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Seismic hazard assessments at Islamic Cairo, Egypt

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ABSTRACT

Islamic Cairo is one of the important Islamic monumental complexes in Egypt, near the center of present-day metropolitan Cairo. The age of these buildings is up to one thousand years. Unfortunately, many of the buildings are suffering from huge mishandling that may lead to mass damage. Many buildings and masjids were partially and totally collapsed because of 12th October 1992 Cairo earthquake that took place at some 25 km from the study area with a magnitude Mw = 5.8. Henceforth, potential damage assessments there are compulsory. The deterministic and probabilistic techniques were used to predict the expected future large earthquakes' strong-motion characteristics in the study area. The current study started with compiling the available studies concerned with the distribution of the seismogenic sources and earthquake catalogs. The deterministic method is used to provide a description of the largest earthquake effect on the area of interest, while the probabilistic method, on the other hand, is used to define the uniform hazard curves at three time periods 475, 950, 2475 years. Both deterministic and probabilistic results were obtained for bedrock conditions and the resulted hazard levels were deaggregated to identify the contribution of each seismic source to the total hazard. Moreover, the results obtained show that the expected seismic activities combined with the present situation of the buildings pose high alert to rescue both the cultural heritage and expected human losses.

1. Introduction

In areas prone to earthquake risk, it is preferred to implement mitigation strategy based on seismic hazard assessments. This strategy will provide information to improve building design and construction. Seismic hazard assessments may be defined as the modeling of expected ground motion at the ground surface due to future earthquake activities at the site under investigation. The modeling process can be conducted using either deterministic or probabilistic approaches. A basic deterministic seismic hazard assessment DSHA is a simple process that is useful especially where tectonic features are reasonably active and well defined. The focus is generally on determining the maximum credible earthquake (MCE) motion at the site (Rodgers and Mahin, 1999–2000). Probabilistic seismic hazard assessment, on the other hand, is introduced to community by Cornell (1968) and has become a standard method widely used and accepted worldwide. It is a method developed to produce, for the engineers, the desired relationships between ground-motion parameters as Modified Mercalli Intensity, Peak-Ground Velocity (PGV), Peak-Ground Acceleration (PGA), etc., and their average return period for the site of interest.

The area under study in the present work is characterized by the presence of ancient and monumental structures that are still in daily use as urban facilities for praying, industry, as well as private dwellings. Many of the buildings there range from a few to several hundred years in age. In general, the present status of the buildings is bad. Henceforth, this work is aimed towards estimating the expected ground motion parameters that could affect the area.

Islamic Cairo is currently an Aggregate of a number of ancient Islamic cities built nearby. Fustat was built by Amr Ibn El-'Ass at the start of Islamic era in Egypt. Fustat represents the oldest Masjid in Africa (Masjid Amr Ibn El-'Ass). Afterward, a number of nearby cities were inaugurated. Cairo itself was built after the Fatimid invaded Egypt more than 1000 years ago. The original city was surrounded by tall stone walls. By time Cairo expanded to include the other neighboring areas. Nowadays, Cairo is a big metropolitan

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area with a high-density population. The concern in the present work is directed to the part of Islamic Cairo that comprises Fatimid Cairo and some later structures related to both Memluk and Ottoman eras.

In the near vicinity of the Greater Cairo area, earthquake activities are commonly observed. Low to moderate earthquakes (with magnitudes seldom exceeds 5) were observed in the vicinity of the study area. On 12th October 1992, an earthquake with magnitude Mw = 5.8 shocked the Greater Cairo area. It caused widespread damage with human casualties exceeding 500 persons. Most of the damaged structures were concentrated in villages near the epicenter, nearby ancient Pharaonic monuments, and many buildings in Islamic Cairo. A number of archaeological Masjids were either totally or partly damaged. From the damage reported, such an event may be termed as the most damaging earthquake in Egypt's recent history. The effects of these nearby seismic sources, in addition to other seismic sources in Egypt and its surroundings, are considered in the processes of seismic hazard analysis in the present work.

2. Location

The center of the area under investigation lies at latitude 30° 02′ 45.24″ N and longitude 31° 15′ 44.64″ E (Fig. 1). Its area is about 1.0 km^2 characterized by narrow crowded streets and alleys (Fig. 2). The area was bounded by tall stone walls to protect the city from enemies. Geographically, the area is located to the east of present-day Cairo city center near the northern cemetery and Al-Azhar Park. Touristic places are also present like Khan Al-Khalily, Al-Azhar masjid and its ancient university campus.

3. Surface geology

Numerous researchers have studied the surface geology of area under consideration (e.g. Moustafa and Abdel Tawab, 1985; Moustafa et al., 1991; EGSMA, 1994 and NARSS, 1997). Islamic Cairo lies near the intersection of Mokattam Plateau and Nile valley alluvial deposits. For the Mokattam Plateau (Fig. 3), two formations are outcrops of Upper Eocene age. The first one is the Maadi Formation composed of soft clastic rock units (clay, silt and sand) in addition to hard dolomitic limestone. The second formation which consists of white fossliferous limestone with marl intercalation is the Giushi Formation. The study area is dissected by different structural elements, most of which have NWN–SES, E–W and NW–SE trends (Araffa, 2010). Said (1981) stated that geological studies yielded that the Nile has developed its course through the area after down faulting of huge limestone blocks extending between Mokattam Plateau in the east and Pyramid Plateau to the west (Fig. 4). Stratigraphy of these deposits comprises several hundred meters of alluvial layers underlain by stiff plastic clays that finally rest on the upper Eocene limestones. The Alluvial thickness is minimal since the area is located near to the shoulder of Mokattam Plateau.

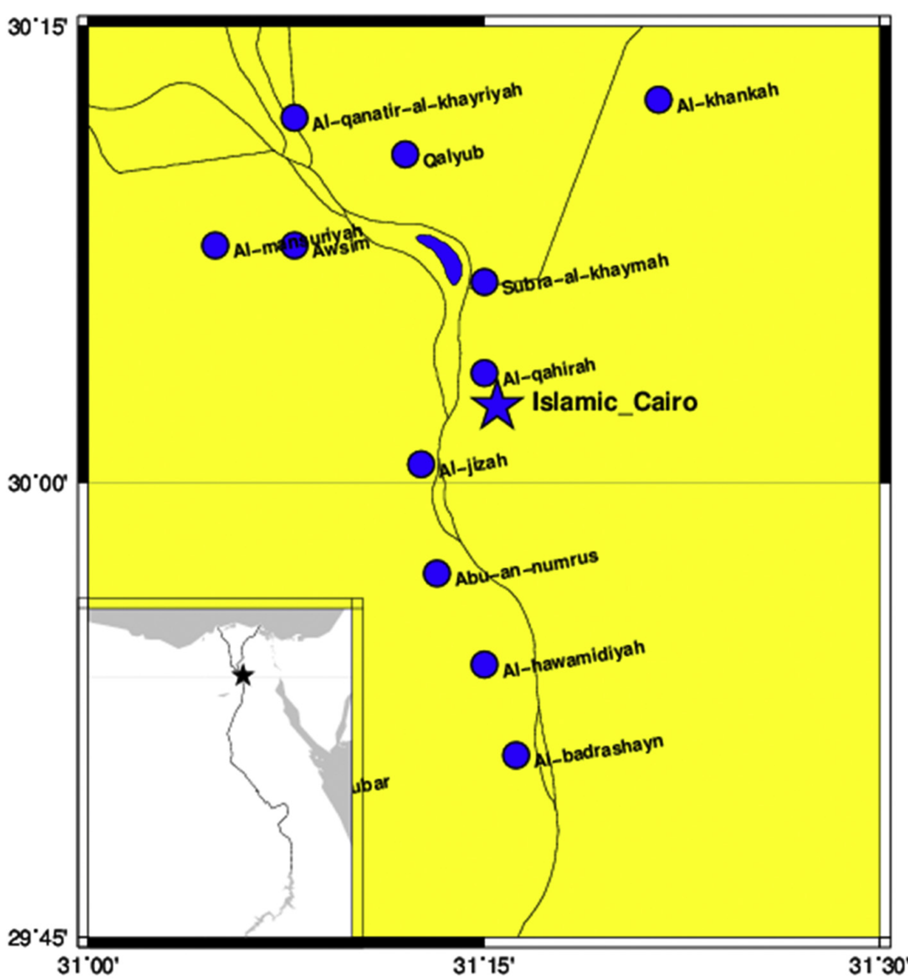

Fig. 1. Location map of the study area (map produced by GMT(Wessel and Smith, 2009)).