Climate Change Adaptation and Natural Disasters Preparedness in the Coastal Cities of North Africa

Phase 1: Risk Assessment for the Present Situation and Horizon 2030 – Alexandria Area

National Workshop – Alexandria, 15-16 June 2010
2. Stability of natural grounds

Geology, geomorphology, seismology and tsunami

presented by

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Alexandria is built on a narrow coastal plain of Pleistocene carbonate sand ridges of 8-10m elevation.

These ridges extend westward parallel to the present coast.

The coastline is backed to the south by a series of different land use/land cover units:
- carbonate ridges
- Maryut lake
- inland depression
- Drain
- Desert
- Urban
- Industries
- Agricultures and Architecture
Main geomorphologic units

- 5 major units:

1- coastal plain:
  - Young plain
    - Degradation shore
    - Aggradations shore
  - Old plain
    - Inland ridges and depressions
    - Underwater ridges
  - Piedmont plain

2- Tableland

3- aggredational depressions
2. Stability of Natural Ground - Geomorphology

4- Deltaic plains

5- Brackish lagoons
- Maryut lake
- Idku lake

geomorphologic units of west of Alexandria
Inland ridges and depressions

1- Ridges

- run parallel to the coast in the backshore from Alexandria to Salum.
  
  - (1st coastal) ridge: from El Agami to El Salum, w: 400m, h: 20m, oolitic sand
  
  - (2nd El Max-Abu Qir) ridge: south of first ridge, w: 800m, h: 20-50m, chalky
  
  - (3rd Gebel Maryut) ridge: h: 35-50m
  
  - (4th Khashm El Eish) ridge
  
  - (5th oldest Alam Shaltut-Alam El Afrag) ridge

- These ridges are missing/deformed at some localities due to local structures and erosion
2. Stability of Natural Ground - Geomorphology

- Ridges represent ancient shoreline of Mediterranean during Pleistocene with elevation range: 10m-100m

- 2- Depressions
  - 1st "coastal" depression, is invaded by tidal sea water
  - 2nd "El Dekheila – Abu Sir" depression, is lying between 1 and 2
  - 3rd "Mallahet Maryut" depression
2. Stability of Natural Ground - Geomorphology

Coastal ridges and depressions
2. Stability of Natural Ground – Stratigraphy

**Stratigraphic units**

- The exposed rocks in the northwestern Mediterranean coastal zone are entirely of sedimentary origin ranging in age from Early Miocene to Holocene with a maximum thickness of about 200 m.

- The surface deposits in Alexandria belong essentially to the Quaternary which are:

  1- Holocene deposits
  2- Pleistocene deposits

- Tertiary deposits are represented as Pliocene and Miocene south of Alex.
2. Stability of Natural Ground – Stratigraphy

- Limestone with sand
- Undifferentiated sands and gravels
- Parallel Alexandria limestone ridges
- Beach carbonate sands
- Sabkha silt and clay
- Sabkha evaporites
- Nile silt
- Stabilized dunes
- Limestone with sand
- Longitudinal sand dunes
- Sand sheets
- Wadi deposits
- Exported Quaternary deposits

Legend:
- Export_quaternary code:
  - N2-Q1kl
  - Q
  - Q1al
  - Q2bs
  - Q2sb
  - Q2sd
  - Q2ss
  - Qb
  - Qds
  - Qg
  - Qns
  - Qw
- shore_500_000
- sea
Tectonic System

1- Alexandria is located approximately 300 to 600 km from three known active plate boundaries:

- Red-Sea
- Gulf of Aqaba – Dead Sea (the levant transform)
- Hellenic Arc (African- Eurasian margin)

Which created 2 major fault zones in Egypt:

- Eastern- Mediterranean Cairo-Fayoum zone (Pelusium strike slip fault)
- Suez-Cairo-Alexandria fault zone (low-medium seismic activity)

2- Afro-Arabic Platform contiguous with southern Alpine overthrust belt, megashear zone running from southern Turkey to Egypt, south of islands of Crete and Cyprus.

3- Nile Delta hinge cone consists of several southward half grabens
2. Stability of Natural Ground – Structure & tectonics

AEG = Aegean Sea
AI = Alexandria City
CY = Cyprus
ERA = Eratosthenes Seamount
FL = Florence
IB = Ionian Basin
MR = Medit. Ridge
LEV = Levantine Basin
LF = Levant Fault
RA = Ras El Hikma
MA = Marsa Matruh
JAK = Jebel AlAkhdar
2. Stability of Natural Ground – Structure & tectonics

**Structure System**

This system is a shallow structure dominating northern Egypt and the northern Red Sea and affecting only the sedimentary crust.

The part located in Egypt around the Nile Valley and Red Sea is the extension of the Najd Fault system in Saudi Arabia. Orientation and rate of relative plate movements are indicated.
Seismic hazard assessment

A. Some definitions:

- **Magnitude (M)**: quantify the amount of *seismic energy* released by an *earthquake* based on the maximum amplitude of the seismic waves.

- **Intensity (I)**: quantify the *effects* of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures. The intensity at a point depends not only on the size of the earthquake (*magnitude*) but also the distance to home, the local geology and topography.
2. Stability of Natural Ground – Seismology

A. Some definitions (cont.)

- **Peak ground acceleration (PGA):** measure of earthquake acceleration on the ground. It is not a measure of the total size of the earthquake, but rather how hard the earth shakes in a given geographic area (important for *earthquake engineering*). Expressed as g (*acceleration due to Earth's gravity*); m/s² or g

- **Peak ground velocity (PGV):** ground motion intensity, by assuming that the soil amplification is constant

- **Seismic hazard:** the study of *expected* earthquake ground motions at any point on the earth in a given time when building houses (to find the best or worst place to locate for earthquake shaking). Take into account site effects; lithology, topography and liquefaction of the ground.

- **Probabilistic evaluation of hazard:** the level of acceleration of the ground likely to be reached (cm/s² or g) for a given period of time
B. Major historical and recent Seisms

- Alexandria city has experienced about (25) damaging earthquakes spanning the period 320 to 2000.

- (9) of (25) are located local offshore of Alexandria with average magnitudes (Ms = 6.7) & intensity IX MSK scale & time of shaking (2-3) sec.

- Other (14) of (25) were located mainly in the Eastern Mediterranean region (i.e., Hellenic Arc), Ms (7.8) & intensity VI & time of shaking (>3) sec. The most sever events

- Events 320 & 365 AC were two of these destructive quakes destroyed 50,000 houses and killed 5000 people in Alexandria

- Events, which are located as far as the Red Sea and Gulf of Aqaba, are felt in Alexandria but without damage (ex.) 1969, 1995 , Ms (6.9, 7.3 respectively)
2. Stability of Natural Ground – **Seismology**

Location of historical and recent earthquakes
### Most well recorded earthquakes occurred in Egypt in the last Century (NGDC)

<table>
<thead>
<tr>
<th>Date</th>
<th>Hour time</th>
<th>location</th>
<th>Focal depth</th>
<th>Magnitude (Richter)</th>
<th>Earthquake effects</th>
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<tr>
<td></td>
<td></td>
<td>Name</td>
<td>Lat.</td>
<td>Long.</td>
<td>-</td>
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<tr>
<td>26/6/1926</td>
<td>Not defined</td>
<td>Lower Egypt</td>
<td>30</td>
<td>23</td>
<td>-</td>
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<td>12/9/1955</td>
<td>6:09AM</td>
<td>Mediterranean</td>
<td>32.2</td>
<td>29.6</td>
<td>-</td>
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<td>6:09AM</td>
<td>Mediterranean</td>
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<td>29.6</td>
<td>-</td>
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<tr>
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<td>6:09AM</td>
<td>Nile Delta</td>
<td>32.2</td>
<td>29.6</td>
<td>-</td>
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<td>31/3/1969</td>
<td>7:15AM</td>
<td>BeniSouef, Cairo</td>
<td>27.7</td>
<td>34</td>
<td>33</td>
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<td>32.6</td>
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<td>Cairo</td>
<td>29..8</td>
<td>31.1</td>
<td>22</td>
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<tr>
<td>22/11/1995</td>
<td>4:15:12 AM</td>
<td>Aqaba bay, Nuwayba</td>
<td>28.8</td>
<td>34.8</td>
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<td>24/8/2002</td>
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<td>Cairo</td>
<td>30.2</td>
<td>31.4</td>
<td>10</td>
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</table>
C. Deterministic hazard assessment

- Evaluation of seismic hazard is based on:
  - The catalogues of historical and instrumental seismicity
  - The characteristics of the strongest seism known in each individualized seismic zone
  - Geological knowledge of the crust and the cover

- El Sayed et al., 1999 estimated the PGA value for the coastal plain of Nile Delta between \(0.15g - 0.3g\) and only until \(0.02g\) in the south of this coastal zone.

- Global Seismic Hazard Assessment Program (GSHAP) generated global hazard map to indicate PGA likely to be reached during one period of 475 years (or 10% probability of exceedance in 50 years).
2. Stability of Natural Ground – Seismology
C. Deterministic hazard assessment (Cont.)

- Project Seismo tectonics and Seismic Hazard Assessment of the Mediterranean Basin (SESAM), 2001:
  - A unified seismogenic source model for the Mediterranean basin, each zone is characterized by the M – frequency parameters and PGA
  - For Egypt, the results found by GSHAP and SESAME are very closed. Concerning the map of PGA calculated for one period of 475 years (what corresponds to a probability of occurrence of 10% in 50 years or, less than 5% in 20 years), the values found for the Alexandria area are between 0.06g - 0.1g.
New source geometries in the SESAME unified source model for the Mediterranean

Seismic Hazard Map

Exceedance in 50 years

Ground Acceleration (g)

Soil

12 0.25 0.50 1.00

m/s² 0.2 0.3 0.4 0.5 0.6 0.7 0.8 1.0 1.3 1.6 2.0 2.5 3.0 4.0 6.0 8.0 m/s²
El Sayed et al., 2004 estimated that for Alexandria offshore sources (approximately 100 km), seism's magnitude (Ms) can reach 6.7 and produce (PGA) 0.3g near the coast which is corresponding to intensity VIII-IX (M_r=6.9-7.0).
D. Seismic scenario for Alexandria

Two assumptions are possible:

1. According to El Sayed et al., PGA is between $0.15g - 0.3g$ for a 475 years return period & between $0.07g - 0.1g$ for a 50 years return period.

2. According to GSHAP / SESAM work PGA is between $0.06 - 0.1g$ for a 475 years return period.

To take into account the possible site effects, analysis should consider the zones characterized by thick unconsolidated or soft sediments, and, for these zones, increase $1(\pm 1/2)$ intensity value deduced from PGA’s.
D. Seismic scenario for Alexandria (cont.)

- According to USGS findings (relation between PGA and PGV) **without taking into account local geological conditions which could amplify seismic motion (site effects)**:
  - PGA ranging between 0.15 g and 0.3 g, the intensity is about VI to VII.
  - PGA ranging between 0.06 g and 0.1 g, the intensity is about V to VVI.

USGS table provides near-real-time maps of ground motion (PGA and PGV) and shaking intensity.
D. Seismic scenario for Alexandria (cont.)

Conclusion on selected Scenarios

- For a 475 years return period (VI) (MSK intensity), and about (VII) in the zones with site effects.

- For a 100 years V-VI, and about VI-VII in the zones with site effects.

- For a 50 years V to V-VI, and about VI to VI-VII in the zones with site effects.

- For a 20 years IV-V to V, and about V-VI to VI in the zones with site effects (zone between quaternary coast deposits and south Pliocene Hagif formation)
Some of damaging historical tsunamis (e.g. 1303 and 1481) in the eastern Hellenic arc also threatened the coastal plains of the Cyprus, the Levantine and Alexandria – Nile Delta regions.

In Egypt, the vulnerability of tsunami occurrence in recent years is much more than those damaging recorded tsunamis, due to coastal economic development and increasing occupation of the coasts.

The two most destroying known tsunamis for Alexandria were generated in Hellenic arc 365 and 1303 with magnitude of seisms that generated tsunami: 8.4 and 7.3 respectively.
2. Stability of Natural Ground – Tsunami

Location of historical Tsunami
For the coast of north of Egypt, 3 potential tsunamigenic zones exist: the west part of Hellenic arc, the East part of Hellenic arc, the Levantine sea. The zones of Hellenic arc are associated with a high potential.
Based on historical data, the average tsunami recurrence in the Cyprus- Levantine Sea region is roughly estimated to be around (Fokaefs et al., 2007):

- 375 years for very strong intensity (5 SA / 8 PF); SA: Sieberg – Ambraseys scale; PF: Papadopoulos -Fokaefs scale
- 120 years, for strong intensity (3 SA / 5 PF)
- 30 years for moderate intensity (2 SA / 3 PF).

Shaw et al. (2008) calculated a 800 years period of return for these very strong destroying tsunamis generated in the Hellenic arc and of type 365 or 1303.

This estimation correspond to:

- **12%** of probability of occurrence in 100 years,
- **6%** in 50 years,
- **Around 2,5%** in 20 years.
Thank you