

Re-producing Traditional Yurt Dome Structures in the Modern World: An Innovative Proposal

Perizat Aitmukhanova¹, Klara Kudabaeva^{2*}, Adil Aitmukhanov³, Baimurat Ospanov⁴, & Zhumabai Baynatov⁵

¹Department of Construction and Building Materials, Satbayev University, 050013, 22A Satpaev Str., Almaty, Republic of Kazakhstan.

²Department of Design, Abai Kazakh National Pedagogical University, 050010, 13 Dostyk Ave., Almaty, Republic of Kazakhstan.

³Department of Clinical Disciplines, Al-Farabi Kazakh National University, 050040, 71 al-Farabi Ave., Almaty, Republic of Kazakhstan.

⁴Department of Design, Astana International University, 020000, 8 Kabanbay batyr Ave., Astana, Republic of Kazakhstan.

⁵Department of Engineering Logistics and Transport Construction, Academy of Logistics and Transport, 050000, 97 Shevchenko Str., Almaty, Republic of Kazakhstan.

*ORCID No: 0000-0002-0034-858X

*Email: kudabaevaklara4@gmail.com

Received	Reviewed	Revised	Published
16.08.2023	06.09.2023	13.09.2023	31.09.2023

<https://doi.org/10.61275/ISVSej-2023-10-09-04>

Abstract

The use of the yurt dates to the 3rd millennium B.C. It was mentioned by the “Father of History” Herodotus, as well as by famous travellers Zemarh, Plano Carpini, Guillaume Rubruk, Ibn-Batuta and many others. The making of yurta and dombra was included in the representative list of non-material historical possessions of people. Today, there is a renewed interest in the construction of yurt dome structures suitable for the modern world. However, the techniques of doing them are not well known.

In this context, this research examines the techniques of making dome structures for modern use by the structural mechanic method through the architectonics and design of central cyclic yurts.

It explores the structural principles conceptualized and presents the ways to do so. It involves a two-story version of the yurt as a novel design. For instance, the yurt’s second floor’s primary structural components have been upgraded.

The solution proposed allows to lower the dome of the yurt up to 0.8 m in winter. However, when it is cold and in case of expected strong steppe winds, the total diameter of the yurt remains the same. The number of uyks has also been reduced by the reduction of the length of two uyks out of three located next to each other, i.e., short side uyks are hinged to the main uyks located between kerege and shanyrak. This solution provides an economy of materials and creates space for the anchors during the movement of the shanyrak.

Keywords: Two-storey yurt, Uyk, Shanyraks, Fastening sickles, Structural mechanics.

Introduction

Today, many designers are engaged in the construction of “yurts” without studying and researching the dome structure and without theoretical justification applying only innovative-technological materials. Information about the use of the yurt in ancient times dates to the 3rd millennium B.C. It was mentioned by the “Father of History” Herodotus, as well as by famous travellers Zemarh, Plano Carpini, Guillaume Rubruk, Ibn-Batuta and many others. The making of yurta and dombra was included in the representative list of non-material historical possessions of people (Andreev, 2016).

Traditional yurt structures are emblematic examples of portable and sustainable architecture, meticulously crafted over centuries to endure the challenging conditions of Central Asian climates while offering a warm and versatile living space. With their circular lattice frame, crowned by the ornate shanyrak, enveloped in insulating materials, and featuring circular entrances adorned with intricate details, yurts are architectural masterpieces that seamlessly balance practicality with cultural significance (Tsovoudavaa *et al.* 2018). The lattice walls, supported by vertical columns and anchored by the tono, create a stable and welcoming interior adorned with textiles, carpets, and traditional furnishings. Natural ventilation is facilitated through the central opening beneath the shanyrak, making yurts not only aesthetically captivating but also well-suited for the nomadic lifestyles that have relied on their enduring design for millennia.

Modern yurt manufacturing principles and practices include the use of natural and renewable raw materials. Yurt manufacturers use high-tech, modern materials such as long-lasting waterproof outer fabrics, lightweight space-age insulation, steel fasteners, and graded lumber to produce yurts that have much higher snow and wind load ratings than traditional yurts while lasting much longer. Yurts are also designed to have a relatively low cost and environmental footprint when compared to “normal” construction methods, making them an attractive alternative sustainable living shelter around the world. In addition, modern yurt manufacturers are adopting environmental initiatives to reduce their impact on the environment (Xu *et al.*, 2019). For example, Pacific Yurts, a yurt manufacturer, has implemented environmental initiatives such as using recycled materials, reducing waste, and using energy-efficient lighting and heating systems in their manufacturing facility. Furthermore, the traditional knowledge and skills of making yurts are being recognized as an intangible cultural heritage by UNESCO (2014), which aims to safeguard and promote traditional knowledge and skills in making Kyrgyz and Kazakh yurts.

Ivandaev (2018) has considered mobile and temporary dwellings of different people and historical periods. He has analyzed the principles of their internal organization and has given their comparative characteristics. According to Khalpakhchyan (1970), a yurt turns out to be nothing other than a capsule that separates the hidden zone from the explicit zone, thereby satisfying a certain number of physiological and existential needs of people. However, further research examining the synthesis, and classification of inhabited portable structures are needed to define an innovative modelling of portable dwellings.

Le Corbusier was fascinated by the completeness, practicality, and interchangeability of the fragments of the yurt. It was that he studied one of the examples of the “Mobile Housing” concept. The yurt, well remembered since ancient times, still inspires architects. Some comparisons can be made about the use of the yurt from antiquity to today in an innovative style, for example, from the Mongolian yurt to the domed house and its interior in Fig. 1.

The construction of new type of housing was used by the Japanese International Dome House, and the main idea is that this very construction requires neither wood nor stones – only foam. However, the Japanese are convinced that houses of this composition are the best option for unstable places (Yut-saviour, 2021).



Fig. 1: From the Mongolian yurt to the domed house and its interior
Source: Mobile architecture..., 2009.

This research examines the historical moments of the development of a portable structure (Skinder and Mironenko, 2011). This study investigates the methods employed to construct dome structures suitable for contemporary applications, utilizing principles of structural mechanics within the framework of architectonics and the design of central cyclic yurts.

Its objectives are as follows.

1. To analyse and document the structural mechanics and design principles underlying the construction of central cyclic yurts, focusing on dome structures suitable for modern use.
2. To develop and present innovative techniques and solutions for the construction of yurt dome structures, including a two-story yurt design with upgraded structural components.
3. To explore the advantages of a two-story yurt over a one-story yurt.
4. To highlight the importance of vernacular architecture in the history of innovative residential construction and demonstrate how lessons from traditional nomadic housing can be applied to modern mobile dwellings.

Theoretical Framework

The study of yurts within the framework of historiography examines their historical origins, evolution, and cultural significance. Yurts, with a documented history dating back to the 3rd millennium B.C., have left a trail of historical accounts and archaeological evidence. Scholars and travelers, including Herodotus, Marco Polo, and Ibn Battuta, have contributed to the historiography of yurts by documenting their construction, usage, and significance in various geographical and temporal contexts (Edmonds, 2008). This historical perspective helps us understand how yurts have adapted to diverse environments and lifestyles over centuries, showcasing their resilience as architectural forms.

The sociological lens focuses on the broader societal implications and cultural significance of yurts. These portable structures are intimately linked to the nomadic way of life and have been central to the social fabric of nomadic communities. Sociologically, yurts represent more than mere housing; they symbolize communal living, shared responsibilities, and the preservation of cultural identity. The central space within a yurt serves as a hub for social interactions, rituals, and storytelling, fostering a sense of belonging and continuity within nomadic societies (Aljanova *et al.* 2015). Additionally, the sociological study of yurts extends to their contemporary relevance, exploring how they adapt to urbanization, global influences, and changing patterns of living. This perspective sheds light on how yurts continue to shape modern sociocultural landscapes.

The construction process of traditional yurts involves a lattice of flexible wood and a felt cover made from the wool of sheep. The lattice is divided into sections called khana, which are collapsible series of crisscrossed wooden poles (Xu *et al.*, 2019). The timber to make the external structure is not to be found on the treeless steppes, and must be obtained by trade in the valleys below. The yurt is assembled by first laying out the felt cover, then erecting the

wooden lattice, and finally placing the roof ring on top. The roof ring is then secured with a tension band, and the felt cover is stretched over the lattice and secured in place.

Yurts have unique thermal properties due to their circular shape and felt cover. A study conducted on the thermal environment of a yurt found that the indoor temperature of a yurt was affected by the outdoor temperature, wind speed, and solar radiation. The study also found that the temperature inside the yurt was relatively stable, with a maximum temperature difference of 3.5°C between the top and bottom of the yurt (Xu *et al.*, 2019). The felt cover of the yurt provides insulation, which helps to maintain a stable indoor temperature.

Yurts have a unique construction process involving a lattice of flexible wood and a felt cover made from sheep wool. The circular shape and felt cover of yurts provide unique thermal properties, which help to maintain a stable indoor temperature.

Literature Review

Following Hollander (2023), the quality of strength and lightness has mainly the usual willow and tallow. It is they, when properly made, that provide the yurt with stability and grace. The timber rim, which makes the vault of the yurt over its upper part, must necessarily be weighty and strong, as the frame with this weight holds and gives reliability to the dome department, and the whole construction of the yurt.

According to Liu *et al.* (2023), there are many types of mobile dwellings, namely yurts, in turn, this leads to the need to implement several analyses and studies, which will gradually identify the national architectural totality with the mobile types of dwellings included in them, corresponding to the size of the production and economic activities of the ethnos.

Tadina *et al.* (2023) determined that mobile housing, the nomadic yurt is a unique result of the construction of a long development, step-by-step improvement of more conventional types of housing. Therefore, there are differences with this work in that the authors have not noticed exactly the importance of the peculiarities of using this type of dome structure, timely study of data and possible causes of failures in modelling, for further prospective development of the application of these yurts to increase the prospects and popularization of these constructions in the modern world.

Zhang *et al.* (2023) have determined that Tuvian people managed to keep their dwellings intact with the help of units of senior masters of yurt construction and household furniture things. The basic type of dwelling of these cattlemen in Tuva, as well as of other Turkic-Mongolian nomads, turned out to be a felt yurt, the tale of which is several centuries old. Over time the nomadic population's yurt has undergone almost no changes of any kind, as it mainly meets the needs of a nomad because of its reliability and practicality.

Ashraf *et al.* (2023) have shown that with time, the yurt increases more and more in parameters and improves in volume. It becomes smoother, squatter, and more reliable against wind gusts. However, it has not been pointed out and considered that the design of the yurt, which is as flawless as possible for that time, has some shortcomings that can be improved.

As noted by Covey (2023), the wood rim for the domed structure of the yurt is made of curved birch bases and dark willow. Kazakh, Turkmen and some masters of Central Asia make blanks for the yurt's hoop from Karagach, which is famous for its heaviness and reliability. It is also necessary to note that this rim was used in the installation of impressive yurts, but its cost is very high.

The residential Mongolian yurt embodies the essence of nomadic culture and its mobile way of life, with behaviour closely intertwined with both the natural environment and the people who inhabit it. Che *et al.* (2023) uncovered five key categories of influence: production lifestyle, natural environment, residential characteristics, cultural beliefs, and emotional experiences. Mongolians residing in yurts on the grasslands expressed higher satisfaction compared to urban housing, attributable to their deep-seated appreciation for nature and freedom. Aspects such as cultural beliefs and emotional experiences added depth to the understanding of residential behaviour, while recommendations for new yurt designs emphasize the need to enhance cultural connotations, emotional experiences, space versatility, and practical considerations like construction, cost, and transportability.

The yurt is a quintessential example of nomadic traditional vernacular architecture that has historically played a crucial role in the lifestyles of nomadic cultures. Tsovoodavaa *et al.* (2018) draws upon extensive literature and scientific research to systematize the architectural, structural, and material aspects of yurts, creating a comprehensive typology for this unique form of housing. Surprisingly, there is a noticeable lack of research on the building physics performance of yurts in professional and scientific publications. Most existing studies focus on the architectural and structural characteristics of Mongolian, Kazakh, and Kyrgyz yurts without considering climate and energy factors. Therefore, the need for analysing the physical performance of yurts, with a focus on efficiency, environmental sustainability, and comfort, becomes apparent.

Research Methods

The methodology for this research on modernizing yurt dome structures involves a comprehensive approach. The study begins with an in-depth literature review, delving into historical sources and references by ancient historians and travellers to understand the historical and cultural significance of yurts. It also explores the recognition of yurts as non-material historical possessions. The research is driven by a clear problem statement: the lack of well-known techniques for adapting yurts to modern needs. The research objectives are set, focusing on the exploration of structural principles and the development of innovative design solutions.

Data collection involves gathering information on traditional yurt construction techniques, materials, and historical context. Special attention is given to proposed modifications for two-story yurts, including changes in structural components and anchoring methods. Architectural and structural design models are developed for both traditional yurts and two-story versions. These designs are rooted in structural mechanics principles to ensure stability, efficiency, and comfort.

The research includes detailed analysis and calculations, employing engineering methods such as equations of static equilibrium and energy calculations. Factors like wind resistance, temperature control, and material economy are considered. A thorough comparison and evaluation are conducted, assessing the performance of traditional yurts against modified two-story versions in terms of structural stability, energy efficiency, and material usage. Benefits like improved temperature control and enhanced air circulation are explored. The findings are meticulously documented and presented in an accessible format, making it practical for designers and builders to implement the proposed innovations.

Within the framework of this study, an interview was also conducted with the students of the Institute of Arts, Culture and Sports of the Kazakh National Pedagogical University named after Abay with the students studying in the direction of “design architecture”. This was done in order to analyse the students' knowledge, development and interest in the design of domed structures, which are yurts. Thus, the authors were able to analyse what percentage of students can be a promising architect in the context of building new-style yurts.

A comprehensive discussion follows, considering the implications of the research in the context of modern housing requirements and sustainability. Conclusions are drawn regarding the efficiency and suitability of the design modifications. The research concludes with recommendations for the practical application of the findings in contemporary construction. It also identifies avenues for future research, with a focus on enhancing yurt design and construction techniques.

Findings and the Discussion

In previous studies, for example in the article, the features of construction and calculation of a two-storey yurt, kerege and uyk, which are made of harness, were outlined (Baynatov *et al.*, 2022). Fig. 2 shows some types of a two-storey yurts.

This research proposes a new form of a yurt in the form of a two-story dwelling. In this, the main supporting elements of the second floor of the yurt have been improved. Instead of the usual kerege, “rabitsa” netting is used and harnesses are used instead of uyks. The round

shape of the yurt on the second floor is created by a collapsible steel ring, which is suspended through the harness (uykov) to the central post of the chimney from the stove.

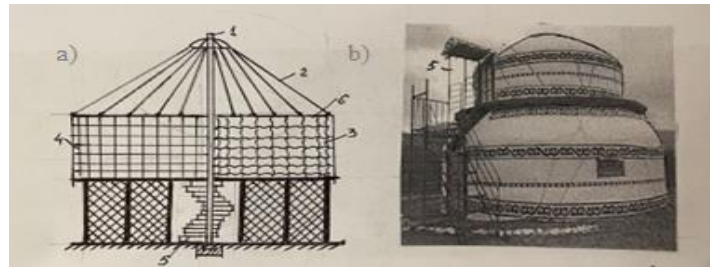


Fig. 2: Two-story yurts and options for the second floor

Note: (a) – developed by Prof. J.A.S. Bainatov No. 32906 RK, 2018 (yurt frame); (b) – constructed yurt in Kyrgyzstan; 1) central post; 2 – uyki made of harness; 3 – kerege made of harness; 4 – kerege made of “rabitsa” net; 5 – ladder marshes; 6 – prefabricated collapsible ring that creates the shape of the yurt.

The staircase location around the chimney shaft from the stove increases the stability of the yurt as a core of stiffness of multi-storey buildings and positively affects the strength of the floor lag by reducing its span (Fig. 2a). The design of the Kazakh yurt is perfectly executed, justified by a centuries-old law of Nature: it is warm in winter and cool in summer. In addition, its design is collapsible, and the technology of assembly and disassembly is available to all. It is proposed to fix on the ring of a continuous cross-section of shanyrak with wires a few tens of sickles, allowing the free movement of the tip of uyks and simultaneously fixing them in the calculated position (Fig. 3 and 4).

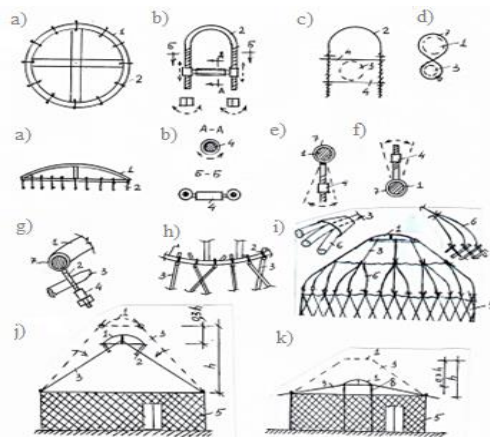


Fig. 3: Improved designs of the shanyrak, dome and uyks

Note: (a) – shanyrak with anchor-style fasteners; (b), (c) – anchor with single and double bridges (plates); (d) – rope (wire) anchor; (e) – location of anchor under and over shanyrak; (f) – scheme of fastening: to shanyrak, uyk and anchor; (g) – possible patterns of uyk arrangement according to scissors or “bicycle spokes” scheme; (h) – scheme of reduction of uyk number by using short side uyk; (i) – changing the height of the shanyrak by shifting the upper ends of the uyks; (j), (k) – changing the height of the shanyrak by shifting the lower ends of the uyks; 1 – shanyrak; 2 – arc of the anchor; 3 – uyk; 4 – clamping crosspieces (plates); 5 – kerege; 6 – short uyks; 7 – connecting wire; 8 – additional racks of shanyrak.

Fixing sickles of any size can be freely purchased at the store. One-time (temporary) securing sickles can be made from wires and ropes in the shape of figure eight. The securing sickles can be installed both under and over the shanyrak, allowing the shanyrak to move vertically. This solution without a hole in the shanyrak allows to change in the material of the structure, that is, the shanyrak rings can be made from lightweight duralumin pipes and rods,

which weigh up to 10.5 kg/m^2 , (steel – 35 kg/m^2). In addition, freely suspended to the shanyrak, the earrings allow the arrangement of the earrings crosswise around the shanyrak ring, i.e., the location of the earrings resembles “bicycle spokes” (RK No. 7636) (Baynatov *et al*, 1999). In these cases, the anchor will have a second clamping plate (Fig. 3c). It is desirable to limit the number of fixing serrations along the ring of the shanyrak, as they become crowded and as a result, there is limited space for turning and shifting the serrations with the whiskers. For this, it is proposed to reduce the number of uyks by combining them in the middle, that is, one of the uyks to bring as it should from kerege to shanyrak, and two sides (neighbouring) uyks attached hinged to a solid (normal) uyks (Fig. 3i).

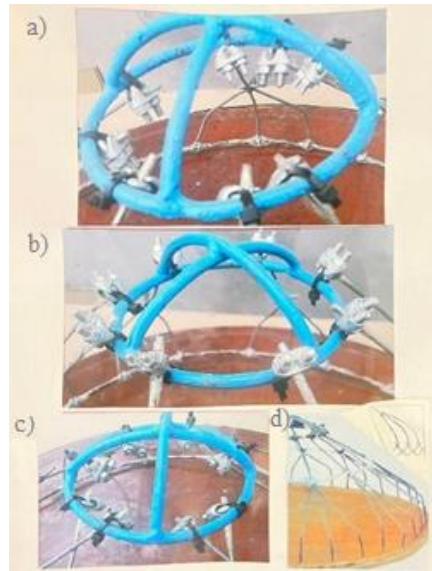


Fig. 4: a) anchors under a shanyrak; b) anchors above a shanyrak; c) cross-shaped arrangements of whiskers; d) optimal arrangements of whiskers

Such a solution partially overloads the one-piece yoke but improves internal space. Here it is possible to suggest that the thickened ends of the short (side) uyks should be fixed to the corresponding rods of the kerege deeper. That is so that the short uyks support the whole yuk not only on the sides but also on the bottom due to the support of the kerege materials and short uyks. Dangerous loads for the high yurt are the simultaneous effects of wind flow and heavy snowfall, resulting in the formation of compacted snow bags on half of the dome area (Fig. 4a). Under Eurocode-1 snow density is 300 kg/m^3 including compaction (according to Kazakh standards 200 kg/m^3).

Yurts can be rectilinear (Mongolian yurt) or slightly concave in the supporting part (Kazakh yurt) (Fig. 5).

To obtain the maximum forces in the yuk, the calculation scheme in the form of a simple beam is considered (Fig. 5c, 5d, 5e). Calculation parameters according to the scheme of Figure 5c; support reactions (1):

$$R_A = \frac{(2q_1 + q_2)}{6} l; R_B = \frac{(q_1 + 2q_2)}{6} l. \quad (1)$$

Coordinates of the dangerous section X_0 and the maximum moment M_{max} (2):

$$X_0 = \frac{1-R}{1-k} l; M_{max} = \frac{q_1 l^2}{6} \cdot \frac{2R^2 - k(1+k)}{(1-k)^2} l, \quad (2)$$

$$\text{where } k = \frac{g_2}{g_1}; R = \sqrt{\frac{1+k+k^2}{3}}.$$

Calculated parameters following Figure 4d (3):

$$R_A = \frac{q(1+c)}{6}; R_B = \frac{q(1+a)}{6}, \quad (3)$$

while (4):

$$a < c; X_0 = 1 - \sqrt{\frac{c(1-a)}{3}}; M_{\max} = \frac{q(1+a)}{9} \sqrt{\frac{c(1-a)}{3}}. \quad (4)$$

Calculated parameters following the scheme of Figure 4d, load projections (5):

$$q_x = q \sin \alpha; q_y = q \cos \alpha. \quad (5)$$

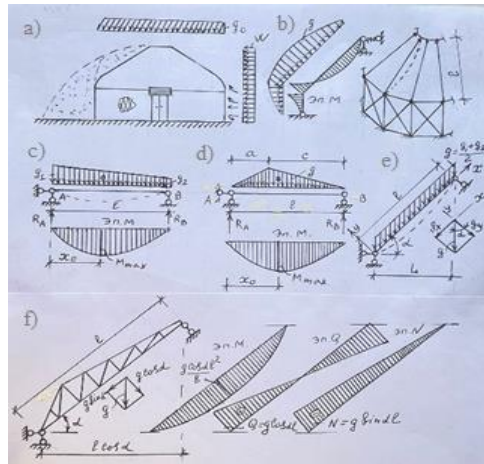


Fig. 5: Calculation diagrams and loading of yurts with a diameter of 10 to 20 meters

Note: a) simultaneous action of snow and wind with the formation of a “snow bag” shape; b) calculation scheme of the yuk; c) beam scheme of the yuk with a trapezoidal load; d) beam scheme of the yuk with a triangular load; e) simplified calculation position of the yuk and load decomposition; f) rafter shape of the yurt dome above 12-14 m diameter with the corresponding M, Q and N force diagrams.

For the shape, the forces M, Q and N from a uniformly distributed load q are determined in the same way as in an inclined beam on two supports (Figure 5f). The actual cross-section of the yuk along its length is not constant and varies according to the law of the truncated cone. To facilitate the calculation, it can be assumed that the yokes have a stepped section along their length (Fig. 6).

All forces and moments applied to each part of the beam are multiplied by the appropriate reduction factor, and the differences ΔQ_i (6) and ΔM_i (7) are applied at the junctions between the sections:

$$\Delta Q_i = (\alpha_{i+1} - \alpha_i) Q_i, \quad (6)$$

$$\Delta M_i = (\alpha_{i+1} - \alpha_i) M_i. \quad (7)$$

To determine the initial parameters $Q_i = P_i$ and M_i it is necessary to construct the appropriate diagrams of transverse forces and moments and to determine the parameters y_0 and φ_0 in the reference books are special tables for different schemes of fixing and loading (Gordeev *et al*, 2007; Vinokurov *et al*, 1988; Umansky, 1972).

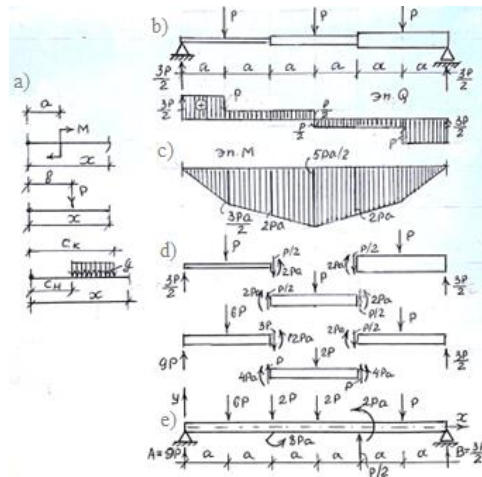


Fig.6: To the calculation of the variable stiffness yoke

Note: a) Explanation of the notation to the equations of the method of initial parameters; b) calculation diagram for determining deflections at the boundary of discontinuous sections; c) Q and M diagrams for a given beam; d) element by element reduced beams; e) calculation beam with reduced cross-section.

A cyclic structure is a structure with strict polar (circular) symmetry and consisting of masses of m vertical and horizontal elements. With some approximation, stationary yurts with large diameters can be referred to in this system. To absorb the vertical and horizontal loads, the kerege is reinforced with stanchions, and the prestressed arcane belts are reinforced with transoms. Cyclic systems are often used in so-called hyperboloids of the Shukhov system and other types of pylons, towers, domes, and masts of articulated-rod type. Considering the yurt in plan with an arbitrary general mass m , denote by $\alpha = 2\pi/m$ the central angle between two adjacent elements, for example, the uprights of the spatial octagonal yurt system shown in Fig. 7.

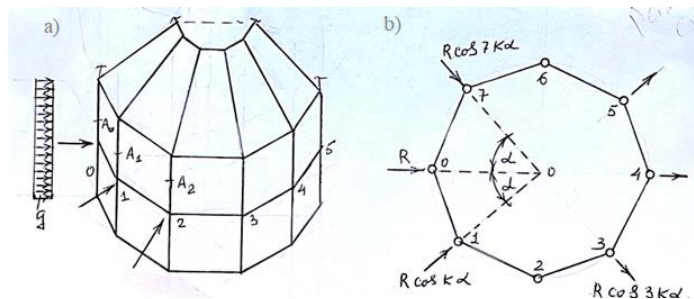


Fig. 7: Rigid construction of a large yurt

Note: a) spatial yurt in polygonal form; b) polygonal yurt model in plan with nodal asymmetric loads causing maximum forces in one direction.

Assume that horizontal forces, changing along the circle according to a certain trigonometric law, are applied to the nodes of the struts and transoms, namely, radially directed forces $R \cos kn\alpha$ (Fig. 7b), i.e., the forces forming such a group: R at node 0; $R \cos k\alpha = R \cos 7k\alpha$ in nodes 1 and 7. $R \cos 2k\alpha$ – in nodes 2 and 6 (Gordeev *et al*, 2007). Here k is an arbitrary integer. Suppose that the authors are interested in the radial displacement caused by this group of forces ρ_0 of some arbitrary point A_0 , belonging to rack No. 0, or radial displacement ρ_n . The “similar” point (symmetrically located concerning the axis of the building) A_n , belonging to rack No. n . The action of any of the forces $R \cos kn\alpha$ (e.g., $R \cos k\alpha$) to any of the radial offsets ρ_n depends, due to the circular symmetry of the frame, on the angle between the vertical plane of the force and the vertical (diametric) plane of the

point under study A_n . Introducing influence coefficients depending on such an angle $(n - l)\alpha$, it can be stated that (8):

$$\rho_0 = a_0 R + a_1 R \cos k\alpha + a_2 R \cos 2k\alpha + \dots + a_6 R \cos 6k\alpha + a_7 R \cos 7k\alpha. \quad (8)$$

Due to the nature of the symmetry of the system and the direction of the forces $a_1 = a_7$; $a_2 = a_6$ and $a_n = a_{m-n}$ while $\cos k\alpha = \cos 7k\alpha$, then (9):

$$\rho_0 = R(a_0 + 2a_1 \cos k\alpha + 2a_2 \cos 2k\alpha + 2a_3 \cos 3k\alpha + a_4 \cos 4k\alpha). \quad (9)$$

The support ring, which takes the strut of the dome of a large yurt, maybe on an integral base, obtained by the walls or on some columns. To derive the formula, consider the cross-section of the dome width of a unit (Fig. 8).

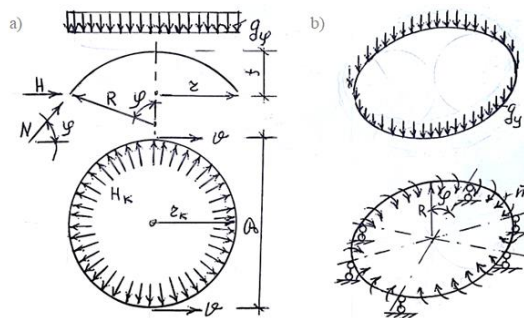


Fig. 8: To determine the forces in the supporting ring of the yurt dome

Note: (a) Cross-section and plan of support ring with spacer load; (b) diagram of ring loading with vertical loads and torques.

Longitudinal force $N=0$. Positive application of the cable-stayed system. The equilibrium outline of the hanging shell of the dome was revealed. Then Perizat Aitmmukhanova and Zhumabai Baynatov started the calculation and design. “Failure to consider these circumstances can lead to unexpected consequences, as evidenced by the experience of erecting one of the most famous hanging coverings-coverings over the Raleigh Arena building in the United States” (Kudabayeva and Aitmukhanova, 2016). “Maldonado emphasized the use of science and technology. Also, the traditional concepts, ‘constituent elements of composition’, have been replaced by the concept of ‘physical structure’, which synthesizes combinatorial analysis and symmetry theory” (Mikhailov, 2004). Today it is the theory of the cable-stayed system, which is widely used in architectural and environmental design. In the absence of tectonics, the design is false, and the construction is of poor quality.

Table 2. Model of the dome structure of the yurt in the modern world, components, criteria, indicators, and levels

Components	Criteria	Metrics	Levels
1	2	3	4
Motivational	Having the right motivational approach to the theory and technology of designing and teaching independent subjects in creative activities.	Yurt; two-story yurt; abstracting, comparing, understanding essence, distinguishing between the general and the particular, goal setting, thinking.	“High”; “medium”; “low”. (for the following experiment “difficult”, and “somewhat hard.” “simple”).
Content	Linear image; colour (tinted) image; methodology for	Yurt; two-story yurt; structure of training assignments in the course “Architecture” –	“High”; “medium”; “low”. (“very difficult”; “difficult”).

	calculating the frame of the dome covering the yurt.	design “two-story house”, the method of structural mechanics.	“somewhat hard.” “simple”).
Procedural	The metal frame structure of a large yurt cover; calculation of one branch of the yurt dome; calculation of the spatial frame of the yurt; calculation of the spatial structure of the yurt according to a cyclic scheme; rigid construction of a large yurt.	Yurt; two-story yurt; estimate modern types of houses; estimate houses in the ennui; yurt; Name modern types of yurts; two-story yurt; uyk, shanyrak; anchor links; analytical and graphical calculations of the frame and support ring.	“High”; “medium”; “low”. (“very difficult”; “difficult”, “somewhat hard.” “simple”).

Currently, the new building materials, with which the market is filled, probably have an advantage over the old building materials. A centuries-old nomadic way of life of the Kazakhs imposed an imprint and on the manufacture of building materials and, accordingly, their application. One such material is “felt” and the most widespread product is a yurt from felt (Kudabayeva, 2016). For example, recommendations are given for the practical use of domed forms of construction and in medicine. The use of such material in the XXI century many people would not consider it reasonable, but mobile, easily assembled, resistant to environmental influences and possessing many useful qualities yurt may well be used in our time, moreover, given the presence of modern technology can improve the quality of felt in the use of the construction of yurts.

It will also be possible to attach and install therapeutic and diagnostic equipment, such as an angiographic unit, computer tomography, and magnetic resonance imaging apparatuses, in additional yurts (Aitmukhanova *et al*, 2019). This hospital will be transported and assembled in the shortest time possible. The mobility of yurts is proven by the thousands of years of nomadic history of the Kazakhs and other nomadic peoples who used yurts. The cost of this hospital will be quite acceptable. It is also possible to use this mobile hospital in remote regions where there are no hospitals and highly specialized specialists (Mukhadiev *et al*, 2020). A description (characterization) of the tentative model of knowledge, skills, abilities, and interests in students on small-form dome construction in the modern world is given.

Experimental work to test the effectiveness was carried out based on the Institute of Arts, Culture and Sports of the Kazakh National Pedagogical University named after Abay with the students studying in the direction of “design architecture”. Analysis of experimental-experimental work on the training of future designers and architects, on design and research activities of the small dome structure in the modern world, showed the following results. 13.6% of students have high knowledge at the start of the experiment, skills – 12.2%, interest – 12.1%; and average 26.3%, skills – 25.6% and interest – 24.6%; low education – 60.1%, knowledge – 62.2%, interest – 61.3%. Figure 9 identifies the students’ data activity, after conducting the plan work on the topic: dome structures of small form in the modern world (architectonics and design of central-circular yurt) to reliably assess students’ critical thinking of design and ideas in the modern world, in two stages the final experimental result was carried out.

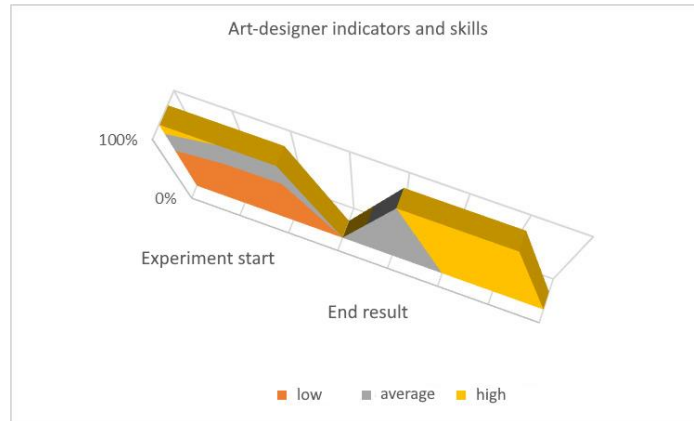


Fig. 9: Initial and final experimental knowledge and skills and motivational dynamics of modern yurt dome construction

According to the results of the final experiment, 39.5% of the “architecture design” students have a high level of education, 35.4% – skills, 55.2% – interests; average – 35.5%, skills – 43.6% and interest – 25.4%; 25% – low education, 21% – knowledge, 19.4% – interest. Thus, higher education increased by 25.9%, secondary education increased by 9.2%, low education decreased by 35.1%; and high skill increased by 23.2%, medium skill increased by 18%, low skill increased by 41.2%; high percentage decreased by 43.1%, the medium percentage decreased by 0.8%, the low percentage decreased by 43.9%. However, the results of the small dome design in the modern world (organization) presented in the first figure showed their effectiveness. However, the results of the model dome design’s small shape in the modern world showed its effectiveness (Table 3).

Table 3. Characteristics of the indicative plan for the development of interest, knowledge, and skills of architects-designers on the structural features of the dome structure

Levels	Initial experiment state			Result experiment		
	Interest	Knowledge	Skills and abilities	Interest	Knowledge	Skills and abilities
Low	61.3%	62.2%	60.1	35.4%	35.4	55.2%
Average	24.6%	26.3%	25.6%	25.4	35.5%,	43.6%
High	12.6%	13.6%	12.2%	19.4%	21%	25%

Thirty people were involved in the survey. The peculiarity of the need for mobile housing lurks in the need for a person to stay outside the urban environment. The planning structure of residential formations is always influenced by both external and internal factors. Specially created for designers’ reference documents have always formed special requirements for designers. This study is based on historical and contemporary analyses of the definition of the dome structure. In this way, the authors made possible to determine assumptions in a modern small dome structure:

1. The transition from open design to enclosed space.
2. The transition from closed to open design.
3. Balcony or terrace.
4. Flexible design.
5. A place for daily leisure activities.
6. Bathroom allocation of space at the entrance (aisle).
7. Bathroom outside next to the pool.
8. Using the principles of technical aesthetics in design.

Small dome structures in today’s world have shown the following results (Figures 10-12).

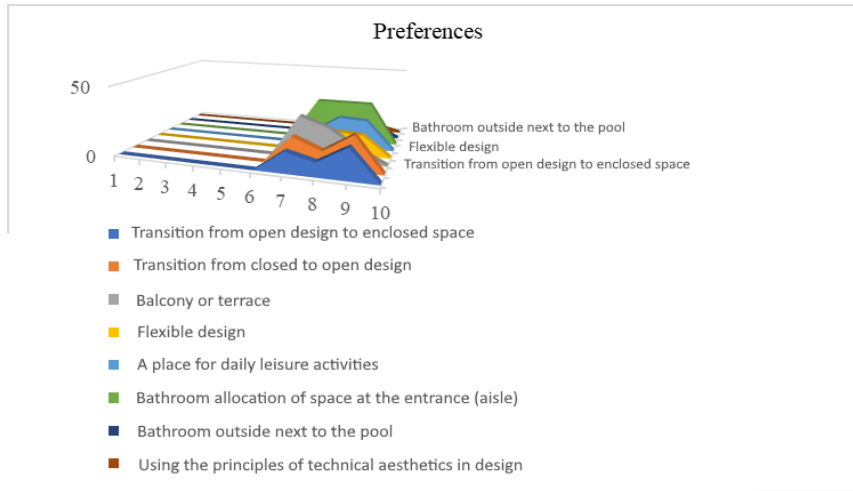


Fig. 10. Preference criteria for a small dome design

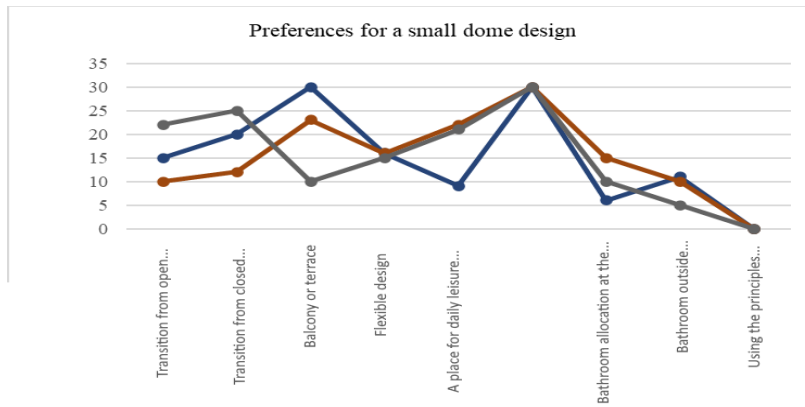


Fig. 11. Indicators of numerical preference for a small dome structure

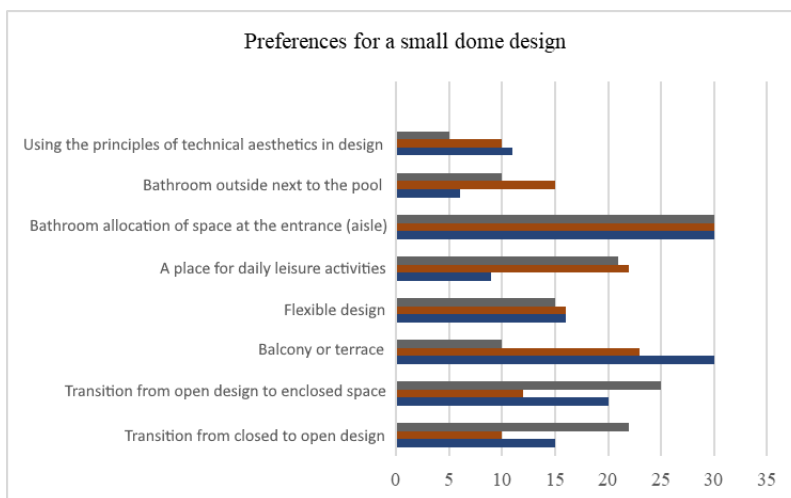


Fig. 12. Quantification of a small dome structure

The quality of research that has been conducted on the dome structures of yurts in the modern world to detect errors and problems in the design of this construction, and their

effectiveness is one of the most pressing issues of the present time, and some problems require immediate solutions. The basic requirement for the material from wood in the manufacture of the lattice base of the vertical partitions of the yurt, made of the split lattice as well as high dome beams, is lightness and at the same time durability.

This research on the construction of the dome structures of the yurt allowed to better understand the causes of errors during the construction, especially in the calculation of strength, to assess the possibility of solving these problems and identify at what stage they may appear. Architectonics and construction of central cyclic Kazakh yurts, necessary conditions for designing a Shaniera yurt. In the development of design and modelling methods to improve the dome structures of yurts in the modern world, many countries and Kazakhstan have made a powerful step forward in the last few years.

Conclusions

The proposed anchoring links simultaneously increase the yurt's stability against overturning in strong winds, provide comfortable temperature conditions, and increase bending and torsional strength due to the vertical movement of the shanyrak and the cross-shaped location of uyks under the shanyrak. That is, the proposed technical solutions increase the efficiency of the position. The technology of manufacturing the shanyrak is simplified and the material is saved. The use of short side wuchs increases the spatial stability and saves material of wuchs up to 30%. The second floor of the yurt used a more technologically cheap modern material – arcan or steel wires as a substitute for uyks and kerege, due to which the diameter of the yurt can be relatively unlimited as the span of cable and suspension bridges.

One of the advantages of a two-story yurt compared to a one-story yurt is that there is much less danger of radiation exposure to radon. In addition, people here are more protected from various poisonous insects and rats and the effects of dampness on the human body. Lower and transport vibrations, better air circulation, and a warm floor have a positive effect on the health and development of children. The second floor can be used as a stage for speakers and artists during festive events. As a result of the study, the following were highlighted: the method of initial parameters, equations of static equilibrium, energy and graphic methods. When performing the calculation of spatial systems, the symmetry of the system is widely used, allowing to simplify the calculation.

In conclusion, this study has successfully achieved its objectives by delving into the construction methods of dome structures tailored for contemporary needs, drawing from principles of structural mechanics within the context of central cyclic yurt architectonics and design. The analysis and documentation of structural mechanics and design principles pertaining to modern yurt construction have shed light on the adaptability and enduring nature of this architectural form. Moreover, innovative techniques and solutions for constructing yurt dome structures, including the novel two-story yurt with upgraded structural components, have been developed and presented. The exploration of the advantages offered by a two-story yurt, notably in terms of enhanced living conditions and multi-purpose functionality, further underscores the relevance of yurts in today's architectural landscape.

References

- Aljanova, N., Borbasova, K.M., & Rysbekova, S.S. (2015) A semiotic analysis of the yurt, clothing, and food eating habits in Kazakh traditional cultures, *The International Journal of Critical Cultural Studies*, Vol. 14, No. 1, pp 27-36.
- Aitmukhanova, P.M., Kisimisov, E.T., Baikulakov, N.T., Mukhadiev, A.M. & Kudabaeva, K.I. (2019) The use of support schemes in teaching architectural design, *International Journal of Engineering Research and Technology*, Vol. 12, Issue 12, pp 2298-2302.
- Andreev, V. (2016) Yurt in Paris. Available from: <http://old.vecher.kz/incity/yurta-v-parizhe> (Accessed 23 June 2023).
- Ashraf, O., Bajwa, O., Leonardo, J. & Altenbaugh, M. (2023) Nontraumatic neurosurgical emergencies, *Critical Care Nursing Quarterly*, Vol. 46, Issue 1, pp 2-16.

- Baynatov, Z.B., Aitmukhanova, P.M. & Myrzageldiev, R.A. (2022) New designs and calculations of elements of a two-story yurt, *Bulletin of Kazakh Research and Design Institute of Construction and Architecture*, Vol. 2, pp 74-98.
- Baynatov, Z.B., Zhayylkhan, N. & Baynatova, A.Z. (1999) Prefabricated housing for livestock breeders (yurt). Available from: <https://kzpatents.com/8-u1250-yurta.html> (Accessed 23 June 2023).
- Bezukhov, N. (1934) Statically indeterminate systems, Moscow: Gosstroyizdat.
- Che, J., Su, W., Bai, L., & Guo, H. (2023) A grounded theory approach to the influence mechanism of residential behavior among Mongolian yurt dwellers in China, *Buildings*, Vol. 13, No. 5, pp 1268.
- Covey, E. (2023) The anti-apartheid movement at Grand Valley State College in West Michigan, *Safundi*. Available from: <https://doi.org/10.1080/17533171.2023.2165013> (Accessed 23 June 2023).
- Gordeev, V.M., Lantukh-Lyashchenko, A.I., Pashinsky, V.A. & Perelmuter, A.V. (2007) Loads and impacts on buildings and structures, Moscow: ACB.
- Edmonds, M. (2008) How yurts work. How Stuff Works? Available from: <https://home.howstuffworks.com/yurt.htm> (Accessed 12 September, 2023).
- Hollander, J.B. (2023) Building science, design, and engineering beyond Earth. In: *The First City on Mars: An Urban Planner's Guide to Settling the Red Planet*, Cham: Springer International Publishing.
- Ivandaev, R.A. (2018) Physics and mystery of the Khakass yurt. Available from: <https://rosuchebnik.ru/material/fizika-i-tayna-khakasskoy-yurty-7429/> (Accessed 24 June 2023).
- Khalpakhchyan, O.K. (1970) General history of architecture in 12 volumes. Volume 1: Architecture of the ancient world, Moscow: Publishing House of Literature on Construction.
- Kudabayeva, K.I. & Aitmukhanova, P.M. (2016). Technology and methods of professional design education, *International Journal of Applied Engineering Research*, Vol. 11, Issue 5, pp 3314-3318.
- Kuznetsov, E.N. (1969) Introduction to the theory of cable-stayed systems, Moscow: Central Research Institute of Building Constructions named after V.A. Kurchatov.
- Liu, C., Ma, C. & Gao, X. (2023) Study on impact behavior of glass fiber/PVC curved sandwich structure composites, *Polymer Composites*, Vol. 44, Issue 1, pp 365-376.
- Livshits, I.E. (1965) Features of the calculation of symmetrical spatial rod structures, *Calculation of Spatial Structures*, Vol. 10, pp 273-298.
- Mikhailov, S.M. (2004) History of design. Moscow: Soyuz Dizaynerov Rossii.
- Mobile architecture (2009) Styrofoam houses, or yurts in a new way. Available from: <https://novate.ru/blogs/260309/11714/> (Accessed 24 June 2023).
- Mukhadiev, A.M., Aitmukhanova, P. M., Ospanov, B. E., Isnyazov, Z. N. & Beisenbekov, Z. Z. (2020) Ethno-design as a means of forming technological and artistic competences of future technology teachers and vocational educators, *International Journal of Engineering Research and Technology*, Vol. 13, Issue 4, pp 2298-2302.
- Segal, A.I. (1938) Fundamentals of statics and dynamics of structures, Moscow: Publishing House of the People's Commissariat of the RSFSR.
- Skinder, Y. & Mironenko, V.P. (2011) Historical preconditions of forming of concept "Mobile architecture", *Bulletin of Kharkiv State Academy of Design and Fine Arts*, Vol. 1, pp 53-57.
- Tadina, N., Tsyb, A. & Yabyshyaev, T. (2023) Main trends in the policy of regionalism formation in the Republic of Altai. In: *Proceedings of Topical Issues in International Political Geography*, Cham: Springer International Publishing.
- Timoshenko, S.P. (1960) Strength of materials, Moscow: Fizmat.
- Tsovodavaa, G., Shih, R.R.L., Bonjar, M.R.G., & Kistelegdi, I. (2018) A review and systematization of the traditional Mongolian yurt (GER), *Pollack Periodica*, Vol. 13, No. 3, pp 19-30.

- Yurt-saviour – The Japanese build houses that protect against earthquakes. (2021) Available from: <https://ru.sputnik.kg/20170802/yaponcy-stroyat-doma-zashchishchayushchie-ot-zemletryasenij-1034559666.html> (Accessed 24 June 2023).
- Vinokurov, E.F., Balykin, M.K. & Golubev, I.A. (1988) Handbook of Strength of Materials, Minsk: Nauka i Tekhnika.
- Umansky, A.A. (1972) Designer's handbook. Moscow: Stroyizdat.
- UNESCO. (2014) Traditional knowledge and skills in making Kyrgyz and Kazakh yurts (Turkic nomadic dwellings), Available from: <https://ich.unesco.org/en/RL/traditional-knowledge-and-skills-in-making-kyrgyz-and-kazakh-yurts-turkic-nomadic-dwellings-00998> (Accessed 11 September 2023).
- Xu, G., Jin, H., & Kang, J. (2019) Experimental study on the indoor thermo-hygrometric conditions of the Mongolian yurt, Sustainability, Vol. 11, No. 3, pp 687.
- Zhang, G., Hou, X. & Tao, D. (2023) The living past: A mural tomb of nomadic elite in the capital Pingcheng of the northern Wei empire (398-494CE), *Archaeological Research in Asia*, Vol. 33, 100419.
- Zhemochkin, B.N. & Pashevsky, D.P. (1959) Structural mechanic's course. Part III. Structure statics, Moscow: Gosstroyizdat.