Applications of Timber Gridshells for Humanitarian Assistance and Disaster Relief Efforts

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Abstract

From 1970 to 2000, 68 percent of U.S. naval operations were categorized as Humanitarian Assistance and Disaster Relief (HA/DR) efforts [1]. These relief efforts uncovered a need for compact, lightweight, and adaptable structures to provide large span shelter for vulnerable populations. That need, and U.S. naval involvement in HA/DR, remains today. Large span shelters are necessary in HA/DR because they provide space for community gathering, emergency services, headquarters, educational facilities, and worship. Gridshells are a solution to this need because of their portability, sustainability, and efficiency. This paper presents the structural design, analysis, and construction of a timber gridshell for use in HA/DR.

Gridshells are highly efficient on account of their high strength to weight ratios and large spans. They are a type of shell structure formed from linear members assembled into a flat lattice and then bent on-site into a curved surface. This construction method allows for a relatively large structure to be built from easily transportable linear members without the use of heavy machinery, as demonstrated in 2014 by the ZA Pavilion in Cluj, Romania [2]. Local sourcing, and reusable materials can be used to construct timber gridshells, contributing to their sustainability. The aforementioned characteristics alone make gridshells well suited for the infrastructure requirements and physical demands of HA/DR, yet their beauty, remains relevant because they offer comfort, physical shelter, and emotional support amidst a crisis.

The design requirements and constraints for the gridshell presented in this paper were established in Athens, Greece by working with refugee populations and NGO's associated with disaster relief. These insights, along with the Sphere Handbook (an internationally recognized set of minimum standards for shelter in HA/DR) and the International Building Code (IBC), determined the design requirements. The structural analysis included a parametric study using *Grasshopper,* a graphical algorithm editor, and *Karamba,* a finite element analysis engine, with *Rhinoceros,* a 3D modeling software. The analysis varied the grid spacing, bracing patterns, and load cases (gravity, asymmetric, and point loads) to determine the global buckling factor for each iteration. Small-scale desktop models were created in order to test the deployment mechanisms, storage schemes, and joint movements. Successful small-scale tests led to a half scale proof-of-concept model. Unveiled at the Harvard Humanitarian Initiative Disaster Simulation in 2019, the model proved that gridshell structures are viable options that meet distinct needs in HA/DR efforts. This project is in collaboration with the Naval War College Civilian-Military Humanitarian Response Program.

References

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