Climate and Seismic Responsive Vernacular Architecture of the Old Settlement of Srinagar, India

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Abstract

The old settlement of Srinagar, Jammu & Kashmir, India, is an open museum for vernacular buildings and has become an integral part of the local cultural heritage. The region is the heart of the entire urban area. It is also often the city's oldest part, constantly shaped with time. The old settlement of Srinagar has always been an important geographical site, despite its varied physical and historical characteristics. Srinagar symbolizes the city's historical heritage as it is located in the heart of the city. Moreover, they are a manifestation of architectural systems optimized over time for the climate and the threat of natural disasters like earthquakes. This research examines the vernacular architecture of the old settlement in terms of climatic and seismic responsive designs.

Its aim is to understand the vernacular architecture of the old settlement, Srinagar. Its objectives are to unravel the vernacular ideas used by the people to make the structures seismic and climate-responsive according to the climate and topography.

It employs a documentary survey and observations as research methods.

The research findings show that traditional architecture proves to be climate responsive and energy conscious due to the inclusion of certain principles and resources. Therefore, the vernacular construction systems like Taq and Dhajji-Dewari; used to resist the ground movement must be utilized in today's construction. The research concludes with the need of preserving lost vernacular architecture.

Keywords*:* Vernacular Architecture, Climate Responsive, Seismic, Kashmir, India.

Introduction

Vernacular architecture has always been a way of building locally in response to a region's cultural, social, and microclimate (Yousuf, 2011). Climate, culture, social and economic characteristics of individuals and their environments have all changed over time. Every area and region evolved distinct features of vernacular architecture that distinguished it from other places over time and via the multifarious interaction of evolution and human adaption to the ambient environment, which is the core of 'identity. Vernacular architecture, in particular, is a result of people, place, and culture; it is one of the many elements of identity.

The manifestation of personal and social identity can be linked to architectural symbolism. “Architecture as identity” has become the equivalent of “architecture as space” and “architecture as a language” as a result of this accretion (McLennan, 2006). Kashmir, meanwhile, exhibits a highly evolved traditional understanding of controlling adverse climatic circumstances through vernacular construction, resulting in human survival for centuries (Salman, 2018).

Raja Pravarsena settled in the area of old settlement in the middle of the sixth century B.C., which has evolved over a period of more than two thousand years (Tiku, 1997). The old settlement region of the city grew in a linear form along the banks of the river Jhelum, a tributary of the River Indus. Itis also popularly known in Kashmir as *Shahar-E-Khaas*, a vernacular architecture-rich region in Srinagar, Jammu and Kashmir, India. With the expansion of the city on the left bank of the river later, emerged the need of bridges for convenient transport of goods and people across the river. Zaina-Kadal bridges were built by succeeding rulers, and by the nineteenth century, Srinagar came to be known as the ‘City of the Seven Bridges’(bridge) was built in the centre of Srinagar as the first permanent bridge over the Jhelum River. The city developed in a linear direction, following the course of the river. The main roads inside of the centre are running parallel to the river. The houses in between, were facing both, the road and the waterfront. However, the main façade was facing the Jhelum River, as the views from this façade were more prominent. (Shah *et al.*, 2018) The area is densely populated, resulting in a loss of Kashmir's vernacular legacy with time (Nissar and Nuzhat, 2016). The fast construction of new structures along the waterfront has raised concerns about the region's vernacular architecture. The research investigates the significance of vernacular architecture in terms of the climatic and seismic responsive design of *Shahar-E-Khaas*- an important town. Furthermore, it proposes that vernacular architecture might be a solution for the climatic and seismic circumstances of the region. The aim of the is to contribute to understand the vernacular architecture of the old settlement, Srinagar. Its objectives are to unravel the vernacular ideas used by the people to make the structures seismic and climate-responsive according to the region's climate and topography.

Literature Review

Vernacular architecture has always been a way of building locally in response to a region's cultural, social, and microclimate (Yousuf, 2011)Vernacular architecture is not static, and it changes with the changing culture and environment. It is indigenous to a region and contributes to the community's and environments long-term viability. With the shifting approach to the built environment, it's more important than ever to grasp the state of vernacular sustainability (Dayaratne, 2018). Vernacular architecture has been growing over time with continuities, changes, transformations and adaptations to the different social and economic conditions of each period in response to actual needs with the available means of every place (Philokyprou, 2015).The vernacular architecture is practically and casually continuing the legacy of the region. For a quite few years, architects are embracing regionalism and the knowledge of traditional buildings as a result of the increased strain brought by ongoing worldwide ecological issues, stating that these structures are energy efficient and extremely sustainable. The interest for economical and sustainable structures, results in the increments in numerous designers to unravel the universe of vernacular design all throughout the planet, so to combine conventional viewpoints with current methods (Nasir and Kamal, 2021).

Significant studies have been carried out on the materials and construction techniques adopted in construction of structures in the old settlement of Srinagar. Kashmir is a seismically active area, and earthquakes big and small will continue to occur. It is not possible to predict when and where an earthquake will strike, nor its intensity. Rural buildings in Kashmir are generally made by the people for their own use without the help of architects. The various forms

of construction have evolved over time with the input of each generation of artisans. Traditional rural buildings use locally available materials and skills. Rural buildings constructed in a traditional way by the people often referred to as vernacular buildings become an integral part of the local cultural heritage. They are a manifestation of architectural systems optimized over time for a particular context with regard to climate, soil or the threat of natural disasters (Dar and Malik, 2013). Structure is an integral part of architecture and both structure and architecture should be addressed to, simultaneously. The normal practice is to incorporate the structural design into an already developed architectural concept. Due to the special circumstance of the earthquake, an integrated approach to structure and architecture was envisaged (Shah and Tayyibji, 2008).

Mohd Akeeb dar and Sajad Ahmad discusses about the traditional systems like *Taq* and *Dajji-Dewari* built historically in Kashmir valley, their architectural significance and how economically these timber framed structures behaved satisfactorily in an event of an earthquake. *Dhajji-dewari* and Taq systems have been put into practice widely. Presently, the cities throughout Kashmir valley can be easily characterized by this typical vernacular Kashmir house. This construction practice is generated from use of local materials, abundantly available blue-pine coupled together to build these Timber framed house which satisfactorily suit the local extreme climate, soil type, distinct natural environment and culture and most importantly the high seismic risk of the area. These typical structures locally referred to as *Dhajji-Dewari* amazed the surveyors as they had performed really well against the earthquake forces. These typical box type houses were simple masonry structures which had a simple patchwork of masonry confined by small vertical and horizontal timber members (Sofi, et al., 2017).

Climate change has impact not just on historic structures, but also on socioeconomic status, which influences the ever-changing and developing cultural landscape. Traditional building materials and procedures that can't keep up with the changing climate are being replaced with foreign-made technologies and materials. Climate change and the emergence of industrial technologies have transformed the environment (Nasir and Kamal, 2021)**.** Consequently, a large part of the vernacular heritage of the region is increasingly morphing into an ugly looking patchwork of the old and the modern. Given the lack of awareness amongst the general public and even in many of the professionals, about how different materials behave and how traditional structures behave, modern additions to old structures also adversely affect their structural integrity. To save this rich yet fast disappearing architectural legacy of yesterday, it is imperative to document it in typologies, styles and traditional building knowledge systems so that measures can be taken to protect it and make adaptive use of the knowledge behind this architectural style (Beg, 2016).

Research Methodology

This research employs qualitative research method. It examines how vernacular architecture responds to climatic and seismic activity as seen in the old settlement area of Sri Nagar Jammu and Kashmir, in India. The research aims to achieve three different objectives.

Data collection includes the government reports on climatic and seismic activity in the region. The data collected in the qualitative research is the data that comes from several case studies and examples that are described descriptively and are supported by illustrations and photographs to reinforce the arguments put forward. Furthermore, it carries out a documentary survey of related to the field study of the area: the old settlement, Srinagar. The physical survey of the study area is done to identify the contextual issues and setting. The survey of the case study of vernacular architecture of Srinagar to understand the typology, architectural style, construction techniques and materials. The basic concepts and backgrounds are investigated through literature and on-line media; an observation to work for qualitative analysis conducted to document and explain the vernacular understandings of architecture of old settlement of Srinagar, Kashmir. The research analyses the supportability, climatic and seismic responsiveness, capability of sustainability of vernacular architecture of the old settlement of the Kashmir region.

Vernacular Architecture in the Old settlement of Srinagar, Kashmir
The Evolution of Form

The Kashmir Valley is surrounded by the main range of the Himalayas on the Northeast and the Pir Panjal Range on the Southwest. Srinagar, the largest city in the valley, is also known as the summer capital of Jammu and Kashmir, India. The capital city is located on the banks of the Jhelum River, which further moves along the lakes of Dal and Anchar. It covers a total area of 294 Sq.Km (Ahmad *et al.*, 2022). The Valley of Kashmir was once thought to be underwater, with settlements located on higher land in the productive areas. Gopadri and Shankracharya are two hillocks that protrude. The Mauryan King Ashoka is thought to have created the first urban centre in this region in 250 B.C., known as Srinagari. This city has extended about a mile and a half East of the Hari Parbat hill. Srinagari was the capital of Kashmir till Raja Pravarasena founded a new city at Hari Parbat hill in the middle of the sixth century A.D. (J &K, 1981). This new city has been named Pravarpura after its founder's name. Ithad extended only on the right bank of the Jhelum River (Tiku, 1997). The two cities that were formed were near each other, due to which the old name, Srinagari has prevailed over the new name. Presently, the area where Raja Pravarsena formed the settlement is known as the old settlement, which took roughly 2000 years to settle (Wakhloo, 2020). The Jhelum River has played a crucial role in the formation of it and development as a linear settlement along the banks.

Most ancient communities' have developed along the riverfronts, and Srinagar's *Shahar-E-Khaas* is no exception. Moreover, this city has expanded along the banks of the river, but the importance of the river as the source of life has never been undervalued. The various developments which have taken place along the Jhelum River include the establishment of residential, commercial and religious sites. Further, the spatial structure of the city has evolved in harmony with the water bodies and topography. The structures which have been constructed have followed the vernacular architecture patterns. This architectural style and pattern that has emerged has been influenced by variables such as the region's climate, the Jhelum River, and the two hillocks of Gopadri and Shankracharya. Moreover, the pattern of development has also beeninspired by the locally accessible building materials as well as the talent and workmanship of the indigenous people, which has resulted in a distinctive stylistic coherence in the architecture along the waterfront.

Local Environment and the Materials

*Shahar-E-Khaas,*Old settlement is a densely populated area of Srinagar and has a large trading community (Azad, 2016). The environment of the region is influenced by the growth pattern along the river Jhelum. The region has narrow streets interconnected, leading to the main roads. These narrow streets are approached by a flight of steps from the river Jhelum (Tiku, 1997) which has been used for transportation and trade, and boats known as Shikara in the Kashmiri language has served the purpose (*How traditional Kashmiri architecture was designed to withstand even severe tremors*, no date). This mode of transportation has maintained the interconnectivity between the different areas of the old settlement and the spots where the boat stops are referred to as Ghats in the Kashmiri language. The structures seen in this area are constructed in a haphazard manner, since the settlement formation along the waterfront has begun.

Today, the region is witnessing haphazard constructions along the Jhelum River, Moreover, it has resulted in demolishing vernacular architecture with no aim of preserving the two-thousand-year-old structures. In addition, the extant vernacular structures are also neglected. These structures have been constructed mainly with a layout for three to four storeys (Saxena, 2019). Locally available materials have been utilized to make the buildings livable in harsh winters and cool summers. Besides, the region faces frequent earthquakes, and the construction of earthquake-resistant buildings is essential at the same time. The city of Srinagar is classified in the seismic Zone V by the National Center for Seismology (N.C.S.), India. To

withstand ground shaking, vernacular buildings employ a variety of techniques and materials. The materials used in the vernacular building have played a significant role in the construction of the structure to make them climate and seismic responsive (Sofi, Raghuprasad and Amarnath, 2017). The types of materials used for the construction include wood, mud-hay mixture, stone, mud bricks, and thatched roofs (*How traditional Kashmiri architecture was designed to withstand even severe tremors*, no date) (Langenbach, 1990). These materials have played a significant role in retaining heat inside the structure during the winters and cooling it down during the summers.

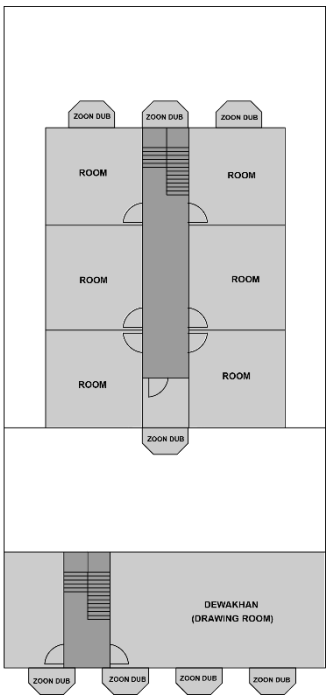
Design Philosophy

Needless to say, vernacular buildings have played an essential role in the lifestyle of the Kashmiri people. They are known to be social and have social groups where they engage with each other. Accordingly, the structures have been designed to fulfill their requirements. Besides, the design of the building has also contributed to the construction of climatic and earthquake-resilient vernacular structures. Three to four storeys high buildings built along the Jhelum river also has a basement (Saxena, 2019). In the most densely populated areas, most dwellings share common walls with their neighbours. *Mohallas*, or small districts, have been formed by grouping the houses. The planning of these dwellings, large and small, has followed a similar pattern. The buildings mostly had square and rectangular layouts (Henderson, 2002). Almost all the buildings have been built on stone masonry plinths with strong timber measuring at least one metre in height (Langenbach, 1990). Furthermore, visitors and guests have primarily used the ground floor, while family members have used the upper floors. The basement, also known as Ta-khan in the Kashmiri language, has been used to store food items, coal, and wood to survive the region's harsh winter.

The basement has been usually accessed via the stairs adjacent to the kitchen, not visible from the main entrance. The basement was enormous, and it has occupied the entire floor. The ground floor of the structure has been accessed via a courtyard with a small flight of steps leading to a corridor, which is known in the Kashmiri language as *Wot*. Multi-functional spaces have been located on each side of the *Wot* and have been utilized for informal events and for the visitors. The kitchen was located on the left side of the dwelling. Adjacent to the kitchen, there was another room where the meals were served and acted as a dining space known in the Kashmiri language as *Dan Kuth* or *Choka*. The first storey has served as a private floor with more family rooms. The second-floor was referred to as *Kani* in the Kashmiri language. The *Kani* floor has been designed as a large room that stretched across the entire second floor or divided into small rooms with carved wooden partitions known as *Wurusi*. This floor has had windows running around its perimeter. The windows were only partially glazed and had shared panels. The modest level of glazing was designed to keep out the cold in the winter and prevent heat loss. During the summer, the *Kani* was used mainly, and the windows were frequently left open to let the cool summer breeze flow through. The family members have utilized this floor to gaze out directly onto the riverbank or the road or participate in the main activity zones. Moreover, for large gatherings and functions, this space has been used. During the winter, it has been primarily utilized for storage.

Apart from the wood mullions, windows, and infills that exhibited vernacular architecture, the *Zoon Dub*, or projected bay windows, was the *Kani's* most remarkable feature. These bay windows were suspended over the river or road, and were cantilevered from the main façade. The circulation between the different floors was done through wooden staircases, which resembled a spiral staircase in smaller houses that took up little or no space. Whereas larger residences often had a straight flight of stairs, with a few dwellings having wooden staircases that wound spherically around the central area with rooms around them. This low divider was also used to mark the doorway to the room in larger houses. The separation requirement was most likely because the rooms were often carpeted wall to wall or had a mat covering due to the chilly weather conditions. The rooms had less furniture and were mostly made up of low chairs along the walls. Furthermore, the structures were created in two different systems, the *Taq System* and the *Dhajji-Dewari* System, to make the vernacular designs seismic-resistant

(Shah and Tayyibji, 2008). These two construction systems are of the backbone seismic vernacular designs. responsive



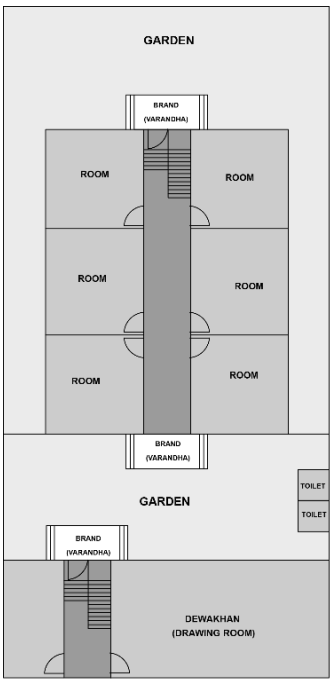


Fig. 1& 2: Ground Floor & Residence
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the First Floors of the

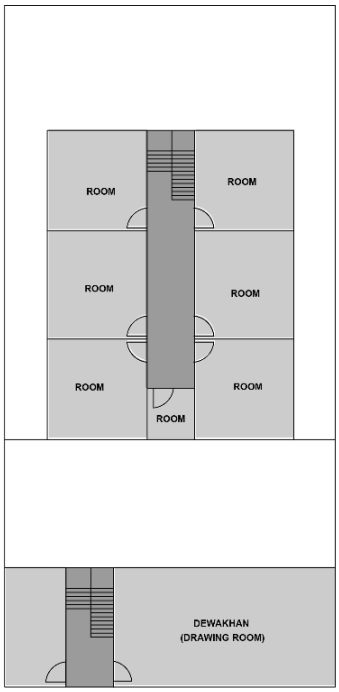

Fig.3: Second Floor Residence
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Construction Techniques

The buildings that have been built in this area are based on only two major techniques that were once popular among the people (Islam and Shah, 2018). That's the *Taq* and *Dhaajji-Dewaari* construction systems. These systems are also referred to as Timber Braced System, which is a substantially lighter and slender wall construction system.

Vernacular Architecture for the Climate of Old settlement, Srinagar, Kashmir.

Macro Climate of the Region

Shahar-E-Khaas- an old settlement faces long, warm, and clear summers. At the same time, the winters are short, yet bitterly cold, and partially cloudy. The yearly temperature of the valley ranges from 28°F to 85°F, with temperatures rarely falling below 19°F or rising over 91°F. *Shahar-e-Khaas* is an old settlement established on the banks of the river Jhelum connected to the extended city through seven bridges known as *kadals*, in different directions on its periphery. The bridges date back from the seventeenth and twentieth century, constructed over different periods. In early times the entire population resided within the limits of *Shahar-e-Khaas* with commercial activities taking place in designated areas serving as a trade hub. (Dad *et al.*, 2021) The neighborhood of the old settlement along the river Jhelum is the most densely populated area of Srinagar. The community is row housing in which small alleys connect dwellings and other structures to the important highways, bridges, and the banks of the Jhelum Ghats, where boats were utilized for trading and transportation. Thus, as per the region's urban fabric, it usually faces Urban Heat Island effect. However, it is equalized with the cold winds blowing over the river Jhelum, making the summer temperature cool. During the winters, Urban Heat Island effect helps in keeping *Shahar-E-Khaas*, area warm. The structures which were built prevented movement of the cold wind inside. Moreover, a rise in humidity is observed due to the waterbody. Besides, the probability of natural disasters like floods that mostly occur due to climate change is less in this region. The Jhelum River is flowing in a downwards direction with a moderate slope which does not allow water to log into the populated area.

In September 2014, the Kashmir valley was hit by floods caused by torrential rainfall (Ahmad, Pandey and Kumar, 2020). The area of *Shahar-E-Khaas*, old settlement was least affected as compared to the other parts of Srinagar, despite being close to the river Jhelum (Nivedita, 2020). Moreover, people from other parts of Srinagar shifted to this area for safety.

Planning and Design of the Structures

Vernacular architecture of *Shahar-E-Khaas*, old settlement has various elements in terms of planning and techniques. These elements were used to regulate the microclimate of the site, and at the same time, it was used to create thermal comfort inside the buildings. Moreover, a proper understanding of materials, planning, and placement of different elements like windows, niches, bay windows, etc., have played an essential role in climate responsive designs. The three to four-floor dwellings constructed along the Jhelum river were of two types, large and small, which had a similar pattern of organization in terms of planning. The plans were mainly made on square planning so that minimum external walls were exposed and the heat was trapped inside the structure in the cold winter (Tiku, 1997). The structures which were constructed had confined spaces with compact planning. The basement and the ground floor of the building were made up of stones that acted as a retaining wall along the banks of river Jhelum. The heavy stone walls were also an element for the vertical damp proof course for the sides of the construction exposed the waterfront. Stone walls with mud-hay plaster from inside had climatic significance as well. During winters, these stones trap heat and radiate that warmth for a long time when adequately insulated with mud-hay plaster from inside. They have high energy density and excellent thermal conductivity. During summers, stone keeps the interior of the building cool. Furthermore, the insulation of mud-hay mixture was used, which is referred to as *Boor* in the Kashmiri language. This *boor* mixture is applied as a plaster for the inside walls of the structure made up of mud brick, called *Maharaja* Bricks. The *Maharaja* Brick was handmade, small, and dense (*How traditional Kashmiri architecture was designed to withstand even severe tremors*, no date). This acted as an insulation to trap the heat during winters and provides thermal comfort inside the dwelling. The window openings were kept small because of the region's cold weather. Besides, different types of wooden windows were placed along the wall's perimeter, which are *Mehraabs* and *Zoon Dubs*. The *Zoon Dubs* are the cantilevered bay windows. At the same time, *Mehraabs* are the arched windows and doors. The vertical circulation of the dwelling, which is the staircase, was mostly located on the back side of the

building with no or minimum openings. All of the levels had a separate staircase approach, preventing the formation of a staircase well, which causes cold winds that circulate throughout the structure. The size of the staircase was reduced, and as a result, stairs in smaller homes have frequently been constricted with risers as high as 10 inches or more. The risers inside the larger dwellings ranged from 6 to 8 inches (Tiku, 1997). The majority of the staircases were made of wood. The landing in the smaller homes led up to the main living area, separated by a low timber wall around the width of a door and about 2 feet high that could be readily passed and delineated the room's area. Mostly the rooms were 10' by 10' in size. The reason was that the smaller the room, the easier it would be to control the inside temperature. A special room called *Hammam* was located on the ground floor in Mosques and the dwellings of elite class people of the old settlement. In *Hammam*, people use to sit in winters, and it also had a bathroom attached with it. It's a raised room and has thick, hand-hewn rectangular slabs of limestone known in Kashmir as *Devaari* Stone which is laid over a hollowed-out floor. *Devaari*Stone columns support the slabs at the joints, which are sealed with mud and limestone mortar. The Hammam's interior walls are lined with lime mortar-sealed bricks. To absorb and maintain heat, the floor is strewn with sand, broken glass, and boulders. In dwellings, one end of the *Hammam* opens up in the dining area referred to as *Wuth* where the fireplace for *Hammam* is located which is called *Gaaeg* in Kashmiri language. This fireplace warms the hollow floor of *Hammam* with the *Wuth* area at the same time. There used to be a copper water tank referred to as *Maeet* in Kashmiri language, placed near *Gaaeg* to heat the water for the *Hammam* bathroom. The *Hammam* bathroom's entrance use to be from the kitchen in dwellings. Moreover, in Mosques, the Hammam *Gaaeg* is mainly located outside the structure.

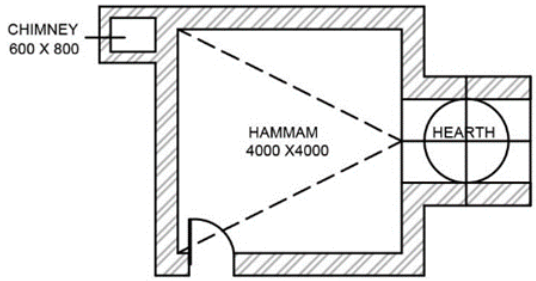

Fig.4: Plan of Hammam
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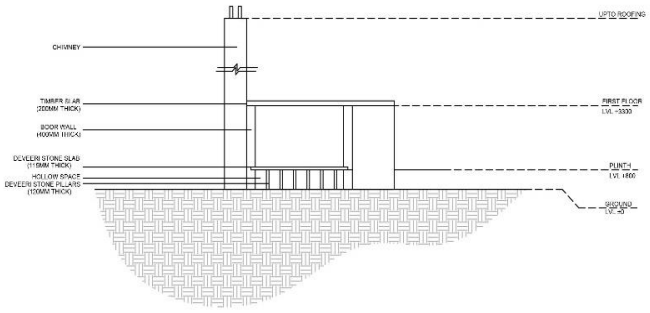

Fig. 5: Section of Hammam
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Passive Techniques Employed in the Vernacular Settlement of Kashmir

Zoon Dubs

The projected cantilevered balcony is known as Zoon Dub in the Kashmiri language and is also referred to as a bay window. The meaning of the word Zoon stands for the moon, and the meaning of Dub is a covered balcony. These Zoon Dubs are the element of the main façade of the building. These cantilevered, covered balconies are located on the structure's topmost story, usually the second floor, which is referred to as Kani. They were built using an

instantaneous and simple approach of extending over the ground joists. These cantilevered balconies are completely enclosed from 3 or 5 sides with Jaali shutters. The Jaali shutters around the perimeter of these projected balconies are the geometric wooden latticework panels also known in the Kashmiri language as Pinjra Kari or PinjraJaali. The family members mostly use Zoon Dubs in summers, where they sit and enjoy the sunny weather. These alcoves formed the window seats inside the residence's different rooms and enriched the facades with bold projections. These bay windows are approximately 4 to 6 inches above the floor level, and the sills of the window were a foot and a half from the seat level, which gave a clear view from the window once seated (Sofi *et al.*, 2017). It captures daylight and keeps the room warm. The geometric wooden latticework panels allow daylight and wind movement inside the structure during summers. Whereas during winters, to allow light inside the houses and to block the wind movement, the oiled newspaper was attached to the Panjra Kari or Jaali shutters (Langenbach, 1990). In this way, wind movement is blocked, and thermal comfort is maintained inside the structure with the help of daylight that enters the building.

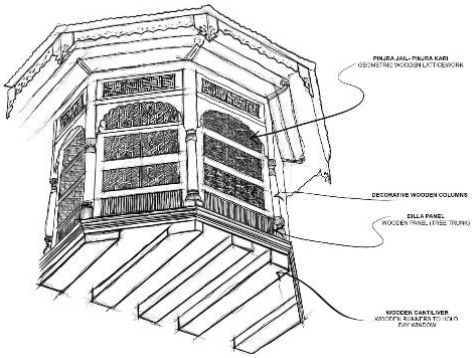

Fig.6: Zoon Dub
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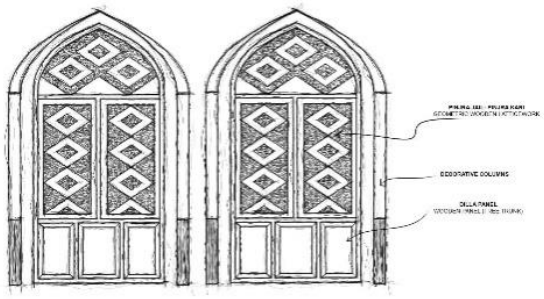

Fig.7: Rectangular Zoon Dub
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Mehrabs

The arched windows and door openings are referred to as *Mehrabs*. The arched windows are made up of timber, having two plank openings. Each plank has *PinjraJaali* or *PinjraKari*, a geometric wooden latticework screen from outside and from inside, it has a wooden plank referred to as *Dilla* (Langenbach, 1990). These *Mehraabs* have a low extent of glazing that keeps out cold in winters and reduces heat loss (Tiku, 1997). *Dilla* planks of *Mehraabs* were kept open in summers so that sunlight could enter, and these planks were closed in winters to create thermal comfort inside the structure. The dimensions were approximately 4 feet in height, whereas the width used differed between 4’ to 6’.

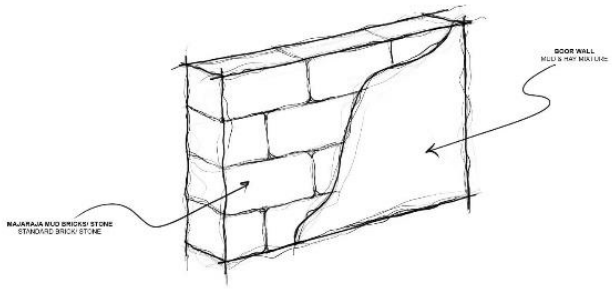

Fig.8: Mehrab
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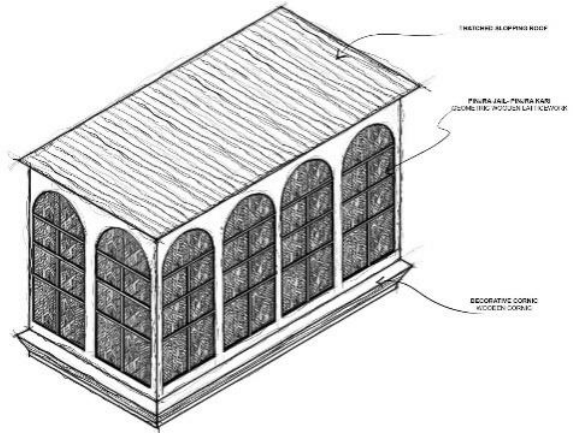

Fig.9: Mehrab
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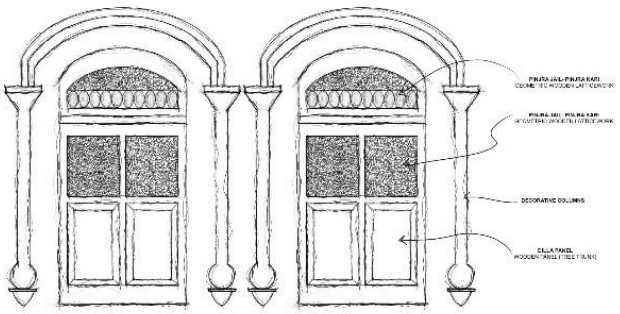

Fig.10: Boor wall representation 3D view sketch
Source-Author

Boor walls

The vernacular construction has walls that are 3 feet thick with insulation which keeps the structure warm in winters and cool in summers. This insulation used here is a mixture of mud and hay called *Boor* in the Kashmiri language. The *Boor* mixture is used as mortar, and at the same time, it's used to cover and plaster the exterior walls from inside so that thermal comfort is created.

Vernacular Architecture for the Seismicity of the Old settlement, Srinagar

Seismicity of the Region

Kashmir is a seismically active area and has witnessed various earthquakes over a period of time (Yousuf *et al.*, 2020). The earthquakes that have struck the region were of high and low magnitude and they tend to occur in the future as well due to the region's geography (Kashmir, 2011). It's not possible to predict the earthquake's intensity or location (Dar and Malik, 2013). Moreover, the Kashmir valley is situated at the fault line of the Indian and Eurasian tectonic plates, and the convergence of these two plates have formed the Great Himalayan Mountains (Shah, 2015). These tectonic plates make the region prone to hazardous seismic earthquakes (*When the Earth Moved Kashmir*, no date). The Valley has been shaken numerous times by earthquakes, the most damaging earthquakes in 1885 of magnitude 6.2 and 30 km to the west to the region (Dasgupta and Mukhopadhyay, 2019). Another major earthquake was caused in the year 2005 of magnitude 7.6, having epicenter 200 km to the south-east to the region (Wyss, 2006). The earthquake of 2005 came with various aftershocks, which caused landslides and falling rocks, causing damage to highways and mountain roads (Britannica, 2017). The estimated magnitudes were taken down by European Macro-seismic Scale (E.M.S.), having intensity between VI-VII (Bilham and Lodi, 2010). Furthermore, Srinagar, *Shahar-E-Khaas* old settlement area is more vulnerable to earthquakes as the region comes under seismic Zone V according to the National Center for Seismology (N.C.S.), India.

Planning and Design of Structures

Natural disasters are unexpected and dangerously powerful, making them a serious hazard to communities nationwide. The vernacular constructions of *Shahar-E-Khaas* were designed and planned so that the buildings could resist the earthquakes and damage caused by them. They used various techniques in terms of planning, construction, and construction techniques. Firstly, for the planning part, the constructed structures were preferred to be squarish and linear. The arrangement of function in the dwelling was distributed in symmetry, as symmetry is the primary principle for earthquake resistance structures. Secondly, the vernacular constructions are divided mainly into two construction systems, *Taq* Construction System and *Dhajji-Dewari* Construction System (Langenbach, 1989). Furthermore, the walls of these construction systems are lightweight, resulting in significantly reduced mass and lateral seismic loads. As a result, these types of construction systems can endure significant ground settlement and major earthquakes without sustaining significant damage. Structures created using *Dhajji* walls, and *Taq* construction technique are known for their ability to withstand earthquakes (Langenbach, 2007). The vernacular structures using these techniques have survived numerous earthquakes and are still standing. Furthermore, few additional techniques in the construction system have served as a backbone for vernacular buildings, such as stone masonry constructions. The movement generated by seismic waves displaces the stones used in the foundation and the walls, which reduces the vertical shocks in the building (Kamal & Brar, 2021). Furthermore, the stones utilized in the wall of the ground floor and basement of the structure are further used as infill for the *Dhajji-Dewari* Construction Systems.

Passive Techniques

Dhajji-Dewari System

Timber Braced System or Patch-Quilt System are other names for the *Dhajji-Dewari* System. The phrase *Dhajji-Dewari* is derived from a Persian word that means "patchwork quilt wall" (Hicyilmaz *et al.*, 2012). It is a vernacular construction system found in the western Himalayas, with similar techniques visible in *Shahar-E-Khaas*, old settlement. It's a simple construction technique that uses indigenous materials like wood, mud bricks, and mud mortar as fill. This is a well-known and practical strategy for building earthquake-resistant structures. The *Dhajji-Dewari* coexists with the *Taq* system of construction. A wooden frame is used in the *Dhajji-Dewari* system, which is filled with masonry. The wooden members can be placed into the masonry wall horizontally, vertically, or inclined. These wooden pieces separate the masonry wall, preventing the crack from spreading over the entire wall and, as a result,

providing strength to the masonry wall. When seismic waves move along these members, they are spread together with these crossed braced timber logs infilled with stone masonry using mud mortar. This wave distribution lowers the earthquake's rapid impact on the structure and stands out as a technique used in earthquake-prone areas. The *Dhajji-Dewari* structure was built using a braced timber-framed structural technique, with 4-9 inch thick brick masonry utilized to fill the spaces between the braces (Beg, 2016). The use of thin mud mortar is the most significant element of this building form. The usage of the *Dhajji-Dewari* system in the top storey walls is a widespread practice in the region (UNISDR, 2008).

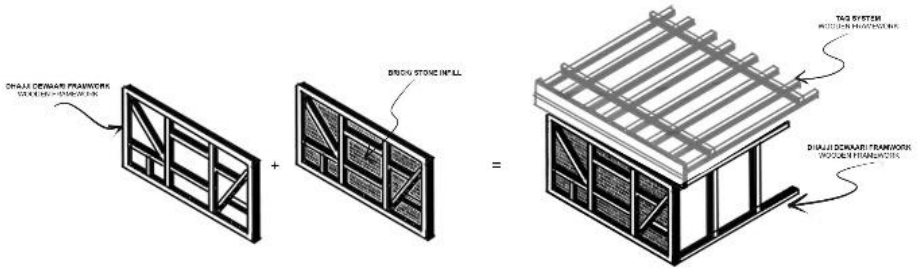

Fig.11: DhajjiDewaari Frame Building
Source-Author

Taq System

The *Taq* system is a wooden interlaced bearing wall masonry construction. The timber beams that make up the *Taq* buildings are not complete frames. Large wooden runners rest along the load-bearing stone walls as an alternative, and the wooden runners lap over the cross walls with the floor beams. The timber is used to connect the structure's walls to the floors. The masonry load helps to prestress the wall, making it more resistant to lateral forces (Hicyilmaz *et al.*, 2012). The *Taq* structure used timber joists to support the floors called *Verami* in the Kashmiri language. Typically, this system was limited to the structure's upper floors or attics. This sort of structure is highly resistant to earthquakes (Beg, 2016).

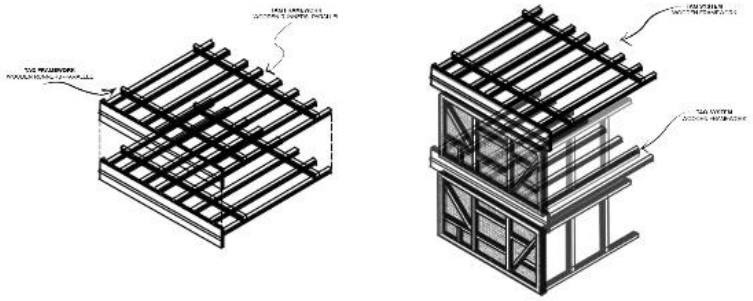

Fig.12: *Taq* Frame Building
Source-Author

Stone masonry

The people of Kashmir are mostly very fond of stones. Most of the constructions which had taken place for ages, especially when vernacular constructions along waterfront began, people started using stone for foundation, plinth, retaining walls, and infill for braced timber walls. The stone has strong seismic resistance when used in the foundation and the plinth with dry stone masonry. The movement caused by the seismic waves leads to the displacement of stones and minimizes the shocks travelling in the vertical direction of the building. Moreover, this stone is also used with mud mortar as an infill material in *Dhajji-DewariSystem*. When the seismic waves travel vertically, they are distributed along these crossed braced timber logs and

infilled with stone masonry with mud mortar. This distribution of waves reduces the sudden impact of the earthquake on the structure.

Fig.13: Dewaari Stone – Elevation
Source-Author

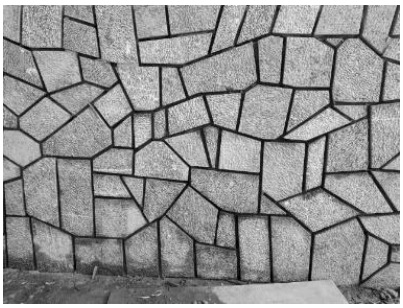

Fig.14: Stone Foundation
Source-Author

Fig.15: Stone Foundation
Source-Author

Findings

To understand impact of vernacular architecture for the climatic and seismic data of the old settlement area of Srinagar, various research papers and books were studied. This data was further used to test the paper's hypothesis that vernacular architecture is a better solution for the climatic and seismic conditions of the old settlement, Srinagar. Further to this, it was found that the vernacular architecture of *Shahar-E-Khaas- an* old settlement positively correlates and tackles the climate and seismicity of the structure. Moreover, the responsive structures can be made when different vernacular passive techniques are used in the construction, which supports the hypothesis of this paper.

The vernacular, indigenous practices are tried-and-true and long-lasting. As a result, more focus should be placed on the documentation and research of indigenous techniques in order to create a knowledge repository. This information base will aid in the formulation of best practices in architecture, which will be combined with traditional techniques. Vernacular architecture of Kashmir region is a symbol of national identity and long-term viability; it is a "mirror" of nations, reflecting place, period, and culture. Architecture that was created by

people and for the people, has evolved over time and through trial and error to meet society's requirements while remaining in harmony with the environment. The search for a new regional identity entail being free of imported ideas and ideologies while maintaining cultural interconnections that benefit human civilization. Regaining a Kashmiri identity is critical to the construction of a new culture, not only in terms of architecture but in all parts of life, in order to leave a mark in an ever-changing world.

There is a necessary aspect of inculcating traditional building skills and knowledge into the design of modern buildings in a creative manner, creating a harmonious blend of old and new. The goal is not simply to replicate the past, but rather to adapt and integrate traditional knowledge to meet present-day requirements. Vernacular structures possess significant advantages, including resilience against disasters, cost-effectiveness, environmental friendliness, and aesthetic appeal. It is only by showcasing these qualities in contemporary design and construction that we can effectively preserve historical knowledge and maintain a continuous creative process that connects our past to our future.

Conclusions

The natural and passive systems in buildings use non-mechanical methods to maintain a comfortable indoor temperature and are a key factor in mitigating the impact of buildings on the environment. The traditional architecture of the past is the best pointer in this regard and constitutes outstanding evidence of being climate-responsive and energy conscious. They display years of embodied experience built on the relationship between building and climate, implying a logical analysis, the consideration of appropriate principles, and rational use of resources. Rapid developments and financial and political globalizations have made tradition and culture much less ‘area-routed’ and more ‘information-based.’ In a state of affairs where the world is changing, survival of vernacular architecture is at stake. The vernacular resources, technology and forms are typically visible to be well adapted to neighborhood climatic conditions and are regularly considered an appropriate base for the environmental layout.

The research was aimed to understand the vernacular architecture of the old settlement, Srinagar, whereas the area of focus was how it was climate and seismic responsive for the region. To understand the vernacular architecture as related to the climatic and seismic activities of the *Shahar-E-Khaas*, the research examined the different aspects of construction. It includes the materials used for the planning and designing of structures with different passive techniques. The paper demonstrated that these strategies have helped regulate the geographical and climatic conditions affecting the structure.

It was discovered that the vernacular architecture of the region employs two construction systems: *Taq* and *Dhajji-Dewari;* constriction system used to resist the ground movement. The stone walls and foundation have been preferred to reduce the seismic waves travelling vertically in the structure. Moreover, for the climactic response, it has employed *Zoon Dubs*, *Mehrabs*, and *Boor walls* were the central area of the focus to keep the building warm inside during winters and cold during summers.

This research aimed at understanding the importance of the lost vernacular architecture of the region. Furthermore, it argues for the physical conservation of a two-thousand-year-old settlement which could increase the understanding of conservation of the vernacular architecture of the old settlement of Srinagar.

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