INTEGRATED GEOPHYSICAL TESTS FOR THE GEOTECHNICAL CHARACTERIZATION OF THE SANDY FOUNDATION FOR PROPOSED METRO-TUNNEL AT THE NAJAF AREA, SOUTHERN IRAQ.

Ammar M.Shakir, Flora Garofalo, Sebastiano Foti
Politecnico di Torino, Dipartimento di Ingegneria Strutturale e Geotecnica
ammar.shakir@polito.it, flora.garofalo@polito.it, sebastiano.foti@polito.it

Basim R. Hijab, Amer Al-Khalidy
University of Baghdad, Department of Earth Science
brhijab@yahoo.com , amer_atyah@yahoo.com

Summary

The present study is aimed to integrate geophysical tests and conventional tests for the geotechnical characterization of the proposed site for an underground tunnel for metro project in Najaf city (Iraq). All the available information will be used for a laterally constrained inversion aimed at reconstructing a global geotechnical model of the area.

Introduction

Near surface geophysical applications are gaining widespread use in geotechnical and engineering projects. The developments of data acquisition, processing tools and interpretation methods have optimized survey time, reduced logistics costs and increase results reliability. However, the use of wide-scale geophysical methods under urban environments faces great challenges due to multiple noise sources and obstacles inherent to cities.

The geotechnical geophysics survey can provide reliable information about the nature and variability of the subsurface between existing boreholes which allow the geotechnical data to be extrapolated over wider areas and enable engineers to reduce the number of required boreholes. Therefore, it is a prerequisite for the successful and economic design of engineering structures and earthworks. (Dobrin and King 1976)

The primary use of surface wave testing in this study is related to site characterization in terms of shear wave velocity profile. The V_S profile is of primary interest for seismic site response studies and for studies of vibration of foundations and vibration transmission in soils. Other applications are related to the prediction of settlements and to soil-structure interaction.

Site description

The study area lies 150 km southwest of Baghdad, in the Al-Najaf Governorate – central southern part of Iraq extending from the Square of the twentieth Revolution to Al-Kufa city Long. (44o19′45″ E- 44°23′57″ E) and Lat. (32°0′0″ N- 32°1′46″ N), which is about 7.5 km length and it is represent a part of Najaf plateau (fig. 1). The surface of this plateau is flat covered by sandy soils which are made mainly of sand of Dibdibba Formation (Pliocene–Pleistocene) which consists of brown, gray, white, red, yellow and yellowish brown, very dense sandstone and pebbly sandstone. The thickness of the formation reaches up to 18 m.

Dibdibba Formation underlying by Injana Formation (Upper Miocene) which divided into two main units the Upper Claystone Unit consists of brown to reddish brown massive, tough claystone, occasionally silty the thickness of this unit reaches 6.0 m or more in some places.

The Lower Clastic Unit consists of alternation of different clastic rocks (claystone, sandstone and siltstone) or admixture of these rocks in different ratios, the sequence shows fining upwards cycles. Generally, the claystone and silty claystone or siltstone beds are brown to reddish brown in color, medium tough to tough; while the sandstones are heterogeneous, cross bedded and grey. The thickness of this unit reaches up to 25 m. (Hassn, K.M, 2006).

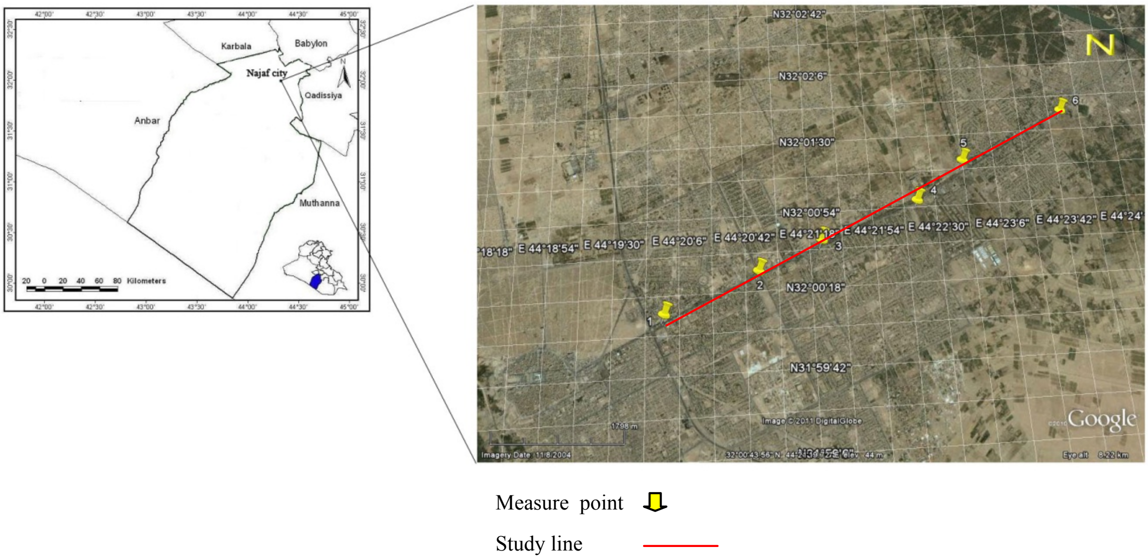

Figure (1): Location map of the study area.

Field works

Ten boreholes were drilling along the proposed route for the tunnel with depth up to 40 m. Standard penetration tests (SPT) have been percome in each borhole and disturbed soil samples have been collected for the soil classification tests. Six sites were selected for geophysical tests along the same proposed route, as shown in Figure 1. At each site seismic refraction test, multichannel analysis of surface wave (MASW) test and vertical electrical sounding (VES) test was carried out and the seismic waves velocities (Vp and Vs) as well as the apparent resistivity values was calculated for each layer.

Boreholes:

As mentioned above, 10 boreholes have been digged along the study area by using a mechanical Flight Augers up to a depth of 40 m from the natural ground surface. Standard penetration tests (SPT) were carried out for all boreholes at variable depths. Three types of samples were collected from all boreholes for the purpose of laboratory tests: disturbed soil samples (DS), Standard Penetration Test soil samples (SS) and ground water samples.

Seismic refraction test:

Seismic refraction test was conducted by using (Terraloc MK6) seismogram with 12 (10Hz) vertical geophones with geophone interval 12.5m, three shot point are made along the spreading line normal (away 10m from the geophone 1), center (between geophones 6 and 7) and reverse (away 10 m from geophone 12) by using a weight drop system (more than 200 Kg) as source for seismic waves. The seismogram setup for this survey was as following: Sampling interval = 500µs, record length = 512 ms, number of samples = 1024.
The purpose of this test is to evaluate the velocities compressional waves Vp profile and determine the water table position, which is also a relevant input for the interpretation of surface wave data.

Multichannel analysis of surface wave (MASW) test:

Two different dataset have been analysed in terms of propagation os surface waves: the dataset collected for seismic refraction test and a second one, on purpose collected for MASW. The latter was collected by using linear spreading with 24 (10Hz) geophones with geophones interval 5m in profiles (1 and 3) and 3m in profiles (2, 4, 5, and 6). Goal of the (MASW) tests is the estimation of the S-wave velocity profile of the subsoil. Both passive and active surface wave tests were performed in order to increase the investigation depth, as no shallow bedrock is expected. The active test was collected by using a 15 kg sledgehammer as source and three shot points: forward (with source to receivers distance equal to the inter-geophone distance), center (between geophones 12 and 13) and reverse. The seismogram setup for the (MASW) test was as following: Sampling interval = 2000 µs, record length = 2048 ms, number of samples = 16384.
The processing of the (MASW) test data allows the experimental dispersion curve to be determined. Multichannel data are processed using a double Fourier Transform, which generates the frequency-wave number spectrum, where the multimodal dispersion curve is easily extracted as the location of maximum spectral (Foti, 2000). Then the dispersion curve is used as the input for an inverse problem aimed at evaluating the parameters of earth model (Vs and depth).

Vertical electrical sounding (VES) test:

VES data were collected by using a Resistivity meter ABEM SAS 4000 with the Schlumberger array configuration with (AB/2) 100 m.
The purpose of this test is to calculate the apparent resistivity for each layers, detect the preliminary ground water table and its variation in study area and to detect the horizontal and vertical variations in the soil. The measurements of vertical electrical sounding are smoothed, and then interpreted using two methods of interpretations: the first method is a qualitative interpretation for a primary evaluation of the resistivity values, while the second method is a quantitative interpretation which includes determination of the resistivities and thicknesses of electrical horizons for VES field curves either manually by using curve matching or with an automated inversion. The results of interpretation must be consolidated by information available from drilled borehole and other geophysical tests results, to obtain a more reliable geologic picture of the subsurface.

Results:

The primary results of geophysical and engineering tests interpretation are quite similar and well correlated for the different locations along the study area. For the purpose of presenting the dataset, the preliminary results for location 1 are reported in the present note.
The stratigraphic log has been reconstructed on the basis of the visual classification of the material extracted from the borehole, in situ tests (SPT) and laboratory tests for selected samples. The classification showed that the stratigraphic column within the depth of interest is composed of three layers (Figure 2). The results for N value (number of blows in SPT test) was generally higher than 50 blows (N>50), indicating very dense materials.
Water table was measured by direct measurement from the borehole during the drilling and after 24 hour. The depth of water table for this site was 3 meters from the natural ground surface.

Age	Fn.		Thick (m)	Description
Holo -cene	Top soil		3	Clayey silty pebbly sand w.t
Pliocene-Pleistocene	Dibdibba		18	brown, gray, white, red, yellow and yellowish brown, very dense sandstone and pebbly sandstone
Miocene	Injana	Upper unit	10	brown to reddish brown massive, tough claystone, occasionally silty
		Lower unit	9	alternation of the brown to reddish brown, tough silty claystone beds and grey sandstones beds

Figure (2): Borehole log for site 1

Seismic refraction tests have been interpreted as a 3 layers system, with average compressional velocities Vp from up-downward 510m/sec., 1467m/sec. and 1951m/sec. respectively. The thicknesses were 3 and 17.8 m respectively (fig 3). The first interface at 3m clearly corresponds to the water table, while the deeper one is likely associated to the transition between young and old sediments reported in Figure 2.

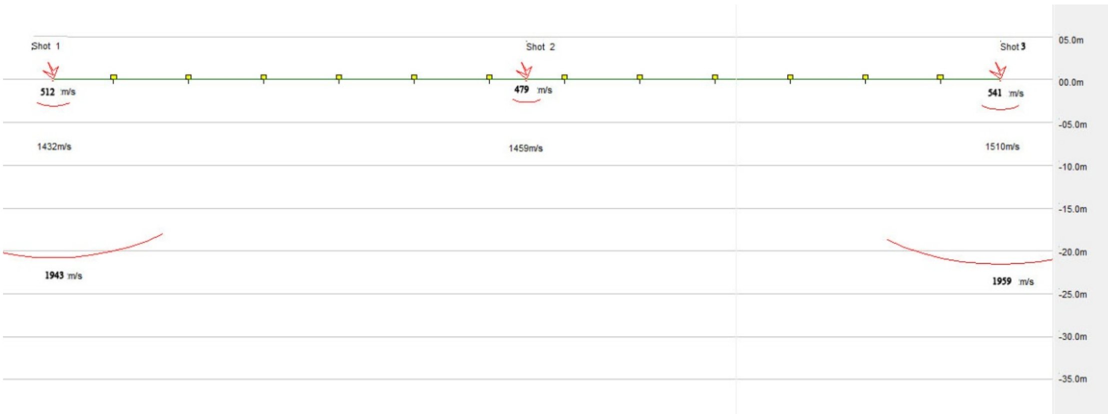

Figure (3): Vp seismic section for site 1

Surface wave analysis results

A preliminary analysis of the dispersion curves extracted for all the profiles of the seismic refraction dataset (12 channels) showed similar condition at the different sites. The results of a preliminary inversion with a Montecarlo approach (Socco and Boiero, 2008) for site 1 are reported in Figure 4.

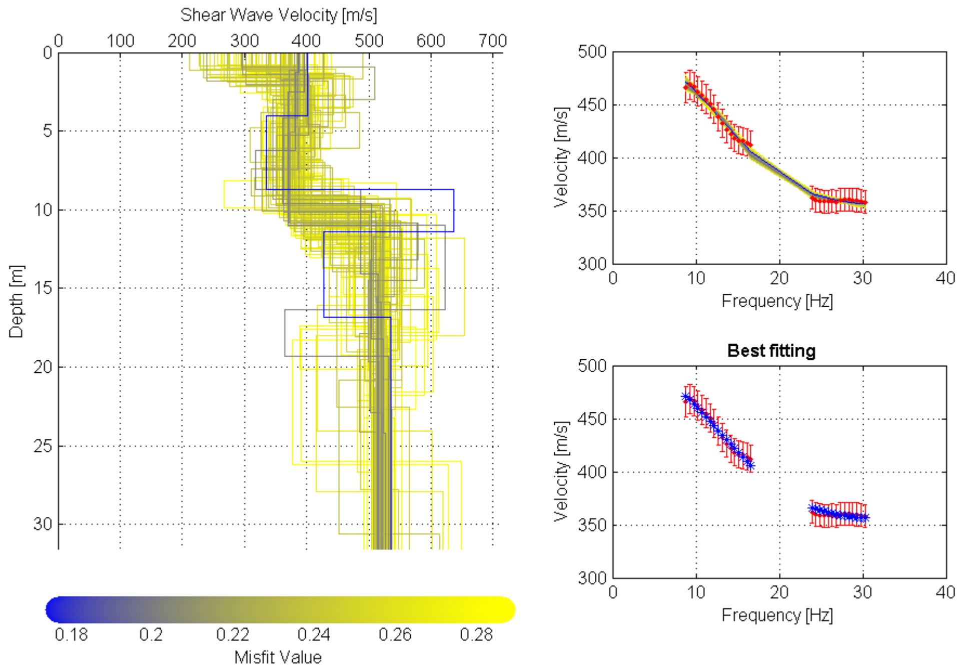

Figure (4): Montecarlo inversion results for site 1: (Left panel) VS profiles (blue = best fitting profile; yellow=equivalent solutions); (Rigth-Top) comparison between the experimental dispersion curve of Rayleigh waves and dispersion curves for the group of selected VS profiles; (Rigth-Bottom) comparison between the experimental dispersion curve of Rayleigh waves and dispersion curves for the best fitting VS profile.

The result shows some critical points: the first layer (depth around 3 m) is not well resolved because the band frequency of the experimental dispersion curve is not wide enough (no datapoints are avalaible for frequencies greater than 30 Hz). Moreover the best fitting profile shows an inversion of Vs values around 10 m depth; likely this is an artifact due to lack of experimental data between 16 and 24 Hz.
In order to improve the solution with respect to the above issues, the additional information from the other MASW dataset will be considered to widen the frequency range.
Moreover the issues related to non-uniqueness of the solution and artifacts in the inversion will relaxed with the Laterally Constrain Inversion (Socco et al. 2009) of the whole datset. Indeed the mutual constrains between the different sites and the addition of a-priori information can provide a more robust solution of the inverse problem and a reliable global model for the whole area.

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