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The road map for seismic risk analysis in a Mediterranean city

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ABSTRACT

The seismic risk analysis evaluation in the Mediterranean area is one of the main tasks for the preservation of Cultural Heritage and for the sustainable development of Mediterranean cities. The Mediterranean area is characterised by a medium–high level of seismic risk, so that earthquakes are the major cause for the destruction of monuments, residential and industrial buildings. A case history regarding the seismic risk analysis for the city of Catania (Italy) is presented, since the city has been heavy damaged in the past by strong earthquakes such as the 1169 earthquake (XI MCS), the 1542 earthquake (IX MCS), the 1693 earthquake (XI MCS) and the 1818 earthquake (VIII MCS) etc., which caused several thousands of deaths. Fault modelling, attenuation laws, synthetic accelerograms, recorded accelerograms and site effects are considered for the evaluation of the seismic action. Vulnerability of physical environment, related to the presence of cavities and to seismic-induced landslides and liquefaction has been analysed, with special reference to the new modelling of such phenomena and to the application of models to given areas. Soil–structure Interaction has been analysed for some geotechnical works, such as shallow foundation and retaining wall, by means of physical and numerical modelling. The paper deals with the vulnerability of physical environment (landslides, liquefaction, etc.), while the road map continues with the analysis of vulnerability of monuments and buildings, with the aim of the estimation of the seismic resistance required to defend against the seismic action given by the scenario earthquake. For the mitigation of seismic risk, structural improvements of R.C. buildings with different methodology and techniques have been analysed, as well as the guideline for the strengthening of buildings. The work shows that the seismic risk of the city is not a summation of the seismic risk of each building, because the vulnerability of the urban system plays an important role on the seismic risk evaluation of a given city. To this aim the vulnerability of the road infrastructures, lifelines, and urban framework have been also analysed in the project.

1. Introduction

The main research activities of the Research Project for the mitigation of the seismic hazard of the Catania city have been related to: characterisation of the expected ground motion and site effects; vulnerability of physical environment, road infrastructures, and urban system; vulnerability and seismic structural improvement of buildings to prevent damage. For the characterisation of the expected ground motion and the evaluation of site effects and vulnerability of physical environment, the research activities and goals to be achieved are reported in the following.

The main goals for the characterisation of the expected ground motion and site effects have been: source modelling of the Scenario Earthquake; detailed geological survey and geological mapping of the urban area of Catania; noise measurements; site effects evaluation; and synthetic accelerograms at the surface and at a given depth (bedrock).

The main goals for the vulnerability of physical environment, road infrastructures and urban system have been: test sites including borings located at the relevant sites; in situ tests performed inside boreholes, undisturbed sampling and laboratory tests in the dynamic field for detecting soil non-linearity behaviour; updating soil dynamic parameters and geotechnical mapping, including all borings, all geophysical measurements and all in situ and laboratory test results; seismic microzonation of the urban area of Catania; modelling of the vulnerability of slopes to the Scenario Earthquake and application of the model to the Monte Po landslide behaviour, located in the urban area of Catania; modelling of liquefaction including instability due to lateral spreading; evaluation of soil–structure interaction; survey of cavities under the Catania area and implementation of a database of detected cavities; road infrastructures vulnerability, including evaluation of seismic instability of slopes, embankments and retaining walls, which can cause interruptions on the road system; urban system vulnerability evaluation.

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Although the analysis of the vulnerability and seismic structural improvement of buildings to prevent damage are outside of the aim of this paper, however, the main goals to be achieved by the road map for seismic risk analysis are: assessment of the construction typology, identification tests and evaluation of vulnerability and earthquake resistance of monumental buildings; evaluation of building vulnerability and earthquake resistance for the most common construction typology of R.C. buildings; evaluation of critical acceleration, for limiting state serviceability vulnerability for most common construction typology of R.C. buildings; remedial works for most common construction typology of R.C. buildings with traditional and innovative techniques; Code of Practice for the improvement of the most common typology of R.C. buildings; transfer of the Code of Practice to the Municipality and other Institution; transfer of the Code of Practice to the Engineers and to the Technicians; transfer to the Municipality office a Land Information System (LIS) database of all the results obtained by the Research Project; criteria for priority on the remedial works execution.

2. Characterisation of the expected ground motion and site effects

The goal to be achieved has been to provide an alternative characterisation of sources of the January 1693 event, which might suggest a modification of the current seismic zoning of the SE Sicily area. The geological, geophysical and laboratory investigations performed provide additional constraints to the surface geological setting of the area as well as to the parameterisation of the physical models. Numerical simulations have been applied with the twofold aim of estimating strong ground motion scenarios for different earthquake hypotheses and evaluating the effectiveness of 1D non-linear and 2D linear methods for the estimation of the local response.

2.1. Characterisation of earthquake sources

An updated intensity database has been inverted automatically, to improve the source characterisation. After treating, by the grid-search technique, various macro-seismic intensity data sets of the two destructive earthquakes of 1693 in SE Sicily, automatic inversions of two updated intensity databases by Barbano and Rigano [1] have been performed. The principal geometric and kinematics source parameters of events have been retrieved by the inversion procedure. The January 9th and 11th, 1693 sources–constrained by the inversions–form a NNE-oriented segmented fault, approximately 60 km long. In conclusion, the retrieved inland complex fault is steeply dipping towards ESE, or WNW, with rupture mechanism from pure strike-slip to 50% strike-slip and 50% dip-slip. This active structure would cross SE Sicily from the Hyblean Plateau to the coast of the Ionian Sea, south of the city of Catania. At the limit of the negative error of the dip angle at a value of 54° makes the line source for the January 11th event compatible with the trace of the Scicli-Ragusa-Monte Lauro active strike-slip fault found in the field, which outcrops 12–14 km to the west.

This study shows that not all features of the January 1693 events have been completely understood. For instance, as a result of another GNDT project "Evaluation of Geological Hazards in the Seas around Italy: earthquakes, Tsunamis and Submarine Slides" [2] show that the Iblean-Maltese fault system has a very complex structure, and although the principal extensional fault (about 50 km long) can be associated to the 1693 event, it should be also emphasized that the partitioning between the different fault styles, as well as the seismogenic potential of each structure, is still to be established. This research provided an alternative characterisation of the reference source commonly associated to the January 1693 earthquakes, and the aim was not to provide an alternative reference earthquake for the ground motion modelling, but rather to provide suggestions for updating the seismogenic zones of SE Sicily.

The main goal for the characterisation of earthquake source has been the deterministic approach for modeling of the scenario 1693 Val di Noto earthquake, while more often up to now the scenario earthquake is evaluated with a probabilistic approach, as reported by Cornell [3] for San Francisco Bay Region, by EERI committee on seismic risk for Los Angeles area [4], by Das et al. [5] for North–East India, by Càceres Calix for the Northern Central America [6] and by Shedlock [7] for the North and Central America and the Caribbean.

The authors believes that the probabilistic approach could be used for seismic action evaluation over large areas such as large countries (China, India, America, Caribbean, etc.), while deterministic approach should be used for smaller areas such as cities (San Francisco, Los Angeles, Catania, etc.).

The 2D Spectral Element Method (SPEM) has been performed for the 2D simulations. The investigated sites are located along transept T_{01} (see Fig. 1), the same which was used for the simulations of the destructive 1693 Val di Noto earthquake in the studies of the first Catania Project [8,9]. The shallow structure of the model has been defined in detail at the seven test sites using all the available geotechnical data (Fig. 2). Seismograms have been computed at several depths (Fig. 3), starting from the ground surface in order to study the wave-field propagation through about one hundred meters of soil. The source is located along the northern segment of the Ibleo-Maltese fault and has pure normal mechanism. The extended source, defined through five elementary point sources, reproduces the rupture propagation along the fault segment and the heterogeneous distribution of the seismic moment along the fault in an approximate way. Different source ruptures have been evaluated, to take into account the uncertainties associated with the source, as well as the uncertainties linked with the attenuation, soil properties and soil effects. A good example of uncertainties linked with this aspect is reported by Oliveira [10], with reference to the scenario earthquake for the Region of Lisbon. For the Catania scenario earthquake, the different source models lead to an evaluation of seismic action at the bedrock ranging between 0.08 and 0.20 g.

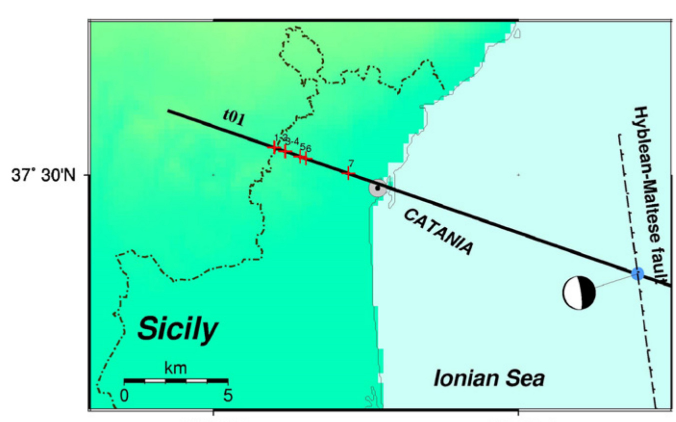

Fig. 1. Base map of the study area, showing the transept position and the sites location. The blue circle shows the position assumed for the reference earthquake of January 11th, 1693.