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Design and Analysis of Technical Fabric - Confined Sand Wall Under Dynamical Impact Load

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Confining granular materials still a very benefic practice to achieve civil different engineering works. In this paper, the design and analysis of a wall shaped structure made of technical fabric-confined sand will be exposed. This composite structure, made of local materials, where, Polyvinyl Chloride (PVC) technical fabric constitutes a containing envelope and sand a filler material.

Designed wall represents a good sustainable development project (idea) to build single story buildings in hot and humid inaccessible areas (Sahara); alternatively, it may provide many other geotechnical applications as retaining walls etc.

An experimental campaign to identify the mechanical and physical properties of the studied structure was conducted. Earlier, and not exposed here, a design and analysis of a 1/5 scale model is achieved to evaluate a bearing ability of the wall under vertical compressive and horizontal flexural loads is done. Test to evaluate energy dissipative power of the wall under impact has been also conducted and discussed.

Keywords: *bearing wall, dynamic load, impact load, technical textile, confined sand, protection structure.*

1. Introduction

Idea of soil confining, applied in Civil Engineering (geotechnics), is relatively older: we can refer to classical used in practice gabion retaining walls, where the material (stone) is confined within steel net.

Geobag structures (geoconteners), using the same practice, developed a few years ago, had allowed the conception of many geotechnical and civil engineering works (Xu, and Huang 2009). Mariotti and Millot (1986) have made banquettes with confined sand, using geotextile bags to reinforce the subgrade of ballast rails in Morocco.

Geoconteners, according French standards and definitions of the company "International Geosynthetic Society", can describe all alveolar structures obtained by alternative connection of flexible or rigid textile bands. In this context, Reiffsteck (1998) had developed an experimental model analyzing a three-dimensional honeycomb structure made of geotextile for use in slope stabilization. Panoply of studies have identified the most influential parameters on the behavior of the designed structural cell, it is mainly geometrical and mechanical parameters (Shimizu and Inui 1990; Rajagopal, Krishnaswany and Madhavi, 1999). This confirms previously published work results, showing that the confinement leads to an improvement of the strength for materials with lower cohesion. The unreinforced and reinforced materials show the same angle of internal friction, while the latter have a high apparent cohesion due to the confinement. As example, Reiffsteck (1996) find out that apparent cohesion for composites made with two different aggregates varies from 156 to 190 kPa.

A technical fabric was used for the first time in confining to make out an envelope within which sand is carefully compacted to obtain a composite vertical wall. Filler works under both shear and compression, while the fabric works in tension (Vacilkov and Simvulidi, 1985). 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 desired.

Analysis of the dissipative power is conducted basing on founded works in the literature. We can cite the work where long geotextile bags with confined sand, were used to constitute an energy dissipative structure by mobilizing elasto-plastic deformation (Mougin, Perrotin, Mommesim, Tonnelo, and Agbossou 2005). Besides, a known "Pneusol-structure" conception, with qualities of energy absorbing is considered as cheaper alternative (Esbeling, Nguyen, Modercin, Ursat, 1994) compared with classical protective dikes (Nicot, Gotteland, Bertrand and Lambert, 2007).

The objective of this work is to conduct an experimental campaign devoted to the evaluation of all aspects of the mechanical and physical behavior of the studied wall

2. Architectural and structural design

The designed wall made of local materials, is characterized by its light weight, easiness of its transportation, installation and implementation. The studied wall should be used as a bearing structural element, to implement a circular in plan single story temporary building (Figs. 1a and 1b), which may be located in difficulty accessible areas (Sahara) (Menaa, 1990). The trapezoidal cross section of the wall, with desired thickness and height involves its good acoustic and thermal insulation, especially in hot and humid areas (Fig. 2). For its efficiency working, it is recommended to protect the technical fabric with special revetment in order avoiding vandalism acts since fabric is conceived to resist to ultraviolet rays.

Another alternative of use of designed wall is anti-impact protection structure. The analyzed composite wall could marry constructions (as petrochemical storage tanks), to receive and absorb potential impact loads. The study focuses on the analysis of composite wall, vertically sited and associated to a lightly reinforced concrete facing to endure and dissipate impact energy, in practice until 1000 kj (Figs. 3a and 3b).

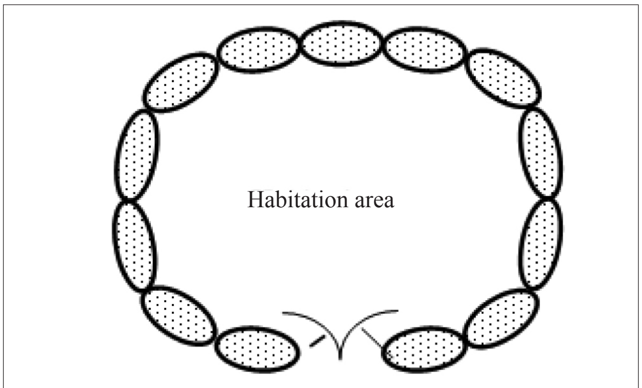


Fig. 1a. *Circular in plan mono-story habitation building*

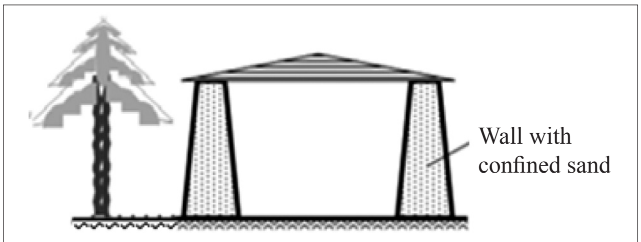


Fig. 1b. *Vertical cross of habitation building*

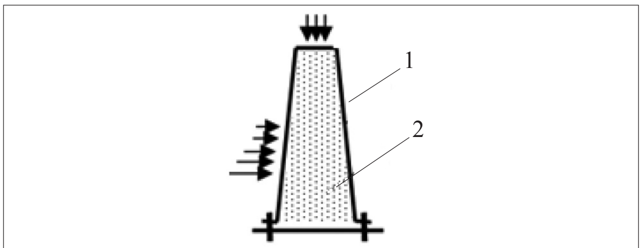


Fig. 2. *Vertical cross section of the wall.* Legend: 1 – Fabric envelope; 2 – Filler sand

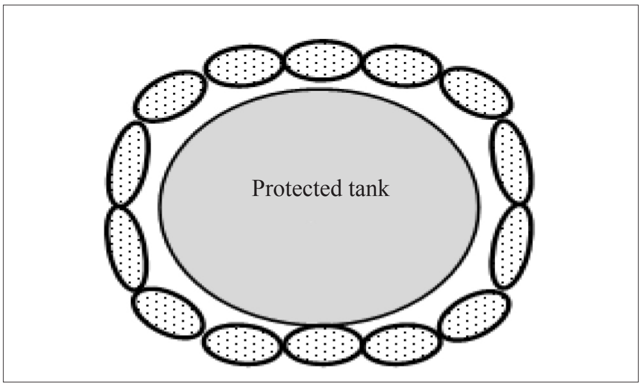


Fig. 3a. *Impact protective structure*

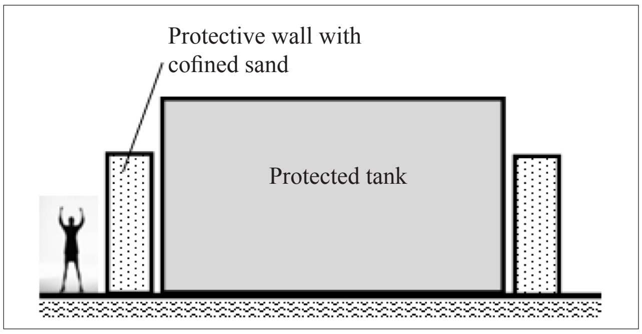


Fig. 3b. *Vertical cross of protective structure*

3. Experimental study

2.1. Characterization of the constituent materials

The technical fabric consists of a polyester reinforcing fabric (support), coated with four layers of polyvinyl chloride (PVC); it has been tested under axial tension using standardized fabric bands (ASTM D1682); results are comparable to those find in the literature (Andrewers 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, Benouali and Bouafia2007).

2.2. Confinement effect vulgarization

2.2.1. Testing method

The parameters governing the shear behavior of sands were evaluated by triaxial compression test, using specimens (17.5 cm x 7 cm) and shear Casagrande box, using specimens (2.07 cm x 6 cm) to test direct shear box were performed. These tests under a confining pressure of 0.3 MPa were conducted to peak characteristics given in Table 1.

Table 1. *Results of the shear test*

Type of sand	**C' (kPa)**	**φ' (°)**	
		Direct shear	**Triaxial test**
Coarse sand	0	-	41.74
Confined Coarse sand	160	63.66	54.39

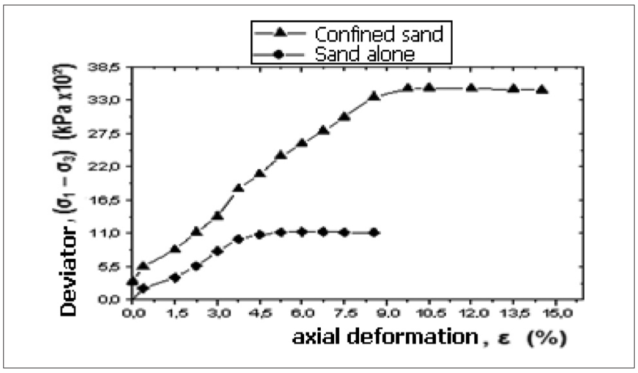


Fig. 4. *Deviatoric stress-strain curve*

2.2.2. Results and discussion

Effect of confinement is highlighted throughout improvement of the intrinsic characteristics of tested material. Results show significant differences between the confined sand and sand alone (Figs. 4, 5, 6); pure sand presents zero cohesion while the confined one presents about 160 kPa cohesion. Moreover, friction angle increases with about 12.70°, witch represents an improvement about of 30%. Furthermore, deformability at failure of confined sand is twice greater than of pure sand. This deformability seems to be related to a mobilized friction within the sand particles. Besides, it can be noted that, the values of the angle of dilation about of 12.80° and a Poisson's ratio about of 0.30.

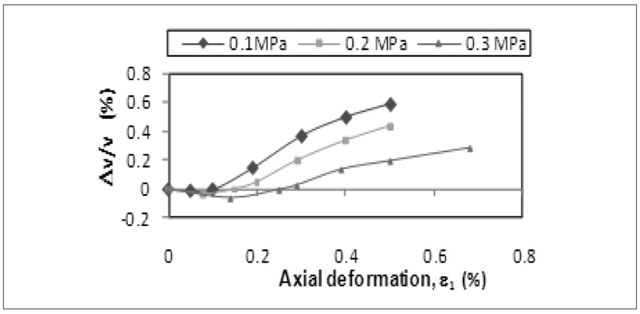


Fig. 5. *Volumic deformation curve*

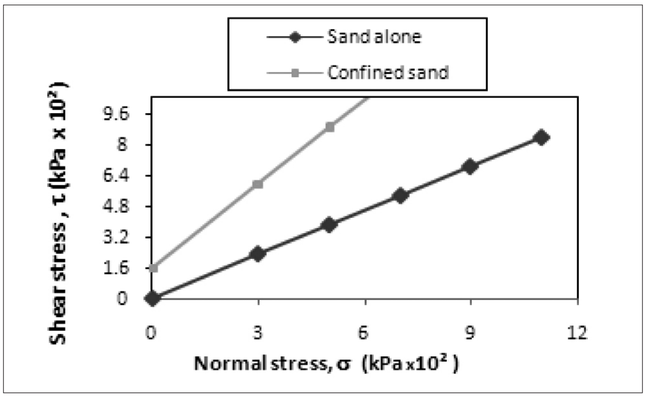


Fig. 6. *Intrinsic curve*

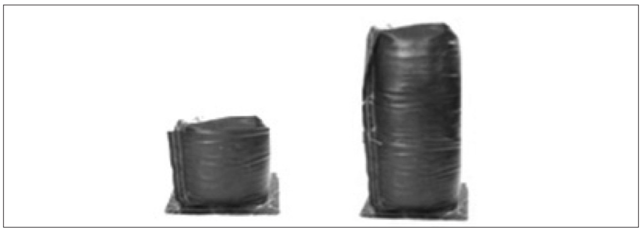
2.3. Study of mechanical behavior keys parameters of the wall

2.3.1. Behavior under compression

The compression test was conducted on 20 cm cubic specimens (Fig. 7a) using a press of 20 kN range. The results of the compression test are shown in figure 8.

2.3.2. Bending behavior

A three point bending test was conducted on prismatic specimens (20 x 20 x 60) cm³ (Fig. 7b) on the same press previously used. Results are shown in Figure 9.



a) b)

Fig. 7. *Photos of tested specimens: a) Cubic specimen (20x20x20) cm³; b) Prismatic specimen (20x20x60) cm³*

2.3.3. Shear behavior

The shear test was also conducted on cubic specimens (20 x 20 x 20) cm³ (Fig. 7 a) using a specially designed testing stand. All results are shown in figure 10.

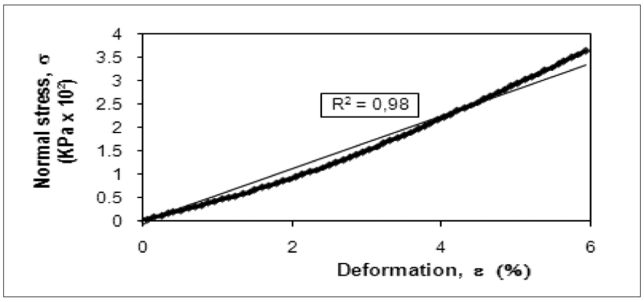


Fig. 8. *Stress-strain compression curve*

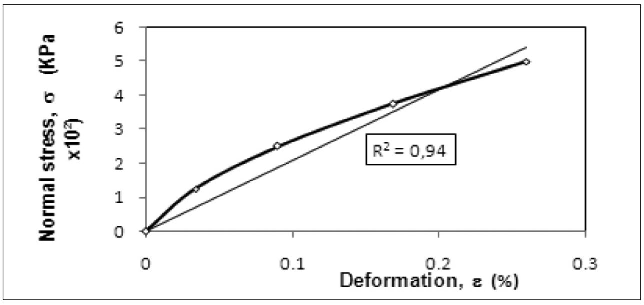


Fig. 9. *Stress-strain bending curve*

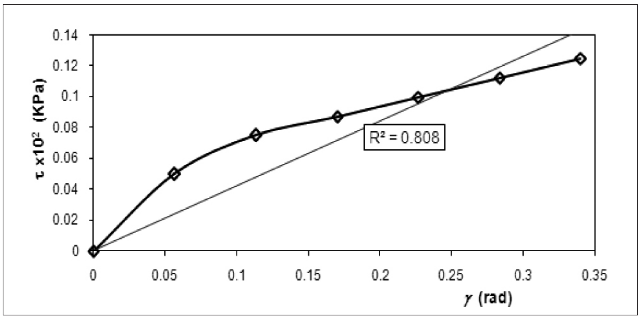


Fig. 10. *Stress - strain shear curve*

2.3.4. Effect of sand type

The effect of the quality of used sand on the specimen's deformation is clearly observed. Deformations are larger with fine sand (sand dunes) than coarse sand (concrete sand), while, well graded sand deforms faster and set off to a stationary elastic state (Fig. 11).

Failure takes place close to line of stitching for strength of 14.6 kN. These results, valid in both compression and shear, seem correlated with those obtained by other studies using geotextiles as an alternative of our technical material.

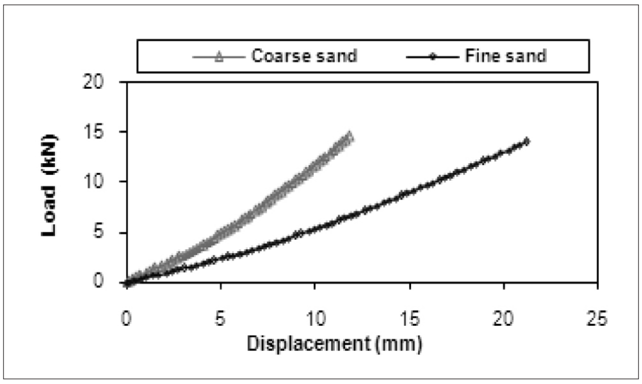


Fig. 11. *Effect of type of sand*

2.3.5. Influence of fabric assemblage

In this test, the compression strength of cubic confined sand specimens is recorded for different types of assemblage: by sewing and thermo-welding. In the first case, the failure occurs at the line of stitching for a force value about of 15 kN; for the second case, we observe a higher tensile strength (about 75 kN), which corresponds to approximately five times the first value. It can be concluded that the thermo-welded linkage leads to a more efficient assemblage (Fig. 12).

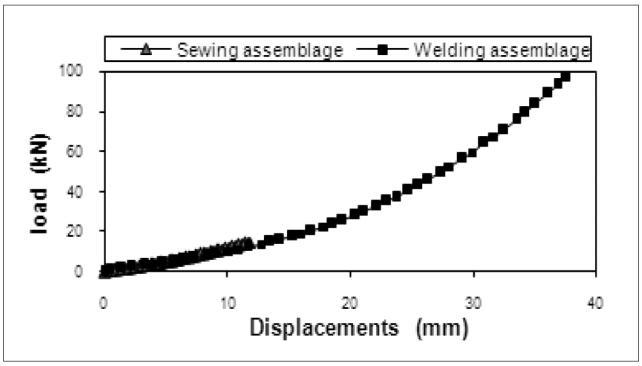


Fig. 12. *Effect of assemblage type*

2.3.6. Effect of loading surface

Study of the relationship between the charged surface and the volume of confined sand is evaluated by compression tests at constant deformation. Accordingly, cubic specimens were tested considering two different loading surfaces: loading surfaces of (10 x 10) cm ² and (20 x 20) cm². The results are shown in Figure 13.

The shapes of the stress – strain curves show the same tendency in both cases of loading area. For the same volume of confined sand and a given stress level, mobilized deformations are rapidly reached when the load area is important; it can be concluded that, the confining fabric enclosure probably tends more rapidly to elastic behavior.

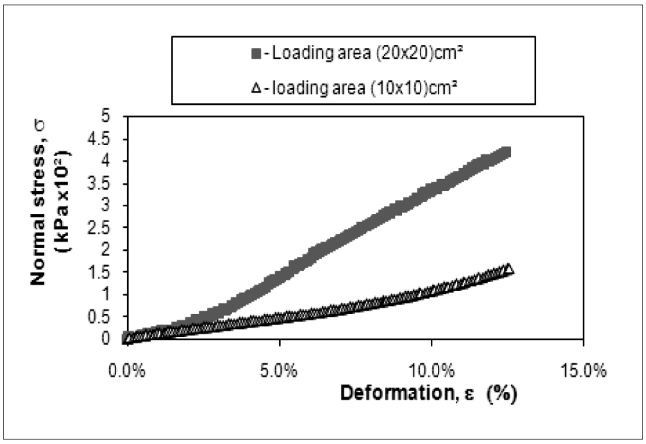


Fig. 13. *Effect of loading surface*

2.3.7. Effect of loading cycle

In order to evaluate the behavior of confined models after plastic deformation mobilization, compression tests under repeated cyclic load of 100 kN, on cubic fabric-confined sand specimens were carried out. The testing results are shown in Figure 14; a stiffening of the specimen is observed for a more high loading cycle.

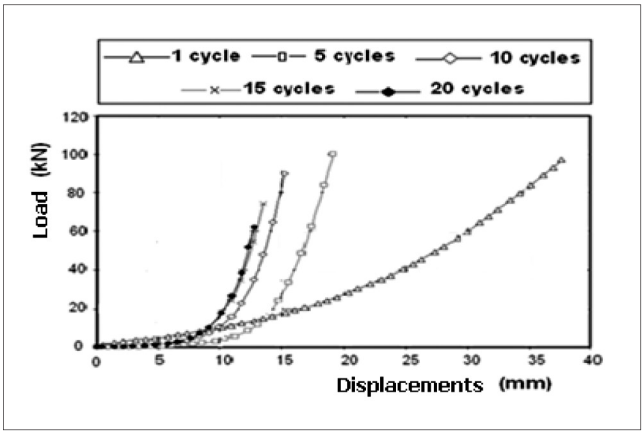


Fig. 14. *Loading cycles curves*

2.4. Scaled model Testing

2.4.1. Study of a wall bearing capacity

Analyzed wall can work in two positions (vertical or horizontal) and under any loading case; three testing cases of a 1/5 scaled model were carried out: first, under lateral loading with a vertical position, then, the vertical wall is loaded simultaneously (vertical and lateral loads); finally, the wall horizontally located, is subjected to a vertical compression loading. In this paper, only results of the first case are presented. The laterally loading test shows a good bearing capacity of the wall, while remaining within the elastic stress diapason (Menaa, Amar Bouzid and Benouali, 2009). The same model is used later to analyze the dissipative power of studied wall (Fig. 15a and b).

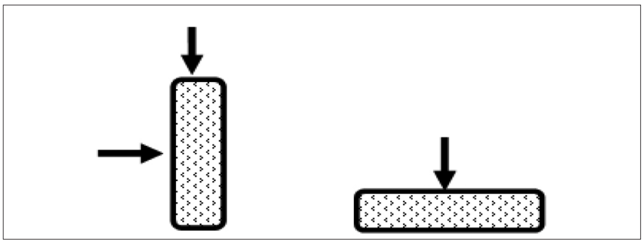


Fig. 15. Testing cases of scaled model

2.4.2. Study of a wall dissipative power

Scaled models of varying thickness sizes (e) and diaphragm spacing (s) (Fig. 16) are tested under the same conditions to measure the impact force and then estimate the rate or dissipation index (A_d). This index is defined as the ratio between the static weight of the launched ball (M) and the measured dynamic force (D) respectively.

This study leads to evaluate the optimal variant of the wall to perform an optimal protection against impacts.

$$A_d = \frac{M}{D} \qquad (1)$$

2.4.2.1. Experimenting stand design

The experimental device consists of a suspended pendulum with a fixed steel ball at its lower end. A sensor, fixed to the support frame, for measuring the impact force is located behind a tested wall (Fig. 17). The various cases are obtained by combinations of different thicknesses (e = 10, 20, 30) cm, and different spacing (s = 10, 20, and 30) cm, with or without concrete facing: 1 – virgin sand 2 - composite fabric-confined sand wall, and 3 – the same composite wall associated with a concrete facing. Launching intensity is about 1000 J.

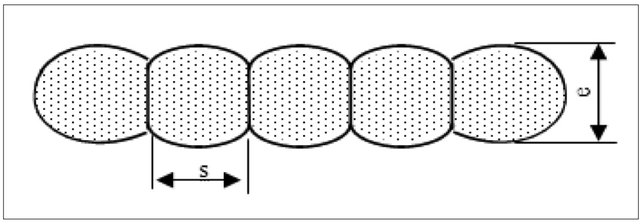


Fig. 16. Horizontal cross section of wall

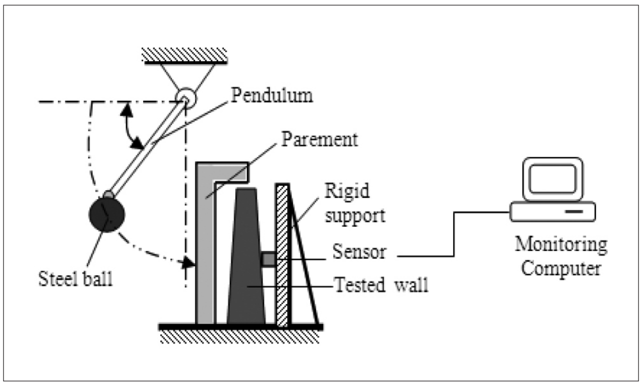


Fig. 17. Impact testing device

***Table 2.** A_d Results for different combinations of (e) and (s)*

e (cm)	10			20			30		
s (cm)	30	20	10	30	20	10	30	20	10
A_d (%)	20,1	30,2	35,1	36,2	40,1	46,1	45,2	50,1	55,3

2.4.2.2. Results

The impact forces transmitted through the composite structure were measured and compared; the objective is to determine the values of dissipation for the different cases of composite walls (Table 2; Fig. 18).

The model made with a thickness e = 20 cm and spacing s = 20 cm gives an index of dissipation close to 40.1 %. This value is in the neighborhood of to the median test results; hence, this case can be considered, as early, as an ideal model to design dissipative and protection structures against impact. Figure 19 shows optimization of wall models using ($A_d - s$) and ($A_d - e$) relations.

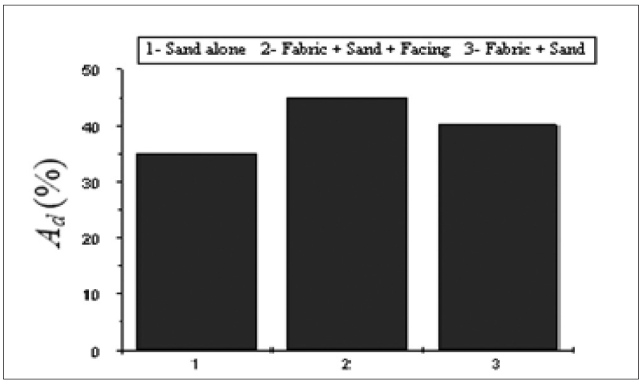


Fig. 18. Histogram of 03 testing cases

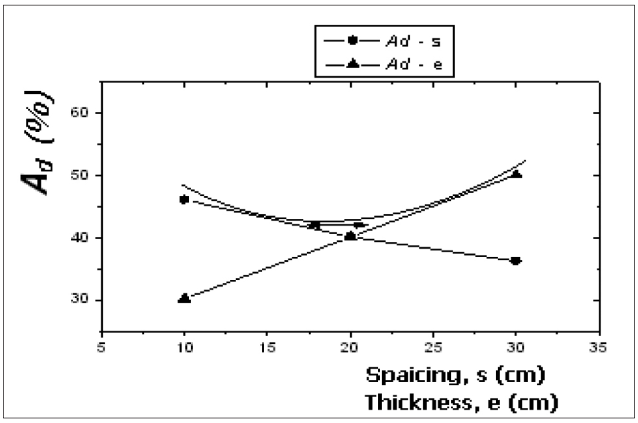


Fig. 19. Geometrical optimization of the model

4. General conclusion and perspectives

Experimental campaign achieved on cubic and prismatic specimens can lead to determine, through appropriate calculus, the equivalent mechanical characteristics of the wall, in particular, the modulus of longitudinal compression (E), the bending stiffness modulus (E_f) and the shear modulus (G).

For small deformations, the initial modulus of elasticity is in the order of 10.50 MPa; the value of the secant modulus increases to the value of 74 MPa, approximately seven times the value of the initial modulus.

Furthermore, results of tested reduced model show a good bearing capacity of the wall, while remaining within the elastic range.

The analysis of the capacity of energy dissipation of the studied structure leads to discuss an alternative application as protection against shock impacts.

As perspectives, a numerical analysis of the wall using a 3D finite elements simulation code can be initiated in the future to validate the experimental results and define the behavior of more or less complex studied structure.

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