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Effect of Cell Shape on Flexural Strength of Honey Comb Structure

(Experimental and Numerical Study)

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Abstract:
This study is concerned with the on the preparation and flexural testing of honeycomb configuration and study effect of cell shape on flexural strength of honeycomb structure. Honeycomb sandwiches construction that has a composite matter particular state, which made via attach two skinny, although rigid skins toward a lightweight excluding broad cores. Low density, high thickness, and high bonding stiffness properties of the materials that is used to make the core. In this study, four different core shapes were used in the fabrication of the sandwiches construction with constant volume of sandwich composite structure in each case; these are hexagonal, rectangular, triangular and circular. The material of the each face sheet is consisting from epoxy reinforced by two layers of glass fibers and the core stiffener material consists from epoxy material. The honeycombs strength investigated by using test of bending with three points according to the ASTM C 393 standards. The highest load result is achieved of honeycombs core that shape is square is equal to (7.5 KN) and less deformation (3.1 mm) from the other core shapes. Ansys workbench (static structural) utilized to analyze the design of honeycomb sandwiches panel composite which results illustrate agreements amid the experimental and numerical consequences.

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I INTRODUCTION

In the late years, to get the superior mechanical performance and light structures, several studies have been conducted where it was found that the excellent solution is the composite sandwiches [1].

Finally, the strength of excellent structures coupled with their lightness and rigidity has led to the increasing use of these structures in industries such as cars, ships and city structures [2, 3]. The material of the sandwiches has consisted of two things, rigid and tough outer skin that surrounds thicks, light weight cores [4] .

Principally, the sandwiches panel's main term is which the front panels carried the bend pressures but shear pressures done on the core [5,6]. Skins materials that used commonly are composite metals and laminates [7]. The cores are, typically fabricated from foam [8, 9] or by utilizing trusses or corrugated or honeycombs frame [10, 11].

Zakeri and Talebi [2010] studied the mechanical behavior of sandwich panels for dynamic loads experimentally. For this investigation, flexural trialindiverseconditions of load was affected strongly through skin thickness, although tensile and compression properties of sandwiches panels depended onmatter of core [12].

Sezgin, et al. [2010]simulated the core thickness effects on the mechanical properties of composite sandwichesconstruction with polymer honeycombs cores and GRRP face-sheets. According to the 3-

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point bending trials, a reduce in cores shear pressure and face sheet bendpressure was shown as the thickness of core raised[13].

Sakhi et al. [2015] investigated the three points bend flexure behavior of the honeycomb sandwich panels experimentally and analytically. It conclude that the max fracturing load with maximum deflections, while the specimen's failures happen as core bucklings that reasoned to the faces sheet dispersion to the cores [14].

Ahmed Fadhil et al. [2016] investigated the flexure and impact behavior of functionally graded rubber-nano composite core for sandwich experimentally and analytically. The results show that the strength values have increased significantly for the proposed structure compared to the conventional sandwich structure while maintaining the weight of the structure [15].

Topkaya et al. [2016] inspected the fatigues behavior of honeycombs sandwiches composite at buckling and bending stresses of three points. The study looksto the effect of the diameter of the cell, core and skin thicknesseson fatigue behaviors. It was illustrated that a cell diameter is mainlyimportantfactoraffecton fatigue below buckling forces but the skin material thickness is the slightestimportantfactor affect fatigue beneath three pointsforces[16].

II MATERIALS AND METHODOLOGY

2.1The Raw Materialsused

- Pvcfoam
- SiliconeRubber
- E-glass fiber (chopped strand mat)
- Epoxy Resin

2.2 Design and Manufacturing Honeycomb Dies

The specimen of the test is designed according to ASTM C393 as rectangle cross section which 20 mm thickness, 75 mm width, 200 mm length, and the total length that is unsupported equal to 50 but the length of the span is 150 mm. In this study to get best comparison between the suggested geometrical honeycomb core shapes of the system, regarded the weight criterion to be constant (i.e. the core volume is fixed) forall specimen.Everyspecimenofevery oneshape of honeycomb is chosen asfollow.

Preparation of honeycomb dies consistsfrom two main parts are (1) Design (2) Manufacturing. A 3D or CNC MasterPattern is created by using CNC machining accordingtothecelldimensionsofspecimen. PVC foam use as material of master mold. Casting method has been implemented in the silicon rubber mold preparation. First, the master mold is installed inside a glass mold, then 380g of silicon rubber is mixed manually with the hardener in 4% ratio, and then poured the mixture into the glass mold around the master to completely fill all the cavitiestoproduceamatchingsiliconmold master pattern, then left for four hours at room temperature to be ready for use.Figures 1 to 4 illustrate the design and prepared of the dies for differentshapes.

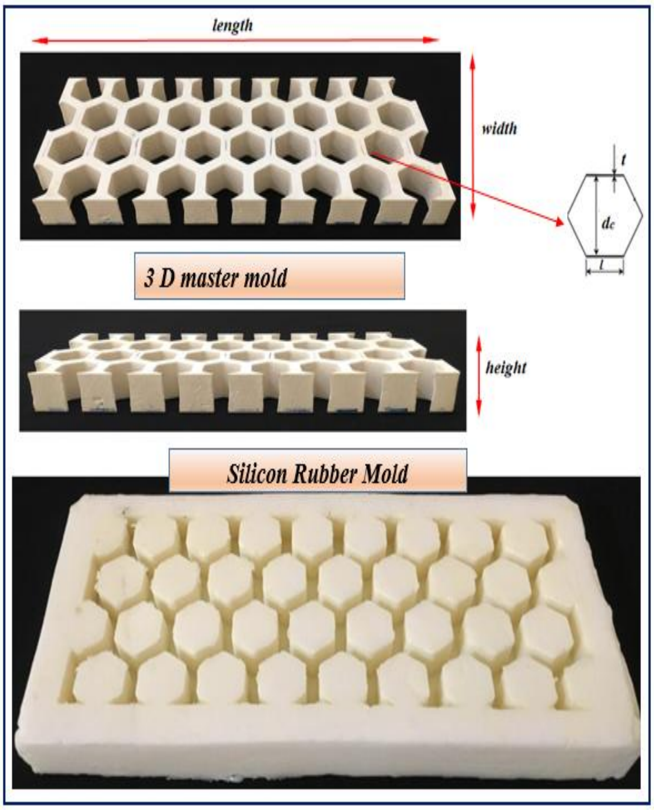

Fig.1. Hexagonal Die Shape

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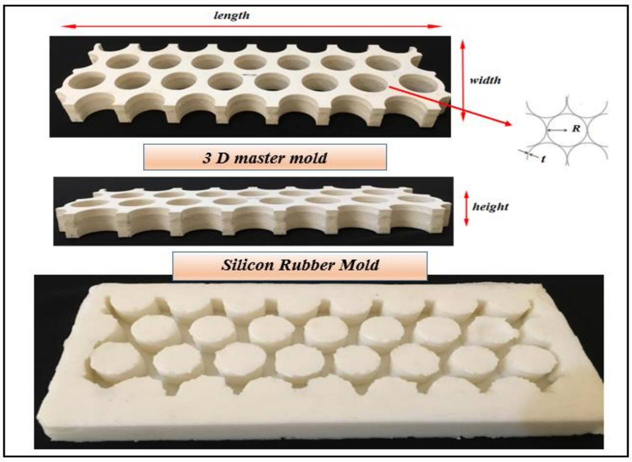


Fig. 2. Circular Die Shape

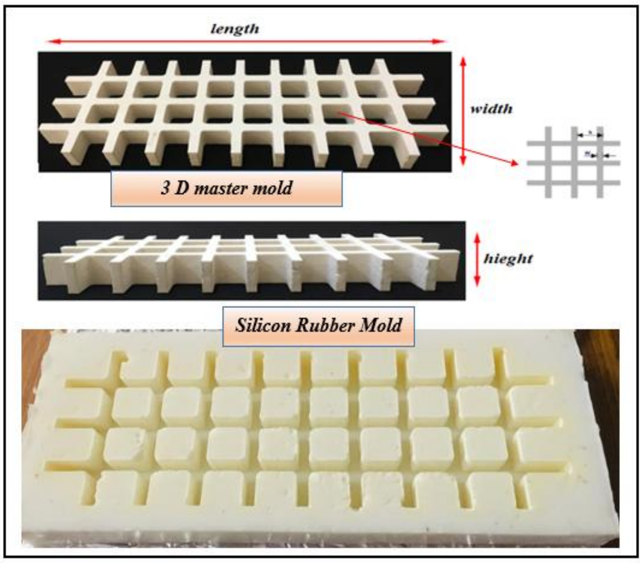


Fig. 3. Square Die Shape

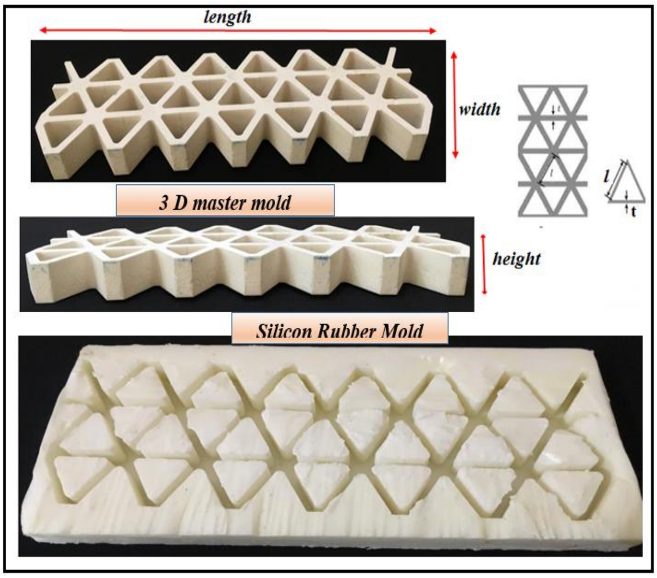


Fig. 4. Triangle Die Shape

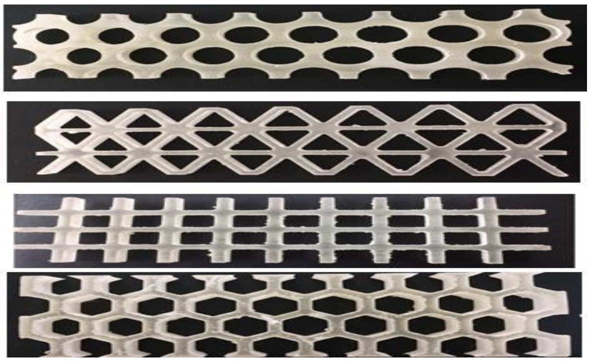
2.3 Sample Preparation

Preparation of sandwich sample Consists from three main parts are (1) Composite facing Preparation (Upper & Bottom Face Sheet) (2) Core Preparation (Honeycomb Core Structure) (3) Produced sandwich panel structure (by bonding honeycomb and face sheet).

2.3.1 Composite facing Preparation

Composite facing Preparation involves several stages starting from raw materialschoice, molds preparations and done with the cutting of specimen by laser. The specimen of composite materialsat this work was mixtures of two different materials, which in combination, produce a material that has some of the best qualities of each. The two materials are epoxy resin as matrix and chopped glass fiber as reinforcement.

In this work, the Hand Lay - up procedure is used due to its low tool cost. Initially the glass mold was



prepared and covered with a piece of nylon paper to prevent the adhesion between the mold and the specimen. Epoxy resin mixed with hardener (with ratio 1:2) and manually mixed for 3-5 minutes. Mixture put in oven under vacuum at 25 °C for 10 minutes to removing bubbles. One part of the polymer mixture is spread in the glass mold, the layers of glass fiber are cuts to necessary shape then first layer of the fiber is placed above the diffused polymer, then another part of the polymer mixture is spread over the first layer of the fiber and then the second layer of the fiber is placed over the diffused polymer, then the remaining part of the mixture is poured overthesecondlayer of glass, and pressed by the roller to eliminateevery

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trap air foam and the polymer excess with shown in figure (5) After the completion of laminate apply, kept it for 24 hours .The sample is then extracted from the mold and the laser cutting is done according to the shape and dimensions required.

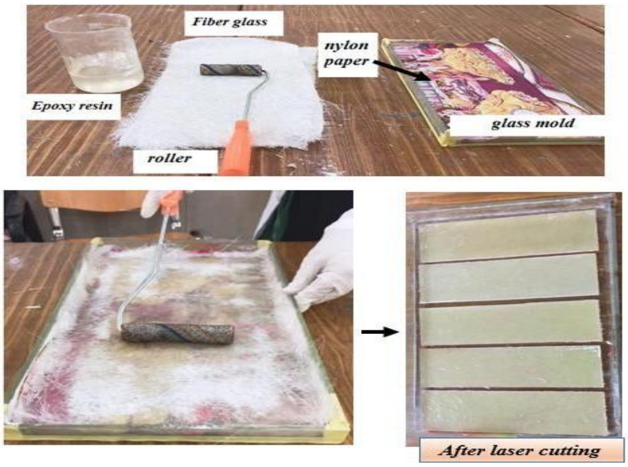


Fig 5. Composite facing Preparation

2.3.2 Core Preparation

Theepoxyresinwasmixedwithhardener (with ratio 2:1) and manually mixed for 3-5 minutes, mixture put oven under vacuum at 25 °C for 10 minutes to removing bubbles. Then the mixture was poured in a silicon mold, which was previously prepared, then left for 24 hours at room. This method was repeated in order to obtain all core forms. Figure (6) explains the steps to prepare the sample. The samples are then extracted from the silicon mold as shown in figure(7).

2.3.3 Bonding honeycomb and facesheet

Theepoxyresinwasmixedwithhardener (with ratio 1:2) and manually mixed for 3-5 minutes. The mixture utilized as adhesive material.Adhesivefilmplacedonthepeak surfaceand the bottom surface of the honeycomb core, then placed honeycomb upon face sheet surfaceandpressingthemmanuallyasshown in figure(8) , and then left for 24 hours at room temperature and curing the sample in the ovenforfourhoursat100°C.Duringcuring process.Theresinflowsandcreatesabond between the face sheet and the honeycomb walls.

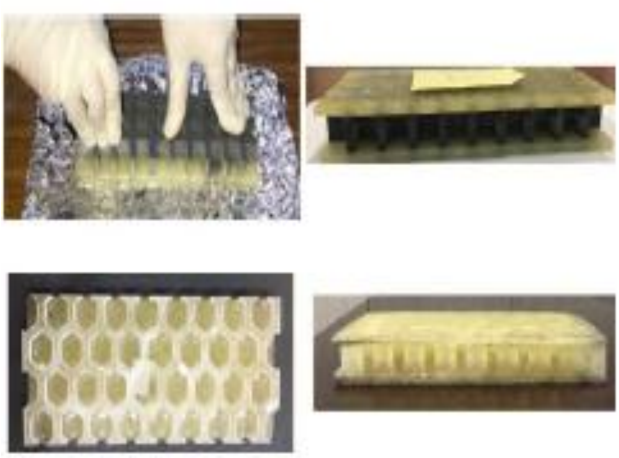
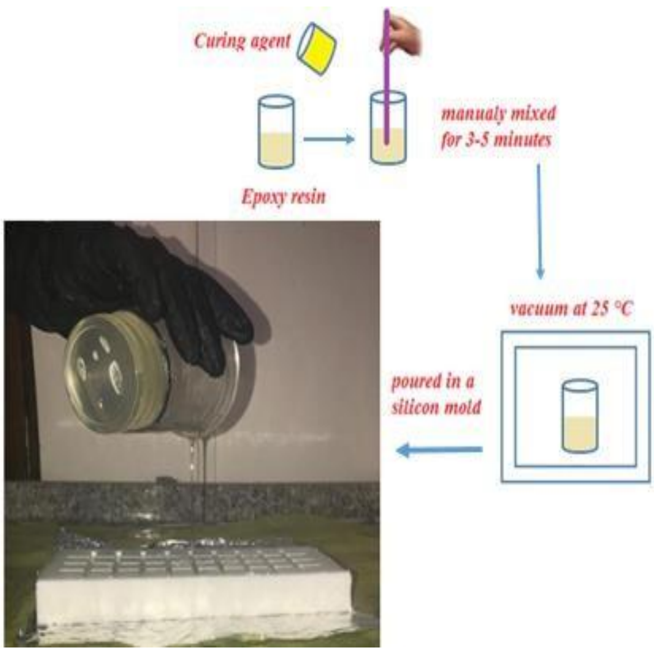


Fig.8.bonding honeycomb and face sheet

2.4. Testing

The sandwich of Honeycombs panel is succeeded utilized as constitutional material for taking the stresses (compressive, bending, and tensile). The panel's strength of bending may be calculated through direct a three points bend trail accordance with ASTM C 393. Figure (9) shows three-points bending trialssystem which done to the panels failure andforces of failure are record.



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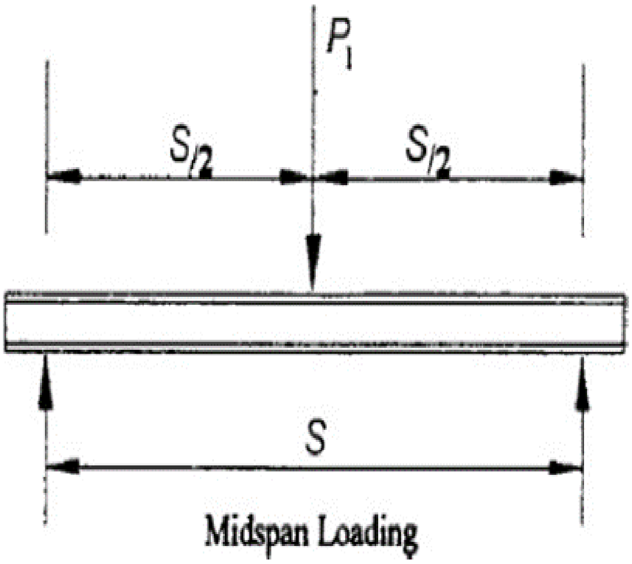

Fig. 9.Three Point bending test and loading configuration

Applying forceby a (30mm) diameter roller. The crosshead speed is detainedstable and is selected (3mm/sec). The displacement of the central loading point was monitored on a computer.

III RESULTS AND DISCUSSIONS

3.1 Experimental result

The most important property of the core is its ability to bonding with the face sheets to transfer the loads between the top and bottom face sheets. A honeycomb core sandwich panel is lighter due to having the core of hollow space; therefore, it must choice a suitable shape of core to support a higher load with smaller deformation. In this study, four different core shapes were used in the fabrication of the sandwich panel with constant volume of sandwich composite structure in each case; these are hexagonal, square, triangular and circular Force-deformation curves and failure mode for all core shapes are shown in the following figures.

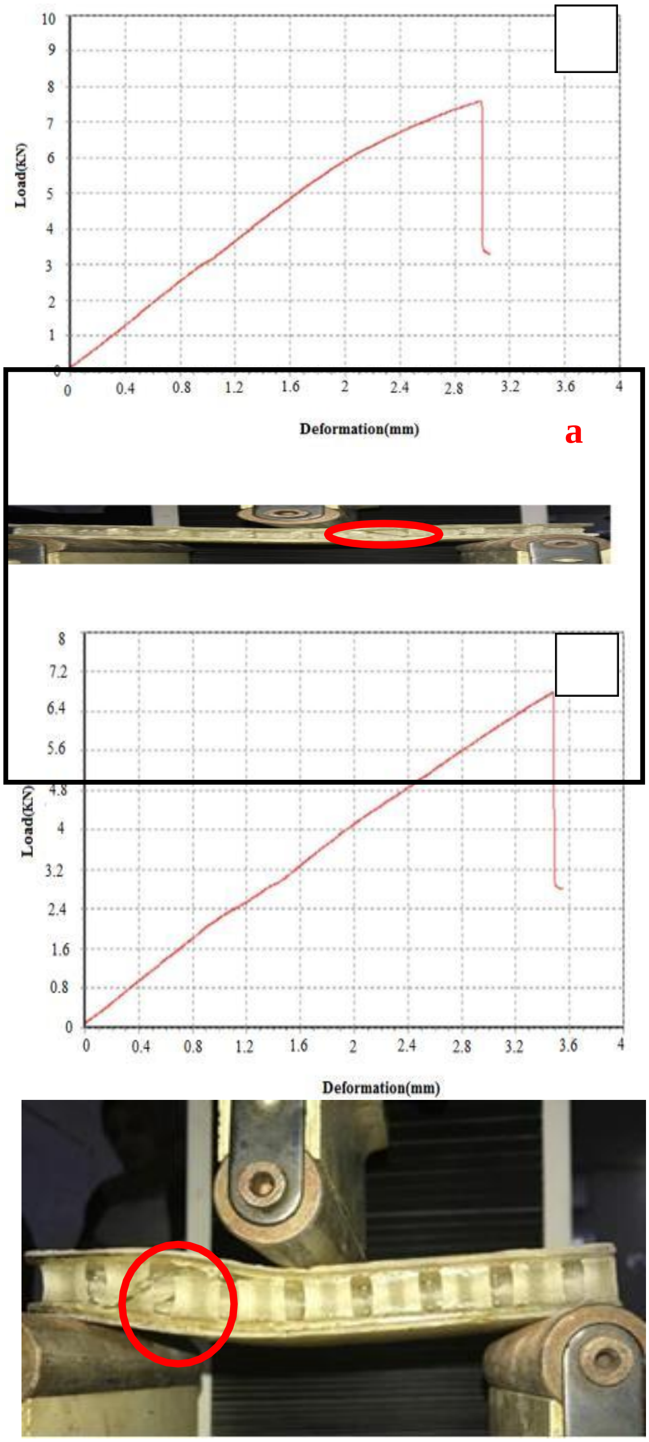

Fig. 10.Load deformation curve and failure mode for (a) square (b) hexagonal

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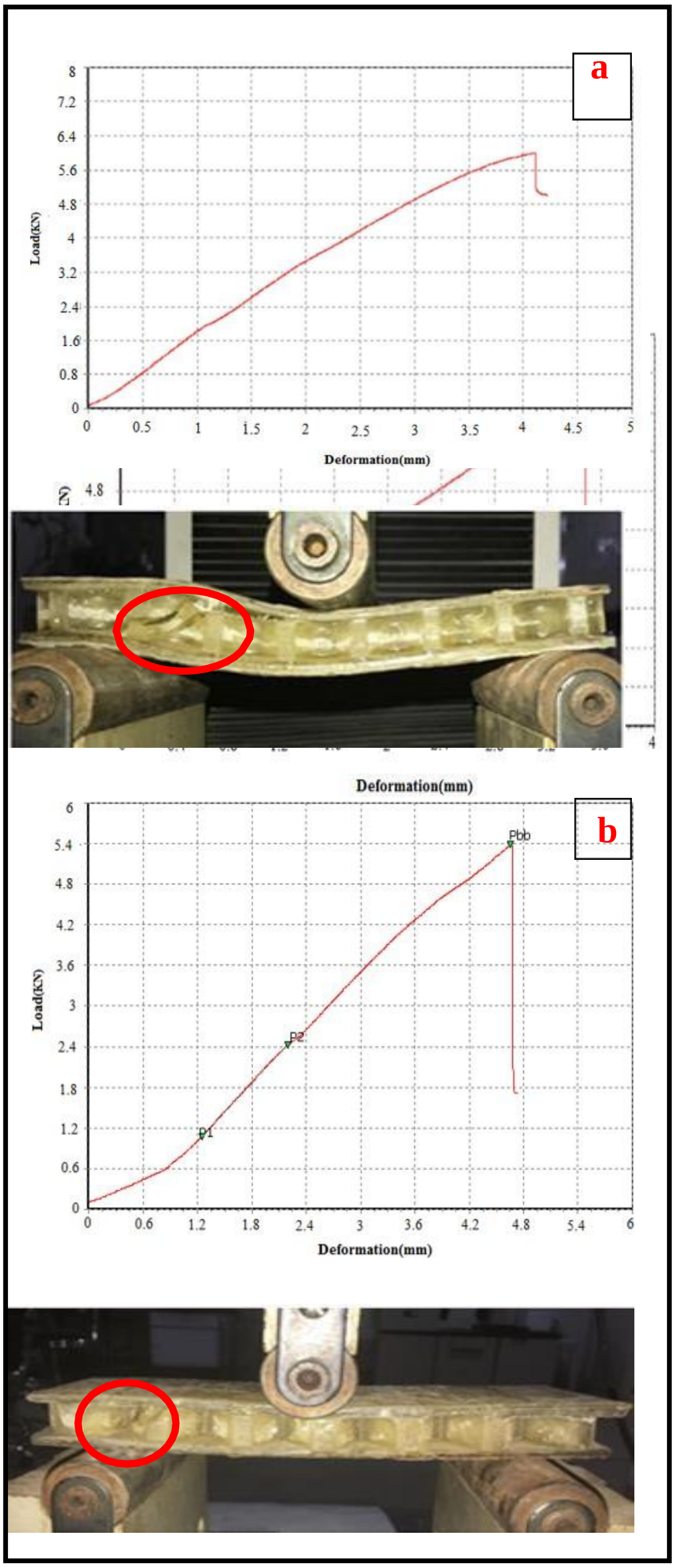

Fig 11. Load deformation curve and failure mode for (a) circular (b) triangle

Can be observed from figures (10 and 11) that the structure with square have the highest maximum load and less deformation; i.e. stiffer structure as compared to other core shapes. This result because of the stiffeners is more compact in square core, and these stiffeners are building up with each other in both transvers and longitudinal directions. The longitudinal stiffeners play important role to avoid the bending in structure where this property not exist in other shape The circular, triangular and hexagonal cores have lower maximum load and higher deformations under the bending loading, demonstrating that these cores reached yielding strength before square core. Bending strength of the sandwich panel is one of the most important characteristics, where this strength will depend on the energy absorbing capability of the entire structure. Therefore, the yield strength of the structure material as well as geometrical dimensions such as cell shape and other parameter is the main parameters to determine the bending strength.

There are several different modes of failure of sandwich composites (core shear failure, face yield, buckling or wrinkling, deboning) when loaded in bending [17]. The structures will fail at the mode that happens at least force; it can be observed shear failure of the core with inclined cracks in the core is occurred in all cases when the sheet's skin are extremely broad and force to broken. In this study at three points bending, the core is mostly sustain to shear and carries primarily the applied shear loading and the failure occurred as the maxi shear load arrived to core material critic strength.

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Table 1
Test Results

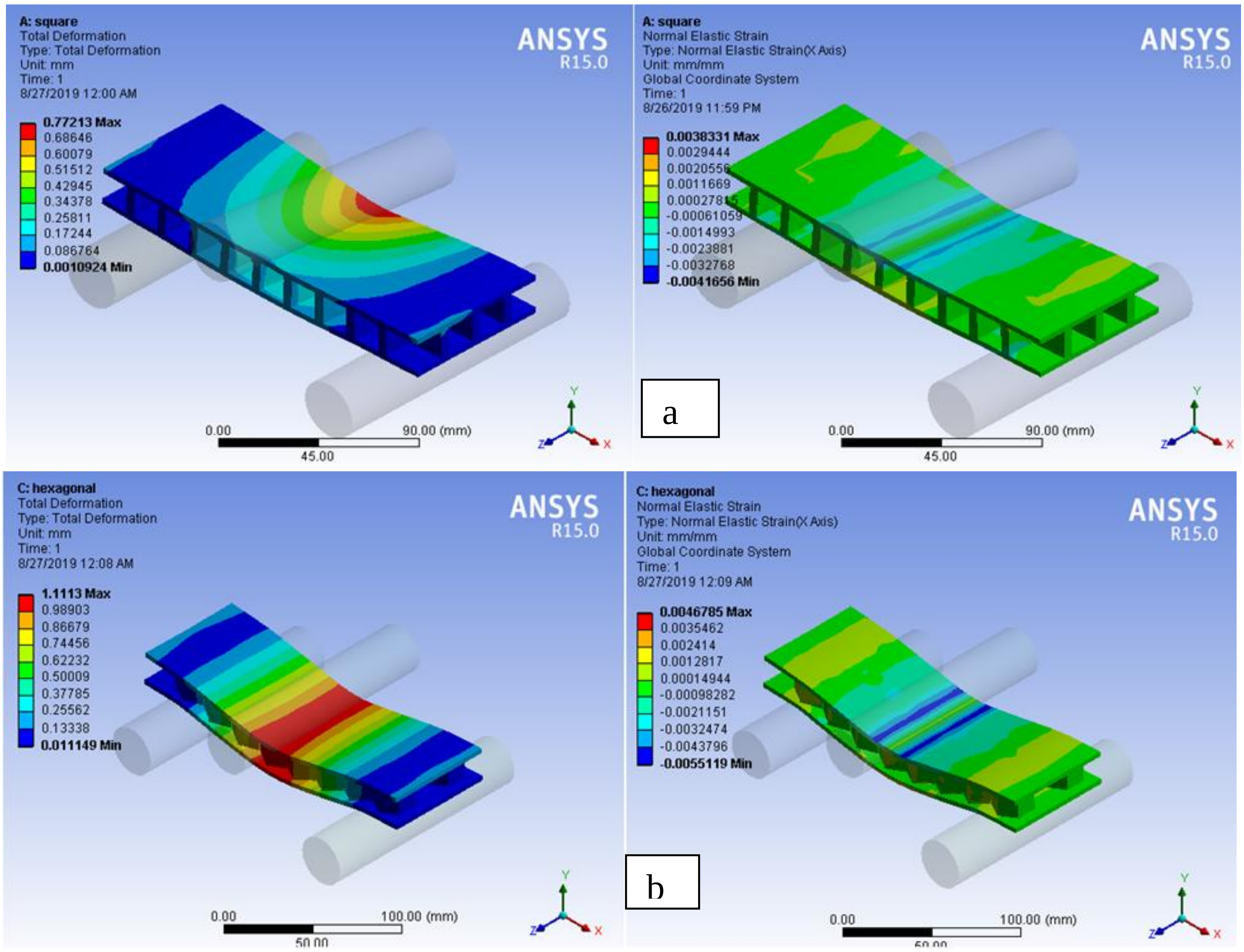
Specimen	Cell shape	Maximum load (KN)	Deformation (mm)
1	Square	7.5	3.1
2	Hexagonal	6.79	3.5
3	Circular	6.04	4.3
4	Triangle	5.4	5.4

2.1 Numericalresult

Ansys workbench (static structural) was utilized to investigate the design of honeycomb sandwiched panel composite to determine the strengthen sandwich panel, it carried out bending load on honeycomb structural composite material having differing shapes of cells(rectangular, hexagonal, triangular and circular), and then observed the honeycomb structural deformity features and comparing the simulation consequences with the investigational test.

The two skins and core are glued together as a whole volume. The bonding between the skins and grid core is assumed perfectly. The symmetric constraints are applied on the structure. The supports of structure designed as solid bodies and sandwich panels faces were assumed to be glued to the rigid supports. The properties (Young's modulus, Shear modulus, Poisson's ratio) of the composite materials are determined theoretically using rule of mixture [18]. While the supports is from structural steel material and its properties from ansysdata .

Figure (12) show the total deformation for different shapes of cells and normal elastic strain under three point bending test by using FEA.



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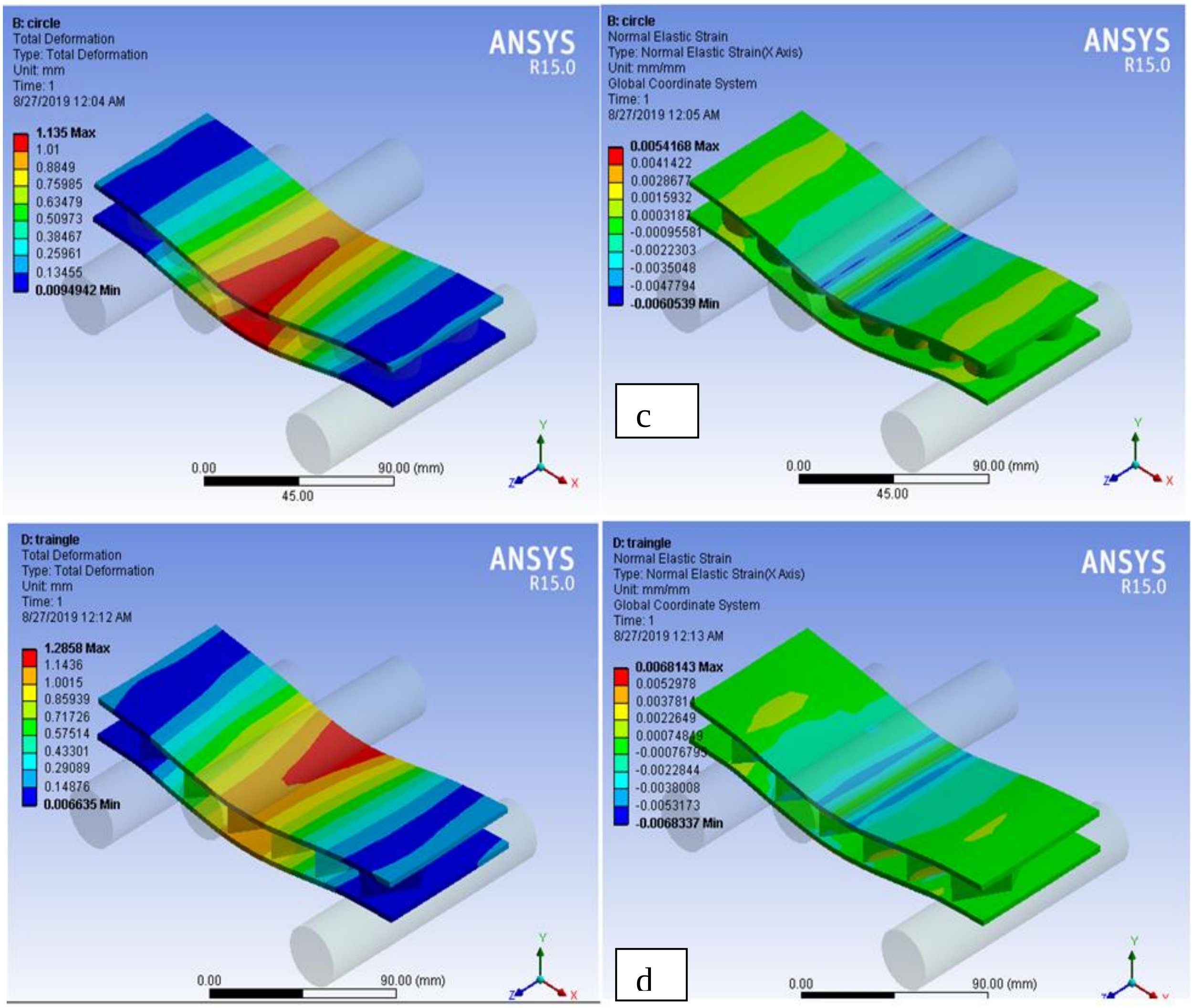

Fig.12. Deformation and normal elastic strain of (a) square (b) hexagonal (c) circular (d) triangle honeycomb core structure

From above figure (12), It is very clear the square shape has small deformation and normal elastic strain compared to other forms for this test (bending load).while the traingle shape has the lowest value.Table (2) shows the maximum deformation and normal elastic strain resulting from the simulated. If want to compare the results of the theoretical and experimental results, will find that there is a good agreement, in both numerical and experimental results, the square shape has less deformation than other cell shape. The disparity ratio between practical and numerical results attributed to device, method of composite fabrication and others.

Table 2
Simulation results

Structural core shape	Max. Deformation (mm)	Normal elastic strain
Square	0.772	0.0038
Hexagonal	1.111	0.0046
Triangular	1.135	0.0054
Circular	1.285	0.0068

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IV CONCLUSION

For this work, it can be concluded that:

1) The variation in the core shape, have a significant affected on the flexural strength of honeycomb sandwich structure.
2) The square honeycomb sandwich structure have the highest maximum load (7.5 KN) ,is much stiffer as compared to other core shapes and the triangle have the lowest value (5.4 KN).
3) The square core structure gaveless deformation value of (3.1 mm) from the other core.
4) Good agreement between numerical and experimentalresults.

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