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# Wind engineering in the integrated design of princess Elisabeth Antarctic base

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ABSTRACT

The Belgian Antarctic Base Princess Elisabeth is based on an elevated building on top of sloping terrain and connected to an under-snow garage. The integrated design of the base was supported by wind engineering testing that looked into building aerodynamics (pressure taps) and snowdrift management. Wind tunnel modeling using sand erosion technique allowed efficient evaluation of the snow erosion and deposition around different building-block shapes during the conceptual design phase. Parametric testing shows that the positioning of the main building on the ridge has a significant impact on wind loading and snow erosion and deposition. Important reductions in wind loading and snow deposition can be obtained by elevating the building and reducing the windward cantilever. The positioning of the garage roof can further decrease the wind loading by acting as a diffuser in the back of the building. This study shows that, not only for safety and cost reduction but also for the integration of renewable energies, important benefits in the design of a building can be achieved if wind engineering is considered since the conceptual phase of the integrated building design process.



## 1. Introduction

The concern about Climate Change has significantly increased the interest of scientific research in Antarctica. Coinciding with the International Polar Year (IPY) 2007–2008, three European research bases were designed and have recently been deployed in Antarctica: Halley VI (United Kingdom), Newmayer III (Germany) and Princess Elisabeth (Belgium).

The new stations put in evidence the primary role that the environmental conditions play on their design, especially when higher levels of sustainability and energy efficiency are pursued, as it is the case for the Princess Elisabeth "Zero Emission" research station.

The integrated design process, implemented in the case of the Princess Elisabeth base, aims at making best use of the ambient conditions in the design of energy efficient buildings with the least impact on the environment throughout their lifetime. The use of renewable energies in Antarctica as primary energy source provides more autonomy, minimizing the fuel consumption with the corresponding savings in logistics, $CO_2$ emissions and risks of oil spill contamination.

The extreme weather conditions make Antarctic construction the forefront of Bioclimatic Architecture, with katabatic winds up to 70 m $s^{-1}$ that induce important structural loading; snow drifting that can produce annual build-ups as high as 1.5 m, making accessibility difficult and increasing maintenance works; temperatures as low as −60 °C that induce important heat losses; and very low humidity that increases the risk of fire. Furthermore, the Antarctic environment constitutes an excellent test bench for the demonstration of renewable energies and energy efficiency technology.

All in all, it is evident that building design in Antarctica requires careful consideration of the environment in order to find safe and cost-effective solutions with the least impact on the environment, a key aspect of the Antarctic-Environmental Protocol (1991).

### 1.1. Philosophy of a zero emission station

The Princess Elisabeth Antarctic research station is situated approximately 1 km North of Utsteinen Nunatak, on a small and relatively flat granite ridge (71°57′S 23°20′E, 1390 m a.s.l.), 173 km inland from the former Roi Baudouin base and 55 km from former Japanese Asuka station. The new station occupies the empty space, in the 20–30° East sector, left by the closing of Asuka station in 1992. The nearest permanent stations are Syowa (Japan), 684 km to the west, and the Novolazarevskaya (Russia), 431 km to the east. The nearest coast is some 190 km north.

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The selected site is very convenient as it provides stable ground for anchoring. The station design makes best use of terrain conditions for the integration of the building following a hybrid design. The main building, above ground-level and anchored onto snow-free rock area is connected, with a weather protected bridge, to an adjacent garage/storage building, constructed under the snow surface (Fig. 1). The summer station is designed for optimal use by 12 people with a surface area (living, technical, research, storage) of 800 $m^2$. An extension, based on heated shelters, make it possible to accommodate another 8 to 18 people.

The system design of the station is based on sustainable technology and high-energy efficiency, with full-year monitoring and remote sensing capability. The station aims at being zero-emissions, making use of renewable energy as the primary energy source and integrating passive building design in a comprehensive energy management regime, thereby minimizing the use of fossil fuels. The power budget of the station is composed of 48% of wind power from nine wind turbines, 20% of solar photovoltaic from 380 $m^2$ of solar panels and 12% solar thermal with 22 $m^2$ of solar panels.

The internal layout of the main building is designed with concentric layers around a central technical core, which holds the control systems, the water treatment unit and the batteries for energy storage. Around the technical core, the kitchen and laundry rooms and the sleeping and living rooms are distributed. A substantial contribution to the zero-emissions target is met by having very good insulation, with a stainless steel outer skin and 7 insulation layers in the walls and triple glazed windows. Passive heating is also an important energy saver because it recycles the heat produced inside the building.

The interested reader should refer to the Comprehensive Environmental Evaluation CEE report [1] for a broader description of the scope of the base and its design particularities. A dedicated website (http://www.antarcticstation.org) is also available for the follow up of the station activities.

### 1.2. The integrated building design process

The Princess Elisabeth base was designed by the International Polar Foundation (IPF). An integrated building design approach was followed whereby multiple design disciplines were assembled from the beginning of the project to obtain a highly synergic design that allows optimizing the performance and efficiency of the building. This kind of approach is the state of the art in building design and it is being adopted in singular buildings or building complexes where high levels of energy efficiency and sustainability are pursued.

A key to successful integrated building design is the early participation of experts from different specialties: civil engineering, architecture, interior and landscape design, energy and wind engineering, etc. The early collaboration among them allows finding opportunities at conceptual level that can produce a very significant impact in the final performance and cost of the design.

In the Antarctic integrated building design process, wind engineering (wind and snowdrift assessment) and energy efficiency lead decisions about the optimal positioning, orientation and shape of the building. The integration of renewable energies and operational aspects like the positioning of entrances, emergency exits or snow collection facilities (for water consumption) are also determined after careful assessment of the environmental conditions of the building envelop.

The aerodynamic design of Princess Elisabeth station had three phases: the conceptual design phase, the building envelop design and the optimization phase. In the conceptual phase, the designers had to decide about the optimum building typology by trading off basic design parameters on a number of building-block concepts. Once the basic typology was selected, the building envelope was shaped and positioned on the ridge considering both internal constraints (internal layout and system integration) and external environmental aspects. From the wind engineering point of view, snowdrift control and wind loading had to be tested in order to assess the aerodynamic performance of different building prototypes and ridge integration alternatives. Finally, an optimization phase looked at more detailed elements of the building like, for instance, localized forces on the corners of the building or the integration of the under-snow garage.

### 1.3. Wind engineering strategy

Wind engineering constitutes a crucial aspect in the design of modern Antarctic bases [3]. Not only for safety and cost reduction but also for the integration of renewable energies, important benefits in the design of a building can be achieved if wind engineering is part of the integrated building design process since the very beginning.

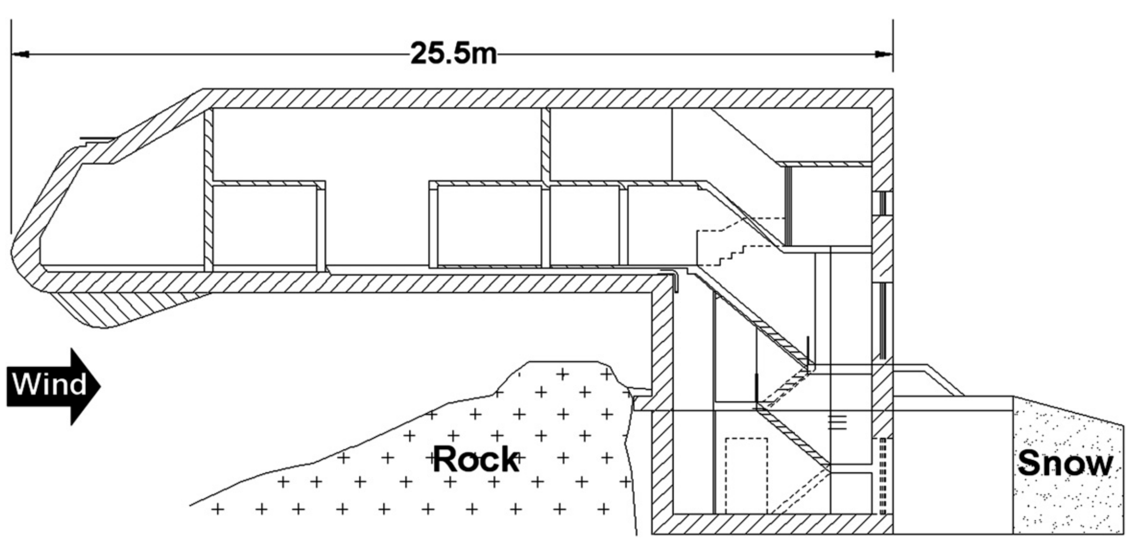


**Fig. 1.** Sketch of the building and its integration in the ridge.