Estimating The flexural and compressive strengths of Polyvinyl Chloride Tubes Core Honeycomb Sandwich Panels

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Abstract

This study focuses on estimating the flexural strength, flatwise compressive strength, and edgewise compressive strength of different types of sandwich panels. The first type was a conventional sandwich panel made of two face sheets of galvanized steel with a polyurethane foam core (PSP). The second is a honeycomb sandwich panel made of two aluminum face sheets with a structural core of PVC tubes (HSP1). The third is (HSP1) with polyurethane foam used to fill the cavities of the core cells (HSP2). The fourth is (HSP1) With the addition of partitions of the same cell material to divide each cell cavity into four cavities (HSP3). The mechanical properties of the sandwich panels were studied. The third sandwich panel (HSP3) has higher mechanical properties values compared to other tested sandwich panels but it had the highest density.

Keywords: Honeycomb Sandwich Panels, polyurethane foam sandwich panels, PVC Tubes, compressive strength, flexural strength.

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INTRODUCTION

With the increase in population density globally in general, especially in city centers and the need to construct multi-story residential and commercial buildings, and the desire for speed and ease of construction and achieving the required construction performance, in addition to these buildings increasing the construction loads on the foundations and soil, the need to use building units appears Lightweight, quick to installation and has good structural strength. To develop construction techniques in this field, lightweight building units such as clay bricks, foam blocks [1], porous blocks [2], or lightweight concrete made of porous stones were used [3]. In some cases, concrete is used with lightweight foam additives [4] [5] or lightweight concrete resulting from the replacement of fine or coarse aggregates with different proportions of polystyrene grains [6] [7].

In parallel with the use of the aforementioned building blocks, the use of lightweight building panels used locally, which are made of two face sheets of galvanized steel with a core of polyurethane foam (PSP) [8], has increased. It may be boards of wood with a polystyrene core or other types of lightweight materials. It is used to contribute to reducing the structural loads of buildings, which reduces the complexity of building design and the general construction cost while achieving efficiency in thermal insulation and energy conservation [9]. However, these panels are not considered load-carrying structural members because of the weakness of their internal structure, so it is relied on concrete or steel structural members to transfer the loads

to the foundations and consider these panels as non-structural members that carry the weight of themselves only [10].

In the direction of developing these traditional panels from a mechanical point of view, researchers have tended to employ honeycomb sandwich panels (HSP) used to build aircraft structures, ships, trains, and space devices with some modifications to be another product added to the sandwich panels. and suitable for building construction and covering steel structures because they collect Between lightweight and strength, in addition to the speed and ease of installation in building construction [11]. extensive researches was conducted on types of honeycomb sandwich panels from different materials for faces and cores, and it was estimated their strength for non-structural effects likely to be exposed to them in the building, and determining their appropriate location in the building design [12].

The low-density foam core of conventional panels, although lightweight and heat-insulating, is affected by harsh weathering and has rather insignificant strength[13]. While it is replaced by a structural core of a variety of materials, shapes and structures in honeycomb sandwich panels (HSP) in order to develop the strength of these panels in general [14].

The core in (HSP) consists of wood, metal, plastic or hybrid materials of these types and these materials are obtained from various sources, which may be plates, tiles, tubes, etc. [15]. Various materials are used as face sheet to manufacture honeycomb sandwich panel. The same materials can be used to fabricate the structural core, and an adhesive is used to assemble the elements and form the entire panel [16].

In previous studies of polyurethane foam sandwich panels, the flexural strength was verified with value (1.2 MPa), as well as flatwise compressive strength (0.4 MPa) and edgewise compressive strength (4.1 MPa) [17]. In the honeycomb research, the flexural strength was estimated at (2.1 MPa). With flatwise compressive strength (3.4 MPa). and edgewise compressive strength (6.6 MPa) [18]. By comparing the strength values of the two types, it appears that the honeycomb sandwich panel has better strengths than the polyurethane foam sandwich panels.

This work aims to obtain panels with higher flexural strength, flatwise compressive strength, and edgewise compressive strength than those obtained by traditional polyurethane foam sandwich panels used locally. It is made of environmentally friendly materials. Aluminum plates were used as face sheets. and (PVC) tubes as structural cells to form the core of the panel. As these materials are available locally. The parts were assembled. The model was glued with an effective adhesive from (Sikaflex 118) [19] and the model was tested in the flexural strength device, flatwise compression strength device, and edgewise compression strength device according to (ASTM C393/C393M–11) [20], (ASTM C365/C365M–11) [21], and (ASTM C364/C364M–12) [22], respectively. The same test was performed for the conventional panel and a comparison was made between the models.

The reason for choosing (PVC) tube is that it is a material with significant compressive and flexural strength as well as lightweight [23]. The reason for using an aluminum sheet is that it is light in weight. has significant tensile strength. and it is commonly used in the manufacture of (HSP) [24]. These are the properties required for the face sheet and structural core, as well as these materials are widely available and used locally.

MATERIALS AND METHODOLOGY

Test specimen

The structural core was made of rings of (PVC) tubes with a diameter of (102 mm) and a core height (50 mm) to obtain the thickness of the panel (HSP) identical to the thickness of the panel (PSP). to make a comparison between the two models to show the best of them in strength. This diameter (102 mm) is better than the larger diameter because it achieves good mechanical properties that the larger diameter may not achieve. It is better than the smaller diameter because it does not generate an excessive weight for the model. The core cells were installed interlocked to achieve more points of contact between the cells, which increases their interconnectedness among them. The face sheets

are made of aluminum plates with a thickness of (0.7 mm) and dimensions (500 * 500 mm). an epoxy adhesive (Sikaflex 118) was used to glue the core with the face sheets together and produce the required panel (HSP1). Figure (1) shows the manufactured model (HSP1) with dimensions. Figure (2) shows the materials used to manufacture the model. Figure (3) shows the (PSP) model and the formation of the core cell of the first model (HSP1). The second model was manufactured in the same manner as the first model with core cells filled with extruded polyurethane foam (sika boom p) [25] according to the product instructions (HSP2) Figure (4). The third model was manufactured in the same way as the first model, with the addition of partitions of the same (PVC) cell material to divide each cell cavity into four cavities (HSP3) Figure (5). It has been waiting for (48) hours until adhesive hardening was completed, according to the product's instructions.

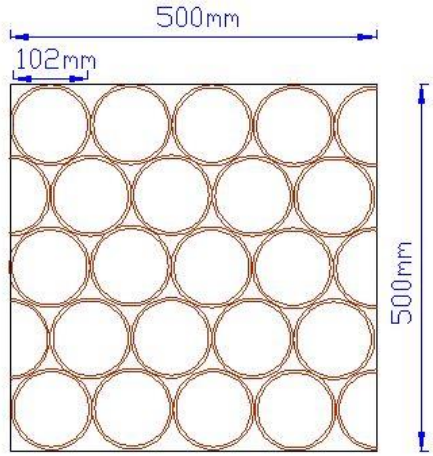

FIGURE 1. HSP1 with dimensions.

(a) (b) (c)

FIGURE 2. The materials used are (a) PVC tubes, (b) aluminum sheets, and (c) adhesive material.

(a) (b) (b)

FIGURE 3. (a) PSP specimen, (b) HSP1specimen shows the core cell formation, and (c) The final form of HSP1.

(a) (b) (c)

FIGURE 4. (a) extruded polyurethane foam, (b) HSP2specimen shows filling the cells with foam, and (c) The final form of HSP2**.**

(a) (b) (c)

FIGURE 5. (a) HSP3specimen Before adding PVC partitions, (b HSP3specimen with PVC partitions, and (c) The final form of HSP3.

Methodology

After cutting the models to the measurements recommended in the Core Shear Properties by Beam Flexure Specification (ASTM C393/C393M–11) (50 x 150 x 350) mm , Flatwise Compressive Strength Specification (ASTM C365/C365M – 11) (50 x 150 x 150) mm, and Edgewise Compressive Strength Specification (ASTM C364/C364M–12) (50 x 150 x 350) mm. The sandwich specimen was inserted into the compression device to test the flatwise and Edgewise compressive strength. and pressure was applied at a loading rate of (0.5 mm/min) and according to the instructions of the compression specification. The sandwich specimen was inserted into the flexural device to test the flexural strength from three points and pressure was applied at a loading rate (6 mm/min) and according to the instructions of the flexural specification. The ultimate force before failure that applied to the specimen was recorded. The flexural strength (MPa) of the specimen was calculated from equation (1). The flatwise compressive strength (MPa) of the specimen was calculated from equation (2). The edgewise compressive strength (MPa) of the specimen was calculated from equation (3).

$$fs\,u = \frac{P\,max}{(d+c)b} \quad (1)$$

Where ($fs\ u$) is the ultimate flexural strength (MPa), ($Pmax$) maximum load before the failure (N), (d) sandwich thickness (mm), (c) core thickness (mm), and (b) is the sandwich width (mm).

$$fc\ ult = \frac{P\,max}{A} \quad (2)$$

Where ($fc\ ult$) is the ultimate flatwise compressive strength (MPa), ($Pmax$) maximum load before the failure (N), and (A) cross-sectional area of the specimen (length × width)(mm2).

$$fc\ u = \frac{P\,max}{w\,(2tfs)} \quad (3)$$

Where ($fc\ u$) is the ultimate edgewise compressive strength (MPa), ($Pmax$) maximum load before the failure (N), (w) width of the specimen (mm), and (tfs) thickness of a single face sheet (mm).

According to Specification (ASTM C271/C271M – 11) [26], the density (dsi) (kg/m3) of each of the tested panels was obtained from the final mass of the specimen after conditioning (W) (gm), final length after conditioning (l) (mm), final width after conditioning (w) (mm), final thickness after conditioning (t) (mm), and equation (4) was applied.

$$dsi = \frac{1000000\,W}{lwt} \quad (4)$$

Five tests were performed for each specimen. The average values obtained were recorded. Figure (6) shows the flexural test machine, flatwise compressive strength test machine, and edgewise compressive strength test machine. Figure (7) shows the strength properties tests for (PSP), Figure (8) shows the strength properties tests for (HSP1), Figure (9) shows the strength properties tests for (HSP2), Figure (10) shows the strength properties tests for (HSP3).

a b c

FIGURE 6. (a) the flexural test machine, (b) flatwise compressive strength test machine, and (c) edgewise compressive strength test machine

a b c

FIGURE 7. (a) flexural test for (PSP), (b) flatwise compressive strength test for (PSP), and (c) edgewise compressive strength test for (PSP)

a b c

FIGURE 8. (a) flexural test for (HSP1), (b) flatwise compressive strength test for (HSP1), and (c) edgewise compressive strength test for (HSP1)

a b c

FIGURE 9. (a) flexural test for (HSP2), (b) flatwise compressive strength test for (HSP2), and (c) edgewise compressive strength test for (HSP2)

a b c

FIGURE 10. (a) flexural test for (HSP3), (b) flatwise compressive strength test for (HSP3), and (c) edgewise compressive strength test for (HSP3)

RESULTS AND DISCUSSION

The flexural strength, flatwise compressive strength, and edgewise compressive strength were calculated for each of the tested models as well as the conventional panel (PSP) in order to make a comparison between the models and to know which models are superior in strength.

Table (1) shows the testing results of the strengths of the four models that were tested in the construction material testing laboratory.

TABLE 1. Average values of the strengths for five specimens for each tested model.

No.	Specimens	Flexural strength (MPa)	Flatwise compressive strength (MPa)	Edgewise compressive strength (MPa)
1	PSP	1.5	0.31	3.49
2	HSP1	2.5	2.94	7.34
3	HSP2	2.81	3.19	7.92
4	HSP3	3.66	4.63	8.87

Table (2) shows the density results for each of the four models.

TABLE 2. Values of the Density for each tested models.

No.	Specimens	Density Kg/m3
1	PSP	120
2	HSP1	304
3	HSP2	336
4	HSP3	440

From table (1) and (2) the results showed the superiority of the (HSP3) model over the rest of the models in the specific strengths because the model (HSP3) has additional partitions made of (PVC) material that develops its ability to bearing loads more than the model (HSP1) that does not contain these partitions. As well as its superiority over the model (HSP2) because the extruded foam material that fills its cavities shows little strength, which does not make a big difference in the results from the model (HSP1). And it is definitely a superior model to the (PSP) model because the (PSP) model has a core of polyurethane foam that has little strength compared to the nature of the more powerful (PVC) material. Also, the adhesion strength between the adhesive (sikaflex 118) and the elements of the honeycomb sandwich panel is definitely better than the relatively low adhesion strength between the polyurethane foam and the

galvanized steel sheet used in (PSP) because the polyurethane foam is not an adhesive. On the other hand, the two models (HSP1) and (HSP2) showed greater strength than the (PSP) model for the same reason that was mentioned in the (HSP3) model. There is also an improvement in the results of the (HSP2) model over the (HSP1) model, because the foam material that fills its cavities shows some strength and adhesion with the face sheet, although the difference is small between the two models. (HSP3) is the best case that was reached in this study because it achieved the highest values of strengths compared to other tested models.

In terms of density values for the tested panels, the lowest density was obtained for the (PSP) model due to the lower density value of the polyurethane foam that fills its core. In contrast to the (HSP3) model, which has a (PVC) core with a higher density than the rest of the tested models, which in turn gives the model the necessary strength to withstand the loads applied on it.

Figure (11) shows the relationship between the density of the tested samples and the calculated strength values for each model.

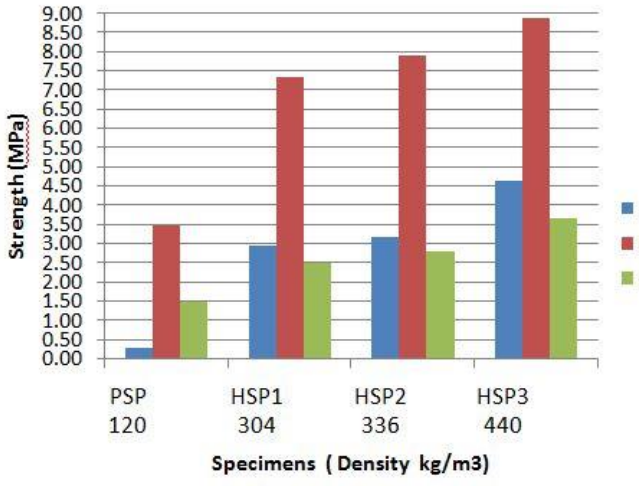

FIGURE 11. the relationship between the density and the strengths for four model.

From Figure (11) the increase in the density values of the samples increases the improvement of the strength values in general and shows a homogeneous increase in the strength values among the tested models. Except for the (PSP) model, which gives the lowest values of strength with a large difference from the gradient of the increase in strength for the rest of the models.

CONCLUSION

The current paper presented the results of the experiment to determine the flexural strength, flatwise compressive strength, and edgewise compressive strength of honeycomb sandwich panels made of (PVC) tubes and aluminum sheets, and the test results of traditional polyurethane foam sandwich panels. A comparison was made between the results and the following conclusion was reached:

The model (HSP3) showed the best strengths among the other panels tested, but it was the heaviest in weight. Therefore, its use is useful in achieving the strength for the sandwich panels if necessary. regardless of reducing the general weight of the building. For the two models (HSP1) and (HSP2), the results of the strength between them were somewhat similar. And because they are lighter than (HSP3) in weight, they are useful in reducing the overall weight of the building while achieving an acceptable strength for the panel against non-structural loads. Since the (PSP) model showed relatively low values in strengths compared to the (HSP1), (HSP2) and (HSP3) models, although it is the lightest among the tested models, it is preferable to use these models as an alternative to the (PSP) model. Unless reducing the structural weight to a minimum is required. Regardless of achieving the highest strength, the (PSP) model is the best to use.

From the given results, the values of the flexural strength and edgewise compressive strength of the honeycomb models were almost twice the values of the (PSP) model. This means that the honeycomb models can be used as members of non-load bearing walls or ceilings for the construction of light structural units such as cold rooms, heat insulation rooms or partitions inside the building because they are It bears loads at a value higher than (PSP). but in the case of constructing large storages, trusses, workshop sites, and factories, they still need to be installed on steel or concrete structures to help them transfer the structural loads to the foundations,

which cannot be transported alone. In addition, it is possible to manufacture honeycomb sandwich panels, which have outperformed (PSP) panels in strengths, with dimensions greater than those of (PSP), and achieve economical use of the structural members on which the panels are installed. As this helps to reduce the dead load of the bearing structural members and thus reduce the overall weight of the building generally. As for the flatwise compressive strength values of the honeycomb models, they outperformed the (PSP) model by nearly ten times, which allows using the tested honeycomb panels in floors instead of using the (PSP) panels that have low compressive strength.

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