ABSTRACT: The paper presents the results of a research project concerned with the structural safety and rehabilitation and more generally, with the re-use of abandoned historical centres through the analysis of a real case study: the ancient town of Laino Castello, located in northern Calabria, in a context characterized by a severe seismic risk and large presence of masonry residential housing, endowed with a high degree of vulnerability and relevant slopes, with a quasi-vertical urban structure. This peculiar configuration, enhanced by bad water draining and possible interaction with the seismic hazard, makes the town particularly weak with respect to landslides and rock falls. Thanks to an agreement with the municipality, a scientific research project aimed at the safety assessment of the site and its buildings has been carried out, using the site as a real laboratory for empirical observations of mechanical phenomena, application of theoretical models on real case studies and experimental in situ testing.

1 INTRODUCTION
1.1 Motivations and objectives of the research study

The research project that is here presented is concerned with the structural rehabilitation of historical centres, in order to answer to the increasing demand for the re-qualification of the urban landscape, and for the correct management of the historical residential housing. Structural rehabilitation, safety, and more generally, the matter of the re-use of an abandoned historical centre are still open questions, and offer an interesting starting point for developing scientific research work.

In particular, these questions are developed through the application to a real case study: the historical town of Laino Castello located in Northern Calabria, within the National Park of Pollino. It is an ancient town, declared unstable and unsafe and currently completely abandoned. In the past it was subjected to a progressive depopulation because of the hard conditions of living and of an urban structure considered primitive and inadequate to the needs of the inhabitants. After some occasional rock falls occurred in the ‘70s, it was definitively abandoned, and a slow deterioration of the structures and the whole town began.

Thanks to an agreement with the municipal administration, the town has been available to the group for experimental and scientific activities aimed at the structural and functional rehabilitation, and, in perspective, at the repopulation and development of the town.

The availability of the town represented an extraordinary circumstance, allowing to use it as a real laboratory for the empirical observation of mechanical phenomena, the application of theoretical models on real case studies and the experimental testing of intervention techniques. The whole research project has been based on an integrated approach to the structural rehabilitation, including architectural and structural analysis, experimental activities, safety assessments, and the formulation of models able to guide the rehabilitation interventions. The proposed research project has found a natural place within an informative system (GIS), that is a well known tool
for territorial and urban planning applications. It is particularly suitable for organizing and managing any kind of information on a cartographic support and building a systematic and easily intelligible common base. An innovative methodological approach is sketched, where the necessity of endowing the structural rehabilitation process with a scientific and systematic nature is reconciled with the need to respect the nature and the history of historic structures, and the technical action is organically integrated within an interdisciplinary path. In this sense, a central point of the project has been the design and development of a Territorial and Urban Informative System aimed at the organization and management of urban re-qualification process, with a particular stress on geotechnics and structural safety aspects.

The Geographic Informative System has been first designed from a general, methodological and organizational standpoint, using the basis provided by the Arcview Platform. Thereafter, field data and information have been progressively introduced, whereas specific algorithms for structural vulnerability analyses and landslide assessment have been implemented. In this context, GIS technology has provided a powerful tool for exchanging information; displaying inputs and outputs on GIS-based maps, and experimenting different damage scenarios.

1.2 A short presentation of the case study and the activities performed

The context in which Laino Castello is located is typical of the Italian territory, characterised by a severe seismic risk and by a large presence of masonry residential housing, endowed with a high degree of vulnerability. Besides, it is characterized by the presence of relevant slopes (50-60 %), with a quasi-vertical urban structure and buildings very close to the cliffs. The stability of the single building is very often strictly dependant on the collaboration with the adjoining structures. This peculiar urban configuration makes the town particularly weak with respect to superficial land slides and rock falls, in the presence of a bad water draining and of a possible interaction with the seismic hazard.

Figure 1 : General view of Laino Castello.
The activities performed during the research project have been organized according to the following scheme:
1. Preliminary historical understanding of the site and its architectures. Characterization of the urban context and constructive techniques.
2. Design and implementation of a Urban and Territorial Informative System for the registration and management of the collected information and data.
3. Landslide Risk Assessment and remote monitoring of mountainsides stability.
5. Development of simplified overall numerical/analytical models for the analysis and assessment of the safety level and for the prediction of damage distribution tuned on the experimental data gathered from the tests and on the detailed constitutive modelling.
6. Definition of protocols for the assessment of the safety level of the buildings and of guidelines for the rehabilitation, suitable for a professional use and for an extension to the local technical codes.
7. Definition/calibration of innovative techniques for the diagnostics; characterization of masonry, constitutive identification and validation of the proposed methods through laboratory and on site testing (on buildings, specimen or scale models).
8. Proposal of techniques for the repair and strengthening both of the structural elements, the structural joints and the whole buildings.

In this paper, an overview of the most significant results attained will be given, focusing in particular on points 1-4.

2 CHARACTERIZATION OF THE SITE AND ITS ARCHITECTURES

The first aspect that has been faced was the preliminary historical understanding of the site and its architectures (the importance of these aspects for a correct management of rehabilitation is widely recognized): diachronic analysis of typologies, masonry textures, structural elements, building layouts, nature and use of materials, interactions within the fabric of the town. In this way, a common base of knowledge has been provided for the successive work.

On site investigations have been performed, collecting and selecting many different data: historical information, territorial, urban and architectural data (hydrology, geology, seismicity, cadastral maps, historical maps). This information has been integrated and completed through specific surveys and on site investigation, selecting the most interesting and significant buildings.
Then, all the available material has been stored and organized (cartography, drawings and maps, historical studies) within the Urban and Territorial Informative System, constructing a wide inventory of architectural types, structural elements, materials, constructive details.

Figure 3: General survey of the buildings of the town.

Figure 4: Detailed survey of one of the building: 3D reconstruction

On selected buildings, more detailed investigation have been performed (geometrical and structural survey at a small scale, identification and classification of materials, structural elements, constructive techniques, details and nodes, decorative aspects, cracking patterns, and damage mechanisms).

The GIS interface has been a fundamental tool in this phase, in order to manage and process the innumerable data involved. On a general scale (the territory and the city) this allowed the construction of different thematic maps and analyzing a number of aspects: structure of the urban fabric mesh, morpho-typological process, organization of the buildings and interaction within the city, location of specialized buildings, typological classification.

On the small scale of the individual building, diachronic study and classification of constructive systems and techniques, masonry types, structural elements have been performed. Moreover, the conditions of masonry structures with respect to deterioration, damage and stability
have been inspected and documented. Results have been summarized in abacuses, where a significant record of cases is provided about the different aspects of traditional constructive techniques:

- Masonry (historical, typological and mechanical features)
- Typological classification of residential housing
- Floor systems
- Structural and constructive nodes
- Door and window frames
- Stairs, decorations, tiles.

Figure 5: An extract from the masonry abacus (left) and from the abacus of the floor systems (right).

3 STRUCTURAL VULNERABILITY AND LANDSLIDE RISK ASSESSMENT

3.1 Assessment and monitoring of geological risk

An important phase of the research has concerned the assessment and monitoring of the geological risk. Using the available geological and geotechnical data, the actual stability and safety of the site has been verified, with the support of the remote satellite monitoring technique for the control of the movements of the soil, which indicated a substantial absence of significant subsiding of the mountainsides.

At the same time, the landslide risk assessment has been performed through the implementation of semi-qualitative algorithms, able to provide an overall estimation of soil instability induced by biasing factors (represented by proper thematic GIS maps).

In order to estimate the landslide risk, a semi-qualitative approach has been adopted, based on the mapping of slopes, lithology and historical landslide events. The interaction among these factors has been modelled within the GIS platform, by dividing the territory in a number of reference areas on which the biasing factors are properly weighted, and a final judgement on the susceptibility to landslides is formulated.
3.2 Structural Vulnerability Assessment

General procedures and operational tools for multi-level vulnerability assessment have been developed. This included the definition of a I level seismic vulnerability assessment, based on poor data, commonly available at the urban scale, and of a II level one, based instead on typological, observational and mechanical data. In both cases, specific forms and procedures for data retrieval were developed. The above mentioned procedure were then applied on the buildings of
Laino Castello, implemented in the GIS and elaborated, providing a description in terms of vulnerability, damage and scenario maps.

Also a very detailed level of analysis has been applied on specific buildings, on which extensive diagnostics activities (of traditional and innovative kind – basically a new set up of flat jack test) have been carried out, in order to tune the experimental methods and provide the needed mechanical characterization for the materials and structural elements. In fact, for this buildings, the seismic verification according to Italian technical codes, through a pushover analysis has been performed.
3.3 Conclusions: use of GIS in Risk Assessment

The GIS system has been used as a valid tool for the structural and geotechnical safety, in which both models for the structural vulnerability assessment and for the landslide susceptibility. By using the information implemented in the associated database, it has been possible to generate thematic maps both simply descriptive (vulnerability index, damage level, distribution of the parameters) and specific elaborations such as damage and risk scenarios for the presentation of the results.

Figure 12: Damage scenario for different macro-seismic intensities (left), and mitigation scenario (right) under certain hypothesis of strengthening.

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