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Comparative Analysis of Energy Consumption in Traditional and Modern Buildings in Village Sapni, a Village in Kinnaur District Located in Western Himalayan State of Himachal Pradesh

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ABSTRACT: High altitude regions of district Kinnaur in western Himalayan State of Himachal Pradesh, due to its high altitude topographical and cold climatic conditions, remains under snow for around six months in a year. Most of these areas receive snowfall around 5 – 7 feet on annual basis. Such extreme climatic conditions have made the life of local habitants difficult. The indigenous people have developed climate responsive architectural styles. Such type of vernacular architecture is based on utilization of locally available resources such as wood, mud and stones etc. The houses have been designed as per set principles of *vastu shastra* and utilize solar energy to optimum level in attaining a level of thermal comfort. It has been observed that such house based on vernacular techniques of housing are found to be energy efficient and comfortable throughout the year in comparisaon to modern cement concrete buildings. One such study of traditional and modern houses at village Sapni, District Kinnaur has been presented in this paper and it has been concluded that the traditional building is consuming less energy (about 50%) to that of modern building at the same site and location.

KEYWORDS: Base Temperature, Heating Degree Days, Modern building, Thermal Comfort, Traditional building, Vernacular architecture.

1. INTRODUCTION

Energy and environment are major concerns for the society. With the increase in world population, and rapid development and globalisation the energy demand is increasing at a rapid rate. In the recent years the rate of consumption of energy has increased manifold. Common consumers of energy are industries, transport and buildings. At present, most of the required energy is derived from fossil fuel based sources such as coal, petroleum and natural gas. As per world energy scenario more than 85% of total energy demand is met from fossil fuels (BP Statistical Review of World Energy, 2019). As a result pressure on resources of fossil fuels has been increased. Moreover, the fossils fuels are likely to be exhausted within few decades. On the other hand with the increased awareness on the ill effects of use of fossil fuels on the environment, a trend has been noticed worldwide in the use of clean and renewable energy (Ingvar B. Fridleifsson, 2003) [1].

India has been noticing a rapid growth in Total Final Energy Consumption (TFC) due to rising demand of electricity putting an increased load on Power generation. It has contributed to increase in Total Primary Energy Supplies (TPES). As per India 2020 – A Energy Policy review, International Energy Agency (IEA), from 2007 to 2017 the TPES have increased by over 55%. Large portion of it has been met out from fossil fuels. The contribution of Coal is 44% of TPES in 2017. This has accounted for more than half of the total energy supply growth in past decade. Oil has contributed 25% of TPES in 2017. However, Natural gas, has noticed a decreasing trend during last five years in terms of TPES.

As Compared to fast growth in the use of fossil fuels, the increase in other sources like bio energy supply has been moderate. The use of Hydro energy has been stable, it has observed an growth of 10% in the past decade. Wind, solar sectors have noticed a rapid increase, but still they are a low level. In 2017 both of them together have accounted for meagre 1% of TPES. The Nuclear power is too at a low level of around 1% to TPES [India 2020 – A Energy Policy review, International Energy Agency (IEA)] [2].

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The pattern of energy consumption is usually classified into three main sectors: industry, domestic, agriculture and others, which include commercial, traction & railways etc. At present the residential and commercial sector is accounting for 30% of total electricity consumption and it is rising at a rate of 8% per annum.This sector include all commercial and public buildings, which also include schools, restaurants, hotels, hospitals, etc. with a wide variety of uses and energy services Heating Ventilation and Air Conditioning (HVAC), domestic hot water, lighting, refrigeration, food preparation, etc.. The increasing population has also resulted in increased demand for energy for buildings (Nagaraju Kaja, 2017). [4]

2. REVIEW OF LITERATURE

The buildings are required to behave naturally to minimise the effect of climatic variations and to make a balance between indoor, outdoor environments. The climatic parameters for different zones, sun's movement throughout the year, the precipitation pattern, wind speed and wind direction need to be considered for proper climate responsive, self sustainable building. The development of a society can be best assessed by the types and aesthetics of its buildings. The civilisations of Harrappa and Mohenjodaro in Indus valley, considered to be the best civilisations, are characterised by the best contemporary architectural planning and buildings designs. The excavated monuments and citadels reveal best examples of engineering and architecture

Vernacular architecture refers to structures built using locally available materials in a functional style devised to meet the needs of common people in their time and place. Most of the vernacular architecture responds to the regional climate. Such structures have been modified and evolved over a long period of time through feed-back mechanisms which are already there in the system, which reflect the environmental, cultural aspects and also the historical context in which they live. As different climates require different architectural responses, in order to satisfy the various necessities, vernacular architectures developed through the centuries has many original and interesting design practices and technologies (Albatici, 2009). [5]

Focus of the building sector today has shifted towards sustainable buildings. Such buildings have positive impact on environment. In today perspective the vernacular architecture has emerged as a solution to the environmental and energy issues. This type of architecture is developed locally by the inhabitants of a particular topography. The basic principle behind the vernacular architecture is to provide a level of thermal comfort without using auxiliary sources of energy. Such buildings have low energy solutions to attain a condition of human comfort. The methodology adopted is integral to the building design and form. These buildings use locally available materials. Analysis of vernacular architecture would provides significant leads for designers/ architects/ scientist involved in energy efficient and sustainable buildings.Halıcıoğlu, F.H has examined vernacular architecture as a source of knowledge for sustainable building solutions. For establishing the facts he analysed the traditional settlements and houses of Sirince in Western Turkey. He concluded that the most significant goals of vernacular architecture and sustainable housing projects are the adaptation to local climatic and environmental conditions. These buildings are long lasting, energy efficient, have low maintenance cost and provide the residents best quality of indoor air. The study indicates that the vernacular architecture of Sirince has important energy efficient features like local building materials and indigenous eco friendly technologies which are responsible for indoor thermal comfort and healthy conditions with minimum of additional sources of external energy. The basis feature common in most of the houses at Sirince are fresh air circulation, natural ventilation, avoiding unnecessary heat gains and shading solutions. Also houses have been built using locally available resources which adapt naturally with the local geo-climatic conditions. The Energy costs for producing and transportation of building materials have been minimised by using locally available construction materials. As explained above, these houses are perform better in terms of energy efficiency and thermal comfort to the inhabitants. Such traditional houses are vernacular and sustainable providing best components for sustainable built environment. Hence, vernacular settlements could be seen as an opportunity for sustainability and an inspiration to professional and designers (Halıcıoğlu F.H, 2012). [6]

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Modern Cement Concrete Buildings

The architectural style, in India, has changed rapidly after independence. The change in building architecture from traditional ones has changed to modern concrete style very rapidly. The principles of traditional architecture and planning have been ignored with the advent of modernism. The traditional architectural practices based on the cultural values and local geography have been lost in the past and new concrete, climatically non responsive blocks have replaced the form and style of the architecture.

Drawbacks of Modern Buildings

The reason for overheating in most of the buildings in hot, tropical and subtropical climates was found to be the excess use of glass surface in the facades of the building. These glass structures have the characteristics of heat storage and therefore cause problem in summers. Consequently this overheating has led to use of mechanical systems.

However, it is observed that the architects and building planners are still using universal design styles which usually focus on form language and neglect the features and characteristics of vernacular architecture (Liedl Hausladen, 2012). [7]

There are different types of architectural built forms on the laps of Himalaya in the city of Shimla, the capital of Himachal Pradesh, India. It was started from the Scottish Baronial style in the time of British rule – when Shimla was chosen as the summer capital of India, followed by the traditional vernacular styles, coming up with the New-Tudor style and in recent times with the Modern Architectural style. However, the raw building materials used for all of these styles are stones, timbers, batten boards and glass. Extensive use of stone and wood makes the built form to be sculpted out from the hills itself to balance the settlement of the built forms with the nature making it harmless for the hills. Use of locally available materials and adopting local construction techniques are more responsive to the climate and geographic conditions (Chatterjee Rajroshi et. al, 2017). [8]

The Climate, Buildings and Thermal Comfort

In cold climatic regions of India, a huge amount of Energy is required for space heating and day lighting in Government offices or other residential buildings. Several parts of Himachal Pradesh in general and the tribal region of Chamba, Lahaul and Spiti, Kinnaur in particular remain covered under snow for more than six months in a year. The residents of these areas are dependent on fire wood, diesel, kerosene for space heating and cooking purposes. The most parts of the State use coal, fuel wood, kerosene, for space heating during these six winter months. The urban populations, however, use electricity and LPG for the above purpose. As the tribal regions are mostly located in the cold desert region, the state government provides the fuel wood and other fuels subsidized rates to these tribal and remote areas in high altitude regions. Hence in such situations the necessity of solar passive housing and solar passive features in buildings could be realised. Such initiatives could reduce the pressure on conventional sources of energy besides being an advantage to the environmental issues (Chandel S.S, Sarkar A, 2014). [9]

Various climatic aspects are to be kept in mind while designing the buildings. These climatic parameters are solar radiation, temperature, humidity, wind speed etc. Climate-responsive design or vernacular architecture is considered to be one of the major components for achieving self sustainable development in building sector. Comfortable indoors are required in modern era as the time utilised inside buildings is increasing gradually. Hence, the use of heating, ventilating and air conditioning devices is increasing rapidly during current years. The energy demands has increase proportionally and increased load on fossil fuels and other sources of energy is being felt world over. It is envisages that the use of energy efficient, self sustainable buildings would be promoted to deal with the present situation of energy crisis (Lala Betty, 2017). [10]

Adaptive Thermal Comfort

The ASHRAE has defined the Adaptive Comfort Standards (ACS). The recommendations for ACS should be adopted during the designing stage of the building. However, these could be used for evaluation of existing buildings. The desirable indoor conditions for naturally controlled buildings should be evaluated using simulation models. The ACS could then be applied to assess the acceptability of those indoor conditions. If unacceptable, then design modifications are must, these could be in design and material. If desirable indoor conditions are still not met then the air conditioning measures can be taken in to consideration. The ACS should be considered as part of operative design guideline. The air conditioning could be used in a limited way to ensure the comfort limits inside the buildings (Richard J. de Deara, Gail S. Brager, 2002). [11]

The amount of energy being consumed in buildings for attaining a level of thermal comfort needs to be controlled in view of global energy crisis. The buildings world over consume more than 48% of the total energy. Indian scenario is not different where 48% of the total energy is used in buildings and about 73% of it is utilised in residential buildings for space heating/ cooling for

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providing comfortable indoors. It could be in the form of air conditioning, heating or cooling. As India has a vast demographic profile, reduction in small fraction could make substantial savings. It is observed that naturally ventilated buildings require less energy in comparison to artificially controlled buildings. In naturally ventilated buildings windows and fans are used for providing indoor comforts. This is noticed that in NV buildings located in warm and humid climates, the comfortable space is attained through natural ventilation. Such ventilation provisions are enough to provide a comfortable space, if the residents are have the options to adapt themselves are per comfort conditions. The thermal environment of naturally ventilated buildings could be uncomfortable if they are poorly designed. It can lead to health issues among residents. However, these buildings can be later on retrofitted with Heating, Ventilation and Air Conditioning (HVAC) which is a costly affair (Thapa Samar et al, 2019). [12]

3. COMPARATIVE ANALYSIS OF TRADITIONAL AND MODERN BUILDINGS AT VILLAGE SAPNI, DISTRICT KINNAUR- METHODOLOGY

SITE - VILLAGE SAPNI, DISTT. KINNAUR

Table: Building Characteristic – Traditional House, Vill. Sapni, Distt. Kinnaur

Parameters	**Building characteristics/ specification**
Type of Building	Traditional Building
Name of Owner	Sh. Sunil Kumar, VPO Sapni, Distt. Kinnaur
Address	Village Sapni, District Kinnaur (35 Kms from Reckongpeo)
Altitude	2650 Meters (absl)
Climate	Cold and Cloudy
Outer Walls	18 inches stone masonry walls
Interior partition Walls	Stone walls with wood panelling
Windows	Wooden with 4mm Glass
Doors	Wooden
Roof Type	CGI Sheet roofing
Floor height	Floor height 9 Feet
Orientation	Longer Axis of the building is making an approximate angle of 20^{o} with North South Direction.
Window Size	Large as compared to modern house
Flooring	Wooden flooring
Vegetation	Deodar Trees, coniferous trees found in high altitude regions
Veranda	No Veranda, only balcony in front of rooms
Snowfall	2 to 3 Feet of annual snowfall during November to March
Monitoring Period	Between December 2018 – February 2019 for 28 days

The building has been monitored for indoor room temperatures for 28 days during December 2018 to February, 2019 at different times of a day. The room under observation is a bedroom. The outdoor minimum temperature of -6.1^{o}C was observed on 28th January, 2019, the indoor temperature at the same time is 2.4^{o}C at 7.00 AM. The maximum temperature recorded during monitoring period is that of 11.3^{o}C at 3.00 PM when the outdoor temperature at the same time is 8.5^{o}C. The temperature during most part of monitoring period lies around 10^{o}C. Heating appliances are used in the room only in extreme cold or snowfall days. Residents adapt themselves to the climatic vagaries through proper warm woollen clothing. It is interesting to note that the traditional building is entirely constructed using locally available wood, stone masonry. The CGI Sheet roof is being used and below it lie the wooden false ceiling.

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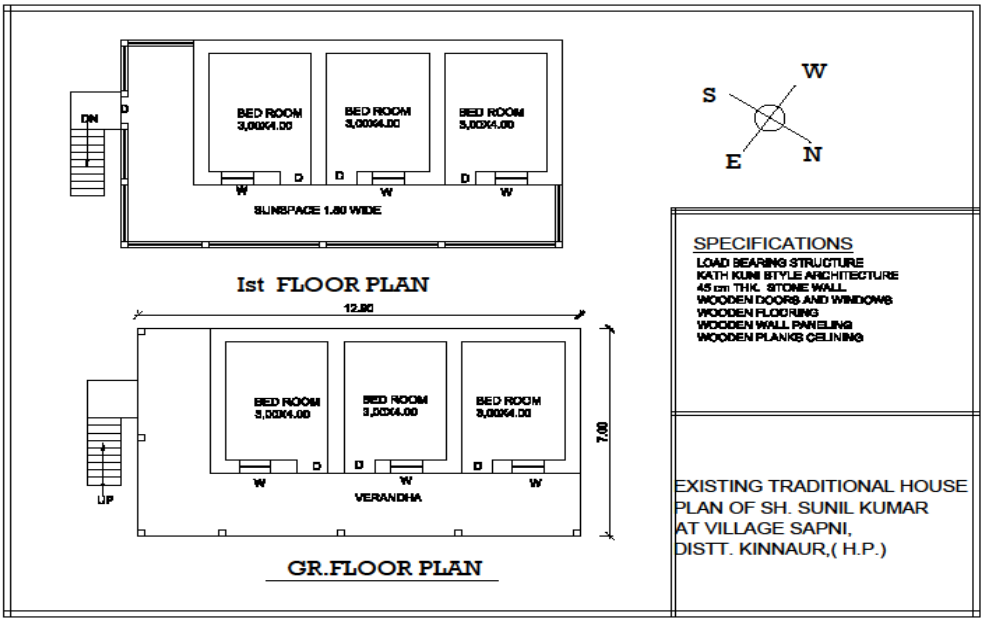

Fig.: Plan – Traditional House, Village Sapni, Distt. Kinnaur, HP

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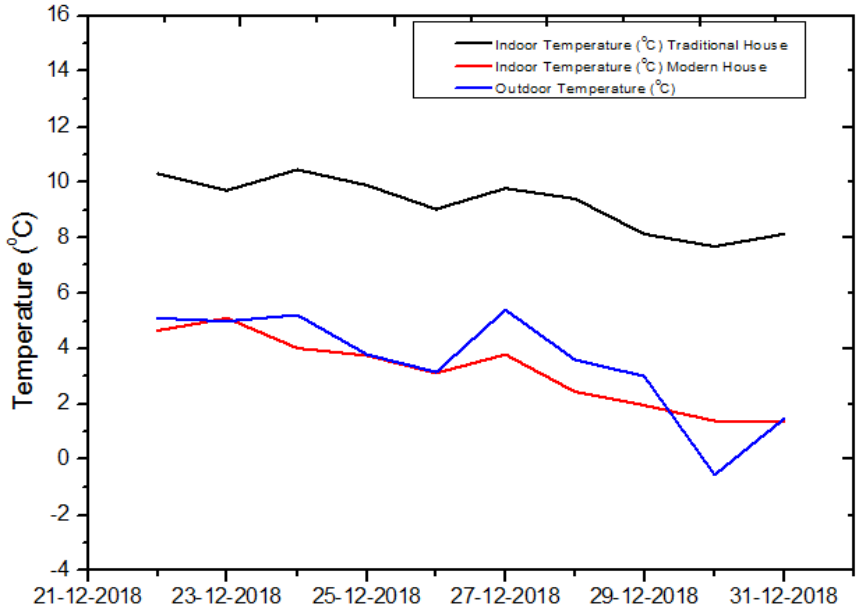

Fig: Comparative Analysis of thermal performance of Traditional House, Modern House and Outdoor temperature for December, 2018.

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Energy Savings in Traditional House in Comparison to the Modern House:

Energy requirements of a building are given as;

Q = $P_{specific}$ X 24 X D/1000 (Kw-h), where $P_{specific}$ is the average heat capacity of construction materials used for the building.

A) For traditional building the $P_{specific}$ = UXA = 0.8X9 = 7.2 W/K

Heating degree days for a site at village Sapni have been calculated for the month of December, 2018 are 195 (using a base temperature of 13.8ºC). hence, the heating requirement of a room in traditional house at village Sapni, District, Kinnaur for the month of December is as below;

= 7.2X24X195/1000 = 33.4 Kw- h

B) Now, the heating requirement of a room in modern house at the same site, i.e. at village Sapni, District Kinnaur is as below;

$P_{specific}$ = U X A = 1.8X9 = 16.2 W/K

Now, heating degree days for site at Sapni = 195

Hence, energy requirement of the room in modern building for the month of December, 2018 = 16.2 X 24 X 195/1000 = 75.8 Kw-h.

It is clearly evident from the above calculations that a room (of dimensions 9 square meter) constructed using modern cement concrete technology is requiring about 76 Kw-h of energy to keep it around a comfort temperature of 14ºC. However, on the other hand, a room of same dimensions in traditional house is requiring only 33.4 Kw-h for maintaining the same comfort temperature of around 14ºC.

4. CONCLUSION

The result of the present study brings to the fore the energy saving features of traditional vernacular architecture. Such architectural designs have been developed by indigenous communities over a period of time by generations. Energy efficient features such as capacitive walls, dhajji walls and use of local materials are responsible for maintaining a level of thermal comfort indoors. The traditional building at the site under consideration is accounting for about 50% energy savings as compared to the modern cement concrete building at the same site. Moreover the traditional building is eco friendly with negligible carbon emissions on space heating.

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