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Static Analysis of Bending Behavior of Sandwich Beams

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1 Abstract

Different types of sandwich beams through suggesting different core configurations were analyze. Six different core configurations were developed, and each configuration was analyzed under three separate ordinations. The aim through these previous steps to figure out the best possible core configuration from the generated configurations, and to optimize the best configuration. it has been noticed that the side orientation was the best orientation in all configurations., where it can be seen that the best configuration is the circular tube and from the side orientation.

Few recommendations are suggested, such as that the design of the core should incorporate the procedure of manufacturin core since its dimensions are small and lots of precise details. Also, studying other core materials such as polymers and recycled paper that may have good performance and feasibility compared to structure steel and aluminum.

2 Introduction

Sandwich-structured beams are made of a core structure attached in-between two plates (Timbers). The purpose of the core is to provide high bending stiffness with a reduction in the overall volume. This report focuses on the study of different core configuration for sandwich beams, and their ability to increase lateral stiffness. The report includes the project objectives, the methodology of the study, core configurations comparison, improvements in the recommended configuration, and conclusion and recommendation.

Sandwich structures have relative blessings over alternative structural materials in terms of improved stability, weight savings, crash goodness and corrosion resistance. so stratified materials and sandwich structures have various and technologically fascinating applications in several areas of engineering.[1][2][11] A sandwich-structured composite could be a special category of composite materials that's fictional by attaching 2 skinny however stiff skins to a light-weight however thick core. The core material is often low strength material, however its higher thickness provides the sandwich composite with high bending stiffness with overall denseness.[3][4][12] Sandwich theory describes the behaviour of a beam, plate, or shell that consists of 3 layers - 2 face sheets and one core. the foremost normally used sandwich theory is linear associated is an extension of 1st order beam theory. Linear native buckling sandwich theory is of importance for the planning and analysis of Sandwich plates or sandwich panels, that ar of use in building construction, vehicle construction, aeroplane construction and refrigeration engineering.[5][6][13] Sandwich composites give wonderful mechanical properties to a lot of lower weight than ancient monolithic materials, like steel. they will even be built with extreme exactness to their loading necessities. Less weight interprets into higher fuel potency, higher speed, higher payload, longer vary and lower transport and installation prices.[7][8][14]

The stresses and failure maps during a sandwich beam that consists of a transversally versatile compressible core between 2 laminated composite skins, square measure bestowed. The stresses and also

the failure maps square measure determined employing a general, systematic rigorous, and high-order analysis that's supported variational principles, and includes the flexibleness effects of the core on the world and native bending behavior of the beam. The analysis uses closed type solutions for any kind of skin construction, rhombohedral or asymmetrical laminated composite layups, any kind of core, compressible or incompressible, any kind of loading, targeted or distributed, and any kinds of boundary and continuity conditions which will take issue from one skin to the opposite, even within the same section. Failure patterns square measure determined with the help of the analytical description of the longitudinal stresses within the skins and also the principal stresses through the thickness of the core. The stresses within the core and also the skins, in conjunction with AN acceptable failure criteria, for a mere 3 purpose bending beam, square measure incontestible within the kind of principal stresses, failure and failure load maps, that indicate attainable failure patterns and locations.[9]
The sandwich beam are often thought of because the multi-layered structure with a symmetrical cross-sectional. during this paper is assumed that the structure is formed by periodical repetition of a unit. The influence of its size on the beam's static behavior in bending was analyzed. The variation of the unit cells variety affects the dimensions of the cell, that the static analysis was performed – the flexural stiffness and therefore the beam's deflection were determined as functions of the unit cells variety. the 2 configurations of the sandwich beams were considered: the beam with the constant cross-sectional on its length and therefore the beam with the sporadically variable cross-sectional. The graphs of the beam's flexural stiffness and deflection variations in terms of the unit cells variety were obtained. it absolutely was ended that once an explicit variety of the cells, the core's density doesn't any influence the behavior of the sandwich beam, beneath the given loading conditions. The conclusion from comparison of the 2 configurations is that the sandwich beam with the variable cross-sectional behaves somewhat higher than the beam with the constant cross-sectional. The FEM analysis has verified all the conclusions from the analytical answer regarding the sandwich beams behavior once subjected to bending.[10][15]

3 Methodology

All analysis will be conducted using Ansys Workbench program. The process that will be followed for this study starts off with the development of six different core configurations, where they will be studied in three orientations (Front, Side, and Top). Each configuration is to be analyzed under the following conditions:

- 50% of core volume left.
- Material for both plates (Timbers) set to Structural Steel.
- Material of the core configuration set to Aluminum.
- The two plates and core will be into one part for continues mesh.
- Load of 1000 N is applied on top face of the sandwich beam.
- Sandwich beam is fixed from one side, while the other side is simply supported.
- Starting Mesh size of 5 mm.
- Convergence test with 1% allowable error is used for the total deformation.
- Maximum of 5 refinement loops.

The best orientation for each configuration is taken and compared with each other, to find the optimum core configuration. The optimum configuration is selected for the next part of the study, which is a configuration improvement. The improvements will be made of the core material, where it will be changed to from aluminum to structural steel. Each material is analyzed under the same previous condition with the addition of standard earth gravity. After selecting the material with the least deflection, the geometry of the core is altered to future reduce the deflection. This alteration in core geometry is then taken as a base for the final step in improving the core configuration. The last step is to change the core volume under the restrictions of cross section and geometry.

The project requires the study of different core configurations for the sandwich beam which can improve the beam's static performance. Also, to studying the effect of changing the core from aluminum to steel.

3.1 Core Alternatives

Six different configurations were analyzed to see which one of the six is the best possible configuration. Each configuration is first studied under three different orientations, where the best orientation is selected for the final comparison between the six configurations.

3.2 Configurations

3.2.1 Configuration One: Circular Tubes

This configuration consists of multiple rows and columns of circular tubes that are uniformly distributed among the volume. The number of the circular tubes are different from one orientation to another. The best orientation is when the circular tubes are parallel to the longest edge of the beam (Side orientation), this is shown in Table 1. Also, Figure 1 illustrates the analysis of the side oriented circular tubes, and Figure 2 is a render of the side oriented circular tubes.

Table 1. Circular tubes configuration results

Orientation	***Deflection (× 10^2mm)***
Front	3.1360
Side	2.4664
Top	2.5442

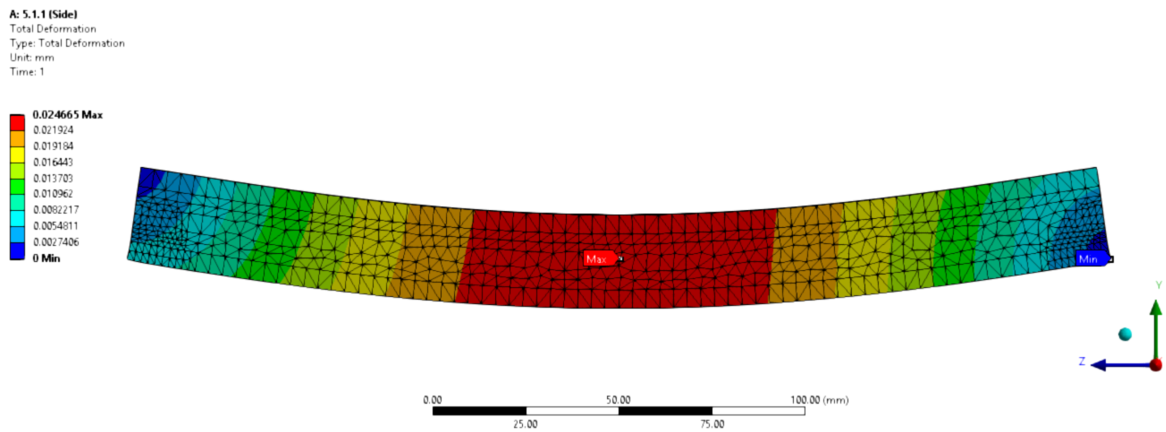


Figure 1. Circular tubes side orientation deflection

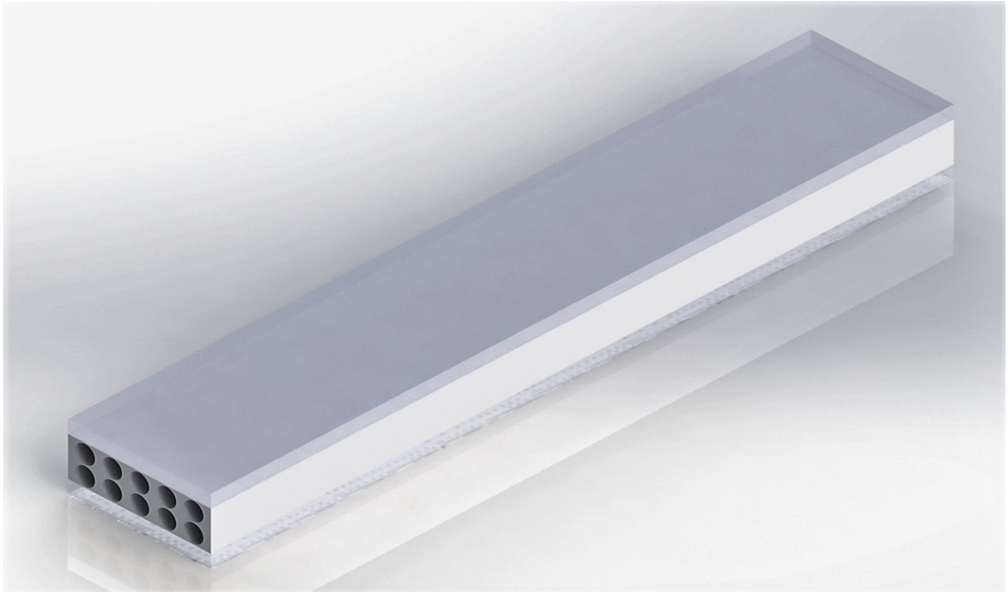


Figure 2. Render of Circular tubes side orientation

3.2.2 Configuration Two: Square Tubes

This configuration consists of multiple rows and columns of square tubes that are uniformly distributed among the volume; it is conducted in three different orientations, while the number of the square tubes are different from one orientation to another. The best orientation is when the square tubes are parallel to the longest edge of the beam (Side orientation), this is shown in Table 2. Also, Figure 3 illustrates the analysis of the side oriented square tubes, and Figure 4 is a render of the side oriented square tubes.

Table 2. Square tubes configuration results

Orientation	***Deflection (*** $\times \mathbf{10^2} \boldsymbol{mm}$ ***)***
Front	3.1344
Side	2.5225
Top	2.5928

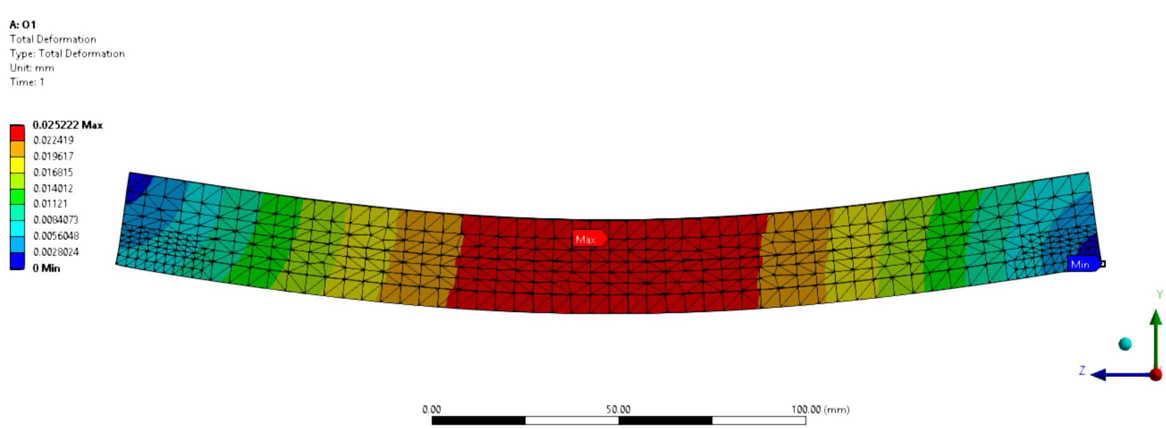


Figure 3. Square tubes side orientation deflection

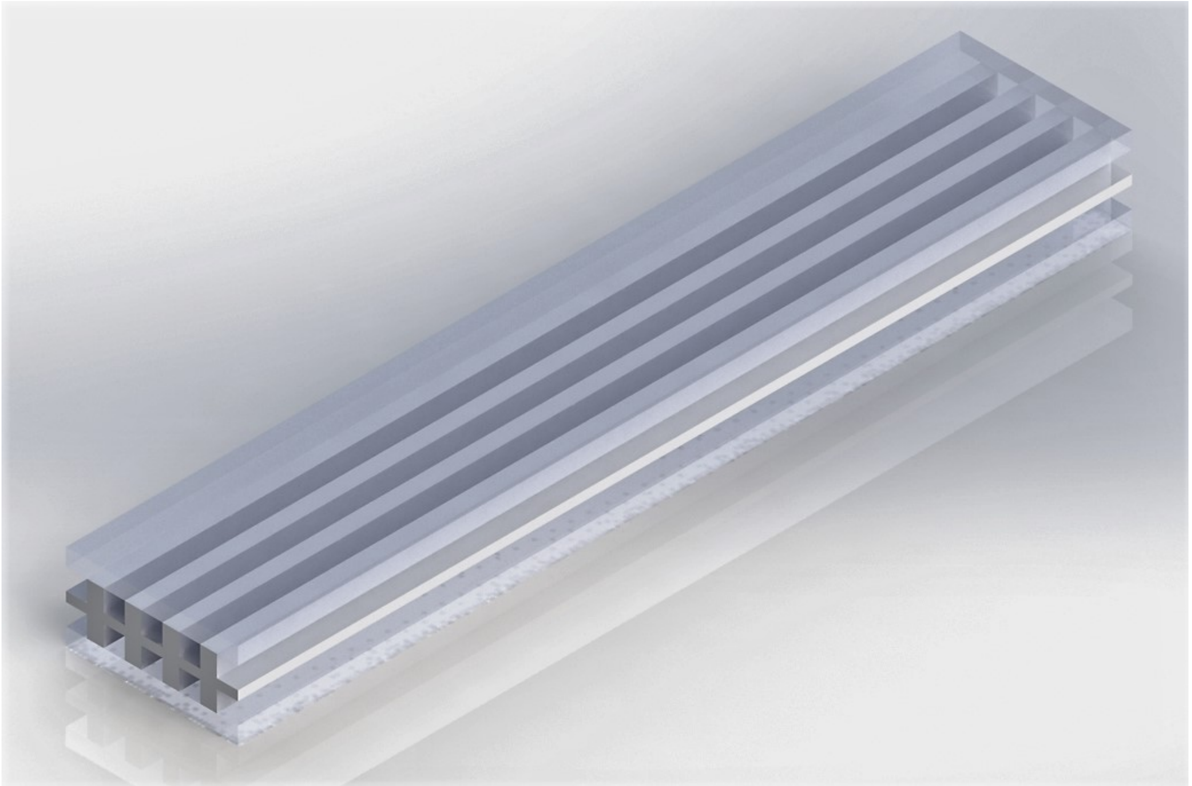


Figure 4. Render of Square tubes side orientation

3.2.3 Configuration Three: Hexagon Tubes

This configuration consists of hexagon tubes, filled in between the two plates. The tubes are distributed along the length of the plate with a small space separating every two tubes. The results of the three different orientations are summarized in Table 3 below. Figure 5 shows the mesh and the resulted deflection of the best orientation out of the three. Moreover, Figure 6 shows a rendering of the beam.

Table 3. Hexagon tubes configuration results

Orientation	***Deflection*** ($\times 10^2 mm$)
Front	3.6194
Side	2.5363
Top	2.6515

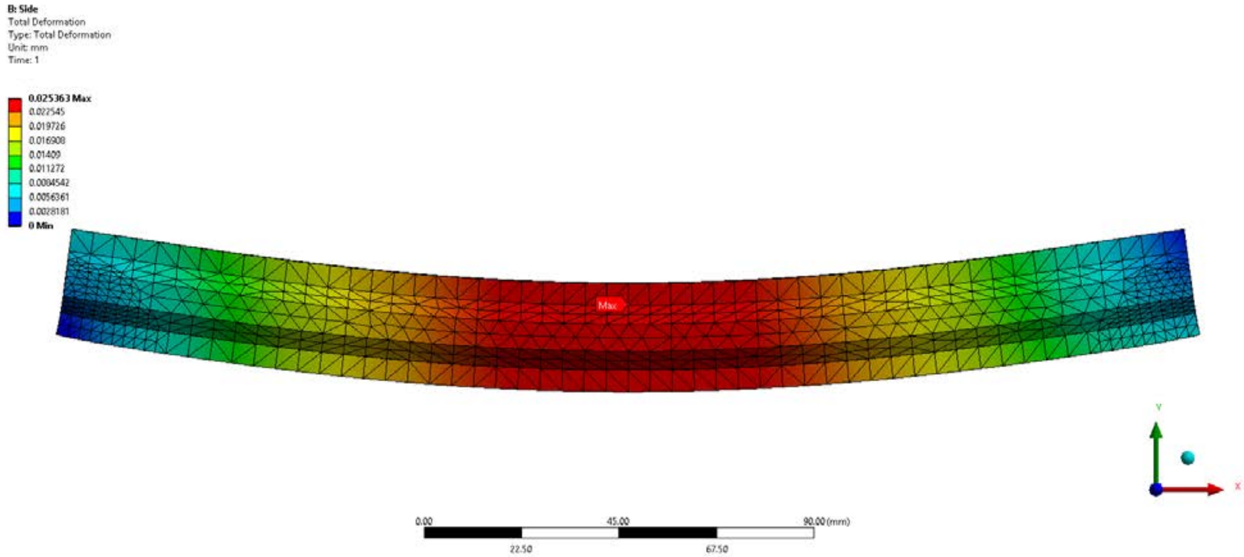


Figure 5. Hexagon side orientation deflection

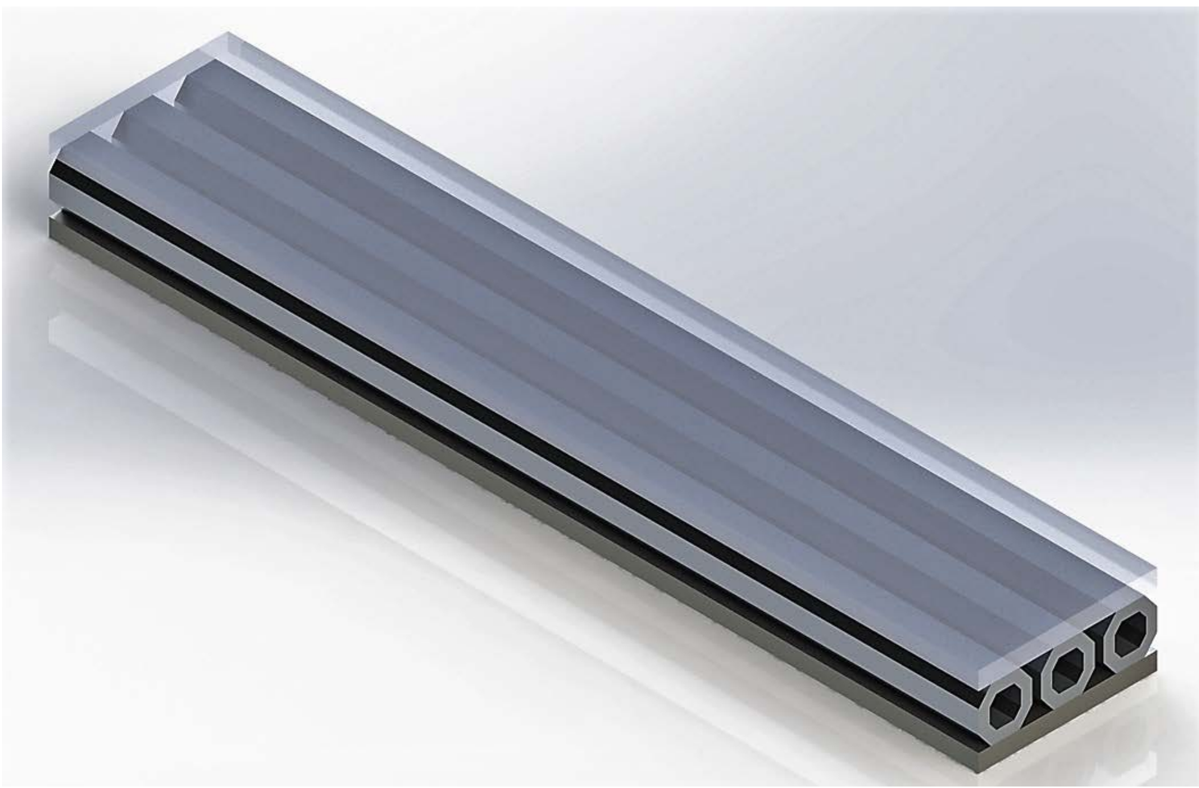


Figure 6. Render of hexagon tubes side orientation

3.2.4 Configuration Four: MW Structure

This configuration consists of inserts on the shape of M and W, filled in between the two plates. The inserts are distributed along the length of the plate with a small space separating every two. The results of the three different orientations are summarized in Table 4 below. Figure 7 shows the mesh and the resulted deflection of the best orientation out of the three. Moreover, Figure 8 shows a rendering of the beam.

Table 4. MW configuration results

Orientation	***Deflection ($\times 10^2 mm$)***
Front	2.8692
Side	2.5181
Top	2.7890

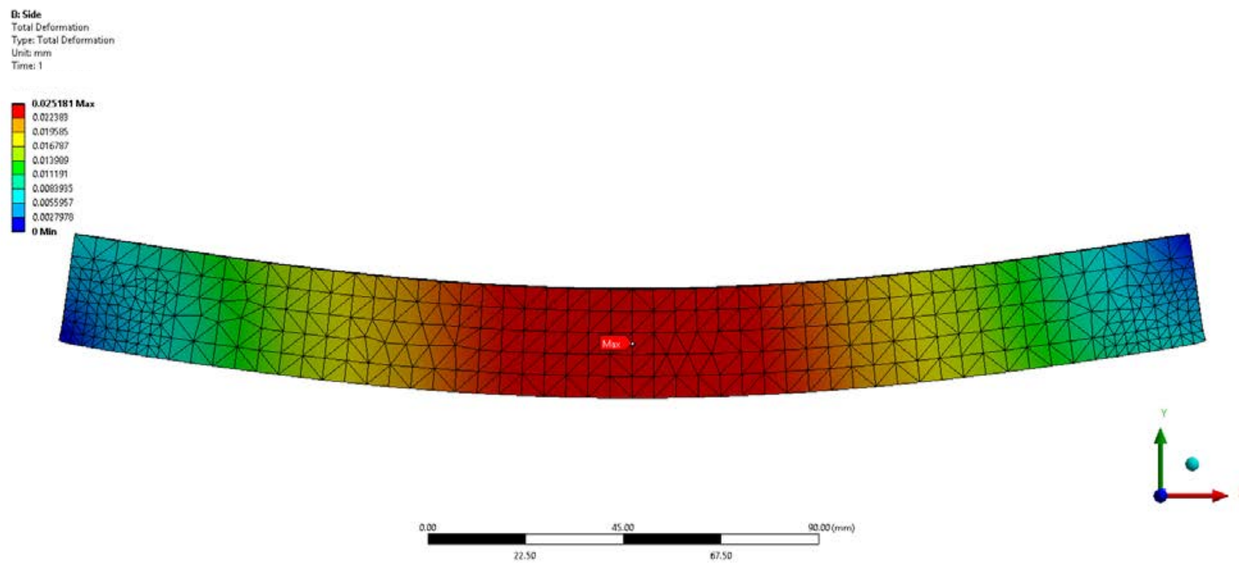


Figure 7. MW side orientation deflection

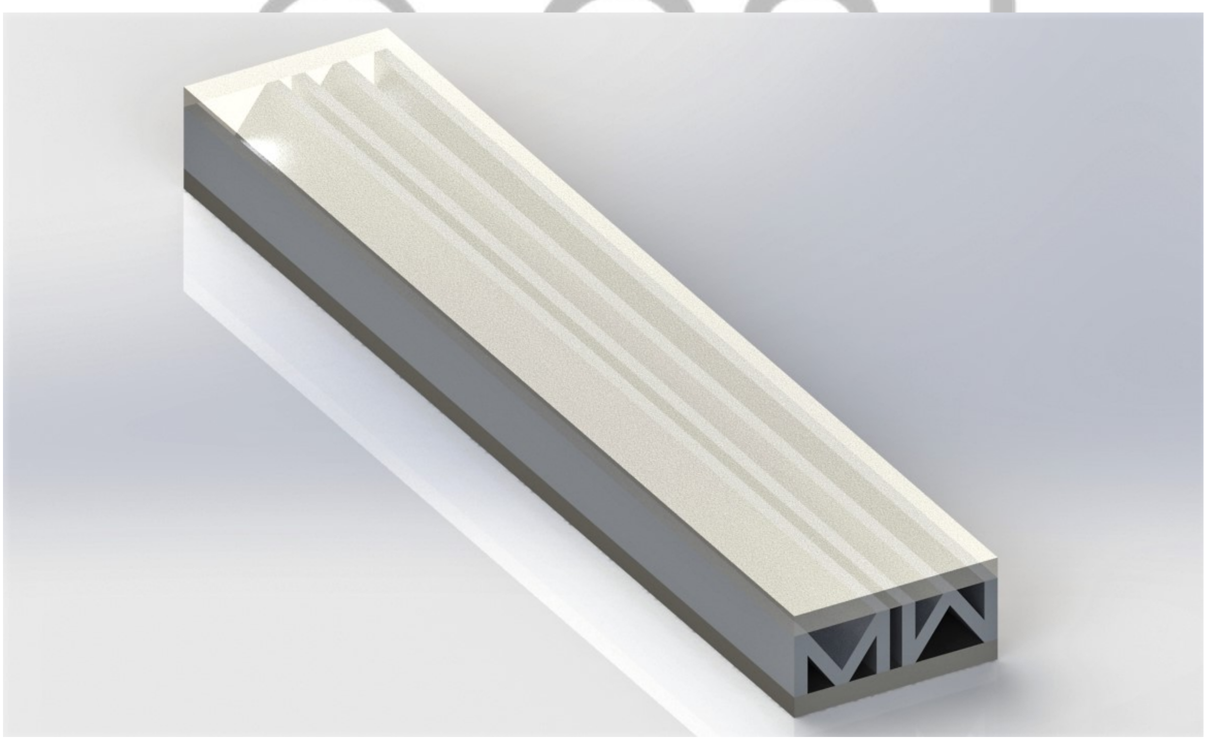


Figure 8. Render of MW side orientation

3.2.5 Configuration Five: Honeycomb Structure

Honeycomb shape was named after the nest structure that bees develop to store honey. The basic geometry of this structure is a hexagonal shape. The hexagonal geometry is a six-sided shape, when combined with its own, creates a structure with no gap in-between. The combined hexagonal structure allows for maximum strength while minimizing the use of material. The results of the analysis shown in Table 5, illustrates that the best orientation for the honeycomb structure is when constructed from the side of the sandwich beam. Although minor differences, however with increasing loads, the slit difference will make a severe impact on the beams lateral stiffness. Figure 9 shows the resulting analysis under magnification of the actual deflection, while Figure 10 shows a 3D render for the best honeycomb oriented sandwich beam.

Table 5. Honeycomb configuration results

Orientation	*Deflection* ($\times 10^2 mm$)
Front	2.7454
Side	2.5391
Top	2.5597

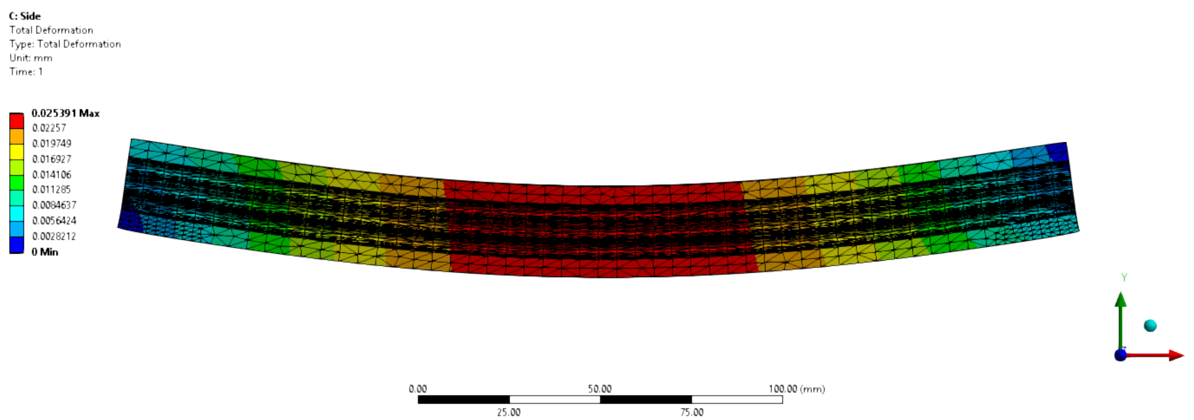


Figure 9. Honeycomb side orientation deflection

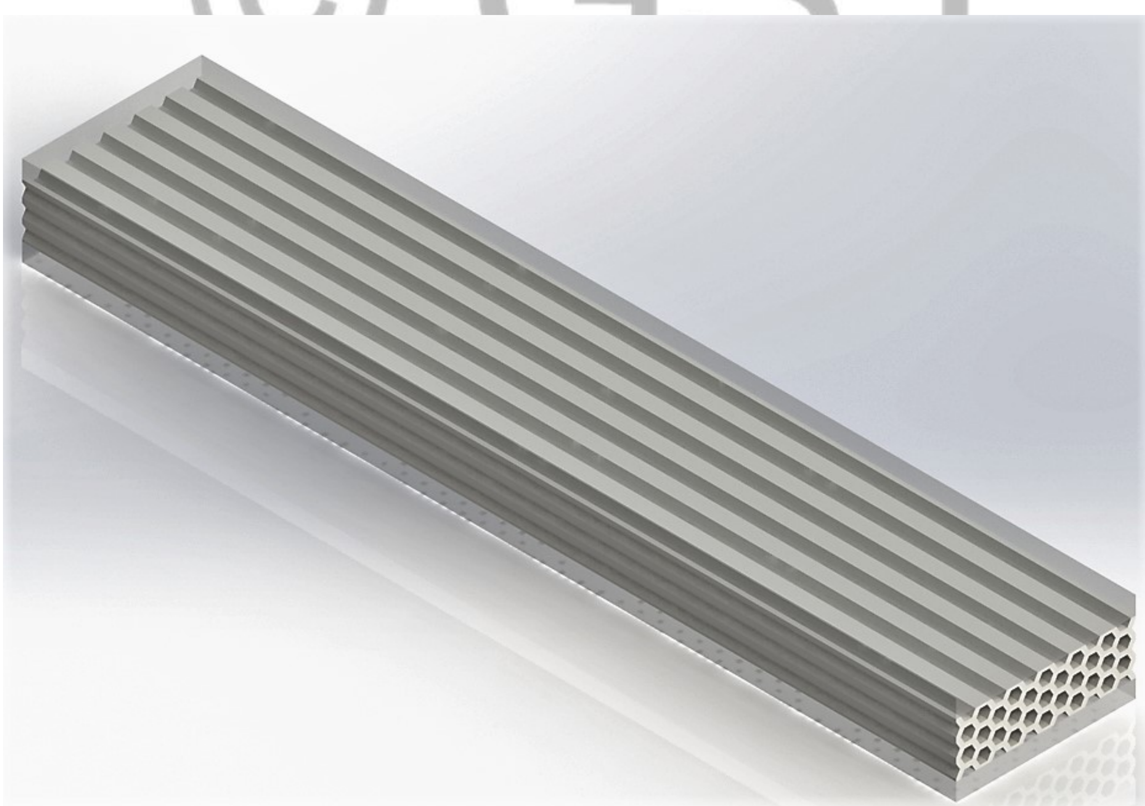


Figure 10. Render of honeycomb side orientation

3.2.6 Configuration Six: Rhombus Structure

The rhombus shape is often described as a diamond. The shape is from the four side shape family. A rhombus is a quadrilateral with all sides being equal. This configuration was developed from combining zig zag patterns, thus creating a rhombus cavity in-between. The results of the analysis shown in Table 6, illustrates that the best orientation for the rhombus structure is when constructed from the side of the sandwich beam. All the configurations were close to each other, similar conclusion to the honeycomb structure. Figure 11 shows the resulting analysis under magnification of the actual deflection, while Figure 12 shows a 3D render for the best rhombus oriented sandwich beam.

Table 6. Rhombus configuration results

Orientation	***Deflection*** ($\times 10^2 mm$)
Front	2.6080
Side	2.5459
Top	2.5724

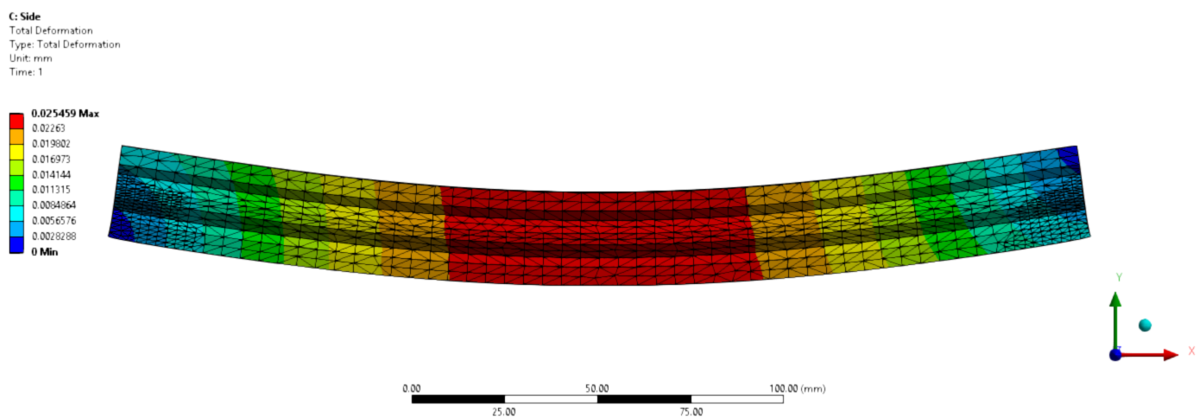


Figure 11. Rhombus side orientation deflection

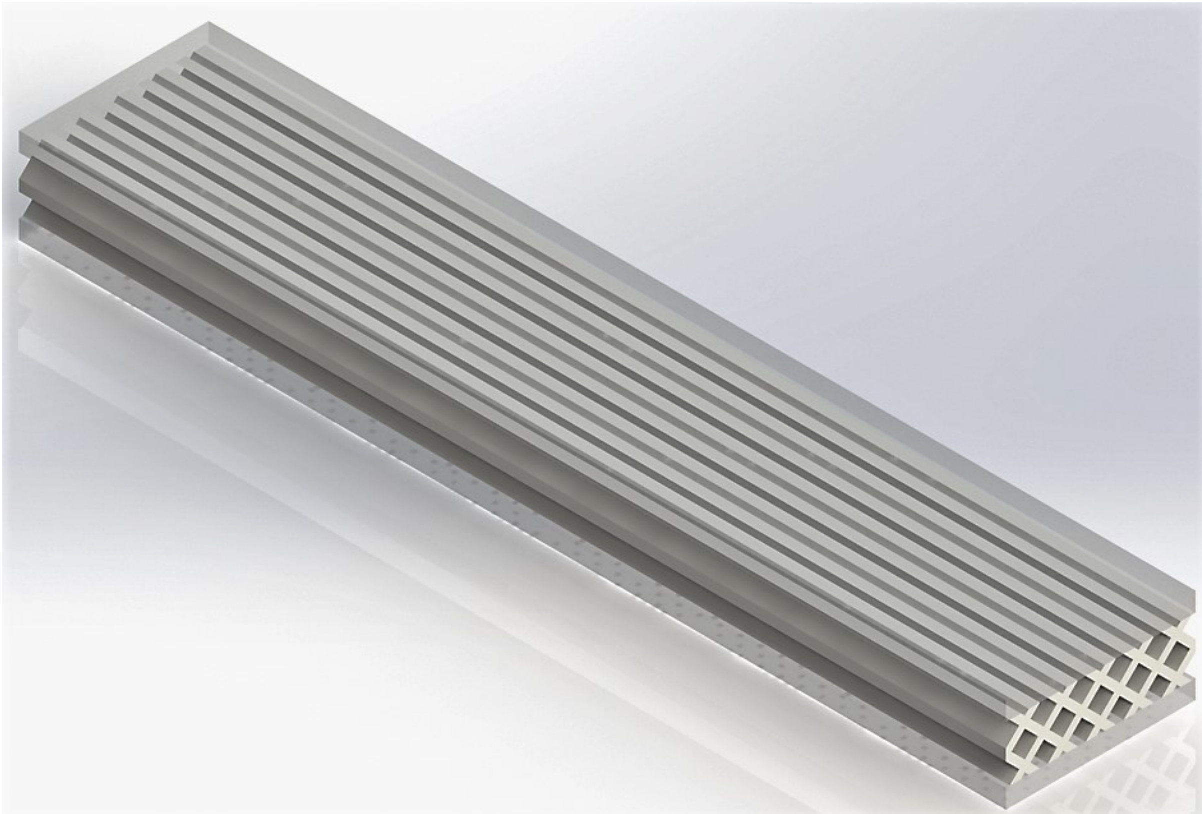
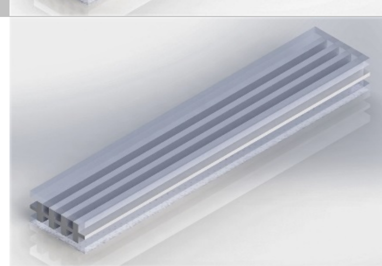


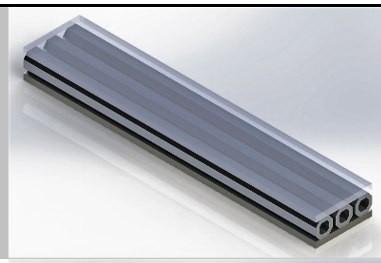
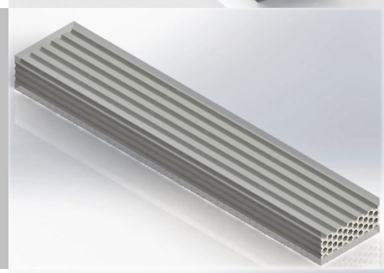
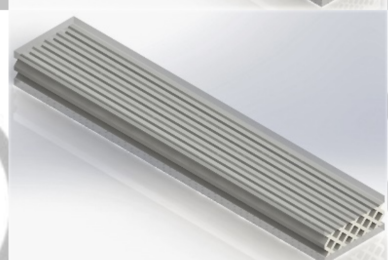
Figure 12. Render of rhombus side orientation

3.3 Recommended Configuration

After developing the six configurations listed above, it has been noticed that the side orientation was the best orientation in all configurations. A comparison must be made between the side orientation of each configuration to show the best one. Table 7 below shows the comparison made, where it can be seen that the best configuration is the circular tube and from the side orientation. Next step now would be to improve on the winning geometry to try and optimize it.

Table 7. Configuration Comparison

Configuration	***Configuration Rendering***	***Deflection ($\times 10^2 mm$)***
Circular tubes		***2.4664***
Square tubes		2.5225

Hexagon tubes		2.5363
MW		2.5181
Honeycomb		2.5391
Rhombus		2.5459

4 Core Improvements

The circular tube core configuration is future improved by first changing its material, then setting the winning best material as the new material for the core. Next, the geometry will be altered within the limits of the cross section. Thus, the optimum geometry is selected, where the step that follows is changing the core volume from 50% to 75% and study the sandwich beam's change in deflection.

4.1 Material Test

A material test is then conducted on the core to try and improve the performance of the beam. Two different materials were taken into consideration, aluminum alloy, and structural steel. The beam with structural steel core exhibited better performance than the one with aluminum alloy core. Then a standard gravity was added to the analysis to account for the difference in density between the material, hence, change in weight. Even with the addition of the standard gravity, the structural steel core performed better than the aluminum core. After that, a decision was made to continue improving on the geometry with the structural steel core in use. Table 8 below shows the results of the test.

Table 8. Material test results

Material	***Deflection ($\times 10^2 mm$)***
Aluminum Alloy	2.4664
Structural Steel	2.1106
Aluminum Alloy with Standard Gravity	2.4977
Structural Steel with Standard Gravity	2.1477

4.2 Geometry Improvements

To improve the geometry, first the volume filled was fixed at 50%, and the number of circular tubes changed from ten to four to three. By analyzing the enhanced geometries using the same boundary conditions and force value, it has been found that at 50% volume filled, three tubes would have the best performance. Table 9 below shows the results of improving the geometry.

Table 9. Results of improving the geometry

Number of Tubes	***Deflection ($\times 10^2 mm$)***
Ten	2.1477
Four	2.1043
Three	2.0886

4.3 Volume Improvements

After optimizing the number of tubes, it was time to change the volume fill percentage. By gradually changing the core volume from 30% to 95% and studying the deflection of the beam, the following Figure 13 shows the relation between the volume fill percentage and the deflection of the beam. Moreover, it can be seen that the relation is semi-linear. It can help in deciding what volume fill percentage to use depending on the application and the loads applied to the beam.

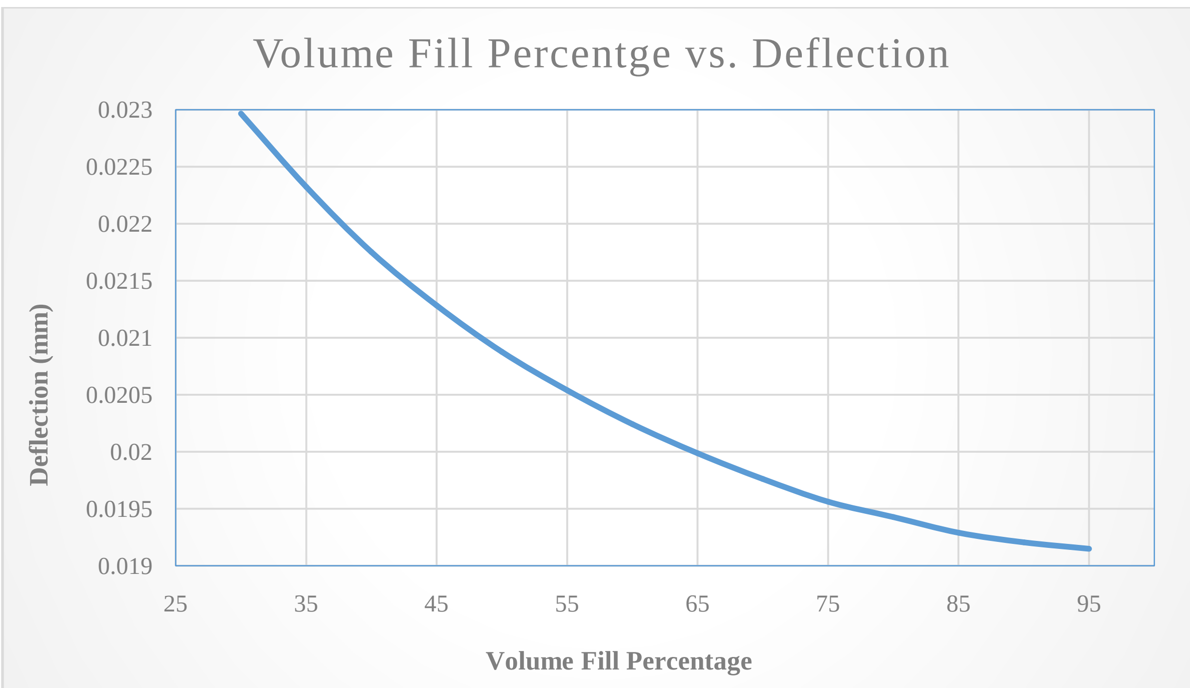


Figure 13. Graph showing the volume fill percentage vs. deflection

5 Conclusion and Recommendations

With the completion of this study, the objective was completed, which was to analyze different types of sandwich beams through suggesting different core configurations. Six different core configurations were developed, and each configuration was analyzed under three separate ordinations. These were reduced to the best orientation for each configuration, where the best orientation for all of the configuration was from the side. The circular tube core configuration was selected since it showed the least deflection in the comparison. The circular tube configuration was improved through changing core material from aluminum to structural steel. This change in material showed a significant difference in the beam's deflection. Thus, structural steel was set as the new core material for the next step which was investigating different core geometries while maintaining the volume at 50% of the total core volume. The results showed that changing the number of tubes for ten to three, increased the core's inertia, thereby, reducing the deflection. After that, the core volume changed from 30% to 95% of the total core volume to study the effect of increasing core volume on the beam deflection. It was found that this increasing of the volume had not much effect on reducing the beam deflection, the only small difference in deflection between using 50% and 75% of the total core volume, and this may be related to our suggested load applied to the beam. If the value of transverse load increas eroc eht neht volume will be selected depending on the maximum deflection that should not be exceeded. The aim through these previous steps to figure out the best possible core configuration from the generated configurations, and to optimize the best configuration. All configurations and their orientations were drawn using SolidWork and studied using ANSYS Workbench. Boundary conditions and the transverse load were unified in all configuration studies to ensure a fair comparison. Few recommendations are suggested, such as that the design of the core should incorporate the nirutcafunam fo erudecorpcore since its dimensions are small and lots of precise details. Also, studying other core materials such as polymers and recycled paper that may have good performance and feasibility compared to structure steel and aluminum.

6 References

[1] A. Lyckegaard, E. Bozhevolnaya "Sandwich Structures 7: Advancing with Sandwich Structures and Materials", 2005.
[2] F.J. Plantema, Sandwich construction, John Wiley&Sons: New York, London, Sydney, 1966.
[3] H.G. Allen, Analysis and design of structural sandwich panels, Pergamon Press: Oxford, London, Edinburgh, New York, Toronto, Sydney, Paris, Braunschweig, 1969.
[4] J.R. Vinson, Sandwich structures, Applied Mechanics Reviews, ASME, 54, 3, 201–214, 2001.
[5] J. Banhart, Manufacture, characterisation and application of cellular metals and metal foams, Progress in Material Science, 46, 559–632, 2001.
[6] A.K. Noor, W.S. Burton, C. W. Bert, Computational models for sandwich panels and shells, Applied Mechanics Reviews, ASME, 49, 3, 155–199, 1996.
[7] C.M. Wang, J.N. Reddy, K.H. Lee, Shear deformable beams and plates, Elsevier: Amsterdam, Laussane, New York, Oxford, Shannon, Singapore, Tokyo, 2000.
[8] P. Iaccarino, C. Leone, M. Durante, G. Caprino, A. Lamboglia, Effect of a thin soft core on the bending behavior of a sandwich with thick CFRP facings, Journal of Sandwich Structures and Materials, 13, 2, 159–175, 2010.
[9] A. J. M. Ferreira, Stresses and failure patterns in the bending of sandwich beams with transversely flexible cores and laminated composite skins, 1996.
[10] Ružica R. Nikolić, Jelena M. Djoković, Jan Bujnak and Katarina Živković1, Behavior of the sandwich beam subjected to bending as a function of the core density, 2016.
[11] Y Frostig, M Baruch. Bending of sandwich beams with transversely flexible core. Aiaa Journal, 1990 , 28 (3) : 523-531.
[12] Y Frostig, M Baruch, O Vilnay, I Sheinman. Bending of non-symmetric sandwich beams with transversely flexible core-bending behavior. Journal of Engineering Mechanics, 1990, 117 (28) : 1931-1952.
[13] Frostig, Y. Behaviour of delaminated sandwich beams with transversely flexible core high order theory. Composite Structures, 1992, 20(1): 1-16.
[14] Frostig, Y. and Shenhar, I. High-order bending of sandwich beams with transversely flexible core and unsymmetrical laminated composite skins [J]. Composite Engineering, 1995, 5(4): 405–414.
[15] PD Soden. Indentation of composite sandwich beams. Journal of Strain Analysis for Engineering Design, 1996, 31(5): 353-360.