3D-Printed Grid Shell in Ice Composite

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Abstract

In the past, record breaking large shell structures with ice composites were successfully realized by spraying the ice mixture on an inflatable mould [1]. This paper presents the application of a new, patented, production technique for ice composites by extrusion instead of spraying. With this additive manufacturing technique, world's first grid shell in fibre-reinforced ice was designed and constructed. The grid shell was realized in a cold environment by printing multiple layers of a water/cellulose mixture on an inflatable mould using piping bags. After the substance has been extruded, the mixture will freeze at temperatures of minus eight degrees Celsius or lower. The form finding and engineering of the grid shell was based on the construction technique in which additive manufacturing was combined with an inflatable mould. The structure was optimized in form, shape and size. With regard to the form finding it had to be considered that the inflatable mould has a circular section in at least one direction. Due to the circular section of the inflatable in the direction of the force distribution the preferred catenary shape could not be achieved. Rather than a circular form, the floorplan was designed with an anti-clastic curvature to increase the stiffness of the structure [2]. Regarding the shape of the grid pattern, different design options were developed in a digital modelling environment and subsequently compared and verified in the finite element program ABAQUS. An iterative process determined the final grid pattern and the size optimization of the struts. Due to the circular shape of the structure, minor negligibly small, tensile forces and bending moments occurred. A theoretical failure load calculation showed that the middle part of the structure could carry more than 6000 kg of additional load, in the case the load is applied on the nodes. To validate the calculations, the structure was tested on site. It was able to hold a load of 3000 kg without any failure. The numerical calculation and the actual execution of the world's first grid shell in ice prove that additive manufacturing techniques are not only restricted to 3D printing of concrete and plastics. This new technique using additive manufacturing of ice composites can have new applications; for example Mars missions, polar missions, temporary foundations, sculptures and moulding.

References

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