Selected Papers from the Proceedings of the Fourth Geo-China International Conference

Geotechnical Special Publication No. 259

Behavior of Geomaterials and Foundations for Civil Infrastructure Applications

Edited by
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GEO-INSTITUTE

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GEO-CHINA 2016

BEHAVIOR OF GEOMATERIALS AND FOUNDATIONS FOR CIVIL INFRASTRUCTURE APPLICATIONS

SELECTED PAPERS FROM THE PROCEEDINGS OF THE FOURTH GEO-CHINA INTERNATIONAL CONFERENCE

July 25–27, 2016
Shandong, China

SPONSORED BY

Shandong University

Shandong Department of Transportation

University of Oklahoma

Chinese National Science Foundation

Geo-Institute of the American Society of Civil Engineers

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Published by the American Society of Civil Engineers

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org

Errata: Errata, if any, can be found at http://dx.doi.org/10.1061/9780784480021

ISBN 978-0-7844-8002-1 (PDF)
Manufactured in the United States of America.

Preface

As a result of increasing and continuous social and infrastructural growth, appropriate ground for living and development becomes progressively scanty. Thus, engineers have been considering constructing buildings and infrastructure at locations with less favorable geotechnical conditions and in some cases in seismically active regions. Therefore, proper understanding of the soil behavior has become significantly important to optimize the design and construction of foundations. This Geotechnical Special Publication (GSP) contains 30 papers that were accepted and presented at the GeoChina International Conference on Sustainable Civil Infrastructures: Innovative Technologies for Severe Weathers and Climate Changes, held in Shandong, China on July 25-27, 2016. Major topics covered in this GSP are dynamic behavior of soils and foundations, and physical, numerical, constitutive modeling of soil behavior. The overall theme of the GSP is Behaviour of Geomaterials and Foundations for Civil Infrastructure Applications, and all papers address different research findings of this theme. It provides an effective mean of sharing recent technological advances, engineering applications and research results among scientists, researchers and engineering practitioners. All abstracts and full papers have been peer-reviewed prior to their acceptance and inclusion in this publication. We are most grateful to all authors and reviewers who have contributed to this Geotechnical Special Publication.

Contents

Offshore Foundations Applied to Renewable Energy Infrastructure (RES)

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Abstract: New sources of energy are necessary today to totally avoid the oil dependence. People around the world are researching on renewable energy systems (RES). In this sense, we present an overview of the current status of the energy production, based on RES technologies, in Mexico. In addition, a typical yield failure envelope obtained with RS3® in 3D is included. The main objective is to present this envelope, which has the special soil characteristics, found in sea sediments. Additionally, we present a response spectrum, since earthquakes are events that frequently impact the infrastructure, making the design always dependant on transient events The time histories of acceleration, used to obtain the spectrum, correspond to earthquakes localized in the area of the Gulf of Mexico.

INTRODUCTION

Worldwide oil dependence involves high economic and environmental costs due to rising use of fuels and derivative and the declining global reserves. One of the main disadvantages for oil exploration is the greater water depth, which is reflected in difficulties to achieve special infrastructure. Renewable energies (RES) are a challenge for economics and clean energy sources in the world. Countries like Mexico require future developments of this kind of energy to support the demand growth. For this, it is necessary to consider the offshore wave and wind potential besides to its onshore potential. Developing RES require of many engineering disciplines and Geotechnics is closely linked to the development of these. Suction caissons are an excellent alternative for offshore wind turbines. These foundations are widely used for oil and gas industry. There are many studies of the suction caisson used in deep waters, nevertheless, few studies have been developed for wind turbines.

RENEWABLE ENERGY

Renewable energies are defined as those practically limitless sources respect to the human lifetime and whose use is technically feasible. General RES classification can be divided in two types: tidal and wind energies.

Types of wind turbines

There are two main systems of wind turbines (WT), based on axes structures: horizontal (HAWTs) and vertical (VAWTs), being HAWTs the most frequently used. From the point of view of Civil Engineering, the WT design needs a study of soil-foundation interaction, by using the environmental forces. Figure 1a depicts the typical loads used in the design.

Foundations for offshore wind turbines

Offshore turbines require special foundations for stability. Worldwide, the monopile foundations have dominated offshore wind structures (Fig 1b), followed only by the gravity bases (Fig 1e). Monopod or tripod/tetrapod are used as shown in Figures 1c and 1d, with piles as a foundation system. Suction caissons may be used as a foundation for offshore wind turbines due to its simple installation procedure and other advantages. They have been mainly used in clays for oil/gas industry, whose efficiency in offshore areas is widely known.

Mexico Production

Power generation in Mexico is dominated by thermoelectric, using fossil fuels. Up today, the power generation based in renewable energy covers only 2.3% of the total electricity generation capacity (SENER, 2011) with an installed electrical capacity of 18,716 MW, while the wind potential is estimated at 71,000 MW (Economy, SD, 2012).

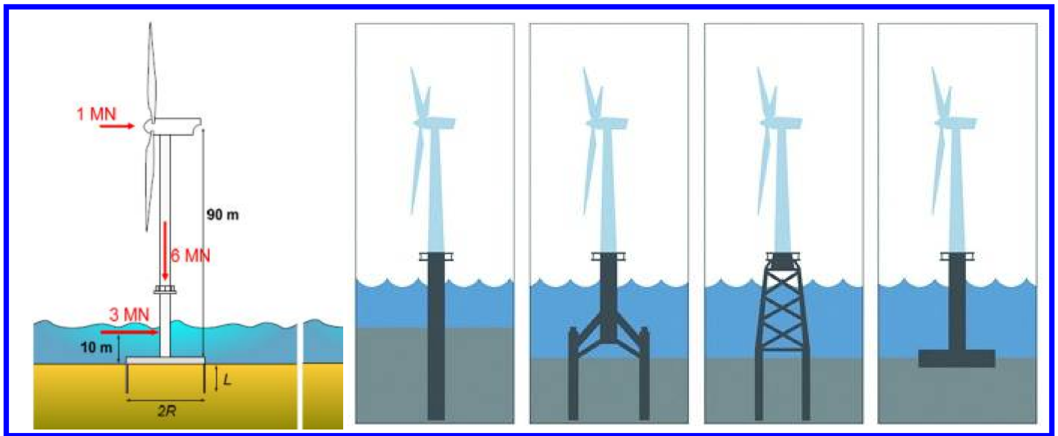
GEOTECHNICAL AND STRUCTURAL CONSIDERATIONS

Soil parameters

Geotechnical parameters were obtained from a shear strength profile $s_u=1.6z$ that matches a CPT profile (Fig 2a), where z is the vertical depth. To obtain effective parameters c' and $\phi'_{s,}$ numerical simulations were done by varying both parameters, until the real shear strength profile was reproduced, using Plaxis 2D®. Shear profile is considered for a linear increase and the elastic modulus E' is constant with depth (z). A linear perfect plastic Mohr-Coulomb model was used by considering a plastic behavior and the water table in the surface of the numeric model. The geotechnical parameters are showed in Table 1.

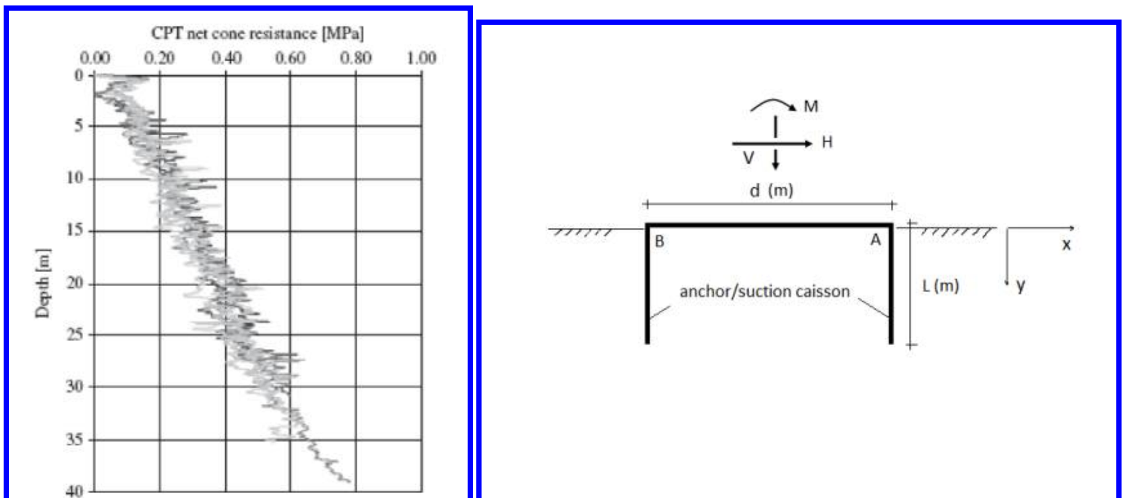
Anchor characteristics

Anchor's geometry is a cylinder, top closed-bottom opened, with a relationship L/d=0.5 (Fig. 2b). The walls and the top anchor were simulated using liner elements according to RS3®, by considering a high stiffness to guarantee a rigid behavior. The shaft friction and the stiffeners, inside the anchor, were not modeled. Points A and B were taken as the references to obtain results of stresses and displacements.



(a) (b) (c) (d) (e)

FIG. 1. (a) Typical loads and dimensions for a 3.5 MW turbine (Villalobos-Jara, 2006) and Typical foundations for wind offshore turbines (b) monopod (c) tripod/tetrapod (d) piled jacket tower and (e) gravity base as reported by Theengineer (2015).



(a) (b)

FIG. 2. (a) CPT profile (Colliat, 1999) and (b) scheme of suction caisson (M=moment load, V=vertical load, H=horizontal load).

Table 1. Geotechnical effective parameters using Mohr Coulomb criterion

Soil	γ_{sat} (kN/m^3)	ϕ'_s (°)	c′ (kN/m^2)	E′ (kN/m^2)	ν′	OCR
Clay	17	27	1.6	9049	0.35	1.0

NUMERICAL MODELING

Mesh

Figure 3a shows the mesh used in all calculations, where it is observed a more refinement in the anchor area to ensure a good accuracy. Boundaries conditions are zero-displacement in the vertical plane (*z axis*), while the base of the mesh is fixed in three coordinates (*x*, *y* and *z*). The mesh has an extension of 66 m in depth and has 150m x 150m. Figure 3b shows the Major principal strain-Sigma xz effective curve obtained at the point A (Fig 5a), using H=5.9 MN, M=0 MN and V=0 MN.