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Effectiveness analysis of a semiactive base isolation strategy using information from an early-warning network

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ABSTRACT

In this paper the possibility to manage data transferred by a Seismic Early Warning network to protect from collapse Base Isolated strategic structural systems by using semiactive devices has been investigated. In particular, by estimating the frequency content of the incoming seismic signal recorded at the accelerometric stations using a Fast Fourier Transform (FFT) technique, a new approach is proposed to estimate the seismic demand of the structure to be protected in order to eventually modify its mechanical features by means of semiactive devices. The analysis concerns a Base Isolated benchmark system equipped with semiactive devices located at the isolation layer, capable of modifying both the stiffness and damping of the overall structural system.

The effectiveness of the proposed strategy has been tested on varying the "anticipation time", namely the range of the time interval between the start of the seismic data elaboration by the recorded stations and the arrival of the seismic S-wave to the interested site, the added stiffness and damping resources, as well as by taking into account different seismic input signals.

The results highlight the practical feasibility of the proposed strategy as well as the critical role played by the considered parameters on the performance of both the isolation level and superstructure. This work has to be intended as a first contribution concerning the potentiality of the Early Warning applications in reducing the seismic risk in built environments.

1. Introduction

Despite the progress recently made by the scientific community, the research on earthquake prediction is still to be considered in a development phase. It is generally accepted that no theoretical approach is nowadays available to forecast the position, magnitude and time of occurrence of a seismic event in a specific area. These spatial and time uncertainties represent the greatest aleatority in seismic engineering, with it also being the main reason why both people and administrative institutions generally tend to underestimate the seismic risk. Recent studies have highlighted how, despite the introduction of new and more advanced seismic provisions, the seismic risk in urban areas is constantly growing [1,2] due to the high vulnerability of the modern communication network as well as the growing complexity of all the systems on which the anthropic activity is based.

The aim of the modern informative seismic system is to estimate, in the shortest time possible, some critical parameters of the occurred event: time, position, magnitude, main features of the ground motion (peak acceleration, velocity and displacement, spectral amplitude, energy content), in order to efficiently address and plan the first aid operations as well as immediately set up the essential services.

This is the context in which the possibility to use advanced seismic protective measures on real time (Real Time Seismic Engineering) has moved from a theoretical speculation to a practical solution in the last years. It is nowadays possible to give a reliable warning to the population about when a seismic event will strike their territory in the next tens of second so as to automatically stop potentially dangerous activities (nuclear plants, high velocity train, construction site, etc.) when the alarm is given. All these measures can drastically reduce the social impact of a seismic event.

The idea of setting up a network system capable of giving a quick response to the need related to a seismic event occurrence is not recent. However, due to the technological and technical progress made in the last years, this idea has become practicable. At the moment, different Early Warning networks operate throughout the world: the "Urgent Earthquake Detection and Alarm Systems" in Japan, which includes more than 1000 seismometers and had a key role in saving lives during the recent Tohoku earthquake event, the "Seismic Alert System" (SAS) to reduce the social impact of the next earthquake events in the Mexico City area, the "Seismic Monitoring System" (SMS) to protect the nuclear plant in Ignalina (Lithuania), the Earthquake Rapid Response System" (ERRS) in

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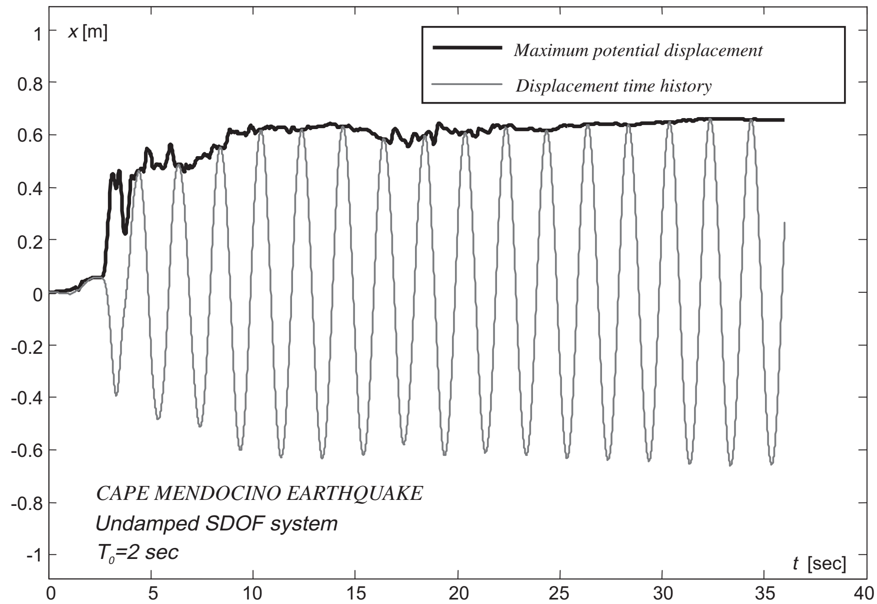

Fig. 1. Fourier spectra amplitude and time–history comparison.

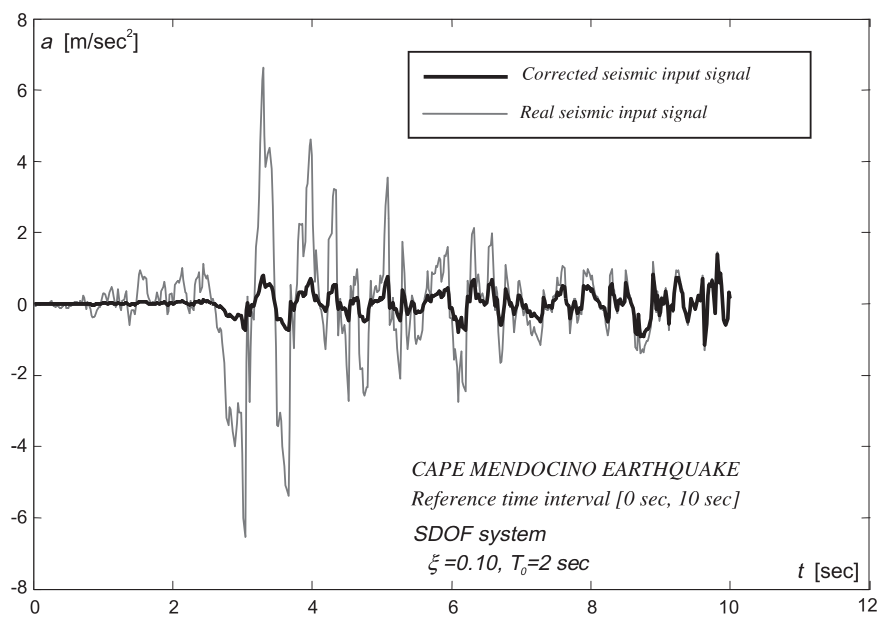

Fig. 2. Real and corrected seismic signals comparison.

Taiwan, the Rapid Earthquake Data Integration'' project (REDI) in North California and finally the ''Campania Region Seismic Network'' in Italy. All these protective networks were designed with the aim to make available, in a very short time after the event, a number of measures to reduce the social and economical losses.

The original Early Warning scheme idea foresees a number of seismic stations surrounding the site to be protected at a given distance. When an earthquake occurs, the stations detect the seismic signal and release an alarm to the site management. Due to the transmission of seismic waves in the soil being affected by dissimilar media, data of various stations should be cross-analyzed to reduce deviations. High-density seismic stations can improve the accuracy of estimations, however this elaboration phase is time consuming and can therefore only be used to protect areas far from the epicentral zone. In such cases, the higher speed of the electromagnetic signals compared to the seismic waves still leaves a margin, namely ''anticipation time'', to switch onto safety mode strategic and critical buildings which have to be operable for emergency management purposes. This approach is generally named as a ''regional early warning strategy''. Contrarily, an ''on site early warning strategy'' consists of a single seismometer located close to the system to be protected, it detects the arrival of the P-waves and processes them in order to estimate earthquake-related warnings. In this case, since the data of only one on-site seismometer is used, the calculation time is greatly reduced providing rapid earthquake response [3]. Recent studies [4] have shown that information carried by P-waves can be processed in real time, thus leading to a probabilistic distribution of magnitude and source-to-site distance. Similar procedures have been subsequently proposed for intensity measures as peak ground accelerations [5], peak ground velocities [6] and Fourier amplitude spectra [7].