Effects of temperature and peel-rate on fracture energy in the peeling process of a commercial safety film by considering a variable peel-angle θ

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Abstract

The use of protective films on glass elements is common also in the civil engineering field but the literature is lacking in definition of the advantages in using protective films on glass impact. The aim of this research is to provide a complete characterization of the adhesive layer at the interface by using in combination experimental tests, theoretical assessment and numerical parametric studies in Abaqus/Simulia. The adhesion strength can be used as a critical parameter in the definition of delamination. In particular, it has been studied how the influence of temperature and aging time can influence the characteristics of these materials.

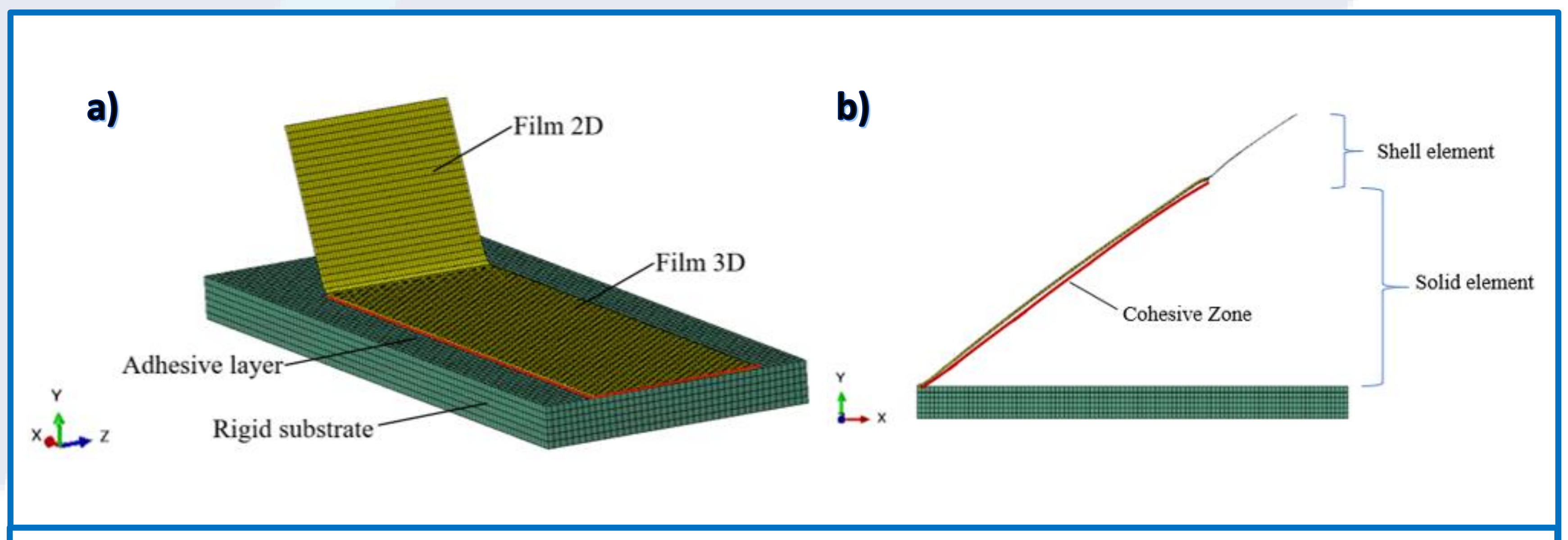

Fig.1 *Fracture Energy FE Model: 3d view (a) and 2d view (b).*

Introduction

In addition to the energy saving features, many experimental studies have shown how the use of films can increase the performance of glass, both in terms of resistance and in terms of safety especially in case of impulsive and unpredictable nature events (e.g., Smith and Brokaw [1]). The numerical ABAQUS model (as shown in Fig.1) has been used to assess the adhesion energy and to develop a consistent cohesive zone law (Fig.2) for the specific protective film (as reported in Fig.3) in a peeling configuration in order to investigated fracture behaviour by properly reproducing experimental setup.

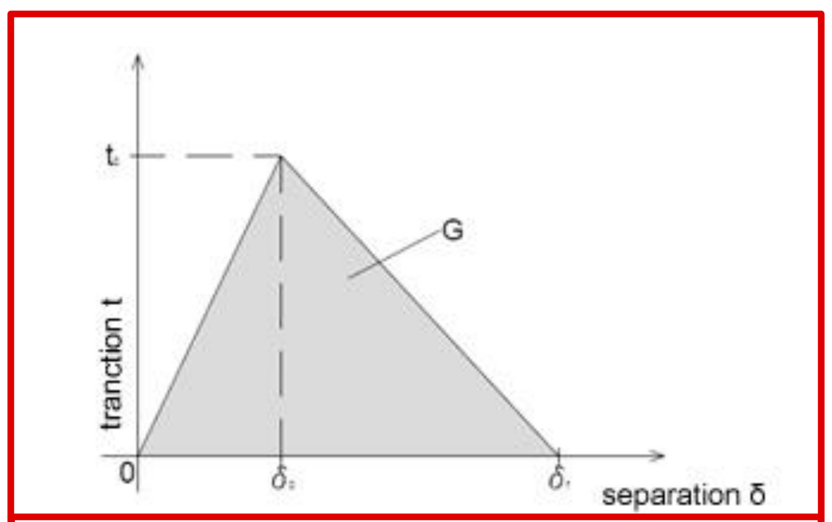

Fig.2 *Traction-separation law.*

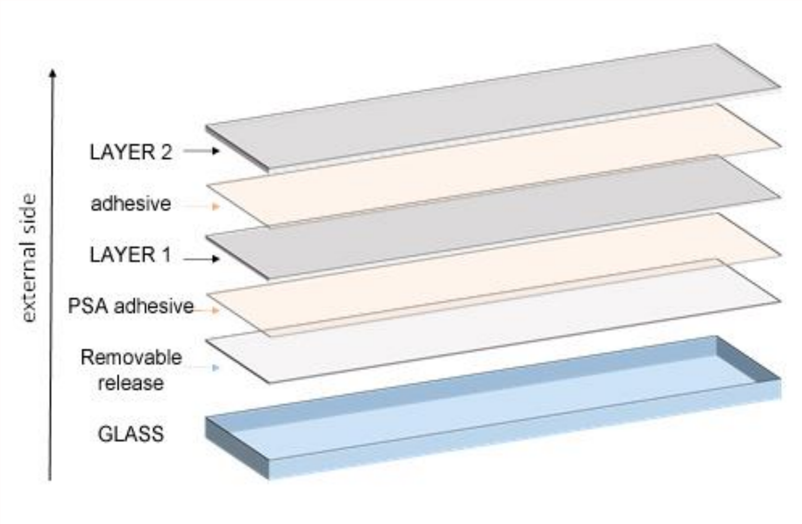

Fig.3 *Stratification detail of safety film on glass substrate.*

Materials and Methods

The experimental program can be divided in two main parts based on the nature of the involved experiments. The first part concerned the characterization of materials making up the film, with DSC and IR Spectroscopy analyses (Fig.4), and its mechanical behaviour while the second dealt with the numerical characterization of adhesive layer. Moreover, a theoretical approach, based on Kinloch discussion [2], was introduced to consider the peel angle variation from an initial 90-degree configuration (i.e., Fig.5).

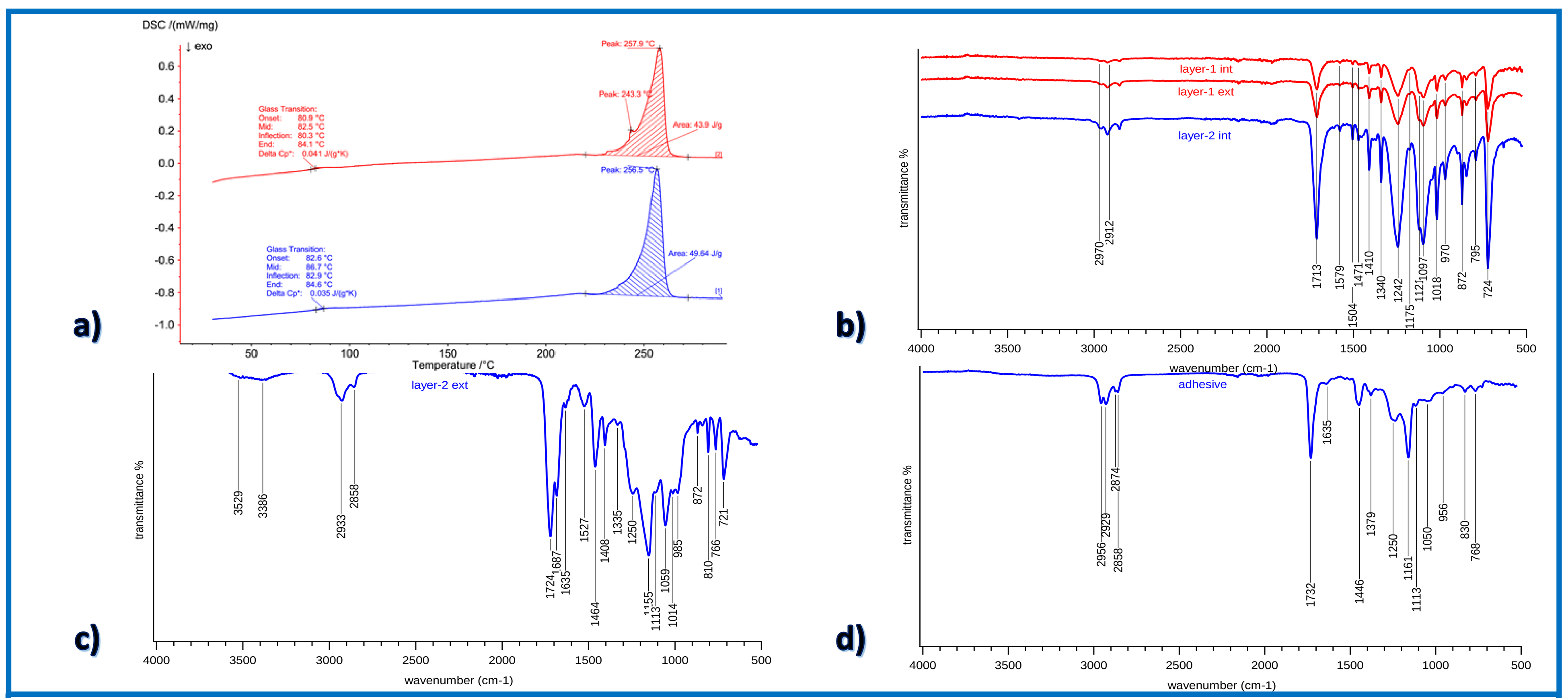

Fig.4 (a) DSC and (b, c, d) IR Spectroscopy analyses.

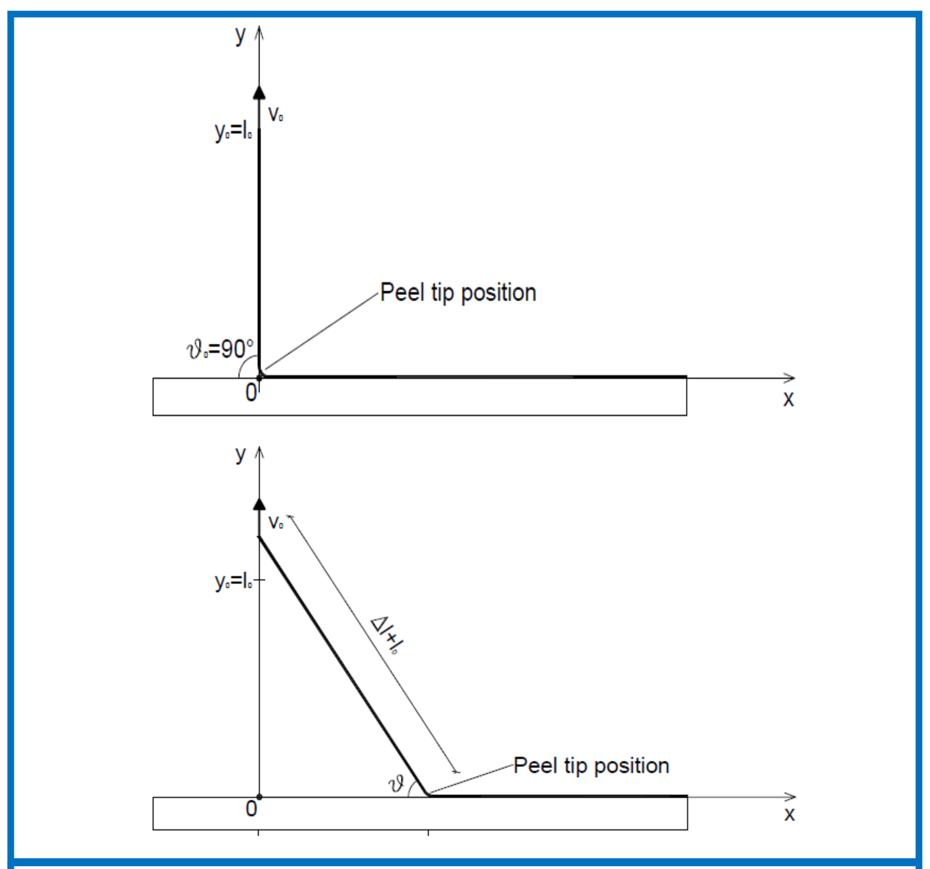

Fig.5 *Schematic geometry of peel-test.*

Results and conclusion

Generally, the temperature, such as peel-rate, is known to significantly influence the mechanical behaviour of polymers. Firstly, it is important to note that although the temperature range explored in this work is below the glass transition temperature (T_g) of the material, the influence of temperature on PET tensile properties has not be neglected in order to properly model the material in FE software. Finally, 54 parametric numerical analyses - eleven samples in function of temperature, ageing time and peeling rate - show a good agreement between the shape of each pair of outputs (numerical and theoretical according to a modified Kinloch approach), as shown in Fig.6, but the effect of the variable peel-angle and the influence of little impurities or inclusion lead to an underestimation for FE simulations.

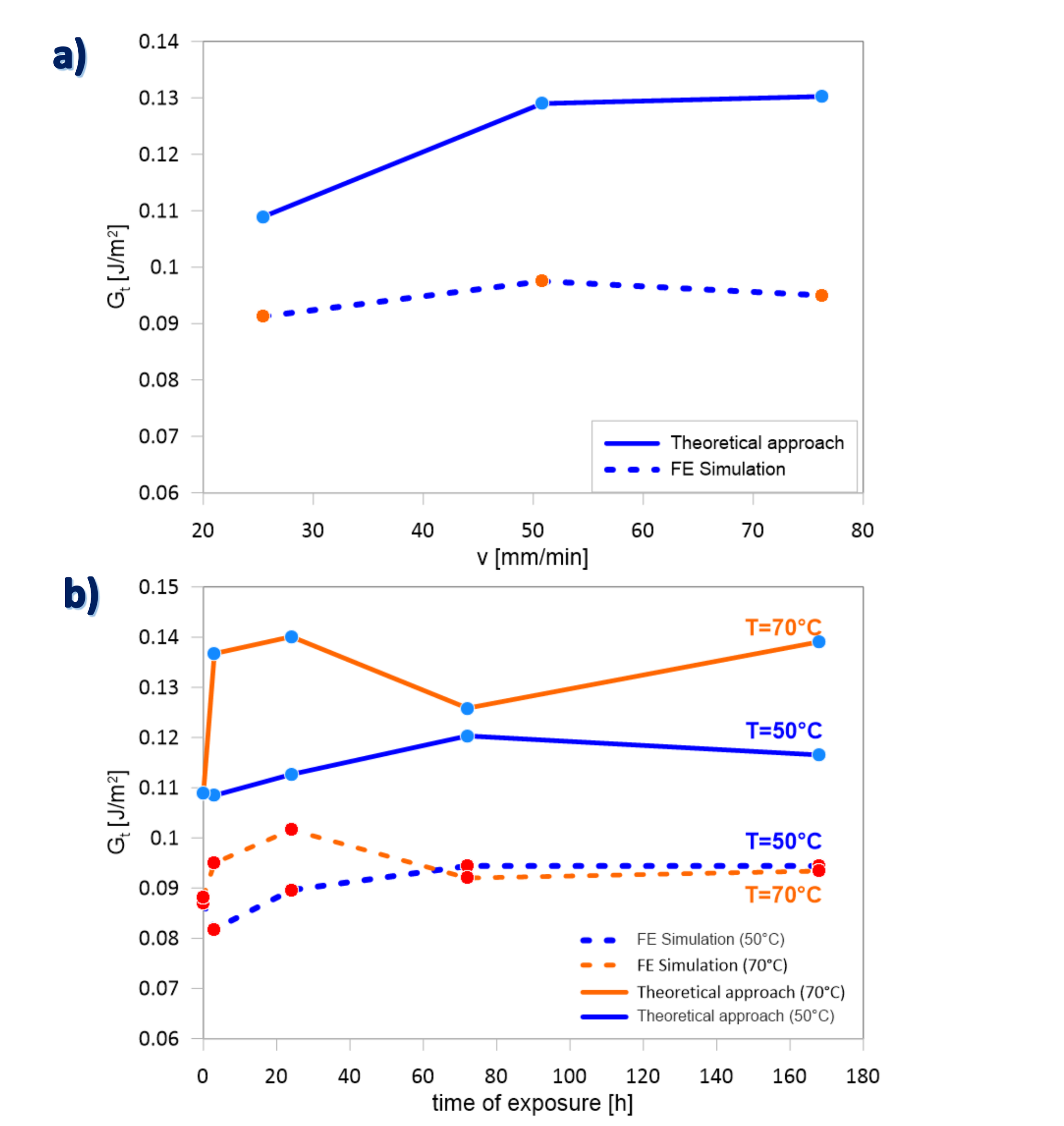

Fig.6 *Fracture energy calculated by the theoretical approach and by ABAQUS simulations as functions of (a) peel-rate and (b) temperature.*

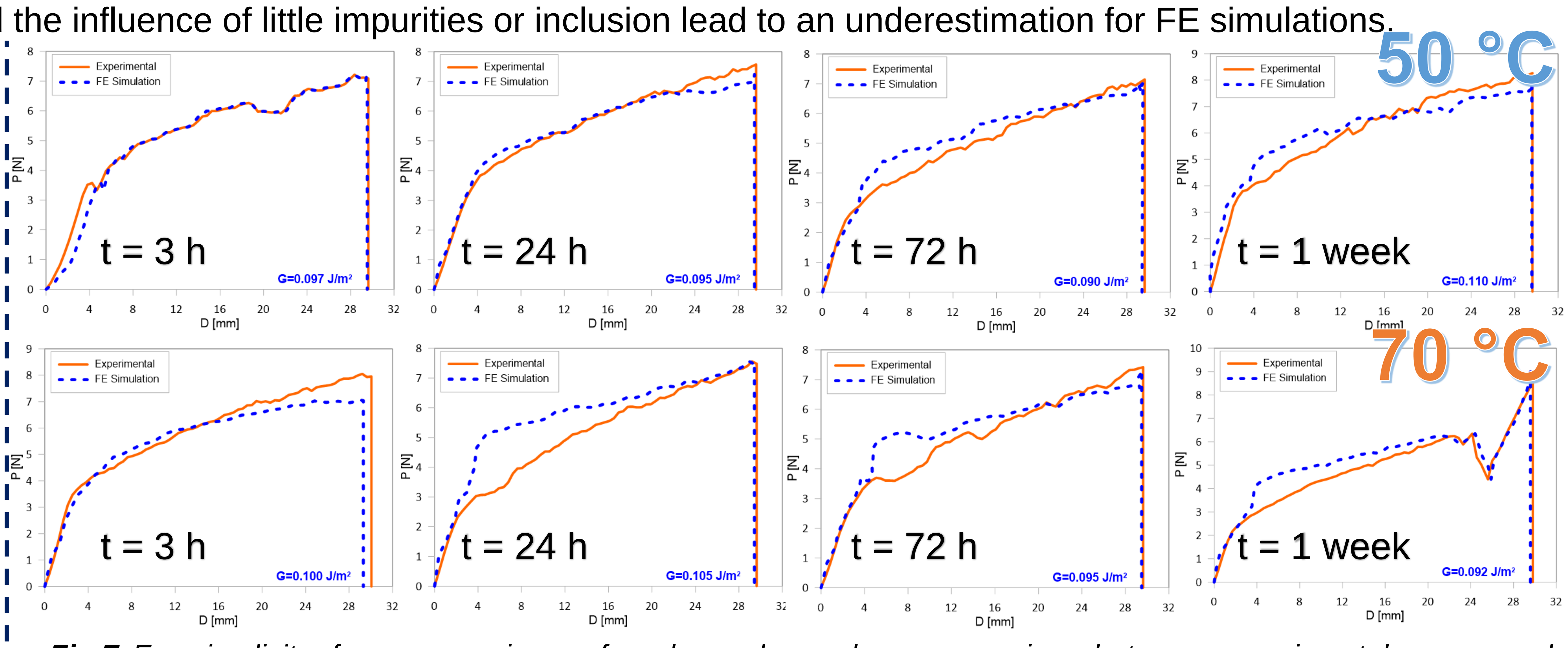

Fig.7 *For simplicity, for one specimen of each aged sample, a comparison between experimental curves and numerical simulations is reported: peel force F versus vertical displacement D for various prescribed aging conditions, according to BS EN ISO 9142:2003.*

References

[1] J.L. Smith, J.T. Brokaw:2000. "Explosive tests for the evaluation of the glass fragment mitigation characteristics of MSC Specialty Films Inc. security window film." Applied Research Associates, Vicksburg, Miss.

[2] A.J. Kinloch , C.C. Lau, J.G. Williams:1994. The peeling of flexible laminates. Int. J. Fract. 66: 45-70.

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