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Preliminary assessment of the building design of a new test house in Nuuk, Greenland

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Abstract. DTU has established a single-family three-level test house in Nuuk, Greenland. The main idea of the house was to have a relatively small heated area but a split building envelope, where a ventilated space behind the rain screen in some areas could be used as a sunroom. This paper describes the process of transforming the architectural ideas to a test building. Main issues have been how to design the rain screen and how to ventilate the space behind the rain screen.

1. Introduction

At the 13th International Architecture Biennale in Venice in 2012 the Danish contribution was called “possible Greenland”. One of the presented projects was a new way of building houses in the Arctic. Terraced houses were sheltered from the harsh climate by a transparent rain screen, covering relatively small “living boxes” (10-15 m² each) with access from an open space that could act as a sun room. The principle of a warmer middle zone is not new, transparent materials in ventilated facades have been used in many double skin facades, and glass domes to cover buildings are also known [1]. In this case, transparent sheets would be sloped as a traditional roof and the gap behind the sheets would sometimes be small like in a traditional ventilated façade, and at other times be of room size. This would create two climate zones; 1) Inner zone with normal temperature, and 2) Middle zone with varying temperatures taking advantage of solar radiation. The aim was to ensure a new building design fitting the Greenlandic way of life and make use of prefab box modules that could easily be installed without heavy equipment [2] under a transparent permanent tent. The concept was tried out in a test house in Nuuk. This paper describes how the architectural ideas were transformed into an actual building, the challenges and the importance of cooperation between architect, engineers, and contractors in the early design phase.

2. The design

2.1. From concept to design; uncertainties and limitations

Although architectural sketches and models had been made to illustrate the ideas of the concept many, more or less connected, things were not clear from the beginning:

- The material of the transparent screen
- The access to the “living boxes” or rooms –through the sun room or through an internal stairway
- If the middle zone areas should be heated to avoid frost, and if so how could it be ventilated.
- The insulation of the inhabited rooms
- The temperature and relative humidity behind the transparent screen, throughout the year



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It was discussed how experimental the building should be, i.e. how many untested solutions were acceptable. To reduce the risk of not being able to understand why the concept would or would not work, it was decided to use tested materials and conventional design as much as possible. For financial reasons, only one single family house was built instead of the terraced houses in the original plan. Furthermore, instead of designing prefab box modules, a more conventional 80 m² home with direct connection to all rooms was chosen. Focus should be on how the concept of the two climate zones could be realised.

2.2. Non-experimental parts

The main construction was a timber construction with specifically designed braces. The walls between inner zone and middle zone were insulated with 240-290 mm mineral wool, equipped with a vapour barrier at the warm side, 21 mm wooden boards on the inside, and cement based chipboards on the outside. A similar design was used for the floor. The building was founded on the rock by timber in post holders. The area under the house was unshielded. Figure 1 and Figure 2 show plan and cross section.

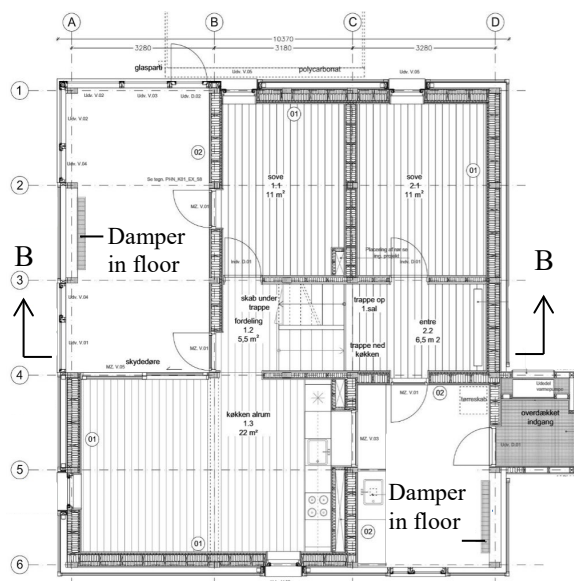


Figure 1. Ground floor plan, areas with middle zone climate upper left corner and lower right corner, ventilation dampers in the floor in these areas

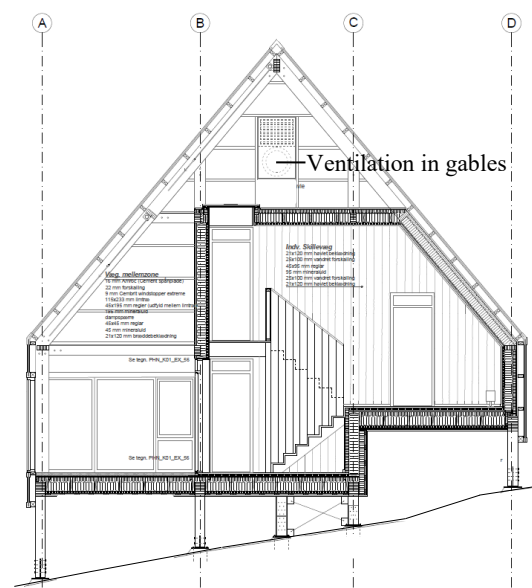


Figure 2. Cross section B-B as seen in Figure 1. Ventilation in the gable is used to prevent overheating.

2.3. The transparent screen

A traditional greenhouse would consist of one glass layer. However, due to the cold climate there was a wish for a higher U-value of the screen. Consequently, it was decided to use 80 mm polycarbonate with an U-value of 0.9 W/m²K. As this product is not as clear as glass there had to be made windows directly from the inner zone to the outside. In these areas, the gap between screen and insulated wall was minimized to 120 mm. Several properties had to be considered before choosing a specific product:

- **Fire safety:** Polycarbonate is flammable but flame retarder is added to some products. Building several terraced houses under the same screen could be problematic due to fire regulations.
- **UV-protection** is important for this exposed use. The UV-sealing should be durable, mechanical abrasion is a problem because of the combination of high winds, dust and ice particles.
- **Sealing of the sheets** to prevent internal condensation in the sheets
- The **mounting system and the joints** must be able to withstand high wind loads, as the characteristic wind load in Nuuk is 1.6 kN/m² [3].

The chosen product had been used in the Alps, i.e. it was tested in cold climate. There would be a risk of condensation at the screen, so the surface of the inner zone were designed for this.

2.4. Temperature and ventilation in the middle climatic zone

Simulations showed that if the middle zone was not heated, frost would occur. At other times there would be overheating. The specific temperatures would depend on the insulation of the inner zone, the U-value of the screen and the ventilation of the middle zone. If the middle zone was heated to at least 4.9 °C, the area could be more used but have a high energy consumption. It was decided to save energy and not heat the middle zone. To reduce the risk of condensation in the winter and overheating in the summer, large ventilation openings in the floors of the unheated rooms and the gables (see Figure 1 and Figure 2) were installed together with traditional mechanical ventilation of the inner zone.

3. The building process

The building was planned for the Arctic. Nevertheless, the building process revealed problems that were not foreseen, partly related to the new technology, partly to unacquaintance with Arctic limitations:

- The “tent” was intended to act as weather protection during construction. However, the inner building envelope had to be mounted before the polycarbonate layer on those parts of the building where the distance of the two layers was 120 mm.
- The original plan of easy installation of “living boxes” under a tent could not be realised. Instead crane and special tools, uncommon in Greenland, were used. This caused errors and delays.
- The container with specially made braces got lost on its way to Greenland. This delayed the building process considerably. The polycarbonate screen was not closed for the winter and fitting out could not be done under a closed polycarbonate tent as intended. If the building had been designed with standard braces, this would not have happened.
- The flashings between windows and polycarbonate was sheet metal work very different from what is usual made in Greenland. Therefore no local craftsmen were able to perform this job.
- The initial balancing of a ventilation system can always be a problem, and in Nuuk there is a shortage of experts who are able to do this.

4. Lessons learnt

The idea of using passive heat in the Arctic and thereby gain more room with comfortable temperatures and light in spring and fall is appealing. However, when the concept was realised, many compromises had to be made, which also compromised some of the original ideas. The idea of a simple glass tent protecting the inhabitants from the arctic cold, could not be realised; it is still very cold under the tent in the winter. A simple construction that could simply be assembled without use of heavy equipment and small prefab living boxes that could easily be installed under a glass tent, enabling finishing works during winter, were not realisable. Instead more advanced design and products were used. Local contractors were skeptical about the concept. Consequently the bids were very high, partly due to materials and methods being different from the usual building technology in Greenland, partly due to an overheating of the construction business. This highlights that the concept should have been carefully scrutinised by engineers and local contractors in the beginning of the project. At the end of the design phase there was an evaluation process [4] but at that time there were only room for small changes.

This is only a preliminary assessment, for the next two years a family will live in the house. Temperature and relative humidity in the zones and walls will be monitored, energy supply measured and the family interviewed about how to live in under a tent. After that, a new design may be developed.

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