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The Static Behaviour of Multiplanar Tubular Steel TT-Joints Excluding the Effects of Chord Bending

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ABSTRACT

Current design codes for the design of welded tubular connections are mainly based on an extensive series of tests on simple uniplanar joints. To extend the number of experiments on multiplanar joints, Paul (1991) carried out experiments on axially loaded multiplanar TT-joints. However, in these tests, failure of the specimens was due to a combination of local failure and overall chord bending. In order to determine the influences of the geometrical parameters on the axial static strength due to local joint failure only, 11 finite element analyses have been performed on TT-joints with the same nondimensional geometrical parameters as the joints tested by Paul. The influence of α (i.e., overall chord bending) has been excluded by applying moments to the chord ends. The influences of β, g_t/d_0 and ϕ on the axial behaviour have been made clear. The numerically determined trends appeared to be in line with the influences derived from the analytical "ring model" approach. After making assumptions for equivalent β ratios, the ultimate strengths of the multiplanar TT-joints have been related to the ultimate (local) strength formulae derived for uniplanar T- and X-joints. As a result, the local strength of axially loaded multiplanar TT-joints has been described with the formulae derived for the local strength of axially loaded uniplanar T- and X-joints. The effects due to overall chord bending should be included separately, in line with the strategy described for uniplanar T-joints (van der Vegte, 1994b). The analyses which include overall chord bending, however, are not considered in the present work.

NOMENCLATURE

d_0	: outer diameter of chord
$d_{0,eq.}$	: equivalent chord diameter
d_1	: outer diameter of braces
$d_{1,eq.}$	: equivalent brace diameter
$f_{y,0}$	: yield stress of chord member
f_u	: ultimate tensile stress
g_t	: transverse gap between braces
l_0	: length of chord
$F_{1,u,loc.}$	: ultimate axial brace force without effects due to overall chord bending
$M_{0,\,chord\,end}$	: compensating moments applied to chord ends
t_0	: wall thickness of chord
t_1	: wall thickness of braces
α	: geometric chord length parameter $2{*}l_0/d_0$
β	: diameter ratio d_1/d_0
$\beta_{eq.}$	: equivalent β ratio
ϕ	: out-of-plane angle between braces
δ_1	: relative vertical displacement of crown point of a brace
2γ	: chord diameter to thickness ratio d_0/t_0
τ	: wall thickness ratio t_1/t_0

INTRODUCTION

Current design codes which are used for the design of multiplanar joints between circular hollow sections (A.P.I. 1991, A.W.S. 1994, Eurocode 3 1992, I.I.W. 1989, Wardenier 1991) are mainly based on extensive tests on uniplanar joints, due to the lack of experimental data on multiplanar joints. In order to extend the number of data on multiplanar joints, Paul (1991) carried out an experimental study of 12 static tests on multiplanar TT-joints. The influences of the diameter ratio β, the out-of-plane gap to chord diameter ratio g_t/d_0 and the out of plane angle between the two braces ϕ were investigated. After nonlinear regression analyses of the experimental results, Paul proposed mean ultimate capacity equations for the static strength of multiplanar TT-joints.

However, similar to uniplanar T-joints, failure for multiplanar TT-joints is caused by a combination of local failure (chord face plastification) and overall chord bending and shear. The most governing parameter between these failure modes is the chord length (α influence). The influence of overall chord bending (α influence) on the static strength has not been included in the strength formulae proposed by Paul. Therefore, in line with the analyses for uniplanar T-joints (van der Vegte, 1994a), numerical models have been set up for multiplanar TT-joints in order to investigate the local joint behaviour by excluding the influence of chord bending.

In addition, a brief description has been given of the results of the analytical ring model approach.

Finally, based on the results of numerical analyses of multiplanar TT-joints and the corresponding uniplanar T- and X-joints, new ultimate strength formulae have been set up for axially loaded multiplanar TT-joints excluding the influence of overall chord bending.

RESEARCH PROGRAMME

The configuration of multiplanar TT-joints excluding the effects of chord bending is shown in Fig. 1, while the dimensions have been presented in Fig. 2.

The research programme of the multiplanar TT-joints is sum-

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KEY WORDS: Multiplanar tubular steel TT-joints, overall chord bending, analytical approach, ring model, numerical simulations.