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ADVANCED NUMERICAL TECHNIQUES APPLIED TO THE STRENGTH PREDICTION OF STEPPED-LAP ADHESIVE JOINTS

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ABSTRACT
This work has as main objective the prediction of the behaviour of step joints using the Extended Finite Element Method (XFEM), with different overlap lengths (L_O). Three adhesives, Araldite® AV138, Araldite® 2015 and Sikaforce® 7752, whose properties are quite different, were used in the analysis. To compare this numerical work, experiments with these joints were undertaken. Peel and shear stresses of the adhesives were analysed, which allows an analysis of the behaviour of the different adhesives under different conditions. For the analysis, different damage initiation criteria were used using stresses and strains. The damage law shape was also evaluated, namely the linear and exponential damage propagation laws.

Keywords: extended Finite Element Method, adhesive joint, structural adhesive.

INTRODUCTION
Currently, adhesive bonds have been used in several areas, more frequently in recent years. These joints have advantages over other methods such as welding. The advantages that stand out are the significant reduction of weight as well as the reduction of stress concentrations. For the joint strength prediction, Fracture Mechanics techniques are often used. The tensile (G_{IC}) and shear toughness (G_{IIC}) are two of the most important parameters to predict the joint behaviour. In relation to adhesives, these are divided into two groups, brittle and ductile. The Finite Element Method (FEM) has been used in the last decades, because this method is much faster in the analysis of the joint strength (da Silva and Campilho, 2012). More recently, the XFEM has emerged, which can also be used to predict the joint behaviour, however, lacking validation for this purpose.

In this work, stepped-lap joints were tensile tested between steel adherends. Three structural adhesives were considered: the brittle epoxy Araldite® AV138, and the ductile epoxy Araldite® 2015 and polyurethane Sikaforce® 7752. The geometrically non-linear XFEM analysis was performed in Abaqus®. Decohesion was promoted by the XFEM formulation, while the adherends were modelled by continuum elements. The analysis was two-dimensional.

RESULTS AND CONCLUSIONS
Figure 1 shows, as an example, the maximum load ($P_{máx}$) obtained by the XFEM for the stepped joints bonded with the adhesive Araldite® AV138, for the different initiation criteria and L_O.

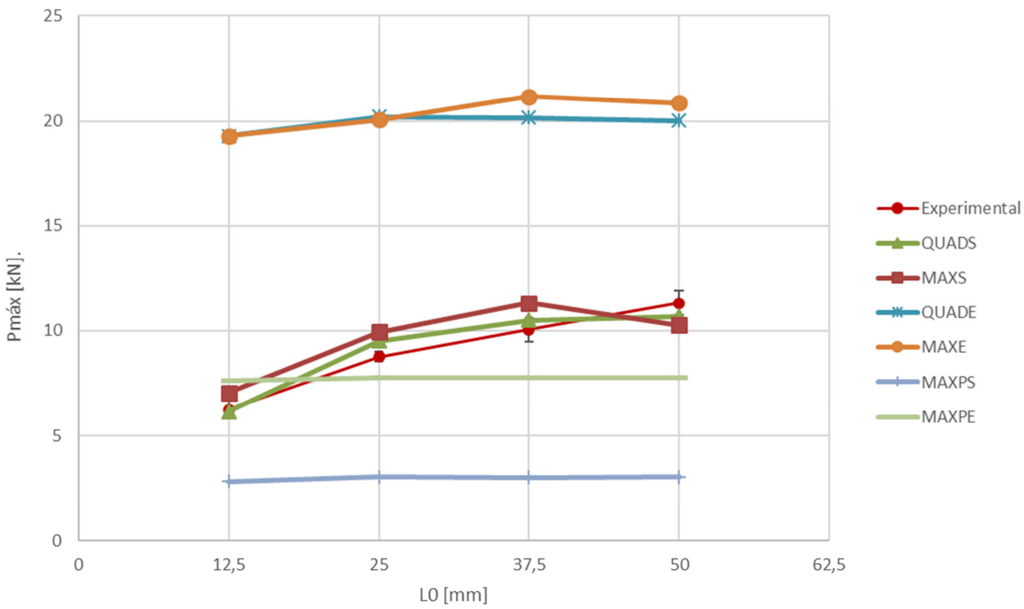

Fig. 1 - Variation of $P_{máx}$ as a function of L_O, for the different damage initiation criteria, using the adhesive Araldite® AV138.

For this adhesive, it was found that the stress-based criteria QUADS and MAXS are those that present $P_{máx}$ values closer to the experimental ones. In the other criteria (MAXPS, QUADE, MAXE and MAXPE), the difference is higher. The MAXPS and MAXPE criteria present, for the majority of joint geometries, much lower results than the experimental ones. For the MAXS criterion, the maximum $P_{máx}$ difference between the experimental results and the results obtained by the XFEM for the Araldite® AV138 adhesive was 13%, for L_O=12.5 mm.

For the QUADS criterion, the $P_{máx}$ difference for the same L_O was -1%. Regarding the MAXE and QUADE criteria, the difference is substantially larger, with a maximum difference of 209% for both, obtained for L_O=12.5 mm. The large values obtained for these criteria are related to damage and failure being governed by the limit deformations of the adhesives instead of their stresses.

In the MAXPS and MAXPE criteria, it is verified that the obtained results are typically much lower than expected, and similar regardless of L_O. The maximum deviations of these criteria are -73% and -31%, respectively, in both cases for L_O=50 mm. These criteria present very low $P_{máx}$ values because the limit stresses and strains are reached quickly in the zones of stress and strain concentration, and because $P_{máx}$ is considered to be attained at the onset of crack propagation.

The XFEM was found to be adequate to predict the joint strength using the QUADS and MAXS criteria, where it presents fairly accurate results.

REFERENCES

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