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Hydraulic Fracture Tests in Heavily Overconsolidated Clay to Determine Conductor Setting Depths

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ABSTRACT

Current methods of determining conductor setting depths are described. These are based on the assumption that existing overburden pressures develop the capability of the foundation to resist hydraulic fracturing. This leads to conservative results and consequently higher installation costs. In an attempt to reduce this conservatism, packer tests have been performed offshore in the St. Joseph field, off the coast of Sabah in heavily overconsolidated clays, in order to measure the hydraulic fracture characteristics directly. This paper describes these tests and the equipment used and discusses the results, both in terms of recommendations for a reduction in the site-specific conductor setting depths and by comparing them to existing hydraulic fracture theories. Following these tests, conductors at a nearby platform in the St. Joseph field, founded on an essentially similar clay, were installed at reduced depths in line with the recommendations from the packer test results. Conductor installation time was reduced by approximately seven days of jack-up rig time.

Proposals for further work are given.

INTRODUCTION

Conductors are required in the drilling of oil and gas wells to prevent the upper portion of the hole from caving in and water from entering and mud from leaving the hole. Offshore, they also protect the well casings from environmental loads. Typically they are 660 mm to 762 mm in diameter and, from a geotechnical point of view, the minimum setting depth below mudline should satisfy the following requirements:

a) The conductor should have sufficient axial bearing capacity, derived from external frictional resistance alone, to transfer self weight and all external vertical loads on the conductor (e.g., blow-out preventors, initial casing hung off) to the soil.

b) The soil below the tip of the conductor should have sufficient formation strength (i.e., resistance to hydraulic fracture or other mechanism that may cause mud losses) to withstand mud pressures applied during drilling prior to setting the first casing. Mud losses cause severe inconvenience to drilling activities and, in some cases, jeopardise the platform foundation integrity.

In general, b) governs the conductor setting depth. Unless unavoidable, it is preferable to set the conductor tip in a relatively impermeable layer, i.e., clay, in order to minimise the potential for excessive washout that can occur in a cohesionless soil. This paper focuses purely on this aspect of conductor design in a heavily overconsolidated clay site, offshore northwest Borneo.

CURRENT DESIGN CRITERIA

Although several phenomena cause mud losses, the current design criteria consider hydraulic fracture to be the governing mechanism. Hydraulic fracture will cause a vertical crack in normally consolidated or lightly overconsolidated soil. In heavily overconsolidated soils a horizontal crack will be formed, since the minor principal stress is the vertical soil pressure. Hence, hydraulic fracture will occur when:

$$P_b > \sigma_3 \tag{1}$$

where P_b = mud pressure at depth L below mudline and σ_3 = total minor principal stress in the soil at depth L.

The mud pressure, P_b, can be written as:

$$P_b > \gamma_m \, (H + L + d) \tag{2}$$

where γ_m = unit weight of drilling fluid, H = water depth, L = depth below mudline and d = height of mud discharge level above sea level.

The total minor principal stress, σ_3, can be written as:

$$\sigma_3 = \sigma_h' + u_o \tag{3a}$$

or

$$\sigma_3 = \sigma_v' + u_o \tag{3b}$$

depending on whether σ_h' or σ_v' is the lesser, where $\sigma_h' = K_o \, \sigma_v'$ = effective horizontal earth pressure, $\sigma_v' = \gamma_s' L$ = effective overburden pressure, K_o = coefficient of lateral earth pressure at rest, γ_s' = effective unit weight of soil, $u_o = \gamma_w \, (H{+}L)$ = hydrostatic pore pressure and γ_w = unit weight of sea water. Thus, to avoid hydraulic fracture, the minimum setting depth of the conductor, L, must meet the following requirements:

$$L > \frac{(\gamma_m - \gamma_w)H + \gamma_m d}{K_o \gamma_s' - (\gamma_m - \gamma_w)} \tag{4a}$$

for vertical fracture, and:

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