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Rethinking Temporary Shelters for Military Use in Ladakh: A Livability-Centric Approach

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Abstract

The incremental troop deployments in Ladakh following the Galwan clash between the Indian Army and the People's Liberation Army (PLA) of China have outpaced rapid infrastructure development, making troops heavily reliant on temporary shelters. Ladakh, often referred to as a cold desert, presents extreme environmental challenges, including high altitude, severe cold, low air pressure and oxygen levels, intense UV radiation, and lack of vegetation. These harsh conditions, combined with the demanding nature of military operations, place significant physical and mental stress on soldiers.

A field survey across various operational bases in Ladakh revealed that existing shelters are impersonal and inadequate, failing to provide necessary protection from extreme weather and offering little human comfort. As a result, troops rely heavily on heating devices, increasing fire hazards. Additionally, issues related to spatial planning, economic feasibility, and sustainability were identified. Despite the introduction of multiple prototypes, a demand-supply gap persists, with excessive reliance on a single, economical but inefficient prototype, underscoring the need for better solutions.

To enhance shelter efficiency, a systematic approach is required—one that integrates user feedback, climatic data, and prototype performance. A well-informed selection or modification of shelter designs will improve livability, affordability, and overall functionality for deployed troops.

Keywords— Temporary Shelters for Military Use , Ladakh, Livability of temporary shelters, Spatial Planning

I. Introduction

Ladakh, a Union Territory in northernmost India, was formerly a part of the state of Jammu and Kashmir. Strategically located in the northwestern Himalayas, it shares a chronically disputed border with both Pakistan and China.

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Figure 1:LOC and LAC

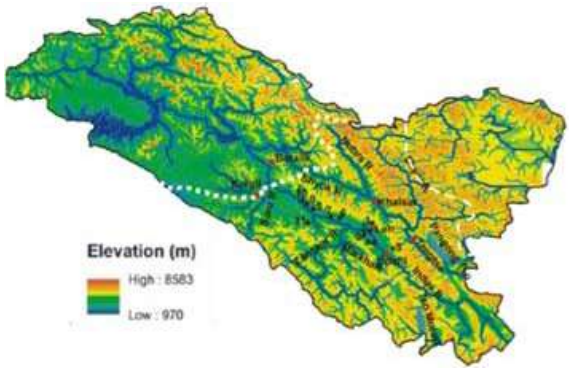

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Figure 2:Topogrphy of Ladakh

The Line of Control (LoC) separates Ladakh from Pakistan-administered Gilgit-Baltistan, while the Line of Actual Control (LAC) marks the contested boundary with China, including the Aksai Chin plateau and areas near the Karakoram Pass.

[1] Despite of being one of the most difficult terrain on earth, Ladakh with average altitude of 17800ft, tough treacherous terrain, and subzero temperatures

(which falls down to -40 degrees in winter), India's military presence in Ladakh is essential due to long standing conflict with PLA and Pakistan. (Sharma, 2024). After the Galwan conflict in May 2020, the Ladakh region saw a significant troop buildup and reorientation. This rapid deployment demanded large-scale infrastructure expansion within a short timeframe, forcing soldiers to rely on temporary shelters initially designed for short-term use.

[2] The current shelters used by the Indian military prioritize ease of installation, transportability, and cost-effectiveness, often at the expense of soldier comfort. Given the functional challenges soldiers face—such as persistent threats, dynamic operational environments, multi-domain roles, extreme climates, and constant mental and physical stress—it is crucial to develop holistic housing solutions that enhance both comfort and operational efficiency. As Healthy housing is shelter that affects physical, mental and social well-being of human as mention in Housing godliness of WHO.

II. Research Methodology

Qualitative approach is used for this study which is primarily based on a field survey conducted at three Operating Bases (OP Bases) of the Indian Armed Forces in Eastern Ladakh. It involves on-site visits to physically examine the shelters, along with user observations and interviews with soldiers to assess their living conditions. Additionally, discussions were held with key stakeholders responsible for the design and deployment of temporary shelters. To understand the execution and maintenance processes, operational policies for the Northern Command were reviewed. Furthermore, relevant research papers on shelter-related challenges and health hazards in high-altitude terrains were analyzed to provide a broader contextual understanding.

III. Discussions

A. Climate and Terrain Ladakh, often referred to as India's cold desert, is characterized by its harsh cold and dry climate. It experiences significant temperature variations both diurnally and seasonally. The annual average rainfall in Leh is approximately 100 mm, (between May and September). Winters (November to March) bring snowfall, adding to the region's extreme climatic conditions.

[4] Situated on the high Tibetan Plateau Ladakh is bordered by the Himalayan Mountains to the south, China and the Karakoram Mountains to the north, and Indian-administered Kashmir to the west. With an average altitude of 17,800 feet, it lies in the rain shadow of the Himalayas, receiving minimal precipitation. The region is characterized by glacial-fed rivers, a lack of natural soil, and sparse vegetation. Due to the extreme altitude, it experiences low oxygen levels, low air pressure, and intense sunlight. The terrain is highly rugged, with a contoured surface shaped by glacial and wind erosion.

[1] Due to its harsh climate and rugged terrain, Ladakh is an extremely challenging region to inhabit, especially for lowlanders, such as the troops of the Indian Army, who face difficulties in adapting to the high-altitude environment and its associated challenges.

B. Field survey

For this study, three operating bases in eastern Ladakh—Lukung, Karu, and Mudh along with capital city Leh were selected to encompass different functions, varied terrain, and diverse prototype types. This selection enables a comprehensive analysis of the wide range of prototype effects influenced by location, function, and their impact on shelters and users.
All four bases are well connected to the road network developed by the Indian Armed Forces in collaboration with the Border Roads Organization (BRO). Each base accommodates an average of 100–150 soldiers.

Figure 3:Filed Survey Locations

	Location	Characteristics	Function	Prototypes
1	**Leh**	Capital city	Administration	FEMS, SHILA shelters
2	**Karu**	On banks of Indus River	Training	FEMS
3	**Mudh**	At base of mountain	Armored unit	Cement sheet Mutti story Dormitory, FEMS
4	**Lukung**	Besides Pangong lake	Guarding the lake, mixed troops of Indian Army, Navy and Airforce	Dome shelter, collapsible shelter, FEMS

Table 1:Field Survey Locations

Electricity supply varies across locations: Leh has a reliable power supply, whereas other locations receives electricity for a limited duration and primarily depends on solar panels, which are highly effective due to the abundance of sunlight. Additionally, diesel generators serve as a backup power source.

However, water supply and sewage infrastructure are lacking. Soldiers rely on tankers for water supply, and sewage is disposed of in trenches, which are later cleared by the local government using suction pumps. The freezing climate further complicates water supply and sewage disposal, making these essential services particularly challenging to manage.

Fast Erectable Modular Shelters (FEMS) are widely used across the region. Multiple prototypes have been developed by the Government of India, various public and private organizations, along with the Indian Army to meet specialized needs of this region with several pilot projects undertaken to enhance shelter efficiency. Despite a well-developed road network and available local labor, temporary shelters are preferred over permanent ones due to the need for rapid deployment and limited resources, even though the average deployment duration is 5–10 years.

C. Shelter prototypes

As the Indian Army follows a defined ativestructure and functional requirements, all operating bases have the following types of shelters tailored to their specific uses.

RESIDENTIAL

Built or occupied with the purpose of housing troops, which possess a unit capacity of accommodating a rifle section i.e. up to 10 personnel. These shelters are located centrally within the perimeter to maintain the security of resting troops. They are further devided into

- Officers shelter
- JCO (Junior Commanding Officers) Shelter
- OR (Other Ranks) sheller

- **ADMINISTRATIVE**
- Office
- Storage

- **COMMUNITY**
- Cook house/dining area
- Mess
- Medical room
- Sarva Dharm Sthal (mandir)

Amongst them OR Shelters are in maximum number. On the other hand, various prototypes are designed to enhance functionality and user comfort. The following types of prototypes were observed in the operating bases.

Since OR shelters make up the majority (80%), they will be considered from each prototype for further analysis

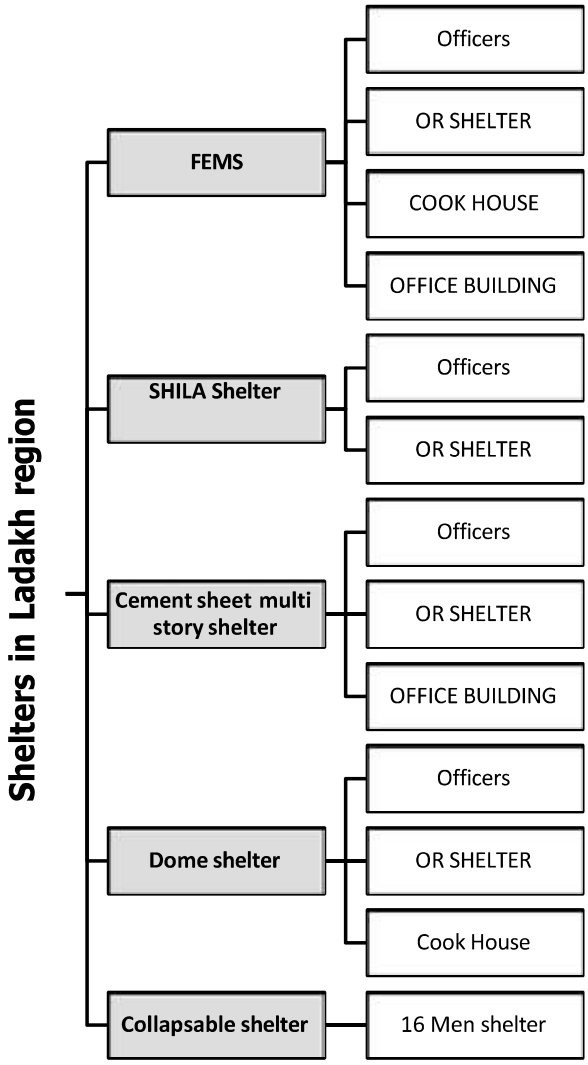

Figure 4:Shelter Prototypes

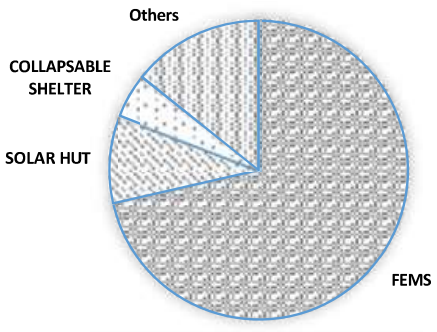

Figure 5:Distribution of Shelter prototypes in Ladakh region

Since OR shelters make up the majority (80%), they will be considered from each prototype for further analysis

Figure 6:FEMS,SHILA Shelter

Figure 7:Cement Sheet Multi Story Shelter, Dome Shelter, Collapsible

The interior space of shelters is primarily divided into a living area, storage space, passage, and toilets in certain prototypes. However, in other cases, toilet and bath facilities are provided in clusters outside the shelters, located approximately 100–200 meters away to ensure better sanitation and hygiene.

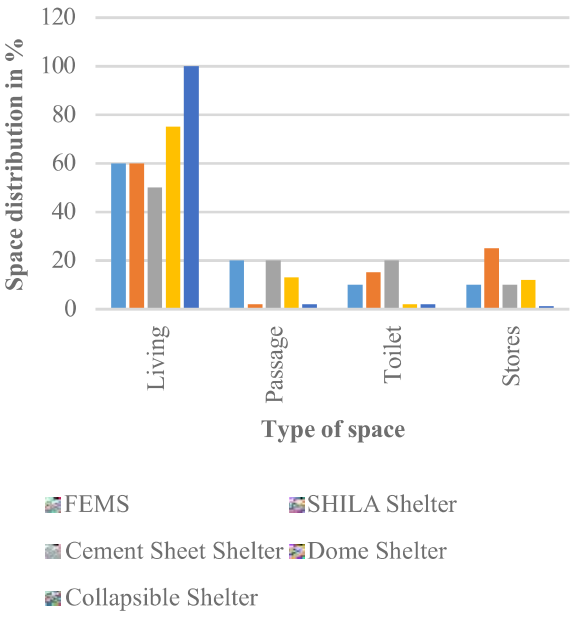

Figure 8:Space Distribution in Various Prototypes

D. Limitations of Current Temporary Shelters

The living space per person in these shelters is 2.9 sqm, which is 15%–30% less than the recommended minimum of 3.5 sqm per person. In most cases, the living area is primarily used for sleeping, and there is no space left for interaction or recreational activities

Figure 9:Interior of Shelters

		FEMS	SHILA Shelter	Cement sheet Mutti story Dormitory	Dome shelters	Collapsable shelter
1	Design/ Developed by	Army engineers	HAIL	DRDO	Patel engineering's	Army engineers +DRDO
2	Area	75 sqm	60 Sqm	360Sqm	78 Sqm	63Sqm
3	Capacity	16 -22 People	8- 16 people	40 -80	8- 16 people	16-24 people
4	Area of living space	45	35	0	62	63
5	Storage	8	8		0	0
6	Toilets	8	13.5		8	0
7	Area /person	2.8	3.10	2.8	3.1	3.5
8	Flexibility for modification by user	Less	Very much	Quite flexible	Very Less	No
9	Material	Steel structural members, polyurethane panels, fibre glass	Wooden Members, sun dries bricks, fibre glass	Cement sheets, steel structural Members	Steel structural members, polyurethane panels, fibre glass	Steel structural members, polyurethane panels, fibre glass
10	Weather protection	Insulating panels Sun roof, passage working as Sun room	Insulating thick wall Trombe wall south side orientation of opening reduction of openings	Insulating wall	Insulating panels minimum openings mechanical heating system below floor	Insulating panels
11	Effectivity of Weather protection	Somewhat Effective during moderate Winters but summers become too hot due to sunroof and in extreme winter need mechanical heating	Quite effective maintains 10-15 degree C	Somewhat effective Fails in extreme winter	Effective if heating system work	Not effective
12	**Time for construction**	25-40 days	30-40 days	35-60 days	10-15 days	4-6 days
13	**Construction method**	Modular	Modular +in situ	Modular +in situ	Modular	Deployable
14	**Construction team**	10 people 2 engineers corps +8soldiers	11 people 1 heil representative +local labor	20-25 people 2 engineers corps soldiers /labor	Install by developers' team	2-3 soldiers
15	**Labor requirement**	Skilled and Semi-skilled	Skilled and Semi-skilled (Local)	Skilled and Semi-skilled	Skilled	
16	**Cost**	Up to 20-25Lakhs	Up to 65 lakhs	More than 1Cr	Not Known	Upto 20-30 Lakh
17	**Logistic**	Vehicle	Vehicle	Vehicle	Vehicle	Vehicle
18	**Provision of air lifting**	Yes	No	No	Yes	Yes
19	**Provision for running water**	No	Yes	Yes, but not working	Yes ,but working only if heating system is on	No
20	**Drainage**	Soak Pit	Soak Pit / Bio toilet	Soak Pit	Soak Pit	NA
21	**Ratio of toilet: user**	Only Urinals 1 urinal :8person	1 Toilet: 5person	1 Toilet: 5person	1Toilet:8person	NA
22	**Electrical supply**	Solar panels included in prototype	Solar panels included in prototype	Centrally install system	Centrally install system	Centrally install system
23	**Mechanical heating**	No provision in prototype	No provision in prototype	Vents are provided to unbaling use of Kero heaters	Embedded heating system	No provision in prototype
24	**Fire risk**	High	Low	Moderate	High	High

Table 2:Comparative analysis of Shelter Prototype

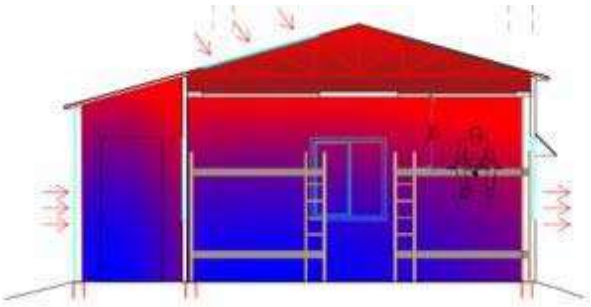

Figure 10: Heat generation inside FEMS in day time

However, in low-height prototypes like FEMS and collapsible shelters, using the upper bunk during the daytime becomes impractical due to intense heat from the harsh sun, as these shelters have a sunroof and a metal outer layer that trap heat. Since soldiers often have night duties, they need adequate resting space during the day. The limited space forces them to take turns resting, leading to a lack of privacy and personal space. Additionally, there is no dedicated space to secure personal belongings, which goes against the SPHERE and UN guidelines for adequate shelter standards. [5],

[6] The heating device/systems provided in the prototypes are inadequate during cold months, forcing soldiers to rely on external heating sources such as kero-heaters and bukharis. However, these devices generate toxic gases like carbon monoxide, further compromising indoor air quality in an already low-oxygen environment. Additionally, they increase the risk of fire hazards, especially in FEMS shelters, as the insulating material used is not fireproof.

Prototypes like FEMS, which have more openings such as windows and sunroofs, struggle to retain heat at night. Additionally, the sunroof causes excessive glare, which cannot be controlled. To mitigate this, troops cover windows and sunroofs with materials like cloth and cardboard, which negatively affect natural lighting.

Moreover, sun direction is generally not considered while placing these prototypes, except for the SHILA shelter. Designed and installed by HEIL (Himalayan Institute of Alternatives, Ladakh) under the leadership of scientist and visionary Sonam Wangchuk, the SHILA shelter is inspired by vernacular architecture and employs passive heating strategies. As a result, it maintains an internal temperature of 12°C even when outside temperatures drop below freezing. [7].

Figure 11:Modification in Shelter: Kero-Heater, Sun roof Covered with Cloth

Additionally, critical environmental factors such as low air density, extremely dry climate, and low oxygen levels are not considered in shelter design, despite their significant impact on soldiers' health. These factors can lead to respiratory issues, dehydration, and altitude sickness, further affecting the well- being and operational efficiency of personnel stationed in Ladakh.

[7]. There are no clear guidelines for the installation or maintenance of shelters. In most cases, soldiers themselves handle maintenance, but they lack formal instructions or a periodic maintenance schedule, which affects the efficiency and longevity of the shelters. Additionally, the Indian Army's operational policies do not include dedicated guidelines for selecting appropriate temporary shelters. This results in individual authoritative personnel making ad-hoc decisions, often lacking a rational and unbiased selection process for prototypes.

According to army officials, the choice of a shelter prototype depends on fund availability, ease of transport and construction, climate control, and user comfort—in that order of priority. While several prototypes have been tested with an emphasis on user comfort and climate control, they are not widely adopted due to high costs, which are three to four times higher than FEMS. Furthermore, recurring costs are often not considered, making the system unsustainable, as seen in the case of dome shelters.
Overall, the current shelter systems used by the Indian Armed Forces are efficient in terms of mobility, ease of construction, and cost-effectiveness. However, they fail to meet basic habitat standards set by UN, SPHERE, or WHO, and do not ensure climatic comfort. This adds additional stress to the physical and mental well-being of soldiers who already perform the herculean task of protecting the nation. [5], [3], [6]

Factors such as isolation, the monotonous terrain, constant environmental and enemy threats, and lack of communication further contribute to psychological stress among troops, making it essential to rethink and improve shelter solutions for long-term deployment. [7].

IV. Conclusion

The government agencies, researchers, and private sector organizations are actively developing prototypes to improve climatic control and user comfort. However, due to large-scale requirements and limited funding, cost-effectiveness remains the primary factor in prototype selection. Additionally, with ongoing infrastructure development and a lack of advanced machinery and tools, ease of construction becomes the second priority. It is crucial to bridge this gap by developing shelters that are both cost-effective and comfortable, ensuring better living conditions for troops stationed in extreme environments.

A systematic critical analysis of all existing prototypes and user requirements should be conducted to evaluate the impact of shelters on soldiers' functionality, physical health, and mental well-being. This analysis can help identify effective design principles and techniques that can be universally applied across various prototypes.

To enhance shelter efficiency, a holistic approach is required—one that integrates user feedback, climatic data, and prototype performance. Currently, shelter-related decisions are driven by immediate constraints. With comprehensive data analysis, dedicated policies for temporary shelters can be developed to ensure a well-informed, rational, and standardized approach to shelter selection and modification.

Furthermore, the findings from this research can serve as baseline data for developing guidelines, an unbiased selection framework, and Standard Operating Procedures (SOPs) for shelter installation and maintenance. This would not only improve efficiency but also enhance the overall well-being of soldiers in extreme conditions.

Ultimately, a well-designed shelter is more than just a structure—it directly impacts troop efficiency, morale, and mental health. Addressing privacy concerns, space constraints, and psychological stressors will create a healthier and more sustainable living environment for soldiers. By prioritizing both functionality and user comfort, future shelter designs can significantly enhance operational readiness, reduce fatigue, and improve long-term resilience in high- altitude deployments.

Tables and Figures

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