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Numerical Simulation of Experiments on Multiplanar Tubular Steel X-Joints

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ABSTRACT

Current design codes, used to predict the ultimate static load of uniplanar and multiplanar X-joints in circular hollow sections, are mainly based on extensive tests on simple uniplanar joints. Very few test results on multiplanar joints are available for verification. Therefore, an experimental research programme, consisting of 3 uniplanar and 9 multiplanar X-joints in circular hollow sections, has been carried out for the determination of the stiffness, the ultimate static load and the deformation capacity. The results of these experiments are presented in IJOPE, March 1991 (van der Vegte, 1991b). In addition, numerical simulations of these experiments have been carried out. The results of these numerical analyses are presented in the present study. Good agreement exists between the numerically and experimentally determined load-deformation curves. Finally, the numerically determined ultimate loads are compared with the values of the ultimate loads obtained from several design codes and recommendations.

NOMENCLATURE

d_0 : outer diameter of chord
t_0 : wall thickness of chord
d_1 : outer diameter of in-plane brace
d_2 : outer diameter of out-of-plane brace
$f_{y0,L}$: measured yield stress of chord member (in longitudinal direction)
$f_{u0,L}$: measured ultimate tensile stress of chord member (in longitudinal direction)
l_0 : length of chord
t_1 : wall thickness of in-plane brace
t_2 : wall thickness of out-of-plane brace
t_w : throat thickness of weld fillet
F_1 : axial force in in-plane braces
F_H : axial force (pre-load) in out-of-plane braces
F_u : ultimate axial load
M_{ipb} : in-plane bending moment
M_{opb} : out-of-plane bending moment
M_u : ultimate bending moment
M_{Yura} : bending moment at Yura's deformation limit
α : geometric chord length parameter $2*l_0/d$
β : diameter ratio d_1/d_0 and d_2/d_0
γ : chord radius to thickness ratio $d_0/2*t_0$
τ : wall thickness ratio t_1/t_0

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KEY WORDS: Tubular joints, X-joints, multiplanar, experiments, numerical simulation.

INTRODUCTION

In offshore structures it is common practice to analyse and design multiplanar joints with braces in different planes as being uniplanar. Initial investigations (Paul, 1989) have shown that, depending on the geometry and the loading, this may result in actual strengths which are either 35% lower, or in some cases even 100% higher than the ultimate strengths for uniplanar joints. Furthermore, the stiffness and the deformation capacity of multiplanar joints are largely influenced by multiplanar loading effects.

Therefore, the influence of loaded and unloaded out-of-plane braces on the static strength, stiffness and the deformation capacity of X-joints in circular hollow sections has been determined experimentally for different types of loading on the in-plane braces. The results of these experiments are presented in IJOPE, March 1991 (van der Vegte 1991a, 1991b).

A clear multiplanar effect was observed for the stiffness, strength and deformation capacity of multiplanar X-joints in comparison to uniplanar X-joints. In addition, numerical analyses have been performed on these 3 uniplanar and 9 multiplanar joints. The results of these numerical analyses are presented in the present study.

Finally, comparisons of the numerically determined results are made with different design codes and recommendations (IIW, 1989; API, 1987; AWS, 1990; Kurobane, 1980, 1981; and Wardenier, 1982).

RESEARCH PROGRAMME

The numerical and the experimental research programmes, which are identical, are summarized in Table 1 and descibed in