and Millot works when geotextile bags were used to reinforce the subgrade of ballast rails in Morocco (Mariotti and Millot, 1986). Reiffsteck had used a three-dimensional honeycomb structure, made of geotextile, in soil slope stabilization (Reiffsteck ,1998).

MENAA Lazazi
Civil and engineering Dpt., University of Medea, Algeria

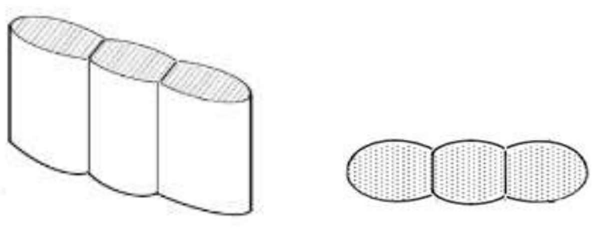
CHERIFI Abdelkerim
Mechanical engineering Dpt., University of USTHB, Algeria

ALLLICH Mounir and ZIRARI Mounir
Mechanical engineering Dpt., University of Medea, Algeria.

Panoply of studies has identified the most influential parameters on the behavior of the designed structural cell, which are mainly geometrical and mechanical parameters (Xu and al., 2009). This confirms previously published works, showing that the confinement leads to an improvement of the strength for materials with lower cohesion (Rajagopal and al., 1999). The unreinforced and reinforced materials show the same angle of internal friction, while the latter have a high apparent cohesion, due probably to the confinement. As an idea, Reiffsteck (1996) find out that apparent cohesion for composites made with two different aggregates varies from 156 to 190 kPa.

As an alternative of geotextile use, technical fabric was used for the first time in confining practice, to make out a flexible envelope within sand is carefully compacted to obtain a composite vertical wall; in figures 1a and 1b illustrated its geometrical cross section characteristics. Filler must working to both shear and compression, while the technical fabric works in traction (Vacilkov B.S. and Simvulidi T., 1985; Menaa L. , 1990). In this case, thanks to the confinement effect and compatibility of deformations and symbiosis collaboration between the fabric and the sand, the structure could assume a sufficient bearing capacity once subjected to vertical or / and horizontal loads, while the qualities of shear and / or damping are required.

Beside a bearing capacity property of the studied structure, confining with flexible technical fabrics seems also benefic to obtain good energy dissipative structures. Analysis of this property can be conducted basing on previously exposed works found in geotechnical literature. We can cite the work where a long geotextile bags with confined sand, were used to achieve an energy dissipative structure by mobilizing elasto-plastic deformation of inner granular material (Nicot and al., 2007).



a) vertical shaped wall b) Transversal cross section

Figure 1. Geometrical characteristics of structure.

The present task represents a perspective and continuity of previously achieved works (Menaa L., 1990; Menaa and al., 2007; Menaa and al., 2009; Menaa and al., 2014); an experimental campaign will conducted in order to identify all aspects of the mechanical and physical behavior of the studied composite structure. Furthermore, except a linear shape of the analyzed structure, a curved shape will be considered.

II. Experimental studies

A. *Materials testing*

The technical fabric, constituting containing envelope, consists of a polyester reinforcing fabric (support), coated with four layers of polyvinyl chloride (PVC); Material has been tested under axial tension using standardized fabric bands (ASTM D1682); results are comparable to those find in the literature (Andrewers, K., 1984).

The filler material (sand) is characterized through its water content, density, and particle size distribution. According to the LCPC classification, used sand is close to the coarse one. Results of this characterization are earlier presented (Menaa and al., 2007).

B. *Confining effect highlighting test*

Effect of confinement is highlighted throughout a triaxial test (Fig. 2a). Results showed significant improvement of the intrinsic characteristics of tested material (Fig. 2b); we can observe a fictive cohesion (pseudo cohesion) with a value about of 160 KPa.

Figure 2a. Triaxil testing.

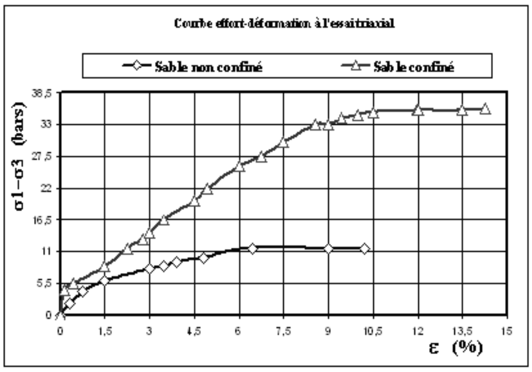


Figure 2b. Deviatoric stress-strain curve.

C. *Mechanical characteristics analysis*

C.1. *Materials and Testing*

This experimental campaign is allowed to determine deformability characteristics under different solicitations (compression, shear and bending) using cubic, prismatic and annular-cylindrical specimens with confined sand (Fig. 3).

a) Cubic b) Prismatic

Figure 3. Tested specimens.

C.2. *Results and interpretation*

Obtained results will be used for interpretation, in order to evaluate mechanical properties of deformability such deformability modulus. These can be later introduced to carry some applications in the next paragraph.

Compression test: showing a hardening elastoplastic behavior, it can be used for the analysis of structures receiving local or distributed loads, inducing static or dynamic stress and leading to their ruin by loss of their bearing capacity. An example of such structures are bearing walls subjected to vertical or lateral loads; to this end, a compressive deformation modulus can be evaluated from the test, equal to about 7.4 MPa; Furthermore, a mathematical correlation (regression) with a power stress-strain tendency is deducted:

$$\sigma = 0{,}46.\varepsilon^{1{,}1}$$

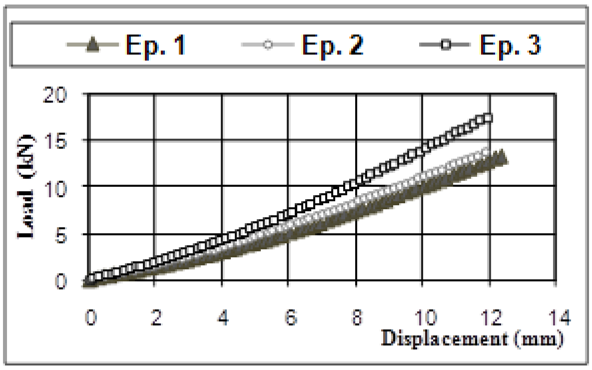


Figure 4a. Three (03) specimen’s compression curves.

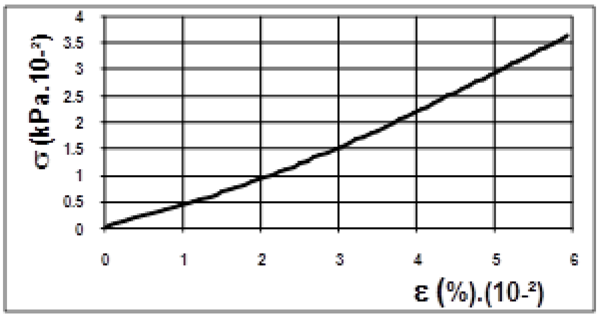


Figure 4b. Average compression curve.

Shear test: showing an elastoplastic behavior, it can be used for the analysis of structures subjected to puncture like structure receiving a local impact, inducing static or dynamic stress, leading to its destruction by punching or tearing (shear). An example of such structures are protection walls against static lateral, repeated or impacts loading; for this purpose, a shear deformation module can be evaluated from the test, equal to about 8.8 MPa; a mathematical correlation with curvilinear stress-strain tendency is deducted:

$$\tau = - 0.926\gamma^2 + 0.646\gamma + 0.007 \qquad (2)$$

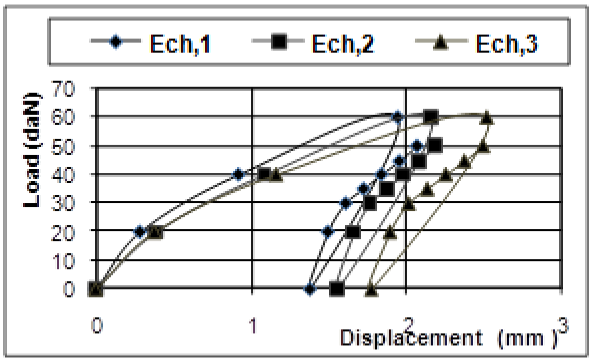


Figure 5a. Three (03) specimen's shear curves.

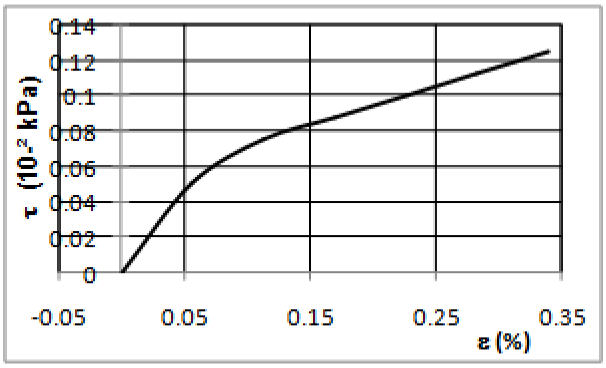


Figure 5b. Average shear curve.

Bending test: the analysis of the flexural behavior relates to structures under lateral loading, inducing frequently their large deformation; this is the case of retaining walls structures. The test still shows an elastoplastic behavior with significant permanent deformation for a loading exceeding its elastic yield. A flexural modulus of deformation bout 25 MPa is evaluated and a mathematical correlation with a curvilinear stress-strain tendency is deducted:

$$\sigma = - 41.05\varepsilon^2 + 29.16\varepsilon + 0.140 \qquad (3)$$

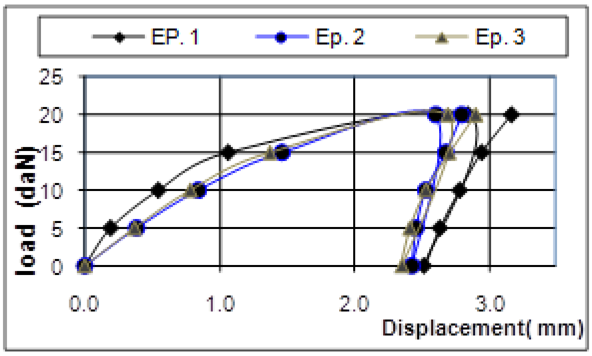


Figure 6a. Three (03) specimen's bending curves.

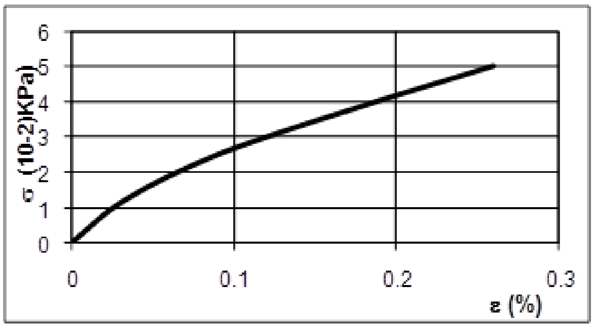


Figure 6b Average bending curve.

III. Some applications

Our composite structure can serve to many civil and geotechnical application like drawn in figures below.

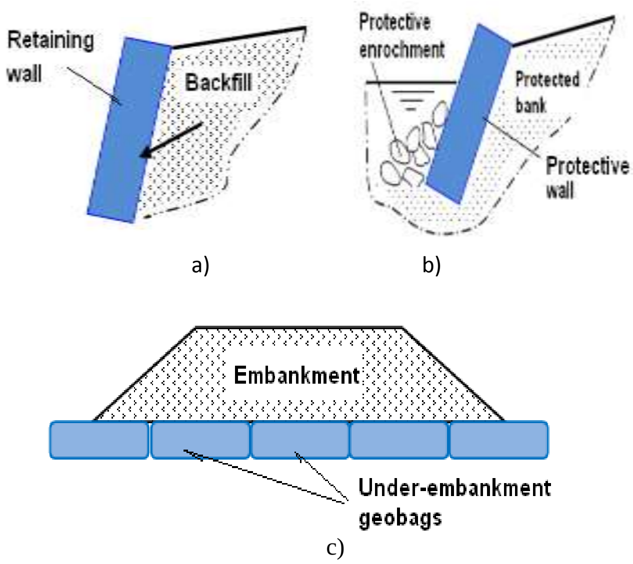


Figure 7. Pratical applications.

A. *Bearing ability study under lateral loading*

In this case of loading, finite element analysis is conducted considering lateral applied pressure simulating earth or water pressure, when structure assuming protection or retaining function. Initially bi dimensional problem with an elastoplastic constitutive law of composite material were considered. A volumic minimum 08 nodes finite element is used. Using ANSYS code, "Solid 95" element with isotropic elastoplastic model were chosen, introducing the equivalent characteristics of the composite material early determined (E = 7,5 MPa ; v = 0.3).

Figure 08 shows tested wall model and figure 09 the meshing and limit conditions of numerical calculation model.

Numerical and experimental results of lateral deflection and stress state of composite wall are shown in figures 10, 11 and 12.

Figure 8. Tested composite wall.

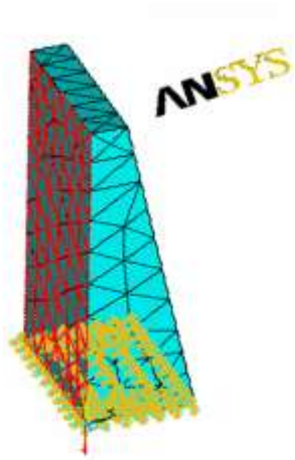


Figure 9. FEM wall meshing ang limit conditions.

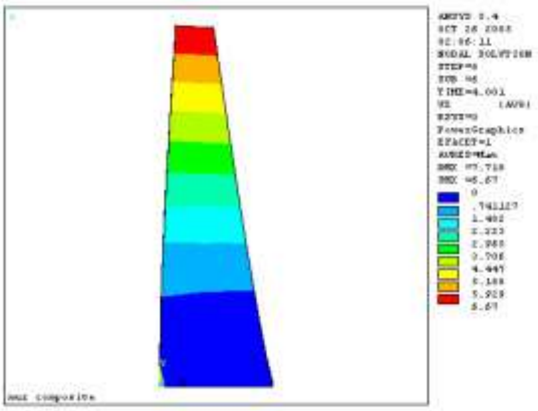


Figure 10. FEM results under lateral loading/Stress state.

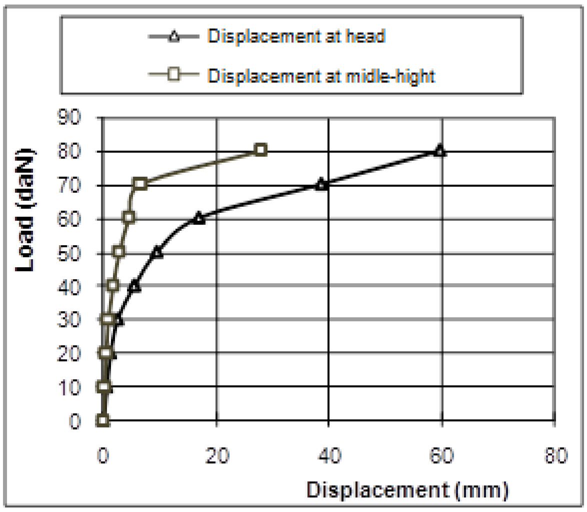


Figure 11. Experimental results under lateral loading.

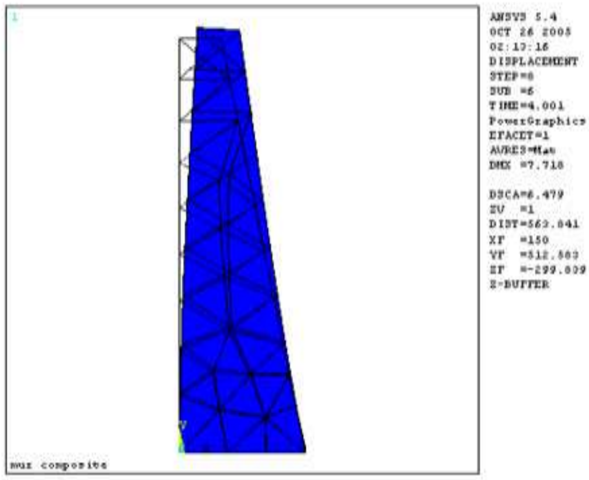


Figure 12. FEM results under lateral loading/lateral displacements.

B. *Dissipative ability study*

After determining of the optimal cross section of the composite wall, dissipative and damping ability of the structure is analyzed, in order to design an against impacts protection structure (Menaa and all, 2014).

This is possible by introducing and calculating dissipative index value defined as the ratio between received impact energy and the measured at the exit.

Experimentally, received impact energy, which is around of 10^3 *J*, can be assumed by a launched metallic sphere with respective mass; impact energy at exit through the wall may be measured by a special sensor.

Numerical analysis task is also assumed by ANSYS code for this study. The same finite element and the same law are considered. Characteristics of the composite material are: E = 7,5 MPa ; G = 8,8 MPA ; v = 0.3.

Figure 13 shows the meshing and limit conditions of numerical calculation model.

B.1. *Results and discussion*

Expected results are lateral deflection and stress-strain values related to the composite wall, under a lateral impact load (Fig. 14). In addition, a value of about 40% of dissipation rate is observed.

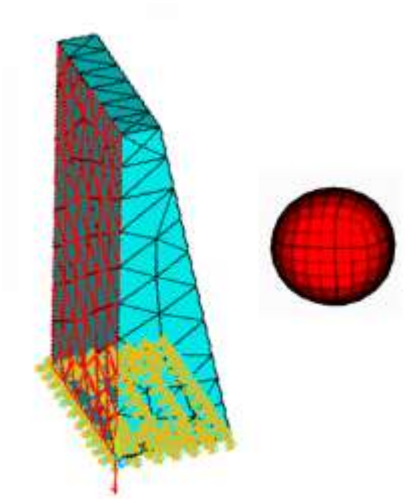


Figure 13. FEM meshing ang limit conditions.

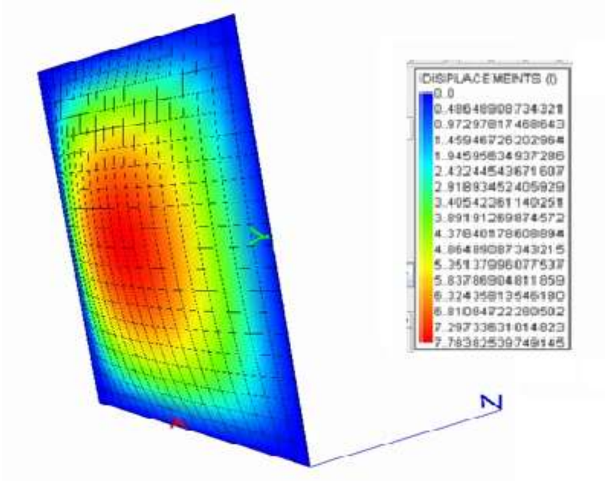


Figure 14. FEM results under impact load.

C. Circular composite structure under traffic loading

The present Study is related to a composite structure's behavior under static applied load, when taking a curved shape. The length is about the unit and a diameter equal 1.5 m (Fig. 15).

In this case, analyzed structure should be working under vertical (static or/and dynamic) loading, simulating a more or less light vehicle.

Applied loads should involve to a composite structure a plastic deformation of inner confined material and tensional stresses in same textile envelope. Composite structure must ensure an acceptable bearing ability and sufficient stability since stress on fabric still no over its limit tear stress.

Loading case and boundary condition are shown in figure 16. Applied meshing, refined at support and application point of concentrated load, is shown in figure 17.

Figure 15 Circular composite structure.

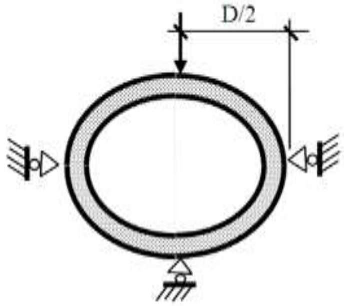


Figure 16. Computationnal model.

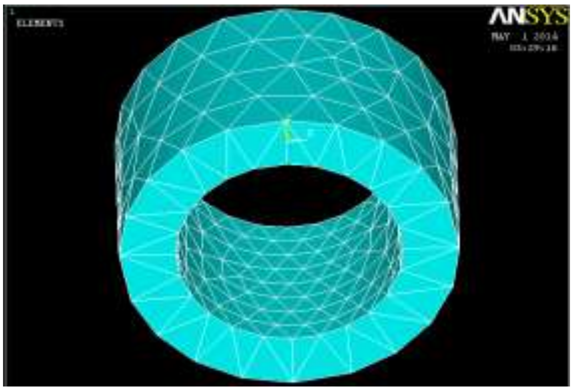


Figure 17. Model meshing.

C.1. Results and discussion

Obtained ANSYS calculation results shows, after ultimate loading deformation, a maximal deflection equal about of 21 cm; maximal stress is about of 0,28 MPa, witch can be compared with the experimental one. (Figs. 18 and 19).

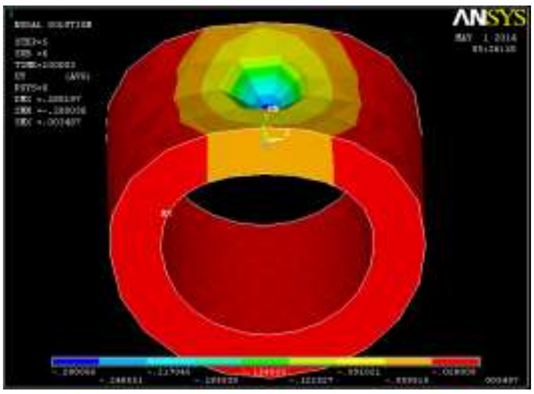


Figure 18. FEM results under vertical load/Stress state.

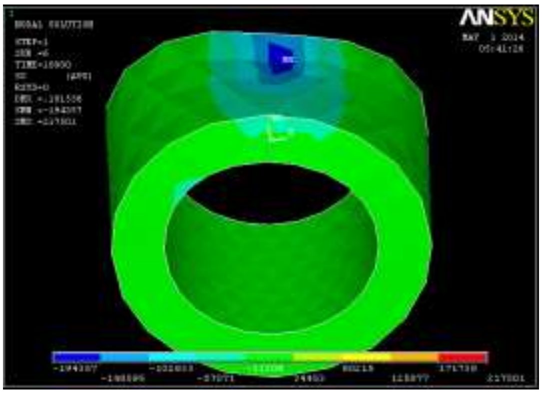


Figure 19. FEM results under vertical load/Deformation.

IV. General conclusions and perspectives

The equivalent mechanical characteristics of the analyzed composite structure, as initial modulus of elasticity and secant modulus with respective Poisson coefficient and more other parameters were evaluated and introduced in the present study;

Deformed shape of structure under acceptable (heavy vehicles) still admissible to assure an acceptable bearing ability, when this later take a curved shape; this used shape of composite fabric-confined granular material (sand) increase its bearing ability, by making it more stable and stronger compared with previously linear shape; this is clearly showed by all obtained and discussed results.

In the perspective, a numerical analysis of the wall using a 3D finite elements simulation code can be initiated in the future.

The composite nature of the analyzed structure and the interaction between granular confined material (sand) and confining textile envelope lead to consider its more or less complex stress-strain character. This leads us to choose more appropriate methods, taking into account this complexity. In addition to Finite Element Method, Discrete Element Method seems to be more appropriate.

An experimentation of a real model is recommended in order to more define a mechanical behaviour of the complex studied structure.

Acknowledgment

Our thanks were advised to CNERIB Laboratory team for their valuable aids to achieve most fraction of this work.

We also thank our Laboratory team for their assistance an effort to accomplish simulation and modeling part of the present work.

References

[1] ASTM D1682, Standard Test Method for tensile strength of Geotextiles, Geomembranes and Related Products.

[2] F. Nicot, P. Gotteland, D. Bertrand and S. Lambert. "Multi-scale approach to geocomposite cellular structures subjected to impact", International Journal for Numerical and Analytical Methods in Geomechanics, 31(1), 2007, pp 1477–1515.

[3] K. Andrewers, "Uniaxial strength testing of woven and nonwoven geotextiles", Journal of Geotextiles and Geomembrane, 1984, 1(1), pp 41-55.

[4] K. Rajagopal, N. R. Krishnaswany, L. G. Madhavi, "Behaviour of sand confined with single and multiple geocells", Geotextiles and Geomembranes, 17(1), 1999, pp 171-184.

[5] L. Menaa, "A PVC textile-sand wall analysis under lateral load (in Russian) , PhD Theisis, Department of Structures, Civil engineering Institute, Moscow, (1990).

[6] L. Menaa, A/h Benouali, A. Bouafia, "Caractérisation mécanique de modèles cubiques en sable confiné", 14ème Conférence Régionale Africaine de Mécanique des Sols et de Géotechnique**,** Yaoundé, Cameroun, 2007, pp. 373-378.

[7] L. Menaa, Dj. Amar Bouzid and. A. H. Benouali. "Experimental and Numerical Analysis of a PVC Textile-Confined sand Structure", Contemporary Engineering Sciences, Vol. 2, no. 4, 2009, pp 179 – 190, DOI: 10.12988/ces

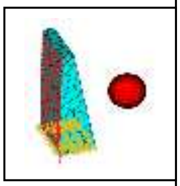
[8] L. Menaa, A Bouafia and. A. K Cherifi. "Design and Analysis of a technical fabric-confined wall under dynamical impact load", Jouurnal of suistainable architecture and civil engineering, Vol. 1, no. 6, 2014, pp 12 – 17, ISSN: 2029- 9990.

[9] M. Mariotti, M. Millot, "Développement de l'utilisation de géotextiles performants dans la stabilité des voies ferrées au Maroc", Service Voies et Ouvrages d'art, Rapp. ONCF, Maroc 86-01, (1986).

[10] P. Reiffsteck,. " Expérimentation et modélisation de structures en sol renforcé par un géotextile tridimensionnel alvéolaire", Revue Française de géotechnique, 82(1), 1998, pp 55-65.

[11] P. Reiffsteck, "Etude du comportement mécanique du géotextile tridimensionnel alvéolaire ARMATER. Analyse numérique et expérimentale", Thèse de Doctorat, Université Blaise PASCAL. (1996).

[12] Y. F. Xu, J. Huang. "Case study on earth reinforcement using soil bags", Geosynthetics in Civil and Environmental Engineering, 8(1), 2009, pp 597-602. DOI : 10.1007/978-3-540-69313-0_111.



After determining of the optimal cross section of the composite wall, dissipative and damping ability of the structure is analyzed, in order to design an against impacts protection structure.

This is possible by introducing and calculating dissipative index value defined as the ratio between received impact energy and the measured at the exit (Menaa and all, 2013).