Contemplating the traditional rural architecture of Nalanda: A case study

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Abstract. The fundamental purpose of a building is to provide a comfortable and safe living environment, which protects from the extremes of surrounding environment, as well as give an opportunity of physical and psychosomatic development. The traditional buildings evolved gradually to meet the eventually changing human needs and lifestyle over a period of time, integrates the environmental and socioeconomic characters of the society in a well manner. These buildings have attained deep reconciliation with site surroundings, and thus, have minimal environmental impact. In spite of rapidly growing concept of advanced technological approach towards sustainability, the concept of indigenous technology and traditional architecture plays an active role. The main objective of this paper is to understand the principles and strategies for sustainability from traditional rural architecture and indigenous technologies. The methodology adopted is documentation of a traditional rural house of Nalanda, India, and analyse the environmental and socioeconomic aspects. The data has been collected from surveys, site measurements, literature, and other secondary sources. The thermal performance of a traditional house is analysed through computer aided simulations in the present investigation. This paper concludes with an appreciation of principles of traditional rural architecture and advocates their integration in the present scenario.

1. Introduction

India is a vast sub-continent comprising more of villages than cities. The culture and traditions of Indian villages are primitive and fundamental, and have been far secluded from the modern civilisation and culture [1]. The hut, unit of rural architecture, has almost preserved its ingenuity since inception, thousands of years ago, and the same is believably true even for the whole pattern of rural architecture in India. This sustained tradition of rural architecture of India, may claim to be the living and organic architecture.

The India rural architecture is characteristically and archetypally primitive and has maintained its distinct rudimentary character, with common use of mud, bamboo, locally burnt bricks and tiles, and thatch in house construction, and with the sense of openness, unity, and space. The physical and psychological needs of the users are at the core of evolution of rural architectural expression, which is intimately related to the nature of amity and tranquillity of the village [2]. The villages have relished isolation from various external philosophies due to remoteness, and have been thus able to preserve a tradition flourished from the roots since the time immemorial [3]. The findings of the present research can further be utilised to discover strategies for improving energy efficiency and thermal comfort in consonance with the preservation of the traditional features, having their own thermal benefits, in the rural housing.
2. Sustainable development and rural architecture

Apart from the country’s political, social and economic conditions, the pursuit of knowledge and art is the basis of shaping the country. The creative architecture must, therefore, satisfy both the tangible and the intangible requirements of life [4]. The integrated design system, thus, must incorporate the eight subsystems of the building design features, which are: functional workability; aesthetical value; economic feasibility; comfortable liveability; environmental sustainability; social acceptability; structural safety; and technical viability, to achieve overall sustainable development (Figure 1).

![Building Design](image)

**Figure 1.** Dynamics of Building Design.

The rural architecture of India has been in consonance with its surrounding environment and evolved as a response to the social requirements as well as the unique interaction between the human cognizance and the natural phenomena [5-8]. The effective building forms have developed overtime that assures the attainment of high level of comfort both inside and outside space of built environment without employing alternate methods [2, 9, 10]. The studies suggest that the aspects such as socio-economic structure, physiographical condition, environmental condition, infrastructure availability, as well as institutional structure contributed to the development of traditional building construction methods [11]. The traditional vernacular buildings are providing edifying illustrations of methods of achieving sustainable building construction. Further, the dependence on modern design methods and materials has resulted in increased cost of construction in recent years, whereas, the traditional building construction methods enable cost effectiveness in terms of locally available materials, indigenous techniques, and simple innovative expertise of the local builders [12]. In addition, the built structure needs maintenance and renovation, which would be easier without consulting an expert that is necessary with the use of unacquainted materials and techniques. The traditional rural architecture can be an inspiration for advancements in environmentally and socio-economically sustainable planning and design [13].

3. Methodology

The methodology adopted in the present paper is to examine the energy performance of an existing traditional rural building, which adopts the traditional construction method, prevailing in the rural Nalanda. The selected case study was intended to determine the extent to which the traditional architecture incorporates the parameters of the building design. The major emphasis has been on examining the environmental sustainability of the tradition building by evaluation the energy performance of the building to achieve thermal comfort. The data has been collected from primary and secondary sources. The climatic data have been collected from the website of ASHRAE (ASHRAE
The data about the study area has been collected from the government bodies. The field measurement, photography, photogrammetry, and surveys have been conducted to collect onsite information. The thermal performance of a traditional house has been analysed through modelling and simulations in the present investigation. The data have been analysed rigorously to find the inferences and conclusion.

4. About the study area
Nalanda, a district in Bihar state, India, is famous all over the world for the ancient International Monastic University established in 5th century BC, which was a learning centre for the subjects of Vedas, Logic, Grammar, Medicine, Meta-Physics, Rhetoric, etc. Nalanda district is located within the Mid-Ganga basin, in the southern margin of the Gangetic plains of Patna. It lies between latitude 24°57' and 25°27' North and longitude 85°18' and 85°56' East and represents mainly flat alluvium terrain. The climate of this region is composite, hot during the summers, and cold during the winters.

A little less than one-third of the houses are in good condition, whereas one-tenth of the houses are dilapidated condition (Figure. 2). One third of the houses have roof made of grass/thatch, mud, bamboo, wood, mud, or handmade tiles (Figure. 3). Most of the (three-fourth) of the houses of Nalanda have mud floors (Figure. 4). A little less than two-third of the houses have walls made of burnt bricks and less than one-third of the houses have walls made of mud or unburnt bricks (Figure. 5).

5. Case study
A small residential single storied typical traditional house, built before 1950 AD, has been selected for the present investigation. This house, an example of vernacular architecture, is situated in the village Mohammadpur, a small village situated on the bank of river Goithwa in Nalanda district, India, having 40 Hectares of land area with total population of 369 people. The west side of the house has a lot of...
vegetation including the paddy fields on the agricultural land of the village. About 80.5 per cent of total land area is agricultural land. There are 71 households in the village. Local materials available in the region, mostly come from the agricultural by-products, are wood, hay, husk, straw, reed, clay, mud, and cow dung. This is a typical single storied rural traditional house built of load bearing burnt brick walls and tiled roof, on the base of earth. The wooden structure of beams and lintels bears the thatched roof, which is covered by burnt clay tiles. The wall and roof are the major cost consuming component of this house. About two-third of the cost of construction of the house has been invested for the construction of walls, and about one-fourth of the cost is invested in the construction of roofs.

5.1 Plan form
The building has rectangular plan form (Figure 2). The building is facing north. The four rooms are in a row, opens in a common veranda, which is open from the north side. The heat gain or loss depends on the surface and volume ratio, smaller the surface and volume ratio, lesser the heat gain or heat loss will be. For the present case, the surface and volume ratio is higher as compared to the modern buildings.

5.2 Layout
This is oriented on east-west direction, and the long elevations are facing north and south, which reduces exposure to the sun (Figure 6). The façade, interface between indoors and outdoors, is facing the north direction. The high boundary walls and a room planned on the opposite side of the house create a courtyard type place. This open space works as a thermal regulator.

5.3 Walls
The solid load bearing 250 mm thick burnt brick walls are constructed using mud mixed with husk and straw as mortar, with columns made of brickwork as well (Figure 6). The walls are heavy with high thermal capacity (U-value is 3.25 W/m²K). The walls have rough texture of exposed brick. The rough texture causes self-shading of walls. This is one of the reasons for low temperature in the traditional building. Brick making is an activity that had been done by the household, which makes the house vernacular and cost effective as well. In the countryside it is often part of the local economy; the locally available soil is mixed with water and sawdust, moulded, and left to dry for several days. Then the green bricks (fired bricks are red) are stacked with thin layers of sawdust and coal between them, resulting in a stack that is a kiln at the same time.
5.4 Floors
The earth floors are sealed by arranging burnt brick, and then plastered with layers of mud and cow dung. This plasterwork is essential in keeping snakes, insects, and rodents out. Cow dung is sticky and has a binding effect, but is easily damaged by termites. Mud is termite resistant, but brittle. By combining these characteristics, a sturdy termite resistant plasterwork is reached through the application of alternating layers of cow dung and mud. The cow dung is dissolved in water and then used to wash the earth floor, by which cracks get repaired, dirt is bound, and the floor becomes more solid over time. The result is a smooth dirt free floor, easy to sweep and pleasant to the feet. It also contributes to quality of the interior climate. This technique requires frequent maintenance and consequently the house demands time from its occupants.

5.5 Roof
The traditional building has red clay tiled roofing over thatched roof, locally available material, with 2.5 m high ceiling (Figure 7). The portion of the building studied has ridge line running east west and the roof slopes to the north. This is a light but insulated lean-to roof, with low thermal capacity. The whole Roof is not exposed to sun due to trees on the south side. The building stores less heat because of lower thermal mass as compared to the concrete roof building (U-value is 0.12 W/m²K). Even though, the inside temperature in the building is high in the noon, it does not extend up to midnight. The tiled roof helps the building in cooling down much faster resulting in higher comfort during nights.

![Figure 7. Details of pitched roofs made of red clay tiles.](image)

5.6 Veranda
The 1.5 m wide covered veranda expresses the hybrid notion of inside and outside very clearly. It is a sheltered outside and still part of the home, protected from harsh weather.

5.7 Openings
The rooms are single banked with small windows, of 0.25m x 0.50m size, in the south wall to ensure air movement. The near absence of windows in the rural architecture is an indicator of this outdoor oriented lifestyle. A small window is enough to allow daylight where needed. The windows in a wall are considered to be a weakening of the protective function of that wall. The percentage of door openings on the north facing side is most. The fenestration is completely shaded in traditional building with deep overhanging eaves.
5.8 Outdoor Space
The area adjoining the building becomes an extension of the indoor spaces, and is treated with equal care. The building is so arranged as to surround a central open space, courtyard or patio, partly, and remaining part is surrounded by the high boundary wall. The courtyard is divided in two sections, private open space and public open space, by a brick wall. In the climate of Nalanda, many of the activities like, sleeping, cooking, eating, playing, and working, are performed in the outdoor spaces. The people, who come to meet and chat from outside, gathers in the public open space created in the compound. The shelter of the building is sought only when the need for privacy or unfavourable weather conditions demand it, and for the safe keeping of belongings. Therefore, there is limited need for indoor space. The balance of indoor and outdoor activities is an important aspect of the way of life of rural people of Nalanda. The house is mainly a place to keep things safe, whereas home activities stretch out around the house. The land around it is part of the realm of the home. The quite high boundary walls surrounding the courtyard or outdoor space not only protects the space from scorching hot wind, dust, stray dogs and goats or other animals, trespassers or the limitation of evaporation and retention of an air pool cooled by evaporation [15]; but also serve the psychological need of privacy. There is a shade for cattle also at the enclosed outdoor space.

5.9 Landscape
The surroundings of the site have dense vegetation with lots of trees and agricultural land plantations. The entire area has similar nature of vegetation. In the compound, an evergreen guava tree is in the middle of the courtyard. There are shrubs and creepers, and the earth is covered by small grass contrasting the barren pathways in between. The creepers are supported by bamboo frames, giving an overhead cover, and pleasant dappled shade. There is an open well used for fetching water, also serves for the evaporative cooling in the enclosed outdoor space. The vertical elements like, walls and the building itself, provide shade only in the morning and late afternoon hours. The plants and creepers give the most pleasant shade, reducing the contrast between bright light and solid shadow with its soft half-light.

6. Result and Discussion
Thermal performance modelling and simulation for the investigated case, as well as comparative analysis of the results, has been done in the present study. The analysis of the measured energy consumption values for different months, from January to December, of the year 2017 with the climatic data of the region for each month, from January to December, of the year 2017, has been done (Figure 8 & Figure 9). It shows that the months of February, April, October, and November are physically most comfortable, as the temperature rarely exceeds the comfort level.

![Figure 8. The sun path diagram and the pattern of light and shadow during a day and night time.](image)

The month of January and February are a little colder; the temperate rarely exceeds the upper comfort level during day time, while the temperature reaches below the comfort level, up to 10\(^\circ\) C in between 5 pm to 8 am. The daily energy consumption during this month is comparatively low (about 17 Kwh), in the present investigation, and most of the energy consumed in heating. The month of March is almost comfortable during the whole day and night as well. The heating loads decreases to zero, and the energy consumption for cooling, only during 1:00 pm to 2:00 pm, is required. The month
of April and May becomes warmer due to intense radiation of sun, and the temperature rises up to 30\(^0\) C to 36\(^0\) C, during the day time, 12:00 pm to 5:00 pm. The daily energy consumption increases up to 34 Kwh in the month of May. Most of the energy is consumed in cooling the air temperature during day time. The month of June can be characterised by high temperature, up to 44\(^0\) C, and moderate humidity; whereas the months of July, August, and September have high temperature and dense humidity during the day time. Thus, the discomfort level reaches its peak during the month of June, July, August, and September, and the daily energy consumption for cooling and circulating the air, is comparatively more (about 34 Kwh). The month of October and November are quite comfortable with moderate temperature during day and night, varying between 17\(^0\) C and 30\(^0\) C. The energy consumed per day is less during the month of October and November, about 28 Kwh and 19 Kwh respectively. The temperature starts lowering and the humidity increases during the month of December. The daily energy consumption, mostly for heating, is low (about 19 Kwh) (Figure 10). It is evident from the analysis that most of the energy required is during the day time; however most of the occupants do not use the building during day time. This study can be used as a reference in efforts to improve energy efficiency and thermal comfort in the traditional rural housing.

![Figure 9. The estimated energy consumption pattern of the investigated building during a day in different months of a year.](image-url)
7. Conclusion
This paper discusses the features of traditional rural building, and examines the level of thermal comfort and wellbeing which is being achieved through these architectural practices. The result shows, in the climatic condition of Nalanda, decreasing heat gain is an important aspect in striving to achieve thermal comfort and energy efficiency of the buildings. The results of the study provide arguments, to navigate the insignificant and trivial trends in house designs, towards the sustainable path. The need is to integrate the principles of traditional rural architecture with the significant contemporary knowledge and technology.

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