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Towards monopod design criteria for uniform reliability

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Abstract

The structural reliability of braced and unbraced monopod platforms is investigated under storm overload. A wide spectrum of monopod geometries is designed for Australian North West Shelf (NWS) metocean conditions using API RP2A-LRFD with the usual environmental partial load factor $\gamma_E = 1.35$. Ultimate strengths and safety indices are then determined. Particular features of monopod platforms result in the probabilities of failure frequently being higher than recommended values for new unmanned platforms, although the values vary strongly with topside weight. Increasing the load factor significantly to $\gamma_E = 3$ is found to achieve commonly acceptable safety index values $\beta > 3$ with much greater uniformity in reliability.

The results are particularly relevant for the design of NWS offshore infrastructure and in ensuring its longterm integrity, given the strong prevalence of minimum platforms and the severe long-term wave conditions in the region. These effects were highlighted by the structural failure of a relatively new braced monopod platform in 1996 during a tropical cyclone [Buchan, S.J., Black, P.G., Cohen, R.L., 1999. The impact of tropical cyclone Olivia on Australia's Northwest Shelf. OTC 10791, *Proc. OTC*, Houston].

Keywords: Monopod platforms; Offshore structural reliability; Extreme storm loading

1. Introduction

The first monopods were installed on the North West Shelf (NWS) in 1986, just 2 yr after offshore production commenced in the region. Monopods have since become the dominant NWS platform solution, as they have cost advantages for exploiting small, shallow water fields and can be fabricated in Western Australia.

Much work has been undertaken internationally to calibrate the API RP2A-LRFD (American Petroleum Institute, 2003) and ISO 19902 (International Standards Organisation) design Codes for fixed offshore structures and to estimate values for the partial load factors. However, this effort has concentrated largely on common jacket configurations (Moses and Larrabee, 1988; Efthymiou et al., 1996). The current paper is intended as a contribution towards deriving a suitable environmental partial load factor for monopod platforms. Two representative monopods of the type addressed in the study are illustrated in Fig. 1.

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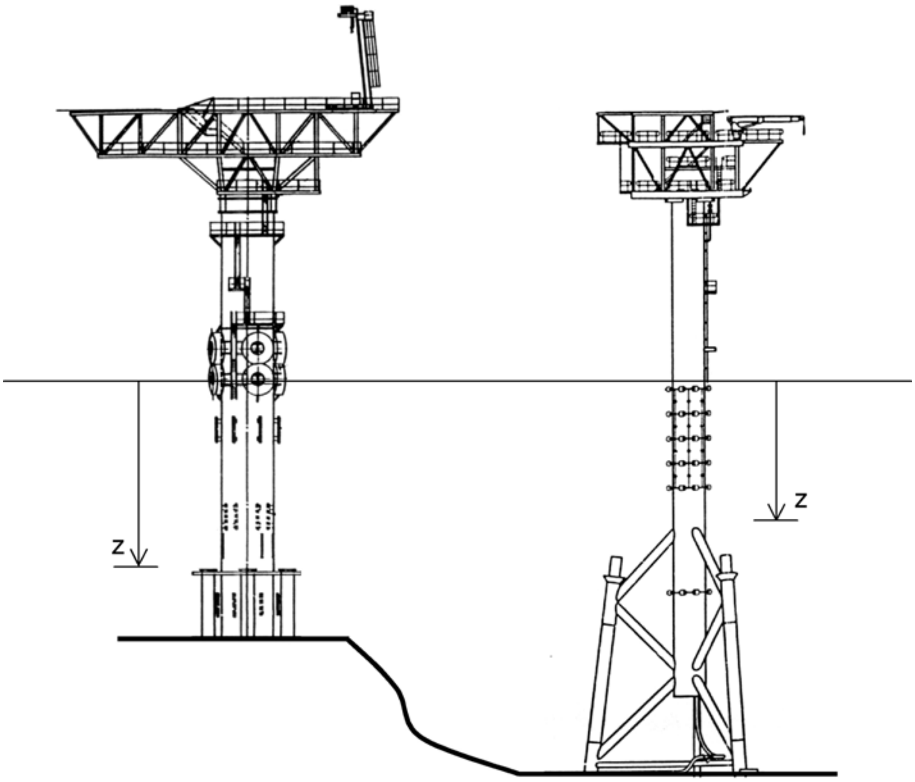

Fig. 1. Typical NWS monopods.

1.1. Monopod reliability considerations

Monopods differ from jackets both in the way they transmit loads down to the foundation, and in their mode of failure under storm overload. These differences have important ramifications for their structural reliability.

A key aspect of this reliability is the long term environmental load relationship E, which may be modelled very simply as

$$E \propto H^{\alpha} \tag{1}$$

(eg Moses and Larrabee, 1988; Bea, 1990; Stahl et al., 1998). Here, the wave height exponent α is a measure of how rapidly the environmental load increases with wave height at increasing return periods. The long term wave height distribution H is strongly influenced by regional met-ocean conditions, whereas α is largely dependent on structural configuration.

For jackets in moderate water depths, α may not vary significantly, and a value of $\alpha \approx 2.2$ is not atypical (eg. Moses and Larrabee, 1988; Stahl et al., 1998). However, as will be seen in a later Section, monopods exhibit a wide range of α values, depending on the water depth, the location of failure down the water column and the caisson diameter. Very high values are possible in some circumstances, which may result in a large environmental partial load factor γ_E being required to achieve adequate reliability.

Topside weight and the partial load factor for dead load γ_D may also play a greater role for monopods. Jacket collapse is commonly triggered by failure of one or more braces. Braces transmit environmental loads through overall frame action, but often carry little topside load, as this passes directly down the legs. As a result, the structure's ultimate strength may be rather insensitive to the topside weight. In contrast, with monopods, both topside weight and environmental load are transmitted through a single member, which is also where failure is commonly concentrated. Thus both of these loading types and partial load factors strongly influence the member sizing and hence the ultimate strength and reliability levels obtained.

A third issue is that monopods are likely to be utilised in shallow water depths, which introduces several complexities. Large waves in shallow water have highly nonlinear kinematics, which result in large α values and increased