MAKING IGLOOS IN THE SUMMER

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Keywords: Igloo, Inflatable Mould

Abstract. *In today's building practice blobs or so-called non-standard architectures are constructed using manual labour of highly skilled craftsmen and complicated structures. These forms can be constructed much more easily by rigidizing inflatable structures and/or pre-stressed tensile structures. Another advantage is that the structure is not separated from the façade of the building, as is the case with a lot of non-standard architecture that is being build today. This paper describes an experiment where an inflatable structure, that has familiar form characteristics with blobs, has been rigidized in ice. The experiment is part of a larger research on rigidizing membrane structures at the Technical University of Eindhoven.*

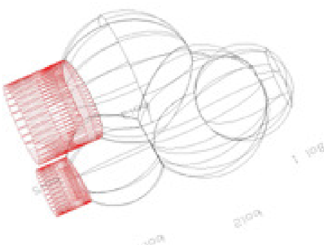
The inflatable mould, used for the construction of the art pavilion at the campus of the Technical University at Eindhoven, was re-used for the construction of an igloo. First rubber tubes were wrapped around it and fixed together with ropes. After the tubes covered the whole pneu, the tubes were connected to a cooling system. The cooling liquid glycol was pumped through the tubes at a temperature about –12 ˚C. When the right temperature had been reached the tubes were sprayed with water. Layers of ice slowly covered the whole pneu. When the layer of ice was thick enoaqwugh the pneu was deflated and removed leaving a perfect stable and beautiful ice structure.

BLOB PAVILION

Last year an Art Pavilion was built at the Technical University Eindhoven (fig) with a mould of PVC coated polyester membrane. The surface of the pavilion was constructed in fibreglass-reinforced polyester. [Pro 04].

Design by Jurgen Bey and students of the Technical University Eindhoven

During the construction of this pavilion we were asked to make an igloo for an exhibition in Amsterdam. Due to a low budget for the exhibition the inflatable mould of the pavilion (Fig) was used. Buitink Technology made the inflatable mould; Tentech engineered the patterns.



SURVEY

A small survey on the Internet showed us two different methods of constructing an igloo. The first is the traditional way [http://home.no.net/gedra/igloo_bg.htm] the other method, developed by a company uses an inflatable mould [http://www.igluformer.com].

The Traditional Way

The only tool needed in addition to a snow spade is a saw. A special snow saw is recommended, but a carpenter's saw will do (as seen in the pictures). A machete or small axe is handy for moulding the snow blocks, but not necessary.

Step 1: Find a suitable spot
A hard field of snow is required to build an igloo - hard enough to make solid snow blocks. Even if the top layer of snow is soft, hard snow can usually be found underneath. Use sticks to make a circle, marking the base of the dome. The snow depth should be at least 1m where the igloo is placed. This igloo is for 2-3 persons.

Step 2: Prepare the snow blocks
The snow blocks are prepared with the saw. They should be solid enough to be carried horizontal without breaking by their own weight. Large blocks are used at the base of the dome, smaller ones at the top. A thickness of 15-30cm is good. The blocks can be made extra strong by setting them up to harden in the wind.

Step 3: The building starts
The edges of each snow block should be smoothed and angled correctly to make a strong bond to the adjacent blocks. A ski with its tip placed in the centre of the igloo is a perfect tool for this. There will always be some (or maybe a lot of) cracks between blocks, but that is fixed later. It is very important that the bottom row of snow blocks are placed aslant, otherwise you are building a tower.

A full circle of snow blocks has been built. Ideally, the blocks should be placed in a spiral. This will make the building easier. Note the entrance. It is made of two vertical placed blocks pointing outwards with a solid block on top to make a small roof. It might look tiny, but a lot of snow is dug out later. At this stage the floor can be lowered from inside the igloo. This way an 10-30cm extra headroom can be created. The dome is starting to form. Remove the snow that is piling up inside.

If everything is done right, the dome will not collapse because the blocks are supporting each other. But in some critical situations, a stick can be used inside to support the topmost blocks until the dome is closed. The last few blocks are moved into the igloo through the entrance and lifted up. There might be need of two persons inside at this stage.

Step 4: Finishing the igloo
The igloo is closed. The cracks can be filled with snow. The inside of the igloo must be smoothed. This is done by hand (your gloves get very wet, bring extra pair!). If the inside of the dome is one, smooth surface, there will be no dripping of water at all. When the smoothing of the inside is done and all the snow has been shovelled out, it is time to finish the entrance. An L-shaped entrance is a good solution, and will prevent any snow from blowing in. First dig an L with a depth of 1m (or more), and then cover it with a square 'roof' made of snow blocks.

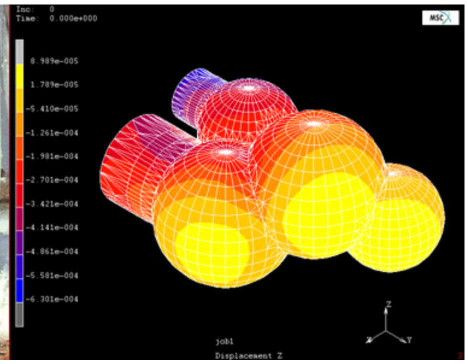
The igloo is finished. Note how the entrance is dug deep enough to allow almost standing height. The cold air will flow into this hollow, which function as a cold sink. During cooking small holes will melt in the roof, letting fresh air in. A small ventilation hole in the roof is recommended. Always keep the entrance open. The floor should be covered with some kind of camping mattresses. Candles can be used as light source, cut a small niche for the candle, with sufficient space above it to avoid snow melting.

Even after hours of cooking, there is no dripping. During the night the water that has melted will freeze again between the blocks, making the igloo stronger than ever.

IGLU FORMER
Iglu former is a company using the same principle of making an igloo using an inflatable mould. (Fig) [http://www.igluformer.com]

HEINZ ISLER
Isler’s experiments with ice were also an inspiration for this research. [Chilton 2000] Every winter Isler made some experiments. When it was freezing Isler sprayed water over all kinds of objects like plants in his garden, inflated balloons, hanging ropes and fine garden netting. His experiments with spraying inflated balloons with a fine mist of water suggested us that in principal our structure could be made. To be sure that our igloo wouldn’t collapse we roughly calculated the shape of the igloo with the help of the program MarcMentat. (Fig)

However in order to make a rough calculation of the igloo, material properties of ice were needed. The difficulty with ice is that it has different material properties at varying temperatures. The material properties also differ in the way the ice is being formed i.e. layered or non-layered. Even the type of water has an effect on the material properties of ice. Since there hasn’t been much research undertaken on the material properties for ice and certainly not for our specific case we had to make do with the data at hand. The elastic parameters for isotropic polycrystalline ice at -16°C were for the Young's modulus $93,3*10^8$ N/m^{-2} and for the Poisson's ratio 0,325. For the density we had to rely on different data; at -15°C ice has a density of 919,4 kg/m^{-3}. The deformations of the computer model showed no concerns regarding the construction of the igloo.



EXPERIMENTS

In The Netherlands it is only freezing some days in a year, mostly in January or February. In September the average temperature is 18 ˚C, therefore a cooling machine was used to get the right temperature. A cooling machine can be used in 2 different ways. Firstly the air can be cooled in an isolated room, like a refrigerator. After some experiments we concluded that this method could be used. But making ice out from water costs a lot of energy. Air is a good isolator with a low heat capacity therefore it will take a lot of cold air to make a man-height size igloo of ice. This is the way ice sculptures are exhibited in areas with a temperature above 0 ˚C. In our case this wasn't an option. The situation and the budget were not sufficient to build an isolated room. (Fig)

The other way of using a cooling machine is the way that skating rings are being made. The ice is kept at a right temperature by a field of ducts on the floor of the skating ring. These ducts will be connected to a cooling machine with glycol of –12 ˚C. Over the cooled ducts a fine mist of water is sprayed. Comparing the two different ways we looked at the heat capacity and heat transportation of water, ice and air.

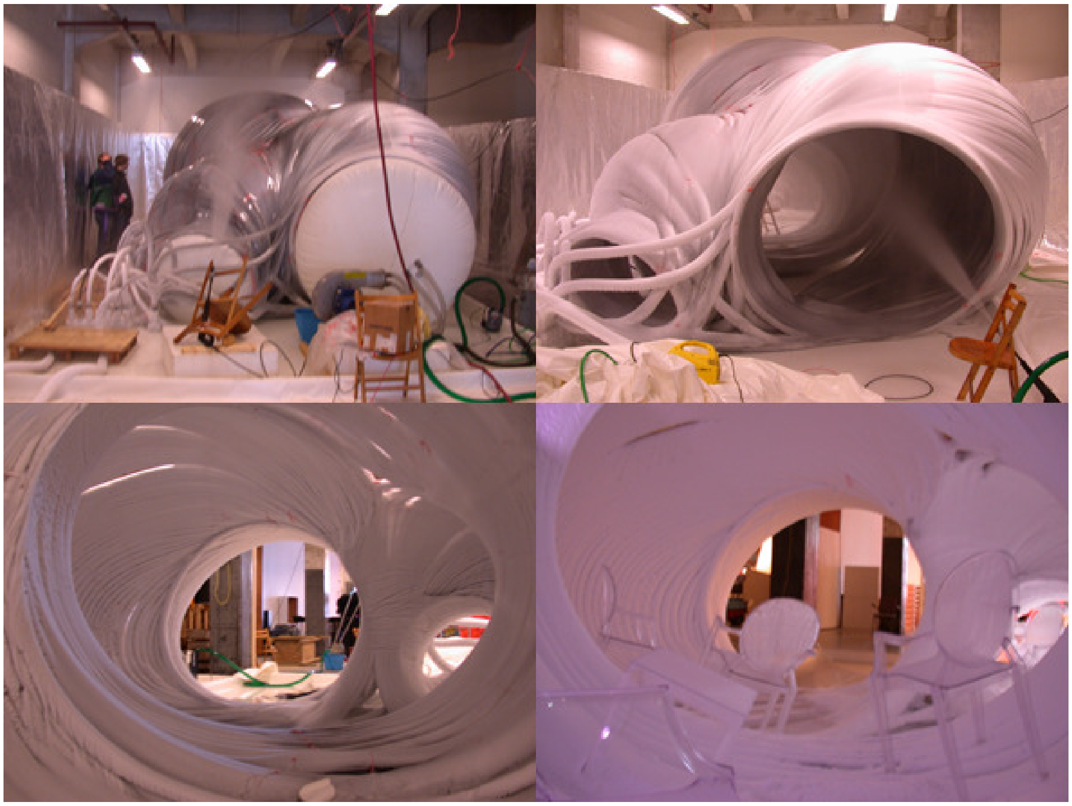
	Heat capacity J/kg.K	Heat transportation W/(m.K)
ice	2,2 x 1000	2,1
air	1,0 x 1000	0,024
water	4,18 x 1000	0,6
Ice into water	345 x 1000 J/kg	

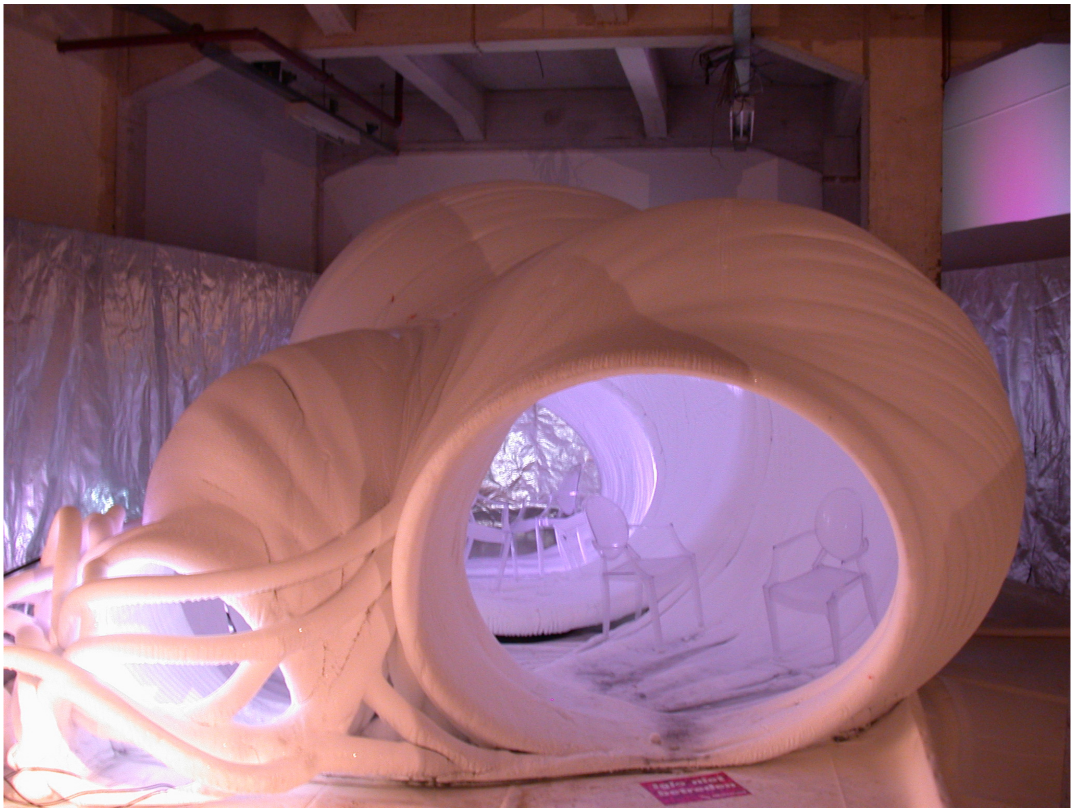
To turn 1kg water into ice 80 times more energy is needed as to raise 1 kg water 1K in temperature. Water has 4 times higher heat capacity than air. Air a 100 times better capacity for isolating. There for cooling with a water glycol solution is much more efficient than cooling with cold air. Because of the low heat capacity of air relatively little energy is needed to cool down the igloo when it is erected and the temperature of the air can be high (+18C). Simple calculation resulted in the needed cooling capacity. We did an experiment with an inflatable mould partly winded with cooling ducts. (Fig) After 1 hour we had 2 mm of ice; the experiment succeeded.

CONSTRUCTION

For the construction of the igloo ducts were winded around the inflatable mould to get a grid with an average distance of 5 cm between the tubes. In total 2000 meters of ducts were used to cover the whole inflatable mould. This work took 3 days and 5 people. (Fig)

After the ducts had been winded around the inflatable mould water was sprayed over the ducts. It took 3 days to get a layer of ice thick enough for a stable ice construction (10 cm). The interior of the igloo was sprayed with water one more day after the inflatable mould had been removed. (Fig)





CONCLUSION

The benefit of this method is that an igloo can be constructed at an air temperature of +18 ˚C with the help of a cooling machine and an inflatable mould but without the need to build an expensive isolated room. This test case can, in the future, have wider applications than just constructing igloos. At this moment new applications for this method are being researched.

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