CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Across the world, traditional houses represent the heritage of a country and also reflect traditional forms and values and the culture of the people of that country. It possesses distinct characteristics as regards to planning, use of materials and location. Traditional architecture in India is largely built without formally trained professionals. Architects or engineers never designed traditional houses. The entire design and planning concept had been perceived and developed by the people i.e. the users according to their need. Buildings were built by construction labors. Continuity of tradition needs planning, design regulations and guidelines as well as the establishment of a code of practice to govern and control the proper implications of immutable, regardless of whether the technology is new or traditional (Saleh and Al-Alkhalaf 1999).

The architects and building professionals of present day are producing enormous amount of buildings making the city a concrete jungle without bothering about the energy need of each building they produce. To mitigate these energy needs, one can possibly look into the older construction design and techniques by investigating the traditional buildings so as to understand their indigenous climate responsive techniques under various climatic zones. Many researchers investigated the climate responsive traditional architecture in their climatic regions. To make a wider knowledge in this area some of the important literatures were reviewed across the world and presented briefly.
2.2 INTERNATIONAL STATUS OF RESEARCH IN TRADITIONAL BUILDINGS

2.2.1 Research on Qualitative Analysis of Traditional Buildings

Al-Hinai et al (1993) have studied and explained about the Vernacular Architecture of Oman: Features That Enhance Thermal Comfort achieved within Buildings. They said that modern building developments in the Arab Gulf States have been accompanied by a recent rapid abandonment adhering to energy-thrift principles as adopted in the vernacular architecture of the region. This has occurred despite the success of these types of buildings in providing thermal comfort, by natural means for many hundreds of years, in the harsh environment of the region. The consequence of this abandonment has been the rapid increase in electricity-generating capacity to match demand (of which, for example, at present in Oman, more than 70% nationally is used for air conditioning modern, energy-inefficient buildings). Considerable parts of these electricity loads represent unnecessary financial burdens upon the nations of the region. This study concentrates on how the vernacular architecture in one of the states in the region, namely the Sultanate of Oman, has in the past utilized successfully ambient-energy sources for achieving thermally comfortable artificial environments. To this end, the country has been considered as four significantly different climatic regions, namely, the coastal, mountainous, desert and southern regions. Lessons have been drawn from the performances of the various vernacular buildings in these regions. Their research concludes with an understanding which should help lower the energy consumptions of modern buildings exposed to such climates.

A’zami Yasrebi and Salehipoor (2005) have done a research on climatic responsive architecture in hot and dry regions of Iran. The research says that providing optimum cooling and heating of residential buildings of hot and dry regions in Iran so far has been according to the relations of
ecology, so that using architectural methods based on climate, local materials and also culture has damaged the environment as little as possible. Iran's traditional architecture has been generated from a climate and the situation which it has grown on it, so that all existing spaces of these regions such as urban spaces of passages, yards and buildings are protected against the atmospheric factors especially undesirable winds and using desirable winds and the sun's radiation are done according to some special arrangements. In order to recreate the least sunlight and heat, outer parts of building walls of urban texture of these regions are condensed to each other and the houses are thickly joined to each other. The lanes are thin and disordered and sometimes they are covered with quite high walls, it is believed that while these situations create a shadow against the sun's radiation they control the speed of Kavir (Salt desert) winds. The idea of courtyard in the houses of these regions has been formed according to the climatic factors, so that construction of courtyard houses of these regions with the indicators such as thick walls of porches, basements, wind catchers, arches and domes show that architects had an explicit concept of environmental conditions. Seasonal usage of spaces, concentration and attention to courtyard and making suitable use of roof are the very functional ways of planning which is in accordance with hot-arid regions. And thus their study says that, Iran's traditional architecture is a constant and sustainable architecture, because with a stable indicator it is able to answer its ecological matters after the passage of so many years.

Salem et al (2010) have studied the concurrence of thermal comfort of courtyard housing and privacy in the traditional Arab house in Middle East. The research qualitatively identifies the physical features of the traditional Arab houses in Tripoli and Libya in terms of their privacy and their physical response to the environment. It measures elements of courtyard housing style and consequently how they adapt to the environment's culture and climate. The physical features of a traditional house and user behavioral preferences of
gender segregation are evaluated for matching. Thus the research concludes by contributing in establishing environmental analogy of man and his habitat. Social, physical and psychological dimensions of housing regionalism are symbiotic. In order to enhance housing sustainability several interrelated sectors like planners, designers and developers need to carefully harness these potentials considering their economical viability.

2.2.2 Research on Quantitative Analysis of Traditional Buildings

Youngryel Ryua et al (2009) have explained about the influence of wind flows on thermal comfort in the Daechung of a traditional Korean house, Daechung, a semi-open space with wooden floor located between the front and backyards of traditional Korean residences, is well known as a cool space in summer due to cross-ventilation, but it has not yet been scientifically explained thoroughly. The purpose of this study is to characterize the wind flow measured at a Daechung to interpret the effects of the wind characteristics on thermal comfort. They have measured 10-Hz turbulence data at the Daechung and partitioned the wind vector into two directions (i.e. backyard to Daechung and front yard to Daechung). Interestingly, the wind from the cool backyard flowing through the Daechung was of less frequency and shorter duration but had higher velocity compared to wind from the opposite direction, which can provide thermal comfort to the dwellers. They have suggested that the wind characteristics were determined by various aspects of the house’s design, such as its location and the degree of enclosure in front and backyards. Their study concludes with results showing the traditional Korean house made use of a natural ventilation system during the summer and the principles of this system could be helpful in constructing environmentally friendly and sustainable residences.

Yılmaz (2007) has done a critical analysis in Evaluation of energy efficient design strategies for different climatic zones by comparing the
thermal performance of buildings in temperate-humid and hot-dry climate. Since the Kyoto protocol signed in December 1997 the majority of governments around the world have committed themselves to reduce the emission of the greenhouse gases. Thus, efficient use of energy and sustainability has become a key issue for the most energy policies. Sustainability and energy saving terms take place in building construction industry too since buildings are one of the most significant energy consumers. It is known that heating energy demand of a building has a great rate in building total energy consumption. In addition to that, the most of the heating energy has been lost from building envelope. TS 825, heating energy conservation standard for buildings in Turkey, aims in reducing of heat loss in buildings through the envelope. But within buildings, one of the fastest growing sources of new energy demand is cooling and especially in hot-humid and hot-dry climatic parts of Turkey, cooling season is much longer than the heating season. Moreover in hot-dry climate heat storage capacity of the envelope becomes more important issue than heat insulation for energy efficiency of the building. Since the Turkish standard is considering only heating energy conservation by using degree-day concept, Istanbul and Mardin are considered in the same zone, however those are in temperate-humid and hot-dry climatic zones, respectively. Therefore In this study energy efficient design strategies for these climatic zones have been explained and thermal performance of two buildings, which are constructed according to the TS 825 in Mardin and Istanbul cities were evaluated to show the importance of thermal mass in hot-dry climates.

2.2.3 Research on Thermal Comfort Survey in Traditional Buildings

Soflae and Shokouhian (2005) have made an extensive study into the Natural cooling systems in sustainable traditional architecture of Iran which concentrates on the results of sustainability caused by natural cooling
systems in Iranian traditional architecture of hot-arid regions. Sustainability in architecture means conserving constructions for the future, in terms of physical durability planet protect conserving on energy resources. In this case, it seems that sustainability would be based on the introduction productive models in which available materials and resources are used more efficiently, rather than being ignored. They say, the knowledge of building ecology focuses on its capacity to integrate environmental and climatic parameters into design and thus enhances space qualities such as comfort ability. Traditional architecture of Iran is perceived sustainable for having sustainable features. It is able to respond to environmental problems from a long period. Its features are based on climatic factors as well as local construction materials of hot-arid regions and natural cooling systems are one of these feature. Further they explain that there are various natural cooling systems in traditional architecture of Iran Like: Showdan, Khishkhan, Shabestan, Hozkhaneh and Badgir or wind catcher. Wind tower is an architectural element in traditional architecture of Iran. That is seen in hot climates, hot & dry and hot humid. It makes available auditable natural ventilation which is known as an important principle for conserving energy. Traditional building techniques are normally well adapted to the climate and we can use them with new technology. By this research they conclude that according to some factors it is possible to address Iranian traditional architecture. Iranian traditional architecture delicates effect of climatic forces on forming of habitable spaces and it explains climate was seen like environmental-constructional subject. It is undeniable importance use of sustainable and renewable source of energy such as wind structure and form of building. Result of this approach is harmony with nature. The aim of this research is to demonstrate the rule of natural cooling systems in sustainability of traditional architecture in hot-arid climate of Iran.
Henry Feriadi and Nyuk Hien Wong (2004) have made a critical analysis about the thermal comfort for naturally ventilated houses in Indonesia. Their research indicates that for naturally ventilated buildings (NVB) located in the tropical regions, thermal comfort (TC) prediction based on predicted mean vote (PMV) standard has shown some deviations from the observed results. Hot and humid environmental conditions throughout the year and personal adaptation could have an effect on expectation and perception about TC. Further through an extensive field survey which they have conducted in residential buildings in Indonesia, 525 sets of data had been gathered. The data analysis revealed that the PMV equation had predicted warmer thermal perception as compared to what people actually felt. Interestingly, it was observed that under hot and humid tropical climate, people indicated preference to cooler environment as compared to what the neutral temperature has shown. The study also investigated the occupant’s adaptive control preferences in creating a more thermally comfortable living environment. Their research explored the reciprocal effects of occupant’s thermal perception and behavioral adaptation. In tropical free-running buildings where the air temperature and humidity might not be modified easily without mechanical means, the people seemed to prefer higher wind speed.

Manioglu and Yılmaz (2007) have made a research on energy efficient design strategies in the hot dry area of Turkey. Climate has a major effect on the performance of the building and its energy consumption. Their study is based on a student workshop, which has been carried out for a hot dry area of Turkey. Further the study first aims to show the similarities and the differences of the traditional housing principles from the climate responsive design point of view. Secondly, it aims to put forward the basic principles and their meaningful changes in usage that can be used in the sustainable housing designs of the future. Furthermore, design strategies in Mardin, a town
situated in the hot-dry area of the south-eastern part of Turkey, were examined and modern and traditional houses were evaluated in terms of design criteria such as, selection of the area, distance between buildings, orientation, building envelope and building form. Thus the research resulted in, a simplified thermal evaluation and comparison of a traditional house with a contemporary house which has been given by using only data derived from the measurements and this evaluation has been done via both measurements and questionnaires which are carried out for 100 buildings.

Lin Borong et al (2004) have made a study on the thermal performance of the Chinese traditional vernacular dwellings in summer. Based on the field measurements of the thermal environment parameters and a long-term auto-recorder of the indoor and outdoor temperature at four typical traditional vernacular dwellings at Wannan area in summer, some wrong viewpoints about Chinese traditional vernacular dwellings are clarified, along with the analysis of the fine structures design such as the dooryard, the structure of the double-pitched roof and the eaves by the measurements of temperature, wind velocity, etc. Some design principles of the traditional vernacular dwellings in Wannan area are revealed, of which sun shading and insulation are of great importance while the natural ventilation is just considered as an auxiliary approach. So their investigations say that the strategy of ventilation design is to restrain the natural ventilation at daytime and to boost it at night. Moreover, the thermal sensation votes (TSV) of the occupants and the predicted mean votes (PMV) are compared and the evaluation standard in a naturally ventilated environment has also been explained.

Ehsan et al (2011) have made a study to explore the learnings from the past by taking a case study of traditional architecture of southern shores of Caspian sea region in Iran. The research says that climate has a vital role in
the design of buildings. Today we are facing some environmental problems such as global warming, Ozone layer depletion and shortage of fossil fuels which make it necessary to consider the effects of climate in the building design. Traditional architecture has always been a good example of climatic design and represents the techniques which our ancestors have found to improve their living conditions. In addition, traditional architecture can be a source of inspiration in the contemporary building design to learn from it and try to adapt modern buildings with the natural environment as far as possible. Thus this research concludes that the traditional architecture of southern shores of Caspian sea region in Iran is explored to find the role of climate in the formation of the buildings. Also Mahoney tables which provide design recommendations on the building design are used to compare with the design techniques in traditional architecture of this region.

2.2.4 Research on Building Materials in Traditional Buildings

Soofia Elias-Ozkan et al. (2006) have made a comparative study of the Thermal performance of building materials. This study focuses on the environmental performance of a selection of buildings in the typical Central Anatolian village of Şahmuratlı in Turkey. The objective of their study was to search for affordable and energy-efficient construction techniques suitable for rural settlements and incorporating traditional cultural values in a semi-arid upland region characterized by long severe winters and hot, dry summers. This was pursued by analyzing temperature and humidity measurements within buildings constructed from a variety of traditional and modern materials. The thermal behavior and comfort, the patterns of energy use and the appropriateness of the different building techniques and materials are analyzed, compared and discussed. Aspects of this ongoing study, initiated by a British Council partnership programme, are presented in this paper which focuses on a traditional mud brick structure, a straw bale house and an aerated
concrete building. By the end of research they were able to demonstrate how a building envelope reacts to outdoor conditions through graphic illustration and show ways in which the research can be extended by the creation of simulations using Ecotect software. This research contributes to the promotion of passive and low energy architecture towards a sustainable future.

Francesca De Filippi (2006) has made a research into the traditional architecture in the Dakhleh oasis, Egypt which deals with space, form and building systems. His research was based on a research project regarding traditional mud brick architecture in the New Valley (Egypt), funded by the Italian and Egyptian Ministries of Foreign Affairs, between the Politecnico di Torino (Italy), and the Assyut University (Egypt). Settlements in the Dakhleh Oasis are collected structures with a strong defensive character; constructions are bound to each other to cope with the harsh hot arid environment. Domestic architecture, according to Islamic principles, is characterized by private and semi-private spaces. Nowadays the old settlements are mostly abandoned and new houses are built on western planning models and new materials, breaking down with traditional uses and not adaptable to the harsh hot-arid climate. The aim of the research was to analyse the main characters of the traditional architecture in the old settlements (Balat, Al Qasr), pointing out both the typological and the technological aspects (local materials and construction processes), focusing on their environmental sustainability (presence of bioclimatic features, integration into the landscape, minimum waste of resources). And thus his research concludes saying that the appreciation and successful protection of the vernacular heritage depend on the involvement and support of the community, continuing use and maintenance. The achievement of his research will allow maintaining or reviving lost abilities and offering sustainable and compatible technologies for adaptation to contemporary living standards.
2.2.5 Research at Traditional Settlement

Vissilia Anna-Maria (2008) has done an evaluation of a sustainable Greek vernacular settlement and its landscape which deals with architectural typology and building physics. Her research was done on Sernikaki, a Greek vernacular settlement that can be imagined as a living organism is the outcome of centuries of optimization of material use, construction techniques and climate considerations. Being mountainous and isolated, this small vernacular settlement has preserved old types of dwellings longer than other areas in Phokida, in mainland Greece, and it can, thus, provide rich material for the understanding of architectural continuity and evolution. In her study, various types of adobe dwellings are surveyed and their response to climate, in terms of site and building design, is evaluated. In addition, the techniques of creating microclimatic conditions by incorporating the existing environmental parameters into the design are considered. Bioclimatic design employs appropriate technologies and design principles based on a thoughtful approach to climate and environment. It is concerned with the layout of the buildings (orientation in relation to sun and wind, aspect ratio), the spacing (site planning), the air movement, the openings (size–position, protection), and the building envelope (walls: construction materials-thickness, roof construction detailing). Her research thus evaluates specific vernacular dwelling types and their response to climate, based on passive design principles that could be adapted to current architectural practice in the area, in order to optimize the relationship between site, building and climate.
2.3 NATIONAL STATUS OF RESEARCH IN TRADITIONAL BUILDINGS

2.3.1 Research on Qualitative Analysis of Traditional Buildings

Anupama Sharma et al (2003) has made an insight into the climatic responsive energy efficient passive techniques in buildings, she made a research on the energy conscious traditional Indian way of life and that architecture evolved out of the great timeless Vedic philosophies, and hence, it was immutably appropriate to the very essence of life based on human knowledge, wisdom and vision of nature-man interaction. Thus, architecture in its nature based manifestations, and appropriateness, integrated to the life, has been most assiduously cultivated in India through ages. The energy conscious architectural heritage, thus, reached its pinnacle of perfection due to the sound principles embedded in man-nature spiritual and moral Indian values and honest dedication to the spatio-temporal creations. The ever alarming cost of energy in buildings enforces a statuary demand of energy conservation passive design techniques in buildings and concludes that the modern buildings reveal inadequate thermal performance and require mechanical devices to bring thermal comfort.

Mathur and Chand (2002) have made a critical research on climatic design for energy efficiency in buildings which explains the necessity and benefits of designing buildings with energy efficiency considerations. They have incorporated all these principles right from the planning stage. The requirements of thermal comfort for various climatic zones have been defined accordingly; Climatic classification map of India has been included for identification of the climate of the building. Further they have worked on the Method of selection of suitable architectural features like plan, form,
orientation, location and size of fenestration, shading devices, treatment of building envelop etc, thus they conclude their research, in such a way that incorporation of these energy efficient principles for designing of buildings would provide thermal comfort with minimum consumption of energy.

Manoj Kumar Singh et al (2009) have made a study of bioclimatism and vernacular architecture of north-east India. Their study explains about the vernacular architecture based on bioclimatism concepts which was developed and used through the centuries by many civilizations across the world. Different civilizations have produced their own architectural styles based on the local conditions. This study is carried out on the vernacular buildings of north-east India across all the bioclimatic zones. A survey of 42 houses, more than 70 years old was carried out at representative locations across all bioclimatic zones.

The study has yielded findings relating bioclimatism, socio-economic status and cultural setup to the vernacular architecture of the region. Also, different solar passive features are available in most of these houses, related to temperature control and promoting natural ventilation. Thus their study indicates that these houses are constructed using locally available materials like wood, cane, bamboo, stone, mud, jute, lime and represent unique examples towards sustainable building design.

Vyas (2005) has made a critical analysis of traditional Indian architecture which deals with the future solar buildings. He explains that the built environment is a manifestation of the technological innovation. The way technologies are applied in design and construction of buildings, have direct implications on the amount of energy consumed. In modern context buildings represent enclosed, isolated boxes/systems where environment is artificially controlled. This requires considerable energy. A problematic relationship between architecture and technology is evident. A large part of Indian
Subcontinent has for majority of year ample ‘Sun’- renewable, non polluting, abundant and direct source of all present natural cycles on earth. For building design in majority of these regions, the necessity is to control and utilize this abundance.

History shows the importance of relationship between human activity and nature. Human lives remained much dictated by solar and seasonal cycles, instead of trying to homogenize living conditions throughout the year. The future is in living and working with nature rather than against it. In traditional Indian architecture this harmony with nature was an important design element. During the course of development, somewhere, harmony was subdued for artificial control resulting in buildings without context. The study deals with exploration and understanding of these principles. This approach is sustainable and a site sensitive approach. The fundamental principles of this approach are buildings to be a buffer against uncomfortable environmental conditions as well as, buildings to enhance the positive natural conditions to reach the internal space and the buildings to be environmentally responsive to their natural surroundings.

Case examples from different regions in Indian subcontinent were studied with respect to their climatic context. His research results indicate that the buildings in harmony with nature have lesser need for energy as compared to energy hungry architecture of today.

Kumudhavalli Sasidhar and Ranee Vedamuthu (2008) have made an architectural approach to study the contemporary Chettiyar dwelling of Tamil Nadu, India. The author explains the anthropology and traditional architecture of Chettinadu house, in that she has made case studies in few number of Chettinadu houses and understood and analyzed the various spaces in Chettinadu houses. The author had categorically created a link between the space created out of the Chettiyar’s occupation like viduthis (Chettiyar
establishment with lodging facilities and cooking facilities attached to temple), urani (reservoirs to store and supply water to the town), sandhai (a planned market place), temples with a temple tank, Aasthale viruksha (sacred tree), providing the basic needs of people and also explain how the Chettiyars built villages on grid plans with well-defined roadways. Further the author explains male and female sections of the houses. The author had formulated the various courtyards and their usage pattern. Furthermore the author explains the traditional value system of the Chettiyars. This research had given a focus on the traditional materials on the building construction and she concludes that Chettinadu houses are traditionally rich, well carved and highlighted the massive architectural manifestation.

Rajashree Kotharkar et al (2008) have made a study about Responding to the Change, making “The Vernacular” Relevant: Case Study ‘Varhad’ region in Maharashtra, India, which says that globalization has brought in the new technology and also newer notions or concepts of life as a whole. It is trying to bring the world under one umbrella by creating a universal world order and whether good or bad this is an irreversible phenomenon. It is also affecting architecture and vernacular type is its first victim. The issue here is not to negate this change but to deal with it sensibly and this calls for a studied and rational response. India being a vast landmass has a lot of variety and complexity in cultures and even in climate. With various climatic regions the traditional architecture of India also displays a lot of complexity and variety. Architecture in every region is a deep-rooted phenomenon. In the past, it had the strength to cater to various physical and spiritual needs of the community. Historically built environment was a result of the responses to many factors in the society. At the physical level it included the knowledge regarding orientation, climate, building material and construction technique. At the spiritual level, the built-form was inter-woven with the lifestyle in all the daily as well as seasonal rituals. With the passage
of time these traditional knowledge systems are vanishing and the new systems are unidirectional hence unsustainable. In building industry the contemporary architecture, which survives on the alien building materials and technology, is already showing its impact. The newer materials are not always environment friendly. The spatial patterns are also not responding to the socio cultural fabric. There is a need to make the built environment sustainable. With the advent of modern materials and technology, a new architectural vocabulary gradually evolved and the traditional regional architectural layer was forgotten. Though the new technology is here to stay it can't be a solution for everything. Developing countries like India have a peculiar scenario. In these countries all the layers co-exist, the traditional as well as modern. Cities are experiencing high level of globalization impact and are moving towards achieving an international image.

The architecture has also responded in a similar manner. It is more about high tech and modern architecture. The cities are also facing problems related to environment, energy, infrastructure, etc. Since the cities are huge powerhouses their problems also get noticed and are funded. The architectural scenario in the towns and smaller towns is very alarming. Historically these towns were self-sufficient, had efficient infrastructure. The built form was also climate responsive and so energy efficient. Today the scenario has changed. The towns are also following the same methods of building as the large cities. Though the level of development is small and may be the socio-cultural pattern has not changed drastically the architectural response has changed. The villages being the smallest settlement type is the most neglected of all the other settlement types. This is certainly creating problems. The cities are full of this crazy graffiti in plastic, glass and aluminum. The smaller cities and towns are also aping their big brother and getting into the consumer culture of architecture. There is no sense of place in our cities or even our towns, which was very evident in the traditional built fabric. Most parts of the
Indian cities and towns are full of insensitive, commercially oriented facade architecture. Rootlessness or placelessness is one of the major issues concerning the Indian architectural scenario today. Architecture is being treated as a commodity, which is driven by the market and the popular taste. Architecture was considered to be an art form capable of influencing the lives of people, having the power to bring in the change in the social order. It is a vehicle for change. But the present scenario is reverse. Architects are building the so-called most saleable architecture and are in the search of short-term commercial gain. It is a typical situation, which forces us to raise certain queries concerning the vernacular and its role in the contemporary context. Is vernacular really environment friendly or it is just a myth? How and to what extent can the vernacular be made relevant in the given context? What are the factors affecting the changes in the vernacular type? Economic, Political, Social? This paper makes an attempt to study the vernacular architecture of Varhad (western vidarbha) in Maharashtra, India in the context of the ongoing architectural battle. In the context of globalization and emerging issues of architectural sensibilities, they conclude the study by understanding the concerns of the contemporary Indian Society at large emphasizing the complex and multifaceted nature of the problem. They also deal with issues of transformation, sense of place, regional identity, responding to the change in the context of vernacular architecture in the Western Vidarbha region, which is also called as “VARHAD” (Kale 2) The other aspect of study is whether the type or kind of change occurring in the vernacular type or settlement is similar throughout the said region. What is the type of transformation occurring? Is the transformation happening in the bigger cities is similar to smaller towns? And if not, how to deal with it? They tried to study and analyze the different vernacular housing typologies of western Vidarbha ‘VARHAD’ region with reference to its response to the socio cultural as well as physical environment (specific to the climate of the region). Further they identify and study the transformations that have occurred in the type and
reasons for the transformation of the vernacular typology of ‘WADA’, identify and understand the relevance of vernacular architecture in the contemporary context. This study tries accommodating this argument and aims at Identifying possible ways and means of making the vernacular architecture relevant.

2.3.2 Research on Quantitative Analysis of Traditional Buildings

Avinash Gautam (2008) has explained in his research about the climate responsive vernacular architecture of Jharkhand, India. His research aims to explore and assess passive solar design techniques that promote high thermal comfort in vernacular houses of the state of Jharkhand in India. The study of these houses provides useful insights for designing energy efficient houses that provide thermally comfortable conditions. An analysis of these houses in Ranchi, the capital city of Jharkhand, India provides a context for the field research. Jharkhand predominantly has two different styles of vernacular houses: huts and havelis. These houses were constructed, without any mechanical means, in such a manner as to create micro-climates inside them to provide high thermal comfort levels. Hence the study of thermal comfort levels in these buildings in relation to built environment in today’s context is significant. As part of his data collection, interviews were conducted with the occupants of ten houses in Ranchi, in June 2007. Two houses of each (huts and havelis) were selected for detailed experimental analysis. Experiment results indicated that all the four selected houses exhibited lower ambient temperature than outside during the day and a higher ambient temperature at night. *Brick bat coba* and lime mortar were the key materials used for constructing high thermal-mass walls. Adequate ventilation is significant in creating conditions that are comfortable. Aperture to volume ratio of less than 0.051 is not adequate enough to cool the thermal mass of these houses. These houses also use attic space to mitigate the heat gain from
the roof. Courtyards and other exterior spaces form an integral part of these houses and influence the thermal conditions in and around the houses. The case studies show that there is a scope for more relaxation of comfort temperature range based on culture and phenomenon of acclimatization. Thus his research concludes that a universal approach in understanding and defining comfort condition fails because the users of these houses were comfortable in conditions defined as uncomfortable by ASHRAE and Nicol.

### 2.3.3 Research on Thermal Comfort Survey in Traditional Buildings

Hom Bahadur Rijal and Harunori Yoshida (2006) have made a critical analysis on winter thermal comfort of residents in the Himalaya region of Nepal. In their research a thermal comfort survey and a thermal investigation were conducted in traditional houses, during the winter in the Mustang district of Nepal. The surveys were carried out over 4 days, gathering a total of 1,584 thermal sensations from 36 subjects. The results show that residents are highly satisfied with the thermal condition of their houses, the mean neutral temperature is 10.7°C and 3°C the neutral temperatures are different according to the thermal environment of the evaluated spaces. These research understanding state that people are well adapted to the thermal environment of traditional houses, as a result of which the neutral temperature is lower than the thermal comfort standard.

Manoj Kumar Singh et al (2010) have done a critical analysis of thermal performance and evaluation of comfort temperatures in vernacular buildings of North-East India. Their investigations state that vernacular architecture of North-Eastern India which represents the principle of climate-responsive architecture still lacks experimental validation and quantitative analysis. Thermal comfort not only makes the occupants comfortable but also governs energy consumption in the building. They have done detailed field studies on thermal performances of typical traditional vernacular dwellings in
different bioclimatic zones. This field study includes detailed survey of 150 vernacular dwellings, field tests and thermal sensation vote of 300 occupants on ASHRAE thermal sensation scale. Field test includes measurement of temperature, humidity, illumination level and building design parameters. Thermal performances of these vernacular dwellings were evaluated for winter, pre-summer, summer/monsoon and pre-winter months of the year 2008. This evaluation is based on ‘adaptive approach’, which is the outcome of the field studies and is now part of ASHRAE standard 55/2004 for predicting comfortable temperature of naturally ventilated buildings. This study also tried to find out the range of comfort temperature in these vernacular buildings for different season of the year. By the end of their research it has been found that these vernacular dwellings perform quite satisfactorily except in the winter months and the occupants feel comfortable in a wider range of temperature.

2.3.4 Research on Building Materials in Traditional Buildings

Rumana Rashid (2008) has studied the traditional houses of Bangladesh which deals with typology of houses according to materials and location. Traditional Houses represent the heritage of a country and also reflects traditional forms and values, fundamental to the culture of the people of that country. It possesses distinct characteristics as regards planning, use of materials and location. Like urban architecture, traditional house is also subject to change but in Bangladesh traditional house has clung to tradition. It has not really changed until recently. For centuries traditional house has been using locally available materials. It is only from that late 19th century that traditional house began to change in the use of housing materials. Traditional architecture in Bangladesh was largely built without formally trained professionals. Buildings were built by construction workers. Any architect or planner never designed traditional house. The full planning concept has been
developed by the people according to need. This traditional house has been changed along with time to fulfill the demand of the user. At the same time planning concept was constant. The aim of this paper is to get natural design principles of different type of traditional houses in Bangladesh according to availability of local materials. The different kinds of house are developed in different regions of Bangladesh such as mud house, bamboo house, stilts house and timber house. Many designers are now interested in adapting traditional feature to modern design but such attempts have had limited success because traditional house design have themselves not been clearly understood. Thus this study can help to convey a good understanding by analyzing different types of traditional house in Bangladesh.

2.3.5 Research on Climate Responsive Traditional Settlement

Madhavi Indraganti (2010) has made a research in understanding the climate sensitive architecture of Marikal, a village in Telangana region in Andhra Pradesh, India. She had documented and analyzed a vernacular settlement, Marikal in composite climatic region of A.P. as part of a large development project. Marikal’s form and structure are a result of centuries of evolutionary process and knowledge transfer, reflecting a set of varying physical and nonphysical determinant forces such as climate and geology, religion, socio-cultural values, economics, technology and administrative factors. It is a closely knit fabric of small clusters of dwellings comprising of thick white walls, heavy roofs, small windows and narrow streets. Many house typologies are identified. The house plans essentially vary in size, shape and detailing, but not in their climate sensitivity. They are in great harmony with the occupation/activities of the occupant. The occupants adaptively synchronize their activities with the spatial environmental qualities of the space. However, the ‘house form’ of Marikal is transforming due to social forces and the availability of electric controls in the recent decades.
Once highly climate sensitive architecture and behavioral patterns are slowly getting metamorphosised into architecture and attitudes that are irreverent to climate and context. This study calls for a code of practice balancing modernization with the vernacular.

Jain et al (2005) have explained about the traditional architecture and planning techniques in Himachal Pradesh, whose research paper highlights the evolution of traditional architecture and settlement pattern in the hill region of Himachal Pradesh. Their study discusses the art and architecture which grew out of the man and natural interaction. It discusses the various architectural styles of temples evolved over a period of time, their construction techniques and materials used by the people of Himachal Pradesh. The design and planning consideration in the hills which require extra sensitivity and care because of the delicate nature of terrain and ecosystem are described. Their research thus suggests that the traditional architecture which is the outcome of man's interaction with nature should not be disturbed. The planning techniques which have been scientifically proved successful due to difficult terrain and the scientific use of locally available material should be encouraged.

2.4 RESEARCH BASED ON COMPUTER SIMULATION IN TRADITIONAL BUILDINGS

Robert Hastings (1998) had explained about the computer design tools for climate-responsive architecture. In his study he explains that designing a building to be climate responsive and hence less energy consuming requires calculation. Intuition can be misleading. With today's personal computers, design tools are accessible to architects. He came up with questions such as what can/cannot such tools analyze? How difficult are they to learn? How accurate are they? What are the next directions in tool
development? These questions are addressed in a critical overview of modeling energy use and comfort in buildings, therefore suggesting the need for computer design tools for climate responsive architecture.

Ahmed Muhaisen (2005) has done a critical analysis on shading simulation of the courtyard form in different climatic regions. The analysis presents a modeling study carried out into the effect of rectangular courtyard proportions on the shading and exposure conditions produced on the internal envelope of the form in four different locations. These locations, Kuala Lumpur, Cairo, Rome and Stockholm, were chosen to represent the climatic regions of hot humid, hot dry, temperate and cold climates, respectively. The study highlights the effect of the climatic conditions on the suggested courtyard ratios and heights to achieve a reasonable annual performance in the examined locations. Also, it clarifies the variation in the courtyard daily shading and exposure performances as a result of changing the location latitude and consequently the sun’s position in the sky. Further, the study suggests guidelines and general rules for efficient courtyard design in the considered climatic regions. Furthermore, it states the ranges within which the parameters of the form can be changed with minimum deviation from the optimum performance. The analysis concludes with the results showing that the shading conditions of the courtyard internal envelope are significantly dependent on the form’s proportions, location latitude and available climatic conditions.

Luisa Parra-Saldivar and William Batty (2005) have done a critical analysis of thermal behavior of adobe constructions. They explained that Adobe is a construction technique that uses soil (a mixture of clay, sand and water), stabilizer and binder as raw materials that are mixed and molded to form sun-dried blocks. The objective of this study was to assess how various
factors affected the dynamic response of the thermal performance of adobe constructions. On the basis of a bibliographical survey the main factors that affect the thermal behavior of adobe constructions were ascertained. Dynamic thermal simulation software, thermal analysis system (TAS), was employed to simulate the performance of adobe constructions using synthetic weather data to reproduce the climatic conditions for three regions from different latitudes in Mexico. An orthogonal array Taguchi was used to define the range of models required to test the various relevant performance parameters and to relate these through observed behavioral patterns. They were able to conclude that with this tool it is possible to develop an understanding of the complex interactions between variables. In particular, dynamic thermal simulation allowed an understanding of the time lag in delivering/storing energy to and from the indoor environment within the adobe constructions and how this affected the diurnal variations of internal temperatures.

Aslihan Tavil (2003) has done a research in thermal behavior of masonry walls in Istanbul. This study is based on thermal performance analysis and evaluation of masonry wall configurations with respect to thermal comfort and energy conservation with the software DOE-2.1E. The analysis comprises the comparison of the annual heating and cooling loads of the masonry wall alternatives of the sample building. Besides, the exterior and interior surface temperatures of the wall alternatives are computed for appraising dynamic temperature effects on their thermal behavior both in heating and cooling seasons under the climatic conditions in Istanbul having temperate humid climate.

2.5 FURTHER RESEARCH ON GENERAL RELATED ISSUES ON THERMAL COMFORT OF BUILDINGS

Marwa Dabaieh (2009) has made a theoretical and practical study of Balat village in Dakhla oasis in Egypt. To understand the importance of
conservation of desert vernacular architecture as an inspiring quality for contemporary desert architecture, he found out that Vernacular architecture was always a product of a natural cycle of sustainable building tradition. People inherit the traditional way of building from their ancestors and the knowledge was transferred and developed from generation to generation along the years. Inhabitants respond to their surrounding environment and climate through trial and error in a way satisfying their needs and aspirations. This natural cycle is about to vanish due to the fact that inhabitants are leaving their houses to deteriorate or they demolish them to build modern concrete houses instead. People are seeking for modern life facilities that their old houses don't satisfy any more. He further says that his research will help laying hands on the know-how of desert vernacular architecture in Egypt. Focusing on how to adjust it to new life demands in a way that keep and preserve the beneficial old traditional techniques. His research will end with a manual and a checklist for a contemporary vernacular building model based on the argument mentioned above. This manual will be tested by a physical model built in site. By this way he says that one can preserve the sustainable desert vernacular architecture as it used to be for centuries and helping to keep the old beneficial values forever. It is a new vision for the future of old and contemporary vernacular desert communities through conservation by modeling. This research is still in progress, a preliminary studies and investigations were done to support the research hypothesis. This research targets planners, architects to take up further research for the future generation.

Ahmadreza Foruzanmehr and Fergus Nicol (2008) have made a study towards new approaches for integrating vernacular passive-cooling systems into modern buildings in warm-dry climates of Iran. Which says currently, energy constraint and global warming are the biggest challenges confronting the planet? The building sector is one of the major energy
consumers in the world. In hot climates, most 20th century buildings are dependent on air-conditioning systems and electricity, reliant on fossil fuels and increasingly unable to adapt to a warming climate. In contrast to modern buildings, vernacular architecture in these regions is more adaptable to the environment according to principles evolved over many generations. Many vernacular technologies are energy efficient and sustainable, although some of them are currently no longer properly functioning because of changed cultural and ecological situations. In this regard, the key challenge is to learn fundamental lessons and principles of vernacular architecture, and to find ways of integrating those principles into development programmes to plan new settlements or to upgrade existing ones. Studying traditional techniques to understand the sustainable strategies used in arid central Iran should make a valuable contribution to the field. They further provide an introduction to and methods for research focusing on vernacular passive-cooling strategies (VPCSs) in warm dry climates. The main objectives are firstly, to find the extent to which VPCSs are viable and usable, and secondly how much reduction in reliance on air-conditioning will be achieved if these strategies are applied in modern dwellings. Three aspects of VPCSs will be investigated, including: cultural acceptance, thermal comfort of occupants and energy performance. The conclusion of their research defines the extent to which VPCSs are applicable to modern dwellings and clarify how much this application could improve their performance, cut their energy consumption and adapt them to climate change. Some preliminary results of the study show that traditional passive courtyard buildings in central parts of Iran, work very well in terms of modulating the temperature swings, lowering the ambient temperature and providing the occupants with spaces of various temperatures in the hot summer times.

Amanda Heal et al (2006) have made an extensive study to show the vernacular as a model for sustainable design. Their research describes an
innovative approach to teaching and learning the subjects of vernacular architecture and sustainable design. The method forms a key part of the world architecture module, which is taught to first year students at The Welsh School of Architecture. A week-long environmental design block course employs the collection of vernacular buildings at St. Fagans open air museum as ‘laboratories’, enabling students to appreciate how design with climate is effectively conducted in vernacular architecture. In this experience-based learning context, students develop skills in measuring, observation, recording and analysis; leading to an embedded understanding of the physical characteristics and environmental performance of real buildings. Following the block course and a series of lectures focusing on issues in world vernacular architecture, students are encouraged to ‘model’ lessons learnt from the vernacular, and to employ them in their own designs. The module uses and addresses issues raised at the recent conference ‘Vernacular Architecture in the twenty first century: Theory, Education and Practice’. The research illustrates both the educational process and outcomes that have been achieved using vernacular architecture as a source of information and inspiration.

Ommid Saberi et al (2006) have made a research on thermal comfort in architecture. The study says that one of the main goals of building design is to provide a comfortable space for living. This was the reason of creation a new field in science called “Thermal Comfort”. So thermal comfort Models should be able to best, help the architects and other building engineers in design process. Different models like Fanger and Adaptive are mostly for defining the comfort zone; either it is static or dynamic. The research aims in making possible a new model with definition of comfort zone in different climates simultaneously to give well advises for climatic design process.
Rumana Rashid and Mohd Hamdan Bin Ahmed (2008) have made a comparison between the thermal performance of a contemporary house and Traditional house in the dense Dhaka city in Bangladesh. Their study explains that Bangladesh traditional houses (B.T.H) which are located in warm humid tropical climate represent a unique phenomenon with device capable to meet the comfort demand through environmental well adapted design. The traditional house and the contemporary design house (C.D.H) for Bangladesh are examined by comparing the thermal performance within the same outdoor condition and the climatic region at the dense Dhaka city. This comparison is based on field measurements of thermal performance of the traditional house and the contemporary design house within the same summer period. Quantitative method is used to measure the thermal performance. The field survey was conducted using two set of thermal data loggers which were installed in both selected houses to record the air temperature and relative humidity of the outdoor and indoor spaces. Data collection was carried out for the hot and wet month of summer period in June. The research result concluded that the traditional houses of Bangladesh provided useful indicators of appropriate architectural design response to climate, particularly in the context of purely passive environmental control. However it is required to adapt a critical approach towards the modern contemporary architectural design strategy of deriving lesson from traditional houses to extend the period of indoor thermal environment inside the contemporary houses.

Tokso Sangowawa et al (2008) have made an extensive study on cooling, comfort and low energy design in warm humid climate with a case of Lagos in Nigeria. The study presents an argument for the need to provide air conditioning in office and residential developments in Lagos, Nigeria while noting the international drive for energy conservation and sustainability. An historical perspective of natural ventilation and mechanical cooling is the outcome of the research. The outcome of recent studies regarding the comfort
criteria for Lagos is also discussed thus providing proposals which are offered for low-energy design of buildings.

Maria La Gennusa et al (2005) have done an extensive study on control of indoor environments in heritage buildings by experimental measurements in an old Italian museum and proposal of a methodology. The study describes some results from an experiment carried out regarding a procedure to be adopted for temperature and R.H. monitoring of indoor spaces designed for exhibiting events, such as museums and similar institutions. The monitored data employed in this study has been collected by the department di Ricerche Energetiche ed Ambientali of the Università degli Studi di Palermo in co-operation with the regional gallery “Palazzo Abatellis” of Palermo. The study analyses a simple method for characterizing the environmental quality of museums so as to ensure the optimal conservation of works of art. This methodology is based on the procedure (where thermal and hygrometry parameters are concerned) proposed by an Italian standard rule. A new technique, firstly applied to the industrial environment, based on the passive reactive monitoring of proper coupons is also proposed for monitoring air quality in museums. The methodology adopted, has been applied to two survey campaigns which were carried out at a distance of 5 years. This shows the two aspects of thermal-hygrometry and levels of indoor air quality aimed at preserving works of art. Thus the study shows that the future developments of the work are oriented towards the definition of guidelines in support of those responsible for the conservation of works of art and improvements in the quality of environments for artwork conservation and for the comfort of visitors through the use of proper HVAC systems.
2.6 SUMMARY

Across the globe enormous research had been carried on in the area of thermal comfort study of buildings, in particular thermal comfort studies are more relevant for ‘residential’ buildings. The literature reviews carried out here exemplify the thermal comfort studies of traditional residential buildings under various categories stated below;

Form the international status of research in traditional buildings it is understood that the vernacular architecture of middle east declines causing an increase in electricity generation for the whole country. The research from Iran pronounces that the Iran traditional architecture is a constant and sustainable architecture; further studies explain the effects of wind characteristics of thermal comfort in traditional buildings. Some of the research on quantitative analysis of traditional buildings explains the importance of thermal mass, the courtyards, the uses of traditional shading devices, etc. Further there are research on qualitative analysis of traditional buildings and research on thermal comfort survey in traditional buildings besides the research on building materials in traditional buildings and traditional settlement.

In National status of research in traditional buildings enormous works had been carried out towards understanding qualitative analysis of traditional buildings and understanding of quantitative analysis of traditional Buildings. In this research process survey in traditional buildings on thermal comfort studies and research on building materials in traditional buildings beside the research on climate responsive traditional settlement preaches numerous techniques and methods, to revive the principles of traditional architecture for the future society so as to have a future green society.