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Using Project Management Techniques to Identify Appropriate Solutions for Building Faulty in Thermal, Acoustic and Waterproofing Insulation

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Abstract

The study aims to identify the primary causes of failures in thermal, waterproofing, and acoustic insulations in buildings and to propose management techniques to inform technical solutions. Several analytical methods were employed to achieve this objective, including statistical sampling for data collection. The text also included analyses of insulation materials, affinity diagrams for action to classify and organize failure causes, and a multi-criteria decision analysis to select the most appropriate solutions. The leading causes of failures identified across the test cases were poor surface preparation of adhesion joints, inappropriate material selection, incorrect installation sequence, inadequate joint treatment, exposure of insulation materials to the external environment before finishing, and lack of coordination among insulation systems. Flaws in insulation give rise to thermal bridges, moisture infiltration, reduced thermal efficiency and damage. Engineering solutions were proposed to enhance insulation based on the research conclusion. Building with an integrated thermal envelope concept, selection of insulation material, storage installation, and execution quality control. The originality of this research lays in a framework that integrates project management techniques for decision-making with construction insulation analysis to improve reliability, reduce failure risk, and enhance the sustainability of building performance.

Keywords: Building faults, insulation material damage, statistical sampling method, multi-criteria decision analysis, decision-making.

1. Introduction

Insulating building systems is vital for energy efficiency, structural integrity, and occupant comfort [1]. Thermal insulation is required to limit heat transfer and energy consumption. Waterproofing is essentially done to protect the building's structural elements from moisture ingress and corrosion [2]. Indoor acoustic insulation improves the environmental quality by decreasing noise. Many studies have confirmed that insufficient insulation leads to increased energy consumption, deterioration of building materials, higher maintenance costs, and adverse health and comfort effects for building users. [3].

Previous studies have primarily examined the thermal performance of insulation [4], sustainable building materials [5], and the enhancement of energy efficiency with phase change materials [6]. Other studies have examined the performance of acoustic insulation and the problem of urban noise [7-8]. Most research examines physical properties and lab test performance of asphalt. By contrast, actual construction errors, execution defects, and insulation failures caused by management in practical projects receive little attention [9].

Moreover, earlier studies seldom use project management decision-making tools in insulation failure analysis. At present, a systematic framework does not link construction practice to error classification and solution prioritization [10].

To fill the gap, the current study employs a systematic project management approach to assess insulation failure in buildings. The study uses statistical sampling, alternative analysis, affinity diagrams, and multi-criteria decision analysis to develop a methodology for identifying cause(s) of failures, proposing solutions to each cause, and selecting the optimal remedial action. To enhance their technical understanding of the project and aid the decision-making process, the engineers and project managers [11].

Finally, the new framework (presented in this paper) integrates the disciplines of insulation materials and construction management to reduce insulation failures, thereby enhancing building performance and sustainable development in construction.

The remaining sections of the paper are presented in the following manner. This encompasses the research blueprint and project management tools that facilitate data collection, organization, analysis, and decision-making. The Results and Discussion section identifies the causes, which were thermal, waterproofing, and acoustic insulation failures, their practical solutions, and the order of implementation of these solutions. The Conclusions and Recommendations present significant findings and outline measures that engineers and project team members can take to reduce the incidence of insulation failure. In sum, the Suggestions for Further Studies propose additional ideas to enhance the framework and to support the development of insulation and visualization models.

2. Methodology

In this study, a suggested methodology can be represented in Figure 1. As shown in Figures (2 to 3), the researcher uses several methods to clarify and simplify the research objectives involving sampling isolation materials used in building insulation, followed by analyses using available methods to determine the cause of building insulation failure. Figures (4 to 6) represents decision-making and data presentation techniques.

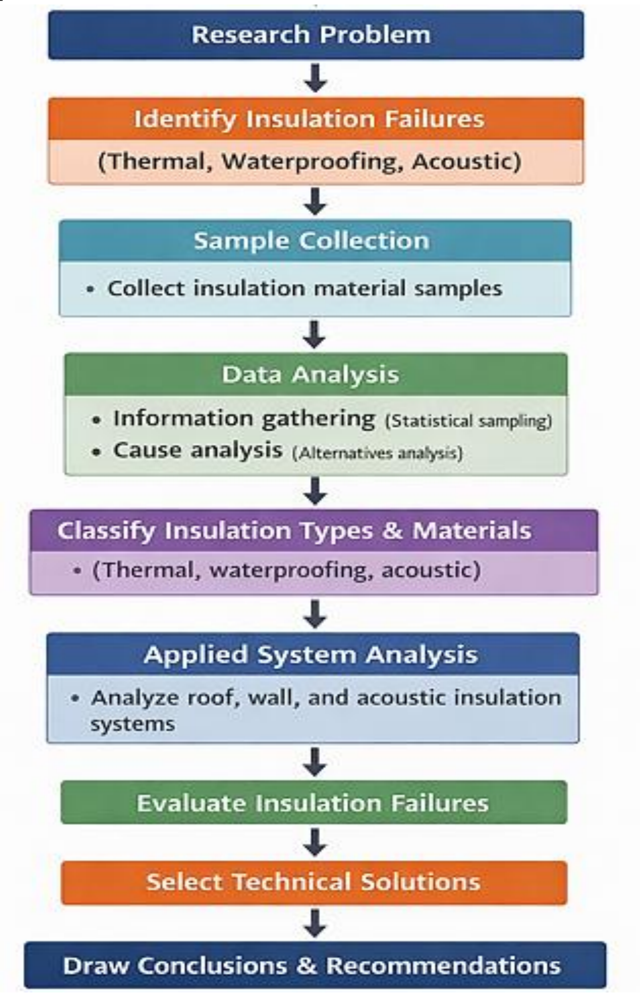

Figure 1: Methodology Flowchart

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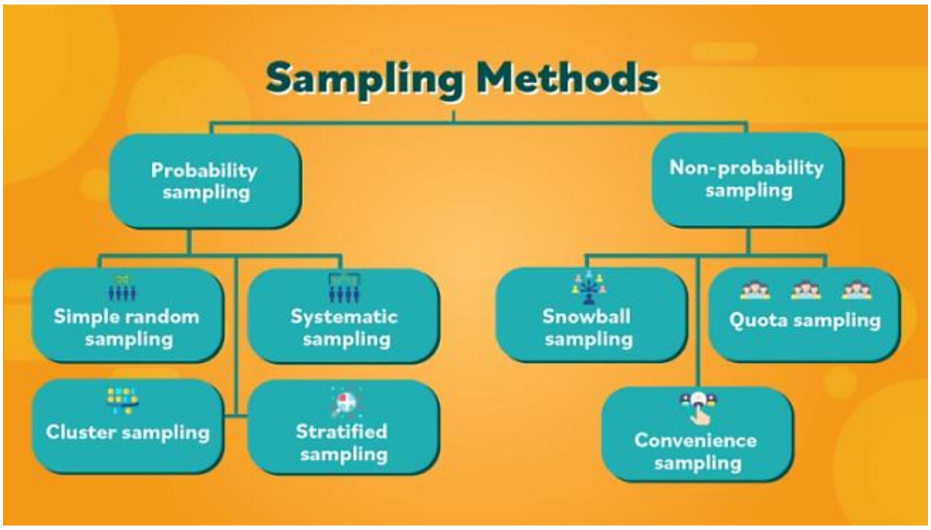

Figure 2: Statistical sampling and Information gathering techniques

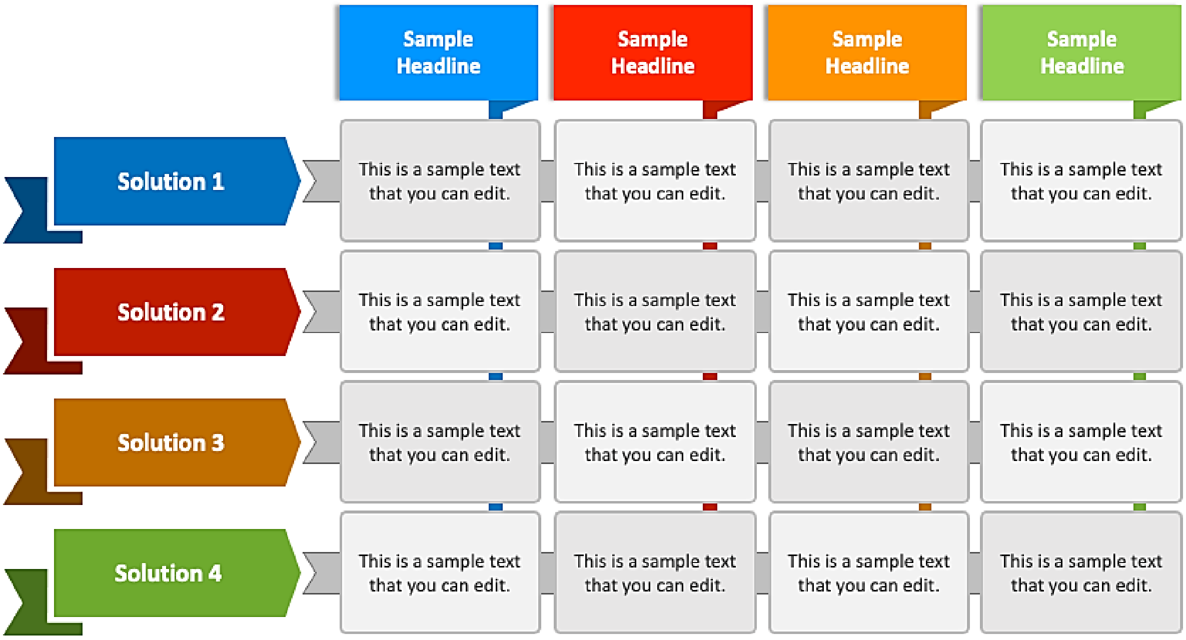

Figure 3: Analysis of alternatives (data analysis techniques)

Figure 4: Multi-criteria decision analysis framework

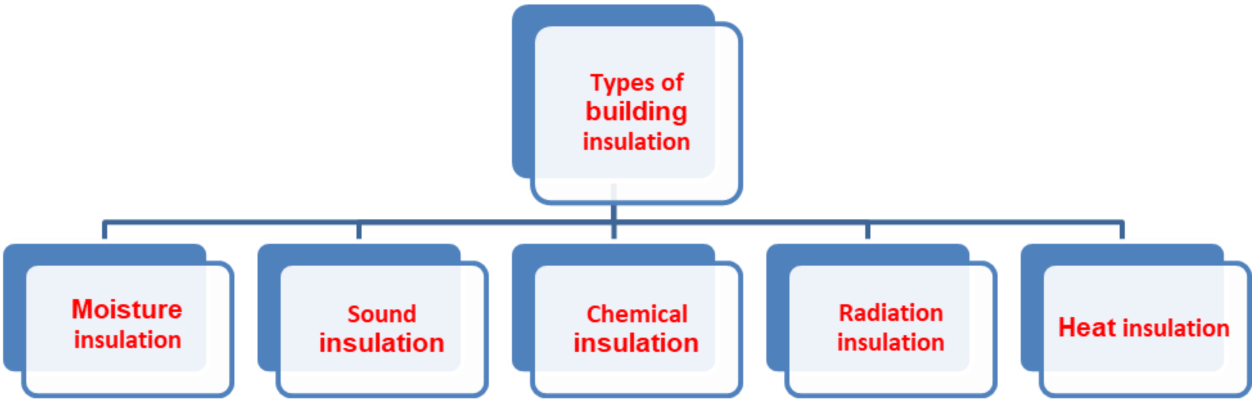

Figure 5: Types of insulation in buildings

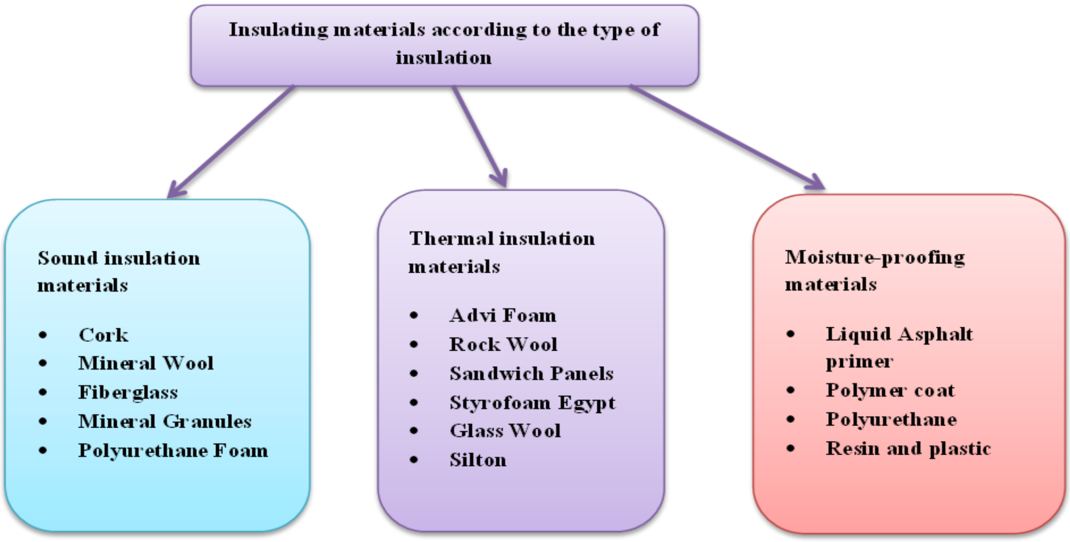

Figure 6: Types of insulation materials

3. Description of Applied Insulation and Waterproofing Systems

a) Figure 7 illustrates the typical layered system used for roof waterproofing and thermal insulation. The system consists of a gravel- or cement-tile finishing layer, a filter layer, extruded polystyrene thermal insulation with a density of 35 kg/m³, an optional filter layer, a waterproofing membrane, a foam concrete slope layer, and a reinforced concrete roof slab, arranged sequentially.

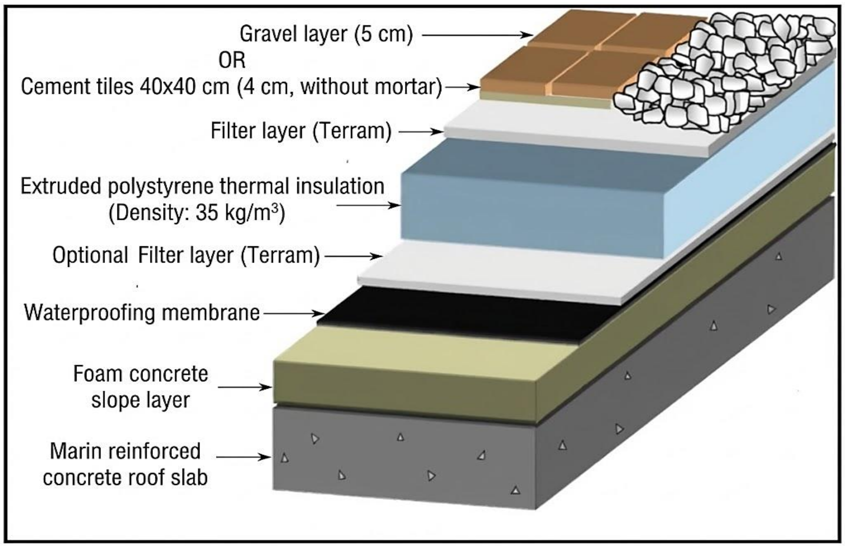

Figure 7: Roof Waterproofing and Thermal Insulation System

b) To ensure continuity of waterproofing at structural penetrations, the waterproofing membrane is extended vertically along the column and connected with the horizontal roof membrane. After complete curing of the concrete, the same waterproofing system, thermal insulation, and finishing tiles used on the roof are applied to maintain complete sealing and thermal continuity as shown in Figure 8.

c) Figure 9 presents wall insulation that can be performed by using the liquid foam injection technique. Holes approximately 25 mm in diameter were drilled in the outer masonry block wall. Once all three blocks were put together, fluid foam insulation was injected into the cavity using an injection gun. Once injected, the material expanded and subsequently hardened within the cavity, resulting in a layer of thermal insulation. The wall system consists of an outer block, an inner block, and an air cavity, if any, connected through metal ties. It can insulate walls without impacting structural work.

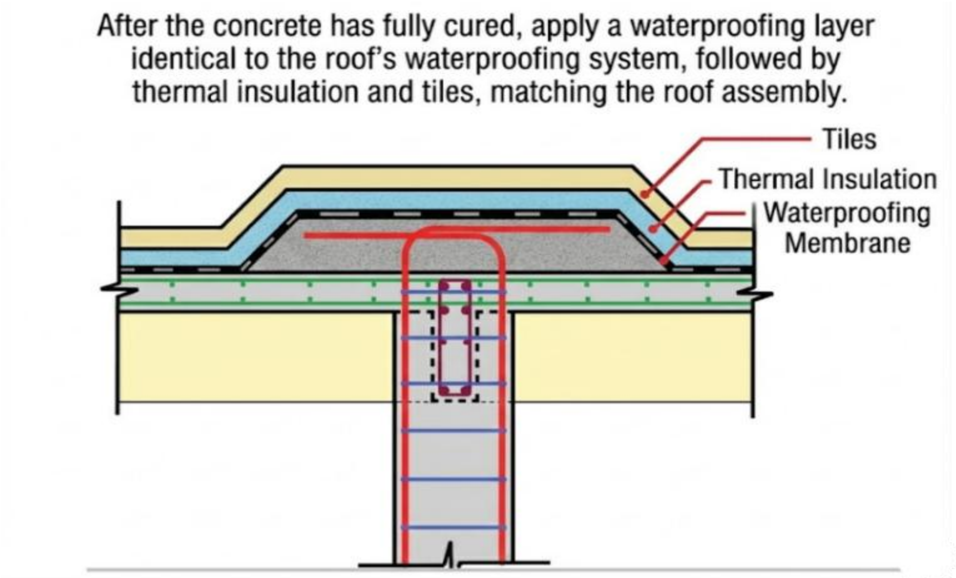

Figure 8: Detail of waterproofing and thermal insulation continuity at column penetration through the roof slab

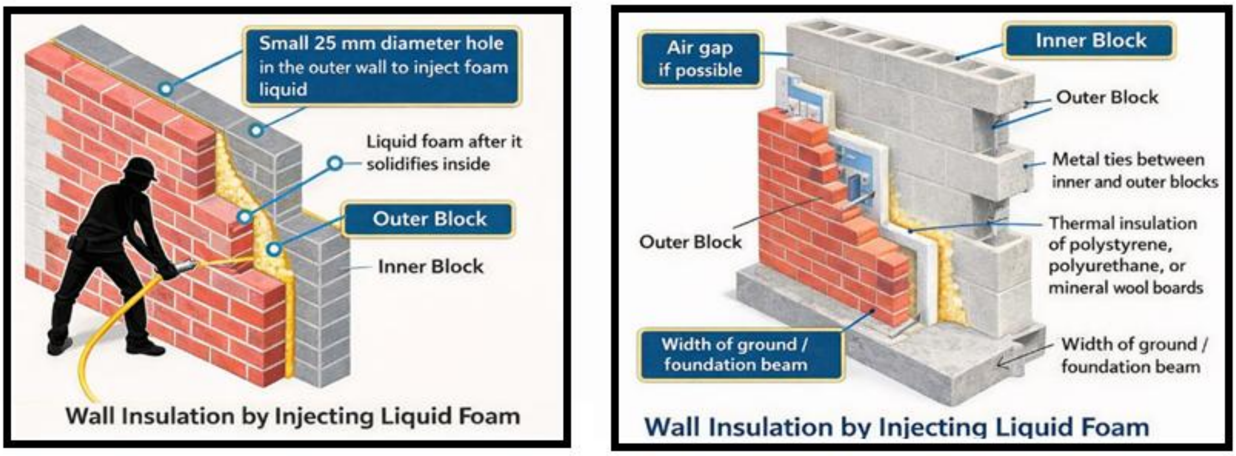

Figure 9: Wall insulation using liquid foam injection between masonry blocks

d) Figure 10 shows multilayer sound insulation system applied to interior walls. The system consists of an original wall followed by a Sono acoustic insulation sheet, two layers of rock wool, an air gap, gypsum board panels, a sound-absorbing foam panel, and an external black fabric covering. These layers are arranged sequentially to enhance sound absorption, reduce noise transmission, and improve acoustic comfort within enclosed spaces.

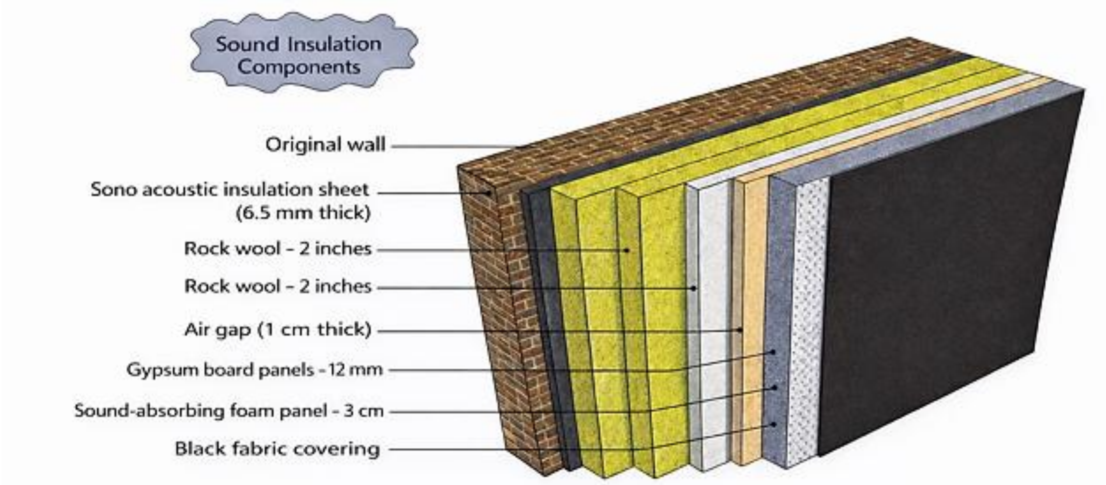

Figure 10: Multilayer sound insulation components used in wall acoustic treatment

4. Results and Discussion

This section discusses the most critical errors and reasons for failure of various types of building insulation, describe their consequences, and identify the most suitable solutions. The data presented in Table 1 demonstrate that insulation failures in buildings are primarily caused by execution errors rather than by material defects alone. Poor surface preparation, failure to follow the correct installation sequence, mishandling of joint treatment, and the use of inappropriate materials for the prevailing weather conditions are the primary causes of failures. When walls, roofs, foundations, slabs, and ceilings are properly insulated, moisture intrusion is prevented, and interior elevations are protected.

Table 1: Reasons for insulation failure of all types and the best possible solutions

Problem	Description	Result	Best Solution
The presence of voids and gaps in a heterogeneous structure	Leaving gaps between panels and improper installation	The formation of thermal bridges causes heat leakage.	Precisely cut the panels and fill the gaps with heat-sealing tape or insulating foam.
Installing panels directly on unclean surfaces	Surface contains dust, oils, and moisture.	Weak adhesion, with panels detaching or effectiveness decreasing over time.	Thoroughly clean and dry the surface. Use a dedicated primer if necessary before installation.
Failure to use appropriate fixing materials	Using an adhesive not intended for insulation or inadequate mechanical fixing.	Adhesive wear or subsequent panel separation	Use heat-approved adhesives suitable for the type of polystyrene board, combining mechanical fastening with special plastic screws and glue.
Do not tightly cover corners and openings	Leaving corners of walls or around windows and doors without adequate insulation.	High heat leakage at critical points	Design and precisely fit custom-made corner and opening pieces. Use flexible or foam materials to seal narrow openings.
Lack of sequence of outer insulation layers	Install the finishing layers only after ensuring that the insulation is stable.	The insulation has been damaged by moisture or has lost its effectiveness.	Adherence to the layer sequence: (Clean surface) → (Adhesive) → (Insulation board) → (Mechanical fixing) → (Fiberglass mesh) → (Finishing layer).
Using panels unsuitable for the site or climate	Use of white polystyrene panels in high-temperature areas	The material deteriorated due to prolonged exposure to sunlight or high temperatures.	Choosing the type of board according to local temperature and humidity EPS is used for interior walls and temperate climates. For roofs and hot or humid areas, XPS or PUR are used; for fire resistance or sound insulation, rock wool is used.
Install the panels horizontally instead of vertically.	Install the panels horizontally in the exterior walls instead of vertically.	Weak adhesion between the panels and easy entry of water through the horizontal joints	The panels are fixed in a staggered vertical pattern using an interlocking brick system to prevent the formation of water and heat leakage lines.
Failure to secure panel junctions (improper interlocking)	Leave the panels to meet at the corners without an overlapping pattern.	Cracks in the exterior finish or air and moisture leaks	The panels are installed with staggered overlap at the corner to strengthen the mechanical connection.

Table 1: Reasons for insulation failure of all types and the best possible solutions (continued)

Problem	Description	Result	Best Solution
Avoid using a glass panel mesh over the insulation panels.	Direct transition to the finishing layer, such as gypsum and cement, without a support mesh	Surface cracks and rapid erosion of the outer layer	Install a fiberglass mesh over the panels and cover it with a leveling compound layer before final finishing.
Failure to protect the panels from sunlight before finishing	Leaving the panels exposed for an extended period during construction	The surface of the panels, particularly the polystyrene panels, deteriorated, and their physical properties changed.	Temporarily covering the panels with fabric or protective materials expedites implementation.
Failure to install insulation at window sills or over exposed concrete beams	Leaving horizontal parts without insulation, such as window sills and concrete beams.	Localized thermal bridges increase heat loss.	Insulate all exposed structural elements with specially shaped panels or panels explicitly cut for that purpose.
Improper storage of insulation panels before installation	Leaving the boards in the open, exposed to sun or rain, or stacking them in an unorganized manner.	Curvature of the panels or loss of their ferroscopic properties.	Store the boards in a dry, shaded place on a wooden base raised off the ground.
Relying solely on insulation in the exterior walls without paying attention to the overall structure	Focus on insulating walls only, without treating windows, doors, or roofs.	Complete loss of effectiveness of the thermal system	Applying the principle of an "integrated thermal envelope" that includes all parts of the building: walls, ceilings, floors, and openings.
Use one type of insulation for all parts of the building	Installing the same type of panels on roofs, walls, and floors without considering the differences	The performance is unbalanced; some parts are well isolated, while others are not.	Choosing a specific type of insulation board for each area: * For roofs and floors, use a moisture-resistant XPS board. * For walls, use dry EPS board. * For small spaces, use PU R board. * In residential units, use rock wool for wall insulation.
Neglecting to check the actual thickness of the panels	Installing panels with thicknesses that do not conform to engineering plans or energy codes	Poor performance and failure to adhere to standards	Thickness is measured using standard tools before installation, and specifications are verified for each batch.
Interference in insulation systems without clear separations	Installing multiple insulation systems, such as thermal, waterproofing, and acoustic insulation, without precise separation planning.	The ineffectiveness of any system due to interference between systems	Coordinating systems in minute execution details, such as separating waterproofing from sound insulation and thermal insulation using a flexible separating layer or vapor barrier

Table 1: Reasons for insulation failure of all types and the best possible solutions (continued)

Problem	Description	Result	Best Solution
Failure to smooth sharp corners in walls before installing panels	Installing insulation panels over protruding or sharp corners or cracks without modification	The panels crack and warp with temperature changes	Level and smooth the corners using cement paste or specialized corner beads before installation.
Merge old and new insulation layers without treating the gap.	Adding a new layer on top of an old, damaged, or loose layer	The layers subsequently collapsed, and the entire insulation system broke down.	Completely remove the old, deteriorated insulation through cleaning and sanding before adding new layers.
Ignore the expansion and contraction of the panels due to temperature changes.	When installing the panels, do not leave gaps between them.	Swelling and cracking in the insulation layers	Leave a small gap of 1-2mm between the panels, and cover them with air- and vapor-barrier materials.
Neglecting to implement fire-resistant insulation in specific areas	Installing flammable panels in areas near heat sources or ventilation openings	The fire and flames spread within the spaces.	Use rock wool or non-combustible materials.

Insulation panel gaps may lead to thermal bridging, which is a grave problem. According to the results presented in [12], there are also discontinuities in the insulation layer, which increase thermal conductance and energy losses. It was observed that minor interruptions also cause an economic loss greater than 30% of the total insulation efficiency [13]. The current research builds upon these findings and offers practical guidance on corrections, such as staggered installation schemes and the use of suitable joint sealants [14].

Another major cause of insulation damage was improper surface preparation. According to [15], dust, oil, and moisture were cited as reducing adhesive strength and shortening the service life of insulating materials. The present study involves construction sites, unlike the previous study, which examined adhesion tests in the lab. It offers instructions for applying the primer and preparing the surface [16].

Another critical issue was the use of insulation materials that were inappropriate for the climate. For example, the EPS will be degraded by high-temperature zones, damaging the other material. The materials' thermal stability is essential for their long-term [17]. Reference [18] provides clear instructions for selecting materials based on climatic conditions and the corresponding insulation types.

Failure to coordinate thermal, waterproofing, and acoustic insulation systems harms their performance [19]. Previous studies have focused on one at a time (e.g. [20-21]), thus giving little attention to this.

The current paper addresses a separation system with flexible barriers and integrated vapor-layer insulation.

Organizing causes of failure and logically selecting corrective actions can be supported by multi-criteria decision analysis and affinity diagrams, which are project management tools [22]. Based on the insulation study data, the analysis does not require a decision [23-24]. A deep analysis of the description is done. The implementation of a decision model has been hindered by technical construction difficulties [25].

Taken as a whole, earlier works attribute restrictions to causes. Nevertheless, the present study's findings suggest that poor performance management causes insulation failure. Project management tools will improve the insulation research method. This provides engineers and project managers with a way to reduce risk and enhance long-term performance.

5. Conclusions and Recommendations

Building insulation is carried out in accordance with strict methods, material specifications, sequential execution, and quality control from the base to the apex. Ensure that you repair cracks in the cleaning layer correctly. We might need to add more sealant to it. This helps achieve proper filling and sealing. When there are neighboring foundations, the insulation of the concrete slab should be connected to the adjacent wall to prevent moisture and heat transfer. Insulation must protrude 10 cm on all four sides of the foundation when a uniform cleaning layer is applied throughout the building. Isolated footings and column necks must be insulated using bitumen, and all surfaces must be level, smooth, solid, and free from defects before insulation. Structural nesting defects must be corrected in advance, and insulation materials must be applied directly to concrete surfaces rather than to intermediate layers, such as bags or temporary supports. Areas left without insulation, known as "thieves' zones," must be identified and thoroughly treated.

Foundations must be insulated from all directions including top, bottom, and edges, and all wires, screws, and metal parts must be removed prior to insulation. Foundation areas in contact with soil should be insulated with bitumen, and insulation materials must be allowed to dry completely before backfilling. Column necks must be insulated from all sides and from top to bottom, and footings and column necks must be insulated before installing the structural chair. Liquid bitumen must be checked for purity and not contain either water or kerosene. Before installation, all openings for drainage and water supply must be sealed. Any additional tie-rod holes shall be grouted, and grinders shall be used to level concrete surfaces and remove honeycombing. The concrete surfaces must subsequently be washed and water-sprayed to remove dust and improve primer adhesion. When insulating walls, PVC insulation must be applied in multiple passes to ensure 100% coverage and adhesion. We must not leave any gaps. Insulation rolls must be fully bonded, with no air bubbles. Adjacent rolls must be connected using thermal welding. Follow an overlap distance of 5 – 10 cm. Upon completion of PVC insulation, protective panels should be installed to prevent mechanical damage. Tanks must be emptied and dried out before applying cementitious insulation. The walls and floors must be fitted at an angle rather than at right angles to prevent the bitumen rolls from breaking. The insulation materials must have the adhesive strips removed before installation. They must be installed vertically and should not be stored horizontally on the floor, as this will deform them. Insulation by bitumen rolls is mandatory for water tanks and swimming pools. Before insulation and finish work, all roof surfaces must be free of dust. The concrete mix guidelines must be followed to ensure a roof slope of 1 cm per meter toward drainage points. The openings of the drain should have the same diameter as the drain's diameter. Moreover, the drain base must be fastened securely. According to the document, the slope development in concrete strings must be guided with a height of 5-7 cm at the drain bases and 15-20 cm at the endpoints. Foamed concrete requires placement at the screed level to ensure proper drainage slopes are achieved. Cement, sand, water, and foaming agents that increase volume and decrease weight are used to produce this lightweight concrete. The mixture needs to be pumped and mechanically blended until it reaches the drain base level. Surface cleaning, drying, and coating with hot bitumen are to be done after curing. Two layers of bitumen rolls shall then be applied at right angles to each other with a 10 cm overlap. Ensure that the pipe gaps and filter edges are well sealed with molten bitumen and well-welded. All drainage openings must be fully sealed, and the roof flooded with water for 24-hour testing. The insulation system will be confirmed successful in the absence of moisture. As a whole, they demonstrate that the performance of insulation depends both on materials and discipline of execution, including sequencing, environmental control, and verification of quality, and that the integrated approach appreciates the durability, energy efficiency, and long-term protection of structures.

According to the researcher, further studies are recommended to improve the current research and extend the scope of the general insulation system. For example, the steps for cementation insulation of water tanks and swimming pools, advantages and disadvantages, determine the quantities to be used for the mix of cementation insulation, and illustrative diagrams for roofs and floors insulation, hollow and interior walls insulation, renovation of old roofs insulation, truss and metal structures insulation, refrigerators and doors, and pre-insulated walls insulation. Additionally, differences between solid and liquid insulating materials, between hot and cold insulation, and between insulated and uninsulated buildings during the off-season can be studied using new scientific methods.

Numerous studies and proposals for insulation systems of various types are underway, along with models for insulating different structural elements and their representation in AutoCAD, 3D Max, and Photoshop. Readers, researchers, students, and users will benefit from these drawings of the insulation layers.

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