Ocean Acidification and Climate Change Geohazards on Artificial Islands: A Focus on Liquefaction Susceptibility

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Abstract

The soil materials used for UAE artificial islands are described as Calcareous sand, which is formed from the skeletal remains of corals, shells and algae from the upper waters of the ocean. the typical carbonate content of this sand is in the order of 90%. The ocean acidification and sea level rise are climate change induced features that may increase the serviceability of the artificial islands from geotechnical perspectives. The triggered micro-seismic effect may increase the liquefaction susceptibility. The purpose of the current research is to evaluate the liquefaction potential with considering effect of these phenomena, and suggesting a know-how practices during the construction to improve the islands sustainability.

Introduction

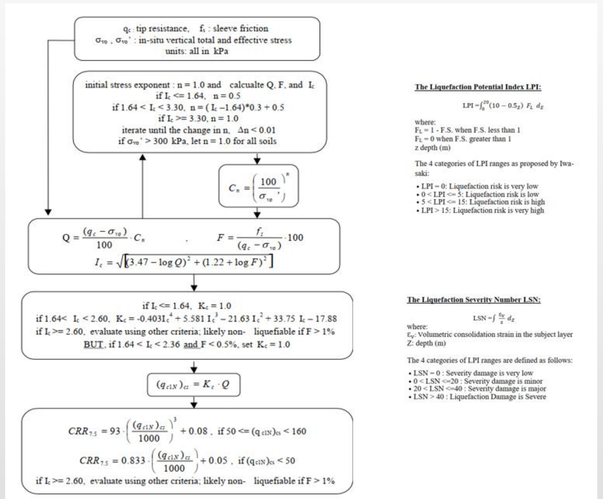
The carbonate content of the calcareous sand material is achieved by the accumulation of benthic organisms, such as-t shells and other bioclassit marine organisms, which are sensitive to the interaction with the carbon dioxide in the ocean acidification process.
The carbonate content in the seabed sand can also have as origin the dregradation of oolites sedimentary rock when reacted with carbonate-rich water. The resultant of above processes will be forming the seabed floor materials, and the bodies of the man-made islands.

Marine Shells exposed to equivalent CO2 concentration at 2100 (Source: NOAA)

It is to highlight that for the artificial islands, a number of climate change features such as the sea-level rise, ocean acidification, potential in-crease in earthquake magnitude, and oceans warming, could have direct impact on the island sustainability considering the geotechnical response especially in cyclic failures mode, such as liquefaction.

Methodology

The below flowchart presents the verification methodology using CPT Raw Data from Artificial Island in UAE, which follows a revised procedure of Robertson & Wride (1998) procedure.



The verification of the factor of safety against liquefaction for every single CPT and along the depth of readings is the most common methodology. For the overall project, two important indexes are also used in the current study, which are the Liquefaction Potential Index (LPI) and the Liquefaction Severity Number (LSN).

Characterized by changes in physical/chemical conditions in the environment, resulting impacts on the biological/geological features globally, and consequently economic and social changes, Climate Change features related to the construction and sustainability of the man-made islands in the middle east environment can be identified in the following three main points:

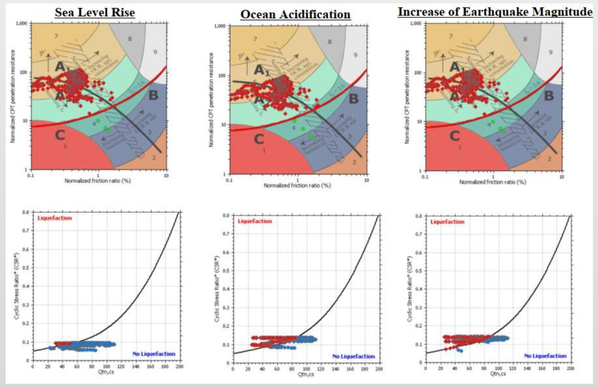
a. Sea level Rise
b. Ocean Acidification
c. Increase of Earthquake Magnitude

Construction Activities of the Artificial Island using carbonate sand (Dredged from seabed)

Analysis Procedure

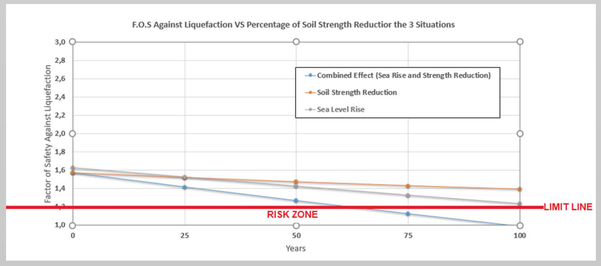
The carbonate ions -which produce the calcium carbonate for building the shells-, reacts with the carbonic acids in the water. This increases the effort of marine organisms for building its shells and consequently the shells end up thinner and more fragile.
In the long-run, the carbonic acids dissolve more rock (marine rocks), which release carbonate ions as result of this reaction. Likewise, the carbonate ions – which produce the calcium carbonate for building the shells-, reacts with the carbonic acids in the water. This makes the carbonate less available and the shells end up pitted and weak.
Sorbonne University Abu Dhabi is performing ongoing research on ocean acidification impact on the artificial islands, the Elastic Modulus of the sand samples is the slope of the loading stress-strain curve. The results of the Elastic Modulus are as follows:

Es = 46 MPa for the basic sample.
Es = 26.5 MPa for the sample exposed to acidification.



Sample of Liquefaction Analysis Results (Features Separated)

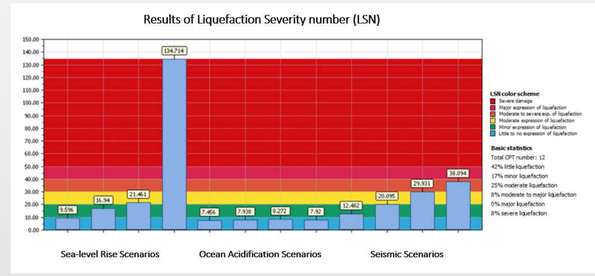
climate change features increase the liquefaction susceptibility, especially when the action of the analyzed scenarios is combined. If the artificial island is facing at the same time sea level rise and degradation of the island's body due to acidification, with a more intense earthquake magnitude, the liquefaction damage could be more severe.
For instance, , the islands built for oil and gas production are accommodating very sensitive facilities, such as chemical storage tanks, oil and gas pipelines, process facilities, flares, etc, where the leakage in any of these facilities could lead to human or natural disasters.



Sample of Liquefaction Analysis Results (Features Combined)

Results and Conclusion

The sea-level rise pertains the most vulnerable feature, especially when considering long projections/extreme scenarios. The similar is noticed for the peak ground accelerations (when considering 200 projections. Below Diagram presents the Liquefaction Severity number for all the features compiled. the liquefaction susceptibility is the most intense for the case of sea level rise. It is to confirm that the sea-level rise and the increase of earthquake magnitude are the more harmful to the resistance against liquefaction severity, when compared to ocean acidification scenarios.



The human activities could lead to positive response to the climate change phenomena and reduce its behavioral risks. The implementation of the ecosystem-based solutions provide a number of key factors that reduce the climate change induced hazards, such as:

- Reduces the erosion of the islands shoreline by controlling the sediment transport.
- Reduces the carbon dioxide emissions in the island surrounding, which results in reducing the ocean acidification rates.
- Plantation of mangroves and similar nature-based solutions protects from the Acid Rain precipitations.

The acid rains could be a fourth climate change feature in parallel to the SLR and ocean acidification features, where the sand materials could face additional strength reduction and degradation if the island environment is not protected enough by sustainability measures and similar nature based solutions.

Mangroves Plantation in Island Development works in Abu Dhabi (Source: Jubail Island.ae)

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