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Thesis project title:

STUDY AND IMPLEMENTATION OF INNOVATIVE METHODS FOR SEISMIC MONITORING AND DAMAGE DETECTION IN STRATEGIC PUBLIC BUILDINGS

Abstract

A large part of the national building stock consists of structures built after the World War II or century-old buildings, which are vulnerable to seismic action for different reasons: primarily because they were built before the adoption of modern anti-seismic regulations, but also due to subsequent alterations, expansions, and poorly executed additions, as well as a lack of maintenance, etc. In addition, several of them belong to Public Entities, so they host functions of primary interest, such as schools, hospitals, and barracks. Furthermore, even those buildings that are designed according to current earthquake standards are designed with performance-based methods, which focus on occupant safety but still tolerate structural damage in the event of rare earthquakes. Finally, Italy's geographical location along the converging margin between the African and Eurasian tectonic plates makes it a "seismic country".

All these reasons emphasize the importance of promptly and objectively assessing the effects of seismic events.

Currently, post-seismic damage assessments and recovery actions are slowed down by lengthy visual inspections by experts, which although increasingly standardized, can still be influenced by subjectivity. Instead, in the phases following a seismic event, decision-makers must quickly choose between two alternative management actions: "evacuating" or "not evacuating" the building affected by the earthquake, or better, whether to continue to allow their use or not. Each choice has important consequences, both in terms of risk and economics: casualties that could have been avoided or unnecessary financial losses due to business interruptions. Therefore, having information on the actual structural condition of buildings after a seismic event is crucial.

To address this need, the scientific community has dedicated significant attention in recent years to the development of techniques and tools for Structural Health Monitoring (SHM), aiming to assess seismic damage. SHM involves a non-destructive and long-term monitoring process that extracts and analyzes some structure-indicative indicators, called "Damage-Sensitive Features" (DSF). These features encode indirect information about the building's state (in the absence of direct force and displacement measurements) and provide timely information about its condition after an earthquake. This enables the evaluation of the structure's suitability for use, supporting decision-making among various alternatives and minimizing the consequences of seismic events. The effectiveness of various DSF in detecting, quantifying, and localizing damage varies depending on the specific structure or problem under examination.

Moreover, SHM does not only detect damage presence but, depending on the sophistication level of the monitoring system, it can also localize the damage, identify its type, quantify its severity, and even predict the remaining lifespan of the structure.

In SHM practice, engineers typically instrument the structure with a limited number of sensors positioned at specific points, and the positioning of these sensors directly affects the system's capability to deduce the behavior of the entire structure. The proliferation of these monitoring techniques is, in part, due to advancements in sensor technology and the availability of computational software for data collection and analysis.

The objectives of this research are to design and install an SHM system in two strategic buildings, both in function and occupancy, owned by the Province of Perugia (the PhD partner entity). These buildings represent two structural typologies, one seismically isolated at the base and one non-isolated. Moreover, the research aims to prepare "Guidelines" for the design of SHM systems and for the interpretation of their results, which can be used in the future by the Public Entity for other strategic buildings, taking into account their specific structural properties: the construction system and the presence of dissipative or isolation systems at the base.

The study aims to equip the Public Administration with instructions, technologies, and tools to promptly assess the damage status of structures after a seismic event for a quick and informed decision on the necessary actions.

The proposed methodology involves studying the structural characteristics of the identified buildings and setting up a structural finite element model based on these features. This model allows the derivation of selected parameters of the structure and guides the placement of sensors for monitoring. Subsequently, for model calibration, these values of parameters derived from the model will be compared with experimental measurements obtained from the initiated monitoring. The model thus created will allow simulations in dynamic analysis to assess the structure's response to stress. In this process, a crucial and particularly challenging phase will be to find an objective criterion to correlate the variation of the monitored parameters with the level of structural damage, in other words to define thresholds to decide whether to evacuate the buildings or not.

The host university ETH Zurich has been working on seismic monitoring for over ten years, the research group has also been the coordinator of a European project on the subject (RISE) and two of the researchers in the group have created a start-up (IRMOS). During my time at ETH, it is my intention to deepen above all the strategies and indicators of structural monitoring of buildings, the optimal sensor placement strategies and the correlation between the monitored parameters and the level of structural damage.

International partner: ETH (Eidgenössische Technische Hochschule) Zürich

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