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Dynamic properties of Byblos municipality building with soil-structure interaction using geophysical methods

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Abstract

Byblos city is located on the coast north of Beirut, Lebanon, and is one of the oldest continuously-inhabited cities in the world. It is exposed to a moderate-up-to-high level of seismic activity, given its proximity to several major faults such as the Yammouneh and the Mount Lebanon Thrust, among others. To mitigate the risk encountered by Byblos buildings facing earthquake threat, a preliminary study of the dynamic properties of the structures is proposed in this paper. The recently-constructed Byblos Municipality building was chosen as a prototype for this study, given its important role as a vital structure for centralizing the emergency response, in the event of a disaster.

The approach consists of using the horizontal to vertical ratio method, HVNR. By analysing the ambient noise recordings, one can determine the structural frequency, damping, and other stiffness characteristics, and identify the natural soil frequency. In order to investigate the soil structure interaction and specifically possible resonance occurrence during earthquakes, the values obtained are compared and analysed. In addition to classical geotechnical tests to reveal the type and properties of the considered in-situ soil, the multichannel analysis of surface waves, MASW, is used to investigate the stiffness of the subsurface conditions and determine the shear wave velocities of the layers. In parallel, the Finite Element Model of the structure is analysed and the result of the fundamental resonance frequencies is compared to the HVNR data, and to the computed values using conventional formulae recommended by classical building codes. Results and comparisons of experimental and numerical investigations are presented for the structure and analysed for further resonance analysis.

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Keywords: Ambient Vibration Method; Soil Structure Interaction; Dynamic Properties

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1. Introduction

Byblos, called Jbeil, is one of the oldest continuously-inhabited cities in the world, and is listed as UNESCO heritage site. The city is located about 40 km far from Beirut, on the north coast. It is divided into two major areas; the old town where masonry buildings date back to 3000 BC until early 20th century; and the new city where buildings are mainly reinforced concrete. Byblos is exposed to moderate-to-high seismic risk, given its proximity to several major faults, such as Yammouneh and Mount Lebanon Thrust, which are capable of generating earthquake magnitude greater than 7. The city was destroyed by several earthquakes such as the ones occurring at April 303 A.D., April 551 A.D., and August 1157 A.D. A detailed study of Byblos resilience, its buildings characteristics and its seismicity were detailed in [1]. To mitigate the seismic risk encountered by Byblos buildings, a preliminary study of its buildings dynamic properties considering possible resonance is proposed. In this paper, the results for the prototype of Byblos Municipality building are presented, since it plays a key role in the post-earthquake recovery process. Byblos geology is presented and soil of the Municipality building is investigated. Then, the ambient noise method is used to obtain dynamic characteristics of the Municipality structure such as the frequency, damping, and spectrum content. Moreover the horizontal to vertical ratio method, HVNR or H/V, is used to determine and compare natural frequencies of the structure and the soil. Indeed, it is a valuable tool to investigate soil structure interaction by identifying possible resonance occurrence during earthquakes.

Soil structure interaction (SSI) influences structural damage while facing seismic loading, since the motion at the base of the structure differs from the free-field motion induced by an earthquake. SSI is the result of mutual effects of structure and soil. SSI is negligible for cases of flexible structures on stiff soil deposits; nevertheless it can be significant for stiff structures founded on soft soils, and their effects increase with increasing structure/soil relative stiffness. Therefore neglecting SSI is equivalent to assuming the structure is supported on rigid materials. This paper is a preliminary study and it is limited to the verification of resonance of the municipality structure. Moreover, the multichannel analysis of surface waves is used to investigate the stiffness of the subsurface conditions and determine the shear wave velocity of the subsurface layers. In parallel, a Finite Element Model of the structure is elaborated and results of the frequencies compared to the ones obtained by the HVNR method, and also to the ones computed using conventional formulae recommended by classical building codes. Results and comparisons of experimental and numerical investigations are presented for the structure and possible resonance discussed.

2. Byblos Brief Geology and Soil Investigation

Byblos is located between the valley of Nahr Ibrahim and the Batroun peninsula. Relatively high cliffs in certain areas in Jbeil border the sea. It is located to the west of Jabal Jaj and mostly formed of limestone and marly limestone rocks from the Cenomanien and Turonien. The orientation of the dip is west towards the sea. Ras Edde to the north of Jbeil is a high cliff reaching a height of 35 m at the Amshit exit. On its edge, the folding of faults obstructs a marly limestone rock from the lower Turonien. On the surface, sandstones alter it. The cliff oriented WSW to ENE penetrates toward the Wadi Qassouba. The current invasion of the land has considerably altered the topography. Large quantities of detritus and waste material are found on coastal area mixed with marine sediments.

A soil sample is collected from a depth of 6 meters from an excavation adjacent to the municipality building of Jbeil. The natural Moisture Content of the soil tested in the lab shows that it is in the dry state with moisture content, w, equals to 7.7%. The obtained percentage of gravel, sand and fine, are respectively 0.2%, 55.1% and 44.7%. This soil is constituted of sand and fine soils. The liquid limit (LL) is equal to 47%. The test shows a Plastic Limit (PL) of 26%, and a PI = 21. The soil tests help us classify the soil as A-7-6 (6) according to AASHTO, it is fair to poorly graded clayey soil. According to USCS, it is Clayey Sand (SC). The shear strength of the soil is determined by performing the direct shear test, with the internal friction angle of $\Phi = 25.2°$ and a Cohesion of 6.1 kN/m^2. It is deduced that it is a clayey soil of high plasticity with the presence of a high water table.

3. Byblos Brief Geology and Soil Investigation

Byblos The investigated four stories reinforced concrete Municipality building, built in 2016, is a dual structural system with an average area 23.48x40.36 m^2 and is 12 m height. The ambient vibration method is used to determine