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INCREASING STRUCTURAL RESILIENCE: A CASE STUDY OF HOSPITAL RETROFITTING IN ALBANIA

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Abstract

The structural stability of many buildings, including important institutions like hospitals, was seriously affected following the 2019 earthquake in Albania. This paper presents a detailed case study of the retrofitting project undertaken for a hospital in Albania, which experienced significant damage during the earthquake. The primary objective of this project was to restore and improve the hospital's structural stability, ensuring its functionality in future seismic events.

The retrofitting strategy used a combined approach, including reinforced concrete jacketing of the masonry walls, installing steel framing for the masonry openings, and using textile-reinforced mortar (TRM) to strengthen the infill walls. Additionally, new reinforced concrete (R/C) walls were added to improve structural irregularity. These measures are designed to address specific weaknesses identified in the existing hospital structure.

This paper discusses the complete assessment of the hospital's structural condition, the design and implementation of retrofitting solutions, and the challenges encountered during the project. The results demonstrate the effectiveness of these retrofit techniques in increasing the seismic performance of the hospital. The findings provide valuable insights and practical recommendations for similar retrofit projects in earthquake-prone regions.

Keywords: structural resilience, retrofitting, post-earthquake reconstruction, building safety, earthquake-resilient design

1. Introduction

The devastating earthquake that struck northwest Albania on November 26, 2019, had a moment magnitude of Mw 6.4 and revealed significant vulnerabilities in the country's building infrastructure [1]. The earthquake caused extensive damage across at least 11 municipalities, including the populated cities of Tirana and Durrës. It impacted over 200.000 people, resulting in 51 fatalities, over 900 injuries, and substantial displacement of residents. The collapse of 10 buildings in Durrës and Thumanë underscored the urgent need for improved seismic resilience in the housing sector [2].

Additionally, the earthquake exposed critical deficiencies in the seismic design codes and construction practices for essential structures, such as educational institutions and healthcare facilities. Damage was reported in 321 educational institutions and 36 healthcare facilities, with estimated damage costs of approximately 64 million euros and 10 million euros, respectively [3] [4]. The absence of established procedures for retrofitting these vital buildings further magnified the earthquake's impact, highlighting the necessity for standardized retrofitting guidelines and processes [2] [3] [4] [5].

The Earthquake Engineering Field Investigation Team (EEFIT) conducted a mission to assess the damage, primarily focusing on the housing sector [3]. Their findings emphasized the need for comprehensive retrofitting programs that address both residential buildings and critical infrastructure. The earthquake's effects on educational institutions, healthcare facilities, and other essential buildings illustrated the importance of a multi-faceted approach to retrofitting that considers all potential vulnerabilities [5].

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This paper addresses these deficiencies by presenting a thorough assessment of the structural conditions and necessary retrofitting measures for the affected buildings. The study includes detailed documentation of the damages, and advanced seismic performance assessments. The findings and recommendations from this project provide valuable insights for future retrofitting initiatives in earthquake-prone regions, stressing the importance of a holistic approach to retrofitting to ensure the safety and resilience of both residential and critical infrastructure.

2. Assessment of Structural Damage

2.1. Initial condition of the hospital post-earthquake

The building, located at the University Hospital Center "Mother Teresa" (QSUNT) in Tirana, currently functions as a hospital unit. Constructed between 1984-1985, it comprises three independent units: a 2-story load-bearing masonry structure (Unit A), a 4-story reinforced concrete skeleton structure with prefabricated elements and perforated brick walls (Unit B), and a 2-story load-bearing reinforced masonry structure (Unit C).

Over the years, interventions have included expansions and openings of doors and windows for access. On the ground floor, some windows have been converted into doors, and new door/window openings have been created. At higher levels, new window openings are concentrated in the transverse load-bearing walls of the exterior facades. Interventions have also been observed in the internal longitudinal and transverse walls, mainly in the form of new doors or door expansions. The most significant interventions have been observed on the ground floor.

In its current condition, minor structural damages due to seismic activity have been observed in elements such as columns, beam-column joints of prefabricated elements, and load-bearing walls. These damages manifest as fine cracks. Non-structural damages are widespread, primarily affecting infill and partition walls, which have been compromised due to interaction with the main structure, especially at their contact points with structural elements. Another issue is the corrosion of steel bars in reinforced concrete elements caused by moisture presence. Additionally, plaster on the facade and protective layers of reinforced concrete elements have suffered damages in many areas.

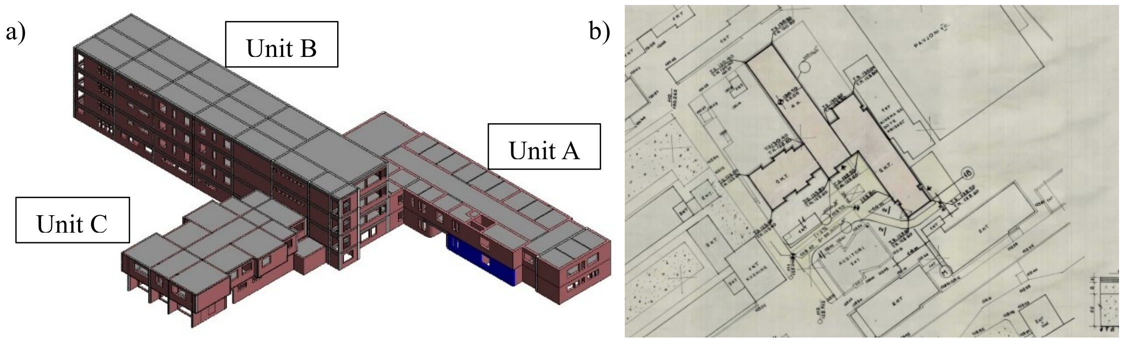

Figure 1. a) The current hospital building in a 3D model; b) Fragment from the original construction project

2.2. Methods used for structural assessment

The seismic assessment of buildings relies on the collection of factual data. This process includes obtaining available documents, field observations, investigations, and photographic documentation. For the building in question, an in-depth expert report has been conducted before, serving as a fundamental basis for understanding the structure and identified issues.

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Figure 2. Observed post-earthquake damages: a), b) corrosion of reinforcement bars; c) Cracks and detachment of plaster layers.

However, in drafting the structural retrofitting project, a detailed field investigation was necessary. The primary objectives of the structural retrofitting project were to ensure the accuracy of the provided drawings and determine the basic information of the buildings. This involved verifying the existing documentation and conducting detailed field investigations to identify any visible structural damages, such as cracks or fractures. These steps were crucial to understanding the current state of the building and planning the necessary interventions.

Additionally, the investigation also aimed to identify potential risks from non-structural elements that could pose a danger if they were to fall. This included assessing ceilings, partition walls, mechanical systems, and other non-structural building elements. Documenting the existing conditions with photographs was also a key objective, providing a visual record to support the findings and recommendations for the retrofitting process.

The data collection process, in addition to field observations and photographic documentation, also includes obtaining existing building documents. For the realization of the structural intervention project, the following documentation was made available:

1. The in-depth expert report conducted for the assessment of the structural capacity, dated 30.04.2020 [6];
2. The implementation project and its specifications for the building, from the Central Technical Archive, including the architectural project, structural project, electrical project, and mechanical project [7].

The collected information and recommendations from the in-depth expert report served as the fundamental basis for the realization of the structural intervention project. Based on the collected data, recommendations from Table 3.1, SSH EN 1998-3, and the conducted in-depth expert report, the level of knowledge KL2 (normal knowledge) has been determined, with a reliability factor CF_{KL2}=1.2 [8].

2.3. Key findings from the previous structural assessments

The in-depth earthquake damage assessment has clearly established the following critical findings.

The 2-story load-bearing reinforced masonry building (Unit C) has sustained corrosion in its reinforced concrete elements and the Unit A displays only minor overall damage. In contrast, the 4-story reinforced concrete skeleton structure (Unit B), which incorporates prefabricated elements and perforated brick walls, shows significant deficiencies including cracks and detachment in plaster layers, minor cracks in beams, corrosion of reinforcement bars, inadequate concrete cover, and voids at column-beam joints.

Material tests confirmed that the concrete grades are C30/37 for the prefabricated structure and C12/16 and C16/20 for the others. Importantly, the reinforcement steel meets the project specifications despite existing corrosion. The masonry characteristics adhere to KTP 9-78 standard [9], utilizing M-75 class bricks and M-25 class mortar.

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Seismic performance assessments, executed per Eurocode 8, Part 3, were comprehensive, employing both linear and nonlinear analyses with a ground acceleration of a_{gR}= 0.240g on type B soil. The assessment rigorously considered significant damage states with a seismic action probability of 10% over 50 years.

The analysis definitively concludes that the load-bearing capacity of the 2-story reinforced masonry building (Unit C) is insufficient, and the two additional buildings fail to meet required performance (Unit A and B). Consequently, retrofitting interventions for all units are not just recommended but essential.

The findings from the in-depth study were crucial for preparing the retrofitting project. They offered a comprehensive understanding of the existing structural conditions, including the identification of damages and material characteristics.

This information was essential for developing effective retrofitting strategies tailored to the specific issues identified in each building unit. In addition to relying on the conclusions from the in-depth study, further investigations were conducted to verify and enhance the recommendations. These additional investigations confirmed the accuracy of the study's findings and provided further insights that were incorporated into the retrofitting plans.

This combined approach ensures that the retrofitting interventions are based on a thorough and accurate assessment of the current structural conditions, leading to more effective and reliable solutions. By integrating the findings from both the in-depth study and the additional investigations, the retrofitting project will address the identified structural deficiencies while also improving the overall safety and resilience of the buildings. This comprehensive strategy is vital for ensuring the long-term stability and functionality of the structures.

3. Retrofitting Strategy

3.1. Challenges encountered during the project

The project faced several significant challenges. Identifying and documenting minor structural damages, such as fine cracks in columns, beam-column joints, and load-bearing walls, required careful field observations and detailed photographic documentation. Widespread non-structural damages in infill and partition walls posed another challenge, necessitating extensive fieldwork to accurately record the affected areas. Corrosion of steel bars in reinforced concrete elements due to moisture presence further complicated the project, impacting the structural integrity of the buildings.

To address these challenges, several solutions and adaptations were implemented. Enhanced documentation efforts, including detailed photographic records and field observations, were undertaken to accurately identify and catalogue both structural and non-structural damages. Advanced seismic performance assessments were conducted using both linear and nonlinear analyses to accurately evaluate the buildings' response to seismic activity. By integrating the findings from the in-depth study with additional investigations, a thorough and accurate assessment was achieved, leading to more effective and reliable retrofitting solutions.

3.2. Overview of the Chosen Retrofitting Techniques

In earthquake-prone regions such as Italy, Greece, and Turkey, structural retrofitting is essential to enhance the resilience of buildings against seismic activity [10] [11] [12]. By strengthening the structural integrity of existing buildings, retrofitting helps ensure that they can withstand seismic forces more effectively [13] [14]. This proactive approach not only preserves the building but also contributes to the overall safety and sustainability of communities in these regions.

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Several advanced techniques are recommended as best practices for the restoration of buildings. Similar methods, extensively utilized across Europe, were chosen as rehabilitative interventions and are described as follows:

1. Jacketing of Masonry Walls: Applying reinforced concrete jacketing with a steel mesh to masonry walls to enhance their strength and stability.
2. Metallic Framing of Masonry Openings: Adding metal profiles to contour openings in masonry walls, such as doors and windows, to improve structural integrity.
3. Textile Reinforced Mortar (TRM) for Infill Wall Reinforcement: Using the TRM system to reinforce infill walls and appropriately connect them to the surrounding reinforced concrete frame.
4. Addition of New Reinforced Concrete (R/C) Walls: Introducing new reinforced concrete walls to create structural regularity and enhance overall stability.

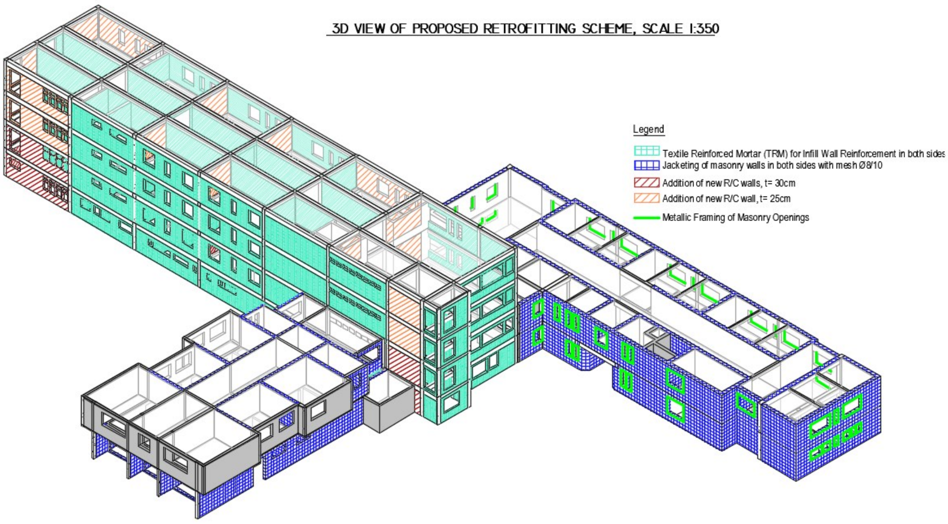

Figure 3. Proposed scheme for implementing the rehabilitation structural interventions.

4. Results and Discussion

A mathematical model was developed to assess the load-bearing capacity of the building in its retrofitting state, following the requirements of SSH EN 1998-3. This model incorporates the geometric dimensions of the structure, the physical and mechanical properties of the materials, permanent and temporary loads, and the proposed retrofitting interventions, which are based on findings from the previously conducted report. The loads used in this analysis were sourced from that same in-depth expert report.

The program 3Muri/TreMuri was utilized for seismic calculations in accordance with Eurocode 8 for the reinforced condition of the two-story units, which features a load-bearing masonry system. For both units, the verification criteria for the building's reinforced condition essentially involve ensuring that the demand, calculated using permitted analysis methods, does not surpass the capacity.

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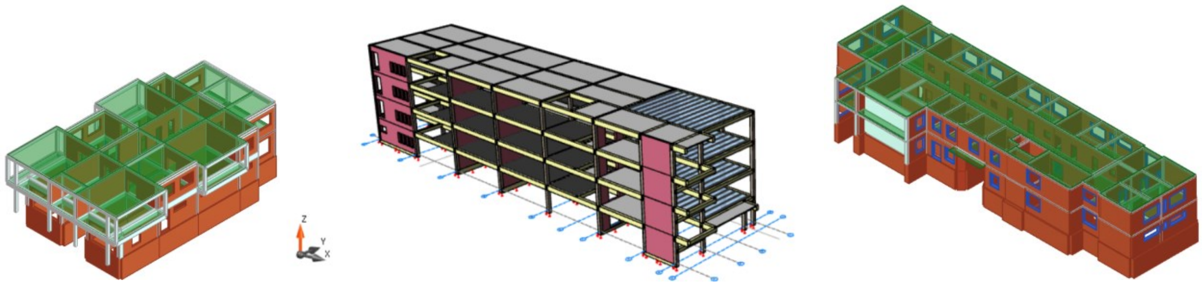

Figure 4. Numerical models of the units: Unit A (right), Unit B (middle), and Unit C (left).

This is assessed by calculating the risk index α (α_{SD}). The seismic vulnerability index (α) serves as an indicator to determine whether the capacity has been exceeded.

The modeling, along with static and dynamic analysis, of the reinforced condition of the four-story unit was conducted using the ProtaStructure calculation program and integrated with OpenSees. According to SSH EN1998-3:2005, Annex A, point A.3.2.3, the structure's capacity assessment for the significant damage limit state is taken as equal to three-fourths of the ultimate displacement capacity of the structure. The ultimate displacement capacity is defined as the displacement at the curve point where the lateral resistance (base shear force) falls below 80% of the peak resistance (the highest point on the curve), due to progressive damage and the failure of elements that resist lateral loads. The target displacement is calculated based on SSH EN 1998-1 (Annex B) for the specified seismic loading.

For each constituent unit, verification is performed according to the significant damage limit state (SD). Additionally, the seismic demand is accepted as increased by an importance factor of 1.4. The seismic loading, per Eurocode standards, relies on the findings of the previous expert report, where the ground acceleration was accepted as a_{gR}=0.240g, with the soil type classified as B.

The seismic vulnerability indices according to SSH EN 1998:1 indicate that the Unit A in its reinforced state, meets the required capacity criterion in both directions. The same conclusion also applies to Unit C.

On the other hand, for the Unit B, there is a high probability of sustaining significant controlled damage if it experiences an earthquake, in reference to the seismic demand and Eurocode requirements.

Table 1. Result details for the Unit A

Unit	Limit state	PGA (m/s^2)	α_{SD}
X direction	SD	4.016	1.706
Y direction	SD	2.528	1.074

Table 2. Result details for the Unit C

Unit	Limit state	PGA (m/s^2)	α_{SD}
X direction	SD	2.938	1.248
Y direction	SD	4.404	1.871

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Table 3. Result details for the Unit B

Unit	Limit state	Defined level of performance	% of members in significant damage region
X direction	SD	Significant damage	97%
Y direction	SD	Significant damage	100%

4.1. Evaluation of the retrofitting effectiveness

The retrofitting effectiveness can be evaluated by examining the improvements in the structural capacity and seismic performance of the buildings. The mathematical calculation model, which includes geometric dimensions, material properties, and proposed interventions, provides a comprehensive assessment of the reinforced condition. The use of advanced programs like 3Muri/TreMuri and ProtaStructure, along with OpenSees integration, ensures accurate modeling and analysis. The findings indicate that the retrofitting interventions have significantly enhanced the load-bearing capacity and seismic resilience of the buildings.

4.2. Comparison of pre- and post-retrofitting structural performance

The comparison of pre- and post-retrofitting structural performance reveals substantial improvements. In the pre-retrofitting condition, the buildings exhibited various structural and non-structural damages, including fine cracks, corrosion of steel reinforcement bars, and insufficient concrete cover. The seismic performance assessment indicated limited capacity to withstand seismic loads. In contrast, for both Unit A and C, the post-retrofitting condition shows enhanced structural integrity, with the buildings meeting the required capacity criteria in both X and Y directions. The reinforced condition of the Unit B building demonstrates a high probability of sustaining significant damages during an earthquake, highlighting the effectiveness of the retrofitting interventions.

4.3. Insights gained and lessons learned

Several insights and lessons have been gained from this project. First, the importance of thorough documentation and field observations in identifying and cataloguing damages cannot be overstated. Accurate data collection is crucial for developing effective retrofitting strategies. This project highlighted the need for thorough attention to detail in documenting both structural and non-structural damages, as even minor issues can significantly impact the overall structural integrity.

Second, advanced seismic performance assessments are essential for ensuring that retrofitting interventions meet the required standards. The use of programs like 3Muri/TreMuri and ProtaStructure, along with OpenSees integration, provided accurate modeling and analysis, leading to reliable solutions. This approach emphasized the value of leveraging advanced technology and software in structural engineering to achieve precise and dependable results.

Third, integrating findings from both in-depth studies and additional investigations leads to more reliable and effective retrofitting solutions. By combining the insights from the expert report with on-site verifications, a more holistic understanding of the building's condition was achieved. This comprehensive approach ensured that the retrofitting interventions were tailored to address the specific needs of each building unit, resulting in more effective and sustainable solutions.

The specific interventions implemented included reinforced concrete jacketing with a steel mesh for load-bearing walls, contouring openings with metal profiles, reinforcing infill walls with the TRM system, adding new reinforced concrete walls for structural regularity, cleaning and removing rust from

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steel bars. These interventions provided valuable lessons on the importance of using appropriate materials and techniques to enhance structural integrity and resilience.

One critical insight gained from these interventions is the necessity of a multi-faceted approach to retrofitting. Each intervention addressed a specific aspect of the building's structural deficiencies, highlighting the need for a comprehensive strategy that considers all potential vulnerabilities. Additionally, the project demonstrated the importance of continuous monitoring and maintenance to ensure the long-term effectiveness of the retrofitting measures. Regular inspections and timely repairs can prevent minor issues from escalating into major structural problems.

Another lesson learned is the significance of collaboration and communication among all stakeholders involved in the project. Effective coordination between engineers, architects, contractors, and other professionals is essential for the successful implementation of retrofitting interventions. Clear communication and a shared understanding of the project's goals and challenges can lead to more efficient and effective solutions.

Finally, the insights gained and lessons learned from this project will be invaluable for future retrofitting efforts. By applying these lessons, future projects can achieve greater structural resilience and safety, ensuring that buildings are better prepared to withstand seismic events.

5. Conclusion

The in-depth study has provided a thorough understanding of the structural conditions and necessary retrofitting measures for the buildings. Key findings include the identification of minor structural damages such as fine cracks in columns, beam-column joints, and load-bearing walls, as well as widespread non-structural damages in infill and partition walls. Corrosion of steel bars in reinforced concrete elements due to moisture presence was a significant issue, impacting the structural integrity. The seismic performance assessment revealed limited capacity for Unit C and insufficient capacity for the other two units, Unit A and Unit B. The retrofitting interventions, including reinforced concrete jacketing, contouring openings, reinforcing infill walls, adding new reinforced concrete walls, cleaning and removing rust from steel bars, have significantly improved the structural integrity and seismic resilience of the buildings.

The findings and interventions from this project have several implications for future retrofitting projects in earthquake-prone regions. First, thorough documentation and field observations are essential for accurately identifying and documenting damages. This ensures that retrofitting strategies are tailored to address specific structural deficiencies. Second, addressing corrosion issues was a critical step in improving structural integrity. The use of protective coatings and corrosion-resistant materials can prevent further deterioration and extend the lifespan of the building. Third, comprehensive material testing and advanced seismic performance assessments are crucial for ensuring that retrofitting interventions meet the required standards. Leveraging advanced technology and software in structural engineering can lead to precise and reliable solutions. Finally, a multi-faceted approach to retrofitting, which considers all potential vulnerabilities, is necessary for achieving greater structural resilience and safety.

Further research is recommended to build on the findings and insights gained from this project. Future studies should focus on developing more advanced and cost-effective retrofitting techniques that can be easily implemented in Albania. Additionally, research should explore the long-term effectiveness of various retrofitting interventions, including their impact on the overall structural integrity and resilience of buildings. Investigating the use of innovative materials and technologies, can provide valuable insights into their potential applications in retrofitting projects. Finally, continuous monitoring and maintenance of retrofitted buildings should be emphasized to ensure the long-term success of the interventions and prevent minor issues from escalating into major structural problems.

One critical issue highlighted by this project is the lack of established procedures for retrofitting important buildings, such as hospitals, in Albania. The 2019 earthquake in Albania caused considerable damage to many such buildings, underscoring the urgent need for standardized retrofitting guidelines and procedures. Developing and implementing these procedures will be essential for ensuring the safety and resilience of critical infrastructure in future seismic events.

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References

[1] Moshou, A., Dushi, E., Argyrakis P.: *A Preliminary Report On The 26 November 2019, Mw=6.4Durres, Albania*, Euro-Mediterranean Seismological Centre, France, https://www.emsc-csem.org/Files/news/Earthquakes_reports/Preliminary_Report_Albania_26112019.pdf?form=MG0AV3, (accessed December 2, 2024)

[2] Lekkas, E., Mavroulis, S., Papa, D., Carydis, P. (2019). The November 26, 2019 Mw 6.4 Durrës (Albania) earthquake. *Newsletter of Environmental, Disaster and Crises Management Strategies*, 15, ISSN 2653-9454, doi: 10.13140/RG.2.2.23801.29281

[3] Andonov, A., Baballëku, M., Baltzopoulos, G., Blagojević, N., Bothara, J., Brûlé, S., Brzev, S., Carydis, P., Duni, L., Dushi, E., Freddi, F., Gentile, R., Giarlelis, C., Greco, F., Guri, M., Isufi, B., Koçi, R., Lekkas, E., Marinković, M., Markogiannaki, O., Mavroulis, S., McKenney, C., Milićević, I., Novelli, V., Sextos, A., Sim, C., Skoulidou, D., Stefanidou, S., Theodoulidis, N., Turner, F., Veliu, E.: *EERI Earthquake Reconnaissance Report: M6.4 Albania Earthquake on November 26, 2019*, https://lfestorage.s3.us-east-2.amazonaws.com/images/earthquakes/2019_Albania_Earthquake/EERI_Earthquake_Reconnaissance_Report_-_M6.4_Albania_Earthquake_on_November_26_2019.pdf, (accessed December 2, 2024)

[4] Andonov, A., Andreev, S., Freddi F., Greco F., Gentile, R.., Novelli, V., Veliu E.: The Mw6.4 Albania Earthquake On The 26th November 2019, A Field Report By EEFIT, Earthquake Engineering Field Investigation Team, The Institution of Structural Engineers International HQ, https://www.istructe.org/IStructE/media/Public/Resources/report-eefit-mission-albania-22102020.pdf, (accessed December 2, 2024)

[5] Sextos, A., Lekkas, E., Stefanidou, S., Baltzopoulos, G., Fragkiadakis, M., Giarlelis, C., Lombardi, L., Markogiannaki, O., Mavroulis, S., Plaka, A., Pnevmatikos, N., Skoulidou, D., Tsiatas, G., Tsopelas, P., Albania earthquake of November 26, 2019, https://www.elekkas.gr/images/stories/pdfdocs/ETAM-Report_Albania2019EQ.pdf, (accessed December 2, 2024)

[6] Polytechnic University of Tirana (2020): Technical Report, In-Depth Structural Analysis, Tirana, Albania.

[7] Central Technical Archive (2023): Original construction project and documentation, Tirana, Albania.

[8] European Committee for Standardization (2005): *Eurocode 8: Design of structures for earthquake resistance-Part 3: Assessment and retrofitting of buildings*, The European Union.

[9] Ministria e Ndërtimit (1978): Kushte teknike projektimi: Llogaritja e mureve dhe themeleve me teorinë e gjendjes kufitare (KTP 9-78), Tirana, Albania.

[10] Fehr M., Baur M., Genesio G., Seismic retrofitting of an existing hospital with external steel brace, SMAR 2024 – 7th International Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures, Salerno, Italy, 8 pages.

[11] Bournas, D. (2018): Innovative Materials for Seismic and Energy Retrofitting of the Existing EU Buildings, EUR 29184 EN, Publications Office of the European Union, Luxembourg.

DOI: https://doi.org/10.5592/CO/3CroCEE.2025.98

[12] Pisapia, A., Piluso, V., Montuori, R., Nastri, E., Frattolillo, C. (2023): Seismic Assessment and Structural Retrofitting of the Day-Hospital Building "G. Pascale Foundation", Appl. Sci. 2023, 13, 1663, doi: https://doi.org/10.3390/app13031663

[13] Carofilis, W., Perrone, D., O'Reilly, G. J., Monteiro, R., & Filiatrault, A. (2020): Seismic retrofit of existing school buildings in Italy: Performance evaluation and loss estimation. Engineering Structures, 225, 111243, doi: https://doi.org/10.1016/j.engstruct.2020.111243

[14] Pertile, V., Stella, A., De Stefani, L., Scotta, R. (2021): Seismic and Energy Integrated Retrofitting of Existing Buildings with an Innovative ICF-Based System: Design Principles and Case Studies. Sustainability 2021, 13, 9363, doi: https://doi.org/10.3390/su13169363