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Pullout Strength of Concrete Plugs in Tubular Piles

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ABSTRACT

This paper presents the results of pullout tests carried out on eight steel tube specimens filled with concrete plugs with variable depths. The pullout force was achieved by steel bars embedded in the concrete plug. Only one tube diameter and one concrete strength were tested. The results of testing included the ultimate pullout force, slip of the plug, longitudinal and hoop strains along the length of the steel tube. Strain measurements on the steel tube allowed the determination of load transfer mechanism from the concrete core to the steel tube. The tests clearly showed that bond strength achieved in tension significantly exceeds that achieved in compression.

KEY WORDS: tubular piles, composite construction, offshore structures, pullout strength

INTRODUCTION

The legs of platforms of many offshore and coastal structures are usually found on tubular steel piles through reinforced concrete pile caps. Wave, wind and earthquake loads tend to induce uplift on the legs that in turn subject the piles to tension. This transfer of tension takes place through concrete "plug" embedded in the top of the pile, see Figure 1.

In recent years, many investigations have proposed analysis and design rules for concrete filled steel columns based on experimental models of steel tubes filled with concrete and tested in compression. The composite action in such columns is due to the bond strength and mechanical interlock. Investigations have shown that these mechanisms depend on the surface roughness of the steel tube and the variation of shape of the cross-section of the steel tube. Values of bond strength reported in literature varied from 0.4 to 1.0 MPa.

In contrast, literature search has revealed that no such investigation was carried out on concrete filled tubes in tension, which is the case of pile plugs subjected to uplift.

The earliest pushout tests were carried out by Virdi and Dowling (1975). A number of parameters were varied to study their effects on the bond strength between concrete and steel. Their conclusion was that the bond was composed of micro-locking and macro-locking due to imperfections in the steel sections and surface roughness. They also concluded that bond is not related to age, strength of concrete, length of interface or tube diameter. They proposed a bond strength of 1 MPa for design.

Further study was conducted by Morishita et al (1979). These tests were based on measuring the strain in steel rather than the relative movement of concrete to the steel. The reason for this was to more accurately mirror conditions in composite construction. The aim of this experimental study was to investigate the relationship between concrete strength and bond. The results showed that, contrary to the Virdi and Dowling (1975) study, there was a relationship between strength and bond. The quoted bond strength was 0.2 to 0.4 MPa. This is considerably lower than that found by Virdi and Dowling.

The second study by Morishita et al (1980) was aimed at increasing the bond between steel and concrete. This was achieved by using expansive concrete and checker plate steel tubes. Both these measures enhance the microlocking and macrolocking described by Virdi and Dowling (1975). The conclusion of this study was that both methods improved initial bond. When only expansive concrete was used, the resistance dropped to levels that normal concrete attained after the initiation of slipping. It also showed that expansive concrete bond increased with concrete strength.

An extensive investigation on the pushout strength of concrete filled tubular members was undertaken by Shakir-Khalil (1991, 1993a, 1993b). The main parameters studied were the shape of the tube, interface length, interface condition and the use of mechanical connectors. The first tests were aimed at determining the difference between CHS and RHS sections in an oiled or non oiled state. The result was that an oiled specimen had approximately half the bond resistance compared to the normal specimen. It was also noted that, in agreement with Virdi and Dowling (1975), specimen length was not a significant factor on the bond strength. Further, it was shown that CHS had a superior load carrying capacity compared to the RHS. The resistance of circular section is enhanced due to the much stiffer confinement of the concrete as it rides during slip over the asperities and irregularities of profile of the steel tube. The design of the specimens in Shakir-Khalil's work was based on British Standard BS 5400 (1979) which specifies the steel-concrete bond strength to be 0.4 MPa.