Internally constrained beam-like model of an elasto-plastic thin pipe

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Tubular thin-walled beams are widely used in industrial and civil applications, e.g., in gas and oil distribution pipelines, aerospace structures, waterworks and many others. It is well-known that conventional beam models (Euler-Bernoulli, Timoshenko) typically fail at the evaluation of their bearing capacity, essentially due to the consequences of the not negligible change in shape of the cross section, for instance in case of uniform bending.

The Brazier effect [1], which relates uniform bending to the flattening of the cross section of thin tubes, induces moreover a possible source of instability, even in case of elastic material, giving rise to a nonlinear softening behavior of the structure and, finally, to the occurrence of catastrophic limit points.

With the aim of dealing with a simple and reliable model of a thin tube, that was handleable and provided an analytical description of flattening in case of bending, in [2] an internally constrained beam model is proposed, where the softening moment-curvature relationship is achieved using mechanical considerations. There, the possibility to include structural foams as core of the pipe is addressed, so as to increase the stiffness and reduce the possibility of instability occurrence.

Here, the model proposed in [2] is modified to account for the case of elasto-plastic nature of the constituent material of the tube. More specifically, the internal constraint between flattening amplitude and bending moment is evaluated in case of elastic-perfectly plastic material, where the stress induced in a region of the cross-section reaches the elastic limit. Application examples show the behavior of the tube under uniform and nonuniform bending, compared with what occurs for elastic material.

Finally, the case of elasto-plastic tube filled with elasto-plastic structural foam is addressed as well, so as to show the combined effect of exceeding the elastic limits of the two constituent materials on the bearing capacity of the tubular beam.

References

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