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Experimental investigation of the mechanical behavior of the core composed of polyurethane foam and scoria mineral pumice for use in explosive energy absorbent sandwich panels

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Abstract

In this article, a new type of explosion energy-absorbing sandwich panel has been introduced and studied experimentally. To investigate and study the mechanical behavior of these panels, 3 different types of experimental tests have been performed. The purpose of conducting the first series of experimental tests is to select the type of matrix used in the core composition. The choice of the core matrix is made among 3 materials: aluminum, resin and polyurethane foam. The core matrix selection criterion is the strength performance and energy absorption efficiency of the sandwich panel core. The chosen core is a combination of polyurethane foam and scoria mineral pumice with two different types of granulation. In the second series of experimental tests, the mechanical properties of the core, including the stress-strain diagram and energy absorption efficiency of the core, are presented by the compression test and its results. In the third series of experimental tests, the mechanical behavior of the sandwich panel and the maximum deflection of its back face by a free blast explosive have been evaluated. The maximum deformation in the samples that used pea-sized mineral pumice in their core composition is 28.5% less than the samples that used almond-sized mineral pumice. In this article, the composition of a new core for sandwich panel has been studied and introduced, which is accepted due to its lightness, proper strength, low production cost, easy production and good energy absorption efficiency.

Keywords: Experimental test, absorbing energy, sandwich panel, polyurethane foam, Scoria mineral pumice

1. Introduction

There are various methods and structures to absorb explosion energy. Aluminum foam is an advanced material that has many applications in absorbing the energy of explosive charges, but the cost of its preparation and production is high and a complex technology is required for its production. Using mineral pumice as an explosion absorber is a good alternative to aluminum foams due to its low density, low price and high energy absorption.

The experimental work includes 3 distinct parts: (1) determining the best interface material (2) examining the mechanical properties of 2 types of cores made of mineral pumice and the selected interface material (3) investigating the energy absorption and behavior of the sandwich panel made under free explosion.

Hansen et al. [1] have measured the energy and impulse transferred to a pendulum. Rutherford et al. [2] investigated the response of sheets composed of two steel plates and aluminum foam core and fully rigid supports to the impact of aluminum foam projectile. Shen et al. [4, 3] investigated the explosion resistance of curved sandwich sheets with aluminum tops and aluminum foam core. Hangai et al. [5] investigated the effect of porosity on the compression properties of aluminum foam. Shim et al.[6] investigated shock wave wear in sandwich structures with aluminum foam core.. Gul et al.[7] investigated shock wave impact with aluminum foam. Rotario et al. [8] investigated the pulse damping in porous granular media. Khandabi et al. [9] studied the geometry of sandwich sheets with polyurethane foam core and aluminum tops under explosive loading. Lan et al.[10] studied the response of cylindrical sandwich sheets with aluminum foam core and 6-sided honeycomb under explosive load. Khandabi et al. [11] investigated the effect of thickness of polyurethane foam core with variable density and aluminum top in sandwich sheets under explosive load. Gangyun Sun et al.[12] studied the sandwich sheet with metal foam core with aluminum, steel and carbon fiber back and front panels against explosion. Zhou et al.[13] investigated the underwater explosion of sandwich sheet with metal shell and PVC foam core. Partmo et al.[14] investigated the performance of a sandwich structure with an aluminum foam core against free blast. Sandhu et al. [15] compared the explosion energy dissipation on foam in shock tube and free explosion. Sarkhosh et al. [16] studied cylindrical sandwich panels with aluminum foam core and aluminum top under explosive loading. Rahmani et al. [17] obtained the mechanical properties of the sample composed of aluminum and porous mineral pumice.

2. Experimental study

The experimental part includes 3 parts: 1) preliminary tests to obtain a suitable intermediate material for the core, 2) quasi-static pressure test to obtain the stress-strain diagram and mechanical properties of the core, and 3) explosive loading on the main sheet.

2.1 Choosing the right interface material

In figure (1), from right to left, sheets made with a core containing resin, aluminum and polyurethane foam can be seen.

Figure 1. Sandwich sheets with different cores

2.2 Determination of core mechanical properties

By using the pressure test, the mechanical properties and the required stress-strain diagram of the pumice samples with a density of 450 and 370 kg/m3 are determined according to figure (2).

(b) (a)

Figure 2. Foam and aluminum samples of pressure test

2.3 Explosive loading on the final samples

Sandwich sheets are made in a square shape and are subjected to free explosion test according to figure (3).

Figure 3- Free explosion test on sandwich panel

3. Discussion and review of the results

3.1 Explosive test on the samples to determine the intermediate material

In figure (4) the back plate, the condition of the core and the front plate can be seen. The core is completely crushed, the front plate is also completely deformed, and the pumice has an effect like splinters on the back plate.

Figure 4- Sample test with mineral pumice core

In the next test, the core with the combination of resin and mineral pumice was used according to Figure (5)

Figure 5- Sheet test with a core combination of resin and mineral pumice

Figure (6) shows the sandwich sheet after the explosion.

Figure 6- Sample with foam core after testing

The core of the next sheets is made with a combination of aluminum and pumice. It can be seen that the back sheet is completely torn and separated from the core edges.
The results of these tests are briefly presented in table (1).

Figure 7- The result of an experiment with a core made of aluminum and pumice

Table 1- Results of explosive loading on prototypes

Core type	Explosive mass [gr]	face thickness (mm)	Material of faces	Maximum displacement of the back plate(mm)
Pumice	8	1	St37	28
Mineral pumice and aluminum foam	8	1	St37	Tearing of the back face
Mineral pumice and resin	8	1	St37	25
Mineral pumice and polyurethane foam	8	1	St37	15
Mineral pumice and plaster	8	1	St37	Tearing of the back face
No core	8	1	St37	35

3.2 Discussion and examination of the results of tests to determine the properties of the core

The experiments conducted to determine the properties of the core materials were conducted and recorded according to Figure (8).

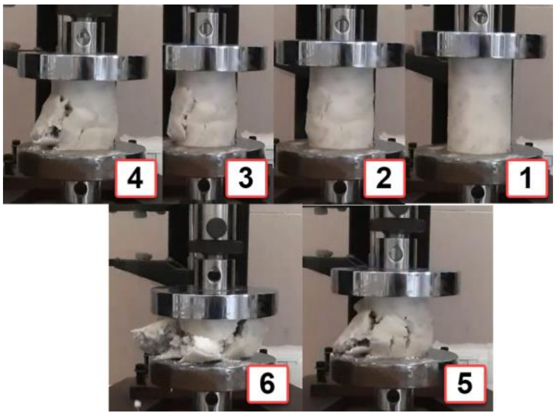

Figure 8- Collapse stages of the foam sample in the pressure test

Figure (14) and (15) shows the test diagram of the sample with a density of 450 and 370 kg/m3, respectively.

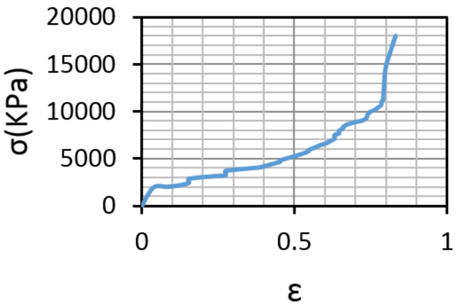

Figure 9- Strain stress diagram from core compaction test with pea -sized pumice

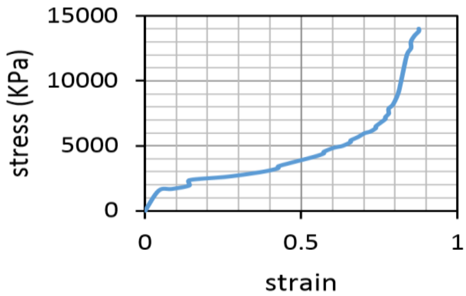

Figure 10- Strain stress diagram from core compaction test with almond-sized pumice

The diagrams show that the 450-density core has a relatively higher strength than the 370 kg / m3 core.
Figures (11) and (12) show the energy-strain absorption efficiency diagram of the core reinforced with pea -sized pumice with a density of 450 and with almond-sized pumice with a density of 370 kg/m3, respectively.

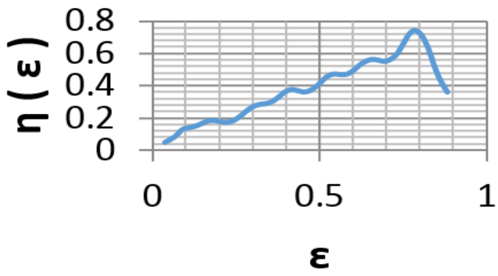

Figure 11- Diagram of energy absorption-strain efficiency of core reinforced with pea -sized pumice

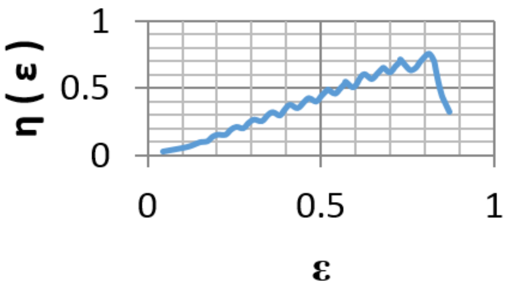

Figure 12- Diagram of energy absorption-strain efficiency of core reinforced with almond-sized pumice

The maximum efficiency of energy absorption in both samples is almost equal and about 76%. The difference in the energy absorption efficiency of these two types of cores is in how to reach the value of 76%.

3.3 Discussion and investigation of explosive loading results on sandwich samples under blast load

The results of free blast loading of sandwich sheets include the maximum deflection of the back plate, which is recorded in table (2).

Table 2. Specifications of the test samples and the maximum deflection of the back panel of the sandwich sheet (dimensions in mm)

Sample NO.	pumice type	face sheet material	The thickness of the face sheets(mm)	Distance of charge (cm)	mass of charge [gr]	Deflection (mm)
1	pea	Al	1	20	30	17.5
2	almond	Al	2	15	40	14
3	almond	St	2	15	40	7.5
4	pea	St	1	20	30	11
5	pea	Al	2	15	40	10
6	almond	St	1	15	40	7
7	foam	Al	2	15	40	31

In figure (13) and (14) the sample with aluminum top and foam core is presented before and after the test.

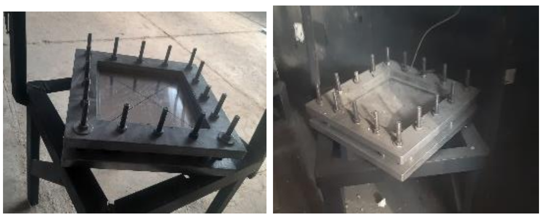

Figure 13- Sample with aluminum face sheet before and after the test

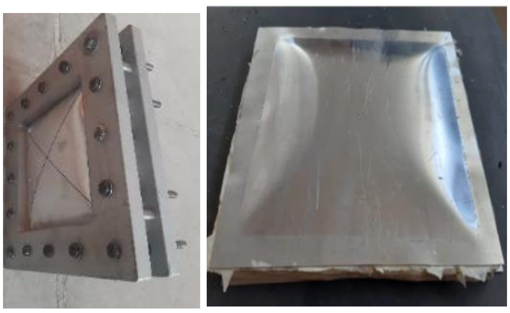

Figure 14- Testing and changing the shape of the face sheet

4. Conclusion

In this article, a new type of explosion energy absorbing sandwich panels has been introduced and studied, whose core is a combination of polyurethane foam and scoria mineral pumice with two different types of granulation. In the experimental process of choosing the intermediate material used in the composition of the core, polyurethane foam has a better performance in terms of strength and energy absorption than aluminum, construction plaster and resin, so that the minimum maximum deflection of the back plate of sandwich sheets to the core with the combination of mineral pumice and dedicated polyurethane foam. In other compositions with a core composed of mineral pumice and aluminum, building plaster and resin, the maximum deflection of the back plate is more or more, or there are tears in them.
Due to the change in the granulation of scoria mineral pumice in the core composition and the consequent change in the core density, the diagram of energy absorption efficiency in terms of strain in the pea sample has an upward and relatively uniform movement and in the almond sample it has a sinusoidal and upward movement to the maximum value. arrive
The use of mineral pumice and its role in energy absorption reduces the maximum deflection of the

back plate of the sandwich sheet. The highest deflection is related to the sandwich sheet with foam core without mineral pumice. The maximum deflection in the core of the sheets in which pea husk is used is less than the sheets in which almond husk is used in their core. The thickness of the tops does not have much effect on energy absorption compared to the grain size of the core and the material of the tops. The maximum deflection of the back sheet is lower in samples with steel top than in samples with aluminum face sheet.

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