Abstract

In the Mediterranean coastal plain of Israel there are loose sands, a relatively shallow water table, and a probability of 10% within the next 50 years for seismic acceleration to exceed 0.09-0.15g, a range considered sensitive to liquefaction. Likewise, worldwide experience shows that liquefaction has occurred in places whose distances from the seismic source are similar to the distance of the coastal plain to the Dead Sea fault system. Thus, there is an apparent potential of liquefaction in the coastal plain. So far, no paleoliquefaction evidence were found in the coastal plain, but since this is a densely populated area and there are many infrastructure facilities as well as commercial and industrial centers, it is important to examine this hazard.

Here we assessed the geological, hydrological and seismological conditions existing in the coastal plain, in order to identify and delineate the zones where a geotechnical investigation is required for evaluating the liquefaction hazard. The study area included the coastal plain from the Mediterranean shore eastward to the foothills of the Judea and Samaria mountains, and from the Carmel coastal plain southwards to the northwestern Negev coastal plain.

From the hydrological aspect, it was found that the earliest recorded groundwater level of the coastal aquifer is that of the year 1934-5. Although it reflects a period of severe draught, it is still higher by several meters than the highest level ever recorded, which was measured in 1995, three years after the rainiest year known since the current operation of the aquifer was begun. Since no break in the routine operation of that aquifer is expected, the 1934-5 groundwater level seems to be the highest (shallowest) level expected, and thus was set as the reference level. Being conservative and in accordance with the common screening methods, it was now possible to identify all areas where the depth to the reference groundwater level is shallower than 20 m as vulnerable to liquefaction, and exclude all other places where the groundwater is deeper.

Examining the geology, several modes of potentially liquefiable materials were distinguished: a) artificial infill, usually not compacted, along the coastline and in reclaimed marine areas; b) beach sands along the coast; c) aeolian dune and sheet sands; d) loose and uncemented sand in the subsurface, interbedded within the kurkar (calcareous sand stone) units; and e) "light" hamra soil, which is a red sandy loam with a small amount of clay.

Cross-checking the geological, hydrological and seismological conditions in the coastal plain, enabled defining the areas sensitive to liquefaction, and grade their relative sensitivity:

Sensitivity 'a', high: areas of artificial fill, where construction activities were conducted, includes the ports and marinas in Atlit, Hadera, Netanya, Herzliyya, Tel Aviv-Yafo, Ashdod and Ashqelon, and other infrastructure facilities.

Sensitivity 'b', moderate: coastal sands, extending along the beach, from the water line to the base of the coastal cliff or to the first westernmost front line of the dunes. Many infrastructure installations are based in this area.

Sensitivity 'c', low: Holocene eolian dune and sheet sands, sensitive where depth to the groundwater level is less than 20 m. Where sand of this type overlies the coastal cliff or the kurkar ridges above the groundwater, it is not sensitive.

Sensitivity 'd', very low: Middle to Late Pleistocene sands that appear in the subsurface, in layers and lenses interbedded in between the kurkar layers, and as "light" hamra soils; in places where the depth to the referenced ground water table is less than 20 m, and independent of the surface geology (the probability of finding loose sands in the subsurface anywhere in the coastal plain is very high).

Sensitivity 'e', negligible: all the areas in the coastal plain where the depth to the referenced groundwater level of the coastal aquifer is greater than 20 m, regardless of the geology on the surface.

In general, the more sensitive areas are close to the sea, at sites of artificial fill (sensitivity 'a', high), and along the coastline ('b', moderate). The flat on top of the coastal cliff is much less vulnerable, unlike the strip between the cliff and the waterline. Low sensitivity ('c') appears where Holocene sands outcrop and the water table depth is less than 20 m. Least sensitive ('d', very low) are the troughs along the drainage basins of the main rivers and the sinks along the kurkar ridges, regardless of the surface geology, since the topography there is low and so is the depth to the water table. These areas gradually broaden northwards because the surface there becomes gradually lower, and thus the depth to the groundwater level becomes smaller. In all the remaining areas where the water table depth is greater than 20 m, there is no potential for liquefaction and therefore the sensitivity is negligible.

The present evaluation is preliminary and qualitative, aiming at pointing out the areas where threshold conditions for liquefaction exists and the occurrence of liquefaction cannot be ruled out. These are "zones of required investigation for liquefaction hazard". Therefore, for engineering and geotechnical purposes, a detailed quantitative examination is needed in order to investigate the specific geological, hydrological and seismological site conditions, and identify local artificial changes. For example, engineering development may change the local topography and therefore the depth to the groundwater; the groundwater level may fluctuate as a result of artificial penetration of water; some parts of the coastal plain may amplify seismic accelerations, beyond that foreseen by the Israeli Building Code (IBC-413).

The sensitivity map presented here constitutes an auxiliary tool in anti-seismic planning and mitigating strong earthquake effects. Integrating the sensitivity map and the appropriate regulations in planning programs may help planners take this hazard into account. Likewise, it will give the authorities suitable tools to plan, control, supervise and enforce what is required to deal with this seismic hazard.

This study was carried out within the framework of the governmental steering committee for earthquake preparedness in Israel.