ABSTRACT

According to the current version of the Eurocode 3, buckling analyses must be addressed in the design of tubular piles. Unfortunately, the state of the art does not allow the designer to take into consideration the presumably beneficial constraining effects provided by the soil surrounding the tubes. As a result, the verification is too conservative. Within the framework of an improved buckling analysis, experimental and numerical investigations of a laterally loaded pile were conducted. In this paper, the results provided by several numerical models are compared to experimental data. The comparison revealed that simple models provide fairly good results and can be used to design the investigated case.

KEY WORDS: pile, lateral, cohesionless, soil, FE, hypoplasticity.

INTRODUCTION

Large tubular piles are used in different growth-oriented major civil engineering applications (single bearing piles in offshore engineering, quay walls for ports and harbours, cofferdams for deep urban excavations, etc).

According to experts (Gijt, 1998) container transport and container vessel growth will both accelerate in the future. Already nowadays and in the near future many quay walls have to be adapted to the new generation of container vessels. These new quay walls have to be of greater depth due to the increased draught of the ships. In the near future the demand for heavy quay walls will increase. Besides that, the type of quay wall, the lack of space, and environmental reasons in densely populated areas enforce engineers to put more and more infrastructures below ground-level (car parks, several railway systems, etc.). This trend is expected to continue or even to accelerate in the future. To that end, the use of economical cofferdams for deep excavation is of essential need.

The only available steel solution for these types of construction (quay wall or cofferdams for deep excavation) is the combiwall. According to the current version of Eurocode 3 (EN 1993-5), buckling analyses must be addressed in the design of such embedded steel structures.

Unfortunately, current codes do not allow the designer to take into consideration the beneficial constraining effects provided by the soil into which these steel elements are embedded. As a consequence of the conservative design, the verification leads to tubular piles which are 10% - 20% heavier than the piles used today. As a result, the cost disadvantage of the steel solution may be a dramatic loss in market share compared to various concrete solutions (caissons, gravity walls, diaphragm (or “slurry”) walls, secant / tangent pile wall, etc.).

An evaluation of the benefits brought by the presence of soil within and around tubular piles becomes a challenge allowing a possible reduction of material consumption. In other words, there is a need to confirm or challenge the new guidelines introduced with the EC3. The European Commission approved and funded a research project called ETIB (for Enhanced Economy of Tubular Piles by Improved Buckling Design) addressing this specific issue. In such a strategy, it is important to better understand the load transfer mechanism and the soil-tube interaction. In order to investigate this issue numerical and experimental studies were planned. In the ETIB project experimental tests on a reduced scale tubular pile were and are performed. A test tube instrumented with a total of 65 strain gauges installed at 5 different levels is being investigated. Set gauges comprise either a configuration in 2 directions (0 and 90° alignments) or a configuration in 3 directions (0, 45 and 90° alignments). Hence, it is possible to measure circumferential and longitudinal strains on the outside of the tube. Before installation of the test tube, a “dummy” tube was instrumented with 8 single gauges for verification. Only the results from tests with the latter tube are discussed in the following.

This paper presents first theoretical considerations on how the problem of single piles can be linked to the retaining wall problem. To that end, numerical results using finite element programs are presented. Then, the paper describes the experimental device developed within the framework of the project. Finally, back-analyses are presented and first conclusions are drawn.

RELATIONS BETWEEN SINGLE PILE AND COMBIWALL

Numerical methods

Since the construction of a combiwall is fairly complicated including