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Advancing Green Building Design in Bangladesh: Empowering Sustainability with Polyurethane Foam for High-Performance Insulation and Eco-Friendly Construction

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Abstract

Sustainable building approaches are being used worldwide to lessen building environmental effect. Green building materials include plant-based polyurethane rigid foam. This has made the green building industry more sustainable and energy-efficient. In green building construction, polyurethane is used to make high performance insulators for roofs and walls that are rigid but light in weight. This technology is better and more viable. Polyurethane foam products can enhance the aesthetic design of green buildings. The quest of this paper is to systematically analyze and report the scenario of green building construction conducted with plant-based Polyurethane rigid foam in the present world. Therefore, this paper depicts the overall condition of the aforementioned sector. This paper also reviews the limitations, challenges, and lastly, the future of this distinctive green building industry. On the basis of valid websites, news, and citation burst research, this paper has built a knowledge epistle for green building made with Polyurethane rigid foam. This paper can assist readers to realize the status quo and uprising trend of green building and the impact of plant-based polyurethane rigid foam on it so as to provide a promising guideline for future research.

Keywords: *green materials; sustainable building; polyurethane foam; insulation; energy-efficient.*

1. Introduction:

The environment and our ability to live in it have declined since we first began turning cities into concrete jungles. The modern construction industry is the world's largest consumer of energy and a major contributor to pollution (Faiz & Bhutta, n.d.). This sector is also a major user of natural resources such as timber and ores. Thirty to forty percent of global energy use occurs in the construction sector, according to the United Nations Environment Programme (UNEP) (Abdallah et al., 2015). The environmentally beneficial alternative to traditional rigid foam insulation is polyurethane foam made from plants. Its exceptional insulating properties make it ideal for use in the walls and roofing of environmentally friendly buildings. According to the US Department of Energy, heating and cooling accounts for 56% of the typical American home's energy consumption. However, rigid Polyurethane foam may help homeowners save money by keeping the house at a consistent temperature and minimizing noise pollution (*Rigid Polyurethane Foam - PT Uretanindo Pasifik Intersarana*, n.d.)

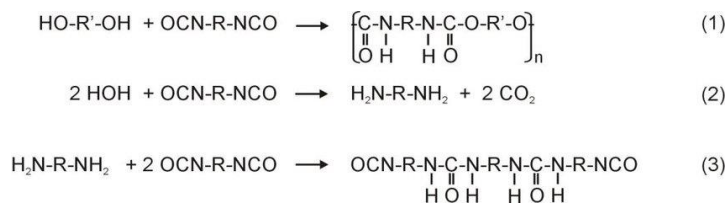
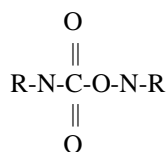


Figure 1: Chemical form of polyurethane foam (Bonnaillie, 2007)

The chemical structure of polyurethane foam is a result of the reaction between polyols and isocyanates. This reaction leads to the formation of a polymer network with urethane linkages. Here is the basic chemical structure of polyurethane foam:



In this structure:

"R" represents the polyol segments, which are typically derived from various sources such as petrochemicals or plant-based materials.

"N" represents the nitrogen atom.

"C" represents the carbon atom.

"O" represents the oxygen atom.

"C-O-N-R" represents the urethane linkage formed between the polyol and isocyanate.

Polyurethane foam can have various arrangements of these linkages, resulting in different types of foam with distinct properties. The specific composition of the polyols and isocyanates used will determine the exact chemical form and properties of the polyurethane foam.

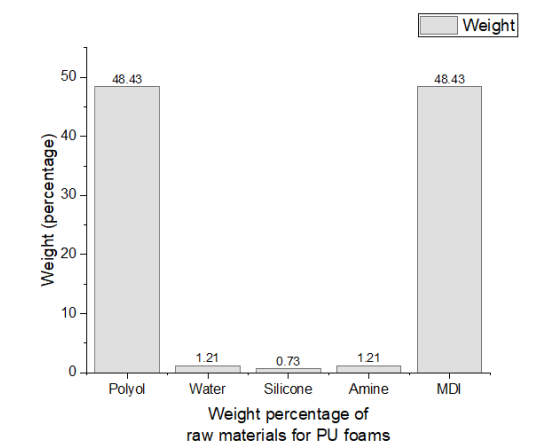


Figure 1:Weight of raw materials for PU foams (%) (Borreguero et al., 2010)

Since the insulating property of rigid Polyurethane foam is better, it opens the door for builders to construct walls thinner. So, constructing a building with it can give more space for any family. Polyurethane rigid foam can also refrain owners from expending extra money, both in decreased construction expenses and reduced utility bills.

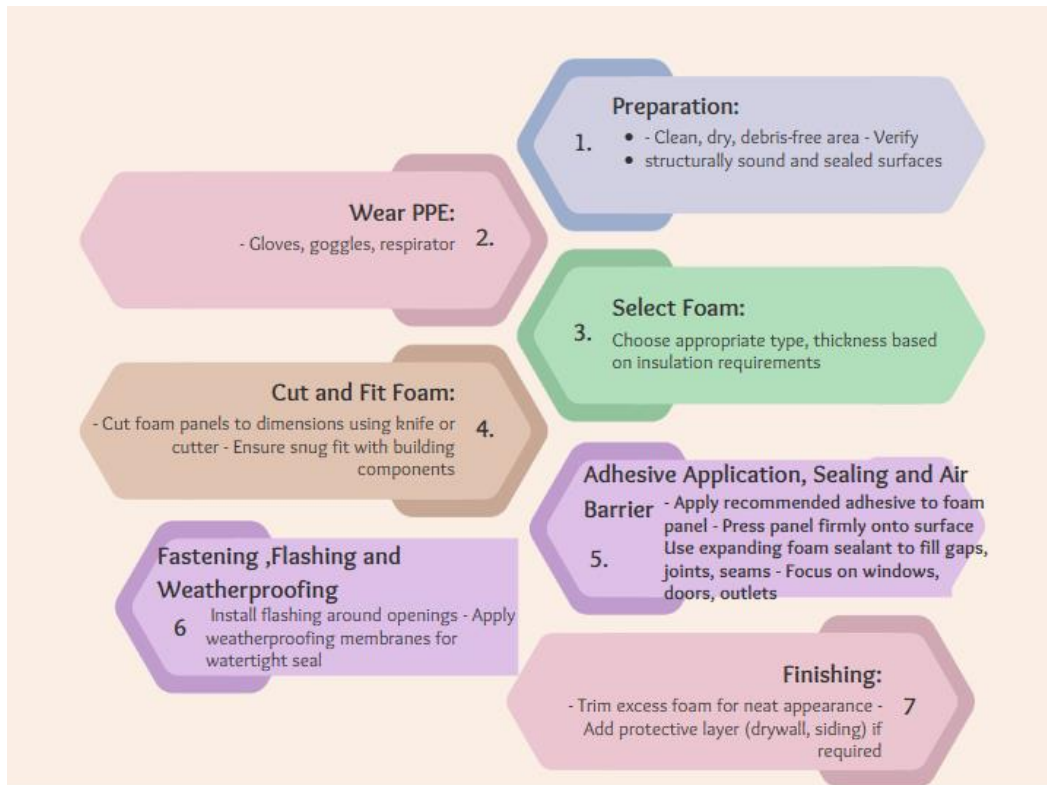
Polyurethane insulating products are also structurally self-supporting and can be linked to a wide range of layers while requiring no extra adhesive (Shi & Liu, 2019). Polyurethane performs like external weather and moisture barriers when it is mixed with the right materials (Gaidukova et al., 2017)

2. Research methodology:

The research methodology for the paper involved an extensive literature review to comprehend global advancements in green building design and the use of plant-based polyurethane rigid foam for insulation. To apply these findings in Bangladesh, conducted an analysis of the local construction industry, considering climate conditions, building practices, resources, and energy usage. Case studies of actual construction projects in Bangladesh using the foam were included, demonstrating its effectiveness in enhancing energy efficiency and sustainability within the country's unique context. This approach blended global insights with localized implementation, offering a comprehensive understanding of how plant-based polyurethane foam can contribute to sustainable construction practices in Bangladesh.

3. Installing Polyurethane Rigid Foam in a Building:

Installing polyurethane rigid foam in a building requires careful planning, proper preparation, and precise application to achieve effective insulation and energy efficiency. Here's a step-by-step guide on how to install polyurethane rigid foam in a building:



4. Overall condition on green building construction by plant-based of polyurethane foam

Rigid polyurethane foam insulation is a sophisticated and very efficient thermal insulation technology for structures. According to a survey, the US Department of Energy says that heating and cooling expenditures contribute to 50 to 70% of the average American house's total energy.

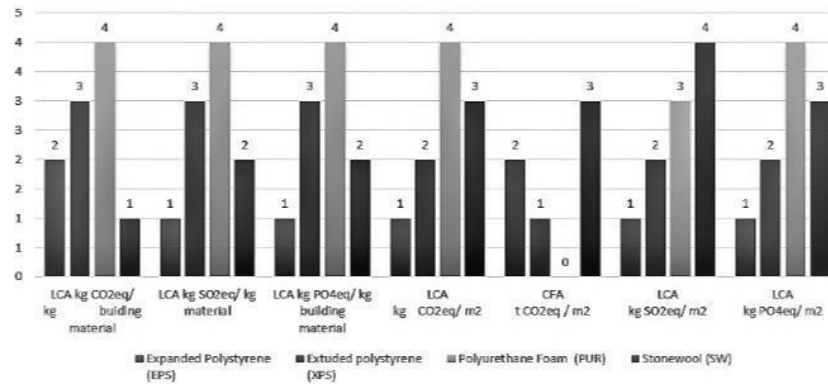


Figure 4: Environmental impact for construction and insulation materials(Giama & Papadopoulos, 2016)

According to the results of the **Life-Cycle Assessment (LCA)** study, the manufacturing operations, as well as the supply chain, contribute mainly to air emissions and, more specifically, Carbon dioxide. CO₂ is the most critical emission in terms of amount in all of the building items investigated. (graph)

The graph shows that polyurethane foam has a tremendous environmental impact comparatively among Expanded Polystyrene (EPS), stone wool (SW), Extruded polystyrene (XPS).

Polyurethane foam is a common material for building insulation. building insulation materials, and the pros and cons of other insulation methods show that it is one of the most fruitful ways to detain heat within a structure. The cradle-to-gate environmental results obtained, mainly relying on insulating materials, revealed that polyurethane foam and stone wool contribute less to the ecological effect categories evaluated than extruded polystyrene and polyurethane foam.

Rigid polyurethane foams, as well as polyiso materials, provide a distinct set of characteristics, as explained below.

6. Advantages:

6.1. High performance with a lower cost:

Saving on transport should be considered since it could be a less overwhelming and bulky fabric than other protected materials. Stiff polyurethane and polyiso foams have a very robust yet lightweight, low-density framework, as well as an easy and rapid spraying application that is highly durable and moisture-resistant content with low vapor transfer. The material can mold into unique forms in quite large quantities and adapts excellently to slant, and rough surfaces enter even the smallest spaces, preventing heat dams from forming.

Because of their low weight and excellent insulating value, these materials are suitable for upgrading the exteriors of older structures, as the current building covering can generally be kept in place, and the current infrastructure would not need to be strengthened (*Rigid Polyurethane Foam - PT Uretanindo Pasifik Intersarana, n.d.*)

6.2. energy conservations:

Polyurethane and polyiso strong foams offer some of the topped lists in the industry. With average R-values ranging from R 5.5 – R 8 per inch. Thinner walls and lower profile roofs are achievable while optimizing efficiency, boosting space usage, and lowering operating costs.

Entry doors with a firm polyurethane foam core assist in decreasing noise and provide insulating value, lowering heating and cooling energy requirements even more. Both heating and cooling systems can be reduced in some situations, enhancing space usage. (*Rigid Polyurethane Foam - PT Uretanindo Pasifik Intersarana*, n.d.)

This benefit of polyurethane foam adds to considerable cost savings in electricity as well as in fuel costs.

6.3. Recyclability:

It is impossible that the polyurethane-based cover will be supplanted all through the valuable life of the building, which helps to diminish vitality utilization and surplus assets. Data from the Life Cycle Inventory (LCI) for used materials shows that to the Polyurethane Foam Association, the recycling component of polyurethane foam is 10%. According to the institute of civil engineers (ICE), standard demolition recovery indexes (DRI) in the demolition protocol recycled deconstructed steel reinforcement and brickwork are deemed 75 percent. Recyclable materials include just 1 percent of decomposed Rockwool and 30 percent of polyurethane foam. (Giama & Papadopoulos, 2016)

6.4. Human satisfaction & health:

This permits heat to be retained in the winter and prevents sunlight from entering in the summer, creating a cooling climate within the house. Entrance doors and garage doors with firm polyurethane foam cores are available in coatings and styles to fit the client's tastes. Gypsum, plywood, and organic wood products can be used as facade materials. In addition to improving the quality of the product, these regulated insulated panels speed up building construction and minimize the quantity of wood required for structural framing. people with allergies and pets, foam insulation is completely safe (*Insulation of a Wooden Ceiling - Can PUR Foam Insulation Be Used in Winter?*, n.d.)

7. Polyurethane Foam in Bangladesh's Sustainability:

Plant-based polyurethane rigid foam is suited for green building construction in Bangladesh. It saves energy by keeping stable interior temperatures. Renewable resources and little environmental impact make it sustainable. Stabilizing interior temperatures and regulating moisture, the foam promotes comfort. Building envelopes may use it because of its adaptability. Local circumstances and professional assistance are crucial for effective implementation. Builders and architects are realizing the energy efficiency and ecological advantages of adopting this material. Polyurethane foam insulation may assist keep the building's temperature stable, decreasing the demand for heating and cooling. It saves energy and makes people more comfortable. Energy efficiency and comfort in buildings are challenged by the country's high temperatures and humidity. However, plant-based polyurethane foam insulation is ideal for the area.

Energy Efficiency: Polyurethane foam insulation keeps buildings at a constant temperature. In Bangladesh's hot environment, this insulation may greatly minimize the need for excessive heating or cooling, saving energy and money.

Sustainability: Polyurethane foam uses plant-based components to decrease fossil fuel consumption. The environmental effect of standard polyurethane foam manufacturing may be reduced by using renewable resources like plant oils or agricultural waste. This fits with the nation's growing emphasis on sustainability and carbon reduction.

Comfort: Polyurethane foam's insulation improves comfort. eliminating heat leakage via walls and roofs helps maintain a more consistent interior temperature, eliminating HVAC system adjustments. It may improve living and working conditions.

Moisture Management: Bangladesh has high humidity, hence building construction need moisture management. Moisture accumulation in walls and roofs may be prevented by polyurethane foam insulation's moisture resistance. Mould and mildew development, indoor air quality, and building integrity are all protected by this function.

Versatility: Plant-based polyurethane foam may be used for wall, roof, and floor insulation. Its adaptability enables builders and architects to incorporate it into diverse elements of a building's shell, improving energy efficiency and sustainability. (*Rigid Polyurethane Foam - PT Uretanindo Pasifik Intersarana*, n.d.)

Plant-based polyurethane rigid foam provides several advantages for green building construction in Bangladesh, however local availability, cost, and compatibility must be considered. Thorough study, local circumstances evaluation, and expert consultation may assist assure this material's applicability and effective implementation in Bangladesh.

8. Conclusion:

To sum up, the utilization of plant-based polyurethane rigid foam is an eco-friendly and energy-conserving substance that is transforming the field of sustainable building construction. Due to its outstanding insulating properties, lightweight structure, and versatility, this material presents several benefits, including cost-effectiveness, energy efficiency, recyclability, and enhanced human comfort. Notwithstanding, it is imperative to tackle the challenges associated with manufacturing impact, disposal, and availability. The utilization of foam in Bangladesh presents a potential solution to the issues of energy efficiency and comfort. In general, the extensive implementation of plant-based polyurethane foam within the context of green building construction has the potential to result in a built environment that is more ecologically sound and sustainable. The successful implementation of the project necessitates strategic research, collaboration, and policy development.

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