# A Showroom with a Mesh Structure in Roppongi, Tokyo: Topology Design of Bracing

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## Abstract

In this report, we propose a method to determine the layout of diagonal braces in a lattice-type grid composed of vertical and horizontal materials. To determine the placement of bracing, we used the fully stressed design method considering the thickness of the braces, which are proportional to the areas of them, as a variable, the value of which keeps getting updated until the tensile stress generated in all the braces reaches the specified target tensile stress. The rigidity and resistance in the direction of compression of the braces were not considered. To obtain a clear and realistic placement, upper and lower limits were placed on the thickness. The thickness was not allowed to exceed the specified upper limit. For braces falling below the specified lower limit of thickness, we propose a method of applying power-law penalization [1] to decrease the effective plate thickness to stress ratio with progressive iterations. By gradually increasing this penalty each time the value of the thickness is updated, all values obtained after a sufficient number of iterations are expected to be more than the specified lower limit.

In an actual building, there exist locations where placement of braces is more difficult than usual owing to reasons of manufacturability, such as workability and difficulty of completion. Simple placement of braces at these locations is undesirable because of the difficulty in construction of the building. Our method devises a way of taking into consideration the differences in the difficulties in the placement of bracing for manufacturability reasons by changing the rate of increase of the penalties mentioned above. The rate of increase of the penalty is made directly proportional to the difficulty of construction, and braces are placed at these difficult locations only if considered truly necessary (*i.e.*, at locations where the thickness exceeds the specified lower limit in the previous iteration).

All modeling and analysis for this building were performed using Rhinoceros and the Grasshopper plugin. This allowed us to reach an agreement with the designer quickly and efficiently, and enabled a flexible response to changes in conditions as the project progressed. This method was applied to the Roppongi 7-Chome Project, a small-scale showroom in Roppongi, Tokyo, which is currently under construction.

## References

[1] M. P. Bendsøe, "Optimal shape design as a material distribution problem.", Structural and Multidisciplinary Optimization, Vol. 1, No. 4, pp. 193-202, 1989.