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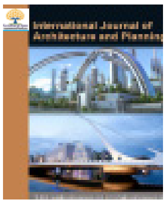

Research Paper **Open Access**

Thermal Performance of Yaranga Style Vernacular Architecture in Chukotka

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Abstract

The indigenous people of Russia's Chukotka Administrative District have their own unique heating system, and this short paper details that system along with other standard elements of construction practice, such as the dimensions and spatial properties of yarangas and how they're put together. The organization of the home's internal space and its typical use is given careful thought. The article explains how to create a warm and pleasant environment within your home. The results of experimental studies into the temperature of the air within a yaranga during normal operation conditions, as well as the results of research into the energy barrier resilience of the insulating walls. Through practical laboratory and field study, we were able to determine the amount of heat lost by the insulating structures both inside and outside of a yaranga, and so compute the simulation of a yaranga.

Keywords: *Thermal performance, Insulating structures, Yaranga style, Vernacular architecture*

1. Introduction

Modern architects are needed to design suitable residential buildings for transpolar Siberian and Far Eastern cities as a result of the discovery of new mineral deposits and the industrial expansion of locations with harsh outside temperatures. While undoubtedly important, using cutting-edge tools and materials is only one facet of developing cutting-edge dwellings in the Far North. The indigenous peoples of this area have thousands of years of experience in construction, which is also very important. Current industrialists may benefit from studying and reconsidering this experience in order to better use available resources.

In instance, "a building with effective use of energy" emerged as a new area of scientific research in construction throughout the 20th century. This paper quantified, detailed, and analyzed the years of expertise the indigenous Chukotka AD people had in energy-efficient domestic building, which may be applied to the present practice of space organization and energy resource preservation in residential construction.

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It is common knowledge that there are no suitable woods for use in climate control in the Chukchi residential region. Energy shortages compelled the Chukchi to adopt energy-saving practices and modify their dwellings. That's why we base our findings on what they've really done in the field.

2. The State of the Issue

At the end of 20th century, Nabokov and Easton (1989) researched indigenous North American vernacular architecture. Simultaneously, a large team of Russian specialists studied the traditional construction practices of Siberia. Sokolova (1998) conducted several anthropological studies of traditional Siberian dwellings. Prior studies mostly concentrated on typological issues and a little bit of structural architecture. Climate science should have been included in this investigation.

In 2006-2007, Oliver started exploring the subject of maintaining an acceptable atmosphere in traditional dwellings. At the UOC, Zhai and Previtali (2010) did extensive study on vernacular architecture based on energy efficiency and feature categorization. From 2010 to 2013, Hom B. Rijal and his colleagues investigated the important topic of traditional Asian architecture. Vernacular architectural heat preservation practices in cold climates have been studied by researchers.

Vernacular architectural climatology places special emphasis on providing relief from the heat. Fernandes *et al.* (2014) did research in Southern Europe, Sakhare and Ralegaonkar researched indoor environmental quality indicators and proposed a measurement tool for vernacular architecture study. Kimura (1994) did some fascinating studies regarding how to modernize historic structures. Indigenous construction methods from throughout the globe may benefit from this knowledge.

3. Climatic Geography

It is Russian autonomous okrug in 66°40' N 171°00' E in the Far East. It's climate is characteristic of the extreme northeastern terminal of Eurasia, where two oceans interact, and complicated atmospheric circulation makes the warm and cold seasons distinct.

In the winter, the European-Asian front, Polar anticyclonic storms, and Southern cyclones all collide with the elevated pressure above Chukotka. Because of this, the climate of Chukotka may change dramatically and unexpectedly, from cold with mild and powerful Northern winds to wet and warm with heavy snowfall or storm. In the warmer months of summer, the polar Ocean coast is dominated by cold Arctic air, anti-cyclones from the Pacific Ocean, and cyclones from Europe and Asia. The circulation forces cause the weather to change, going from warm to cool and even freezing at times. Snow may fall in the summer at any time.

Here, the Northern winds quickly give way to the Southern ones; the average wind speed is 5-12 m/sec, with gusts reaching 40 m/sec. Strong winds of 50-to-60 metres per second occur virtually yearly.

On the Eastern-Siberian shore, the mean annual air temperature in Chukotka is between 4 and 14 degrees Celsius (Nawarin and Raucha, respectively). Moving westward from Chukotka's eastern summit, the climate becomes more continental. In a relatively small area, temperatures in July average between +4 and +14 degrees Celsius, while average January temperatures span a chilling 18 and 42 degrees Celsius.

Northeastern reindeer husbandry was impacted by the known progression of harsh climate in Eurasia from the south to the west and from the north to east, with a climax in Chukotka at the continent's extreme northeastern edge.

The indigenous people of Chukotka had to adapt their dwellings, means of transportation, and even their clothing to the harsh climate. The weather in Chukchi was chilly and windy. The rugged terrain of Chukotka limits nomadism to the lowlands among peaks and tundra close to the coast.

4. The Chukchi People's Building Methods and the Spatial Dimensions of their Dwellings

Yarangas are moveable framework-based homes used by indigenous northeast Asians (Chukotka AD, Magadan Region). Chukchi reindeer herders and sea hunters utilized this form of housing most. Northerners Koryaks, Evenks, and Yukaghirs create yarangas.

Sites for nomadic Chukchi communities often have anything from one to ten transportable structures aligned west to east. Many Chukchi choose to stay put and live in fixed yaranga communities of up to 20 units each along the coast (Levin and Potapov, 1956, 913).

The construction is supported by long wooden poles and, in certain cases, by the bones of marine animals. Framing is another common usage for whale ribs (Sokolova, 1998, 77). The symmetry of a yaranga is off. The design of a yaranga shifts its centre northward by a radius of around 1/4 to 1/6 of a circle. This method enhances the building's aerodynamics in high winds. Aside from that, an asymmetrical plan may be made more comfortable by installing a shade structure (polog) in the larger half of the room. The sturdy structure is wrapped with reindeer or walrus skins. 45-50 skins from average-sized reindeer are needed to make a yaranga. Stitched belts hold together the over-lapping borders of the hide. The average cover has two layers. Fur is removed to improve the durability of skins. For permanent yarangas, the framework might survive for generations whilst the covering is swapped out every year. When the covering is changed, the soft floor of the canopy is warmed by the old covering.

Yarangas have outside belts. The lower belt ends are connected to sleds or large stones to immobilize the covering. Stones and sod are used to seal the bottom of the covering to keep the wind out.

The hide covers the side entrance. A wooden door protects the entryway during snowstorms. A yaranga is simple to deconstruct, fast to build, and compact for movement. A yaranga takes a few hours to a day to put up.

The inhospitable conditions of the Arctic required a new approach to residential design. The comfortable temperature inside was achieved with the aid of a multi-stage heating system. There are two main components to a yaranga: the central dome, which covers the chottagina (the cold area of the abode), and the canopy. The shade structure (ioronga or polog) serves as a smoke-free, heated tent. It is lit from inside by a grease lamp. Even in the coldest winter months, the canopy creates a comfortable sleeping environment, with temperatures ranging from +15 °C to +10 °C. The awning hangs from a yaranga wall that faces the front door. With the ioronga entrance facing the opposite direction as the chottagina one, draught winds are mitigated. Within the shelter, a rectangular structure of poles made of wood or as an enclosure of light-planed sticks supports a sack of dressed reindeer skins. A single-layer covering with fur inside is usual. To keep the canopy in place, the framework poles pass through a number of loops sewn on the skins. Typically, an ioronga will be 1.5 metres tall, 2.5 metres broad, and 4 metres long. The carpet on the floor of an ioronga dates back at least a year.

Sacks of hide scraps are near the canopy exit at the head of the bed. People wrap themselves with reindeer skin blankets. Twelve to fifteen reindeer skins comprise the canopy, while 10 huge hides make beds. Yarangas have reindeer antler seats. Within the umbrella, people dine at low-legged tables or immediately around plates.

Canopies (pologs) in a big yaranga are counted according to the total number of families living there. This was a communal fire pit. The smaller vaults are reminiscent of iorongas. Up to six separate rooms would be used for sleeping, storage, and other purposes in a yaranga tent.

Canopies provide shelter for furniture and other household items, while the ioronga, which runs beside the hearth, is used to store food. Household tasks and visitor greetings take place in the open space that connects the yaranga doorway and the hearth.

The chottagina, the thermal barrier that surrounds the centre, is heated by the yaranga fires that also prepare the food. Fuel originates from polar shrub twigs and loop-shaped roots pulled out and processed in preparation. Plates for cooking are hung from horizontal bars made from tripod poles.

Brushwood, straw, and worn-out blankets are sometimes used to protect the flooring in Chottagina homes.

5. Yaranga Insulation Structures have High Heat Resistance

Insulating structures were tested to determine their efficacy against heat transfer, which was then used in a theoretical estimate of the per-unit thermodynamic range of the investigated structure. Uncut, one-third cut, and two-thirds cut samples were used in the study. bi-layers of thick reindeer skin are used to make traditional winter yarangas, and the fur hair is clipped to about two-thirds of its length. Outside the yaranga, the fur on the highest point of the indoors hides people's faces. The coverings are woven with animal ligament thread from the skins of large winter reindeer or, less often, seals.

In order to maximize the insulating properties of the fur, it is first cut short to avoid the accumulation of moisture and the creation of snowmelt and ice crust. As the ice accumulates, the weight of the barrier above it increases, putting stress on the yaranga.

The inside side of the hide's covering becomes soggy, wet, and droopy because the frost crust prevents air and moisture from flowing through the hide. If it had been used for an extended period or has not been thoroughly smoked, it falls down as the dwelling's pleasant humidity and temperature setting breaks down. The thermal-technical properties of the covering were evaluated using a liquid crystal display thermal indicator on a sample.

Experiments on each of the sample types show that the thermal-technical characteristics vary nonlinearly as a function of the percentage of covering that is removed, suggesting a non-critical shift in thermal resistance. When the length of the fur hair is reduced, the operational characteristics and service life of the insulating material increases.

For yarangas, the cutting at two thirds lengths of fur hair hide has a thermal conductivity () of 0.018 W/m*°C, whereas the uncut hide has a of 0.012 W/m*°C. Thermal resistance of insulating covering materials may be shown by theoretical calculations (Bogoslovskij in 1991) to back up the findings of practical experiments.

For the computation, we will use the following equation:

$R = \delta / \lambda$

where λ is the thermal conductance of the insulating material and δ is the layer thickness.

Therefore, the values are:

1) The overall heat-flow resistance of the insulation is = 14 mm for a double-layer outside covering of reindeer skin with the fur shaved off.

   R = 1.56 (m^2*°C)/W

2) The overall resistance of the heat passage of the in-sulation is = 20 mm for a single layer of reindeer skin with uncut fur covering the inside of the canopy.

   R = 1.67 (m^2 *°C)/W

That means the total heat resistance between the outside temperature and the inside temperature of the covering R equal to 3.22 (m2*°C/W), which appears to be quite efficient even for current norms pertaining to obstruction of the flow of heat of buildings in the investigated region.

6. Daily Variations in Typical Use: Field Measurements of Interior and Outdoor Air Temperature Dynamics

In the field, we replicated typical meteorological and geographical factors to perform an experimental examination of interior temperature. The Chaunsky district of the Chukotka Independent District served as the experimental site, with a family of four living in a yaranga of 91.5 square metres, located 22 kilometres to Perevek, the territory's administrative centre. Yaranga went east-west. The structure's aerodynamics are enhanced in strong winds as a result. The sturdy framework is wrapped with reindeer hides. There are two outside layers. The fur is slashed to a thickness of two-thirds. The flooring of a chottagina are made of brushwood and straw and are covered with antique rugs. Windows and daylight are few in Yaranga. Space for insulation was 286.8 square metres. There's fur on the interior of the canopy's single layer. The ioronga floor still has its old coverings on it. To insulate Ioronga, we used 40.73 square metres of material. 85%+ of the time, people were under a canopy. Yaranga inhabitants wear deerskin street wear, whilst ioronga residents use indoor clothes.

There were three parts to the trial that occurred between December 2013 and March 2014.

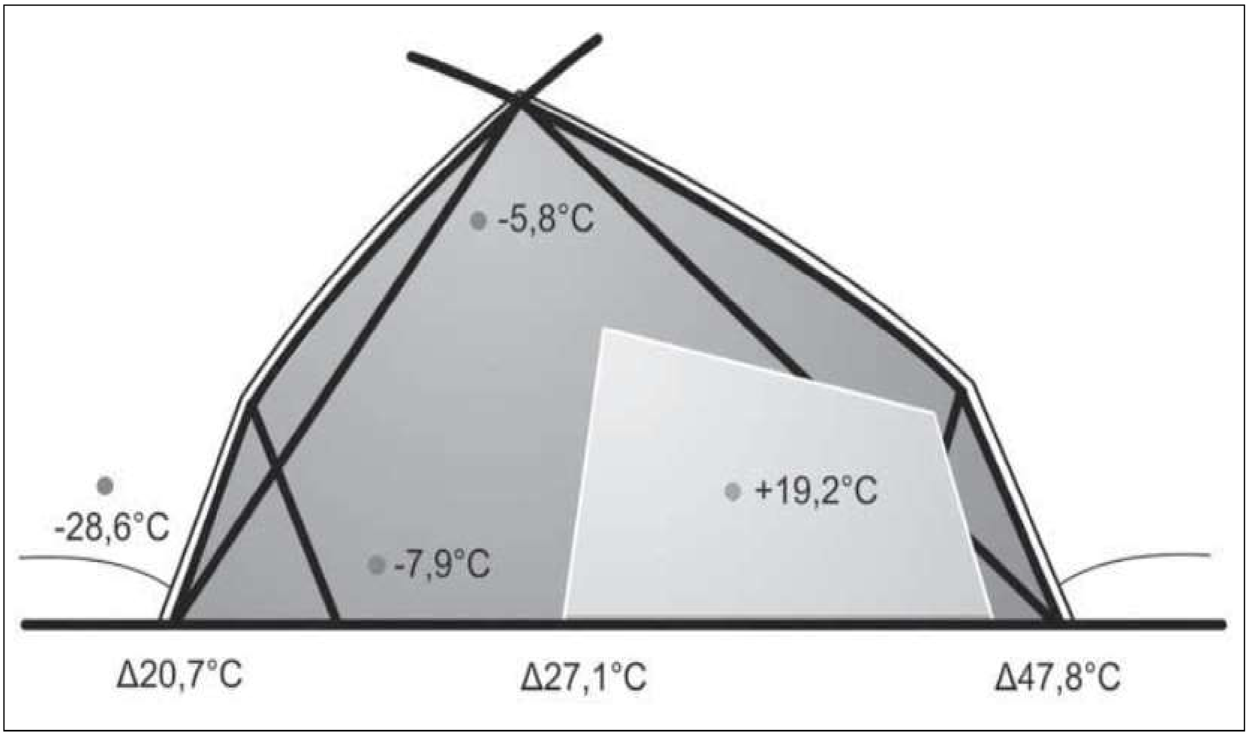
8 thermal imaging sensors with an accuracy of ± 0.09-degree centigrade to monitor the inside temperature within a yaranga from – 50 to + 50 degree centigrade. The data from the sensors was recorded in the computer. It took 30 minutes to acquire the temperature data from the devices. The snow layer was measured at 0.3 metres, the bottom of the yaranga was measured at 0.3 metres, the yaranga was measured at 2.3 metres, and the canopy (polog) was measured at 1.2 metres.

Information was gathered for a total of three days each from the month of December 8-11 (period 1), December 22-25 (period 2), January 11-14 (period 3), January 30-February 2 (the period 4), February 18-21 (the period 5), and March 10-13 (period 6).

Across six separate measurements, the average outside temperature was 28.6 °C, or around 4 °C lower than normal. A yaranga's (chottagina's) main room averaged 7.0 degrees Celsius inside, but the canopy's air was a comfortable 19.2 degrees Celsius, with temperature variations of less than 1.1 degrees Celsius.

From 1 to 3 p.m. (postmeridian), there is a sharp increase within the temperature of the air in the yaranga's centre region, a time frame often used for starting fires and preparing meals. When the air temperature in the canopy (polog) is relatively constant, a grease lamp with temporary fire extinction may function. The temperature of the air within a chottagina seldom fluctuates in response to changes in the ambient air temperature. No link exists between the external temperature of the air and dome interior air temperature. The four yaranga people spent the night under the canopy, where the temperature was more stable.

It was on average 47.8 degrees colder under the canopy than it was outside.



7. Heat Loss from the Structure, Based on Theoretical Calculations

The theoretical thermal-technical concept of a yaranga was created after lab and field tests revealed heat loss via inside and exterior insulating features. Two separate estimates of heat loss were made, one for each thermal divider. Temperature data from experiments, both inside and out, and data on the thermal-technical properties of various materials were used.

Q = k A del(t)

where:

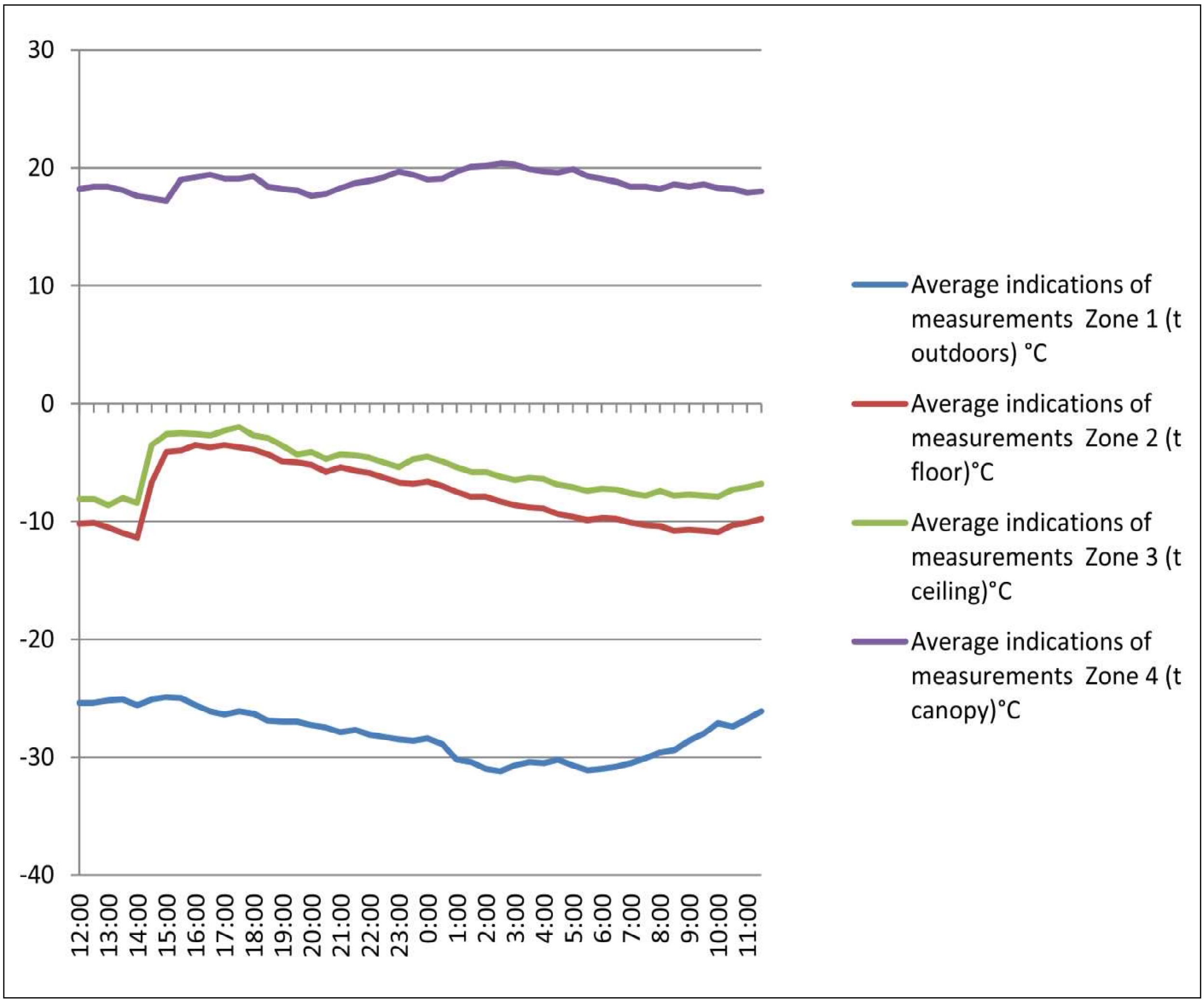
- k represents the index of thermal conductivity, W/m^2*^{o}C,
- del(t) represents differential in the temperature of the indoor and external, ^{o}C,
- A represents the surface area of the insulation, m^2.

Difference between major heat loss from shielding structures (showing theoretical estimations for the geometry of the primary as well as the secondary thermal shields) and the yaranga's Q(W) total heat loss.

According to the numbers, the building is losing about 5700 W of heat.

Dry wood logs are used as fuel to heat homes. These logs have a heating value of 3.3-3.5 kW*h/kg when burned. As an added bonus, a greasy lamp can provide 300 W of heat to a house. The subsequent heating barrier, ioronga, is thought to theoretically need just 15%+ of the total consumption of energy, which may be met nearly completely by home heat radiation and a little grease lamp. The ambient temperature within this room is suitable for prolonged stay.

Chottagina, requires extra heat, however a few logs of waterless wood burnt in the fire-place while cooking are enough to make up for the heat lost via the outside insulation.



8. Conclusions

The yaranga was the most common Chukchi dwelling in the Arctic because it could be built quickly and efficiently using locally available resources.

Yarangas feature wood pole frames. Reindeer skins are used to cover yarangas. Mud or semi-mud houses could not be built on permafrost, but because of their nomadic lifestyle, the tribes were able to quickly dismantle, transport, and rebuild their dwellings.

The Yarangas' double-barrier heating technique is essential for human survival in freezing environments. This form of heating conserves energy while keeping buildings at a comfortable temperature, even when the outside temperature is quite low. The yaranga has an envelope size of 30-50 m^2 and a shell size of 250-300 m^2 (ioronga or polog).

With no air vents and a total loss of heat of four thousand nine hundred Watts thanks to reindeer skin insulation, the external shell is kept at an even temperature of -5 degrees Celsius to -8 degree celsius. This makes it possible to make up for the loss with only 5-8 kg of wood that is dry being burned each day. The hot burning residue under the dome aids in heat utilization and slows down the cooling of the cottaging. The inside of the dome is cooled and heated by the wind.

The average difference between the air temperature on each side of the first barrier is 293.7 K. The second thermal shield's average interior temperature makes the building comfortable to use for extended periods of time. It's now 292.2 K outside. To counteract the 811 W needed to maintain a temperature gradient across the second barrier, residential heat radiation and a tiny grease lamp are installed within the compact canopy (polog). The typical temperature gap at the barrier is 300.1K. The difference between the outside and canopy areas was 320.8 K.

9. Suggestions

This article discusses a space-organization technique that might be adopted in existing Far North structures to reduce energy consumption during very cold weather. Overall and individual dimensional-spatial options for created structures may convey the experience of indigenous Chukotka people.

This attempt does not seek to develop and assess contemporary building design outputs. This article may be the continuation of an ongoing line of inquiry. Researching how locals in the Siberia Yakut and Alaska Aleutian regions save energy in the face of extreme conditions, such as weather, might provide important scientific insights.

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