

S1: Governing equations

Yielding on the left section of the critical state line causes to softening behavior (dilation), while on the right section results to compaction. When the material reaches the point of the critical state line and yield surfaces, it experiences isovolumetric changes. The yield surface is defined through (Crook et al. 2006):

$$\Phi(\sigma, \varepsilon_v^p) = g(\theta, p) \times q - (p - pt) \times \tan \xi \times \left[\frac{p - pc}{pt - pc} \right]^{\frac{1}{n_p}} \quad \text{Eq. S1}$$

Where σ , ε_v^p , θ , p , q , and n_p shows stress, volumetric plastic strain, Lode angle, mean effective stress (Eq. 4), deviatoric stress (Eq. 5), and p-q plane shape parameter respectively. Here $g(\theta, p)$ is implemented to control the shape of the surface:

$$g(\theta, p) = \left[\frac{1}{1 - \xi^\pi(p)} (1 + \xi^\pi(p) \frac{r^3}{q^3}) \right]^{N^\pi} \quad \text{Eq. S2}$$

Where

$$\xi^\pi(p) = \xi_0^\pi \exp \left(\xi_1^\pi p \frac{pc^0}{pc} \right) \quad \text{Eq. S3}$$

Here pc^0 and pc represent the pre-consolidation pressures at the start of deformation and the current state, respectively. These values are used to calculate the material constants of ξ_0^π and ξ_1^π . By taking into account the deviatoric stress tensor as S and 3rd deviatoric stress invariant as J'_3 , following equation can be used to obtain r :

$$r^3 = \frac{9}{2} S : S = \frac{27}{2} J'_3 \quad \text{Eq. S4}$$

The compaction or softening behaviour is regulated by adjusting the intercept of the yield surface with the effective mean stress axis which are defined through Eq. S5 and Eq. S6:

$$pc = pc^0 \exp \left[\frac{V \varepsilon_v^p}{\lambda - \kappa} \right] \quad \text{Eq. S5}$$

$$pt = pt^0 \exp \left[\frac{V (\varepsilon_v^p)_{max}}{\lambda - \kappa} \right] \quad \text{Eq. S6}$$

Where n shows the porosity and V (specific volume) is obtained through:

$$n = \frac{V - 1}{V} \quad \text{Eq. S7}$$

Plotting V against $\ln(p)$ during loading and unloading results in λ as the angle of inclination of the normal compaction data and κ as the angle of inclination of the offloading curve (Albertz and Lingrey, 2012).

S2: Simulation Results Overview

The following section presents simulation results for plastic strain, the horizontal-to-vertical stress ratio, maximum shear stress-to-mean effective stress ratio, and porosity values corresponding to each case identified in the main manuscript (Fig. S1- Fig. S42). For clarity, each case includes six subplots, featuring plastic strain plots at 2, 4, and 7 Ma. It is important to note that the color legend for the 2 Ma plots remains consistent across all cases, while the color legends for the other two time points vary. The subplots also include horizontal over vertical stress at 7 Ma, maximum shear stress over mean effective stress at 7 Ma, and a porosity field at 7 Ma. Throughout the simulations, sedimentation initiates at 5 Ma and continues until 7 Ma, contributing to the evolution of the depicted parameters.

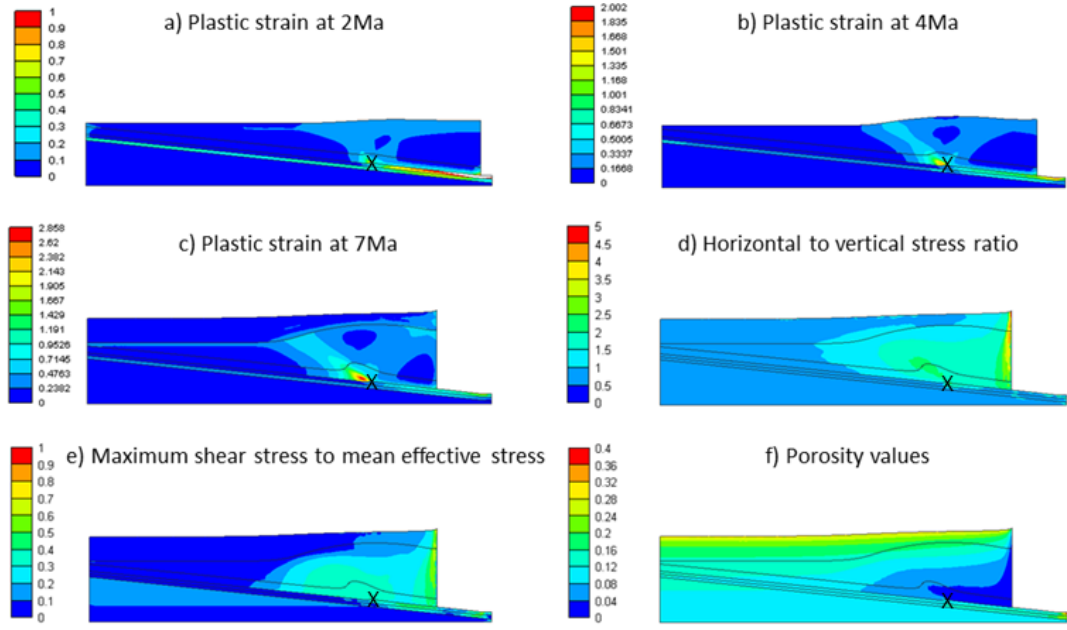


Figure S1: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #1 ($\beta = 6^\circ, \alpha = 0^\circ, \mu_{decol.} = 0$, and $p_c = 2.5$ MPa).

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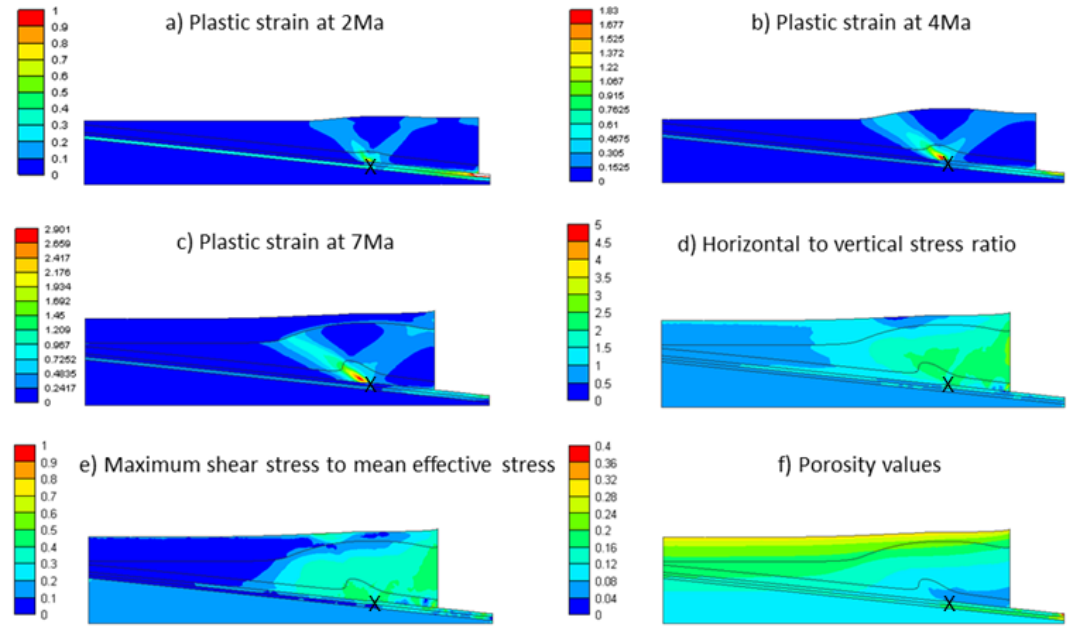


Figure S2: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #2 ($\beta = 6^\circ, \alpha = 0^\circ, \mu_{decol.} = 0$, and $p_c = 5$ MPa).

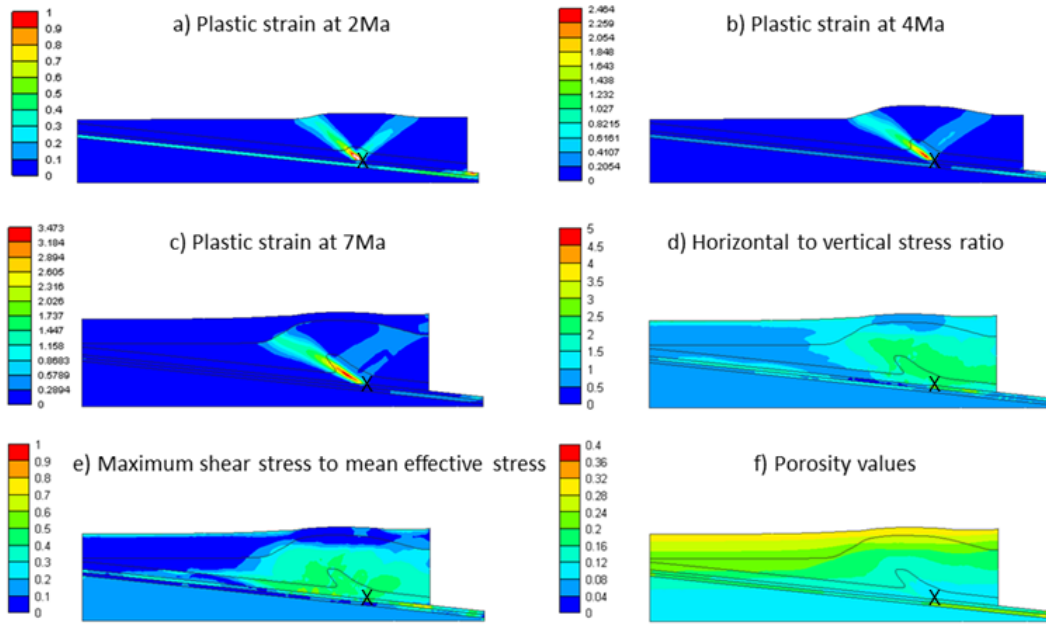


Figure S3: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #3 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0$, and $pc = 10$ MPa).

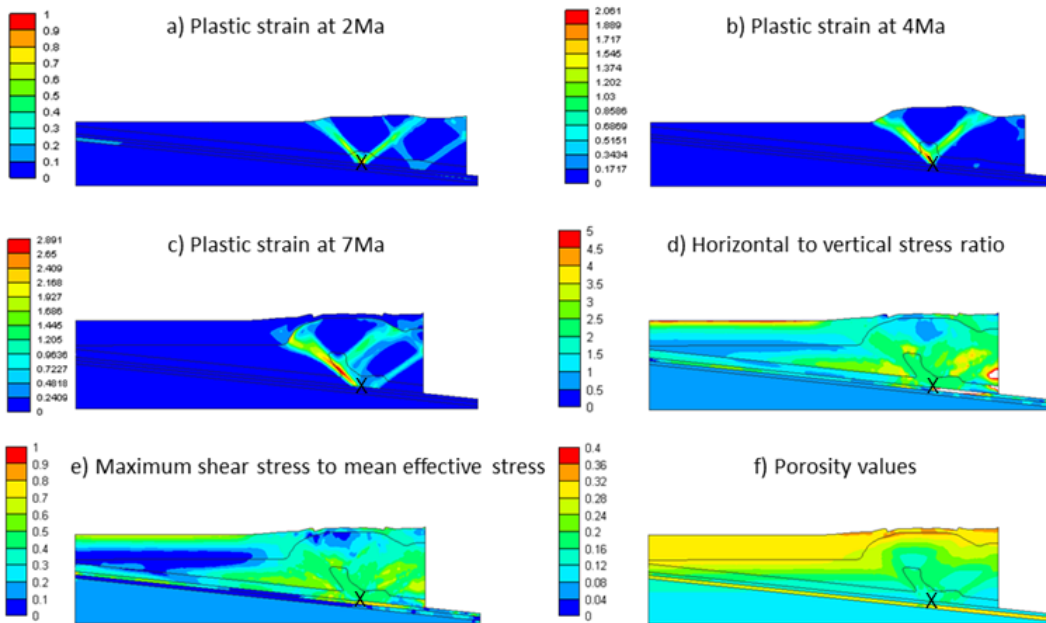


Figure S4: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #4 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0$, and $pc = 50$ MPa).

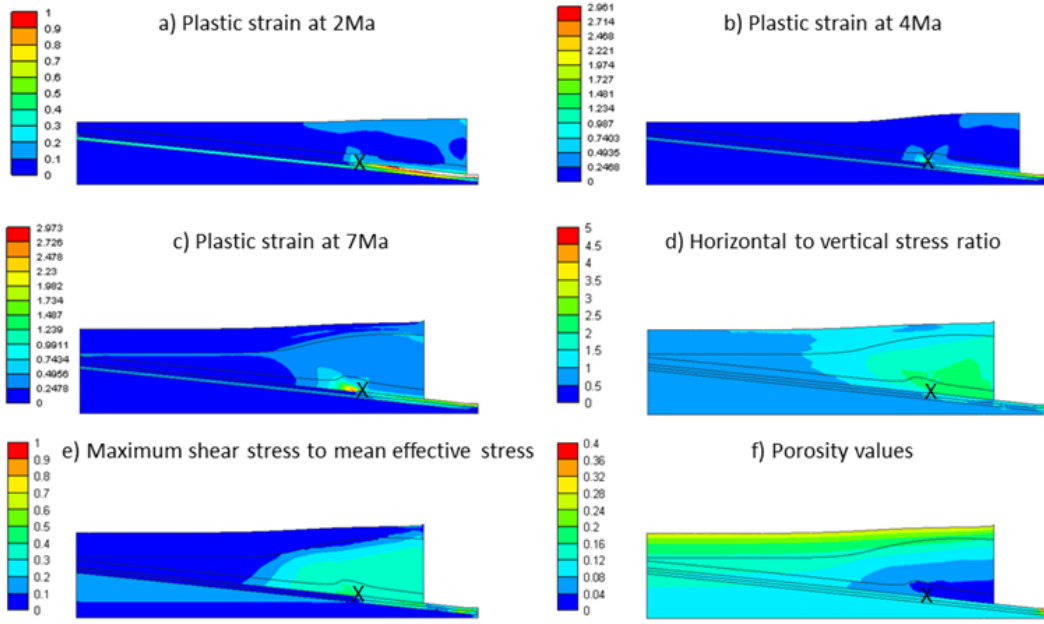


Figure S5: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #5 ($\beta = 6^\circ, \alpha = 0^\circ, \mu_{\text{decol.}} = 0.15$, and $p_c = 2.5$ MPa).

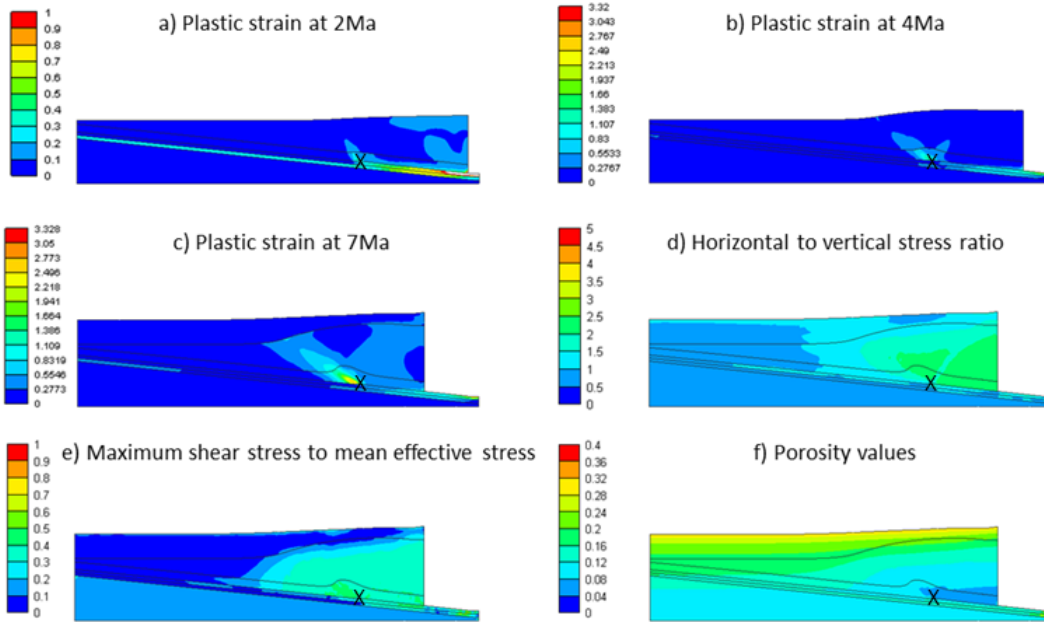
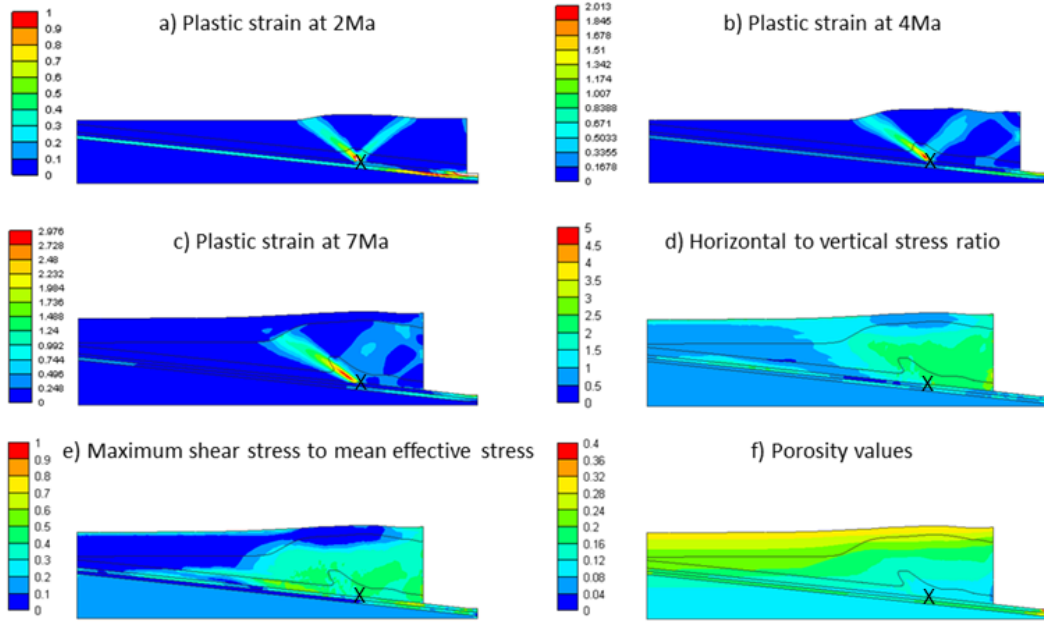
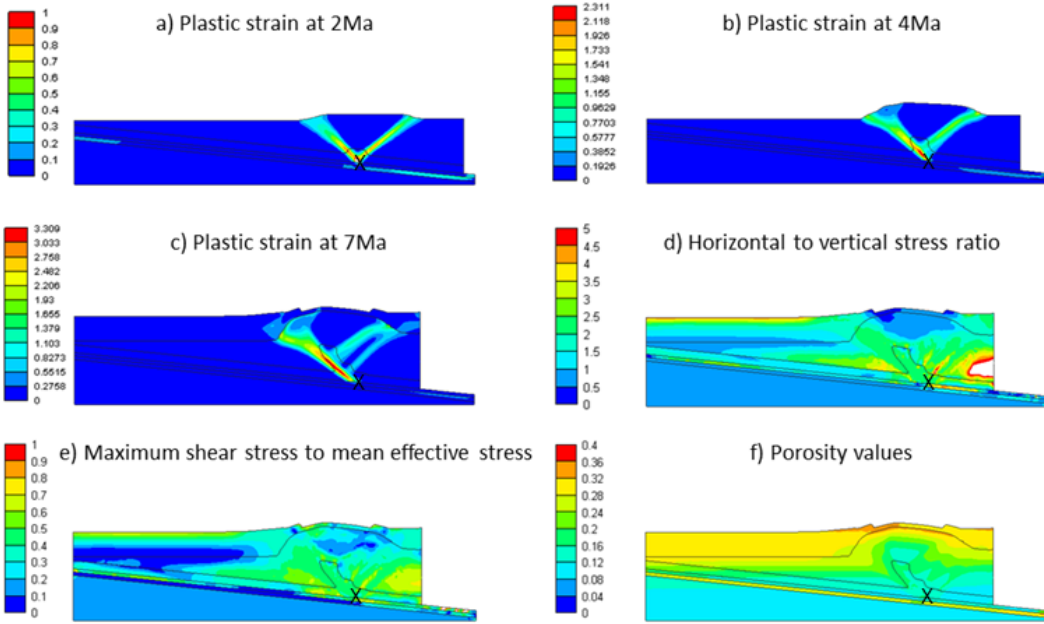


Figure S6: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #6 ($\beta = 6^\circ, \alpha = 0^\circ, \mu_{\text{decol.}} = 0.15$, and $p_c = 5$ MPa).



80 Figure S7: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #7 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.15$, and $p_c = 10$ MPa).

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90 Figure S8: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #8 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.15$, and $p_c = 50$ MPa).

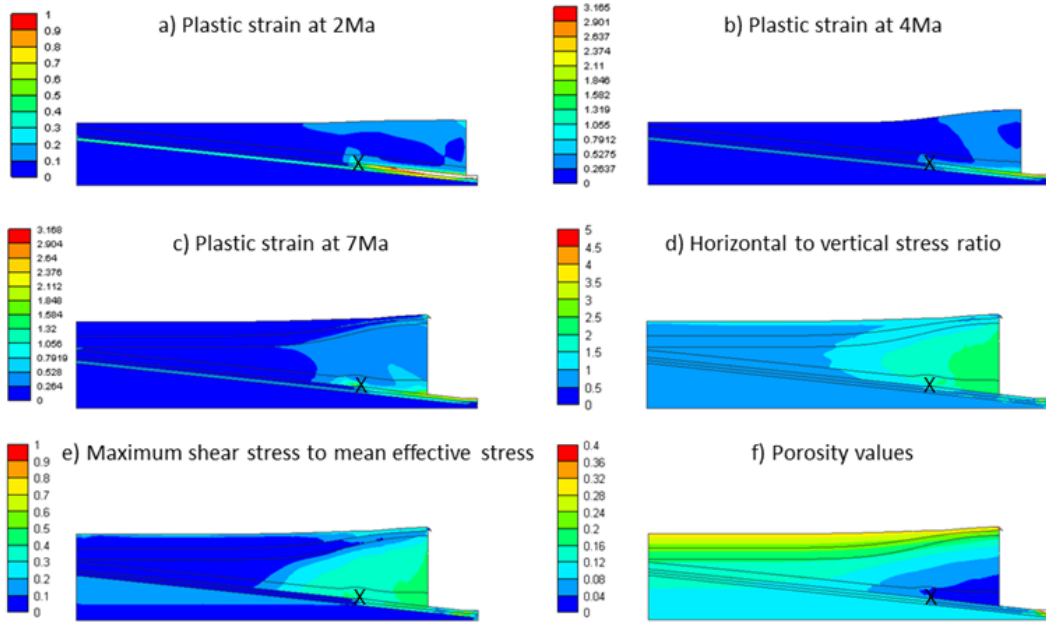


Figure S9: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #9 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.3$, and $p_c = 2.5$ MPa).

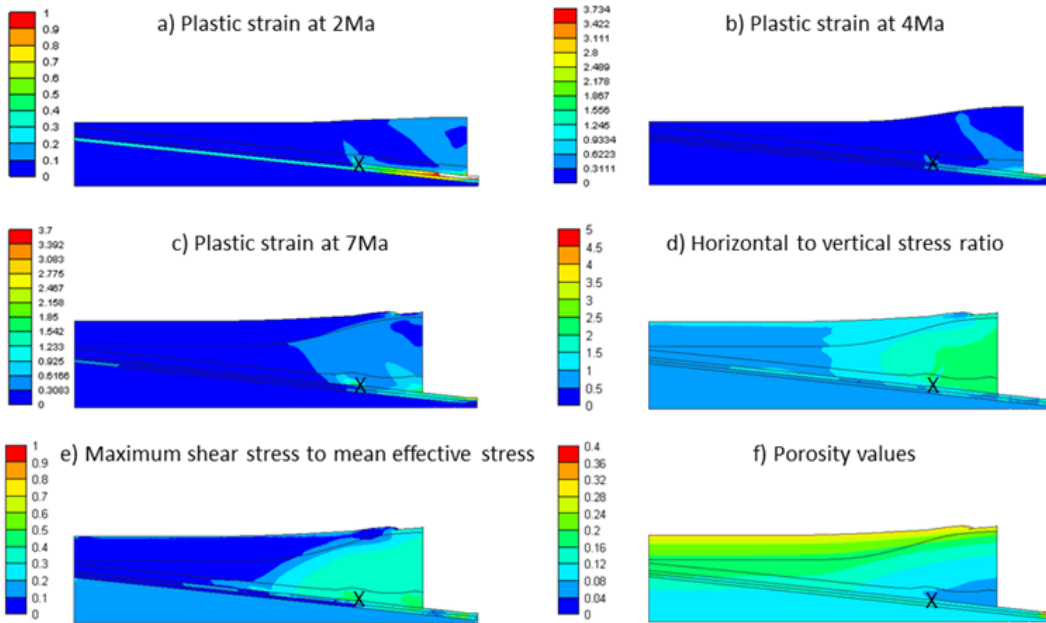


Figure S10: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #10 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.3$, and $p_c = 5$ MPa).

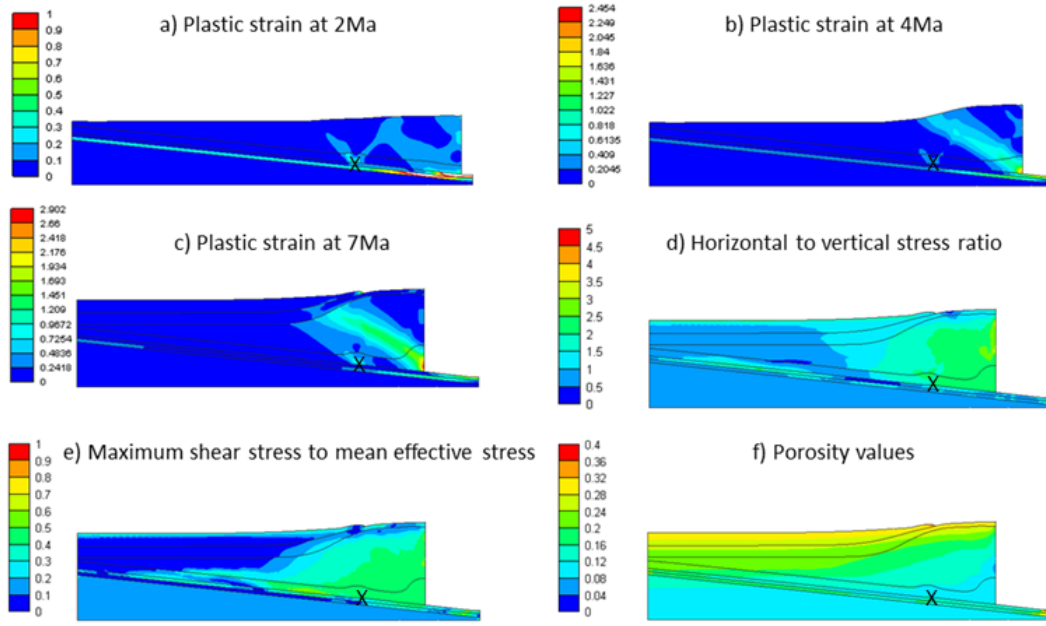


Figure S11: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #11 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.3$, and $p_c = 10$ MPa).

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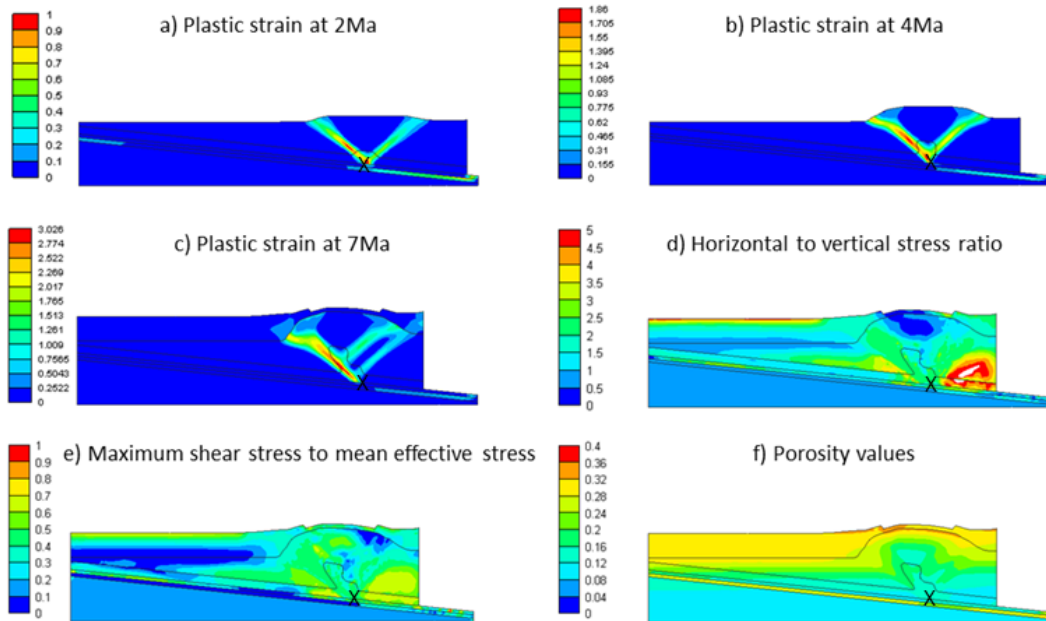


Figure S12: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #12 ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.3$, and $p_c = 50$ MPa).

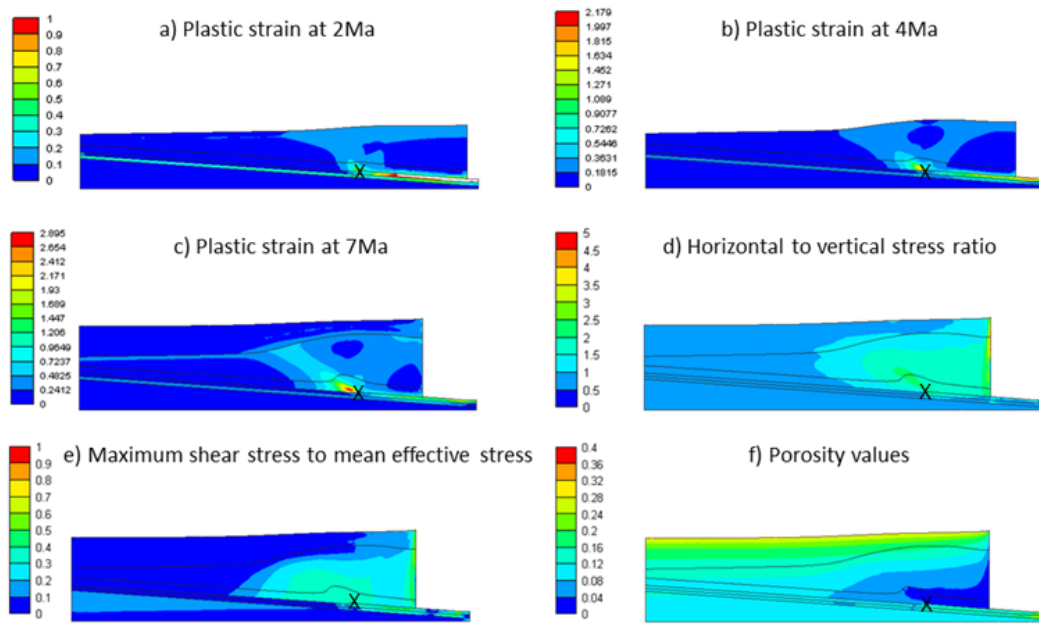


Figure S13: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #13 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0$, and $pc = 2.5$ MPa).

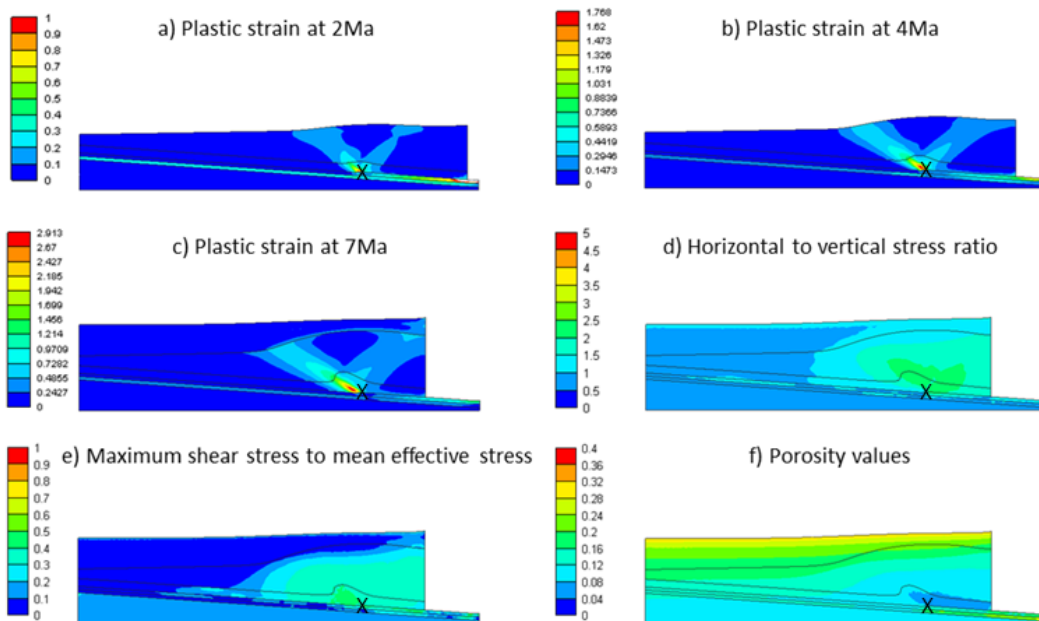


Figure S14: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #14 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0$, and $pc = 5$ MPa).

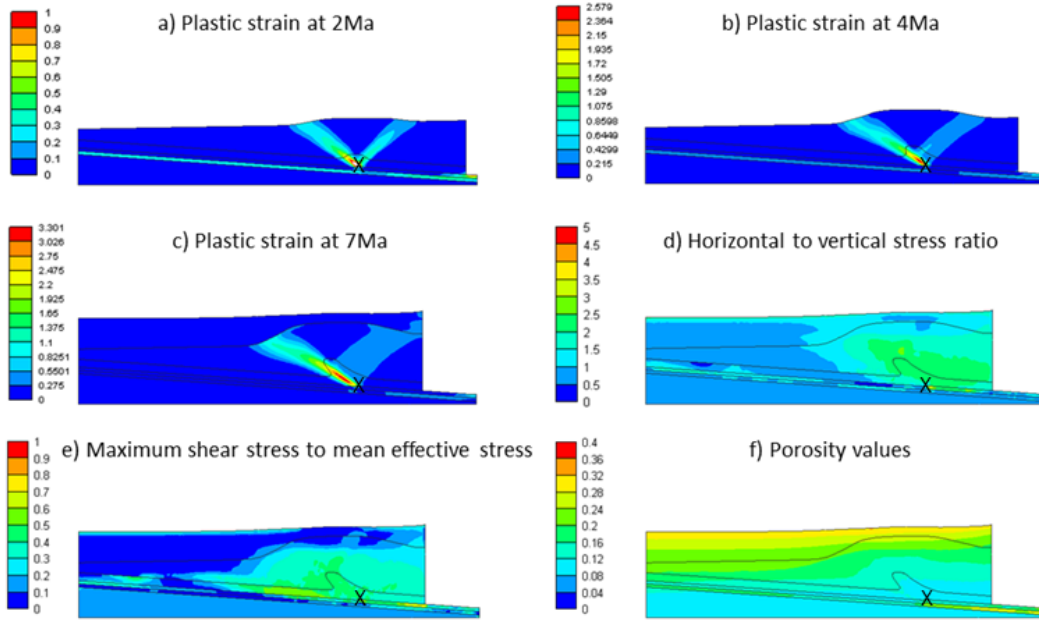


Figure S15: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #15 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0$, and $pc = 10$ MPa).

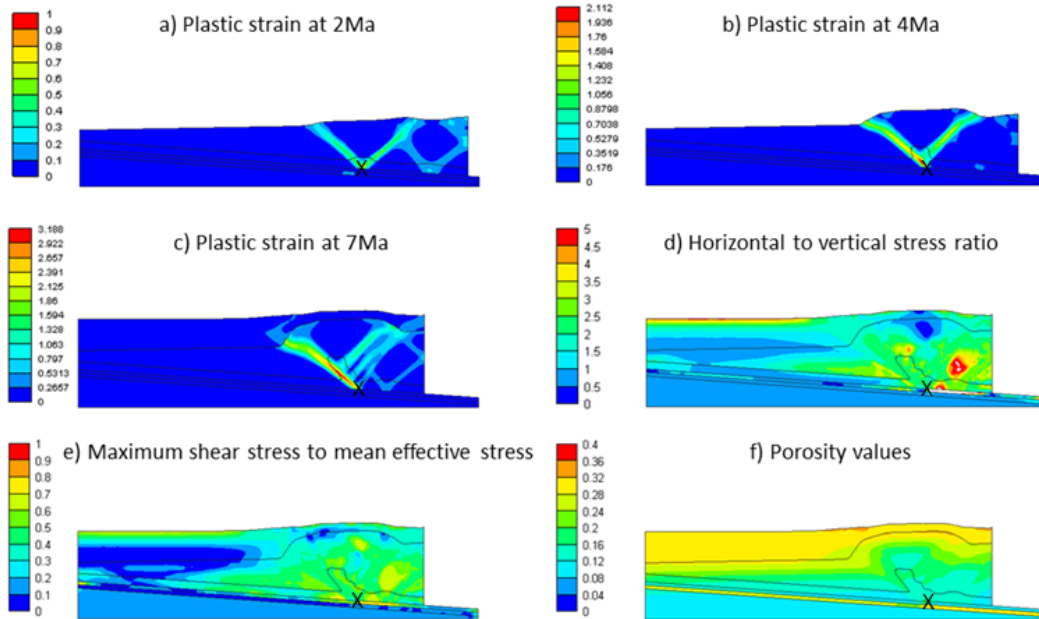


Figure S16: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #16 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0$, and $pc = 50$ MPa).

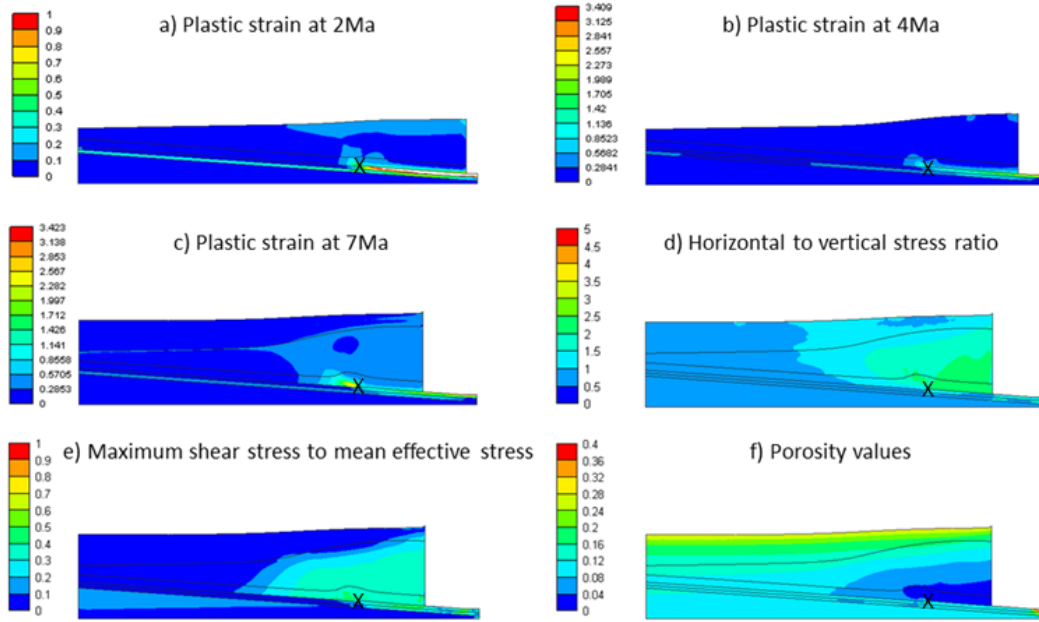


Figure S17: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #17 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0.15$, and $pc = 2.5$ MPa).

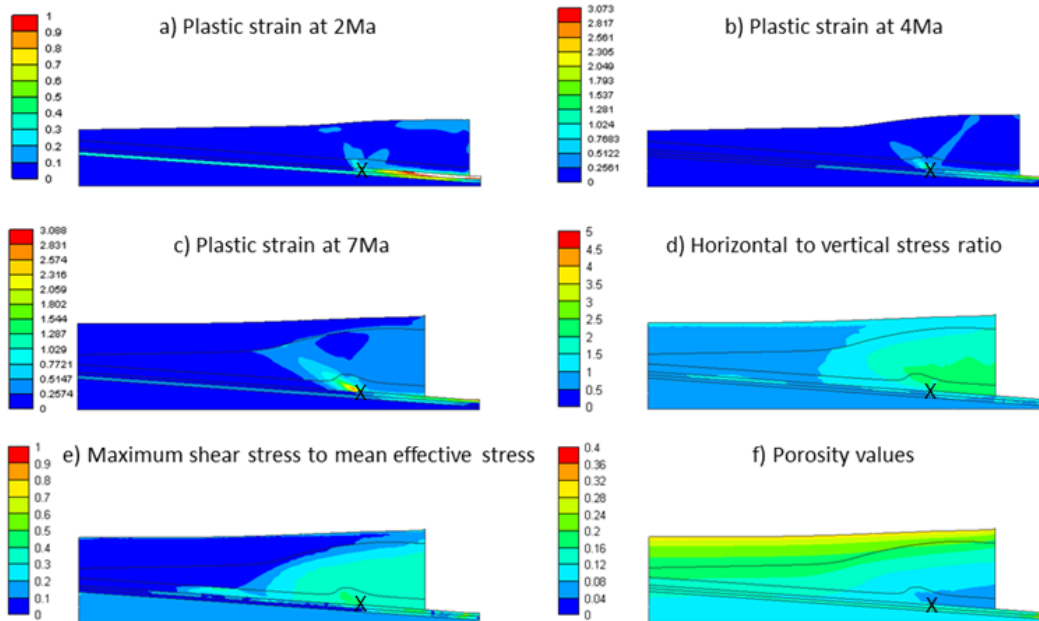


Figure S18: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #18 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0.15$, and $pc = 5$ MPa).

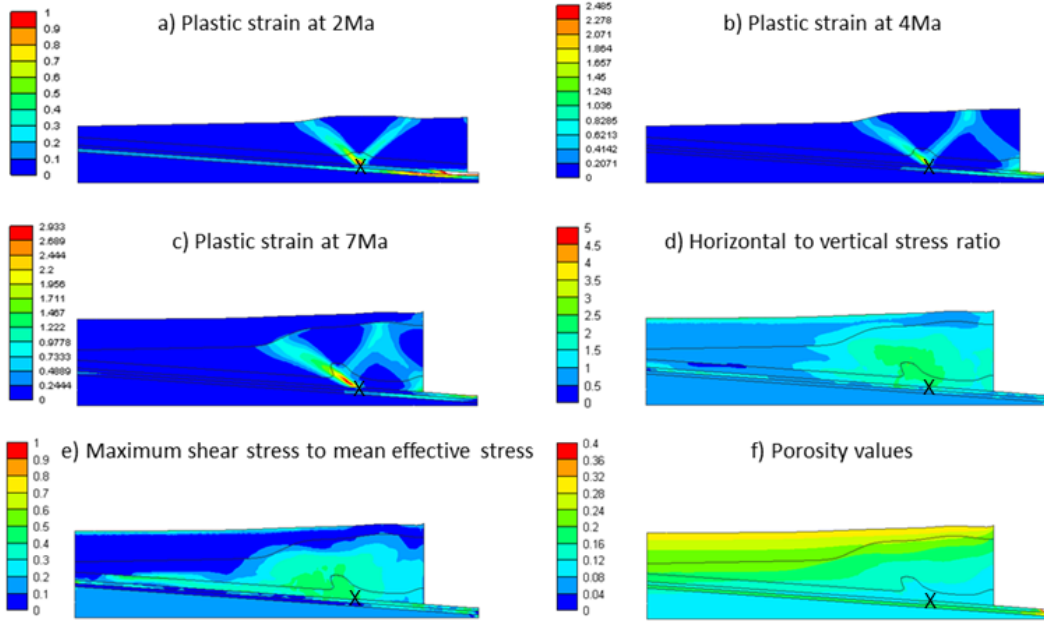


Figure S19: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #19 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{\text{decol.}} = 0.15$, and $p_c = 10$ MPa).

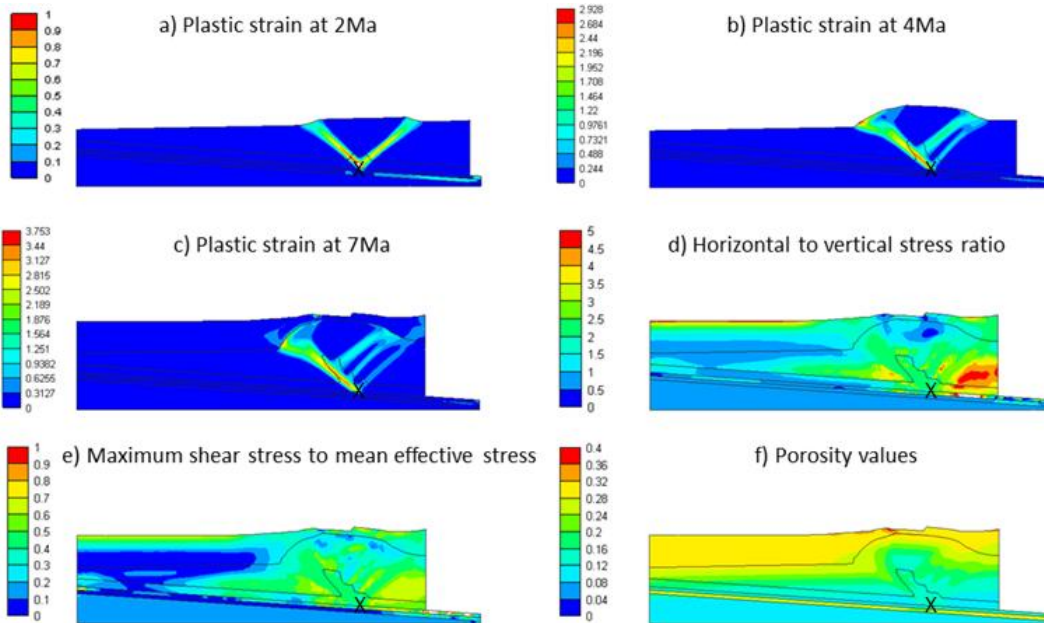


Figure S20: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #20 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{\text{decol.}} = 0.15$, and $p_c = 50$ MPa).

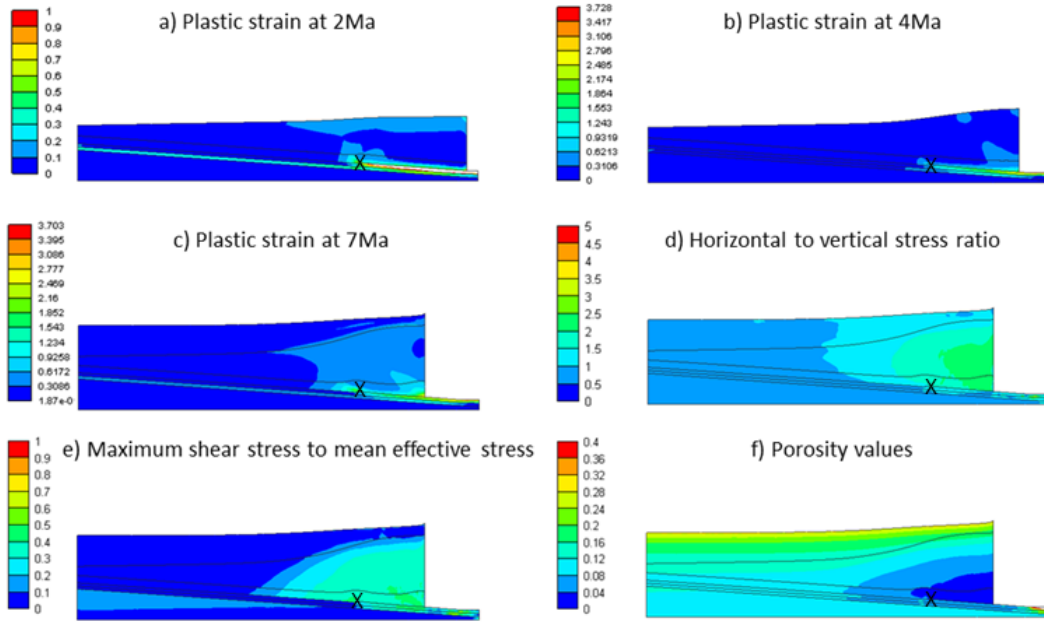


Figure S21: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #21 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0.3$, and $pc = 2.5$ MPa).

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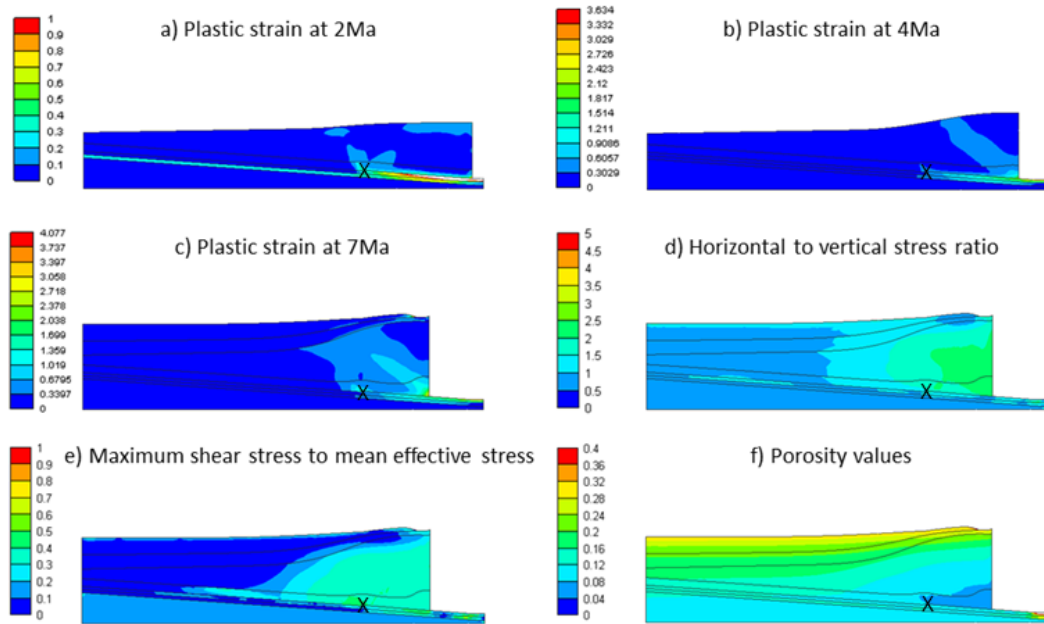


Figure S22: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #22 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0.3$, and $pc = 5$ MPa).

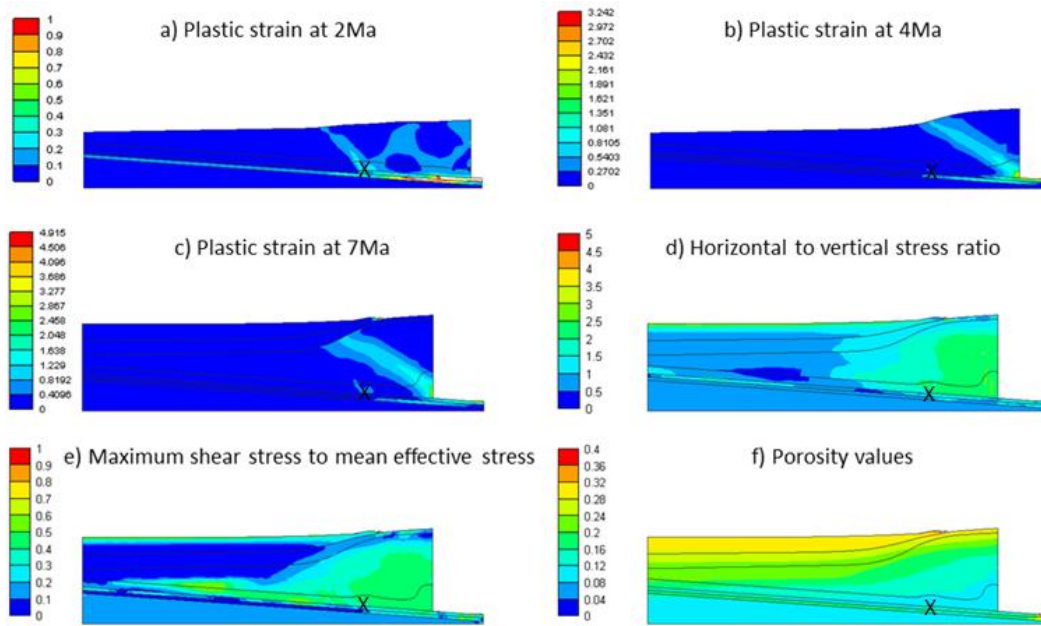


Figure S23: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #23 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0.3$, and $pc = 10$ MPa).

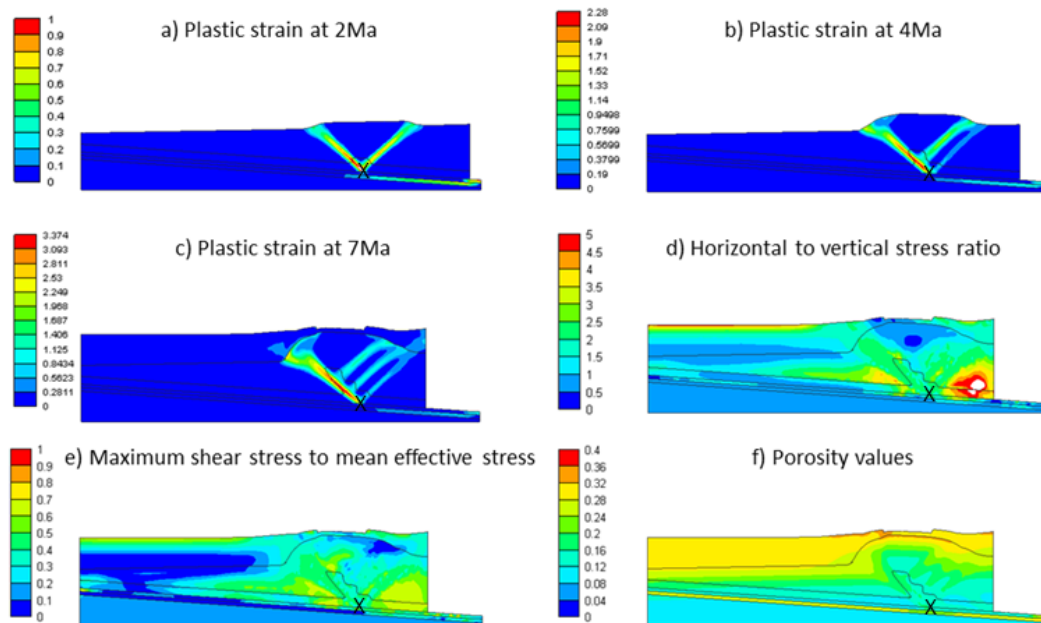


Figure S24: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #24 ($\beta = 4^\circ$, $\alpha = -1^\circ$, $\mu_{decol.} = 0.3$, and $pc = 50$ MPa).

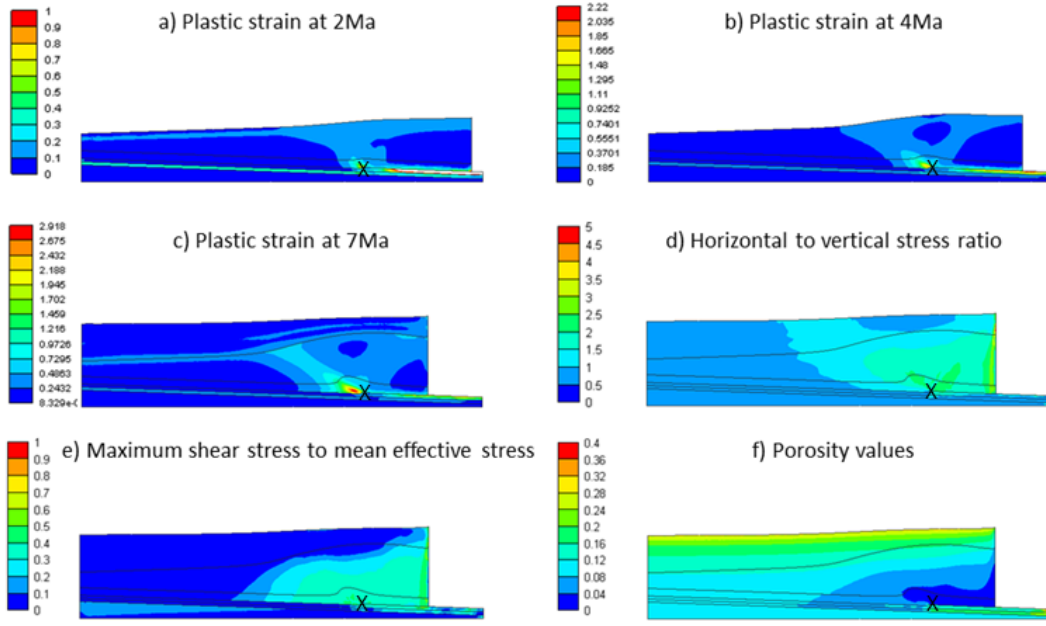


Figure S25: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #25 ($\beta = 2^\circ, \alpha = -2^\circ, \mu_{decol.} = 0$, and $pc = 2.5$ MPa).

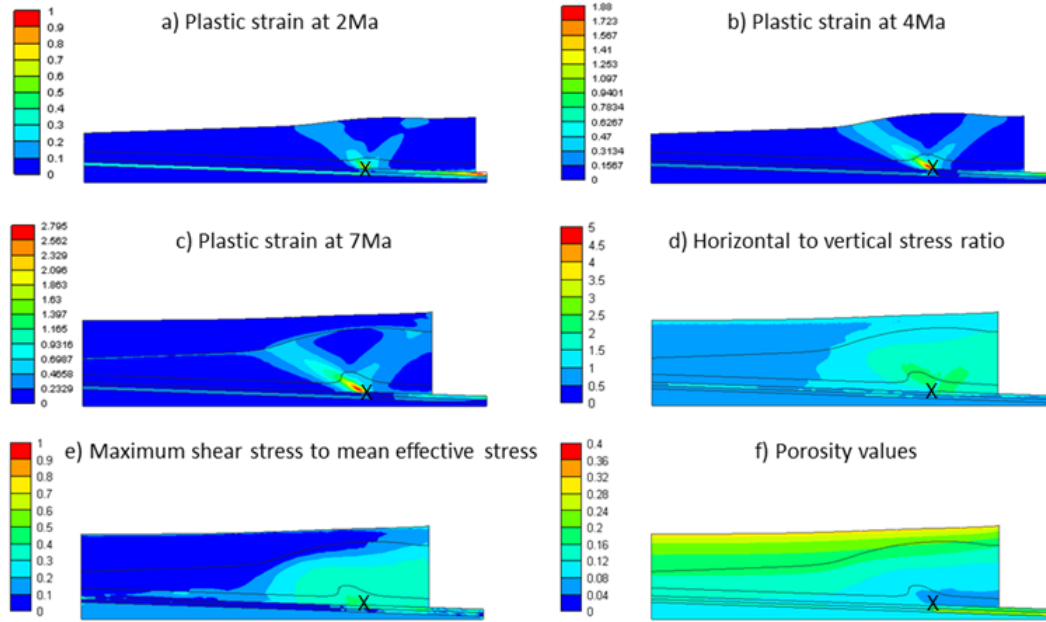


Figure S26: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #26 ($\beta = 2^\circ, \alpha = -2^\circ, \mu_{decol.} = 0$, and $pc = 5$ MPa).

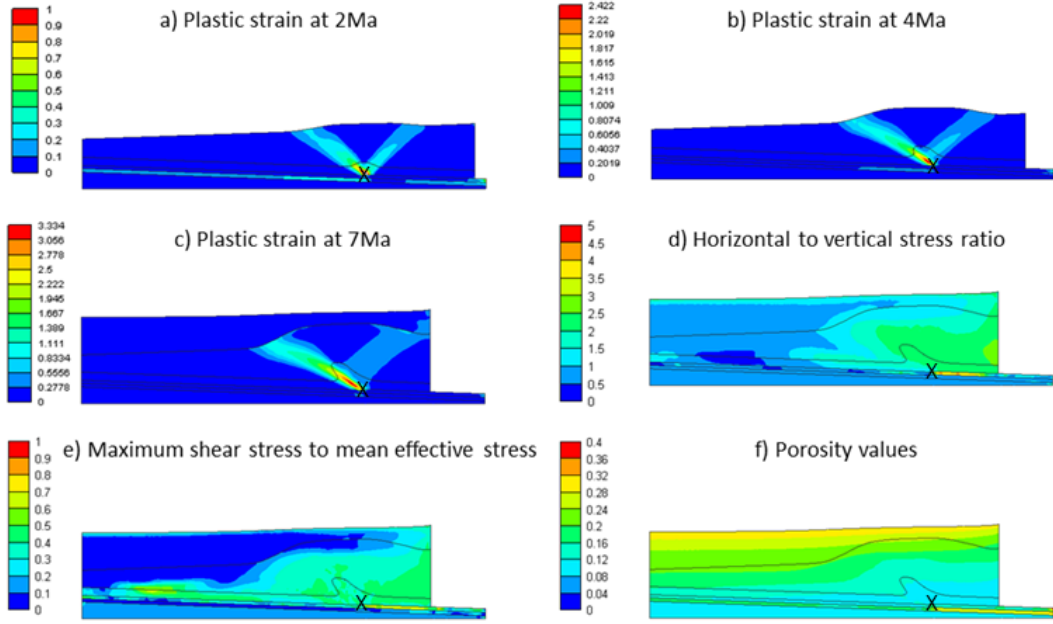


Figure S27: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #27 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0$, and $pc = 10$ MPa).

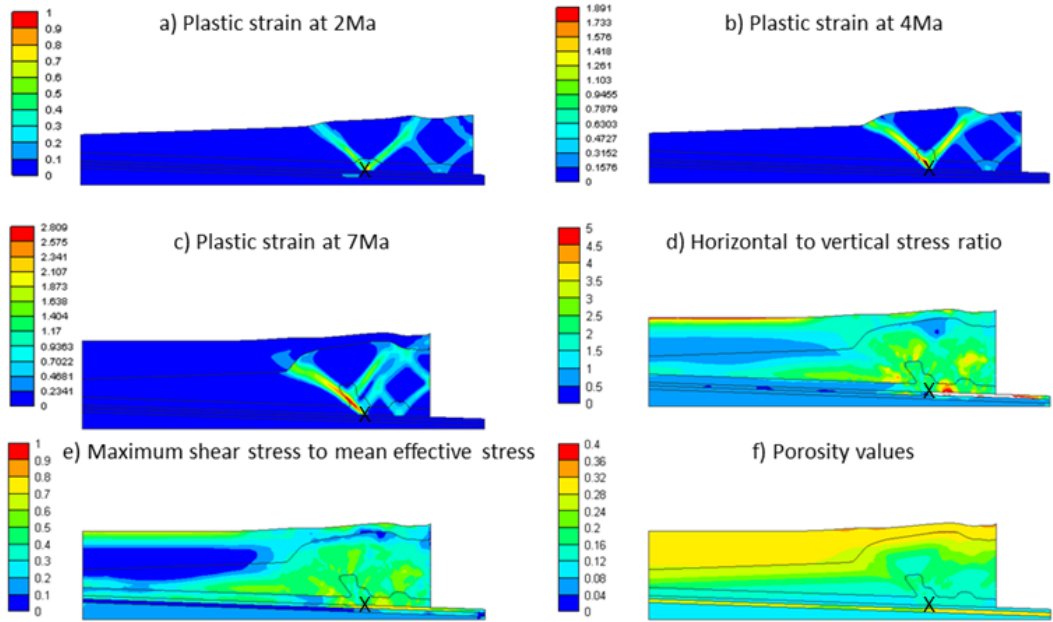


Figure S28: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #28 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0$, and $pc = 50$ MPa).

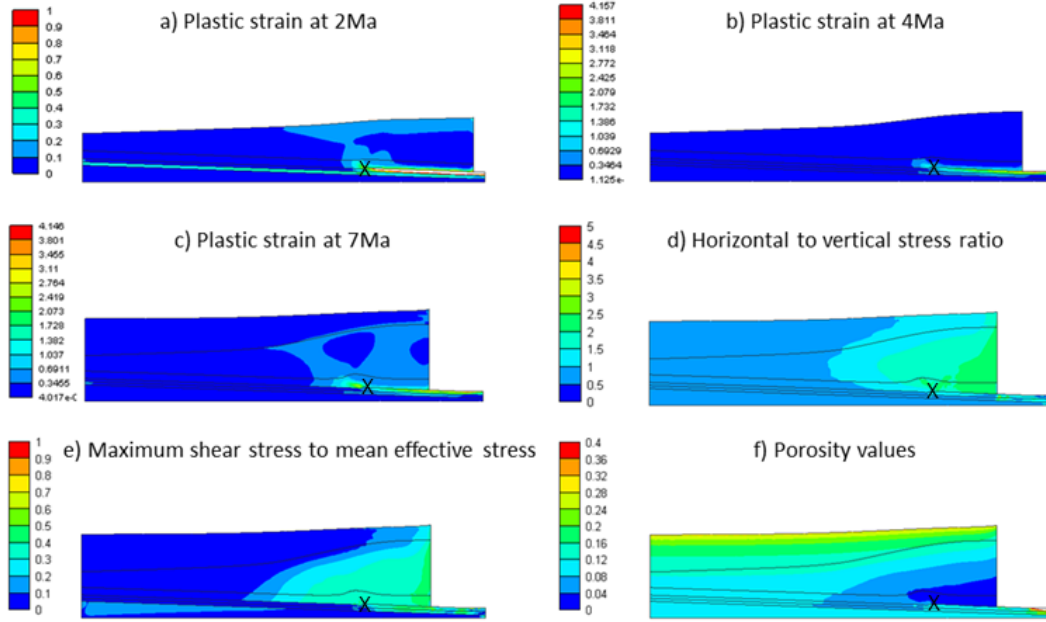


Figure S29: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #29 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.15$, and $pc = 2.5$ MPa).

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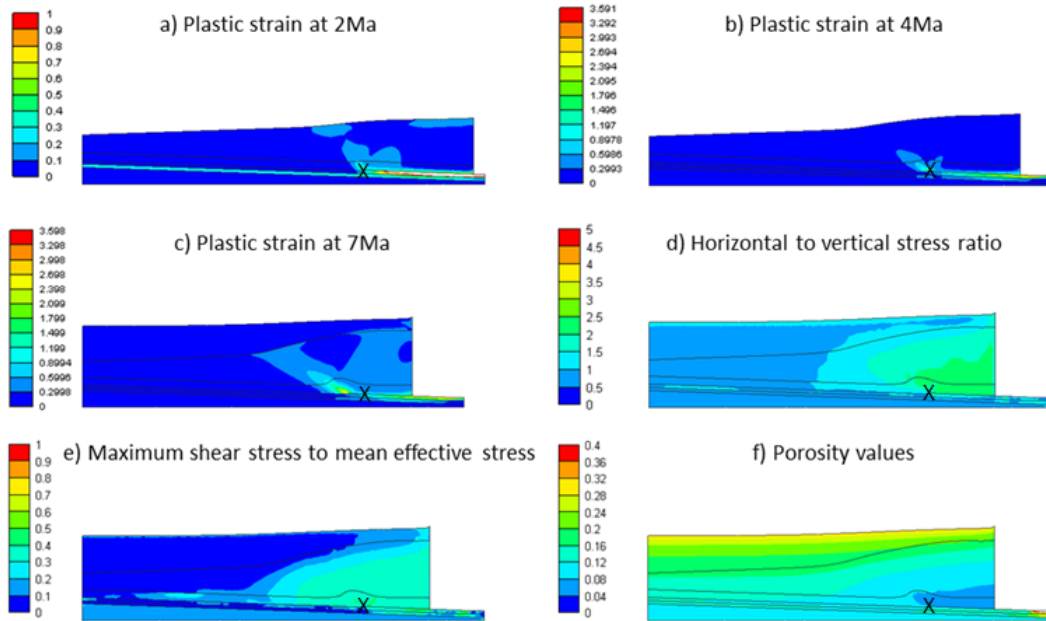


Figure S30: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #30 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.15$, and $pc = 5$ MPa).

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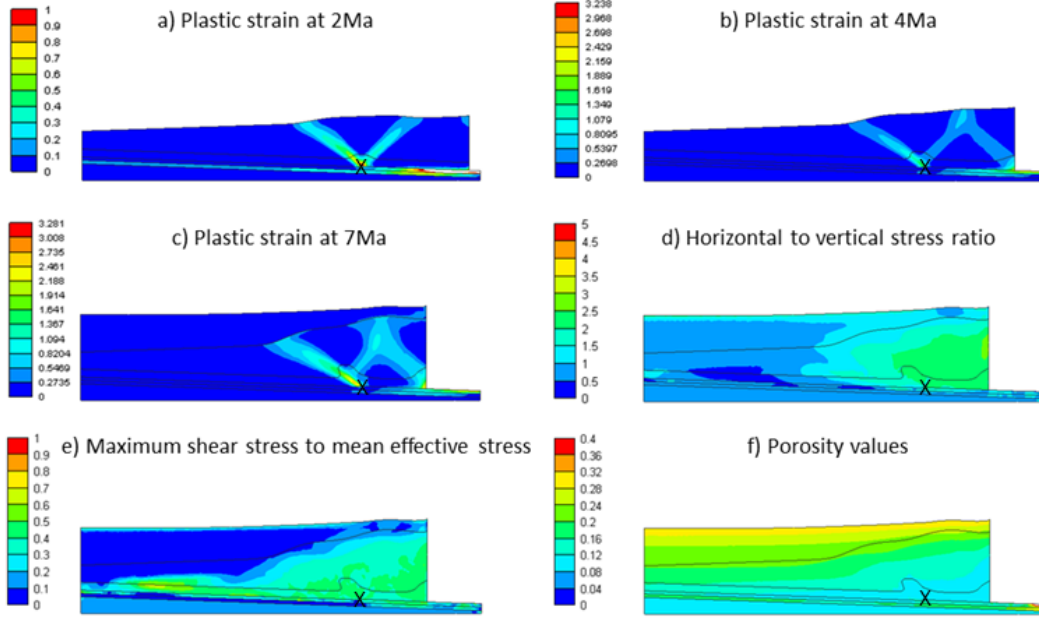


Figure S31: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #31 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.15$, and $pc = 10$ MPa).

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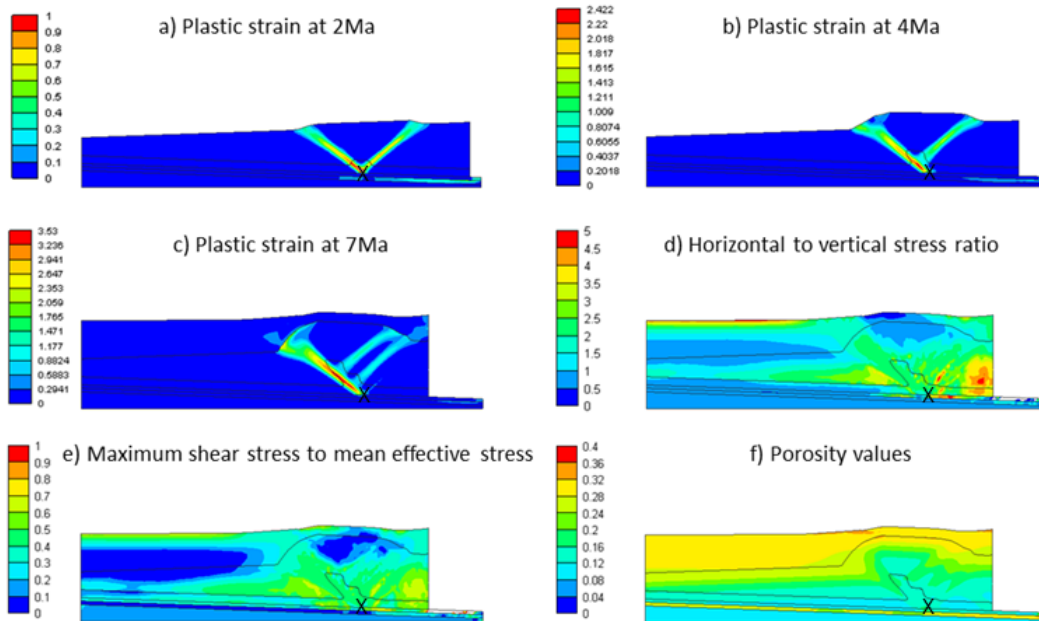


Figure S32: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #32 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.15$, and $pc = 50$ MPa).

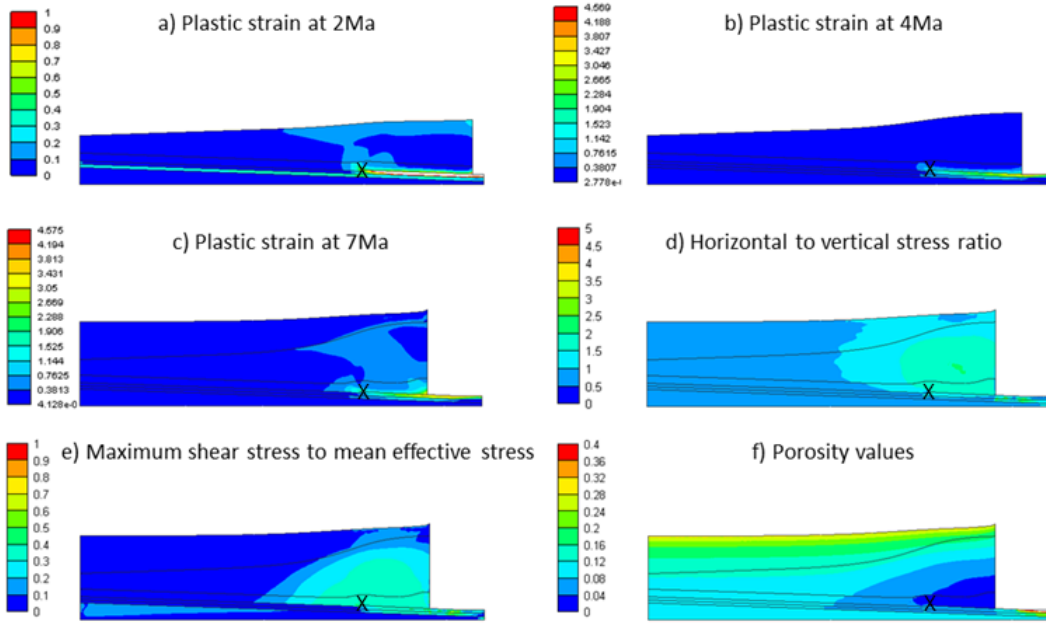


Figure S33: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #33 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.3$, and $pc = 2.5$ MPa).

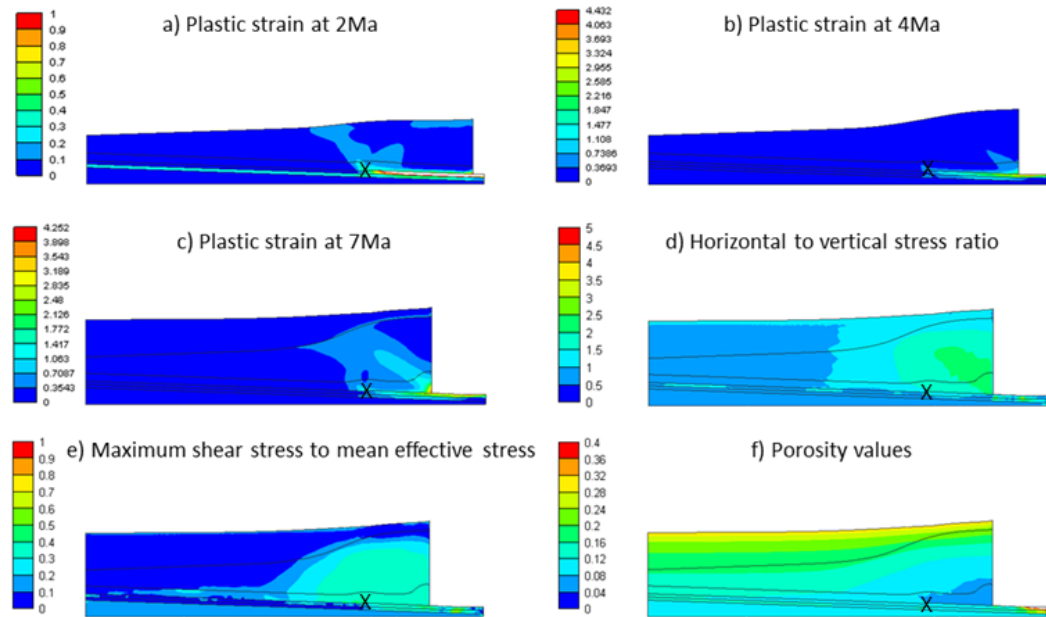
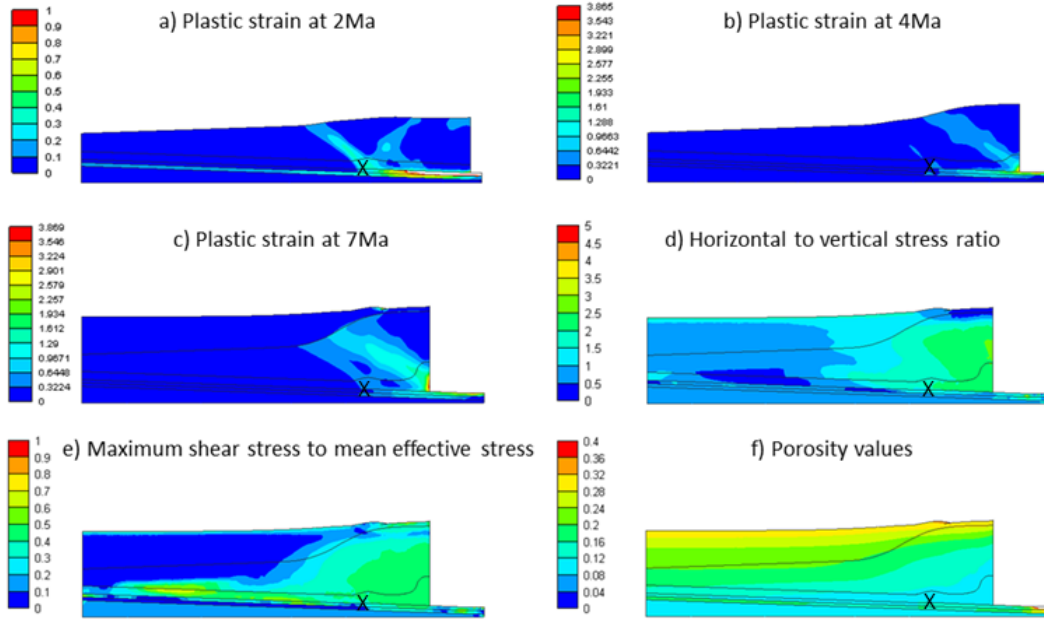
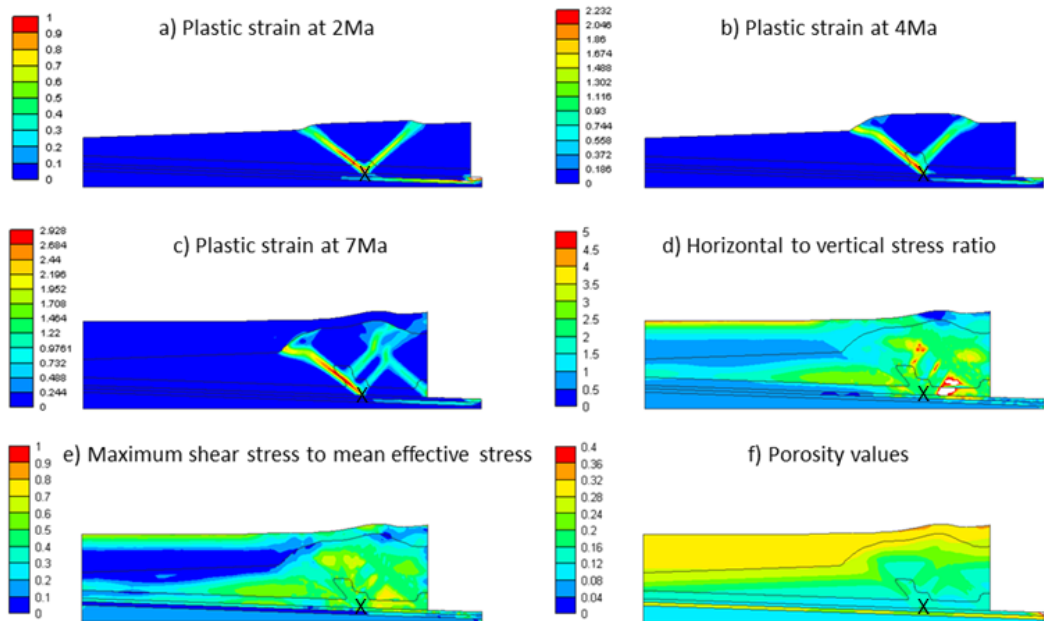


Figure S34: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #34 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.3$, and $pc = 5$ MPa).



275 Figure S35: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #35 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.3$, and $pc = 10$ MPa).

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Figure S36: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #36 ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.3$, and $pc = 50$ MPa).

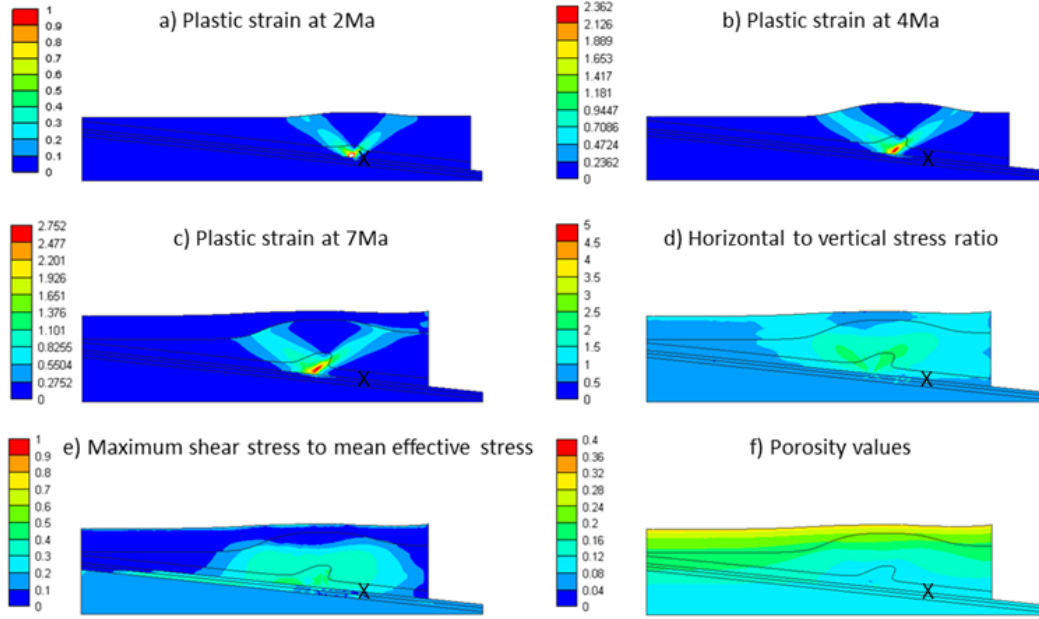


Figure S37: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #2* ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0$, and $p_c = 5$ MPa).

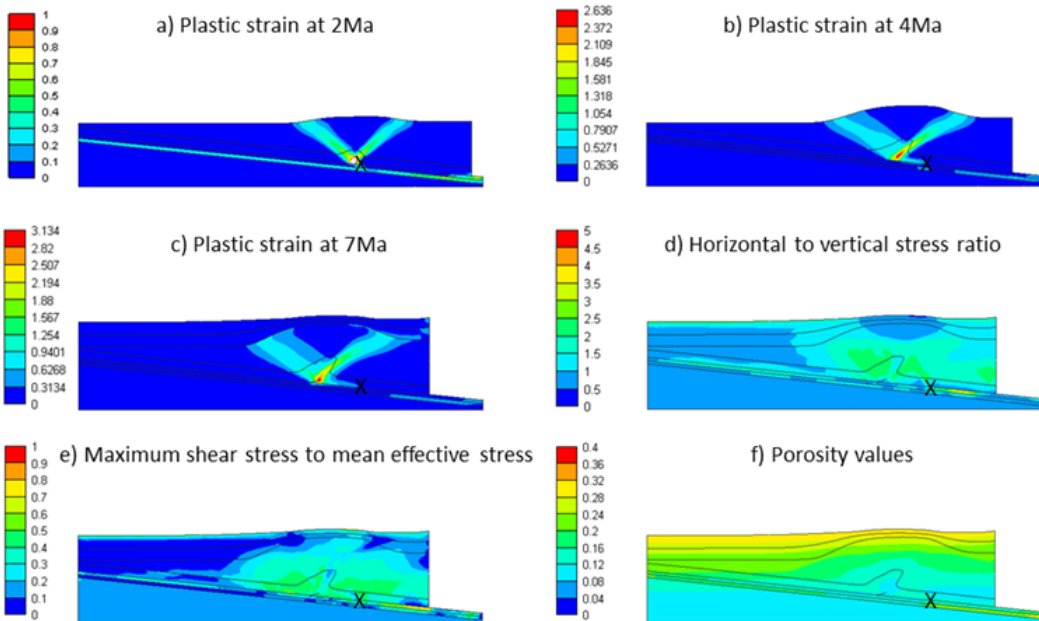


Figure S38: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #3* ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0$, and $p_c = 10$ MPa).

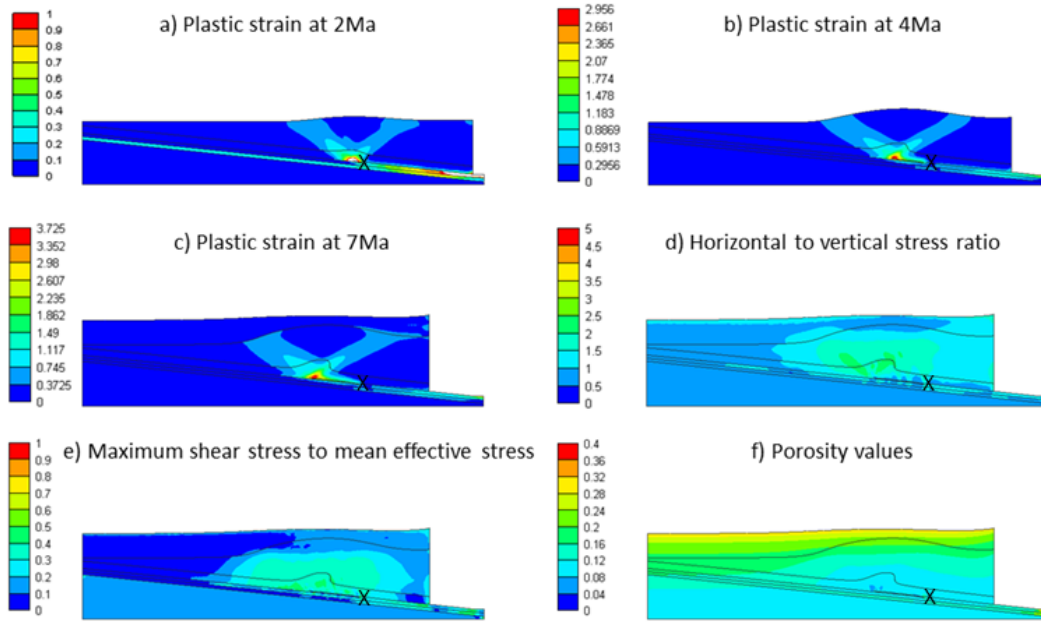


Figure S39: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #6* ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.15$, and $p_c = 5$ MPa).

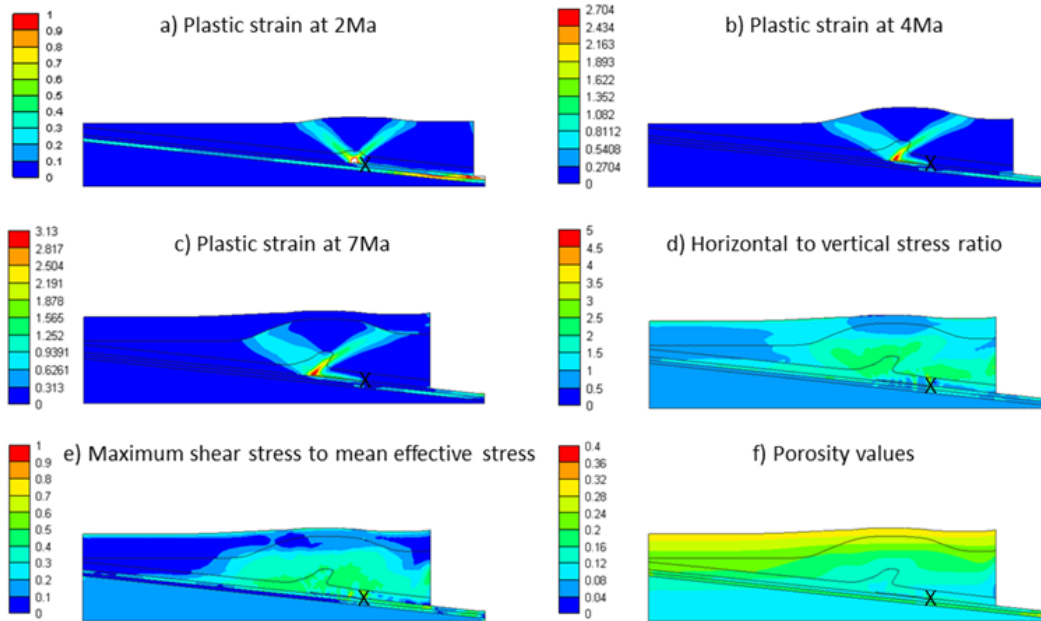


Figure S40: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #7* ($\beta = 6^\circ$, $\alpha = 0^\circ$, $\mu_{decol.} = 0.15$, and $p_c = 10$ MPa).

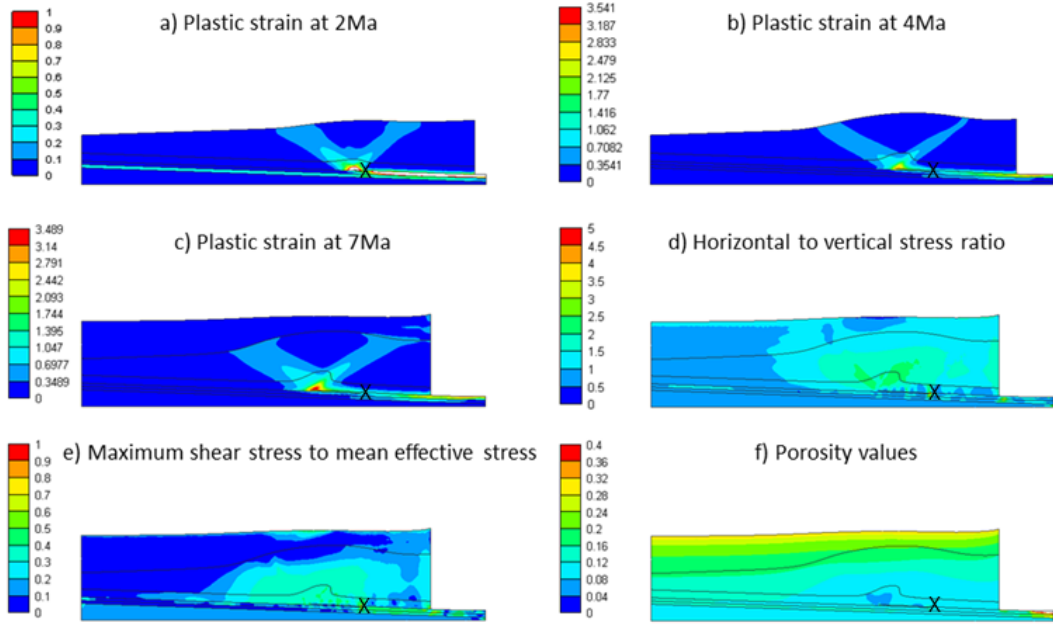


Figure S41: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #34* ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.3$, and $pc = 5$ MPa).

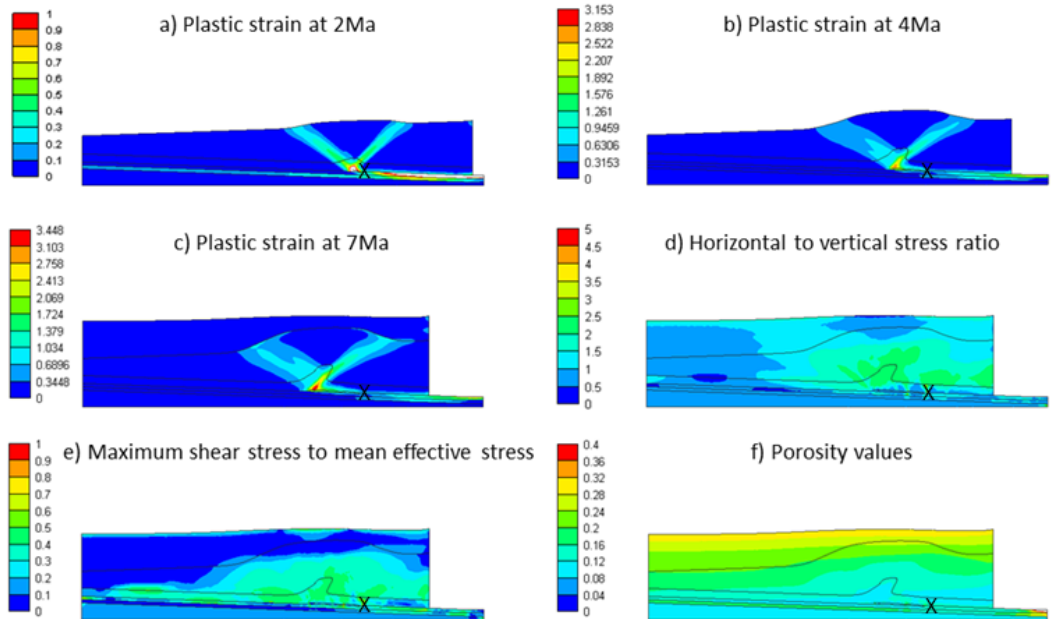


Figure S42: Progressive development of plastic strain and the final values of the σ_{xx}/σ_{zz} , τ_{max}/p and n for the case #35* ($\beta = 2^\circ$, $\alpha = -2^\circ$, $\mu_{decol.} = 0.3$, and $pc = 10$ MPa).