I. INTRODUCTION

I.1. BACKGROUNDS

Civil engineering is a field in which the structures to design and build are often subject to actions which are described as cyclic (alternating) or repeated. These solicitations are added to the permanent forces applied to the structures and can have a significant influence on their stability and behaviour throughout their lives. The highly random number of actions encountered in the field of civil engineering (earthquakes, waves, wind, etc.) which can have an important dynamic component, make them difficult to model in a sufficiently reliable and realistic manner. The structural designs and dimension studies often under-estimate the resulting risk factor.

The present work will focus more on the engineering problem usually met for deep foundations such the one used in the petroleum extraction industry. These structures used for oil and gas exploitation are highly varied and must be able to withstand various types of solicitations, especially their foundations. The foundations for offshore structures are subject not only to a repetitive vertical stress due to the use of platforms, but also to alternating horizontal stresses as well as alternating moments because of the transfer of wind load on the structure and the strength of the swell. These charges have cyclical low and high frequencies. The loads are important enough so that the forces of the waves induce reverse shear stresses only in the highest part of the piles. These shear strains introduce favourable and unfavourable effect on the strength and stiffness of the soil around the foundation. There may be an increase in the capacity of piles with the speed of loading, and a decrease in shear resistance due to the loss of contact between the foundation and the soil. A simple study on the piles behaviour would not be sufficient to understand the phenomenon that could happen to this "contact". Therefore, several research projects were initiated to study the behaviour of an interface between a foundation and a soil.

Several studies have already been published in order to help understanding the behaviour of interfaces. Different experimental methods, including direct shear strain tests, simple shear strain tests, and so-called "ring torsion" tests (Yoshimi and Kishida, 1981; Desai and al.1985 Kishida and Uesugi 1987, Bolt, 1989; Evgin and Fakharian, 1996) were presented. These studies revealed that the main factors that affect the behaviour of the interface include the roughness of the interface (the surface of contact), the mineralogy and the classification of the soil, the soil density, and normal pressure. The roughness of contact is often seen as the most critical factor. The updated summary of the various tests done on the interface can be found in Hu and Pu (2004). It was also found that a very thin layer of soil near the surface of contact, in addition to the roughness of the interface, greatly influences the behaviour of the interface during shear tests. This thin layer of soil has been called thickness (width) of the interface and has been estimated at 2 to 15 times the average diameter of the soil D50 (Uesugi and Kishida, 1987; Wernick, 1978; Yoshimi and Kishida, 1981; Bolt , 1989; Hoteit, 1990).

Constitutive models of soil-structure interface have also been a topic of study in the field of soil-structure interaction due to the rapid progress made in applying the finite element method to the analysis of the soil-structure. In addition to the construction of a constitutive model, elements of the interface and algorithms have also been proposed to model the soil-structure interface (eg Goodman et al., 1968; Katona, 1983; Kalyakin and Li, 1995; Villard, 1996). However, modeling the normal dilatancy is difficult using such methods. With the proposal of the isoparametric thin layer by Zienkiewicz et al. (1970) and Desai et al. (1984), the use of certain models to simulate the constitutive behaviour of the soil-structure interface has become possible, and different models have been proposed. Desai et al. (1985) used a model of non-linear elasticity to simulate the behaviour of the interface, but were unable to replicate its normal dilatancy. Aubry et al. (1990), Shahrour and Rezaie (1997), Ghionna Mortara (2002), and Fakharian Evgin (2000), Edil Zeghal (2002), Gennaro and Frank (2002), Mortara et al. (2002) and others have developed an elasto-plastic constitutive model of soil-structure interface. Desai and Ma (1992) proposed a model based on the concept of surface damage, DSC (Surface Damage Concept). Hu and Pu (2004) used this damage mechanism to model the behaviour of the interface. Liu, Song and Ling (2006) studied the constitution of a model based on the concept of soil MRSC (Critical State Soil Mechanics) by adapting it to an interface. All these authors have highlighted the analogy between the soil's behaviour and the behaviour of a rough interface with a sandy soil, as proved by Boulon and Nova (1990). Most of these models are able to reproduce the main behaviours of the soil-structure interface, including the phenomenon of standard dilatancy.

I.2. OBJECTIVES

This work was done primarily to model the behaviour of the soil-structure interface for a cyclic and monotonic solicitation, using the software FLAC, ITASCA 2005. In order to continue the previous study led by Riyono, who performed the first implementation of a FLAC model as part of his final project in 2004, this study had the following objectives:

- Better understand the global behaviour of the interface.
- Build a model of the interface to reproduce its behaviour for a monotonic solicitation, applying as a first approach the fundamental laws of solid mechanics and adapting the equations developed in previous studies.
- Introduce new laws in the model to simulate the behaviour of the interface during cyclic loading.
- Analyze and validate the results of the proposed models by comparing them with the existing experiments.

I.3. CONTENTS

This report is divided into seven parts:

Chapter I: Introduction

This chapter describes the background, objectives and assumptions chosen for this study.

Chapter II: Experimental results and interface behaviour

This chapter summarizes the different behaviours of the soil and the interface during a shear stress test in a monotonic or cyclic fashion. The interface's characteristics presented are based on existing experimental studies.

Chapter III: Modeling of the interface for a monotonic solicitation

This chapter sets out the approaches, assumptions and theories adopted to model the correct behaviour of the interface in a monotonic solicitation.

Chapter IV: Modeling of the interface for a cyclic solicitation

Similarly, this chapter sets out the approaches, assumptions and theories adopted to model the correct behaviour of the interface under cyclic loading this time.

Chapter V: Implementation on FLAC

This chapter presents the principle of operation of the FLAC software stack applied to the modeling of the interface. To present the implementation of the model on FLAC, the main algorithms developed will be detailed in this chapter.

Chapter VI: Results

This section presents the results of the simulations when tested under monotonic and cyclic stress, and the analysis of the interface behaviours resulting from these simulations.

Chapter VII: Conclusions and recommendations

This final chapter presents the findings of this study and provide new avenues and recommendations that can be useful for future studies.