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IMPROVING INSULATION IN SRI LANKAN HIGH-RISE BUILDINGS: DEFECTS, CAUSES, AND SELECTION CRITERIA

M.P.G.I. Priyanjith[1], H.W.N. Madhusanka[2] and K.A.D.M. Natasha[3]

ABSTRACT

Insulation plays a crucial role in achieving energy efficiency, thermal comfort, and sustainability in high-rise buildings. However, when there are problems with the insulation such as water leakage, crack formation, and thermal bridging the building performance is affected. The paper analyses the most prevalent defects in insulation together with their causes and principal factors considered in selecting to enhance insulation performance within high-rise buildings. A qualitative research approach has been adopted by carrying out case studies on 15 high-rise buildings located within Sri Lanka and through 40 respondents survey including semi-structured interviews with five professionals from the industry. The study reveals that water damage and pest infestations are common defects at 86.7%and 80%, respectively. The foremost factor is linked to inadequate climate considerations, coupled with insufficient standards of workmanship as well as material selection. Besides these issues, maintenance has been inadequate; neither have regulations governing insulation been adequate. Experts' views indicate that the three most important factors in selecting suitable insulating systems are building profile, technology, and material properties, which can be avoided by effective design strategies, quality of materials selected, and regular maintenance. This will contribute to the field since there is a need for some structured selection criteria using BWM to improve insulation longevity; costs of maintenance would also be reduced, while performance as a whole could be enhanced. Further research is recommended on new technologies concerning insulating systems along with regulatory criteria aimed at maximizing efficiency for insulations utilized in high-rise constructions.

Keywords: *Causes; Defects; Factors; High-Rise Buildings; Insulation.*

1. INTRODUCTION

In the high-rise building sector, maximizing energy efficiency depends on the reduction of heating and cooling, which helps to minimize operational costs (Martin et al., 2012), as well as emissions and other associated environmental impacts (Bond et al., 2013). High-rise buildings have been rapidly increasing worldwide due to insufficient land availability in populated areas and their primary role as essential buildings in modern cities and capitals (Shakir et al., 2021). Identifying and rectifying structural defects is

[1] Undergraduate, Department of Building Economics, University of Moratuwa, Sri Lanka, isurupriyanjith47@gmail.com
[2] Senior Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, nandunm@uom.lk
[3] Junior Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, miyukin@uom.lk

essential to extend building lifetime and improve their overall performance (Ahzahar et al., 2011). Kumar et al. (2020) explained that the building envelope insulation is crucial for an energy-efficient and comfortable indoor environment because the envelope accounts for 50–60% of total heat gain or loss in a building. Building insulation plays a vital role in maintaining indoor thermal conditions by reducing heat transfer between the building and the external surroundings (Al-Sallal, 2003). Overall, recognizing defects early can enable buildings to take preventive actions to improve insulation, ultimately leading to enhanced energy efficiency, lower energy costs, and more comfortable living space (Osorio, 2023).

Straube and Finch (2009) argued that moisture is one of the primary causes of insulation defects often resulting in mold growth, corrosion, and deterioration of building materials. It results in costly structural repairs, downtime for operations, interior finishes, and items being damaged or lost, among many other repercussions (Nguyen et al., 2018). While past studies have been focused on energy efficiency and insulation materials, there has been limited exploration of insulation defects, their causes, and selection criteria to prevent failures (Xing et al., 2021; Liu et al., 2017), researchers have not focused on how to select proper insulation considering their significant factors. In the Sri Lankan context, customers are dissatisfied due to the aspects of less stability and durability of the structure (Karunasena & Ranatunga, 2009). Therefore, the study investigates common insulation defects in high-rise buildings, exploring their causes and impacts, assessing the impact on maintenance requirements in high-rise buildings and developing an assessment methodology to rank the insulation selection criteria.

2. LITERATURE REVIEW

2.1 THE ROLE OF INSULATION IN HIGH-RISE BUILDING

Insulation plays an essential role in maintaining indoor thermal comfort and reducing energy consumption in high-rise buildings (Al-Sallal,2003). However, energy demand strongly depends on the effectiveness of the applied strategies which include the proper design of the building envelope and the choice of proper components within a building to minimize heat loss or gain (Al-Homoud, 2005). Further author stated that insulation is considered a simple yet highly effective energy-saving technique that can be applied across various sectors, including residential, commercial, and office buildings, to improve high-rise buildings' thermal efficiency, maintain structural stability, and guarantee occupant comfort, insulation has played a fundamental aspect of modern construction technique. According to Kumar et al. (2020). To ensure optimal thermal performance it is essential to consider various elements of a well-designed insulation system, including appropriate materials, installation methods, and regular maintenance strategies to its sustained effectiveness over time. Furthermore, utilizing thermal insulation brings other benefits, including fire protection, personal comfort, condensation control, and sound control (Aditya et al., 2017).

2.2 IMPORTANCE OF INSULATION

The structural system of each building is exposed to the influence of individual external effects (Pasek & Kesl, 2015). To mitigate these effects, low heat absorption pavement includes heat shielding, water retentive, thermal resistance, and permeable types that have been developed to reduce temperatures and lessen heat impact on nearby structures (Chen et al., 2018). Acoustic insulation is the capability of insulation material to dissipate sound energy due to resonance or thermal and friction loss (Schiavoni et al., 2016). In fact, to improve this importance, insulation materials should meet various requirements, including the lowest thermal conductivity, mechanical resistance, adaptability of the construction site, emission of fumes during a fire, robustness, resistance to freezing or thawing, water resistance, cost (Villasmil et al., 2019) and environmental impact (Liu et al., 2017). The optimum insulations are assessed through the life-cycle cost analysis (LCCA), a useful economic assessment tool to achieve sustainable objectives that lead to better long-term performance of the building with lower operating costs (Tam et al., 2017; Islam et al., 2014). Buildings with good insulation reduce discomfort from extreme temperatures and provide a comfortable living and working environment (Çomaklı, & Yuksel, 2004).

2.3 COMMON DEFECTS IN INSULATION SYSTEM

Straube and Finch (2009) argued that moisture is one of the primary causes of premature building enclosure deterioration. As indicated by Straube and Schumacher (2007), inconsistent indoor temperatures are one common sign that may suggest thermal bridging areas where heat transfer is insufficient insulation layers. Overall, recognizing these signs early can enable buildings to take preventive actions to improve insulation, ultimately leading to enhanced energy efficiency, lower energy costs, and more comfortable living space (Osorio, 2023). Table 1 below presents the common defects that occur in an insulation system.

Table 1:Common defects in an insulation system

Source	Indicator									
	Aging	Mold Growth	Bad Odour	Pest infestation	Cracks	Water Damaging	Loss of Flexibility	Moisture damage	Changes in Temperature	Peeling Paints
(Berardi & Nosrati, 2018)	✓	✓			✓	✓		✓		✓
(Al-Homoud, 2005)	✓	✓			✓	✓				
(Berge & Johansson, 2012)	✓					✓		✓	✓	
(Straube & Schumacher, 2007)		✓			✓	✓		✓	✓	
(Johnson, 2024)		✓		✓		✓		✓		
(Kumar et al., 2020)			✓					✓		
(Schiavoni et al., 2016)				✓		✓				
(Abu-Jdayil et al., 2019)							✓	✓	✓	
(Dong et al., 2023)								✓	✓	

Source	Indicator									
	Aging	Mold Growth	Bad Odour	Pest infestation	Cracks	Water Damaging	Loss of Flexibility	Moisture damage	Changes in Temperature	Peeling Paints
(Rezaeı, 2020)									✓	
(Karamanos et al., 2008)								✓	✓	

Accordingly, scholars have identified moisture, aging, and changing temperature as the main indicators of insulation issues. Water damage as infiltration is dependent on the tightness of the building construction, exterior shielding, temperature differences, wind velocity, and building height (Al-Homoud, 2005).

2.4 CAUSES FOR INSULATION ISSUES IN HIGH-RISE BUILDINGS

High-rise building integrity is further complicated by the possibility of structural damage and health risks such as mold growth resulting from neglecting thermal bridging and moisture control (Azim & Torii, 2024). This exposure defects the interior of the building and must be fully-prevented due to its adverse effect on human health (Stanaszek-Tomal, 2017). To avoid those issues, it is essential to use quality materials, hire qualified workers, implement a proper management system, and ensure adequate supervision throughout the construction process (Borku, 2020).

According to the findings of the literature review, it can be mentioned that poor material quality, moisture accumulation and poor installation practices are the most common causes of poor insulation.

Table 2: Causes for defects

No	Causes	Source
01	Poor material quality	[1], [2], [3], [4], [5], [6],
02	Inadequate climate & Environmental Exposure	[1], [9],
03	Workmanship and design errors	[6], [10], [5]
04	Moisture Accumulation	[2], [7], [10],
05	Biological Growth	[6], [7]
06	Lack of Standards for Biological Protection	[6]
07	Inadequate supervision	[8]
08	Thermal bridges	[6], [9]
09	The rate of permeability and water absorption	[7]
10	Biological Infiltration	[11]
11	Acidic Metabolic Byproducts	[11]
12	Poor installation practices	[6], [9], [10]
13	High Diffusion Resistance of Insulation	[6]

No	Causes	Source
14	Lack of maintenance	[11]
15	Improper Paint Selection	[11]

(Azim & Torii, 2024) [1], (ASHRAE, 2021) [2], (Schiavoni et al., 2016) [3], (Abu-Jdayil et al., 2019) [4], (Ruivo et al., 2016) [5], (Stanaszek-Tomal, 2017) [6], (Karamanos et al., 2008) [7], (Borku, 2020) [8], (U.S. Department of Energy, 2020) [9], (Tenwolde & Rose, 1996) [10], (Savva et al., 2018) [11]

2.5 FACTORS NEED TO BE CONSIDERED WHEN SELECTING BUILDING INSULATION

Table 03 below provides a summary of the research's findings with reference to the deciding criteria in the selection of insulation.

Table 3: Factors to be considered when selecting insulation.

No	Causes		Source
01	Purpose of application	Materials	[1], [2], [3], [4], [7], [11]
02	Easy application		
03	Material design & availability		
04	Durability		
05	Thermal conductivity		
06	Thickness & Density		
07	Resistant to UV		
08	Porosity and permeability		
09	Sustainability of Materials		
10	Mechanical effect	Technology	[10], [6], [7], [8], [12]
11	Special skills and equipment		
12	Testing requirements		
13	Building orientation and Location	Building Profile	[4], [6], [11], [15],
14	Structural elements of the building		
15	Operating Condition		
16	Occupancy		
17	Cost of materials	Cost	[3], [4], [5], [10], [8], [10], [18]
18	Transport cost		
19	Laying cost		
20	Labor cost		
21	Operating cost		
22	Temperature Fluctuation	Climate and Environmental condition	[4], [9], [14], [19]
23	Environment sustainability		
24	Chemical & Biological reaction		
25	Local Codes and Standards	Legal requirements	[14], [13], [16]
26	International Codes and Standards		

No	Causes		Source
27	Experience	Suitability of contractor	[17], [18]
28	Reputation		
29	Maintenance		
30	Cost, Time & Quality		
31	Availability of human resource		

(U.S. Department of Energy, 2020) [1], (North American Insulation Manufacturers Association, 1996) [2], (Aditya et al., 2017) [3], (Mahlia & Iqbal, 2010) [4], (Kumar et al., 2020) [5], , (Berardi & Nosrati, 2018) [6], (Villasmil et al., 2019) [7], (Abu-Jdayil et al., 2019) [8], (Azim & Torii, 2024) [9] ,(Tam et al., 2017) [10], Schiavoni et al., 2016) [11], (Wei et al., 2015) [12], (Windapo & Cattell, 2010) [13], (Dong et al., 2023) [14], (Albatayneh et al., 2018) [15], (Zagorodnyuk et al., 2017) [16], (Plebankiewicz, 2009) [17], (Sodangi, 2011) [18], (Pasek & Kesl, 2015) [19]

The building insulation contributes to a positive net energy balance through a larger amount of energy saved through the insulation application than the energy required to manufacture the insulation material itself (North American Insulation Manufacturers Association, 1996). Insulation of buildings is done by using a variety of building insulation materials accompanied by its thermal conductivity (Aditya et al., 2017). In addition to that Mahlia and Iqbal (2010) stated there are relevant factors to be considered during material selection, such as cost, durability, climate factor, availability, heat transfer mode, the ease level of installation, and building orientation. In the realm of sustainable construction, recent research has also emphasized the use of advanced technologies to optimize energy efficiency and reduce carbon emissions (Azim & Torii, 2024). Further author stated that future research should explore emerging insulation technologies and their impact on energy efficiency. Therefore, exploring new insulation technologies could advance energy efficiency in building practices. Mechanical strength is a crucial factor when selecting insulating materials (Abu-Jdayil et al., 2019).

Optimal building orientation is a very low-cost solution in architecture that can significantly reduce energy consumption in the building sector (Albatayneh et al., 2018). For energy conservation, selecting efficient structural elements is essential when renovating buildings (Brauers et al., 2012). The author indicated that the method for insulation of the building envelope is selected depending on the structure, building materials, and the purpose of the partition, as well as other objectives. Occupancy behaviours account for about 30% of the variance in overall heating consumption and 50% in cooling consumption (Dong et al., 2023). One of the most important factors to consider when selecting building insulation material is cost (Mahlia & Iqbal, 2010). The building insulation investment is linked to the reduction of thermal energy consumption necessary to heat a building; the costs are related to the purchase, transport, and laying. Labor costs for insulation depend on materials and finishes (Aldykiewicz et al., 2022).

The review of existing literature also pointed out that the environmental performance of building insulation materials depends on their climatic conditions (Kumar et al., 2020). The structural system of each building is exposed to the influence of individual external effects like temperature fluctuations. The structural system damage risk of representative building caused by cyclical temperature changes depends on the character of insulation on the building envelop and the probability of damage of construction insulated from the internal side caused by temperature changes increases with the increase of the stiffness of the construction (Pasek & Kesl, 2015). The legal obligations concerned with thermal insulation have become stricter, and the changes are made regularly (Abu-Jdayil et al., 2019). According to Abu-Jdayil et al. (2019),, the international standards related to the specifications of traditional thermal insulators will be referred to in the subsequent sections when valid. Applying the principles of the law to the creation of insulation solutions, build a system from its constituent elements (Zagorodnyuk et al., 2017). Contractor prequalification is a complex process that usually involves multiple decision-makers with different levels of experience (Alhumaidi, 2014). Choosing a qualified contractor increases the chances of successful completion of a project by achieving the client's goals of keeping the schedules of the cost, time and quality (Sodangi, 2011).

2.6 APPLICATION OF BEST WORST METHOD APPROACH (BWM)

The best criterion is compared to the other criteria, and all the other criteria are compared to the worst criterion, in the comparison oriented MCDM method known as BWM (Abadi et al., 2017). The BWM can be used to compare decision-making factors on insulation because it approaches a pairwise comparison-based method that offers a structured way to make the comparisons (Ahmadi et al., 2017). The benefit of this approach is that it lessens the degree of ambiguity or inconsistency in the outcomes, fewer violations, reduced pairwise comparisons, and its total deviation, flexibility, and simplicity make this method perform better than other MCDM methods (Rezaei, 2015).

3. RESEARCH METHODOLOGY

The methodology outlines the approach to carry out the intended study objectives. Initially, a literature review on the insulation in high-rise buildings and factors influencing the selection of proper insulation was carried out. Secondly, the case studies were carried out focusing on the insulation of high-rise buildings having a minimum of 20 stories. A total of fifteen high-rise buildings located in Western Province Sri Lanka were chosen, representing four different building types to capture a diverse range of insights. The selection included two office buildings, four hotel buildings, four commercial buildings, and five residential buildings. These buildings were intentionally chosen through purposive sampling to align with the study's objective. During the case study, semi-structured interviews were conducted with industry experts in building insulation. Purposive sampling is used to select interviewees who have expertise in and interest in the research subject being investigated (Etikan et al., 2016). Table 04 includes details about the experts who were selected.

Table 4:Details of respondents

Respondent	Profession	Designation	Experience
E1	Engineering	Civil Engineer	25 Years
E2	Engineering	Chief Maintenance Engineer	18 Years
E3	Engineering	Chief Engineering Manager	20 Years
E4	Manager	Maintenance Rectification Engineer	22 Years
E5	MEP Engineering	Assistant Director Engineer	17 Years

According to interviews and case studies most influencing sub-factors were identified under different categories. Five expert interviews were carried out with professionals who had direct involvement with the selected buildings. They were from four of the 15 buildings two from the same building and three from different ones. The interviews focused on gaining general insights into insulation challenges, importance, and selection criteria. In total, 40 respondents (including five experts) who are engineers and facility managers in the field were surveyed for the preference data collection of main factors to be considered in the selection of building insulation. Under the case study, different types of defects and their causes were explored through observation, documentation, and photographs. Manual content was used to analyze the collected data. In particular, the priority level of the elements influencing the decision to building insulation was ranked using the Best Worst Method (BWM).

4. RESULTS AND DISCUSSION

Information gathered through the expert interviews and case studies were analyzed using manual content analysis. Based on the expert opinions on the main selection factors, priority levels were developed. While some buildings were maintained in such a way that they optimally performed, those buildings presented significant defects such as moisture damage, water damage, cracking, and pest infestation. In many cases, insulation defects were due to ineffective or failure to prioritize maintenance practices leading to a lack of attention to insulation. Expert interviews revealed that maintenance is essential for insulation performance but many high-rise buildings often do not prioritize maintenance activities properly. All experts highlighted that "Insulation failures could be reduced through routine inspections and preventive maintenance".; However, E3 argued that "*there should be a proper insulation selection factor consideration for reducing defects from the initial stage*", a view supported by E4 and E5.

4.1 INSULATION DEFECTS AND CAUSES

Figure 1: Insulation defects

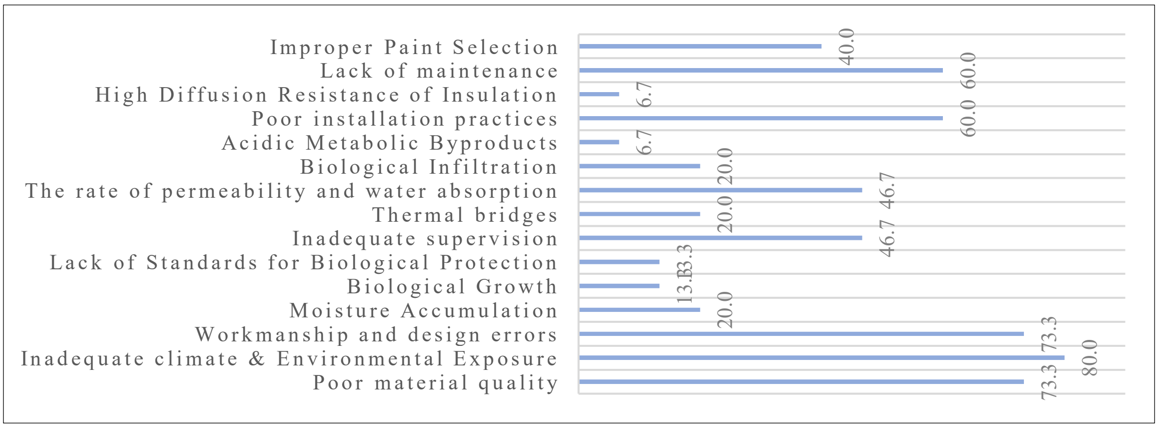

Figure 2: Causes of insulation defects; frequency percentage

Figure 01 shows that all buildings experienced a variety of insulation defects. By analysing the data collectively, the percentages shown in Figure 02 were calculated based on the total number of identified causes across all defect observations.

Table 5: Frequency of common defects in buildings

Frequency of common defects		
Defects	**Observations**	
	Percentage	**Number of Buildings Having**
Water damaging	86.7%	13
Pest infestation	80%	12
Cracks	80%	12
Moisture damage	73.3%	11
Peeling paints	66.7%	10
Aging	60%	9
Staining	53.3%	8
Changes in temperature	33.3%	5
Mold Growth	13.3%	2
Loss of flexibility	13.3%	2
Bad Odor	6.7%	1

Table 05, on the other hand, lists which specific defects occurred in each building, thereby supporting the data interpretation and ensuring transparency in the analysis. Water damage (86.7%) and infestation from pests (80%) stand as the main defects observed in these buildings. Additionally, insulation systems are showing structural or material weakness based on the high frequency of observed cracks (80%). Observational data reveals structural issues in insulation systems that reduce their performance capacity for insulation and building functionality.

According to experts' interviews, data demonstrates that weather conditions are the significant cause of insulation defects since all respondents identified it as a primary cause. Experts indicate that poor material quality is the next critical concern, with 4 out of five of responses, highlighting "*the importance of skilled installation practices and technical knowledge*". Further E03 demonstrated "*wrong material selection along with degradation of building insulation systems hence underscoring the need for durable and suitable materials*". E04 stated that "*inadequate design along with insufficient maintenance stands as major contributors to insulation problems*". This experts' statements prove top three causes shown in Figure 02 based on case studies.

The causes shown in Figure 02 have direct relationships with previously observed defects in Table 05 the combination of inadequate climate consideration (80%) and poor workmanship (73.3%) results in cracking and temperature changes because the design fails to environmental factors. Better design processes combined with suitable material selection and regular maintenance practices will help significantly reduce defects and improve building performance. The research findings confirm previous studies that link moisture accumulation, poor material quality, and improper installation problems to insulation failure (Straube & Finch, 2009; Nguyen et al., 2018). According to Osorio (2023), thermal bridging due to poor installation is a critical factor affecting insulation performance.

4.2 MAINTENANCE PRACTICES

The case studies revealed that while all buildings acknowledged the importance of insulation maintenance, it was often not prioritized. Most maintenance activities were reactive rather than preventive, typically addressed only when defects became severe or repairs were unavoidable. Instead of following a scheduled maintenance plan, practices were carried out on an ad-hoc basis, resulting in delayed responses to insulation issues.

Figure 3 illustrates the frequency of maintenance practices observed in the selected buildings. It shows that 93.3% conducted general inspections, and 73.3% involved skilled experts in evaluations. However, only 66.7% monitored temperature differentials, and just 26.7% checked for odour changes, reflecting the lower occurrence of odour-related defects. Overall, the findings emphasize the need for consistent and scheduled maintenance to prevent major insulation failures and to enhance building performance and occupant comfort.

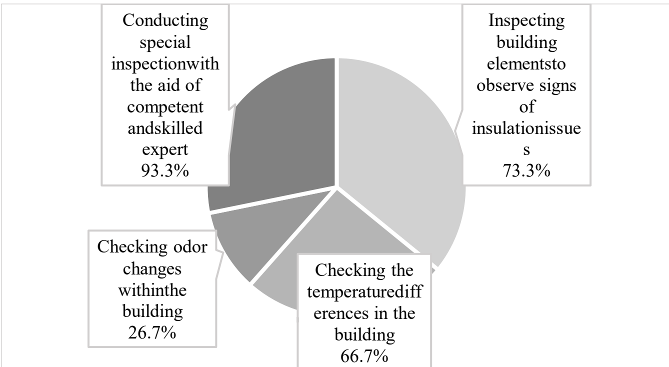

Figure 3: Maintenance practices percentage

4.3 INSULATION SELECTION CRITERIA

As the building is being constructed from scratch or renovated, selecting the right insulation system from the early design stage is the best approach to ensure long-term efficiency and performance. Clients select the cheapest available options, such as the cheapest materials, low-budget contractors, prioritising cost over other important factors. However, as agreed by all respondents, building profile, technology, and materials are the most considerable factors when selecting an insulation system. To mitigate the above defects, experts illustrated that insulation selection should prioritize building profile factors, such as structural design, and building orientation to match building specifications. Building insulation practice requires updating its installation technology and testing requirements in combination with fastening approaches to reduce thermal bridge defects. Choosing materials with the combination of moisture resistance, durability, and thermal efficiency to prevent early degradation and improve long-term performance.

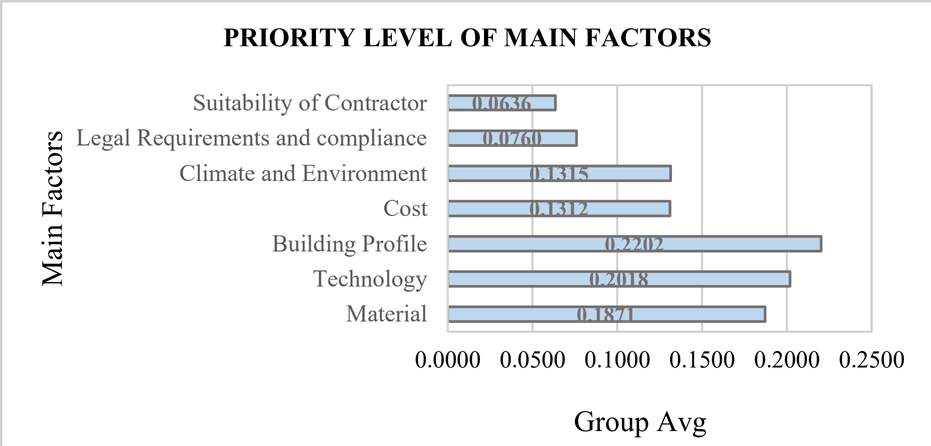

Figure 4: Priority level of insulation selection

According to the survey requirement, respondents were selected to provide their rankings by taking into account the primary insulation selection criteria. Consequently, the bar graph (Refer to Figure 04) represents the view of a preference survey regarding the criteria that should be considered sequentially while choosing insulation. Simply expressed, the graph illustrates that the experts and respondents applied the BWM to indicate the subfactors' relative importance within each set of factors, based on how they perceived it, and the corresponding weights and averages were generated in accordance with their perceptions. The global weights were determined using group average and the corresponding weights were generated in accordance with respondents' perceptions for each main factor. The BWM was applied by identifying the best and worst criteria, followed by pairwise comparisons using a scale of 1 to 9. Respondents entered their preferences into an Excel-based model, which automatically calculated the optimal weights through linear optimization. Final weights were averaged to determine the priority ranking of selection factors. The most important category for affecting the choice of insulation, according to Figure 04, was one associated with the building profile, whereas the category with the least influence was one related to the suitability of the contractor. While selecting the optimal insulation decisions, the final results provided a clear understanding of the most important decision factors. The findings of this study provide valuable insights into the insulation decision-making process in high-rise buildings in Sri Lanka, with particular emphasis on the prioritization of selection criteria using the Best-Worst Method (BWM).

4.4 DISCUSSION

These findings are aligned with previous studies, such as by Asadi et al. (2012), who emphasized the importance of energy performance in sustainable building design, and by Al-Homoud (2005), who highlighted the long-term benefits of thermal insulation on building performance. Moreover, the identification of key determinants and causes of insulation defects contributes to addressing performance gaps observed in local construction practices. The methodological approach used in this study, combining expert judgment with BWM, also proved effective in quantifying subjective decision criteria, offering a structured path for future decision-making in the construction sector (Rezaei, 2015). Additionally, the BWM's ability to reduce inconsistency in expert evaluations made it particularly suitable for this study, where decision factors span technical, environmental, and economic dimensions.

This study also highlights limitations and future research opportunities. One major limitation is the reliance on expert opinion, which, although valuable, may introduce subjectivity and may not capture the full range of stakeholder perspectives, such as developers or end-users. Furthermore, the study was geographically confined to Sri Lanka, limiting the generalizability of the findings to broader contexts. Future studies should explore comparative analyses across different regions or building typologies to validate the applicability of the identified criteria. Incorporating diverse views would also enrich the findings and better reflect real-world decision-making scenarios. Integrating life cycle cost analysis (LCCA) and environmental impact assessment could also enhance the robustness of the insulation selection process (Ding, 2008). Moreover, the study's findings could serve as a practical guideline for facilities managers, engineers, and policy makers in implementing more informed insulation strategies tailored to local building needs. Overall, the study provides a strong foundation for further research aimed at enhancing sustainable building performance and supports informed decision-making in high-rise construction.

5. CONCLUSION

This study is mainly concentrated on the impact of insulation defects on high-rise buildings' performance and energy efficiency. As the main technique, the researchers followed the three-phase process that included a study of 15 buildings, 40 respondents who answered the survey, and interviews with five industry experts. The study confirmed the fact that moisture damage, pest infestation, and cracking are the most frequent insulation problems. This information was provided by experts who stated that these problems primarily stem from poor material choice, unsuitable installation techniques, and not considering environmental factors. In order to determine the ranks, the initial phase of the BWM implementation incorporated both the most critical and the least significant factors. The research recognized that building profile, technology, and material properties are the most critical factors in selecting effective insulation systems. It has been reported that negligence in meeting these aspects would lead to higher maintenance costs and premature insulation failures. To further enhance the situation, the regulation of the industry and increasing awareness in the industry can help minimize insulation failures and enhance long-term building efficiency. The findings can serve as a benchmark for improving insulation standards and reducing operational inefficiencies that can guide industry practitioners in selecting and maintaining insulation systems more effectively, ultimately contributing to improved building performance, energy efficiency, and occupant comfort. In addition, this study offers recommendations for both industry and academia, such as integrating insulation into facilities management plans, considering climate-based selection criteria, and applying smart monitoring systems. While the study provides valuable insights, it is limited by its geographic scope, being focused solely on high-rise buildings in Sri Lanka's Western Province. This study suggests future research on IoT-based smart monitoring for insulation, integrating insulation into facilities management, considering building profiles in retrofits, climate impacts on insulation choices, and insulation maintainability. Further limitations included access restrictions to data from some organizations, some expert interviews being held online, and respondents' unfamiliarity with ranking certain insulation factors.

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