Composites Part B 108 (2017) 190–199

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

Structural failures due to anthropogenic sinkholes in the urban area of Naples and the effect of a FRP retrofitting

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ARTICLE INFO

Article history:
Received 15 August 2016
Received in revised form
12 September 2016
Accepted 14 September 2016
Available online 28 September 2016

Keywords:
Defects
Fracture
Stress concentrations
Computational modeling
Damage mechanics
FRP retrofitting

ABSTRACT

This work is about the hypothesis of structural health monitoring of architectural heritage in masonry exposed to collapse risk in the city of Naples. We analyze the collapse mechanisms in static terms relating the planimetric layout of the underground cavities of Naples with some recent collapses of structures that occurred in the city. The present work focuses on the relationship between these collapses and the presence of underground cavities. Constructions in masonry, contrary to common opinion, are structures that provide comparatively level of safety depending on to the strength of materials and construction techniques adopted, together with the fact that they are able to settle and to find a new equilibrium configuration; in other words they embody the prototype of resilient structures. The main critical issue able to put in crisis a huge masonry building is the subsoil subsidence. In fact, the structure reaches the collapse for the creation of cavities or chasms under it, which literally remove the support surface of its foundation. In particular, the present work aims to analyze the collapse of two buildings of the Department of Veterinary Medicine of Federico II, that occurred in Naples last December and, starting from a real case of the collapse of a masonry building, the research aims to correlate this collapse with one of the cavities present in the subsoil of Naples and evaluate the possibility that the cause of the collapse to be related the corresponding cavity (or to a newly formed) situated below a corner of the building. The effect of a possible retrofitting intervention, consisting in three FRP strips glued to the surface of the structure, is also considered.

1. Introduction. Neapolitan underground: resource or risk?

Neapolitan territory is one of the Italian urban areas characterized by the presence of one of the most widespread network of underground cavities. The goal of this research is to understand if, and how, the cavities in the subsoil of Naples really affect sudden collapses of buildings on the surface. Are these cavities a main risk factor? Since a large part of the Neapolitan subsoil consists of tuff rock, we can say that the presence of these cavities do not involve problems related to sudden subsidence; in presence of cavities, the real problem is the interaction of water with other materials that constitute them (e.g. layers of vegetable ground and lapilli) [1]. In every city around the world, when the water interacts with the materials in the subsurface, impregnates them, creates a constipation of the same, small depressions and, more often, comes to light on the surface; a fast action can prevent the worsening of the depressions of the soil and yielding of artifacts. In Naples this does not happen, precisely because in its subsoil there are also cavities and thousands of wells, whereby the water, which basically tends to move downwards, always finds a preferential way towards a well and, in it, washes out the loose material overlying the tuff, creating inverted cones that become evident on the surface with pits in which most of the time the buildings are involved. The problem, therefore, arises when the water that flows in the subsoil runs through spaces where there is no rock, or there is the soil [2]. In Fig. 1, some examples of the misuse of the soil that represents the real risk factor for the city are reported; on the right, some cavities used as a garage or rainwater that from the sewers comes down to the cavities and that can be the causes of the creation of sinkholes, are shown.

Recently happened in Naples the sudden collapse of a historical building at Riviera di Chiaia (Fig. 2), whose collapse occurred because of the excavation for the construction of the new

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http://dx.doi.org/10.1016/j.compositesb.2016.09.043
1359-8368/

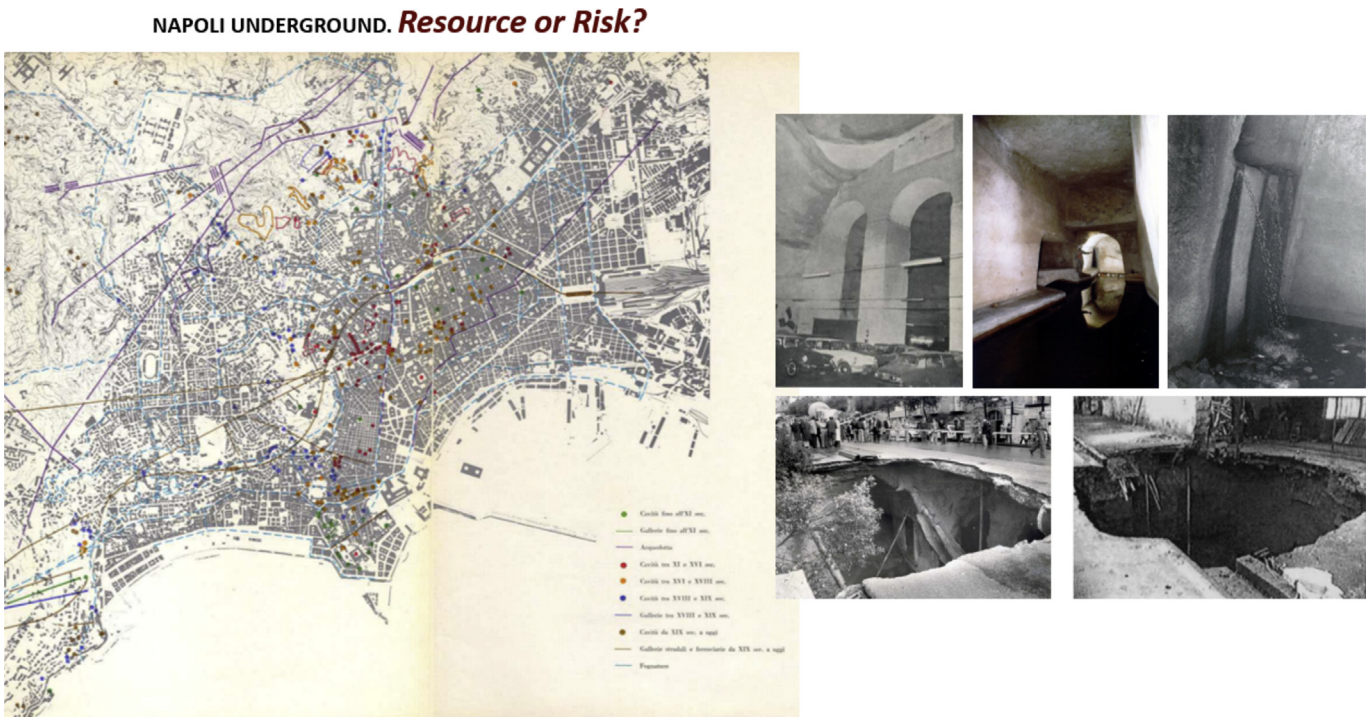

Fig. 1. Map of cavities in the city of Naples and, on the right, pictures of cavities and sinkholes. (From "Il sottosuolo di Napoli", Relazione della Commissione di Studio, a cura del Comune di Napoli – 1967.)

Fig. 2. Collapse of the building at Riviera di Chiaia, Naples.

underground tube line; by during the tunnel, the water has filtered into the cavity, the ground was completely transported from the water and, lacking the support to the building, the collapse of the structure was produced.

In Campania Region, in Italy, historical and recent ground failures are well known, also in urban settings, which can be ascribed to either the presence of underground cavities or to piping sinkholes. The term "sinkholes" tends to identify any subsidence or collapse, both natural and anthropogenic. Sinkholes are phenomena that affect the entire national territory, even if in different way. According to the data IPSRA (Higher Institute for the Protection and Environmental Research), Rome and Naples are the most exposed cities to Subsidence risk that threaten urban centers occurring in a sudden and devastating way. The picture below (Fig. 3) represents a site plan with the distribution of sinkholes in the city of Naples.

As case studies for the analysis of sinkholes effects the collapse of two buildings of the Faculty of Veterinary Medicine of Federico II, that occurred in Naples last December is considered.

2. The case study of the department of Veterinary Medicine of Naples

2.1. The building collapse

On December 9, 2015 two buildings located between Via Federico Delpino and Santa Maria degli Angeli alle Croci, namely the