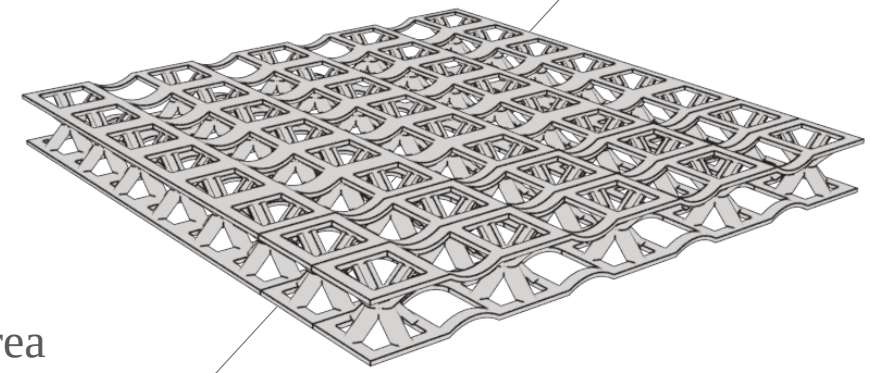
Comparison of injection molded core layer and additive manufactured core layer for polymer sandwich panel



Polyolefin 2017
February 26 – March 1, 2017

Min-Young Lyu[1], J. H. Park[1], S. Kim[1], J. S. Hwang[2], D.-Y. Yang[2]
[1] Seoul National University of Science & Technology, Seoul, S. Korea
[2] KAIST, Deajeon, S. Korea

Content

1 Introduction

2 Kagome Structure

3 Injection Molded Product Vs. Additive Manufactured Product

4 Concluding Remarks

Needs of Light Weight

Demand for eco-friendly/High efficient product

Appearance of new application area

Adaptation to new demand

Increase in demand for non-metallic material

→ **Light Weight Product**

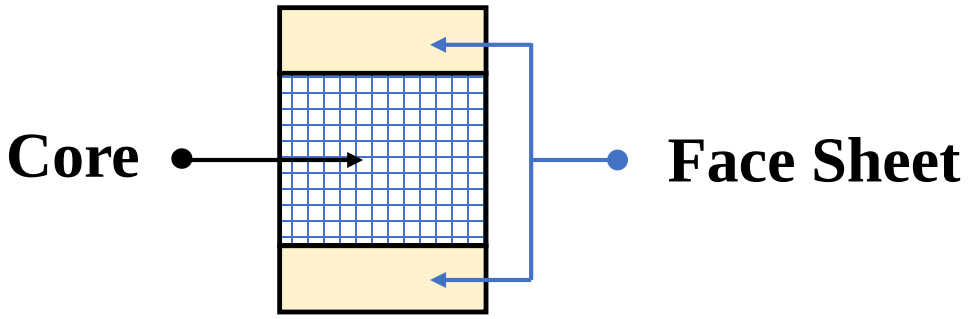
→ **High Value-added, Multi-functional Product**

→ **Develop Structural Material and Application**

→ **Light Weight Sandwich Panel**

Light Weight Sandwich Panel

Sandwich Panel



Space between neutral plane of bending and outer surface gives rigidity

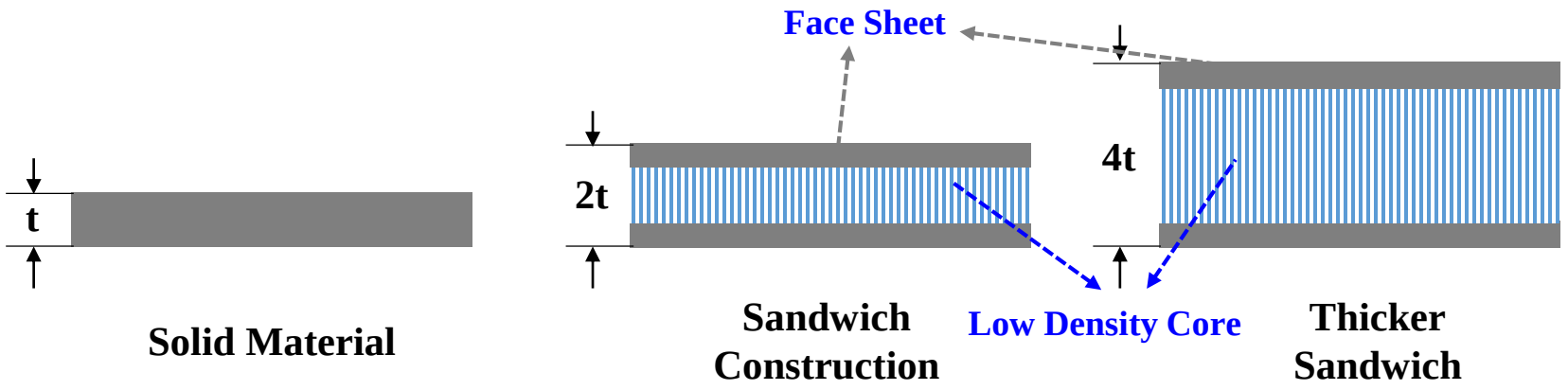
Mechanically high light weight ratio material

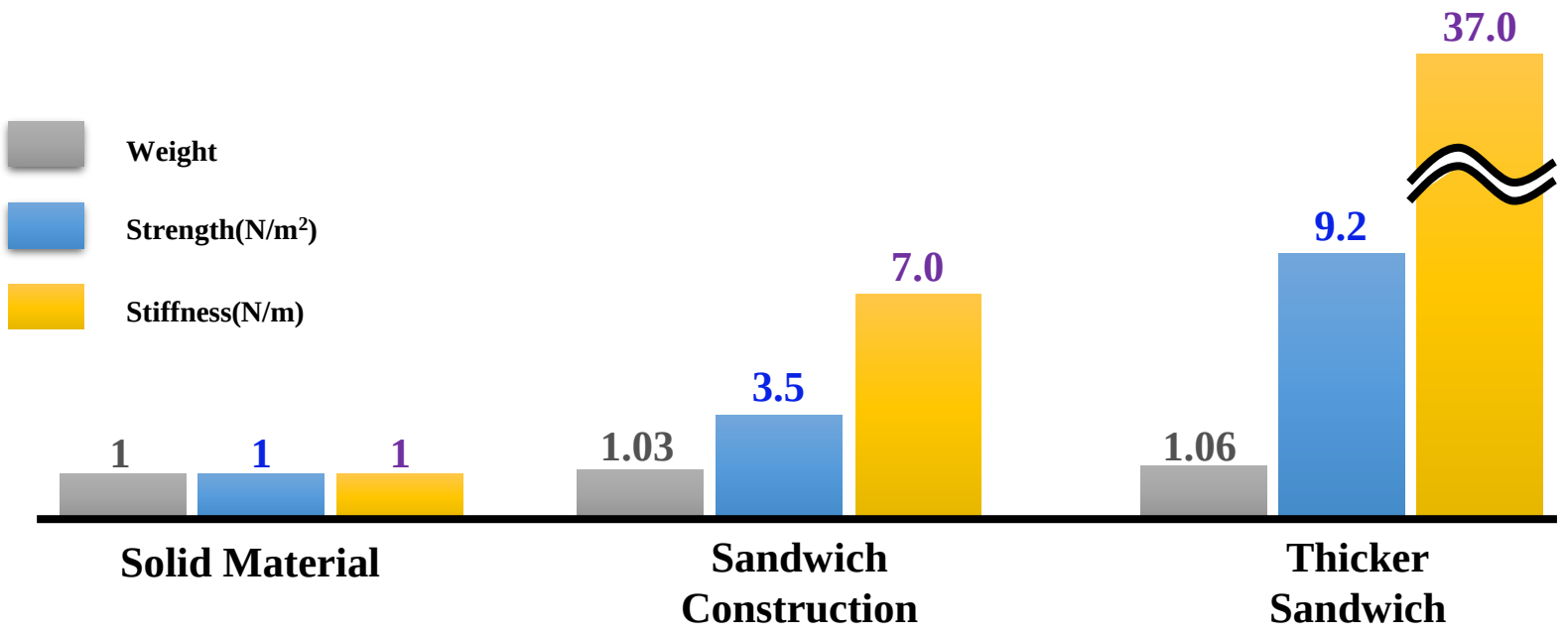
Diverse materials for face sheet and core layer

Variety of application according to material

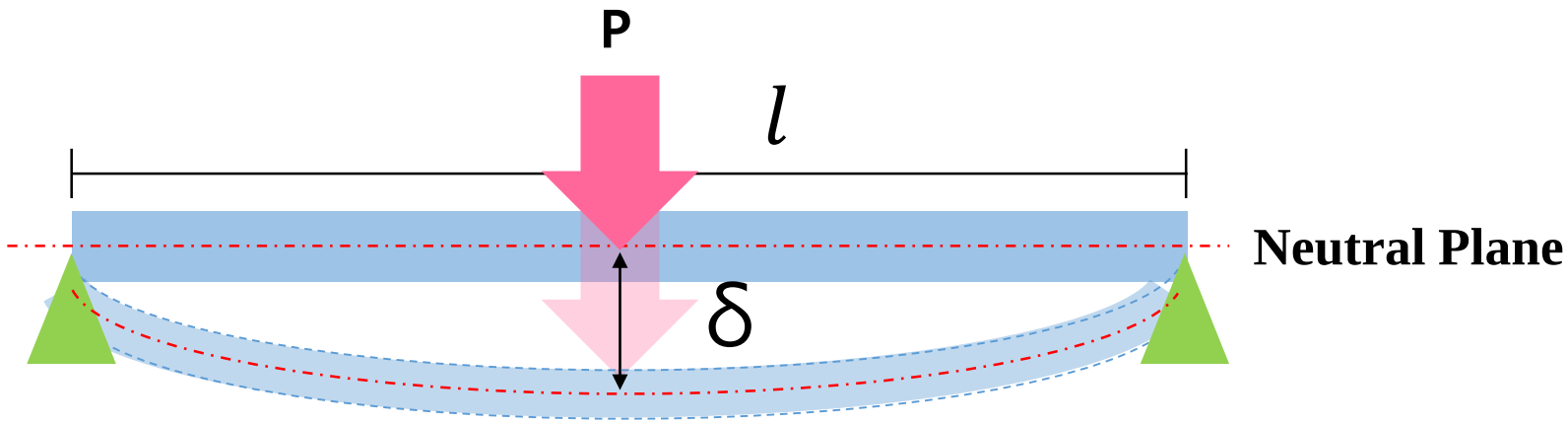
Various functions using filler in the core space

Efficiency of Sandwich Panel





Moment of Inertia



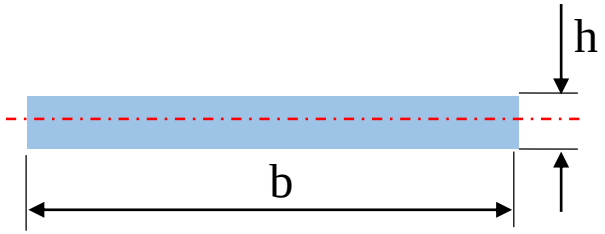
$$I = \int_A r^2 dA$$

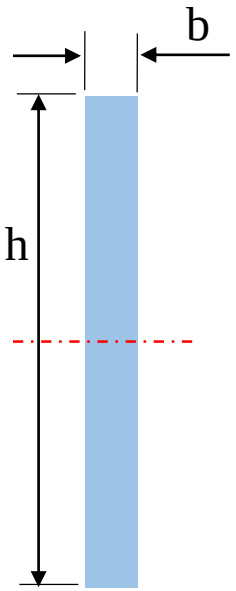
$$\delta_{max} = \frac{Pl^3}{48EI}$$

E: Elastic Modulus
I: Moment of Inertia

Moment of Inertia for Rectangular Bar

$$I = \frac{bh^3}{12}$$

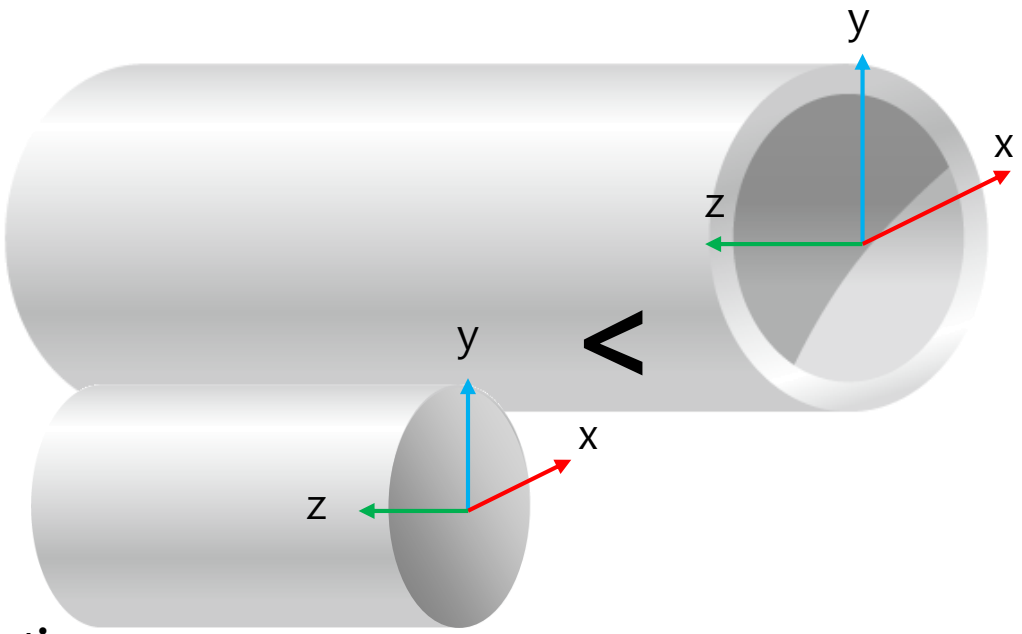




Examples of High Moment of Inertia

I Shaped Beam of Rail

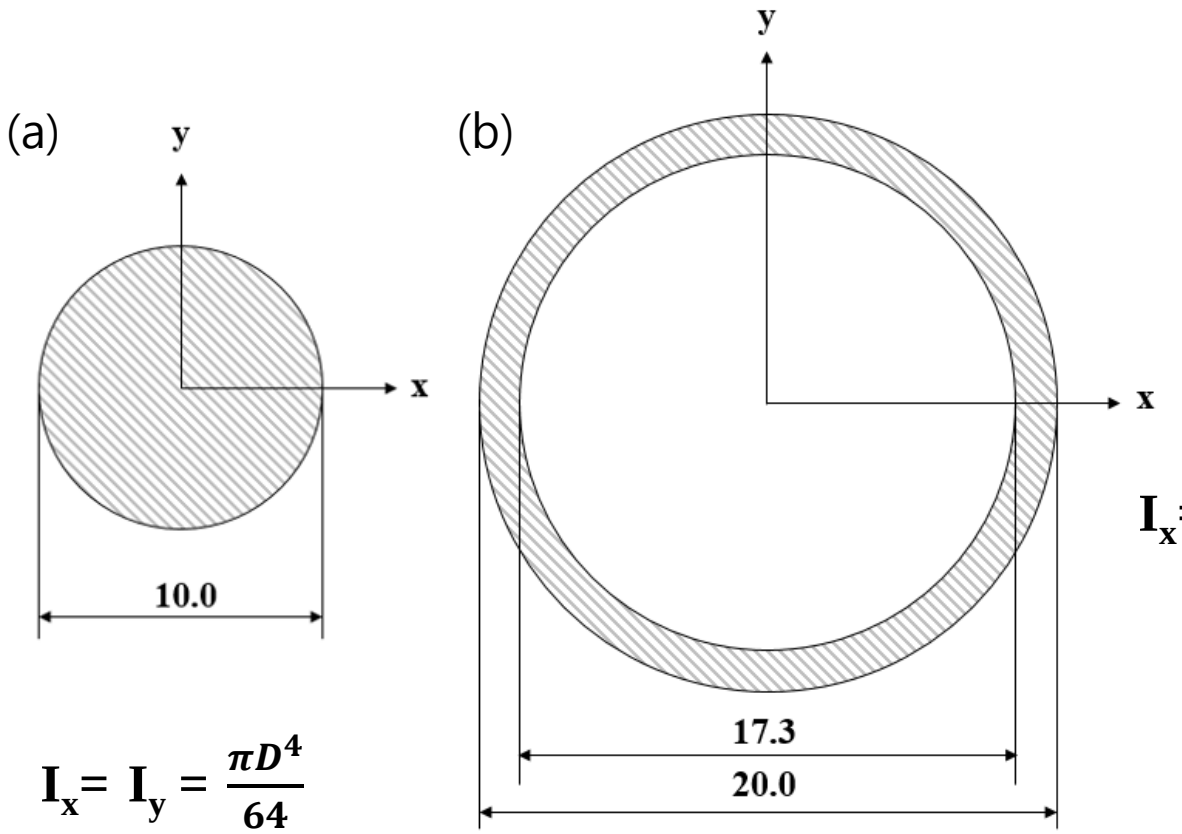
Resistance to deflection



Cross-section of Horizontal Bar

Annular Cross-section gives higher moment of inertia

Moment of Inertia for Circular Shape



$$I_x = I_y = \frac{\pi D^4}{64}$$

$$= 490.87$$

$$x = \frac{D_1}{D_2}$$

$$I_x = I_y = \frac{\pi D_2^{\,4}}{64}(1 - x^2)$$

$$= 1963.5$$

Four times higher

For same area,

material located in far-off from neutral plane

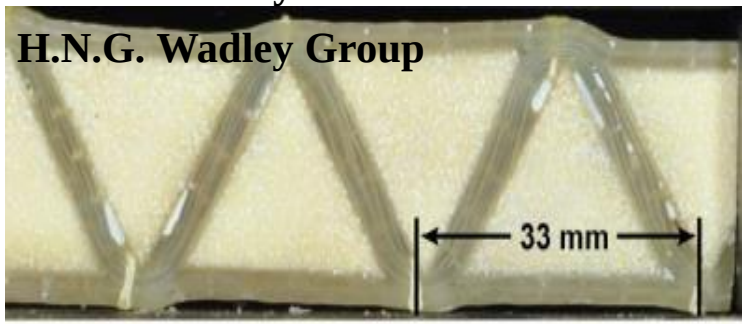
→ Increases Moment of Inertia

→ Increases rigidity

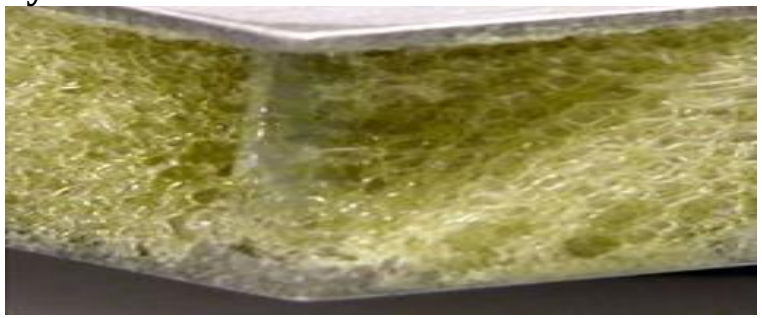
Examples of Sandwich Structure

Styrofoam Structure

GFRP & Divinycell Foam

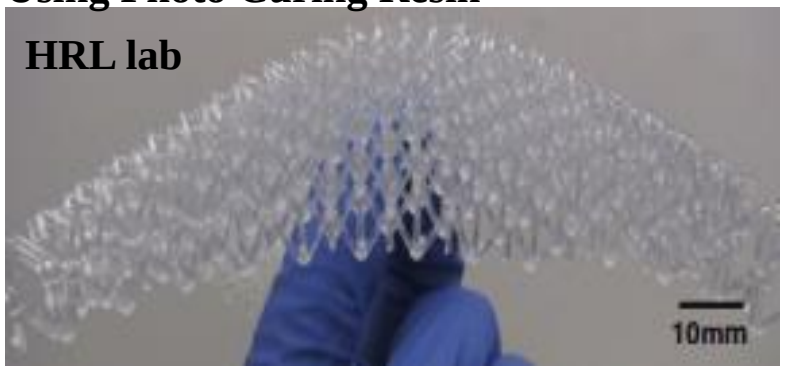


Pyramidal Structure and Foam Structure



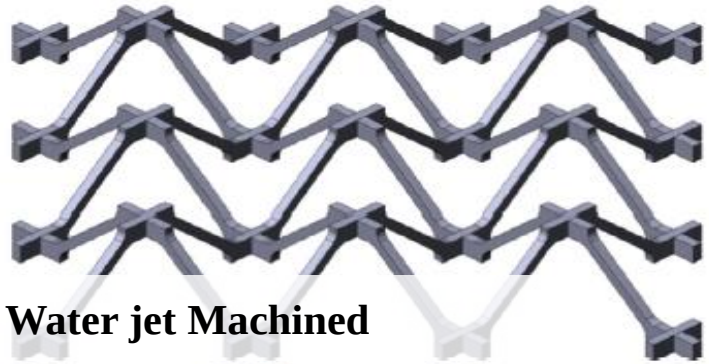
Honeycomb(polypropylene) & GFRP

Using Photo Curing Resin



Need a research on the polymer truss structure and manufacturing

Machined CFRP Truss (L. Wu Group)



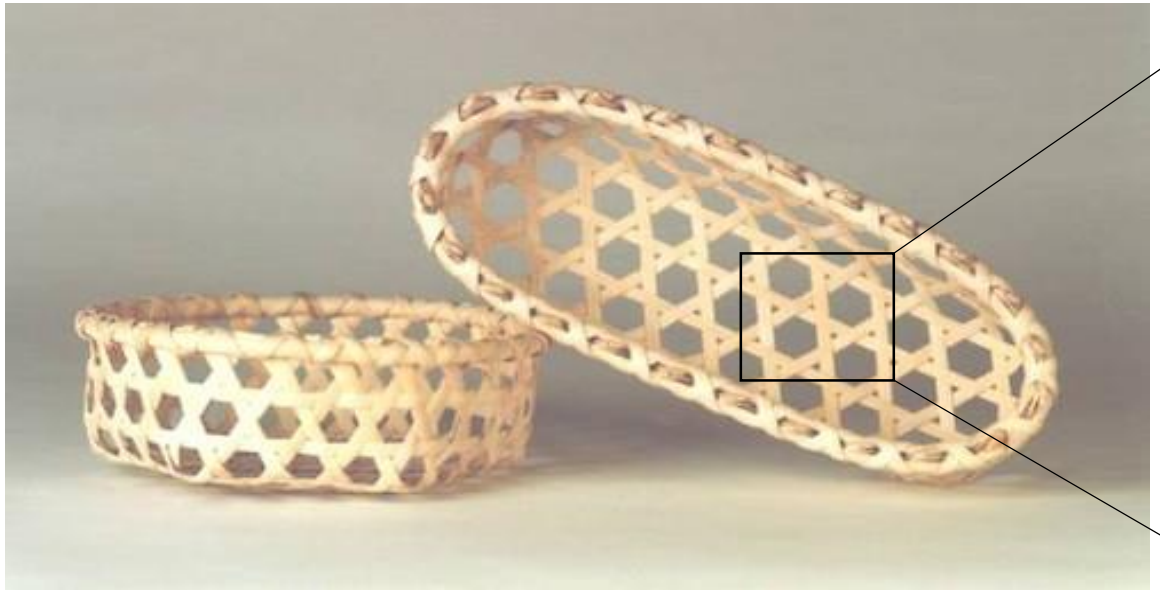
Water jet Machined

Develop sandwich panel using Kagome structure

SEOULTECH

Kagome Lattice

Kagome Lattice : Array of Woven Basket

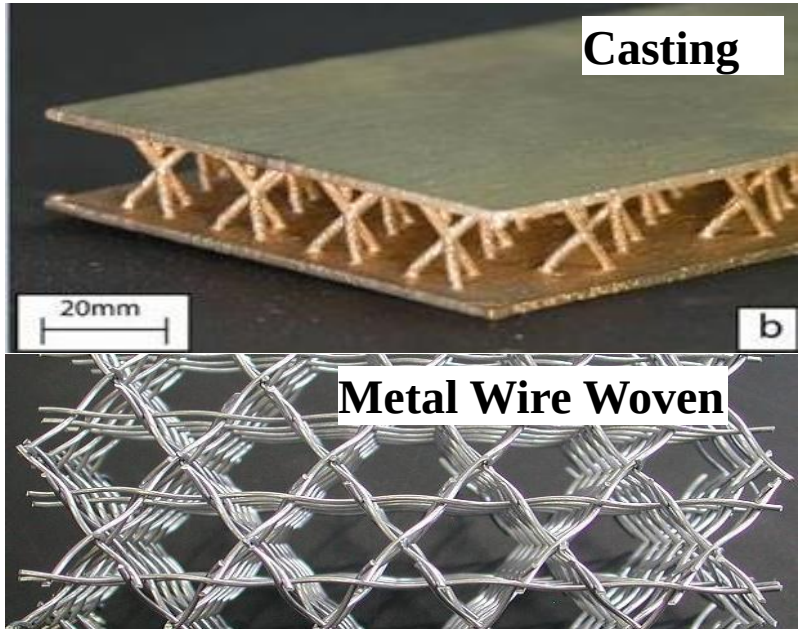


High Specific Strength Using Core Design in Sandwich Panel

Kagome Structure

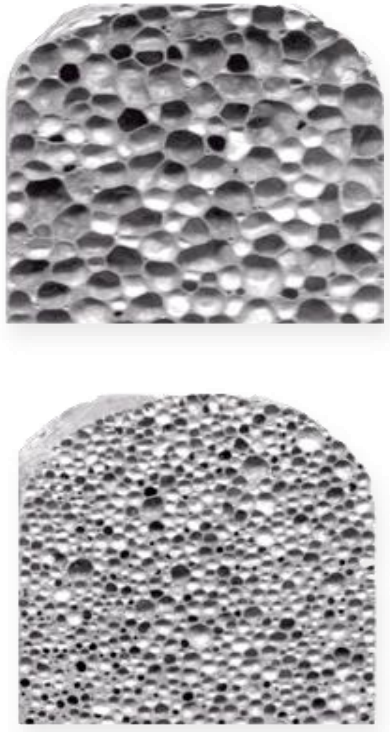
7-10 times higher specific compression stiffness compare to porous material

Wadley et al, Porous Materials 63 (2003)

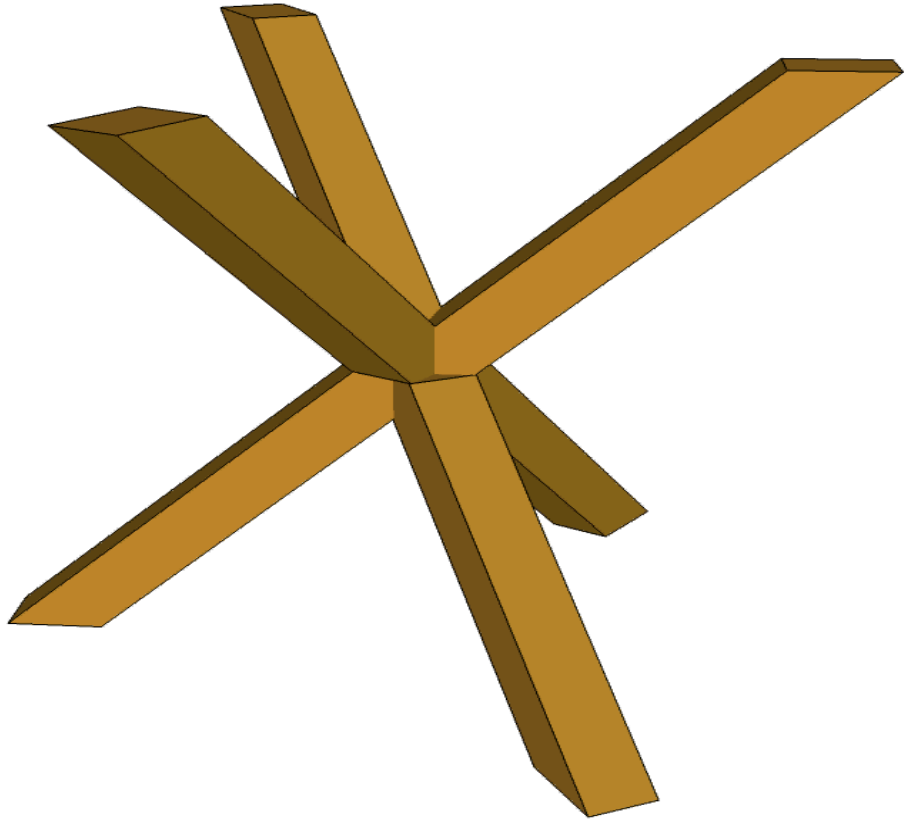


Lim, Kang, Int Jour of Solids and Structures 42 (2006)

Porous



Kagome Structure: Perspective View



Rigidity of material depends on cross-sectional shape for same amount of material
Need a cross-sectional shape design for high rigidity

→Increase moment of inertia
→Material located far-off from neutral plane of bending

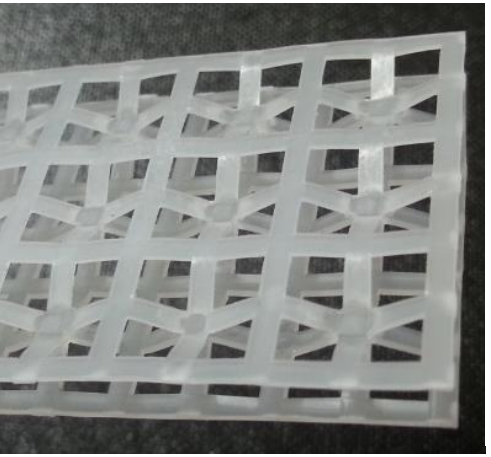
Foam Structure → Most Effective Structure

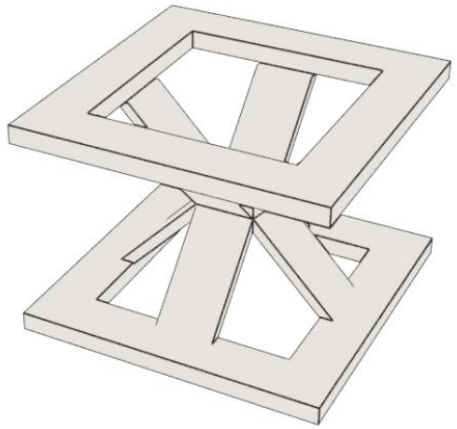
How can we make material being located for-off from neutral plane of bending?
Shape of core in sandwich panel?

Suggestion of Kagome Structure in Plastic Sandwich Panel

The most rigid structure among the truss structure

- **Kagome is a basket pattern**
- **Kagome structure is most stable**



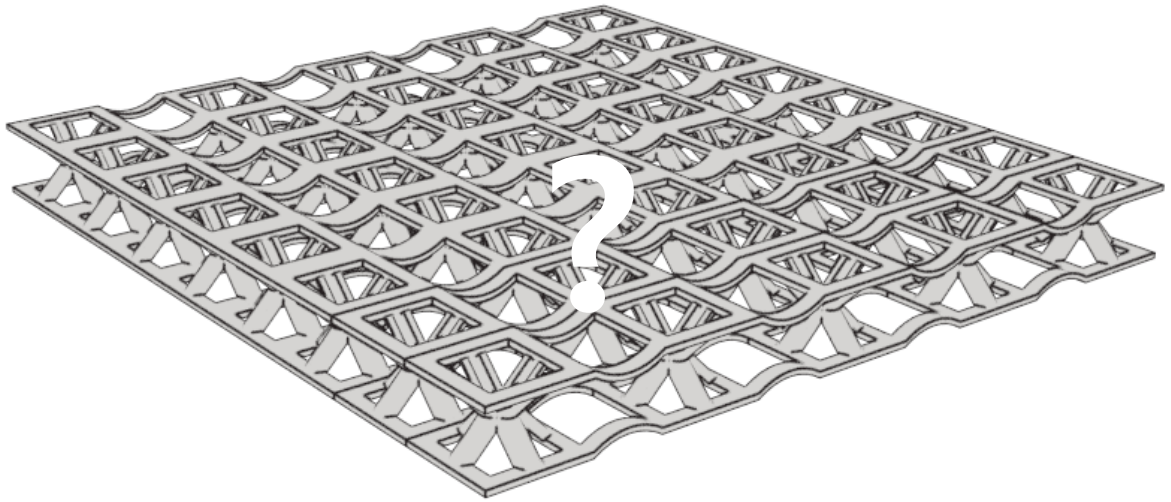


→Suggested pyramidal kagome has a merit of kagome structure and easy fabrication

June-Sun Hwang, Tae-Gyun Choi, Dongyoung Lee, Min-Young Lyu, Dai Gil Lee, Dong Yol Yang, "Dynamic and Static Characteristics of Polypropylene Pyramidal kagome Structures", Composite Structures, Vol. 131, 17-24(2015)

June-Sun Hwang, Tae-Gyun Choi, Min-Young Lyu, Dong Yol Yang, "Investigation for the Bending Modes of a Semi-circular Pyramidal Kagome Sandwich Structure and the Bending Load Calculation, Composite Structures, Vol. 134, 10-17(2015)

3 INJECTION MOLDED PRODUCT Vs. ADDITIVE MANUFACTURED PRODUCT



Injection Molded Product Vs. Additive Manufactured Product

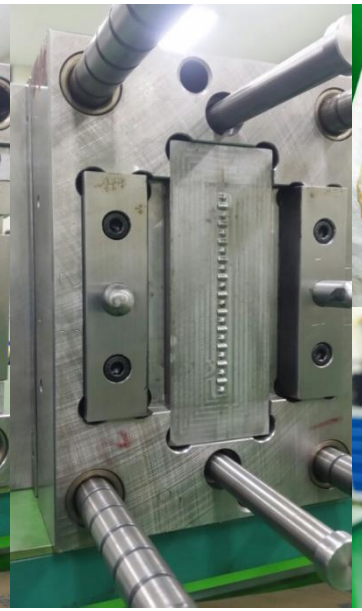
Injection Molding and 3D Printing for Plastic Kagome Core Strip

Injection Molding

Material Grade : PP(J-560S, Lotte Chemical)

Injection Time: 10 Sec

Merit: Mass production with short cycle time/ Demerit: High cost of mold



3D Printing

Model: Connex500

Manufacturer: Stratasys

Printing type: Polyjet Matrix

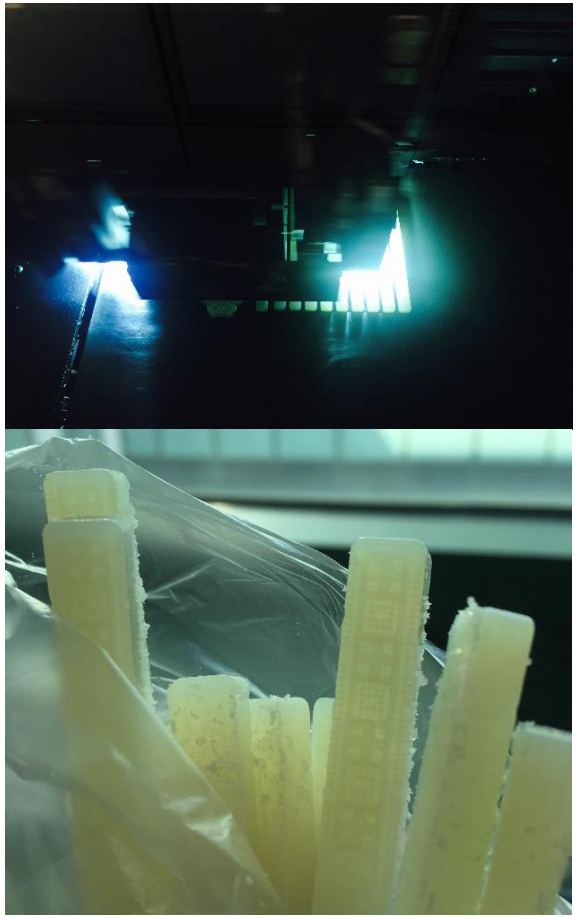
Resolution: X-axis: 600 dpi / Y-axis: 600 dpi / Z-axis: 1600 dpi

Layer thickness: 16 microns (0.0006 inch)

Operation Temp.: 18˚C to 22˚C (64.5˚F to 71.5˚F)

Material Grade: VeroWhitePlus RGD835

Fabrication Time: 45 min. for 20



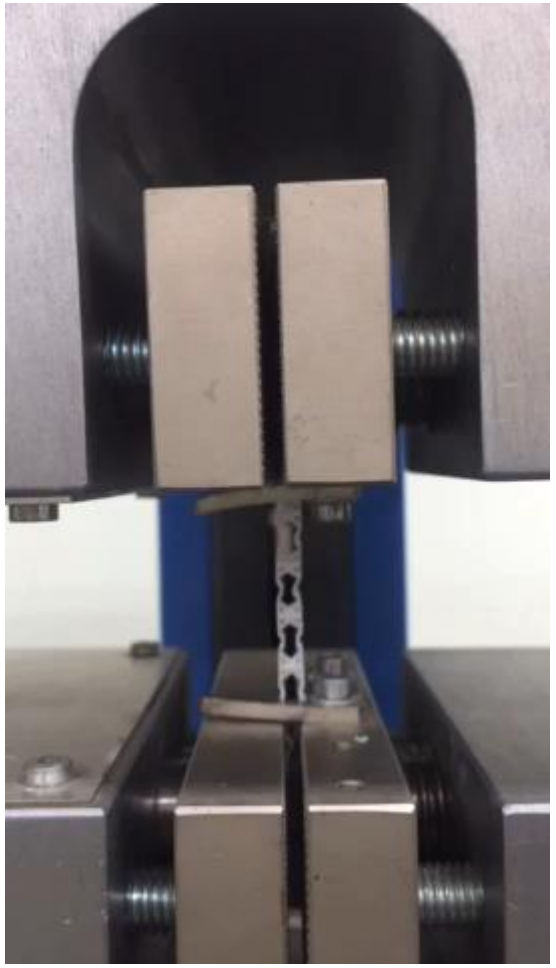
It can fabricate thin, small and complicated kagome structure

Comparison of Kagome Core Strip

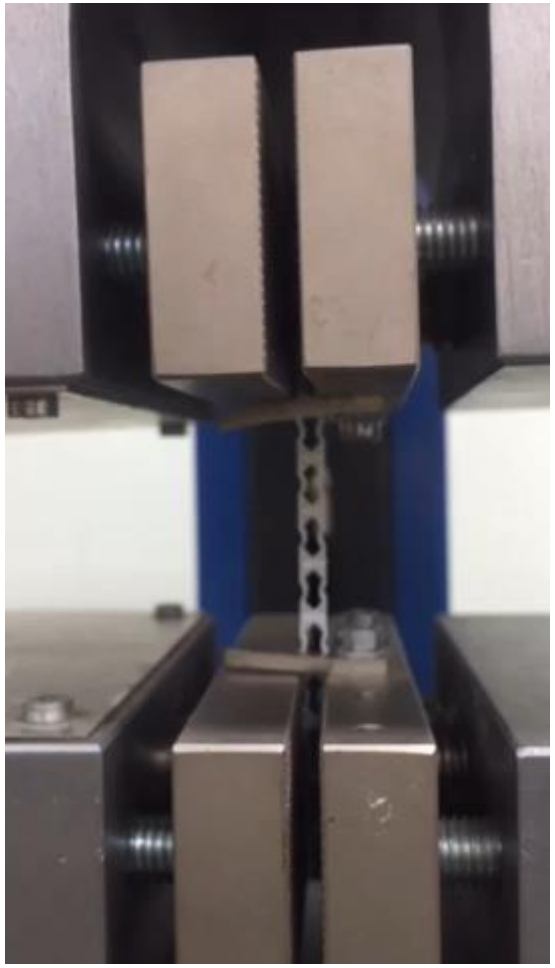
Injection Molded Product

3D Printing Manufactured Product

Tensile Test of Kagome Core



Injection Molded Product

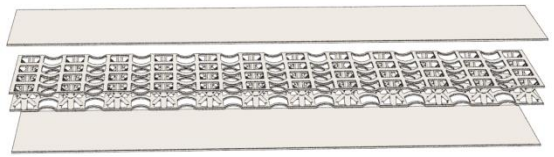


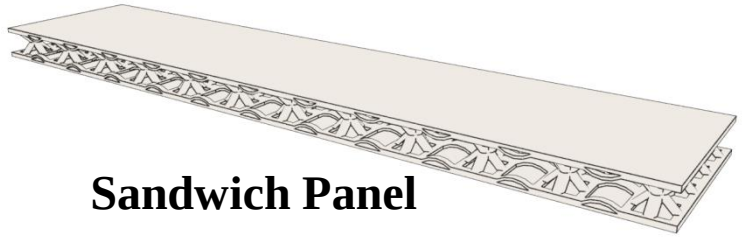
3D Printing Manufactured

- **Equipment: EZ20, LLOYD INSTRUMENTS, England**
- **Tensile Speed : 1mm/min**

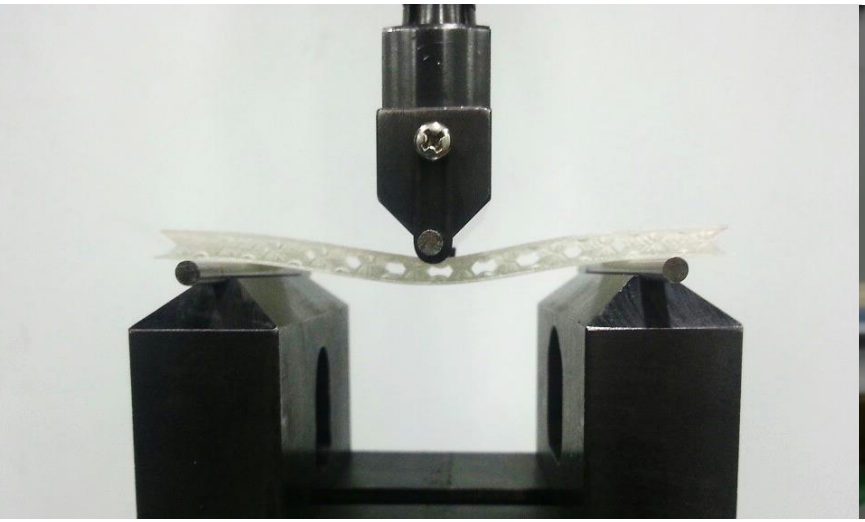
Bending Test of Sandwich Panel

4 Kagome Core Strips

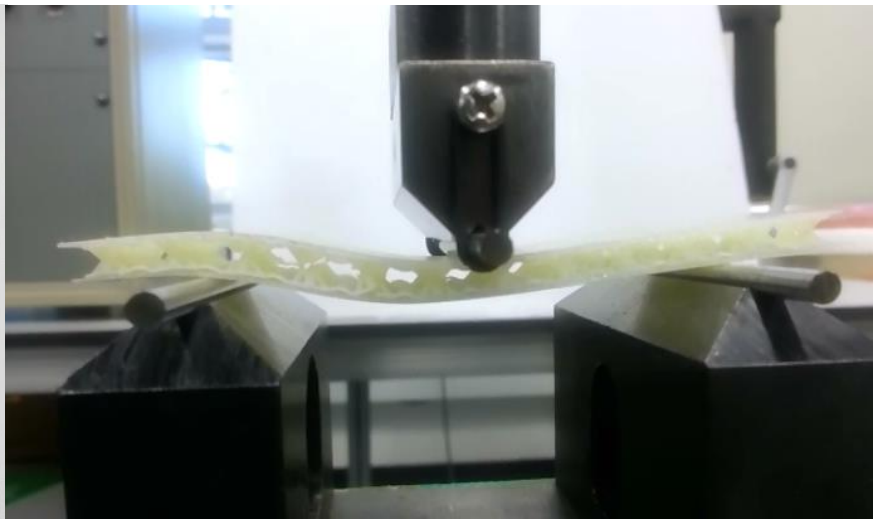




Sandwich Panel



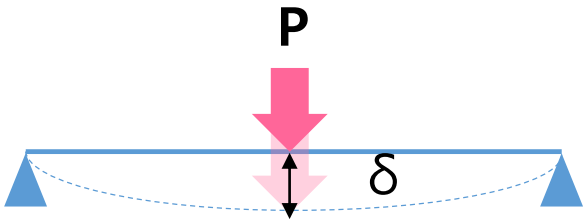
Sandwich panel with kagome core made by injection molding



Sandwich panel with kagome core made by 3D printing

- **Compression Speed: 2mm/min**

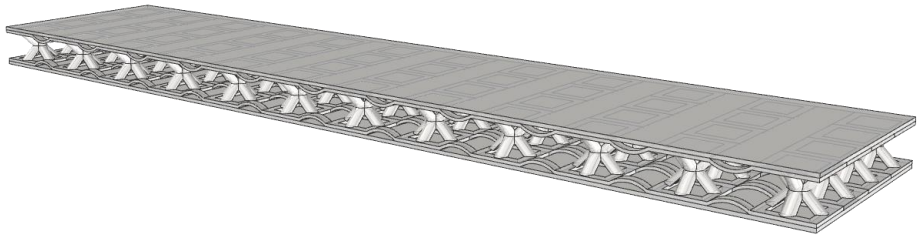
4 CONCLUDING REMARKS



$$\delta_{max} = \frac{Pl^3}{48EI}$$

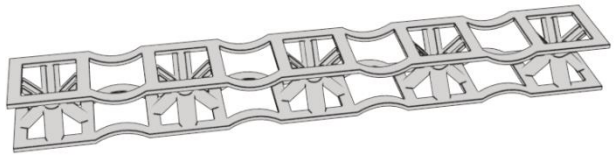
Moment of Inertia ↑
➔ Stiffness ↑

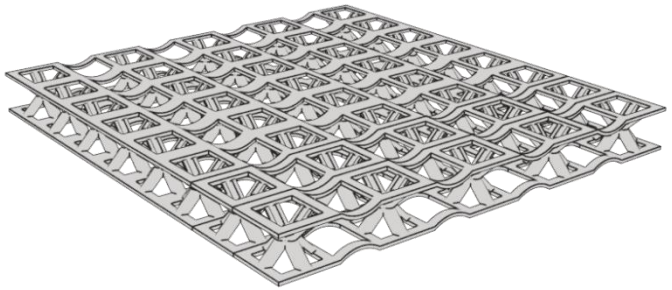
Need space between neutral plane of bending and outer surface



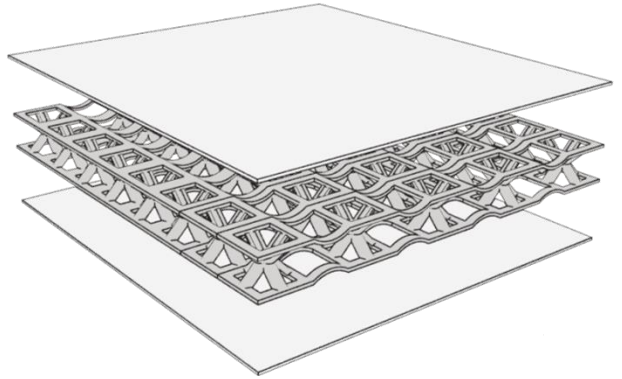
Plastic Panel with Arrangement of Kagome Core Strip

Core Strip

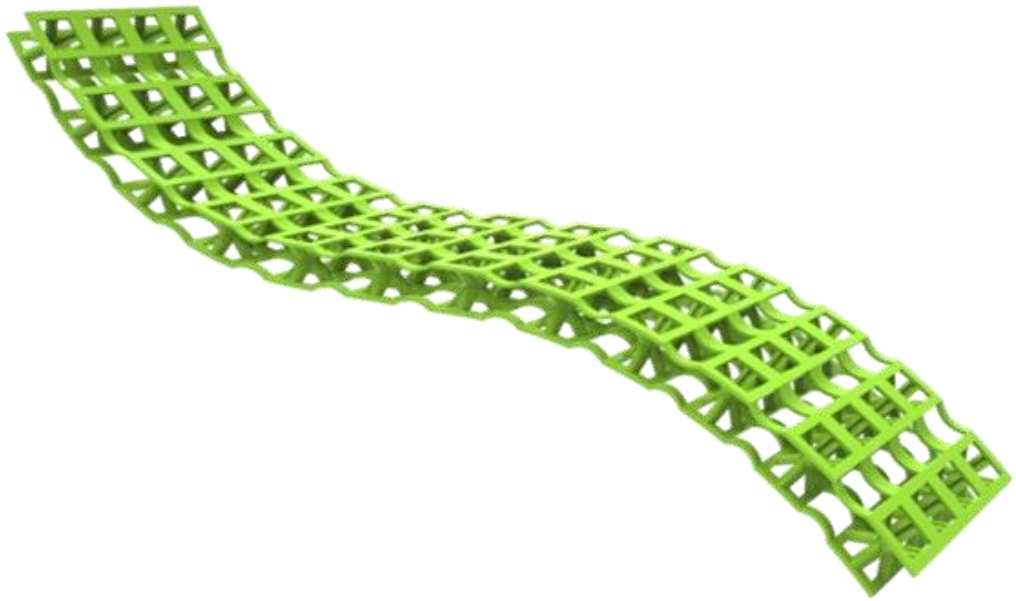


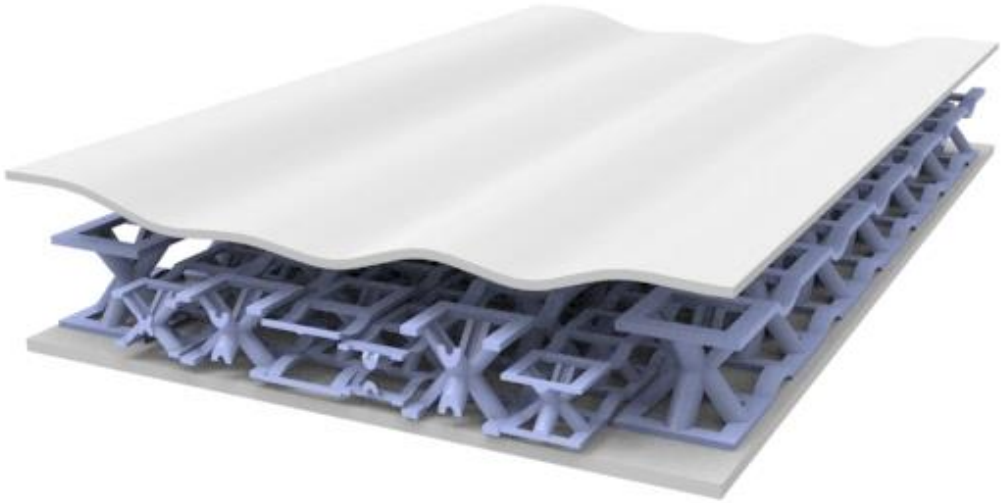


With Face Sheet



- **Most stable structure for core → Pyramidal kagome structure with semicircle truss**
- **Core layer → Kagome structure → Difficult to fabrication**
- **Additive manufactured core shows weak strength, however it can be a role for making space between face sheets**
- **Additive manufacturing has a high degree of freedom for fabrication for various three dimensional structures**





Various and complicated 3D core structure can be fabricated using AM