

This review covers building materials, design and construction methods used for 'Bases' in the Antarctic, from the heroic age to today. The main structures concentrated on are Shackletons Hut at Cape Royds, New Zealand's Scott Base and the Australian bases collectively. The review looks over time how Scott Base has evolved with regards to building materials and design and looks at how buildings in Antarctica have changed the way of 'life as we know it'.

To provide an understanding about building in Antarctica I have included a section of Antarctica's environment and considerations that need to be taken into account when designing a building south.

Safety considerations impact on the design of buildings in this environment, therefore I felt it necessary to include a section on this.

1.0 Introduction

Since the first explorers to the Antarctic built huts to seek refuge from the harsh environment, to today as scientist work in laboratories, in which permanent accommodation is provided, there have been many advances in the types of building materials, methods and designs over the time.

The limitations the Antarctic poses with its inhospitable surroundings create logistical nightmares and the extreme weather conditions people and buildings need to endure to create life on the ice, it would seem of high significance to get building structures accurate.

This review aims to interpret written material to provide an understanding of how buildings have advanced since the early explorers.

2.0 Antarctic Environment

The principal features affecting a building are (Icoll, 1980):

- High winds
- Low temperature
- Drift snow
- Melt water
- Abrasive Grit

Key factors that accelerate the decay of buildings include the following (Jackson, 2002):

- High UV and light levels
- High and low humidity levels
- Extreme temperatures
- High winds (katabatic)
- Effects of sea salts
- Penguin guano and moult causing chemical deterioration (at Cape Adare and Cape Royds)
- Environmental threats

3.0 Historic Era

3.1 Building Construction Methods and Materials

The historic huts were built with timber and insulated with a number of different materials.

Borchqrevink's Hut built in 1899 and constructed of interlocking Norwegian spruce boards 5.5 m x 6.5 m. The interior comprises an office/storeroom, darkroom, living area with stove, and 5 double-tiered bunks. Windows were a single pane and insulation was in the form of paper mache (Rubin, 1996).

The Terra Nova Hut built in 1911 at Cape Evans comprised a hut with seaweed for insulation. The design of the hut divided it into a "mess deck" and "wardroom". The "mess deck" was used for living and comprised a stove, the "wardroom" contained sleeping quarters and working space (Rubin, 1996).

Shackleton's Hut at Cape Royds built in 1908 was a prefabricated hut 7 m x 8.5 m. Insulation was adhoc and improved by stacking boxes of supplied around the outside walls and by filling the space between the volcanic scoria. The hut was constructed of stout fir timber from London. It was erected in London and marked for re-erecting on site. Construction began with digging 22 holes for foundations. Galvanised iron was placed along the northern wall to protect the hut from damage by the ponies (Rubin, 1996).

Extra buildings built mainly for storage were of timber construction and generally used canvas for the roof. One store room was built entirely of cases with hammocks sewn together for the roof. This structure blew down after the first strong blizzard.

Foundations comprised timber piles set into the ground, floor joists at approximately 350 mm and a tongue and groove floor. Wires were used diagonally across the roof to provide resistance to wind uplift. A cold porch located on the western elevation had a lean-to roof (AHT, 2003).

Internally, the rooms were not split amongst the men, the sleeping quarters were open, except for Shackleton's own bed was contained in a private room lined with canvas. Each man's bed built was constructed by themselves made from packing cases or petrol

cases and upholstered boards with wood shavings. Some beds were made of bamboo and canvas (Harrowfield, 1981).

3.2 Design

The design of the historic huts were very simple. Generally living, sleeping and working were all contained in the one area. Buildings, as they are today, were still placed the direction the wind would suit with reinforcing used to maintain the buildings strength against strong winds.

Privacy was not high on the agenda during the historic era. Rooms were not separated as quarters were very cramped (Icoll, 1980).

Scott's Discovery Hut design can still be found in rural Australia where it was purchased, with its wide overhanging verandas. This accommodation failed, as it was difficult to heat so instead it was used for storage and repair work. It commonly became known as the "The Royal Terror Theatre" as it was used as an entertainment centre (Rubin, 1996).

4.0 Today's Buildings

4.1 Building Construction Methods and Materials

4.1.1 Scott Base 1957-1970

Construction of Scott Base started on 12 January 1957, approximately 60 years since the first hut had been built in Antarctica. Ponder (the Architect) said the building should be "in first-class order in 100 years' time" (Harrowfield, 1997). Since this time the base has been built in stages, each time becoming more advanced in design incorporating new initiatives.

4.1.2 In the Beginning

The prefabricated huts, built in Melbourne, comprised fire-resistant wall and roof panels with foam insulation and were clad in an aluminium alloy sheeting to avoid water vapour penetration. Steel tension rods were used through the panels and would tie them together. Two huts were made in New Zealand comprising heavier framing, a plywood outer skin, fibreglass insulation and a fire proof inner lining. There were small window each 23 s.m. which were double glazed and in some cases, tinted against snow glare. Refrigerator type doors were set in pairs for each hut with a “cold porch” between (Harrowfield, 1997).

The huts were mounted on rafts of Oregon timber laid on jarrah rail-way sleepers to spread the load evenly over the ground surface, if it was to be on ice, permafrost or rock. Each hut would have a steel rod net over the roof which would be securely tied to anchor rods in the ground. Concrete foundations could not be utilised due to the cold. (Harrowfield, 1997).

The huts were heated by a 6kVA diesel generator for electricity and supplemented using Colman lamps (Harrowfield, 1997).

4.1.3 Scott Base 1970-2003

In December 1970 it was announced that within a decade Scott Base would need to be rebuilt. It was stated that the base would be bigger and better and that before long activities such as gathering ice for the melters would become a thing of the past. In 1973 the planning for the rebuilding of Scott Base took place. The buildings at this stage were not rundown but the maintenance costs has increased. During this time there were approximately 60 people on base, space was stretched, there was limited space to sleep and the mess was cramped and recreational facilities were non-existent. A better water supply and waste system was necessary (Harrowfield, 1997).

Reconstruction began in 1976-1977. A new 2 level prefabricated accommodation block was erected (Q Hut). This was constructed of a steel frame with external steel trusses and columns and had an insulated floor. This time the building was lifted off the ground 1 metre to allow for snow drift, unlike previous structures. This space provided for offices, sleeping accommodation, a library and storage area on the first floor (Harrowfield, 1997). Q Hut is still in use today, mainly for sleeping accommodation for guests, the library is still on the first floor and storage space is utilised but lacks the strength to be utilised as sleeping accommodation. I am aware that this building is planned to be replaced over the next 5 years. Giving a building life of approximate 35 years, out-living the expected 25 years.

A new powerhouse with the capacity of 135 kVA was constructed in 1978-79 along with a reverse osmosis water distillation plant, capable of producing 6500 litres of fresh water daily. The ice melter once used was put aside for emergency use, it was capable of producing 2000 litres per day (Harrowfield, 1997).

The base is heated by a reticulated hot water system which is a by-product from generator exhaust and water-jacked heat-exchangers and supplied by oil-fired boilers. Construction of the new powerhouse comprised steel-clad polyurethane foam sandwich panels that were fastened with nylon bolts to a steel frame which was similar to the cold-store construction. At this point in time a new fire protection system was installed and included automatic heat and smoke detector units (Harrowfield, 1997).

In the summer of 1980-1981 stage 3a was completed. This stage included further sleeping quarters for 43 people and ablution facilities. In 1982-1983 3b was completed comprising alterations the mess building and ablutions was opened and by late December the construction team had completed the shell of stage 4, the Command Block. Stage 5 comprising a 195 s.m. facility utilised for scientific equipment, the Hatherton Lab. Stage 6 began in 1985-1986 comprising a 1,000 s.m. extension to provide areas for workshops carpenters, electricians and base engineers and a mechanic shop for the emergency power plant. The final stage, stage 7 comprising the vehicle workshop and storage facility was

completed in 1986-1987. The construction of these stages used a steel rod bracing system rather than the previous guy ropes used (Harrowfield, 1997). Guy ropes are no longer used for the construction of the Australian bases (AAD, 2003).

The 135 kVA generator was upgraded in 1986-1987 to 180 kVA (Kestle, 1999/2000).

4.1.4 Construction Details

Foundations

At Scott Base between 1957 to 1999 Oregon rafts on Jarrah sleepers were used, this has since changed to Pinus Radiata jackstuds and bearers set in 1.5 metres into the ground using 'Antarctic concrete'. This does not incorporate cement but uses gravel, water and steel reinforcing rods. Concrete was however used in the foundations of the heavy workshop. The concrete contained air entraining agents for ease of transport and placement. (Kestle, L. 1999). By contrast the Australian bases use reinforced concrete (Icoll, 1980).

When Q Hut was built it was placed on steel stilts. This method of construction proved to be time consuming, subsequently an alternative was designed to have buildings on timber poles to allow for snowdrifts. Timber meant that due to the contour of the land the foundations could be easily adjusted and therefore save time (Mitchell, 2001).

Framing

Framing over the construction of Scott Base changed from timber to steel comprising a series of external lattice trussed portal frames when Q Hut was built, the internal comprised timber floors. After Q Hut steel lattice trussed were still used but rather than a hollow web a solid frame was used. Steel joists, cleats and girts became the norm. (Kestle, L. 1999). Australian bases also use steel in a very similar manner (Icoll, 1980).

Claddings

Cladding material used at Scott Base were originally constructed from plywood in 1957, when Q Hut was built, 200 mm thick prefabricated panels, clad with plywood and lined with Gibraltar board were use. These had a polythene vapour barrier behind the Gibraltar board to prevent water vapour. The panels used for Q Hut were difficult to work with as they were heavy to transport and provided limited insulation. Since the construction of this Hut, further buildings have been designed to be lightweight built with cool-store type panels. These are easily handled and do provide effective and reliable thermal insulation (Mitchell, 2001). These panels were used for the development stages that followed, Stage 2 to Stage 7. The panels used polyurethane foam exterior with steel sheet facings. The most recent building built, the abolitions in 1999, comprised polystyrene insulation due to the previous polyurethane no longer being produced in NZ. The polyurethane foam provided greater insulation than the polystyrene and the difference in thickness of 150 mm required of polyurethane as compared to 250 mm required of polystyrene to provide the equivalent insulation (Mitchell, 2001).

Australian bases have used a number of materials over the years including plywood, asbestos cement with a spray to provide protection from flying grit, to aluminium and fibreglass. In 1980 the norm was a polystyrene core faced with zincalume protected steel (Icoll, 1980).

Joinery

Scott Base joinery used has changed from timber framed double glazed windows to triple glazed. Doors are specified to be 150 mm thick polyurethane steel clad refrigeration doors with quick release handles (Harrowfield, 1997). Australia use triple glazing with a P.V.C exterior (Icoll, 1980).

Internal Linings

Scott Base internal linings comprise standard 9 to 12.5 mm gib board with a 1.5 to 2 hour fire rated thickness, these have been used since Q Hut was built. Before this chipboard was used, over time this material shrank causing squeaks (Harrowfield, 1997).

4.1.5 Australian – Davis Base

Buildings at Davis were installed in the late 1970's and early 1980's. While comfortable inside, they are little more than steel frame sheds with insulated cladding (Icoll, 1990).

The new construction of Davis (1991) used experimental materials. The amount of glass was significantly greater than previous. Triple-glazed windows are positioned along the building away from prevailing winds and across the roof. Windows are filled with argon, an inert gas that won't allow the transfer of heat (Icoll, 1990).

The exterior construction comprises walls of resin-bounded material, made of fibreglass, carbon and Kevlar and an end grain plantation balsa wood core with fire-retardant internal lining (Icoll, 1990).

Since this reconstruction Davis is now being considered again for redesign. Details follow under design considerations.

4.2 Design

When designing a base factors affecting human condition need to be taken into consideration, these can be categorised into the following: (Futamui *et al*, 1962)

- a) all the functions required for living
- b) items concerning the mentality and morale if the base members
- c) the independence and privacy of individual rooms

- d) considerations for community rooms as collective living
- e) considerations for monotony and variations in living

In designing a base transportation costs and ease of erecting buildings both need to be considered. There are limited hands to help out in these areas and are therefore critical to the development of the base. There is no craneage and minimal scaffolding is allowed for (Kestle, 1999/2000).

4.2.1 Scott Base

The base was provided from prefabricated huts broken down into compact components that would fit into the hold of a small ship. The base was designed in a series of six huts connected by covered walkways. (Harrowfield, 1997)

The huts contained:

- mess, radio room and Leader's office (A Hut)
- scientific hut with laboratory and darkroom (B Hut)
- large sleeping hut with 14 individual cubical (C Hut)
- accommodation hut with 6 bunks in separate cubicles and medical room (D Hut)
- ablutions and generators (E Hut)
- work shop containing generators (F Hut).
- 2 smaller huts (G and H Huts) containing 2 magnetometers and 3 seismographs.

The huts were designed as refrigerators in reverse. They were separated as a precaution against fire but connected together by a covered walkway made of rolled corrugated iron. In the "cold porch" of each hut there was a fuel cabinet and a thermodatically controlled electric-fired, oil burning Waterbury heating unit with a Coleman stove as a standby plant. The huts were linked by telephone and a general alarm system. (Harrowfield, 1997).

Six 6kVA generators would provide power for the lighting and heating, while a system of cold and hot air inlets and outlets would be used for three 1350 litre ice-melters. (Harrowfield, 1997).

Plans were made for a light weight hanger but did not eventuate until further down the track in 1958–1959. (Harrowfield, 1997).

The hanger was constructed from 6 steel portal frames and a plywood batten exterior. The building was then recladded in the late 1980's with a lightweight steel ribbed panel cladding (Harrowfield, 1997). The hanger is currently being used for storage of field gear. Construction was underway to replace this facility.

The reconstruction of the base in 1976-77 provided some highly initiative designs, one including the holes in the fire stop doors to enable the fire fighter to place the fire hose through the door rather than smashing down the door. (Harrowfield, 1997).

The aim of this redesign was to "...design a base that provided safety and security in an extreme environment as well as comfortable living and working space for the people living there" (Mitchell, 2001).

A change to design when stages 4, 5 and 6 were included allowed more flexibility and possible future usage. Unlike the Mess buildings these stages were built with independent internal portal frames in the transverse direction. This meant that the removal or alteration of internal partitioning would be carried out without affecting the building's structural strength (Mitchell, 2001).

4.2.2 Australian - Davis Station

Australian Antarctic bases have made a leap forward and have come up with a space-age design to provide a home away from home on the ice. An Australian architecture firm, Allen Jack & Cottier designed a building simple enough to be built in four weeks, small

enough to fit into a six metre long shipping container, cost effective and “of its time”. The design accommodates up to 130 staff over the summer and cosy enough for the 20-30 winter over residents. The space includes all indoor recreational and social facilities – kitchen/dining areas, coffee bars, library, museum, theatre and more (Croaker, 2003).

The base leader describes the present design at Davis as being friendly, cosy and functional. In summer, the living conditions are “woefully inadequate”. Problems occur with limited space to get people through the mess so others can eat quickly after finding a seat. “The other facilities are crowded and not too functional”. The kitchen is cramped then and it is arguably even hazardous. It is facilitating the summer months that derived the decision to need larger living quarters (Croaker, 2003).

To come up with the perfect design the team of architects analysed every conceivable building type, structure and material that could handle the Antarctic conditions. This process included detailed analysis of objects including an egg, Esky, tent, igloo the space shuttle, a jumbo jet and an Americas cup hull (Croaker, 2003).

Final drafts of the Davis reconstruction project show a two storey, 800 sqm house, featuring every high-tech creature comfort within a smooth exterior of soft curves and large areas of glass. This smooth, slim design has resulted in providing the buildings thermal and acoustic insulation, and the compressive and tensile strength required to carry the required structural loads (Croaker, 2003).

This new building was to be completed over the 2003 Christmas, in which rigorous testing of the structure of the structure and materials will follow before construction goes ahead before the following summer.

The new building at Davis will become the hub of activity for residence, allowing living quarters to be redesigned as sleeping quarters, the original quarters will be demolished.

It has been said that this new design will be of particular interest as it is quick to assemble, gives the opportunity to put together larger scale building in a short time with a small crew. It is flexible enough that it has the potential to be used for a range of purposes across Mawson, Davis and Casey stations. An aim of this design project if it proves successful is to adopt the system for use as field huts (Croaker, 2003).

Since this article the modular design has received an Innovation Award from the Royal Australian Institute of Architects in 1986 (AAD, 2003).

4.2.3 McMurdo and South Pole

Designs of America's base on Ross Island originate from Hawaii. The question has been asked, what are Hawaii architects doing in Antarctica? The answer to this is simple in that both Hawaii and the Ross Island are volcanic islands. This team from Hawaii have produced structural designs and snow studies. As a result, they came up with innovations like the 45 degree angle between floors and walls that would let the snow blow under buildings instead of burying them (Taketa, 1992).

A major problem with the South Pole base is the limited amounts of fuel and diesel used. Study is being carried out to harness the 24 hours of sunlight as a source of energy. This study is also being carried out at New Zealand's Scott Base.

The new South Pole station will replace the current dome (20 years old). The new design concepts of the base incorporates plans for self-supporting food supplies, closed-loop waste disposal systems and new sources of power generation (Taketa, 1992).

4.2.4 Italian – Concordia

The Italian station Concordia is Italy's latest construction development. This is made up of two, with three floors each, cylindrical buildings that are joined by a sheltered passage. The structure is supported by 6 large iron feet and is elevated 14.5 metres above the ice.

surface. The design of the structure allows for one “noisy” space and one “quiet” (PNRA, date unknown).

4.2.5 Other buildings

Australia is looking at a building that is a portable inflatable shelter. This would allow for temporary accommodation that is easily transportable and required little man power to assemble. The construction of these designs consist of an inflatable envelope made of rigid polyurethanes which are sprayed on after inflation, or a high pressure inflatable that consists of a fabric cover supported by tubes which are inflated. One limitation to these designs is that the building would need to be erected on snow or ice, soil or rock has not been seen as a requirement (Green, date unknown).

5.0 Safety Considerations

The main threat to buildings in the Antarctic is fire. This is because water is difficult to obtain in the freezing conditions and therefore makes it difficult to fight fire. Detection and control systems become vital in this environment. All habitable buildings have fire warning systems such as smoke and heat detectors. Part of Mc Murdo is fitted out with sprinkler systems. Buildings are also split up into sections to isolate fires. Georgian wired glass panels in the doors are used for fire safety (Harrowfield, 1999). Scott Base is fitted with heat detectors and fire hose reels (Kestle, 1999/2000).

Other issues include snow drift driven from wind. This can potentially cover and obstruct doors, windows ventilators and potentially burying buildings. To overcome this the building and its placement need to be considered and orientated away from the direction of the prevailing winds. This snow drift can also create havoc to small openings in the structure, therefore any flashings and cavities need to be effectively covered with elaborate precautions taken place.

The buildings had not been specifically designed to be earthquake proof as there had been no earthquake activity yet but it is understood that some seismic resistance was incorporated. The main concern for this being the wind load (Kestle, L. 1999/2000).

Humidity can also create problems for building structures. Scott Base relative humidity (RH) inside ranges between 15-30% hence static electricity is a problem and the potential of warping of timber framing. Using steel mitigates this problem. (Kestle, L. 1999/2000).

6.0 Conclusion

Since the heroic era both building materials and design have changed. The method of construction though, is similar in that erecting buildings is limited by numbers of people. It is of significance that prefabricated buildings are still being used. This seems most appropriate for the situation.

Building designs have changed greatly with more emphasis of making a pleasant working environment or a “home away from home”. This could be contributed to the changes in society from the bases motherland which has then reflected through to their needs on the ice. After reviewing the literature it was noted that there has been continued emphasis on the “hub” of bases when they are designed. This is the area where base staff spends their spare time and it important to get this area adequate for the base to keep up morale.

Gone are the days of using seaweed and paper mache for insulation. Since using foam and fibreglass, buildings have become more advanced. Commonly sandwich type materials are used with the theory of making a freezer inside out.

Timber is rarely used for the exterior construction cladding, as it was once the only material that was used. New materials are lighter weight allowing lower costs to get to the Antarctic and logistically easier to construction with limited numbers of people.

Precautions have been taken to prevent fire and now new more environmentally friendly means of sourcing energy and getting rid of waste are of high importance.

Buildings are now built off the ground, where as the huts had not given the consideration of snow drift little thought. Steel structural framing has become the norm and guy ropes are no longer required.

Areas of this review that lacked written or varying material included New Zealand's Scott Base. I could not locate a study of building materials in the Antarctic from New Zealand. The Building Research Association New Zealand (BRANZ) carries out Government funded research on building materials in New Zealand. There may be some requirement that a similar research program be undertaken in Antarctic. From my visit I did find a testing site near Cape Royds, of different timbers and how they perform in the Antarctic conditions. I understand that this test is carried out primarily for the restoration of the historic huts.

My understanding is that reducing the "footprint" of bases is a concern. From reviewing the literature this issue was not commented on.

Another issue that lacked written material was with the design of sleeping accommodation. I could not find any discussions providing the common design of using two per room. There was nothing stating that this is the best method or if it was necessary to provide more privacy for base staff. From talking to Scott Base staff this was one of the concerns and it seemed that this issue can be the cause of problems in such a confined space.

I understand that Scott Base does not have the facility to shut down half of the base over the winter period. I was interested in finding out any written material on this matter but unfortunately nothing turned up.

Finally, buildings have changed over the period from the historic era. The future development of the bases will be interesting since Australia has designed the new modular buildings. Where Scott Base will be in the next 20 years is a thought provoking topic and before future plans are made I would feel it necessary for New Zealand to carry out materials testing and take onboard some designs of other bases, such as the new Australian design. With buildings being produced from space age designs such as America Cup boats, who knows what the buildings will look like in another 60 years?

7.0 References

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