Low-carbon high-rise construction with thin-shell concrete floors: A parametric case study

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Abstract

The production of steel and concrete for construction accounts for one third of global industrial CO_2 emissions [1]. With the world-wide floor area of buildings projected to double over the next 40 years, structural engineers have the opportunity, and responsibility, to ensure that these materials are used sparingly. A significant majority of the mass and embodied energy in a building's structure exists within the floors, making these a primary target for efficiency improvements.

It is hypothesized that material can be minimised by harnessing membrane action, rather than bending, since stresses are more uniform and cracking is reduced. This project therefore proposes a novel concrete flooring system using textile reinforced concrete (TRC) shells spanning between columns. Lateral thrust is resisted using a network of steel ties, and a foamed concrete fill is cast in-situ to create a level floor surface.

A range of shell geometries were explored in a previous investigation [2], with parametrically optimised cross-vaults chosen as the preferred solution. A novel strength design methodology for TRC has been developed [4], and quarter-scale prototypes have also been constructed and tested [3] to verify the structural behaviour.

Building on this work, this paper explores the implementation of the system in practice. Feasible designs are developed for a typical high-rise building of variable span, accounting for ground settlement, lateral stability, non-uniform live loadings, accidental damage and serviceability requirements. Significant savings in embodied CO_2 are demonstrated compared with concrete slabs and composite steel floors of equivalent performance. This highlights one way in which structural engineers can reduce the environmental cost of construction through creative structural design.

References

[1] J. M. Allwood *et al.*, *Sustainable materials: with both eyes open*. Cambridge: UIT Cambridge, 2012.

[2] W. Hawkins, J. Orr, P. Shepherd, T. Ibell, and J. Bregulla, "Thin-shell textile-reinforced concrete floors for sustainable buildings," presented at the IASS Annual Symposium, Hamburg, 2017.

[3] W. Hawkins, J. Orr, P. Shepherd, and T. Ibell, "Design, Construction and Testing of a Low Carbon Thin-Shell Concrete Flooring System," *Structures*, In press. 2018.

[4] W. Hawkins, J. Orr, T. Ibell, and P. Shepherd, "An Analytical Failure Envelope for the Design of Textile Reinforced Concrete Shells," *Structures*, vol. 15, pp. 56-65, 2018.