The Extreme Climate Housing of KST-Hokkaido

JAMES WASLEY
University of Wisconsin-Milwaukee

My ancestors had to endure harsh winds and snow in a remote village in Kanazawa, Ishikawa Prefecture, more than 100 years ago, and considered how to be independent during winter.... For the past 100 years [my grandparents and parents] made use of winter, which was regarded as a nuisance, rather than challenging it, and nurtured a harsh winter as a precious asset.... I take it as my destiny to ensure a sustainable, independent Hokkaido through the development of winter.

— Akira Yamaguchi
Founder and President, KST-Hokkaido

INTRODUCTION

This paper reports on a visit to the corporate headquarters of KST-Hokkaido, a unique housing manufacturer located on Japan's northernmost island. The visit was made possible by Professor Jack Spengler of the Harvard School of Public Health. Professor Spengler's chair is endowed by KST Hokkaido, and this three day visit of four researchers from the U.S, Denmark and Sweden was one of many that he has led, providing KST with both international exposure and critical feedback on its goals and operations.

KST-Hokkaido is unique in its commitment to environmental sustainability. This is seemingly the result of company founder Akira Yamaguchi's 'bioregional' vision for the company. This vision is rooted in and celebrates the winter conditions of the island, which he calls "Hokkaido's largest untapped regional resource." While there are many aspects of Yamaguchi's bioregional philosophy and work, this paper will limit itself to the adaptation of the typical KST house to the extremes of Hokkaido's winters.

THE HOUSING OF KST-HOKKAIDO

KST-Hokkaido is a family owned business founded by company President Akira Yamaguchi in the 1950's and headquartered approximately an hour east of Sapporo, the largest city on the island of Hokkaido. In 1995 the company employed 1,300 people and built 800 houses per year.

While I do not have the perspective on Japanese housing production to put KST's operation into context. the business is striking in its vertical integration. Timber from the island is milled, dried and made into housing at the KST factory. The housing is built using a unique panelized system based on traditional Japanese heavy timber framing and joinery. KST also manufactures interior finishes and furnishings for their houses, and is moving towards a goal of using only Hokkaido based natural resources. Fittingly, they are given the name 'Kinoshiro' or 'wooden castle.'

KST's Kinoshiro houses are seemingly indifferent to context in their blocky modernist articulation, though that aspect of their aesthetic does not appear to be much different from the bulk of contemporary housing in Japan. What is absolutely astounding about the houses is the level of craftsmanship that they achieve within. This craftsmanship is dedicated to traditional Japanese forms and details, reinforcing the philosophical commitment of the founder to preserving traditional culture.

Hokkaido is prone to earthquakes, and the design of these houses could also be seen in light of this 'extreme' environmental force. The ground floor construction is in all cases a heavily reinforced monolithic concrete box that is intended to provide a stable platform for the wood frame construction above. The traditional heavy timber framing is similarly justified in reference to earthquakes, and much of the exquisitely crafted built in furniture is justified on the grounds that it does not tip over.

HOKKAIDO'S WINTER CONDITIONS

Hokkaido is located between 41 and 45 degrees North latitude and has a climate that is typically compared to northern Europe. On our January visit to the island, our Swedish team member commented repeatedly on the similarity between the landscape that we saw and that of rural Sweden. Annual average temperatures in Sapporo, the island's largest city, swing from approximately 20F in January to 80F in August. Presumably, temperatures are much colder throughout the mountainous interior of the island. Average precipitation rates vary from approximately 30 inches/year to 60 inches/year across the island, with much of it falling as wet snow that tends to pile deeply on buildings. KST literature claims that over much of the island, total snowfall can be up to five meters, or well over 16 feet. Unlike other parts of Japan, the island does not have a rainy season, but is characterized by high humidity year round. Average relative humidity hovers between 70%-80% all twelve months of the year. Reflecting this fact, winters tend to be overcast, something that we experienced first hand.

KST-Hokkaido's bioregional philosophy is grounded in the need to build appropriately for these conditions, and much of its rhetoric appears motivated by a love of the Hokkaido landscape and climate. This is not at all surprising- the island is far less developed than the rest of Japan, and widely regarded as home to Japan's most spectacular natural landscapes.

RESPONDING TO WINTER

Four Season Construction Responding to this harsh climate effectively would appear to be what has made KST an extremely successful commercial enterprise. Their literature repeatedly mentions KST's research into the 'unexploited possibilities of winter,' in terms of expanding production capacity, in terms of regional job creation, and in terms of marketing. The most striking aspect of this is their method of construction, which is credited with giving the company a distinct edge on the island. This system involves both a factory based panelized construction system and a method for erecting the concrete first floor structures under tents during the winter months. An additional technological edge related to winter construction is the use of specially modified trucks that use the heat of their exhaust to keep sand and water warm during cold weather plastering.

According to KST's literature, they are "the only housing manufacturer in Hokkaido to successfully develop a technology for performing construction work in winter," a long and otherwise idle period on the island. This factory based production was apparently developed throughout the 1960's and 'year round construction' fully introduced in 1976.

External Form

The massing of the Kinoshiro house varies little from smaller to larger plans. The basic form is a compact, rectangular three story volume, with the first floor constructed of reinforced concrete and the upper floors wood. The rectangular volume becomes articulated to a limited extent in the larger models, but they all can be thought of as simple to build forms with minimal exposed surface area.

The second consistent feature of the plans is the addition of continuous second and third floor balconies on one or two adjacent faces of the plan and vertical fin walls that project from diagonal corners of the plan to bound these balconies. The balconies are associated with sliding doors, which relate to the communal rooms and are oriented to the south, making the building form ideally configured for passive solar heating. The vertical fins are themselves described as wind blocks, working to enhance the microclimate created on the porches. The porches can also be seen as a way to provide easy access to much of the exterior of the building for maintenance purposes, a reading that is consistent with other expressions of concern for durability and maintainability.

Fig. 1. Early large KST house design, possibly 'Elm' model. Note the monolithic concrete base, balconies and wind breaks.

The most striking feature of the houses' external form are their inward draining, low slope metal roofs. This 'slip free' roof system was first built by KST in 1960, and is one of the signature innovations of the company. This roof is explained as a solution to the problem of snow drifts on traditional sloping roofs, which are said to lead to many deaths and accidents due to people falling from roofs while shoveling drifting snow. In addition, pitched roofs on tight urban lots are shown creating mountains of snow packed between buildings in ways that lead to structural or moisture damage. The KST roof design, in contrast, is relatively flat for safety and drained internally to avoid directing snow between structures. On some or perhaps all models it is accessible through a ladder that extends from a balcony through the overhanging eave. It is described as being made of 'ultra-high-durability galvanized steel, and is treated as a 'cold roof.' built with a large vented cavity between the roof surface and the line of insulation in the ceiling below.

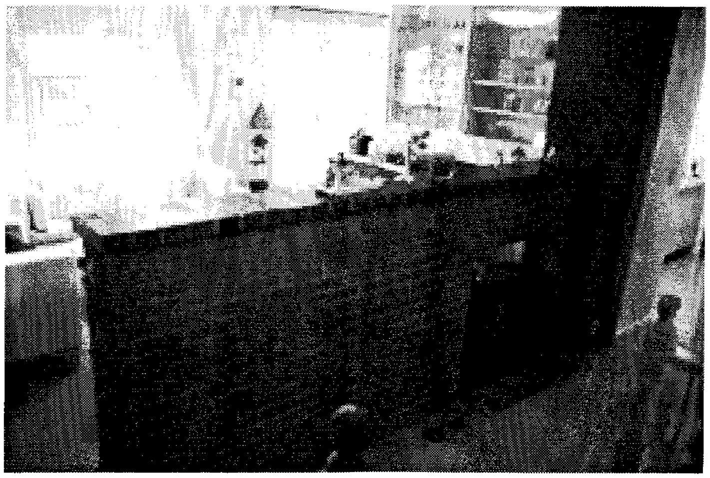

Fig. 2. KST Museum exhibit photograph of typical low slope roof.

The Building Envelope

The wall system of the KST Kinoshiro house is worthy of the title 'wooden castle.' As they claim in their promotional literature, the houses use three to five times as much wood as a conventional house would use. The typical wall section is composed of 12cm (approx. 5″) square posts approximately six feet on center, mortised into beams using traditional wooden joinery, and stiffened with diagonal bracing. Between these posts, approximately 1″x4″ vertical studs are centered and strapped on both faces with horizontal members of similar dimension, bringing the infill panel dimension out to the post dimension.

Where the heavy timber framing is constant, there are several different versions of the secondary wall details shown in different sources. In all cases, the cavities between the vertical 1x4's are filled with fiberglass bats, which are foil faced on the interior to provide a vapor and radiant barrier. In the promotional literature, the exterior of the bats is shown faced with a porous plastic film as an infiltration barrier and sheathed in a single layer of plywood, a layer of tarred felt, and a metal cladding system. The cladding system is itself insulated, consisting of an approximately ..." thick core of isocyanurate clad in aluminum and designed as interlocking vertical panels formed to stand proud of the sheathing. In the museum mock ups, the insulation is un-faced on the exterior, sheathed in two thin (approx. 1/4 or less) layers of plywood separated by another system of approximately 2x2 sleepers, and sheathed in the same insulated metal cladding. One way or another, the emphasis is on multiple layers better managing heat and moisture movement through the wall.

The Window System

The custom manufactured sliding window/ door system used throughout exhibits the same emphasis on layering as the wall system. The assembly consists of two wooden sashes containing insulated glazing and a third single pane aluminum sash as the exterior layer. This creates what KST describes as a 'three layer, five pane window.' There are no low-e coatings and no inert gasses used in the insulated glazing units. The wooden frames and sashes are beautifully made to key together and seal well, but do not employ added gaskets. KST's primary concern in developing this system has been to eliminate condensation and drafts.

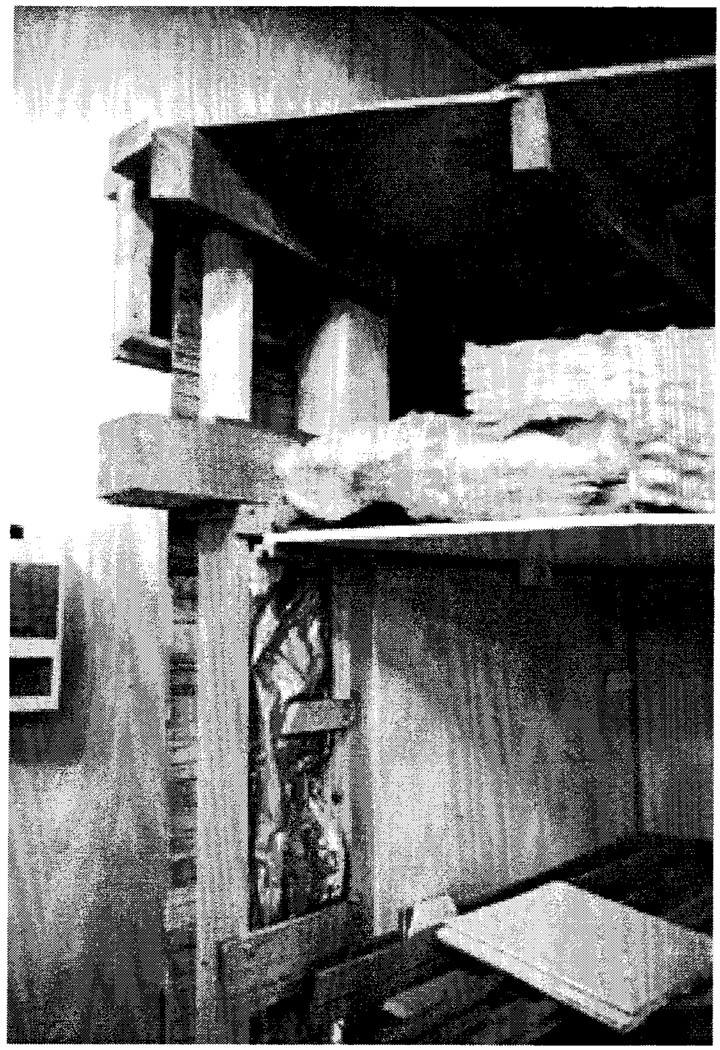

Fig. 3. Construction mock-up Factory floor version. Wall/roof framing.

Heating and Ventilation

The heating and ventilation strategies of the Kinoshiro houses are as interesting and as challenging to the sensibilities of our team of indoor air quality experts as the construction of the shell. The houses are heated with a central kerosene stove built into a large masonry labyrinth known as a traditional Siberian Petchka. KST literature marks the introduction of this 'ultra-energy saving Petchka' as 1960, and claims that the masonry mass of the Petchka captures as much as 60% of the heat of the stove. Promotional literature also alludes to the ability to now capture most of the remaining 40% of heat that escapes through the chimney, but it is unclear what technology would be used, as the use of mechanically powered heat exchangers was dismissed by KST's chief architect as discussed below. It is worth emphasizing that there is no ducted air distribution through the house. True to the traditional logic of the Petchka, heat is distributed through the compact volume of the house radiantly from the masonry mass surrounding the stove, which occupies a central position in the plan. In addition to this, heat rises through the generous open stair, another constant feature of these houses.

The question of ventilation goes hand in hand with heating in this extreme climate, and KST makes an issue of the structural and indoor air quality problems caused by moisture in conventional construction on the island. As noted above, much of the elaborate layering of the building envelope is aimed at preventing moisture related problems. Given this, it was surprising to our group then that KST expressed a dislike of mechanical ventilation, and that the primary method of allowing for fresh air is instead the penetration of the building envelope by small vent tubes apparently mandated by Japanese building code. These approximately 3" diameter passages create a direct connection between inside and out. They are hooded and screened on the exterior, and on the interior covered by small, hinged, insulated covers. The spacing is unclear, but they are located high on the wall in both the large common rooms and in the kitchen and bath. Accordingly, there is no bath fan. The kitchen range hood is the only fan used in the houses, and this fan is vented to the exterior. The use of vented range hoods is apparently not required by Japanese code, but is customary in Japanese hosing.

Critique and Questions for Further Research

First impressions of this remarkable extreme climate housing are inseparable from first impressions of contemporary Japanese Housing in general. As a group, we were visiting Japan to attend a conference on indoor air quality problems, which by the evidence presented can be as bad or worse in Japan as you could find in the United States. Apparently, much contemporary Japanese housing is very poorly built, with many of the same flaws that we see here, related to inadequate moisture control and the use of toxic building materials in tightly sealed environments.

More striking is the impression that there is a cultural predisposition to assume that housing will not last longer than a generation, and that the ideal is always to build new. Several of our hosts claimed that there is little or no market for existing housing in Japan- that people would rather tear existing

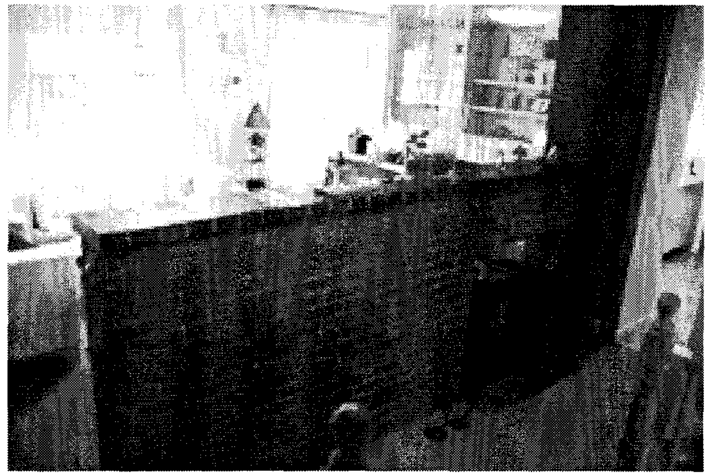

Fig. 4. Masonry Petchka with kerosene stove. Note flue clean-out covers at far left end of masonry wall.

structures down and start again. This may be explained by the poor quality of the aging post war housing stock, or it may reflect deeper biases towards the new and hygienic that seem so powerful to the outside observer. Regardless, this context puts the values expressed in the KST houses into sharp relief. These structures have been honed over the forty year life of the company to be durable in extreme conditions, and to last for generations.

The overall forms of the Kinoshiro houses are very strongly related to the severity of the climate. They are rigorously efficient, compact forms that both minimize exposed surface area and create buffered micro-climates around the building. Only the low-slope roofs drew any discussion from our group, and this was quite agitated, with both the Swede and the Dane shaking their heads in disbelief that a flat roof would be a valid solution. Their concern was that the roof would in time fail and lead to moisture related problems in the house.

I also find the roof a fascinating question, though I am much more persuaded by the documented record of KST's experimentation with variations on the design through the 1960's, and with their exclusive commitment to the approach since 1970, meaning that many such roofs are now over 30 years old. While the documentation we were presented was in the form of a company history exhibit and not a research report, photographs clearly show features such as the size and design of the internal drain being altered over time. The fascinating question for further investigation is the role of the form in minimizing problems with drifting snow, the expressed reason for the flat roof design. Does the flat roof actually influence wind patterns to create less drifting? Is the drifting simply contained or directed to less problematic places? Or is the roof simply safer to work on while shoveling the snow off? KST would claim all of the above. The idea that the form responds constructively to the extreme demands of the climate is worth understanding in depth.

The wall system and what it suggests about the entire building envelope is equally intriguing. The fact that the traditional joinery of Japanese temple construction has been mechanized to construct timber frames that are then concealed within the walls is truly amazing to someone accustomed to the inelegance of western construction practices. Leaving aside the claim that this structure is earthquake resistant (and also presumably better able to deal with extreme snow loads), the system raises many questions in terms of thermal performance.

While the timber frame creates thermal bridging and displaces insulation, the amount of effective insulation seems, on first impressions, to be equal to or better than a conventional 2x6 wall. The insulated cladding probably assures that this is the case. The more interesting question is how the system addresses air and moisture movement.

Given the panelized construction and timber frame, the aluminized plastic vapor and radiant barrier is discontinuous at the posts. It is installed with the inside layer of strapping between it and the inside wallboard, which makes it impossible to make continuous as a vapor barrier but does separate it somewhat from the wallboard, enhancing its function as a radiant barrier. It also is somewhat protected by the strapping and protective of the insulation in this position, given that the wall panels are transported and erected without an interior finish layer. Finally, the factory controlled conditions and the high level of craftsmanship seemingly insure that even though the barrier layer is discontinuous, both it and the insulation are very well fit, so that large passages where bulk air movement might occur are minimized.

Another potential flaw in the system that begs further investigation is how the pieces fit together on site. It does not appear that any special material or detail is used to seal the joints between panels, a traditional weak link in stick framing. On the other hand, the timber frame concept leads to the floor structures being constructed within the insulated envelope rather than penetrating it as they do in platform framing.

A final question about the wall system concerns the insulated metal sheathing. On the one hand, the isocyanurate insulation could add significantly to the R value of the wall. On the other hand, these panels are faced front and back with aluminum, creating thermal bridges through the isocyanurate at each joint and placing a vapor barrier on the exterior face of the building, exactly where it shouldn't be. On closer inspection, the panels are shaped so that they create a gap between their back face and the building paper. Is that cavity vented enough that it doesn't become a potential condensation point in the assembly? And does it in fact provide any insulation value if it is vented?

Similar products exist in this country, but I am not aware of any clear consensus on their wisdom.

The sliding window/ door system, like other features of the Kinoshiro houses, seems over-elaborate and limited in its technological sophistication to North American eyes. Gas filled, multi-layer, low-e coated glazing units can certainly achieve similar or better thermal values, with higher visible and total solar transmissivities. At the same time, the five layers of 3mm glass did not seem noticeably obscured. Hypothetically, one could argue that there is a strong argument to be made against the use of sealed glazing units at all, because of gas leakage and because replacing a broken unit means replacing both panes of glass. On this score, the KST windows do not go far enough in the opposite direction- they don't employ coatings or gas fillings, but they do use insulated glazing units. More surprisingly, the glazing appears to be set within the solid stock rails as they are built, so that replacing a broken unit would mean replacing an entire sash. The question in this case is whether having fewer pieces and no applied seals or gaskets means better durability over the long haul?

The Petchka as a heat source brought out differences between the European and American members of the party. By its nature, the center of the house is warm and the sleeping rooms colder. This pleased the Europeans and seemed quaint to the Americans. In truth, the guest house that we stayed in was well enough insulated that the entire house was quite pleasant, and the radiant warmth of the masonry combined with the visible flicker of the flame was a true luxury that made the American preference for invisible uniformity seem odd. From a technical viewpoint, one might wonder about the potential for combustion gasses to be introduced into the dwelling through the labyrinthine masonry flue.

The Petchka also plays a role into the ventilation of the house, as it is drawing combustion air from the house continually. Here it appears that the pieces of the puzzle fit together very well as a whole. The window system, which prevents condensation *in spite of its leakiness*, appears to assist in providing a path for make-up air. The fact that KST does not use any mechanical fans to vent the bathrooms or kitchen at least means that there is no competing draw out of the building to cause back-drafting of the Petchka. Even the dryer, in the model we stayed in, was a vent-less washer/ dryer combination unit.

This still leaves many indoor air quality questions unresolved in this extreme climate. In particular, the group had deep reservations about the passive ventilation of the bathing area. One wonders why large icicles weren't dangling off of the open vent ports, or how efficient the insulation of the building shell really is when it is filled with so many direct openings to the exterior.

My guess is that the answer to these questions, and to the overall fitness of these remarkable structures to their extreme environment, is that they are not as efficient as they theoretically could be, but that they are, in fact, far more fit than most. What this speaks to more than anything else is my sense that they are so well built and so thoroughly proven that they work as designed, unlike much of what we might consider more 'sophisticated' examples. It is interesting to ponder how more efficiency could be achieved with subtle changes, and how many questions still remain after our brief but stimulating stay. What remains vivid in looking back is the way that these pragmatic design components all work together to create architecture that really does capture something archaic and deeply satisfying about winter.

BIBLIOGRAPHY

"Creation of Sustainable Society and Bioregional Housing Systems" KST Hokkaido International Environmental Institute brochure. Contact 3-2, Kita 39, Nishi 7, Kita-ku, Sapporo 001, Japan.

"Fuyu Soken 21" Winter Research Institute Corporation publication. (contact same as above.)

For more information about KST-Hokkaido see: *http://courses.dce.harvard.edu/~environment/kst/KST-1.html*