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Comparison of Energy Efficiency of traditional Brick Wall and Inco-Panel Wall: A Case Study of Hotel Sarowar in Pokhara

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Abstract:

Energy efficiency is understood to mean the utilization of energy in the most cost-effective manner to carry out process or provide a service, whereby energy waste is minimized, and the overall consumption of primary energy resources is reduced. Various measures can be employed to attain energy efficiency in building such as reducing demands for heating, cooling, lighting, consumption for office equipment and appliances demand, reducing energy requirement for ventilation, using energy efficient building materials.

An energy efficient home is designed to keep out the wind and rain while reducing energy waste. Modern homes are built with variety of different materials. They are no longer built using only bricks and mortar. A wide variety of energy efficient building materials are now available. Recycled Steel, Insulating Concrete Forms, Plant-based Polyurethane Foam, Straw Bales, Structural Insulated Panels, Plastic Composite Lumber, Vacuum Insulation Panels, Inco-panel are among alternatives available.

Among those various wall materials, energy performance analysis in terms of heating and cooling load is done in this thesis. For this study, under construction Hotel Sarowar is chosen for analysis. This study compares heat transfer on the building when Inco-panel is used as wall material and conventional brick masonry is used as wall material. The heat transfers through those walls are calculated using MS Excel and ANSYS Software.

Keywords: ANSYS, Brick, Energy Efficiency, Inco-Panel

1 Introduction

Residential sectors contribute to 22 percentage of total energy consumed in the world i.e. 9384 Mtoe [1]. Energy efficiency of buildings has recently become a major issue because of growing concerns of CO_2 and other greenhouse gas emissions, and scarcity of fossil fuels. Buildings worldwide account for a surprisingly high 40% of global energy consumption [2]. In certain regions highly dependent on traditional biomass, energy use in buildings represents as much as 80% of total final energy use [3].

In case of Nepal, energy demand from the residential sector constituted almost 89 percent of the total energy consumption in the country in 2008/2009 [4]. Residential sector contributes 80.36 % of total energy consumption of 376.2 million GJ for the year 2011/12 [5]. Nepal contributes, though negligible, 1.9 tons of CO_2 out of 22981 ton of CO_2 produced in the world [6].

In buildings, the energy is used, especially, 42% for maintaining the thermal comfort of the occupants, 12% for working lighting devices, 13% for hot water supply and 33% for miscellaneous equipment. A considerable amount of energy goes for compensating the heat loss/ gains occurring in the building's envelope. The building envelope is composed of walls, floors, roofs, fenestrations, and doors. For residential buildings in Turkey, heat-losses occurring through building envelope are respectively 25% in roofs, 25% in windows and doors, 20% in building structural system and 15% in walls. Similarly, the heat gains are 25 - 35% in roofs, 25 - 35% in windows, 15 - 25% in walls, 10 - 20% ground floors, and 5 - 25% air infiltration. More heat losses and gains are translated into more energy consumption to maintain the thermal comfort [7].

An optimal building envelope design contributes to reducing the energy consumed for heating/cooling and lighting. The heat losses and gains in the building envelope occur because of three main thermodynamic phenomena: conduction, convection, and radiation. The heat transfer performance of a building envelope element is related to several parameters which are thermal resistance (R-value), thermal mass for opaque elements (wall, roof, etc.), heat transmittance coefficient (U-value), solar heat gain coefficient (SHGC), and visible light transmittance (VT) for transparent elements (windows, skylight etc.) By taking into consideration the above mention thermal properties of the materials and the climate conditions of the building's site, it can be designed more energy and cost-efficient buildings.

1.1 Background

Improvement of envelope insulation can bring further energy savings between 26% and 50%. Different from passive design optimisation, adding insulation results in similar relative savings in all climate regions of the country. On average, about 42% of HVAC energy demand can be reduced by increasing the envelope insulation in hotel buildings to a cost-effective level [8].

The most energy efficient combination is low-e glass + 100 mm (Expandable Polystyrene) EPS + Window Wall Ratio (WWR) 50% for cold climate regions and reflective glass + 100 mm EPS + WWR 50% for hot climate region. Also, the most cost-efficient combination is clear glass + 100 mm EPS + WWR 50% for both regions [7].

An external Living wall application on an opaque part of west-facing wall and an extensive Green roof made up of Australian native plants can reduce 15-20% cooling energy consumption of commercial buildings in the sub-tropical climate of Australia [9]

Traditional building i.e. load bearing wall of 450 to 600 mm built with multilayer of Burnt Red brick *(pakki apa*), Sun dried brick (*kachi apa*) and mud plaster placed from outside to inside in external walls saves, minimum 10-20% energy for either heating or cooling both in summer and winter than modern buildings of Kathmandu [10].

The difference in cooling loads energy reduction can reach up to 77%, outlining the huge impact even simple facade design changes can make on the performance of a building. The best façade combination in this simulation consists of the use of Thermal Blocks for walls and the 32mm glazing type with the lowest shading coefficient of 0.23 [11].

Having control over the dominant factors in a building envelop design is ultimately the path to achieving energy savings and carbon reduction for the city [12].

By increasing the thickness from 0 up to 32 cm the annual requirement for heating and cooling is halved, while a first increase in thickness from 0 to 2 cm generates a saving of 25% in the annual requirement [13].

1.1.1 Building Energy Efficiency

Energy-efficient approaches are the measures that aim to improve the energy efficiency of buildings. These measures are the ways through which the energy consumption of a building can be reduced while maintaining or improving the level of comfort in the building. Therefore, an energy-efficient approach for buildings can be defined as an approach that can assist in reducing energy consumption in the form of electricity, improving the greenhouse gas (GHG) impact of operations and reducing operating costs of buildings.

The energy efficiency of a building is the extent to which the energy consumption per square meter of floor area or per square meter of envelope area (kWh/m^2/yr) can be reduced compared to existing envelope for that particular type of building under defined climatic conditions.

An efficient building is one that applies energy-efficient technologies while operating as per design, supplies the amenities and features appropriate for that kind of building, and which can be operated in such a manner as to have a low energy use compared to other similar buildings. The concept of "energy-efficient buildings" has some implications that depend on regulations, economics, energy demand and the environment. There are many concepts regarding energy-efficient buildings; the elements can be divided into three parts [14].

a) The building must contain energy-efficient technologies, when operating as designed, to effectively reduce energy use.
b) The building must deliver the amenities and features appropriate for that kind of building.

The building must be operated in an efficient manner. The evidence of this operation is low energy use relative to other similar buildings.

1.1.2 Building Energy Efficiency Improvement

There are many approaches to improve the energy efficiency of buildings. Usually the designer and architects use different tools to make a building energy-efficient at the design stage. Measures and techniques may be different for existing buildings. It varies as per nature of building systems and the age of a building itself. Some of the areas are identified by some researchers to improve the energy efficiency of buildings. These include improving the performance of building envelope system, efficient HVAC system, application of Green technologies and others [2].

A building's location and surroundings play a key role in regulating its temperature and heat gain. For example, trees, landscaping, and hills can provide shade and block wind. In cooler climates, designing buildings with south-facing windows increases the amount of sun entering the building, minimizing energy use by maximizing passive solar heating. Tight building design, including energy efficient windows, well-sealed doors, and additional thermal insulation of walls, basement slabs, and foundations can reduce heat loss by 25 to 50% [15].

1.1.3 Inco-Panel as Alternative Wall Material

Inco-panel is Expanded Polystyrene (EPS) core Panel system is a modern, efficient, safe and economic construction system for the construction of buildings. These panels can be used both as load bearing as well as non-load bearing elements.

EPS core panel is a 3D panel consisting of 3-dimensional welded wire space frame provided with the polystyrene insulation core. Panel is placed in position and shotcrete on both the sides. The EPS panels consist of a 3-dimensional welded wire space frame utilizing a truss concept for stress transfer and stiffness as shown in Fig.1.

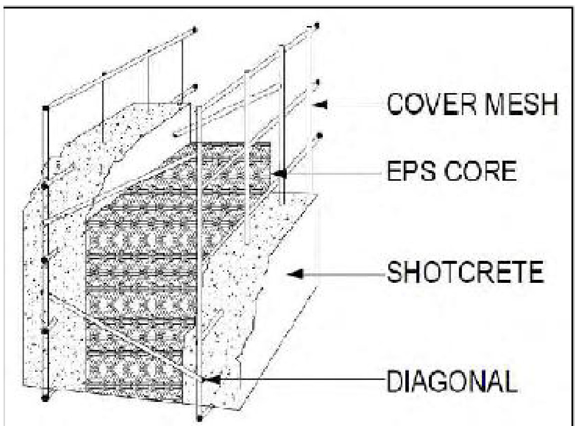

Figure 1: Typical cross section of Inco- Panel

EPS panel includes welded reinforcing meshes of high-strength wire, diagonal wire and self-extinguishing expanded polystyrene uncoated concrete, manufactured in the factory and shotcrete is applied to the panel assembled at the construction site, which gives the bearing capacity of the structure.

EPS panel has the following five components:

a) The outer layer of shotcrete (37 mm).
b) Welded reinforcing mesh of high wire.
c) The core of expanded polystyrene sheet (50 mm).
d) Diagonal wire (stainless or galvanized wire).
e) The inner layer of shotcrete. (37 mm)

The welded mesh fabric connected piercing polystyrene with truss of steel wire, welded to the welded fabric at an angle. It gives a rigidity spatial structure, and simultaneously prevents polystyrene core shifting.

2 Research Methodology

Collection of data of the study building in Pokhara for reference and data input to excel sheet. A data sheet has been prepared based on the type of information required for the energy efficiency analysis. All the information relevant to building heat gain parameters, building elevations and drawings, physical and thermal properties of building material has been collected from, building owners and literatures.

2.1 Building structures

The dimension of the building which cooling load is to be air conditioned is, 92' * 54' in size. It has eight floors excluding lower basement, upper basement, Attic-1 and Attic-2. The exterior walls of building consist of: from inside to outside, paint layer + Plaster (12.5 mm) + PCC (37 mm) + Expandable Polystyrene (EPS) (50 mm) + PCC (37 mm) + Plaster (12.5 mm) respectively. The roofing of the building is composed of stone coated metal sheet, insulation (6 mm) and plywood (19 mm) from to top to bottom respectively. The flooring of the building will be RCC. Finishing shall be putty and paint.

The comparison of above-mentioned building shall be made with conventional brick wall of brick masonry in cement mortar. The exterior walls of building consist of: from inside to outside, 12.5 mm plaster + 230 mm common bricks + 12.5 mm sand cement plaster. The roofs consist of 125 mm concrete, with 12.5 mm sand cement plastering on both sides.

2.2 Determination of U-value

When the wall, floor or ceiling are made up of layers of different materials, then the overall heat transfer coefficient 'U can be calculated by the formula given below.

$$U = \frac{1}{\frac{1}{h_o} + \frac{x_1}{k_1} + \cdots \dots \dots + \frac{x_2}{k_2} + \frac{1}{h_i}} \quad (1)$$

Using above formula, the U-value of the two building wall materials is found to be 0.62 W/m^2.^{0}C and 1.192 W/m^2.^{0}C

2.3 Heat transfer

The rate of heat transfer from outside air to inside air is calculated by the formula.

$$Q = U * A * \Delta T \quad (2)$$

Where,

U = over all heat transfer coefficient (W/m^2.^{0}C)

ΔT = Temperature difference between outside and inside of building (^{0}C)

A= surface area (m^2)

The inside temperature shall be maintained at 20 degree Celsius to maintain thermal comfort.

3 Result

3.1 Energy Savings

Using Inco-Panel as building material saves energy consumption in the building which would be used to maintain indoor thermal comfort in comparison to brick wall. Maximum amount of energy is saved in January and minimum in March which is because the variation in between indoor and outdoor temperature is large in January in comparison to March.

A total of 53737.41 kWh in a year of energy can be saved while using Inco- Panel as building wall material instead of Brick Masonry in order to maintain indoor temperature of 20 degree Celsius.

Table 1: Energy Saving, using Inco-Panel as wall material

Months	Energy Savings while Using Inco- Panel (kWh)
Jan	1781.50
Feb	835.52
Mar	48.83
Apr	362.04
May	869.27
Jun	1102.86
Jul	1300.86
Aug	1179.46
Sep	1041.65
Oct	331.85
Nov	673.44
Dec	1414.09

3.2 Cost Savings

The cost savings while using Inco-Panel is calculated, using monthly energy savings and rate of electricity as per Nepal Electricity Authority (NEA). Saving is maximum at month of January and minimum in March.

The total cost saving while using Inco- Panel as building material is 698,586.39. This amount of money can be saved by less consumption of electricity to maintain temperature of thermal comfort within the building.

Table 2: Cost Saving while using Inco-Panel

Months	Cost Savings (NRs.)
Jan	23159.46
Feb	10861.77
Mar	634.79
Apr	4706.52
May	11300.49
Jun	14337.21
Jul	16911.19
Aug	15332.94
Sep	13541.45
Oct	4314.08
Nov	8754.69
Dec	18383.23

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