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Energy Optimization Potential and Thermal Comfort: A case of Use of Rat Trap bond in Residential Building of Terai Region

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Abstract
Currently in Nepal, extensive use of modern material and technology is seen in construction industry. Buildings consume large share of energy in every stage of its life-cycle. The global context shows that approximately 40 percentage of energy is consumed by building industry at various stages and large amount of such energy is used for maintaining indoor thermal comfort. The use of construction materials, technology, orientation, roof typology, provision of ventilation etc. plays an important role in maintaining indoor thermal comfort. The major heat transfer takes place through walls and roof. But lack of awareness about heat transfer rates from various parts of building, climatic context of building and thermal properties of materials and technology had led to poor indoor thermal environment. Due to unsatisfactory thermal environment, occupants inside the buildings try to be thermally comfortable by use of active and passive methods. The active methods such as fans air conditioners etc. not only places stress on electrical energy, but also on global warming. Therefore, renewed interest towards passive techniques which are more cost effective, eco-friendly and suited for the local climate is being developed nowadays. Several building construction techniques and environment friendly materials have been introduced. One such building technique to control heat transfer through walls in order to enhance thermal comfort and save energy is the use of 'Rat Trap Bond' (RTB) masonry. The purpose of this research is to study residential thermal comfort of the type design constructed in Ramnagar, Butwal .Simulation tool is used for analysing thermal comfort and field study based on survey questionnaires with house owners is used to validate the simulated data. NEA Electric bills of 21 residences were accessed to identify electricity consumption for maintaining thermal comfort in summer and winter .Attempt is made to compare and contrast the thermal performance of conventional brick bond wall and RTB brick wall. For this a typical residential building constructed with solid wall on ground floor and RTB wall on first and top floor was purposefully selected for simulation to keep all the other parameters constant.

Keywords
Construction Technology, Rat Trap Bond, indoor thermal Comfort, Energy Efficiency, Thermal Performance

1. Introduction

The building industry is one of the largest energy consuming sector accounting for larger proportion of total energy consumption than both industry and transportation in many developed countries . The data shows, in 2004 the building sector accounted for 40, 39 and 37 percentage of the total energy in USA, the UK and the European Union respectively. in context of china, building energy accounted for about 24.1 percentage in 1996 of total national energy use, rising to 27.5 percentage in 2001, and was projected to increase to about 35 percentage in 2020 [1]. Large quantity of energy consumption in buildings is found for cooling and heating by heaters and air-conditioner systems [2]. The selection of building materials affect indoor thermal comfort as well as appearance of the building. Therefore, there is a need for alternative building technology which could effectively address the issues of energy demand indoor thermal comfort along with sustainable development.

Nepal lies in tropical region with the geographic co-ordinates 26° to 30° latitude. Tropical climate is found in 60m to 1200m above the sea level with average temperature of 40°C (summer) and 6°C(winter) [3]. Due to these warm climatic conditions, occupants inside the buildings try to be thermally comfortable by use of active and passive methods. The active methods such as fans air-conditioners etc are not very much suitable for a county like Nepal because it is at its development stage. These active devices consume much electricity and that causes problems to the economy of the country because energy crisis has been a vital issue in this era. Therefore in order to minimize the life cycle cost t of the buildings, indoor comfort by passive means are utmost important. So the engineers and architects should pay their attention on integrating passive concepts to the buildings in order to minimize the energy consumed by the building due to warm humid climatic conditions [4]. While designing the buildings to have a better thermal comfort the designers should pay their attention to the surrounding macro and micro climatic conditions, geometry of the site, and construction materials available. The factors affecting the climate and their interaction are solar radiation, air temperature, atmospheric humidity, wind and precipitation. In context of Nepal, in the name of development rapid construction works had been carried out with concrete and glass materials resulting in reduction of use of local materials available. Thermal comfort of the inhabitants is rarely considered during the design and construction phase which has resulted in poor thermal environment within the building. For maintaining thermal comfort, mechanical systems are installed. Such practice has led to higher electricity consumption. Innovative use of material and construction technology could be one of the key issues for sustainable building design for different climates.

The rat trap bond is a masonry technique, where the bricks are used in a way which creates a cavity within the wall, while maintaining the same wall thickness as for a conventional brick masonry wall. While in a conventional English bond or Flemish bond, bricks are laid flat, in a Rat trap bond, they are placed on edge forming the inner and outer face of the wall, with cross bricks bridging the two faces.

Figure 1: Rat Trap Bond Wall [5]

The main advantage of Rat-trap bond is reduction in the number of bricks and mortar required as compared to English/ Flemish bond because of the cavity formed in the wall. The cavity also makes the wall more thermally efficient. This also reduces the embodied energy of brick masonry by saving number of bricks and the cement-sand mortar [5].

2. Literature review

The study made by Ar. Bhavana Patil and Dr. Sheeba Valsson studied the thermal performance of rat trap bond wall masonry with filler slab and mud block with Guna tile vaulted roof for finding and comparing its suitability for thermal comfort in Hyderabad, India. T he study shows that average indoor temperature from 9 am to 5 pm was 32.8°C with RH 52.5 percentage for rat-trap bond block and 33.7°C with RH 48.6 percentage for mud block respectively. The research concludes that thermal conditions are more favourable in the building constructed with rat-trap bond, filler slab and brick jali [6].

Similarly,Baskaran and his friends made research on thermal performance of rat-trap bond and the plastered English bond in Sri Lanka. English bond and rat trap bond models were used for research purpose with orientation in west direction .The finding of research shows that Rat-trap bond behaves thermally well than the plastered English bond and the house constructed with rat-trap bond is giving a lower cooling load than English bond with plaster [4].

Similarly, study carried out on comparison of performance of rat trap brick bond with the conventional brick bond in Islamabad, Pakistan by Ullah has concluded that RTB brick wall performed very well in saving energy and reducing the electricity bill cost. The cavity within the RTB bond wall enhances thermal comfort as its R-Value is 0.70 m2K/W which is twice in comparison with English and Flemish bond [7].

The research also has shown that Rat Trap bond is not only good to save the electricity consumption but also very good in the thermal load reduction as shown in table above.

Table 1: Electricity Cost Comparison of Rat Trap and Conventional Construction [7]

S.N.	Month	Rat trap	Conventional	Percentage difference
1	Jan	117.92	253.35	53
2	Feb	11.34	35.5	68
3	Mar	237.15	373.25	36
4	Apr	1901.25	3477.25	45
5	May	2934.5	5453.5	46
6	Jun	2915.5	5427.75	46
7	Jul	2673.25	4959.25	46
8	Aug	2592.5	4803.25	46
9	Sep	2208.5	3945.25	44
10	Oct	1703.25	3308.25	49
11	Nov	90.35	149.25	39
12	Dec	70.25	177.82	60

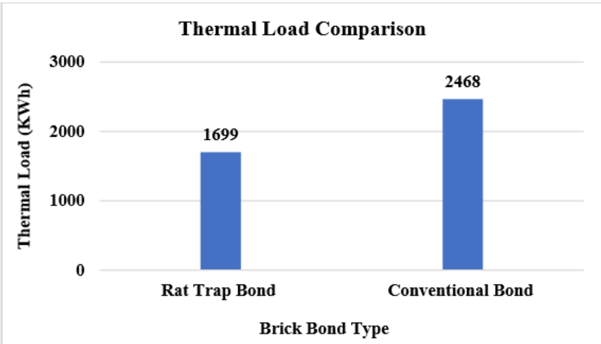

Figure 2: Thermal Load Comparison [7]

The figure above shows less thermal load incase of rat trap bond as compared to conventional bond.

3. Methodology

The methodology is based on both Quantitative and Qualitative survey. The research involves of relevant literature reviews followed by data and information gathered during discussion and interviews on site area. The qualitative data is gathered through individual interviews using semi-structured and structured questions, while quantitative data is acquired from secondary source (books, reports, internet).

3.1 The study area

Terai region having dominating hot climate was suitable for research purpose, so Ram Nagar area of Butwal sub-metropolitan is selected as study area . The study area has highest average temperature records at 30.6°C in May and March to October accounts higher temperature; above 25°C. Almost 9 months in a year is recorded with high humidity. i. e. >70 percentage [8]. In order to fulfill the objective, quantitative method has been carried out in field. The main research focuses to field study with monitoring thermal performance of these two types of residences on the month of February. The evaluation of thermal environment of buildings contains with field data, sample analysis, followed by discussion and aiming to draw the results and conclusions.

3.2 Investigated buildings

Residential buildings of two to three storey has been selected.Planning and construction technologies of sixteen buildings has been reviewed. Similarly, temperature and humidity was measured by using digital thermometer. Orientation of the buildings has been measured with mobile compass. Satisfaction condition of the occupants has been observed through informal interviews with questionnaire survey. Energy consumption of buildings of the study area has been accessed via.electric bill from NEA to observe the difference in summer and winter caused by fans and coolers for maintaining comfort .

4. Computer Simulation

4.1 General

The walls of the observed buildings have different sizes, dimensions and facing different directions. The experiment was done by using small models so as to keep all the variables constant except the type of brick bond. The isolation of individual effect will make easy to predict the results without any difficulty. Computer simulation is a best tool since it gives wide range of flexibility to handle different cases [4].

4.2 The Simulation Software

The software adopted for the simulation of this project is Autodesk Ecotect 2011. After combining the weather file in Ecotect, thermal analysis was the major concern to study comfort level of the house. Here, a few parameters were set and calculated to study energy performance of the building. Parameters such as hourly heat gain/ loss, monthly load of active system, fabric gain/loss and passive solar breakdown were calculated for thermal analysis. The building is simulated by changing the construction technology of building as different scenarios. Overall compare and contrast was performed to dissect pros and cons of different construction methods. Similarly, energy performance of various construction methods were studied through energy modelling.

4.3 Building selected for simulation

A two and half storey building was selected for simulation purpose. This building was chosen because it involved both RTB and solid wall construction method.

Figure 3: Building selected for simulation

The ground floor involves solid wall construction with 9" thickness of outer wall. Partition walls were of 4" thickness with 10mm mortar on external and internal surfaces. The first and top floor was constructed using Rat trap bond technology. Upper floors were constructed after years when the owner was introduced with that technology. The walls were built from brunt clay bricks. Likewise, the roof was flat type concrete slab. The house is oriented towards south with southern façade having balcony and a porch. The fenestrations have single glazed windows and have no proper sun shading device, hence there is direct sunlight in both summer and winter season.

5. Results

Three scenarios (i.e. base case scenario, modified scenario and optimized scenario) were developed to compare the energy consumption by building. The base case scenario involved hybrid construction technology with English bond on ground floor and RTB in first and top floor. Following results were obtained from analysis.

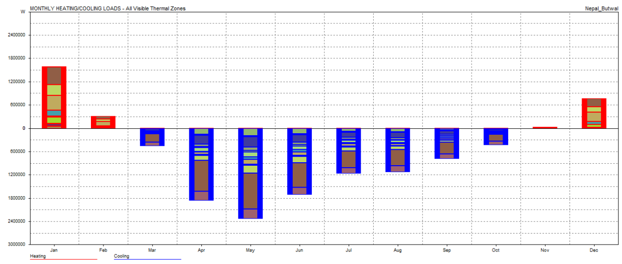

Figure 4: Scenario 1 Monthly loads/discomfort

Max Heating: 9240 W at 23:00 on 12th January Max Cooling: 13743 W at 12:00 on 23rd May

Similarly, in case of modified scenario, all the wall (both outer and partition wall) is transformed to 9 inch brick wall to test the heat transfer performance of the building. Following results were obtained from analysis.

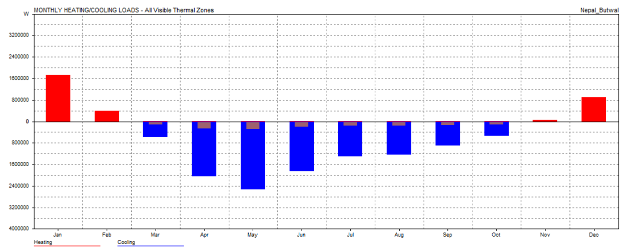

Figure 5: Scenario 2 Monthly loads/discomfort

Max Heating: 10295 W at 23:00 on 12th January Max Cooling: 15008 W at 12:00 on 23rd May

Finally, optimized scenario was developed with all the walls (both outer and partition) with RTB technology .Following results were obtained.

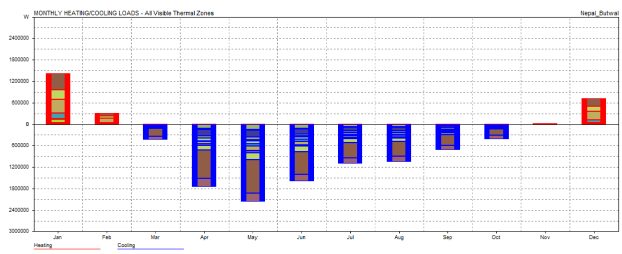

Figure 6: Scenario 3 Monthly loads/discomfort

Max Heating: 8931 W at 23:00 on 12th January Max Cooling: 13309 W at 12:00 on 23rd May

Table 2: comparison of annual energy demand in different cases

Load (KWh)	Base case Scenario model Existing (Scenario 1)	Scenario 2 (modified model with all 9"thick brick wall)	Scenario 3 Optimized model (Cavity Wall)
Heating	270.2114	305.3256	249.1133
Cooling	990.8025	1101.3891	926.1060
Total	1261.0139	1406.7146	1175.2193

The table above shows annual heating and cooling load for the simulation building.the data obtained from ECOTECT is in Wh which is converted to KhW for convenience.

6. Findings and discussions

When all the parameters except construction technology were kept intact, the total energy consumed for maintaining thermal comfort in case of existing scenario of hybrid construction technique (i.e. solid wall in ground floor with 9"thick outer wall and 4" thick partition walls) is 1261.0139 KWh .Out of 1261.0139 KWh , 270.2114 KWh of energy is required for heating purpose. Similarly, 990.8025KWh of energy is required for cooling purpose. Cooling load is far greater than heating load since summer season holds longer duration extending from March to October. Extremely hot climate prevails in May with highest cooling load of 13743 Wh. Similarly, the total energy consumed for maintaining thermal comfort in case of scenario 2, with alternation of wall materials from hybrid construction to 9" thickness of all the walls including partition walls is 1406.7146KWh. Out of which, 305.3256KWh is required for heating purpose and 1101.3891KWh is required for cooling purpose. Finally in case of scenario 3, in which the wall technology is changed to rat trap bond for all the walls including partition wall, the total energy consumed for maintaining thermal comfort is 1175.2193 KWh. Out of 1175.2193KWh, energy required for heating purpose is 249.1133 KWh and for cooling purpose, 926.1060KWh is required. This reduction in energy is due cavity in Rat Trap Bond technology which acts as insulation .hence it is seen that RTB technology can contribute in saving energy for in the building for achieving indoor thermal comfort.

7. Conclusion

Rat-Trap Bond(RTB) Masonry Technique can be a good initiation for achieving thermally comfortable residence in hot climates of terai region where brick is used as major building material.This technology is energy efficient as well as cost effective building construction. It's simple, and easy to construct also reducing its impact on the environment by achieving a huge saving in the embodied energy consumption. RTB technology can further aid in light weight construction in earthquake prone zone like our country. This is the peak time that our governments take up this issue on war-foot level and promote and subsidize as much as possible the use of such green, environment-friendly and cost-effective technologies. This will help from individual /local level to contribute in energy efficient building construction with improved thermal comfort.

8. Recommendations

The study carried out during project work has illustrated that rat trap bond technology has huge potential in enhancing indoor thermal comfort and energy saving. Thus, detail research can still be carried out to make it more economical and reliable in the field of energy efficiency. There are many gaps for the further future works , few of them are as listed below.

1. Rat trap bond wall technology can perform differently when roofing technology is changed.

2. Addition of insulating material can further enhance thermal performance of the building.

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