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Energy Efficiency Potentials of Vernacular Buildings in improving the Residential Design and Construction - A Case Study of Dang Deukhuri Valley

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Abstract

The aim of this research is to evaluate the vernacular material and construction technology of residential buildings to assess its comparative energy efficiency cost over modern residential building. The research is entirely based in the Dang Deukhuri Valley because it was determined that this location is ideal for achieving the research's goals. To determine the vernacular materials and technology used in residential constructions, case studies and field investigations were conducted. Energy consumption pattern were examined through software called Ecotect and energy consumption cost were analyzed and compared through excel. Vernacular building was found to bear the minimum energy consumption cost over vernacular with cgi and modern r.c.c. building. Further, 75 participants were made involved in kobo toolbox questionnaire survey for qualitative analysis. Respondents were given the option to describe the characteristics of their homes based on factors such as thermal comfort, house typology, materials and construction technology used , energy cost, etc. and then result were drawn through statistical figure such as bar graph, pie chart. Additionally, RII analysis was used to discuss the relative impact of house typology, thermal comfort, and energy cost. The RII value in this instance further revealed that the vernacular buildings were of more significance than other buildings. The research can be helpful to traders, regular inhabitants, designers, architects, engineers, constructors, and more. They can use vernacular materials and construction technology for long term energy cost benefits in building projects.

Keywords

Vernacular, Ecotect, House typology, Thermal comfort, Energy cost

1. Introduction

Construction technology includes the selection of building materials as well as the "means and techniques" employed. The choice of technology will have a big impact on overall building cost, and vice versa. For instance, compared to resources imported from outside, local and plentiful construction supplies might lower shipping costs and minimize price inflation. Additionally, when a technology is quickly embraced by the construction sector locally, the need for expensive outside specialized labor or contractors is removed. [1] The maintenance and life cycle costs of buildings can also be reduced by using locally available technologies and materials that are strong and affordable to maintain. To progress the local industry in the most suitable directions with regard to construction technologies, policy makers must continue to assess contextual circumstances and formulate policies. Technology selection should consider both the economic and social implications. In order to promote more suitable solutions, construction technology must therefore be continuously evaluated and, when necessary, redirected by appropriate legislation. In general, a variety of elements may affect the choice of construction technique, but the most logical criterion for weighing the options is total cost. [2, 3, 4]

2. Literature Review

2.1 Sustainable Building

A sustainable building, often known as a green building (GB), is one that has been designed, constructed, renovated, utilised, or repurposed in a way that is resource and environmental efficient. The following factors should be taken into account before constructing a green building: quality of the internal environment, occupant health and well-being, efficient use of water, energy, and materials, and sustainable site planning and landscaping. A step towards sustainable development is the primary objective.[5] According to another definition, a green building (GB) is one that, in comparison to a traditional structure, maximizes energy efficiency, conserves natural resources, uses less water, produces less waste, and offers occupants a healthier atmosphere. It incorporated numerous techniques to finally lessen the effects of buildings on constructed environment and places a focus on utilizing the benefits of renewable resources, such as reducing rainwater runoff, capturing rainwater, utilizing trees through green roofs and rain gardens, and utilizing sunshine through photovoltaic, passive solar, and active solar technologies.[6, 7]

2.2 Cost optimization

Cost is the sum that must be paid or forfeited in order to obtain something. In the business world, it is customarily a monetary appraisal of the work, resources, materials, time, and utilities expended, the consequent risks, and the possibilities missed in the production and supply of a good, service, or product[8]. [9] describes optimization as a concerted effort undertaken to increase profit margins and produce the best results possible under specific circumstances or circumstances. Cost optimization, according to [10] , entails minimizing undesirable factors and maximizing desired ones in order to perform the same tasks or more at a lower cost. In other words, cost optimization entails finding alternatives with the highest achievable performance or cost effectiveness given the constraints. [7, 10]

2.3 Circular Economy

Using the cyclical nature of nature as an example, the circular economy can be a system of resource utilization where the 3Rs (reduction, reuse, and recycling) of elements prevail, reducing waste to a minimum, and recycling the rejected products back into the environment through the use of biodegradable products.[11, 12, 13] The resilience of natural resources is encouraged by the circular economy paradigm. The goal is to produce durable things that can be repaired or easily disassembled and recycled in place of the old linear economy model of quick and inexpensive manufacture and cheap disposal. A circular economy-based production model encourages the potential of repairing, refurbishing, and reusing things before they actually reach the end of their usable lives in addition to extending the product's useful life (when it will be recycled into materials that become raw resources). The circular economy paradigm seeks to imitate natural processes that take place in ecosystems.[14, 15]

3. Research Methodology

3.1 Research Framework

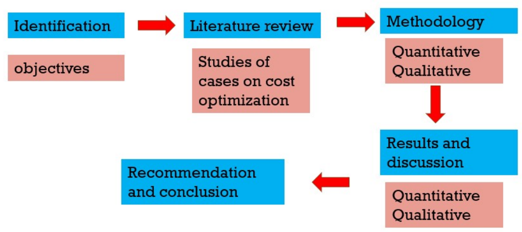

Figure 1: Research Framework step-1

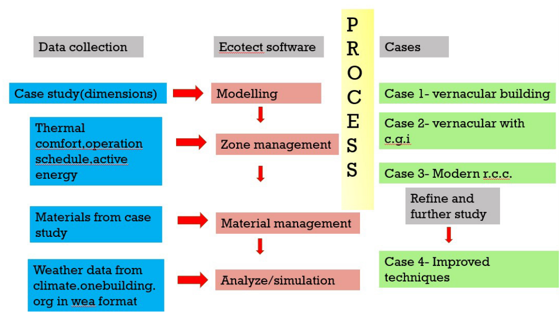

Figure 2: Research Framework step-2

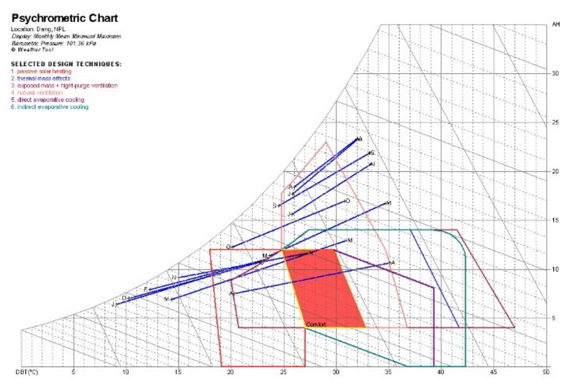

Figure 3: Psychometric chart for dang deukhuri

It helps to obtain the thermal comfort range for the location. It ranges from (24-29) deg. Celcius.

Data were gathered through case studies and field trips in order to identify vernacular construction methods and materials. Based on the materials used for walls, roofs, and floors as well as the building methods employed, the chart table was created. Houses were found to be composed of vernacular materials (mud, stone, bamboo, rice husks, Sabai grass), concrete and steel reinforcement bar (r.c.c.), and vernacular with cgi (all materials linked with vernacular except the roofing is of cgi sheet). As stated in the table below, specific information on each home was collected:

Case-1(vernacular):

Table 1: Data of case 1 on field visit

Introduction

Owner name	Location	Number of occupants	House typology	Area of House	No. of rooms
Bimala basnet	Lamahi-2,dodai gaun, dang deukhuri	2	Vernacular	328 sq. ft.	2
No. of floors	**Floor height**	**Shading device**	**Operation schedule**	**Orientation**	**Roof type**
1	5'-7" and 11'-1" from ridge	1'-4" projection	12 hrs.	south	Two way slope(thatched)

Building/construction Technology used

s.n.	components	Materials used	dimensions	thickness	Numbers
1	floors	Mud mortar with wheat residue,sabaigrass, cow dung		2-3"	
2	walls	Salwood post, bamboo, sabaigrass, wheat residue,mud,cow dung		2-3"	
3	ceilings	Simal/kadam wooden planks		3-4"	
4	roofs	Sabaigrass,salwood rafters,purlins.		6"(ridge thickest and edge thinnest)	
5	doors	Sal wooden frame and shutter	2'-3"X4'-8"		2
6	windows	Sal wooden frame and shutter	2'-0"X2'-9"		2

Active energy system (hvac,fan,cooler,heater etc.) if used:

s.n.	Device used	specification	numbers
1	Table fan	wega company	3 nos.
2	Motor for water pumping		1 nos.

Lighting system:

s.n.	Device used	specification	numbers
1	Led bulb	9 watt	7 nos.
Amount paid monthly for electricity bill			Rs.50/-

Case-2(vernacular with cgi) :

Table 2: Data of case 2 on field visit

Introduction

Owner name	Location	Number of occupants	House typology	Area of House	No. of rooms
Laal mohan chaudhary	Ghadhwa-3, gobardiha, dang deukhuri	5	Vernacular with cgi roof	481 sq. ft.	4
No. of floors	**Floor height**	**Shading device**	**Operation schedule**	**Orientation**	**Roof type**
1	7'-6" and 13'-8" from ridge	2'-0" projection	12 hrs.	east	Two way slope(thatched)

Building/construction Technology used

s.n.	components	Materials used	dimensions	thickness	Number
1	floors	Mud mortar with wheat residue,sabaigrass, cow dung		2-3"	
2	walls	Salwood post, bamboo, sabaigrass, wheat residue,mud,cow dung		2-3"	
3	ceilings	Simal/kadam wooden planks		3-4"	
4	roofs	Cgi sheet covering,salwood, rafters,purlins.		2 mm thick.	
5	doors	Sal wooden frame and shutter	2'-6"X5'-9"		1
6	windows	Sal wooden frame and shutter	2'-6"X2'-3"		5

Active energy system (hvac,fan,cooler,heater etc.) if used:

s.n.	Device used	specification	numbers
1	Table fan	Aircool company	2 nos.
2	Lpg gas		1 nos.

Lighting system:

s.n.	Device used	specification	numbers
1	Led bulb	7 watt	5 nos.
Amount per month for electricity bill			Rs. 30/-

Case -3(Modern r.c.c.) :

Table 3: Data of case 3 on field visit

Introduction

Owner name	Location	Number of occupants	House typology	Area of House	No. of rooms
Kamara giri	Maurighat, rapti r.m., dang deukhuri	4	Modern r.c.c.	641 sq. ft.	3
No. of floors	**Floor height**	**Shading device**	**Operation schedule**	**Orientation**	**Roof type**
1	9'-6"	1'-6" projection	12 hrs.	east	flat

Building/construction Technology used

s.n.	components	Materials used	dimensions	thickness	Numbers
1	floors	Brick soling, p.c.c , punning with cement		4"	
2	walls	Brick wall with cement-sand mortar		4"	
3	ceilings	r.c.c. with cement sand plaster		4"	
4	roofs	r.c.c. slab		4"	
5	doors	Sisau wooden frame and shutter	3'-0"X5'-10"		6
6	windows	Sisau wooden frame and shutter	4'-0"X3'-0"		6

Active energy system (hvac,fan,cooler,heater etc.) if used:

s.n.	Device used	specification	numbers
1	Table fan		1nos.
2	Ceiling fan		2 nos.
3	Fridge		1 nos.
4	Rice cooker		1 nos.
5	Lpg gas		1 nos.
6	Drinking water		1 nos.

Lighting system:

s.n.	Device used	specification	numbers
1	Led bulb	9 watt	10 nos.
Amount paid monthly for electric bill			Rs. 500/-

Case -4 (Improved techniques) :

Roofing : Since Khapra tiles can be made of clay, they are recommended for roofing. The Dang Deukhuri Valley has the necessary supplies and skilled labor, and the thermal insulation is a wonderful complement. With a possible lifespan of more than 100 years, many clay roof tiles even outlive the buildings they are affixed to. Khapra tiles are also suitable for all kinds of occupant Since, it will be offered in the neighborhood market, and is affordable for all socioeconomic groups. It may also look nicer than typical roofs, too. It is also possible to place it over a concrete structure.

Figure 4: Local Manpower making pot from clay

Figure 5: Locals laying khapra tiles over r.c.c building

Wall : Rat trap bond is proposed for wall masonry work. Rat trap bond is a brick masonry technique for building walls in which the bricks are arranged vertically rather than typically horizontally, leaving a cavity (hollow area) within the wall as a result. According to research, it uses about 25 perc. less bricks and 40 perc. less mortar than conventional

Figure 7: Hand made clay ready for making bricks.

masonry, which results in significant construction cost savings. The interiors are cooler in the summer and warmer in the winter because to the improved thermal insulation that a cavity-induced in wall gives. As a result, it offers advantages in terms of operational costs and thermal comfort. Rat trap bond in a Building construction can therefore be a long-term investment. The field visit demonstrates that there is sufficient clay in the Dang Deukhuri Valley to produce bricks for rat trap bond.

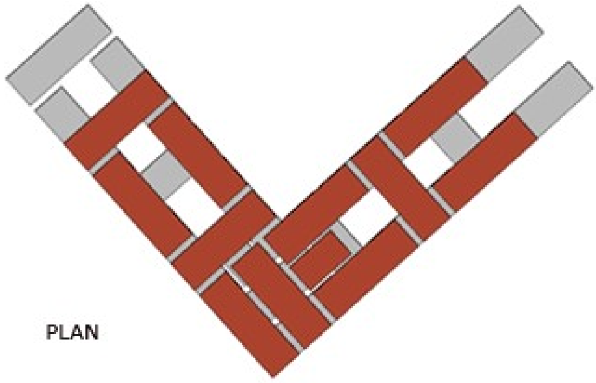

Figure 6: Rat trap bond for wall masonry construction

Questionnaire survey :

Sample Size n=(z2.p(1-p))/e2 = 68
z = 1.64
p = 0.5
e = 0.1
n0= (1.6452*0.5*0.5)/0.1*0.1= 67.5 $\approx$ 68

For questionnaire survey, 75 participants were taken for analysis through kobo toolbox. They were allowed to choose option which define their house characteristics on the basis of materials and construction technology, house typology, thermal comfort, energy cost etc.

4. Results and Discussion

Case-1:

CASE -1 /MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 1074 W at 00:00 on 9th March
Max Cooling: 1273 W at 15:00 on 13th April

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	355302	0	355302
Feb	181879	0	181879
Mar	98730	33151	131881
Apr	0	224276	224276
May	0	228791	228791
Jun	0	191500	191500
Jul	0	140879	140879
Aug	0	147115	147115
Sep	0	152065	152065
Oct	0	78550	78550
Nov	83852	0	83852
Dec	261352	0	261352
TOTAL	**981115**	**1196327**	**2177442**
PER M²	**33146**	**40416**	**73562**
Floor Area:	**29.600 m2**		

Case-2:

CASE-2/MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 3927 W at 04:00 on 6th March
Max Cooling: 5090 W at 17:00 on 13th April

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	1517781	0	1517781
Feb	835768	0	835768
Mar	558554	306367	864920
Apr	18071	700893	718964
May	0	744420	744420
Jun	0	641765	641765
Jul	0	440181	440181
Aug	0	477636	477636
Sep	0	454593	454593
Oct	78886	212962	291848
Nov	507659	3670	511330
Dec	1147127	0	1147127
TOTAL	**4663846**	**3982488**	**8646334**
PER M²	**157562**	**134544**	**292106**
Floor Area:	**29.600 m2**		

Case-3:

CASE -3/MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Adaptive - Average (± 1.75)

Max Heating: 8836 W at 02:00 on 6th March
Max Cooling: 11634 W at 15:00 on 13th April

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	3019734	0	3019734
Feb	1622293	0	1622293
Mar	1237992	582805	1820797
Apr	42294	1973052	2015346
May	0	2023117	2023117
Jun	0	1670368	1670368
Jul	0	1216582	1216582
Aug	0	1263334	1263334
Sep	0	1309810	1309810
Oct	207690	794204	1001894
Nov	1053552	22224	1075776
Dec	2331024	0	2331024
TOTAL	**9514580**	**10855496**	**20370076**
PER M²	**131690**	**150249**	**281939**
Floor Area:	**72.250 m2**		

Case-4 (Improved techniques):

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 1063 W at 02:00 on 8th March
Max Cooling: 1223 W at 15:00 on 13th April

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	319266	0	319266
Feb	170053	0	170053
Mar	112011	5386	117397
Apr	0	198288	198288
May	0	207076	207076
Jun	0	177433	177433
Jul	0	133201	133201
Aug	0	137268	137268
Sep	0	142609	142609
Oct	0	59761	59761
Nov	93452	0	93452
Dec	239957	0	239957
TOTAL	**934739**	**1061020**	**1995759**
PER M²	**31579**	**35845**	**67424**
Floor Area:	**29.600 m2**		

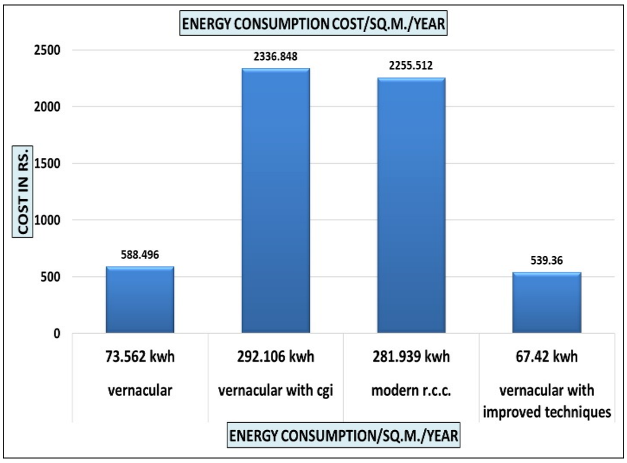

Figure 8: Comparative analysis of energy consumption cost.

Here, total loads or energy required to maintain thermal comfortness is determined. Total loads for a year per sq. m. is determined in all cases and then loads(energy) is converted to electricity cost. The electricity cost is put as Rs. 8 per unit (Kwh).

Results of questionnaire survey:

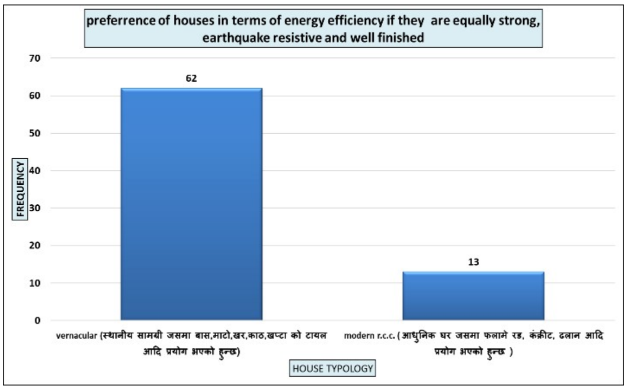

Figure 9: Preference on the basis of energy efficiency

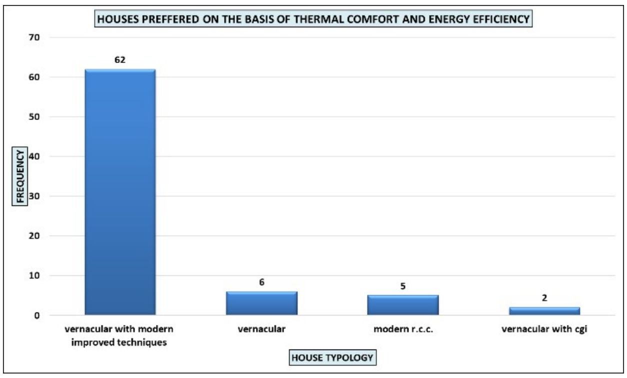

Figure 10: Preference on the basis of Thermal comfort

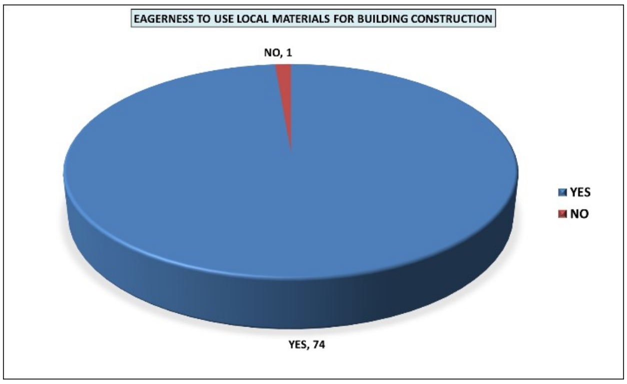

Figure 11: Eagerness to use local materials for building construction

5. Conclusion

Here, the vernacular materials and construction technology is best and optimum solution for long term investment in building construction as it reduces large amount of operational cost and also creates healthy environment to indoor space and occupants.

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