The Importance of Regular Structural Inspection, Assessment and Maintenance of Existing Buildings

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1.Introduction

Unfortunately, it is an acknowledged fact that in Cyprus, as in most European countries, a large proportion of the building stock is ageing, a significant part of which is either poorly maintained or abandoned. According to data regarding Cyprus from the official Statistical Service (2021 data), of circa 500,000 residential units, 49% were constructed prior to 1994, that is, during a period when there were no mandatory requirements for seismic design or compulsory supervision, 56% were constructed prior to 1999 and 39% were constructed between 1994 and 2011.

A considerable number of these buildings exhibit some form of structural vulnerability, insufficient and sometimes total lack of maintenance and development of structural pathology. Also, if the country suffers from earthquake events, many of those buildings may have sustained damage during the various seismic events that have occurred from the time of their construction to the present day, and it is possible that such damage has never been properly identified and rectified accordingly.

In addition, the natural degradation affecting a structure over time, particularly its primary structural materials, further reduces its strength and durability. Consequently, this process diminishes the structure's capacity to withstand seismic actions and associated load effects.

Consequently, many of the buildings forming part of the existing building stock were erected prior to the introduction of modern Eurocode regulations, or in the absence of any proper regulatory framework, rendering them vulnerable both to dynamic and seismic actions and to structural failures, resulting mainly from ageing and lack of maintenance. This reality underscores the urgent need for targeted structural inspection, followed by proper assessment and the planning of appropriate repair, rehabilitation, or strengthening works, with the protection of human life and the safety of the built environment as the primary objective.

2.Types of Inspections / Assessments

Through this article, an initial attempt is made to describe and classify the various types or levels of inspections and assessments that a consulting Civil/Structural Engineer may be requested to carry out. In my opinion, the three principal categories of inspection/assessment are as follows:

1. Those arising within the framework of the periodic inspection or routine assessment of a building. These may consist of visual inspections accompanied by brief engineering reports or more comprehensive structural assessment reports including recommendations for the repair of identified defects and pathologies, and may also be supported by sketches, drawings and repair methodology descriptions. Where required, such inspections may involve different engineering disciplines and may be based on structured documentation. In Cyprus these documents were prepared by the Technical Committee for Regular Inspection of buildings (such as ETEK standardised forms, ΕΓΟΕΚ forms), or corresponding documents issued by other international organisations.
2. Those arising within the framework of structured pre-seismic assessment of buildings. For this type of inspection, well-structured forms prepared by the ETEK Technical Committee (EOE and EPOPEK forms) have been available for several years and constitute primary-level assessment tools. In cases where a building does not satisfy the primary assessment criteria, secondary or tertiary assessment is required in accordance with Eurocode 8, Part 3, and the revised National Annex. Relevant reference is made in **Figure 1**.
3. Those arising or required to be carried out following a seismic event, or any other dynamic or catastrophic event (post-seismic inspection and assessment). These forms are of a different type and philosophy, as they are not conducted on a preventive basis, unlike the previous two categories of inspection/assessment.

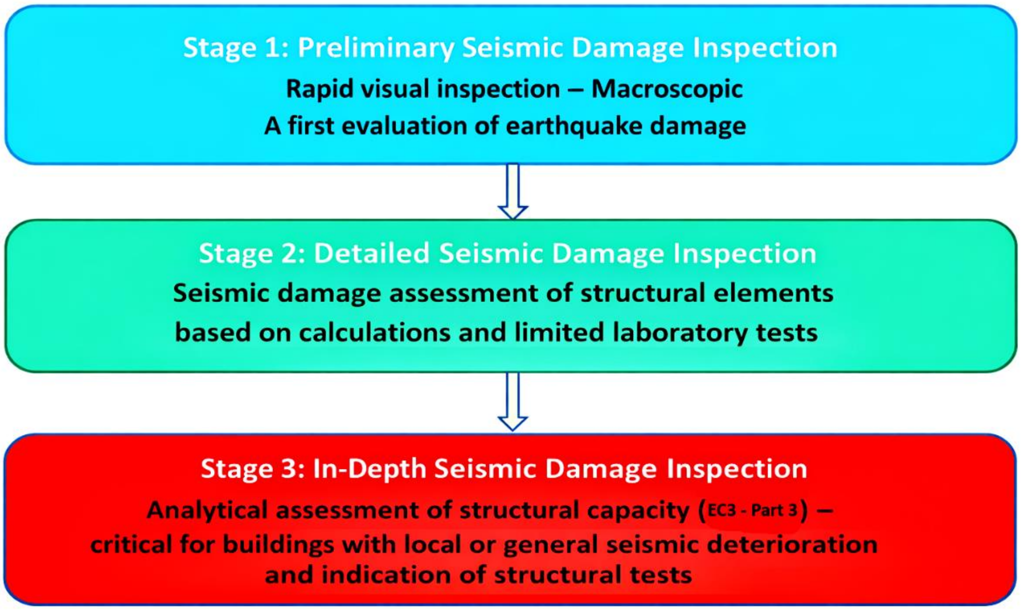

Figure 1: The Three Stages of Pre-Seismic Assessment of Buildings

3.Pre-Seismic Assessment and Inspection of Buildings

When the inspection is carried out within the framework of structured pre-seismic assessment of buildings, it is performed in three stages, aiming the evaluation of the seismic vulnerability of existing structures (see Figure 1).

The first stage, referred to as the Primary Pre-Seismic Assessment, consists of a rapid, macroscopic visual inspection to which all buildings are subjected. For Cyprus, this procedure includes an initial visual evaluation of the building, based on the Primary Visual Inspection Form (E.O.E.) and, where required, on the Visual Pre-Seismic Inspection of Buildings Form (E.P.O.P.E.K.). In cases where the building is being inspected for the first time, completion of both inspection forms is mandatory in order to ensure its proper classification and evaluation. This stage, also referred to as Primary Assessment, aims at the visual appraisal of the building's overall vulnerability condition, utilising standardised tools developed by the Ad Hoc Committee of Cyprus Scientific and Technical Chamber (TEK/ETEK). Those documents can be easily downloaded from ETEK webpage (https://etek.org.cy/)

These forms are available for free in editable digital format and allow for the incorporation of photographs and sketches, thereby enhancing the documentation process. It should be noted that the Primary Assessment functions as a preliminary screening tool and does not substitute a structural assessment study or a modelling and capacity evaluation of the building's load-bearing capacity.

Where indications of potential inadequacy are identified during the Primary Assessment, the second stage follows, namely the Secondary Pre-Seismic Assessment, which includes an approximate evaluation of the building's seismic capacity. Within this framework, a more detailed and technically specialised assessment is carried out, including preliminary laboratory investigations (such as material strength testing and reinforcement exposure), preliminary geotechnical investigation and foundation assessment, either in situ or through desk study. At the same time, some basic calculations and base shear checks are performed to estimate the structure's level of risk, the probable causes of the identified deficiencies are investigated. Where required, a preliminary estimate of repair costs is prepared, together with localised repair procedures of identified defects and pathologies.

Of course, it is possible for the Civil Engineer to proceed directly to the Tertiary Assessment without preparing a Secondary Assessment study, particularly where deficiencies and problems are serious and clearly evident from the Primary Assessment.

If following the Secondary Assessment, indications of structural vulnerability and serious deficiencies arise, the Civil Engineer proceeds to the third stage, the Tertiary Pre-Seismic Assessment, which constitutes the most detailed and technically demanding phase of the process. During the Tertiary Pre-Seismic Assessment, a full and comprehensive evaluation of the seismic capacity is carried out in accordance with Eurocode 8 – Part 3 (EN 1998-3) and relevant national annexes. For this type of evaluation both local and global seismic deficiencies are examined.

The assessment includes the application of advanced methods, such as analytical modelling of the structural system through mathematical simulation, investigation of structural materials, evaluation of geotechnical data and the execution of dynamic analyses in relation to rehabilitation or strengthening scenarios. Overall, this process ensures a reliable and well-documented evaluation of the seismic performance of existing buildings, with the objective of preventing and mitigating risks associated with future seismic events.

In summary, the third stage, the Tertiary Assessment, is recommended to include thorough laboratory testing and full geotechnical investigation, verification of the geometric data of the existing structure and its structural elements, and inspection/exposure of the foundation system, with the aim of conducting a detailed analytical assessment of the building's load-bearing capacity in accordance with the provisions of the European Standard EN 1998-3:2005. Where strengthening of the structural system is found to be necessary, a strengthening design study is prepared and a preliminary cost estimate of the proposed strengthening works is prepared and presented, in order to assess the economic feasibility of the upgrade/intervention.

4. On-Site Assessment and Inspection

The first and most critical step prior to any form of inspection, report preparation, structural assessment, completion of custom or standardised forms, repair works or structural intervention, is the systematic and detailed on-site inspection and evaluation of the building's condition. This process is carried out through thorough and in-depth site inspections and the collection of construction-related information and data by experienced and qualified Civil Engineers (with knowledge of structural analysis and behaviour of structures and elements, as well as building materials), in accordance with ISO 13822:2010 or other applicable European or international standards.

The Civil Engineers carefully examine the structure, review the project file, the original construction drawings and all available design information, in order to understand the philosophy, approach and intent of the original design, as well as any subsequent modifications or alterations made to the drawings. During the inspection, verification of the correct implementation of the design drawings in relation to the as-built condition is undertaken, and all pathology and visible signs of damage are recorded, such as cracks, deformations, settlements, corrosion or moisture ingress.

Comprehensive photographic documentation of all identified deficiencies is prepared, sketches and notes indicating the location of damage are compiled, and the building's history is recorded through relevant testimonies, where available. Building inspection may be conducted within the framework of any level of assessment, as outlined in Section 2.

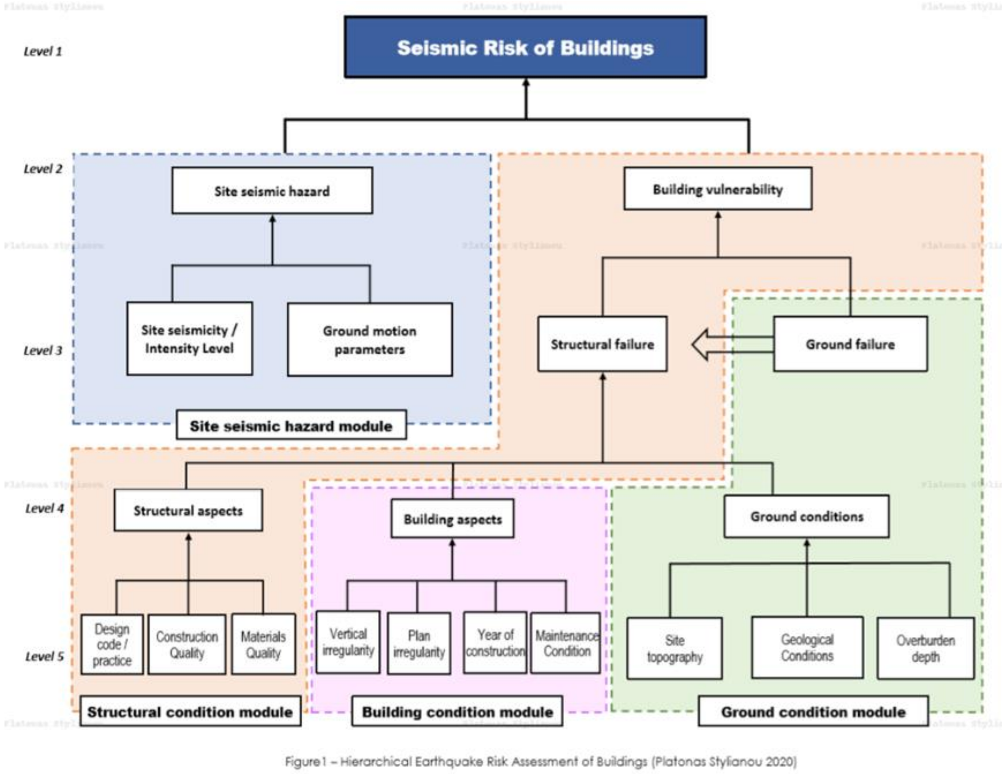

Figure 2 : Hierarchical Risk Assessment of Buildings (Platonas Stylianou 2020)

During the on-site inspection and assessment, an initial damage evaluation should also be carried out. This must be performed in a systematic and comprehensive manner, with proper recording and documentation of the pathology affecting the structural elements, such as load-bearing masonry, beams, columns, timber elements, steel structures, slabs, etc. Cracks and other significant defects identified should be documented in terms of their location, geometric characteristics and properties, while all indications of vulnerability must also be noted, such as concrete cover spalling, delamination, disintegration, pulverisation, reinforcement corrosion, salt formation (efflorescence) or the growth of microorganisms (Figure 3).

Although this approach is macroscopic in nature, when applied through a structured and methodical process it enables engineers to form an initial yet clear understanding of the extent of the damage, without necessarily requiring extensive and destructive laboratory testing. Of course, where feasible or deemed necessary, laboratory investigations should be performed and properly evaluated.

The purpose of this assessment is firstly to "understand" the building, to formulate a reliable diagnosis of the existing condition and to propose, where required, the most appropriate repair, rehabilitation or strengthening solution for local elements, with the objective of restoring the integrity and functional performance of the existing structure.

The decision regarding the necessity of repair and, more importantly, the type, method and category of repair or rehabilitation, presupposes adequate investigation of the cause of the damage and accurate identification of the nature of the problem.

Careful identification, study, documentation, evaluation and analysis of both the pathology and the vulnerability of a structure lead to sound and effective intervention strategies and repair proposals.

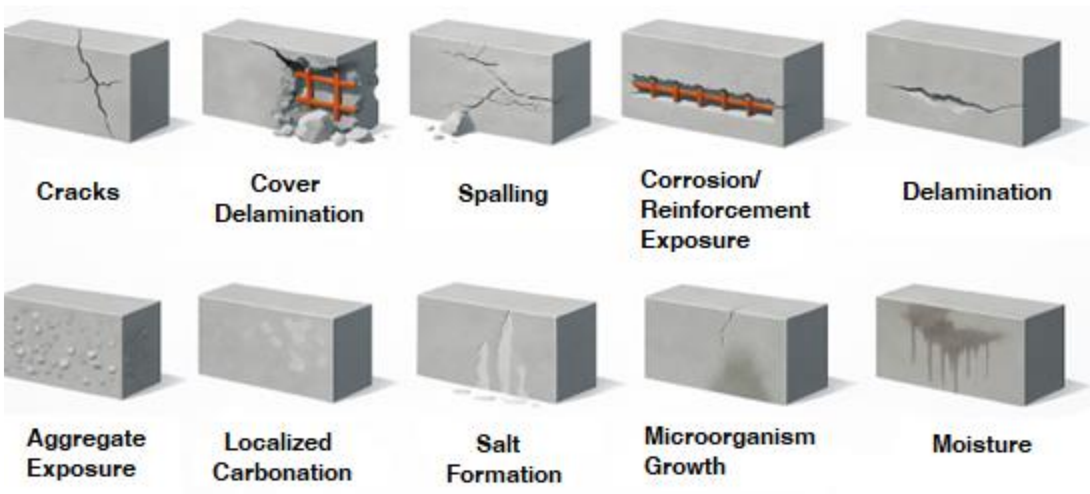

Figure 3: Damage Documentation

5. Appropriate Repair and Strengthening Interventions

The intervention strategy to be adopted must be carefully tailored to the type, cause, extent and severity of the damage, as well as to the specific characteristics of the building itself, and must be based purely on technical criteria. The methodology should rely on thorough documentation and analysis of the identified deficiencies, leading to the selection of the most appropriate technical intervention.

Strengthening interventions, depending on their severity and extent, may be classified into at least five principal categories:

- **Category I,** primarily concerns the repair of localised defects and limited damage or pathology (repair and rehabilitation only – small-scale interventions).
- **Category II,** aims at repairing defects while also improving ductility and energy dissipation capacity through local strengthening of existing elements. For example, by the application of steel plates or composite

materials to columns, and by managing infill walls to prevent the formation of short-column mechanisms.

- **Category III,** includes the enhancement of strength and stiffness through strengthening of existing elements, confinement or jacketing of beam-column joints using composite materials, increasing the thickness of selected structural elements through reinforced concrete jacketing, improving reinforcement anchorage at joints, and repairing identified damage and pathology.
- **Category IV,** combines the increase of strength, stiffness and ductility (global measures) through strengthening of the existing load-bearing system, for example by increasing the thickness or length of shear walls, applying reinforced concrete jackets to columns and beams, introducing new seismic shear walls to resist seismic actions, and strengthening the foundation system.
- **Category V,** involves the incorporation into the structure of passive or active mechanical energy dissipation systems, such as dampers, tuned mass dampers, or base isolation systems.

For Categories IV and V, which concern more extensive and global interventions, it must be emphasised that these should be implemented in conjunction with the repair of all existing damage and the elimination of pathology. Since seismic rehabilitation and strengthening cannot be meaningfully undertaken without first addressing and repairing the identified deficiencies.

The selection of the appropriate strengthening scheme is project-specific, as it is multidimensional and influenced by numerous factors of both general and technical nature. General criteria include cost, available technological resources, accessibility and constructability, and the architectural character of the building. Technical criteria relate to the results of the structural assessment, material strength properties, the level of seismic adequacy of the structure, regularity requirements and the requirement for enhanced ductility.

Proper implementation of the selected and designed interventions requires diligent and continuous supervision by the Supervising Engineer. Systematic and rigorous site supervision, combined with quality control procedures, ensures the correct application of materials and compliance with relevant standards, so that repairs and strengthening works remain durable and effective.

Figure 4: Crack Repair in Load-Bearing Masonry building

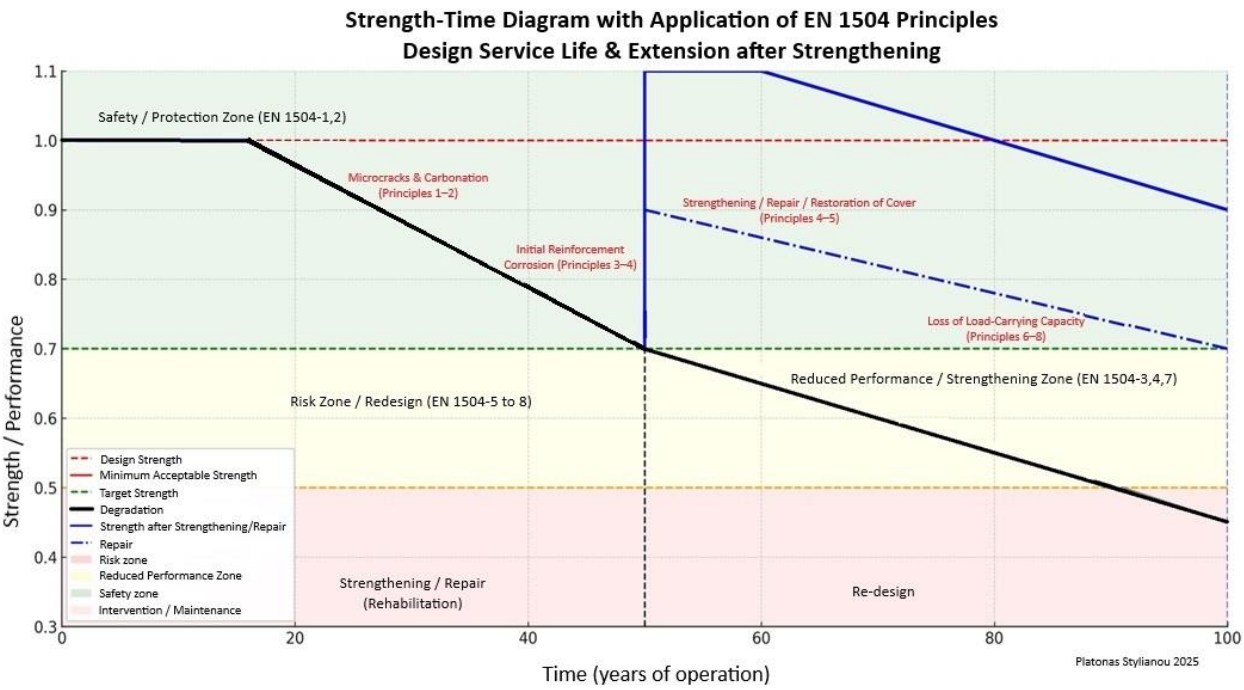

Figure 5: Strength-Time Diagram with Application of EN 1504 Principles (P. Stylianou 2025)

6. Conclusion

The regular inspection, assessment and maintenance of buildings constitute a critical pillar in preserving structural integrity, ensuring safe use, and maintaining the operational reliability of structures. Regular inspection and assessment enable the timely identification of pathology, deterioration, functional deficiencies and structural inadequacies which, if left unaddressed, may lead to extensive damage, disproportionate repair costs and increased risks to public safety.

Furthermore, the implementation of repair and protection procedures in accordance with European Standards (EN 1504) ensures compliance with technical requirements and the optimal performance of maintenance interventions. At the same time, the adoption of standards such as ISO 15686 (Service Life Planning) contributes to the long-term management of the building stock, extending the service life of buildings while simultaneously reducing carbon emissions and their environmental footprint.

Therefore, the formalization and implementation of comprehensive inspection and maintenance programmes, aligned with international and European standards, constitute good practice and represent a strategic necessity for the sustainable development of the built environment, the preservation of cultural heritage and citizens' property assets and the protection of the society.

Finally, I would like to emphasise once again the necessity for our society to promptly develop the required culture of regular inspection and maintenance of its building assets. Regular inspection and maintenance should be undertaken on a preventive basis and integrated into all stages of project design and implementation, encompassing the entirety of our building stock both the existing built environment and new projects being designed and constructed.