



Research Article

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Structural Assessment for Improving Energy Efficiency in Public Buildings

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Abstract

This paper explores the pivotal role of structural assessment in enhancing energy efficiency within public buildings. Structural assessment, a systematic evaluation of building components and systems, is essential for ensuring safety, longevity, and sustainability. By identifying weaknesses and improvement opportunities, structural assessment provides valuable insights for stakeholders to enhance operational efficiency and compliance with safety standards.

The symbiotic relationship between structural integrity and energy efficiency underscores the significance of prioritizing structural considerations in sustainable building design. Material selection, design principles, and maintenance practices are crucial factors influencing energy performance. Structural assessments aid in pinpointing critical issues contributing to energy loss, such as air leaks, thermal bridging, and inadequate insulation. Recommendations derived from these assessments enable targeted interventions to improve energy performance and occupant comfort.

Case studies of three schools highlight the tangible benefits of energy efficiency retrofits informed by structural assessments. These retrofits result in significant reductions in energy consumption, enhanced indoor comfort, and a diminished carbon footprint. A structured strategy for conducting seismic structural assessments and subsequent energy efficiency improvements is proposed, emphasizing the importance of a comprehensive approach to building sustainability.

In conclusion, structural assessment serves as a linchpin for advancing energy efficiency in public buildings. By leveraging insights from structural assessments, stakeholders can drive transformative change towards a greener and more sustainable future, fostering environments that promote human well-being and environmental stewardship.

Keywords: Structural Assessment, Energy Efficiency, Public Buildings.

1. Introduction

Structural assessment stands at the nexus of ensuring the safety, longevity, and sustainability of built environments. In its essence, structural assessment entails a meticulous evaluation of building components and systems, aimed at identifying potential

weaknesses or defects that could compromise structural integrity or hinder operational efficiency. This systematic process is indispensable for stakeholders, including building owners, engineers, and regulatory authorities, providing valuable insights into a structure's condition and offering recommendations to ensure compliance with safety standards and enhance operational efficiency.

Structural integrity, a cornerstone of energy-efficient buildings, is intrinsically linked to the optimization of energy consumption and the effective operation of energy-efficient systems. A robust building envelope and foundation not only minimize energy loss but also facilitate the operation of energy-efficient technologies such as renewable energy systems and high-performance HVAC equipment. Recognizing the symbiotic relationship between structural integrity and energy efficiency underscores the significance of prioritizing structural considerations in sustainable building design and construction.

In this context, the importance of structural assessment becomes paramount. By scrutinizing various structural elements, assessing their condition, and identifying improvement opportunities, structural assessment lays the foundation for creating healthier, more sustainable built environments. This introduction sets the stage for exploring the goals, contributions, and future implications of structural assessment in the context of energy efficiency and sustainable building practices.

2. Grasping Structural Assessment

Structural assessment involves meticulously evaluating building components and systems to ensure safety, reliability, and longevity. This systematic process scrutinizes various structural elements to identify potential weaknesses or defects that could compromise structural integrity or performance. Stakeholders, including building owners, engineers, and regulatory authorities, rely on this analysis for valuable insights into a structure's condition and recommendations for ensuring compliance with safety standards, extending service life, and enhancing operational efficiency. Ultimately, the goal is to safeguard occupants, preserve property value, and uphold the sustainability of the built environment.

Structural integrity plays a crucial role in energy-efficient buildings by minimizing energy loss and supporting the operation of energy-efficient systems. A strong building envelope and foundation reduce air infiltration/exfiltration, thermal bridging, and heat transfer, enhancing insulation system effectiveness and reducing the need for heating and cooling. Additionally, a stable foundation supports the installation of energy-efficient technologies like renewable energy systems and high-performance HVAC equipment. This relationship emphasizes the importance of prioritizing structural considerations in sustainable building design and construction to optimize building performance and occupant comfort.

3. Goals of Structural Impact on Energy Efficiency

A. **Material Selection's Influence on Energy Performance:** Optimal material choices significantly enhance energy efficiency by regulating heat transfer and minimizing thermal bridging. Materials with high thermal resistance properties reduce the need

for excessive heating or cooling, while those with high solar reflectance and thermal emissivity help mitigate heat absorption. Additionally, selecting materials with lower embodied energy reduces environmental footprint, contributing to sustainable building practices.

B. **Design Principles for Energy-Efficient Structures:** Passive solar design and efficient space planning minimize reliance on active HVAC systems, reducing energy consumption and operational costs. Strategic orientation of buildings maximizes solar exposure during winter while minimizing direct sunlight penetration in summer. Sustainable material selection and construction techniques enhance thermal performance, contributing to energy savings and environmental stewardship.

C. **Maintenance Practices' Role in Sustaining Energy Efficiency:** Effective maintenance, including regular inspections, repairs, and upgrades, ensures optimal operation of building systems over time. Timely interventions address inefficiencies and prevent further deterioration, extending the lifespan of assets and minimizing operational disruptions. Ongoing monitoring and performance tracking enable informed decision-making to uphold operational efficiency, minimize energy waste, and advance sustainability goals.

4. Structural Assessment's Contribution to Energy Efficiency

4.1 Identifying Weaknesses and Improvement Opportunities

Structural assessments are integral to enhancing energy efficiency in buildings by conducting thorough evaluations that pinpoint weaknesses and opportunities for enhancement. Through meticulous examination and analysis, these assessments unveil critical issues contributing to energy loss, including air leaks, thermal bridging, and insufficient insulation.

A primary focus of structural assessments is identifying air leaks within the building envelope. Often imperceptible through visual inspection alone, these leaks allow conditioned air to escape and outdoor air to infiltrate interior spaces, leading to significant energy wastage. Employing techniques such as blower door tests and infrared thermography, structural assessments precisely locate areas of air leakage, facilitating targeted sealing measures to bolster energy efficiency.

Moreover, structural assessments excel at detecting thermal bridging, where heat bypasses insulation via structural elements like studs, beams, and concrete slabs. This phenomenon results in localized heat loss or gain, undermining the building envelope's overall thermal performance. Through meticulous analysis and modeling, structural assessments identify thermal bridging areas, enabling the implementation of remedial measures such as thermal breaks or additional insulation to mitigate energy loss and enhance thermal comfort.

Additionally, structural assessments evaluate insulation materials and installation practices to ensure compliance with prescribed standards and performance criteria. Inadequate insulation or improper installation can lead to thermal inefficiencies, escalating energy consumption and compromising comfort levels. By assessing insulation levels, distribution, and integrity, structural assessments inform recommendations for optimizing insulation performance and reducing heat transfer, thereby elevating energy efficiency.

In conclusion, structural assessments serve as indispensable tools for identifying energy loss and inefficiencies within buildings. By uncovering issues like air leaks, thermal bridging, and insufficient insulation, these assessments provide valuable insights that enable targeted interventions to improve energy performance, enhance occupant comfort, and advance sustainability goals.

4.2 Evaluating Building Component and System Performance

Structural assessments offer a thorough evaluation of building components and systems to gauge their condition, functionality, and role in supporting energy efficiency. This assessment extends beyond the structural integrity of the building to encompass critical energy-related components like HVAC systems, lighting, windows, and other key systems. Through rigorous analysis and testing, structural assessments provide insights into component performance, aiding decisions on maintenance, upgrades, and optimizations to improve energy efficiency.

Central to building comfort and energy performance, HVAC systems undergo comprehensive scrutiny during structural assessments. Parameters such as system capacity, efficiency ratings, air distribution effectiveness, and operational performance are evaluated. By measuring airflow, temperature differentials, and energy consumption, assessments determine HVAC system efficiency in maintaining indoor conditions while minimizing energy usage.

Lighting systems significantly impact energy consumption and occupant comfort. Assessments evaluate lighting efficiency, fixture types, controls, and daylighting strategies to identify energy-saving opportunities. Through audits and illuminance measurements, assessments recommend upgrades to energy-efficient lighting technologies and optimization of natural daylight usage to reduce energy consumption and enhance comfort.

Windows affect thermal performance and daylighting. Assessments examine window condition, insulation properties, and solar heat gain coefficients to assess their energy impact. Thermal imaging and U-value measurements identify opportunities for upgrades such as low-emissivity coatings or advanced framing techniques to minimize heat transfer and improve energy performance.

Structural assessments also cover insulation, air sealing, renewable energy systems, and automation controls. Evaluating their effectiveness in supporting energy efficiency goals, assessments identify areas for improvement. By considering holistic system performance, stakeholders can implement targeted interventions to enhance energy efficiency, reduce costs, and promote sustainability.

In summary, structural assessments comprehensively evaluate building components and systems to identify opportunities for improving energy efficiency. Leveraging insights from these assessments, stakeholders can make informed decisions to enhance energy performance, occupant comfort, and sustainability within buildings.

4.3 Recommendations for Enhancing Energy Efficiency

Structural assessments provide insights for targeted recommendations to upgrade building systems for improved energy performance. Prioritizing cost-effective measures, these recommendations include HVAC upgrades, lighting retrofits, envelope enhancements, and energy management strategies. By optimizing the building en-

velope, addressing thermal losses, and integrating renewable energy technologies, stakeholders achieve significant energy savings and promote sustainability.

5. Case Studies

Three schools in Albania, namely Schools X, Y, and Z, situated in suburban areas within the municipalities of Elbasan, Shkodra, and Lezha respectively, have been serving K-12 education since their construction around 1975 as reinforced concrete structures. Despite their age, these educational facilities house classrooms, administrative offices, and sports halls. Driven by concerns over escalating energy expenses and a dedication to sustainability, a project sponsored by the European Union was initiated to enhance energy efficiency while ensuring comfort for students and staff. The climate in these areas is similar, providing a consistent basis for assessment.

A thorough structural assessment identified critical areas necessitating energy efficiency improvements:

Structural Integrity: Visible small cracks, particularly noticeable in plaster layers and specified structural elements, especially those adjacent to staircases, indicate structural fatigue from past earthquakes, exceeding expected lifespans according to technical standards and seismic criteria.

Inefficient HVAC Systems: Outdated HVAC systems operate below optimal efficiency, resulting in uneven temperature distribution and increased energy consumption.

Inadequate Lighting: Existing fixtures fail to provide sufficient illumination levels, leading to discomfort and reduced productivity.

Poor Building Envelope: Insulation and air leakage issues within the building envelope exacerbate thermal inefficiencies, leading to heightened heating and cooling demands.

Aging Windows: Single-pane windows contribute to energy loss due to inadequate insulation and the absence of solar heat gain control.

6. Recommendations

Informed by the structural assessment, the following energy efficiency retrofit recommendations were proposed:

Structural Retrofitting: Obtain official certification to meet current technical standards.

HVAC System Upgrades: Install energy-efficient HVAC units with variable speed drives and programmable thermostats, along with implementing zoning controls and sealing ductwork to optimize system efficiency.

Lighting Retrofits: Replace outdated fixtures with energy-efficient LED lighting, supplemented by occupancy sensors and daylight harvesting controls to reduce energy consumption.

Building Envelope Improvements: Improve thermal performance by adding insulation to walls and roofs, sealing air leaks around windows and doors, and applying reflective roof coatings to minimize heat absorption.

Window Upgrades: Retrofit windows with double or triple-pane insulated glass, incorporate low-emissivity coatings, and upgrade window frames to enhance insula-

tion and durability.

6.1 *Implementation*

The energy efficiency retrofit project will be executed in phases to minimize disruption to school operations. Estimated structural retrofitting costs for each school, excluding energy efficiency measures, are approximately 181 euros per square meter. Specifically, School X's retrofitting cost is projected at 168 euros per square meter, School Y at 190 euros per square meter, and School Z at 185 euros per square meter.

7. **Results**

Upon completion of the energy efficiency retrofit project, significant improvements in energy performance and occupant comfort are anticipated:

Nearly 20% reduction in annual energy consumption, resulting in substantial cost savings.

Enhanced indoor comfort with consistent temperatures and improved lighting quality.

Reduction in the school's carbon footprint, aligning with environmental sustainability objectives.

The energy efficiency retrofit of Schools X, Y, and Z underscores the positive impact of strategic upgrades on building performance, occupant comfort, and sustainability. Through investments in energy-efficient technologies and building envelope enhancements, the schools aim to achieve substantial energy savings while fostering a healthier and safer learning environment for students and staff.

8. **Strategy for structural assessment**

Proposed plan:

Here's a structured plan for conducting a seismic structural assessment followed by energy efficiency improvements:

1. Initial Documentation Review

Gather all relevant documentation related to the building's construction, including architectural plans, structural drawings, seismic design codes applicable at the time of construction, and any previous seismic retrofitting or structural assessments.

Review historical seismic activity records for the region to understand potential seismic hazards and design considerations.

2. Seismic Vulnerability Assessment

Conduct a visual inspection of the building's structural elements, including columns, beams, slabs, and foundations, to identify any visible signs of damage, deterioration, or structural deficiencies.

Perform non-destructive testing (NDT) techniques such as ultrasonic testing, ground-penetrating radar (GPR), or rebound hammer tests to assess the condition of concrete and masonry elements.

Evaluate the seismic resistance of the building's structural system in accordance with the seismic design codes applicable at the time of construction.

3. Structural Analysis

Perform structural analysis to assess the building's response to seismic forces and identify potential vulnerabilities.

Evaluate the adequacy of structural members, connections, and overall system performance under seismic loading conditions.

Consider dynamic analysis techniques such as modal analysis, pushover analysis, or time-history analysis to assess the building's seismic response in more detail.

4. Seismic Retrofit Recommendations

Based on the findings of the seismic assessment, develop recommendations for seismic retrofit measures to strengthen the building's structural system and improve its seismic performance.

Prioritize retrofit measures based on their effectiveness, cost-benefit ratio, and feasibility of implementation.

Consider a range of retrofitting techniques such as strengthening existing structural elements, adding new lateral bracing systems, or enhancing foundation support.

5. Energy Efficiency Assessment

Once the seismic retrofit measures are implemented or planned, conduct an energy efficiency assessment to identify opportunities for improving the building's energy performance.

Evaluate the building envelope, insulation levels, windows, doors, and HVAC systems to identify areas of energy loss and inefficiency.

Utilize energy modeling software to simulate the building's energy usage and assess the potential impact of various energy efficiency measures.

6. Energy Efficiency Improvement Recommendations

Develop recommendations for energy efficiency improvements based on the findings of the assessment.

Prioritize energy efficiency measures based on their potential for energy savings, return on investment, and compatibility with the building's structural and architectural constraints.

Consider a range of energy efficiency measures such as upgrading insulation, installing energy-efficient windows, optimizing HVAC systems, and implementing lighting retrofits.

7. Implementation and Monitoring

Implement the recommended seismic retrofit measures to strengthen the building's structural system and improve its seismic performance.

Implement the recommended energy efficiency measures to reduce energy consumption and improve occupant comfort.

Monitor the performance of the retrofitted building over time to ensure that both seismic and energy efficiency goals are achieved and maintained.

By following this structured plan, structural engineers can ensure that buildings are not only structurally sound and resilient against seismic hazards but also energy-efficient and sustainable for long-term occupancy.

9. Conclusion

In the realm of sustainable building practices, structural assessment emerges as a linchpin for enhancing energy efficiency in public buildings.

Through meticulous evaluation and analysis of building components and systems, structural assessment provides invaluable insights into weaknesses and improvement opportunities, thus laying the groundwork for transformative energy efficiency interventions. The journey from grasping the significance of structural integrity to implementing strategic energy efficiency improvements underscores the pivotal role of structural assessment in creating healthier, more sustainable built environments.

The structural assessment contributes to mitigating environmental impact, reducing operational costs, and fostering occupant comfort and well-being.

From optimizing material selection and design principles to implementing maintenance practices conducive to sustained energy efficiency, structural assessment permeates every aspect of building performance, ultimately shaping the trajectory towards a greener and more sustainable future.

In conclusion, structural assessment serves as a cornerstone for advancing energy efficiency in public buildings, driving transformative change towards a more sustainable future.

By harnessing the insights gleaned from structural assessments and translating them into actionable strategies, stakeholders can forge a path towards building environments that harmonize with the natural world and promote human well-being.

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