THE GEOMETRICAL AND STRUCTURAL EFFICIENCY OF A VARIABLE DENSITY KAGOME MESH COMPARED TO A REGULAR ONE.

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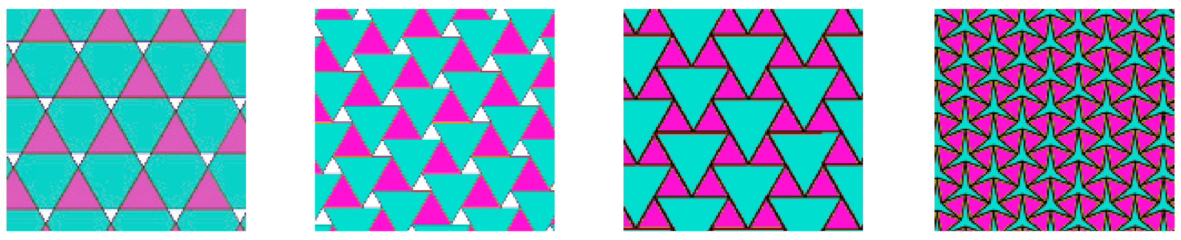
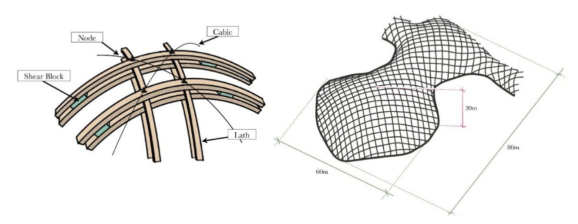
INTRODUCTION

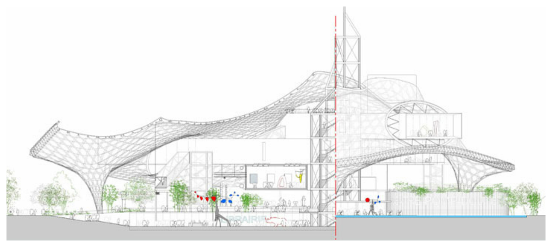


In geometry, the trihexagonal tiling is one of 11 uniform tilings of the Euclidean plane by regular polygons. It consists of two hexagons and two triangles which alternate around each vertex, and its edges form an infinite arrangement of lines. Its dual is the rhombille tiling. It's isotropic and not static determined.

STATE OF THE ART



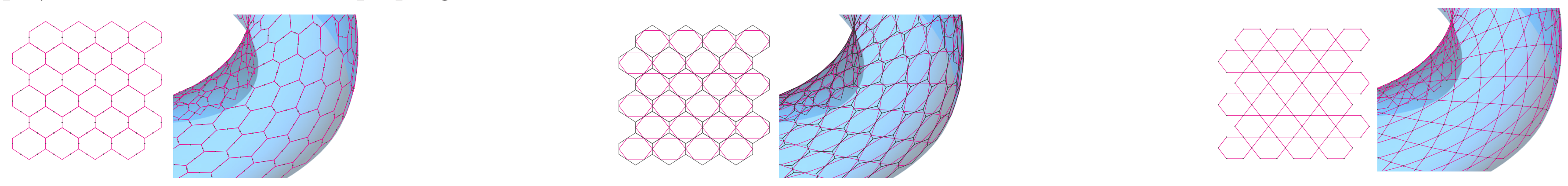
Manheim Multihalle. Frei Otto.
Hanging chain model, pure tension shapes. When inverted, pure compression shell results. The curvature found in the hung quadrangular chain net meant that there was no in-plane shear stress in the lattice that replicated that same shape.



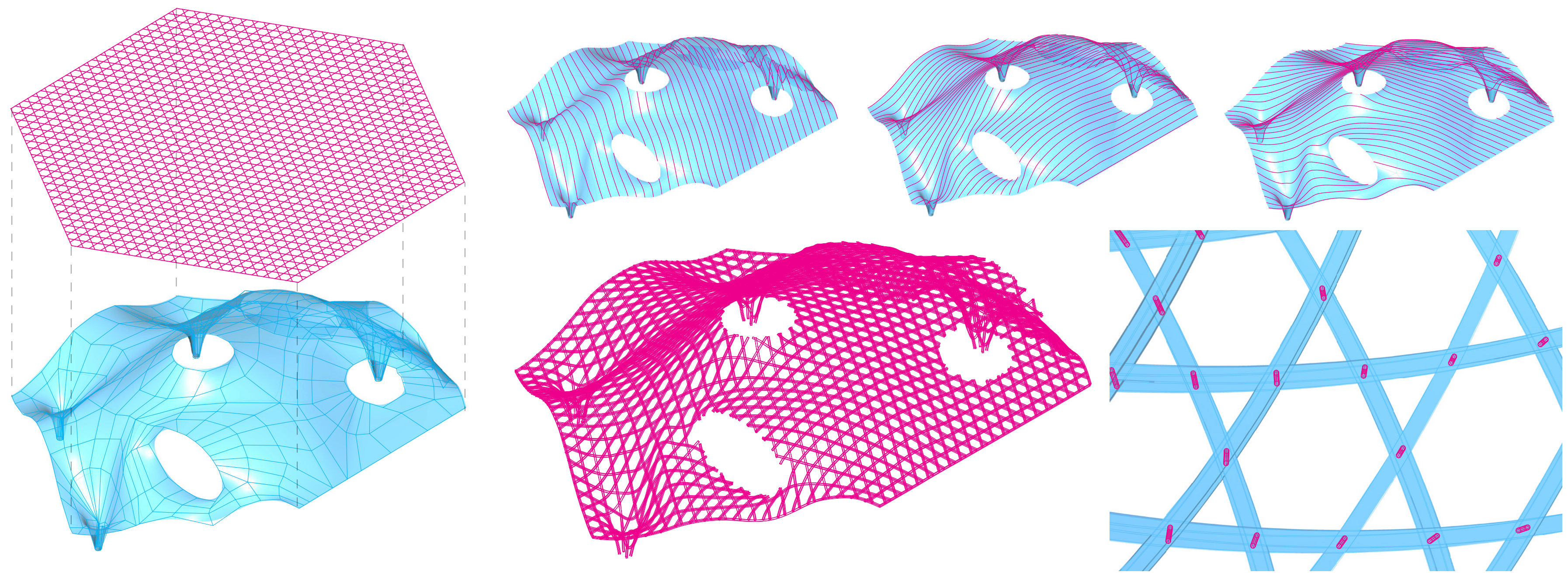
Shigueru Ban Architecture, Specially Pompidou Metz
Structure made out of an hexagonal and equilateral triangles pattern, inspired on the traditional hats and baskets in Japan. The trihexagonal surface subdivision is adapted to a double layered superposition of same direction beams.

CASE STUDY

In the following cases, other possible adaptations of the initial intention are examined in cases of surfaces with wider ranges of curvature and smaller spans.
In order to get the lattice projected into a given surface, we need to apply the "surface mapping" assuming, that the lattice is not like a cloth projected into the surface but a proper grid.



Approach on the projection of the Kagome grid



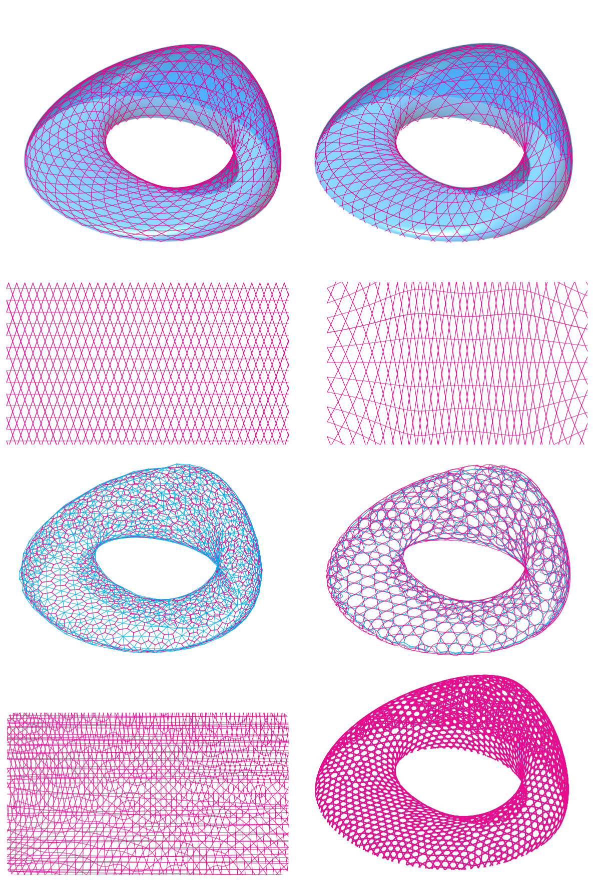
1. Kagome lattice application to surface's flat projection.
A hexagonal flat surface is the boundary of the tri-hex grid.
2. Vertical projection of grid on surface.
Three directions of curves vertically projected onto the surface.

3. Superposition of layers
Each direction-group is projected on consecutive offsets of the initial surface.
4. Intersection Bolts and Shear Blocks

HYPOTHESIS

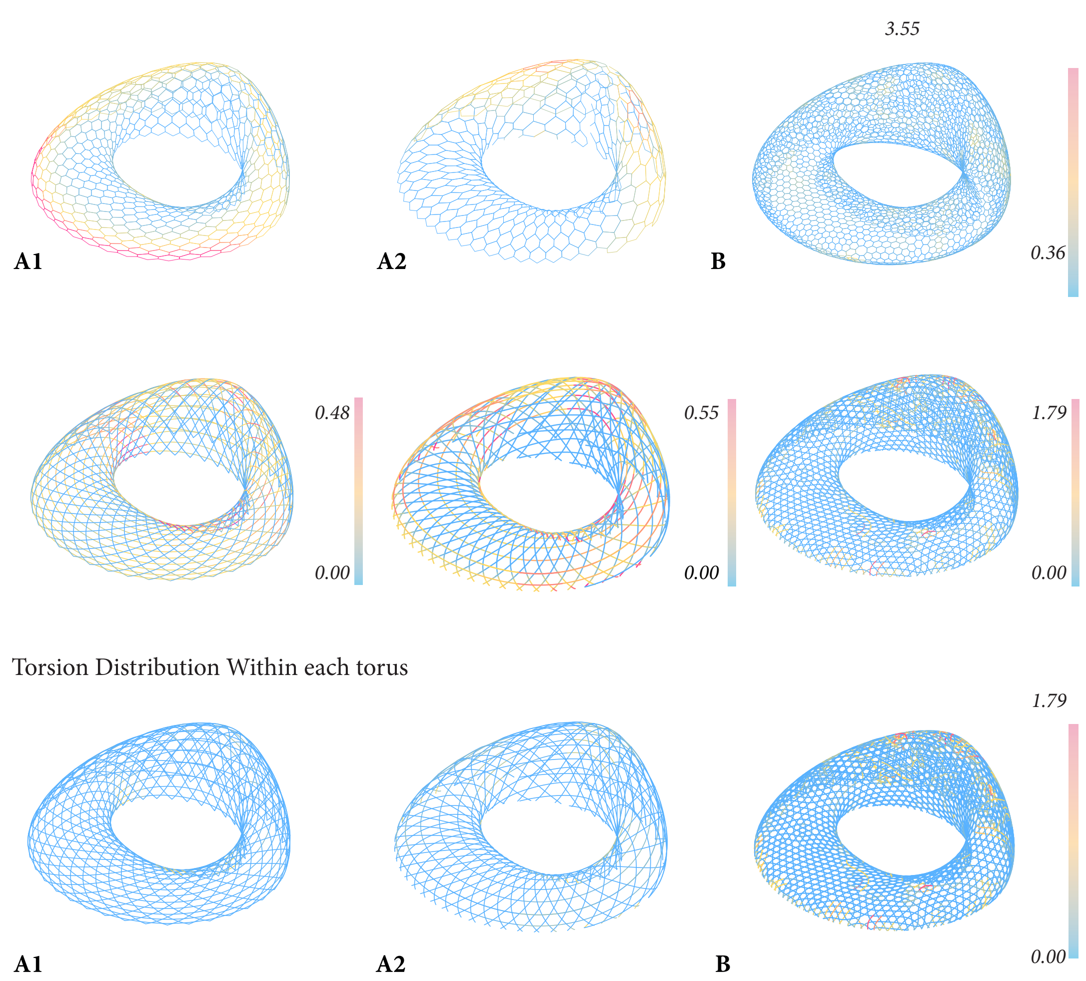
The aim of this article is to compare the structural performance of two types of trihexagonal gridshells.
First, there's a geometrical analysis, where different intents of getting a better topologically-wise and more efficient projection of the structure are presented.
First, a regular Kagome gridshell, constituted of a regular pattern of triangles and hexagons. The second, a gridshell in which the pattern is non-regular, determined by the structural needs (more dense for bigger structural strains and less where not so much effort is needed, thus determining the most economically efficient

Adaptation strategy



A. UV mapping of lattice from flat surface
[1] Hexagonal grid applied to flat, orthogonal surface. Mapping to toroidal surface by direction, Kagome formation and offset layering. Mapped pattern: isometric.
[2] Steps repeated, but in this case the hexagon grid is trimmed by a surface scaled by the U section curve lengths of the toroidal surface. Mapped pattern: distorted.

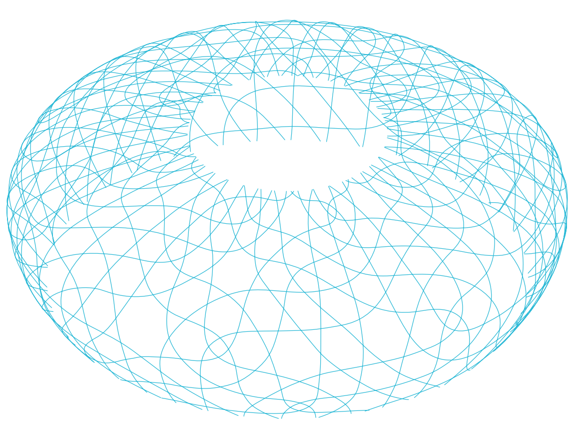
B. Topology based mesh approximation
We propose a mesh approximation of the torus surface, of same-length edges. The application of the above process on polygonal grids on the dual mesh, produces a polygonal segmented lattice. Out of the joint of these segments we come up with continuous beams.
We are able to unwrap the pattern of beams



Conclusions - projection of the grid

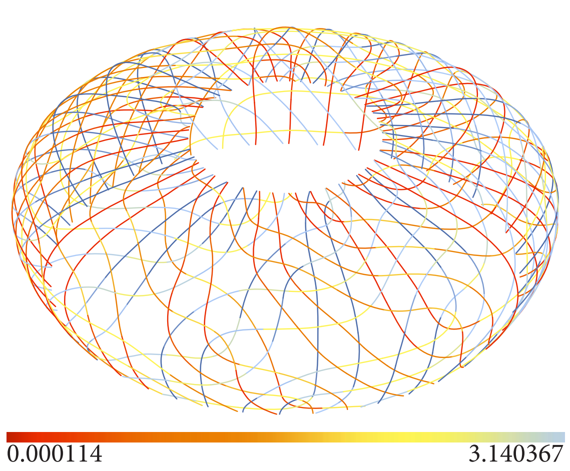
The vertical projection system applied in Pompidou Metz is only efficient in surfaces where the ratio area-projection surface area is near 1. Most efficient alternatives are the ones where the trihexagonal grid derives from inherent characteristics of the surface, in proportions or topology.
In further, future research we could examine the relation between geodesical curves as a base for the Kagome lattice, in order to avoid any material waste during fabrication.

Structural analysis - efficiency



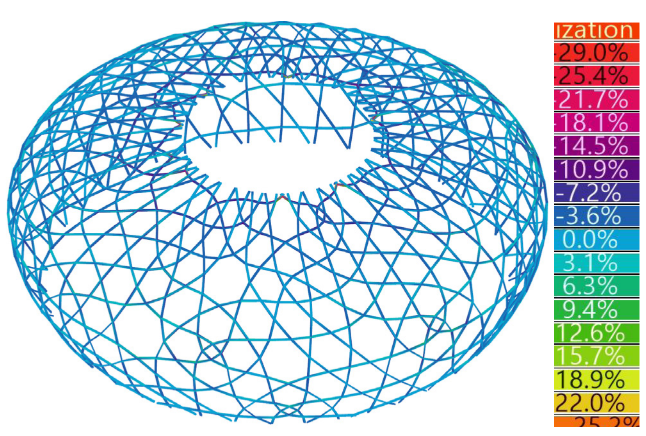
To create the regular grid the method explained before is used, assuming the topological approach is the most convenient and efficient geometrically-wise.

Torsion analysis on each beam



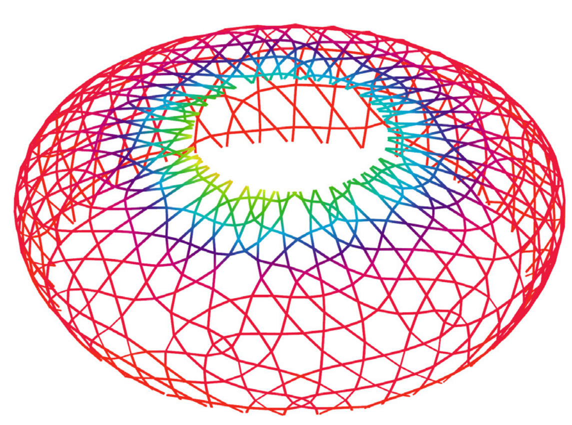
Minimum torsion = 0.000114
Maximum torsion = 3.140367

Utilization

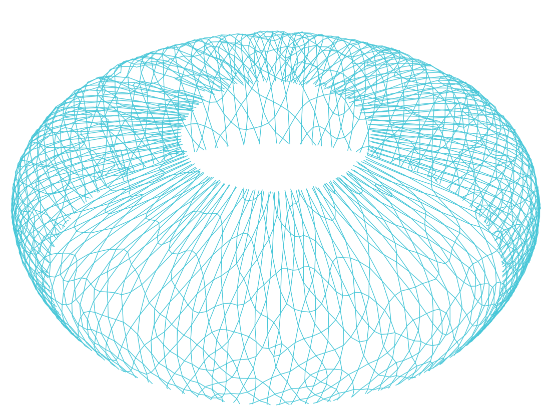


Minimum utilization (max. compression) = -21,7%
Maximum utilization (tension) = 3.1%
Avg. stress = -1.8% (compression stress)

Displacement

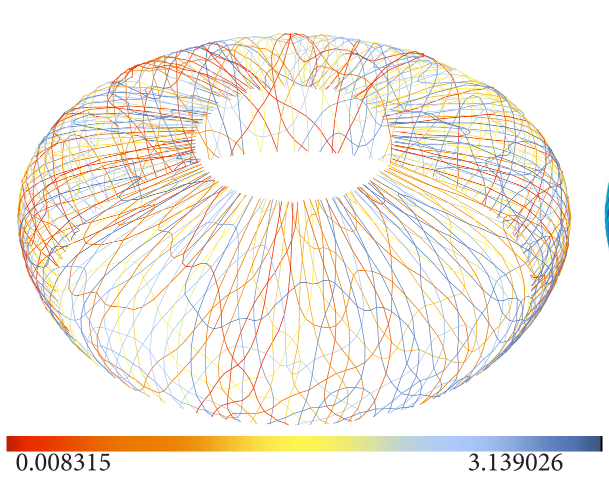


Maximum displacement= 0.00261



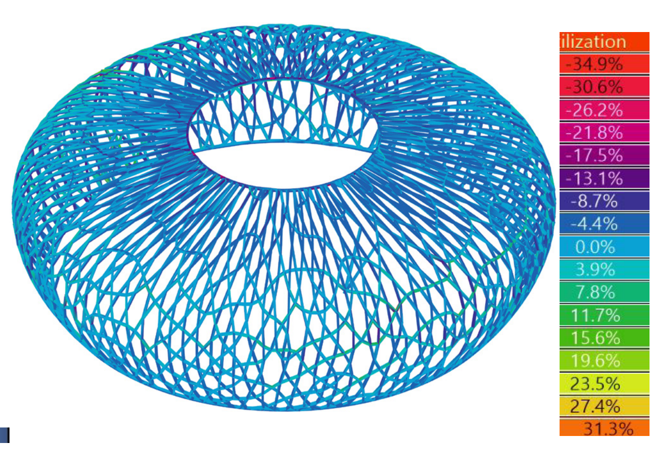
Irregular grid, based on the different structural needs of the shape.

Variable density grid beam torsion



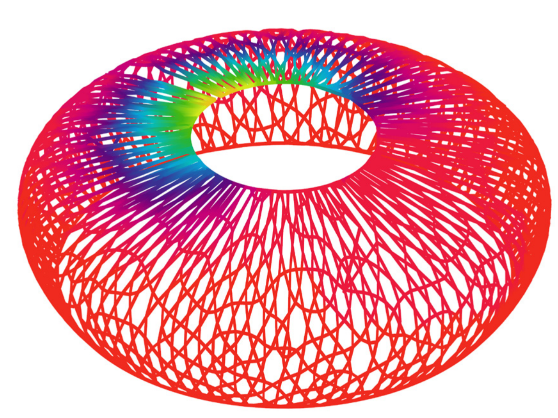
Minimum torsion = 0.008315
Maximum torsion = 3.140367

Utilization



Minimum utilization (max. compression) = -17.5%
Maximum torsion = 11.7%
Avg. stress = -2.2% (compression stress)

Displacement



Maximum displacement = 0.022177

Conclusions- grids efficiency

TORSION

In this case, the minimum torsion has a better value on the regular grid, although the irregular one is better in the case of maximum torsion.

UTILIZATION

The maximum compression turns out to be better for the variable density (which is good against buckling). However the results for tension are better in the first case. Neverthless the extremes are not as representative because they represent a very little portion of the whole structure. Despite this, we can find the average results which demonstrate a more regular structure works better towards stresses, still, the difference is not big.

DISPLACEMENT

Analysing the displacement in both cases bof a box cross section of 6 cm, the results make evident that the regular grid works also better agains displacement, this is due to the fact that the loads go down to the ground in a more efficient way.