COLLABORATIVE BIM-BASED WORKFLOWS FOR A NEW SUSTAINABLE COMPRESSION-ONLY STRUCTURAL BLOCK CONSTRUCTION SYSTEM

Lombe Mutale

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Abstract

Currently, the construction industry is the largest industry in the world and contributes 8% per year to greenhouse gas emissions mostly due to concrete which is the most common material used for construction. Reinforced concrete needs steel reinforcement which is prone to rust when the concrete cracks and deleterious materials reach the steel. Widespread steel corrosion affects the durability of the entire structure, reduces its service life, and increases the need for rehabilitation and maintenance during its lifecycle. An interesting alternative, for the sake of optimisation, durability, and material waste minimisation, would be to make concrete structures solely endure compression forces and hence avoid the need to use steel reinforcement. This can be achieved through applying form-finding methods to achieve optimised structural shapes. Precast systems can further optimise and increase the industry's productivity more than the traditional on-site construction systems can. Additionally, digitalisation through BIM and computational design processes can automate and assist in cost savings and quality assurance.

This dissertation proposes the use of low-strength concrete to create precast compression-only concrete structures. Each discrete part of the structure is made through flexible moulds that are adaptable to a wide range of geometries. The structural components are connected by prestressing cables (not made of steel and not prone to corrosion) which are installed in-situ thereby creating a new construction system. In short, the system aims to satisfy the following requirements i) self-supporting during construction, or only needing some propping ii) optimised structural behaviour (compression-only – no bending moments), iii) high durability and long service life (no reinforcement).

Computational and parametric design were used to create a compression-only shell structural shape through the Particle Spring form-finding method in Rhinoceros/Grasshopper 3D. Once the overall structural shape was obtained, it was thickened and tessellated thereby defining its discrete elements. The construction sequence of precast elements was implemented automatically with a cellular automata algorithm. Then, a custom tool was created that linked the structural shape generated to the structural analysis software DIANA and automated the phased analysis which incorporated the construction sequencing. Thereafter, finite element analysis (FEA) was used to assess the structural behaviour. Finally, a collaborative workflow was set up such that engineers and architects can work together to create the most optimal structural shape in a BIM environment.

Through a case study to evaluate the framework, results show that with the proposed workflow, any arbitrary compression-only structural shape can be defined using form-finding principles. FEA can be performed for structural analysis and a BIM model produced for construction. Although, there are some tensile stresses present during the phased construction they can be almost eliminated with the use of minimal construction supports.

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Presentation video:
https://youtu.be/DUGnyjJFcyo

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