

## Supplementary A: 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):

$$\Phi(\sigma, \varepsilon_v^p) = g(\theta, p) \times q - (p - pt) \times \tan\beta \times \left[\frac{p-pc}{pt-pc}\right]^{\frac{1}{n_p}} \quad \text{Eq. A1}$$

Where  $\sigma$ ,  $\varepsilon_v^p$ ,  $\theta$ ,  $p$ ,  $q$ , and  $n_p$  shows stress, volumetric plastic strain, Lode angle, mean effective stress (Eq. 2), deviatoric stress (Eq. 3), and p-q plane shape parameter respectively. Here  $g(\theta, p)$  is implemented to control the shape of the surface:

$$g(\theta, p) = \left[\frac{1}{1-\beta^\pi(p)} \left(1 + \beta^\pi(p) \frac{r^3}{q^3}\right)\right]^{N^\pi} \quad \text{Eq. A2}$$

10 Where

$$\beta^\pi(p) = \beta_0^\pi \exp\left(\beta_1^\pi p \frac{pc^0}{pc}\right) \quad \text{Eq. A3}$$

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  $\beta_0^\pi$  and  $\beta_1^\pi$ . By taking into account the deviatoric stress tensor as  $S$  and 3<sup>rd</sup> deviatoric stress invariant as  $J'_3$ , following equation can be used to obtain  $r$ :

$$15 \quad r^3 = \frac{9}{2} S : S : S = \frac{27}{2} J'_3 \quad \text{Eq. A4}$$

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. A5 and Eq. A6:

$$pc = pc^0 \exp\left[\frac{V\varepsilon_v^p}{\lambda - \kappa}\right] \quad \text{Eq. A5}$$

$$pt = pt^0 \exp\left[\frac{V(\varepsilon_v^p)_{max}}{\lambda - \kappa}\right] \quad \text{Eq. A6}$$

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

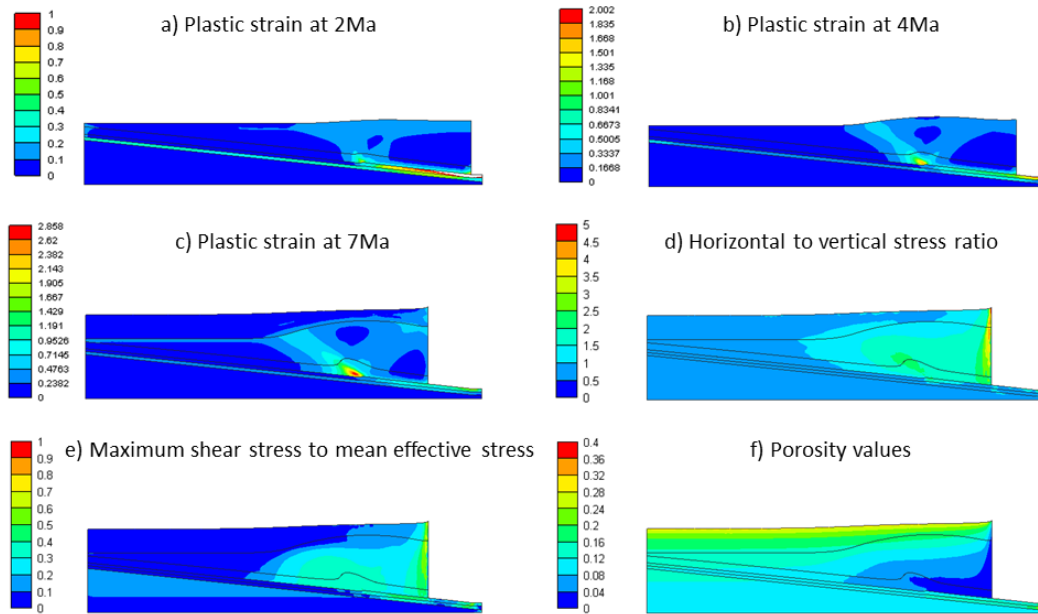
$$n = \frac{V-1}{V} \quad \text{Eq. A7}$$

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

## Supplementary B: Simulation Results Overview

25 The following section presents simulation results for plastic strain, the horizontal-to-vertical stress ratio, deviatoric-to-mean effective stress ratio, and porosity values corresponding to each case identified in the main manuscript. 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, 30 sedimentation initiates at 5 Ma and continues until 7 Ma, contributing to the evolution of the depicted parameters.

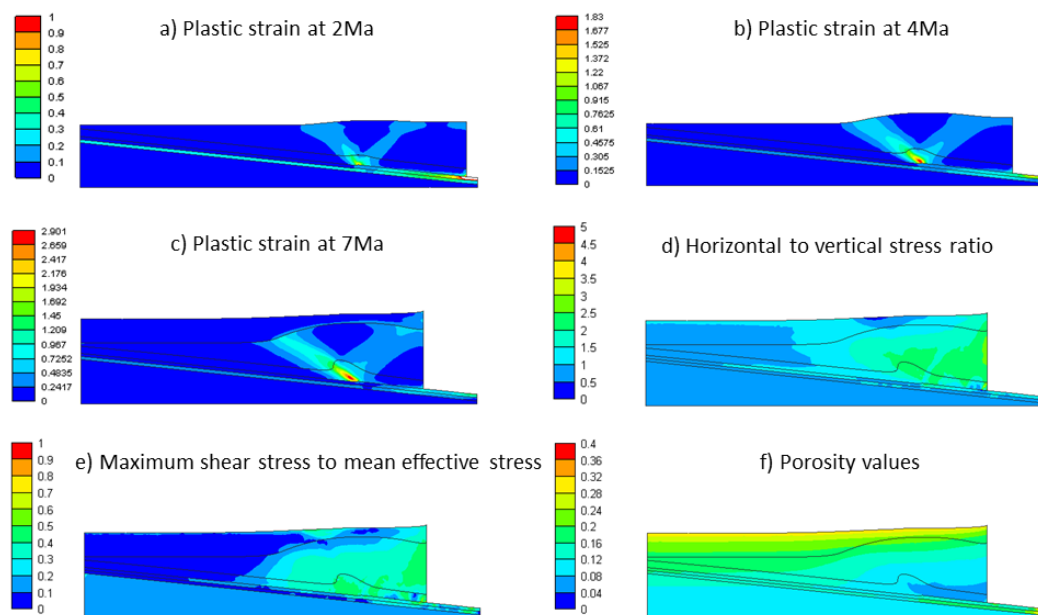
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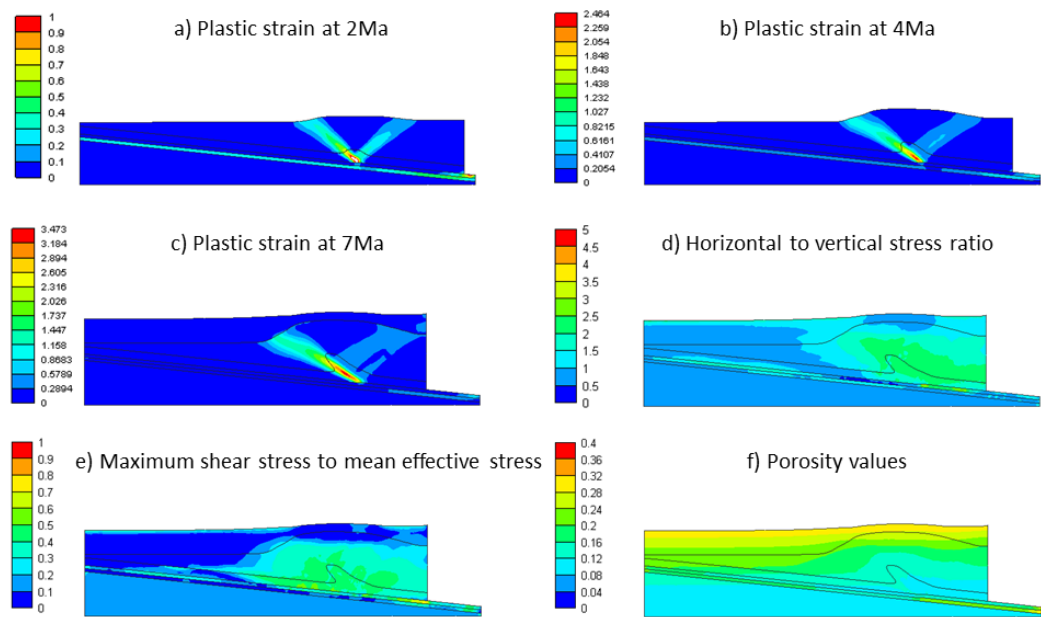


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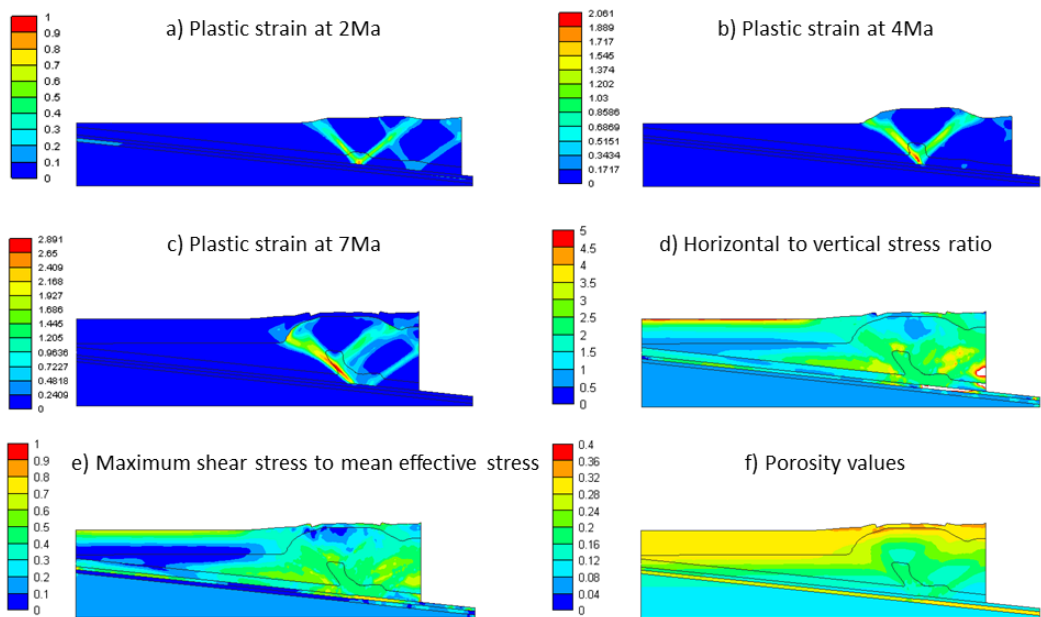
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## Case 2



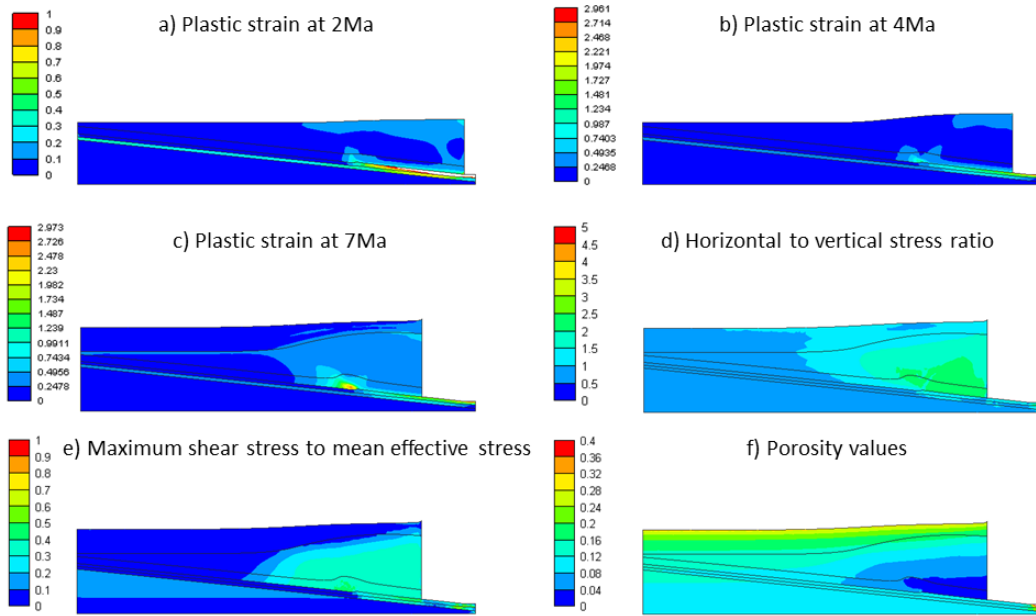


Case 4



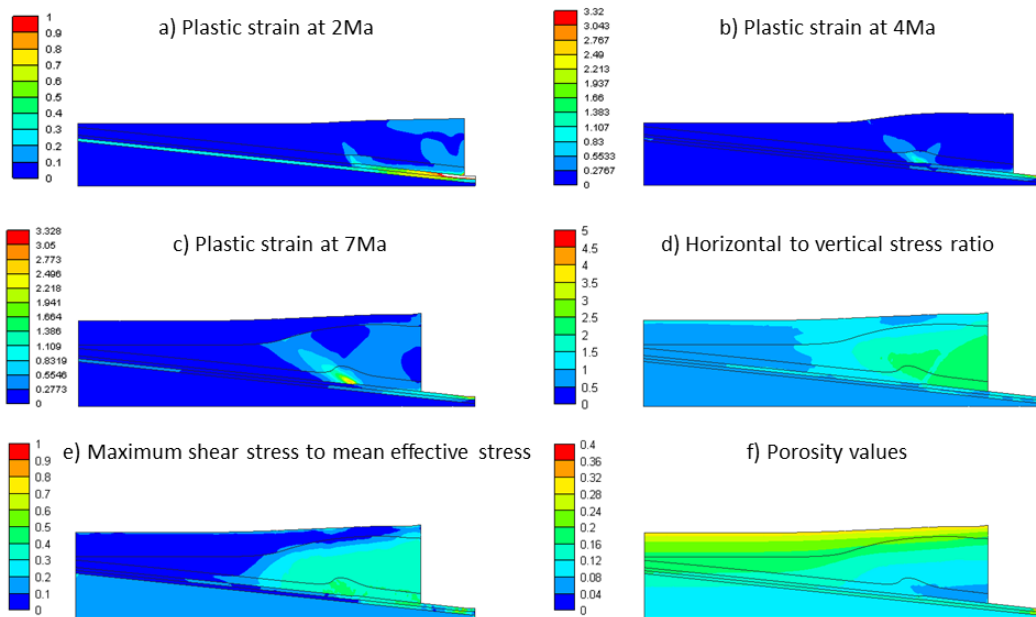
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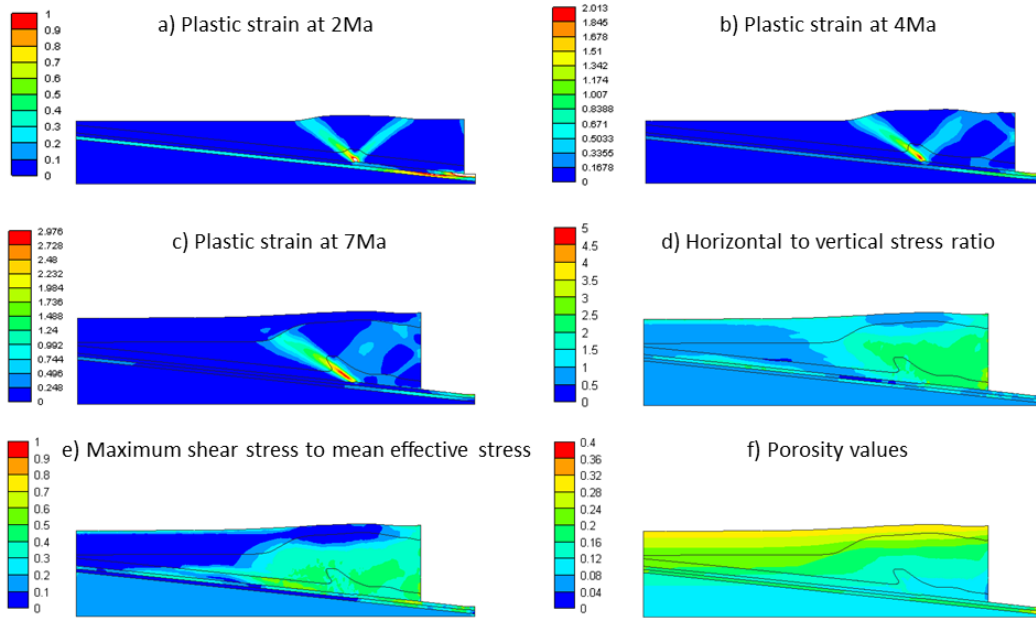
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## Case 6



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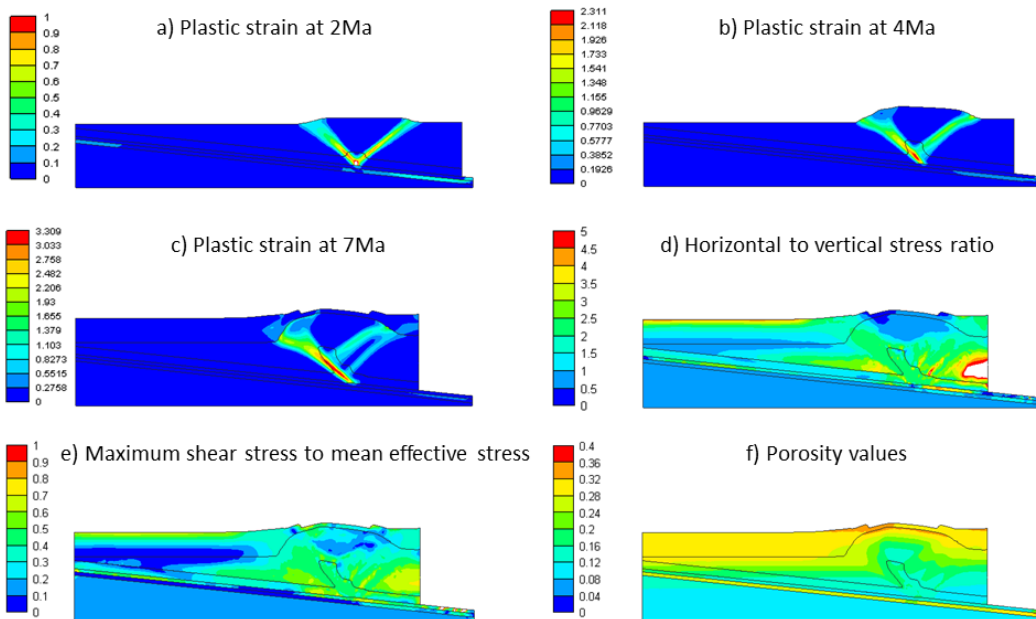
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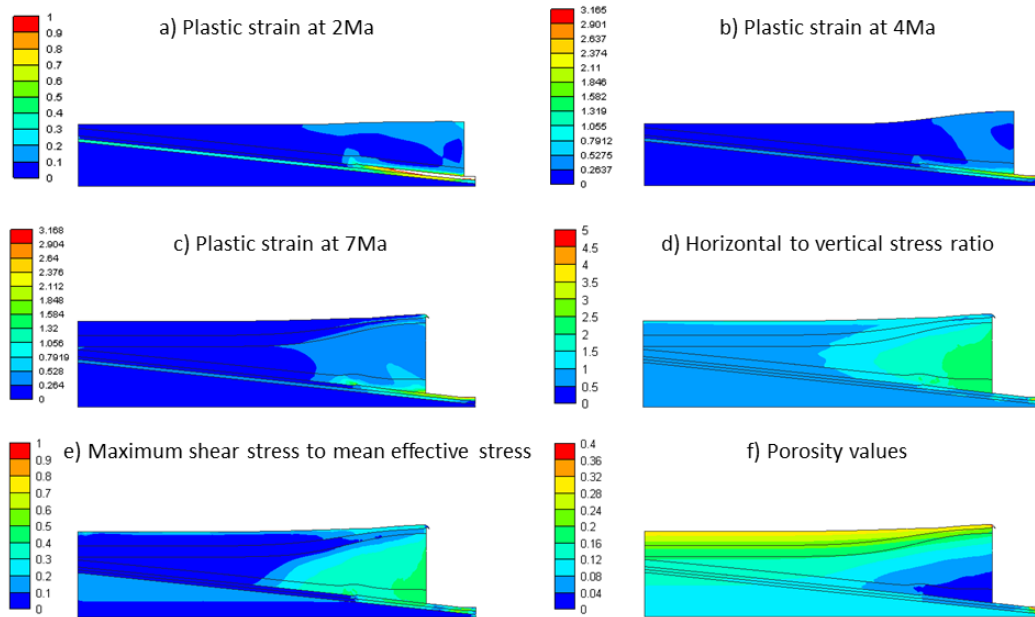
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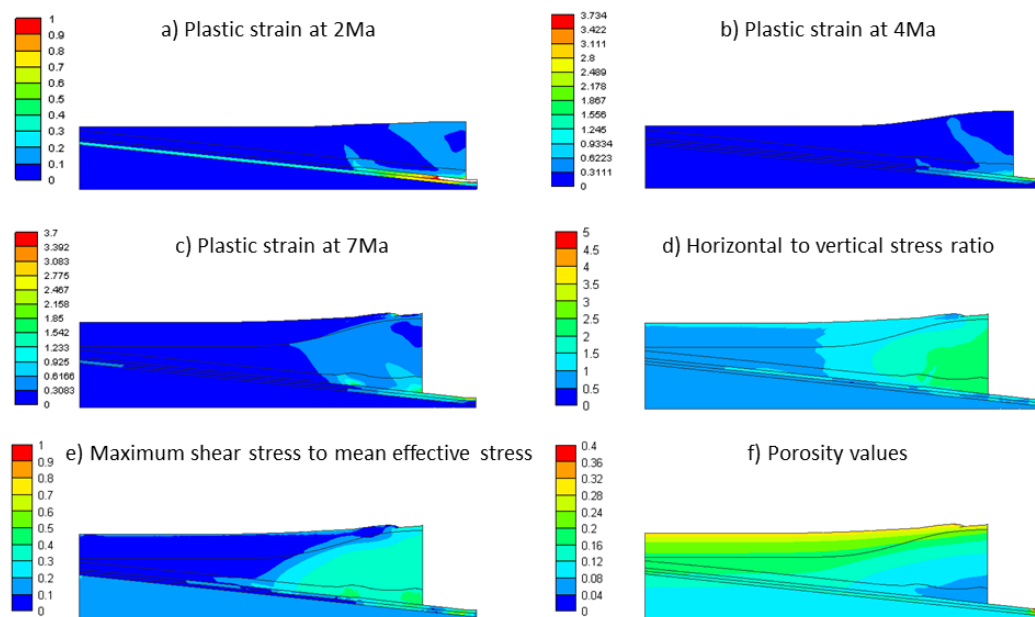
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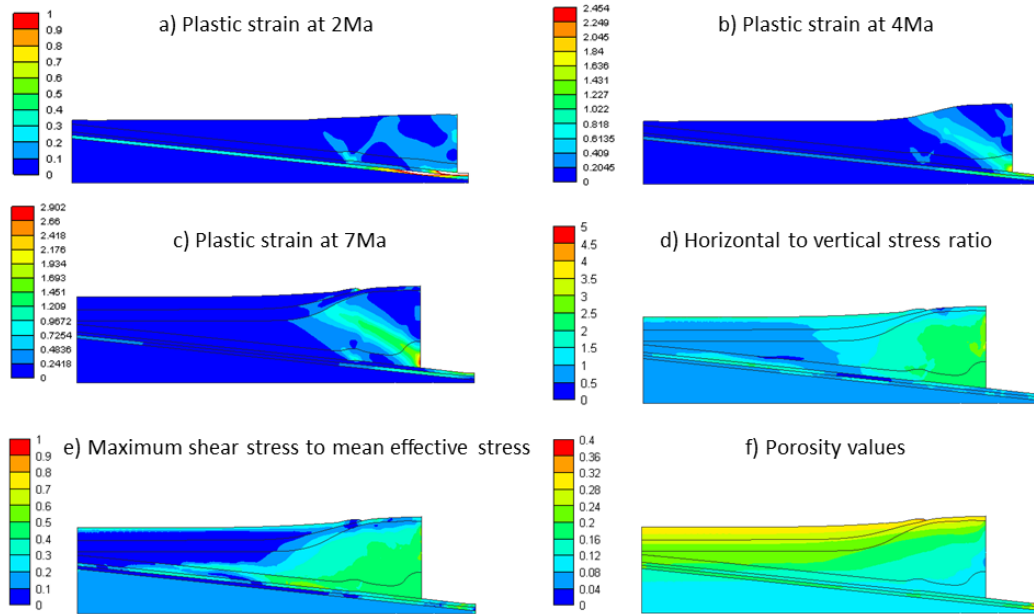
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## Case 10



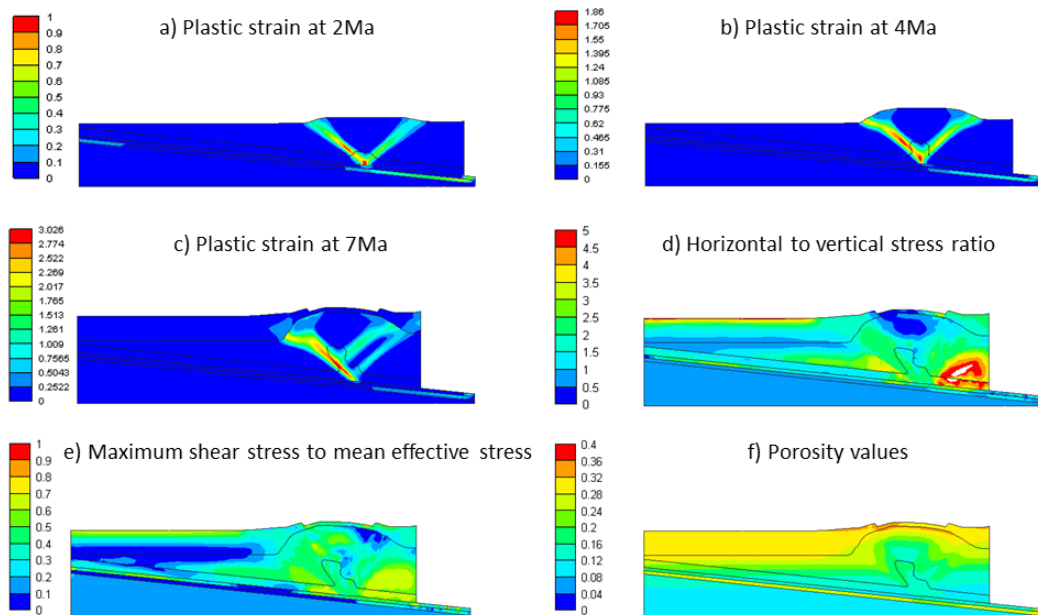
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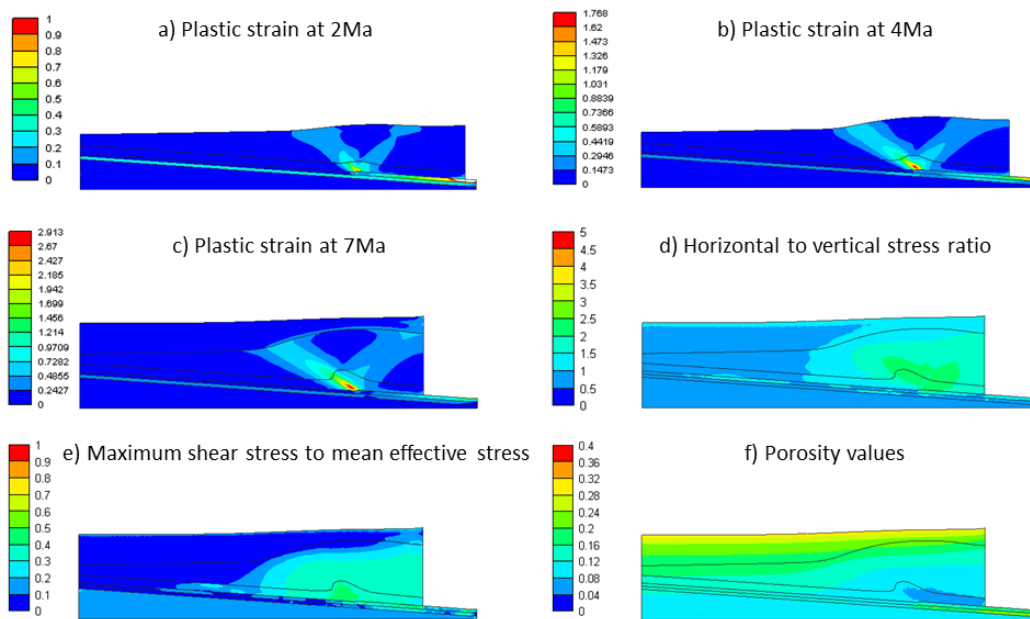
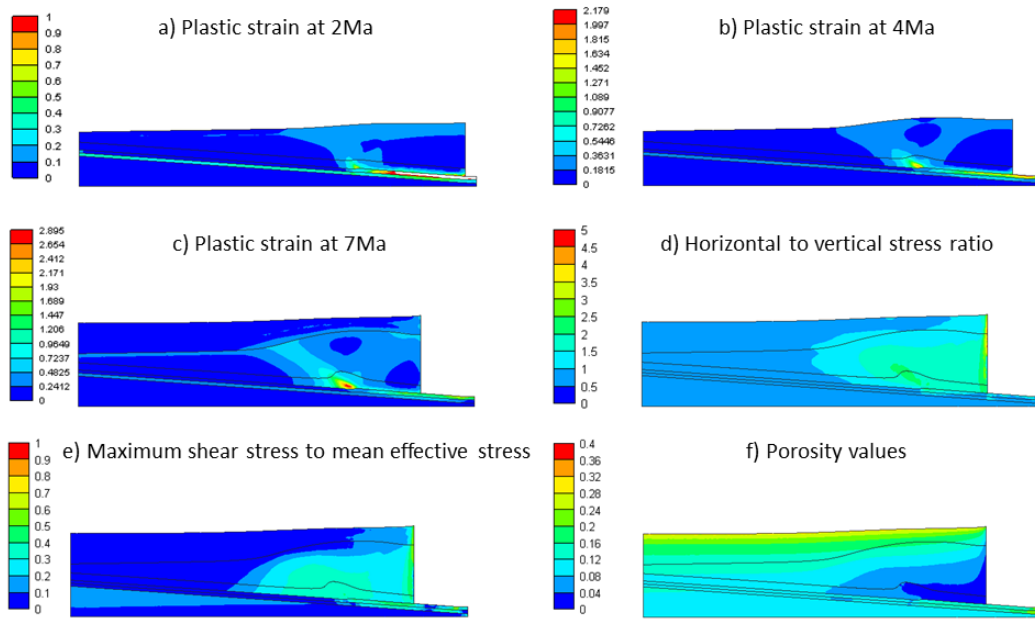
# Case 11



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# Case 12

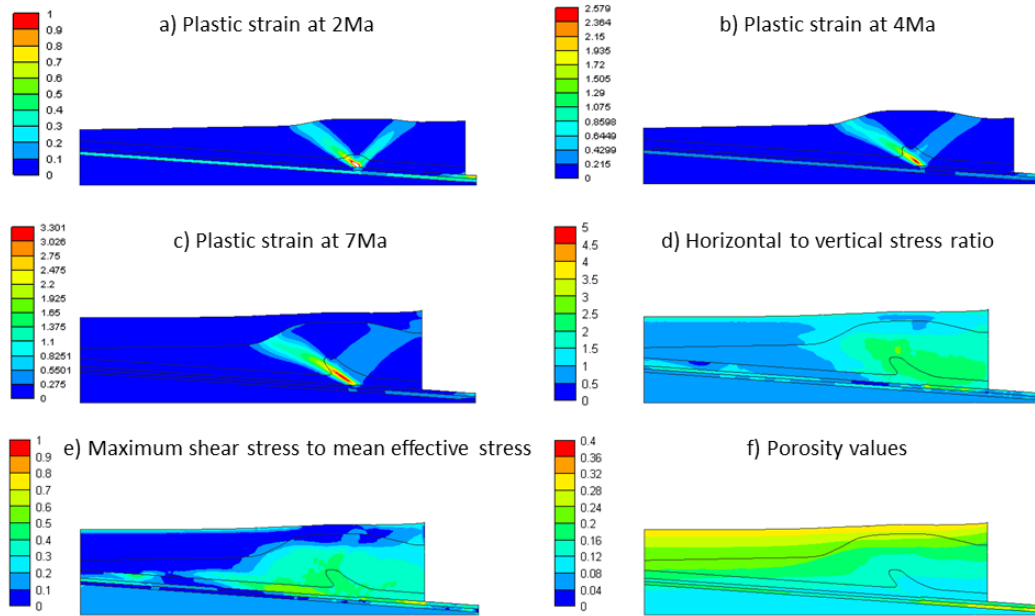






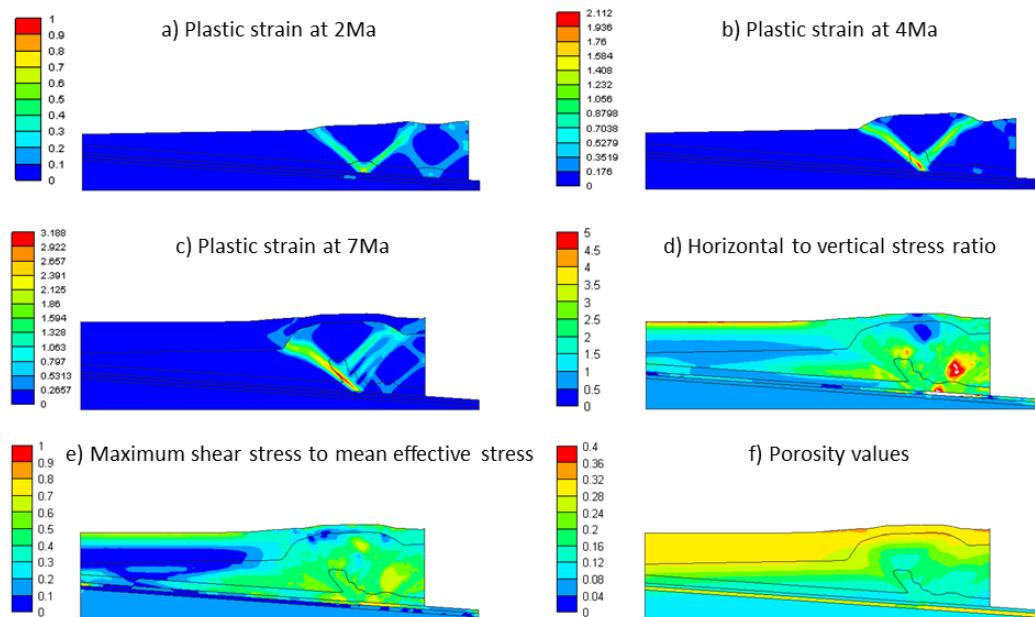
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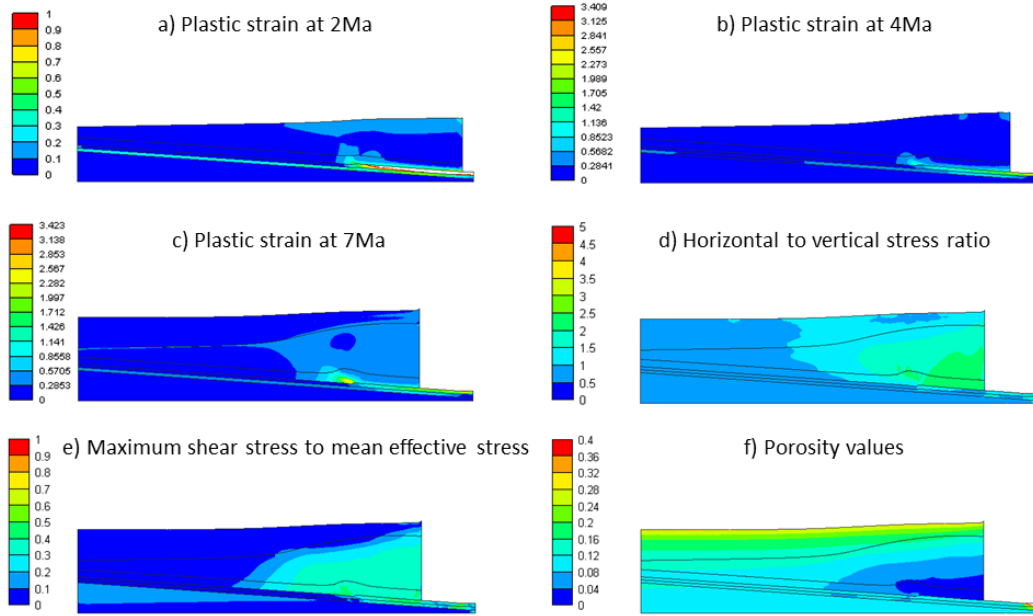
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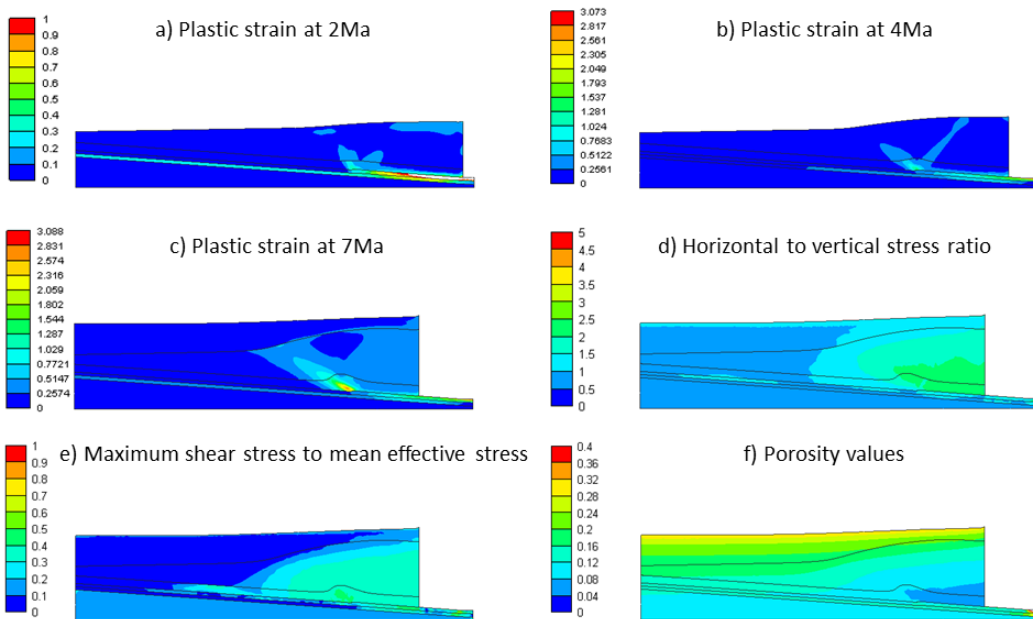
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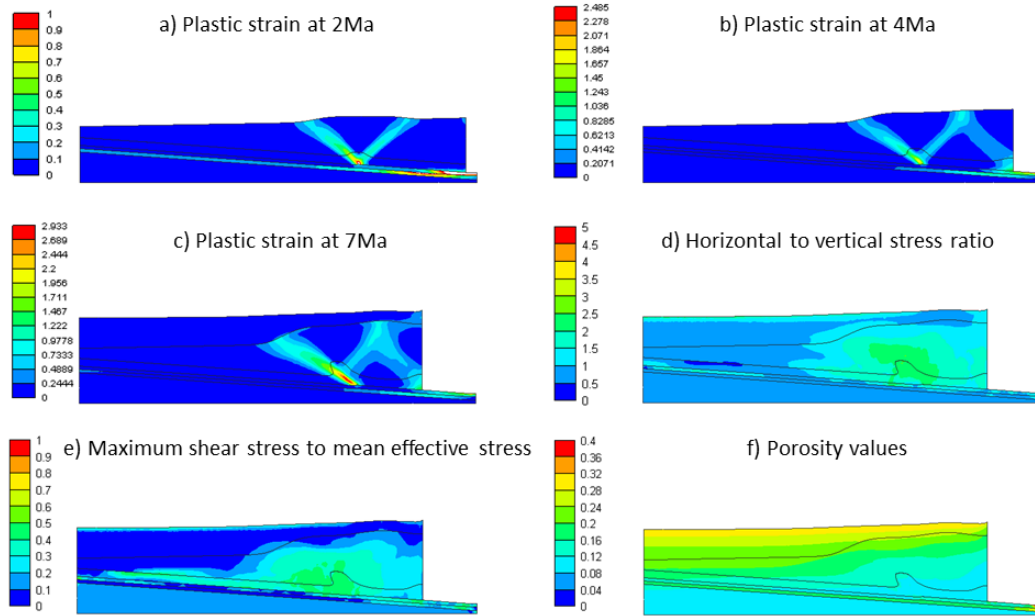
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# Case 18



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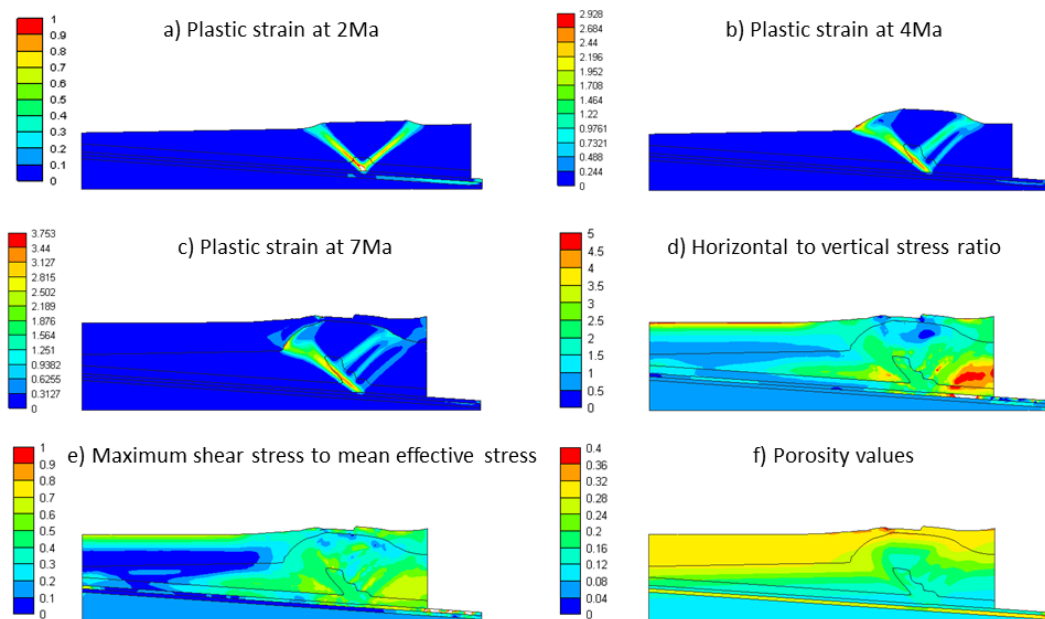
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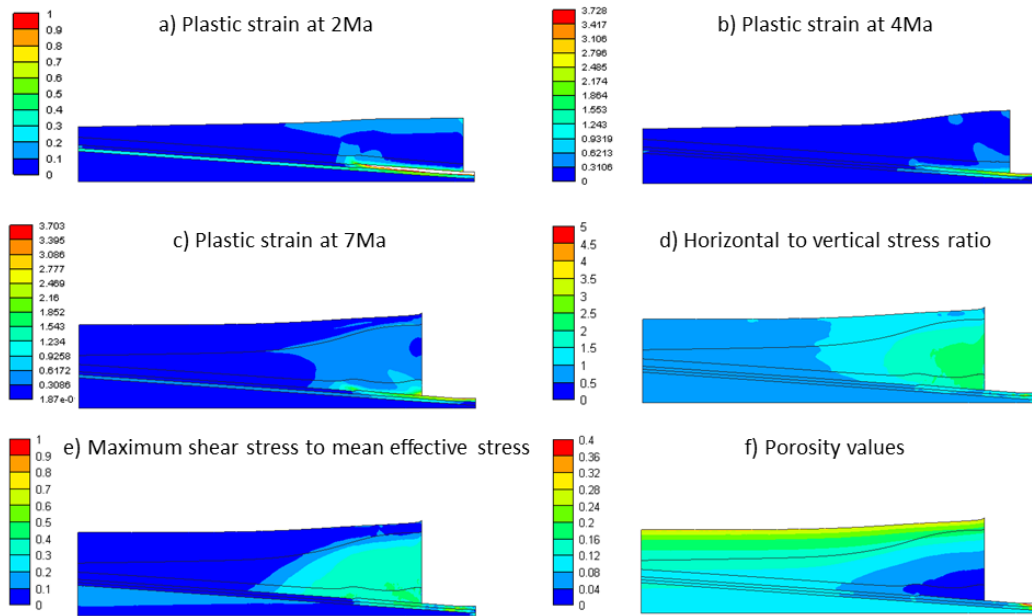
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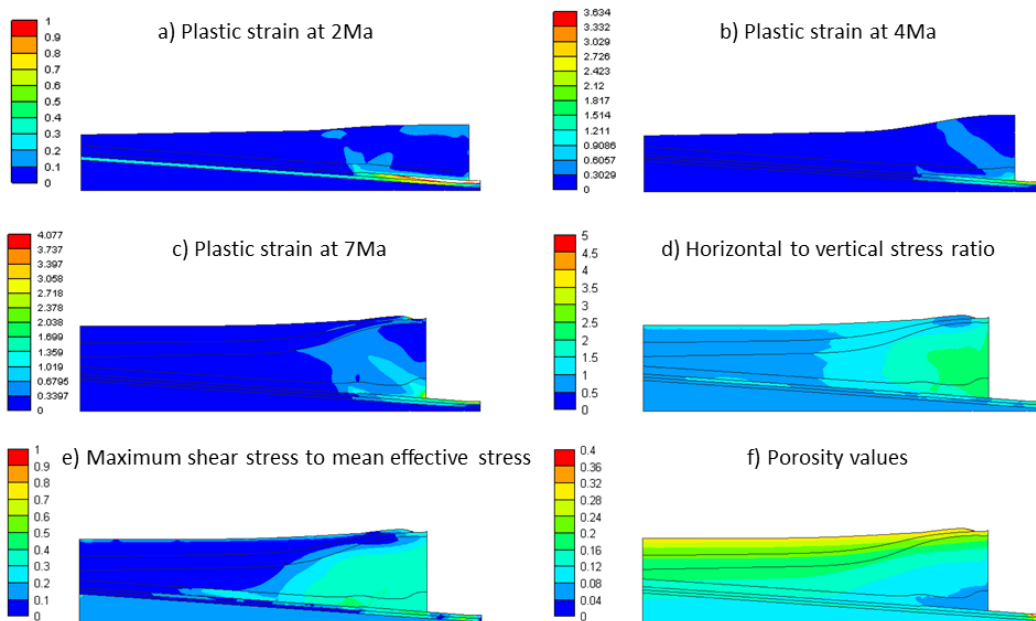
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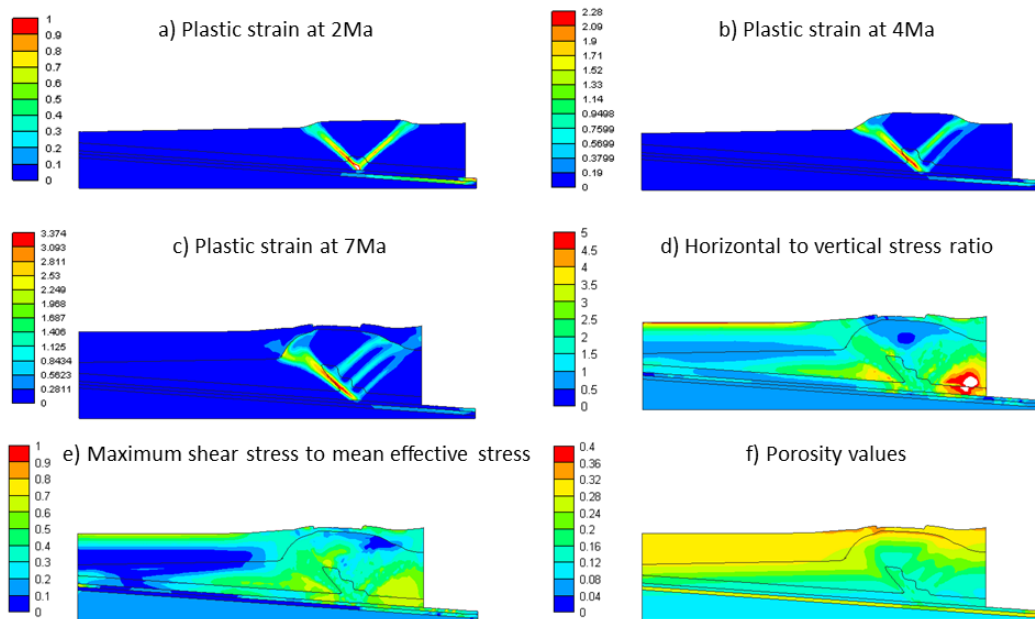
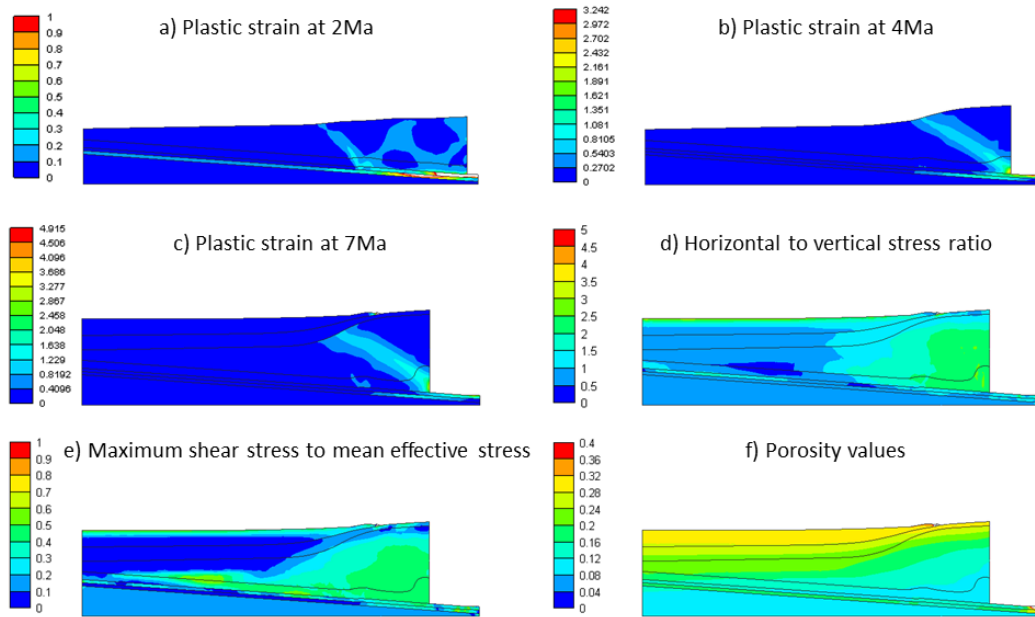
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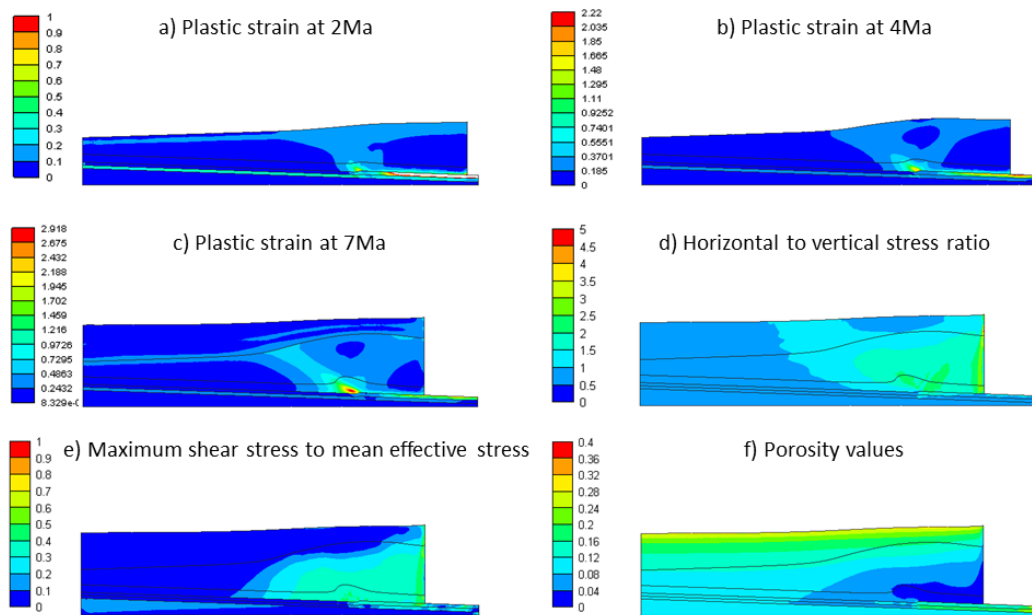
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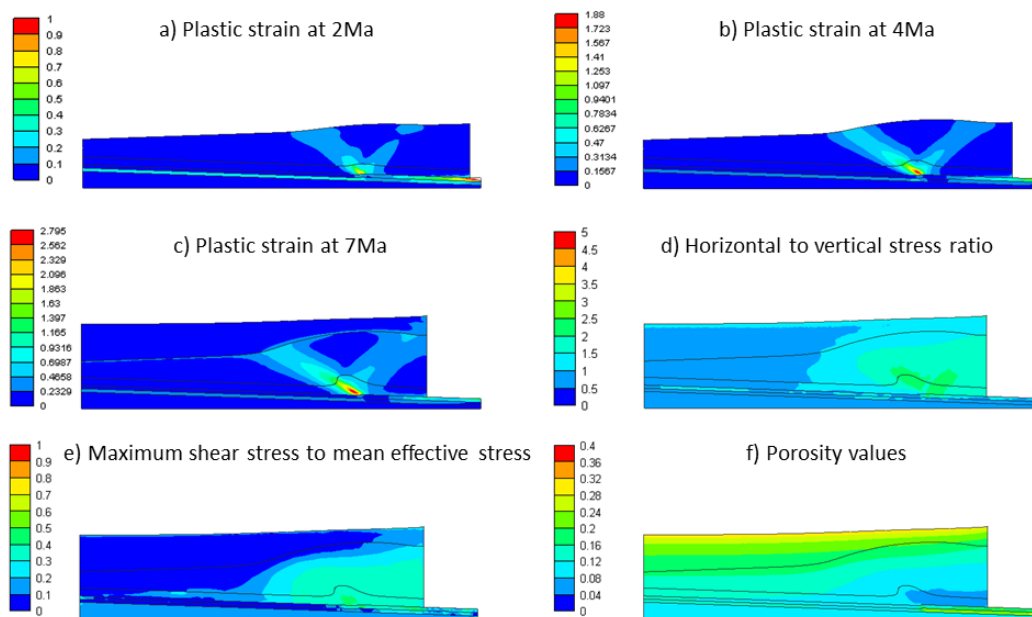
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205



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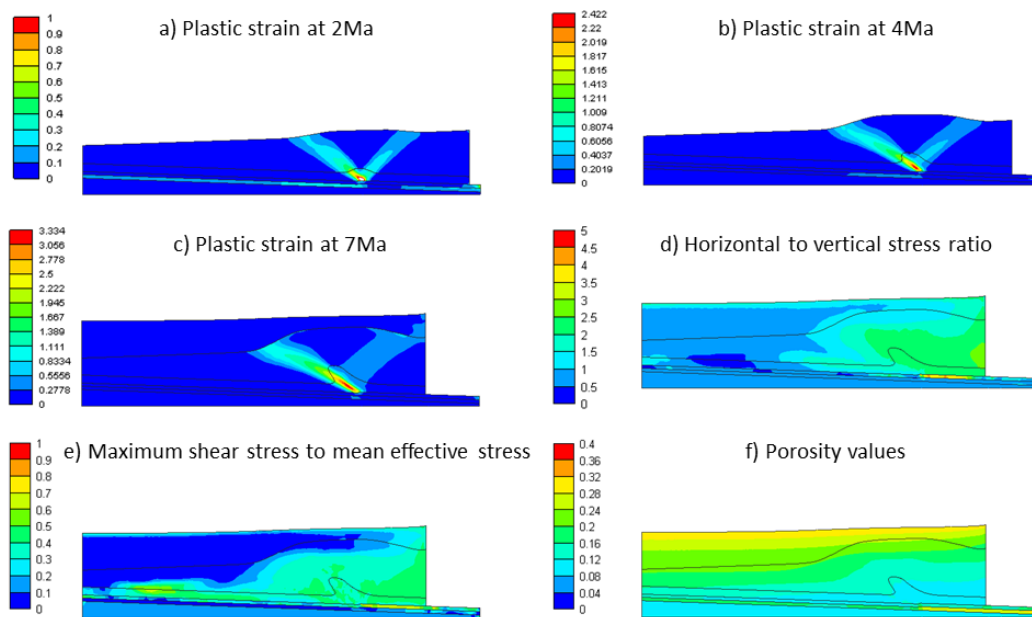
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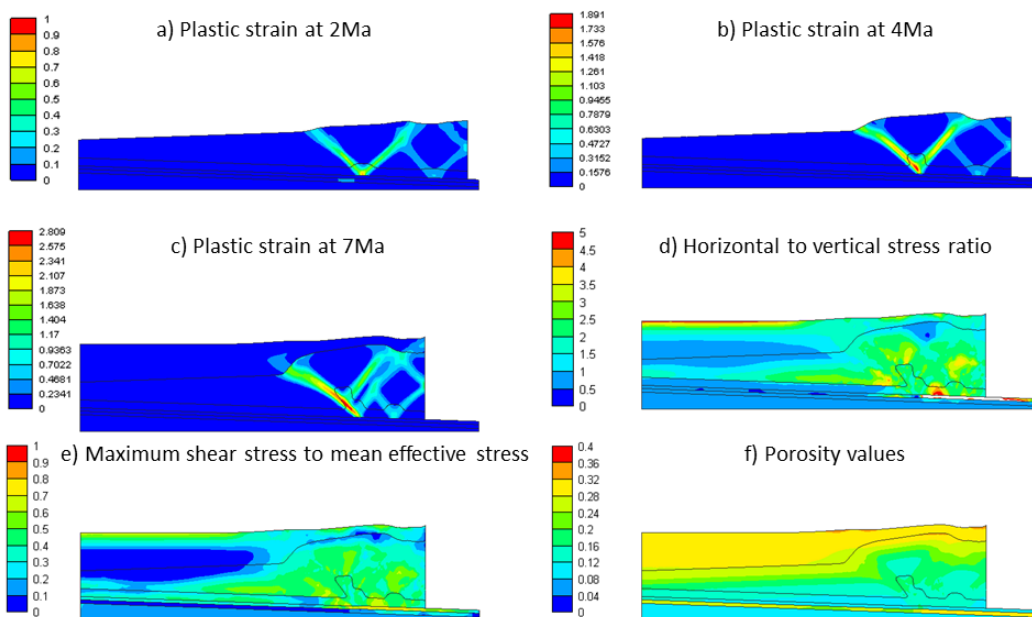
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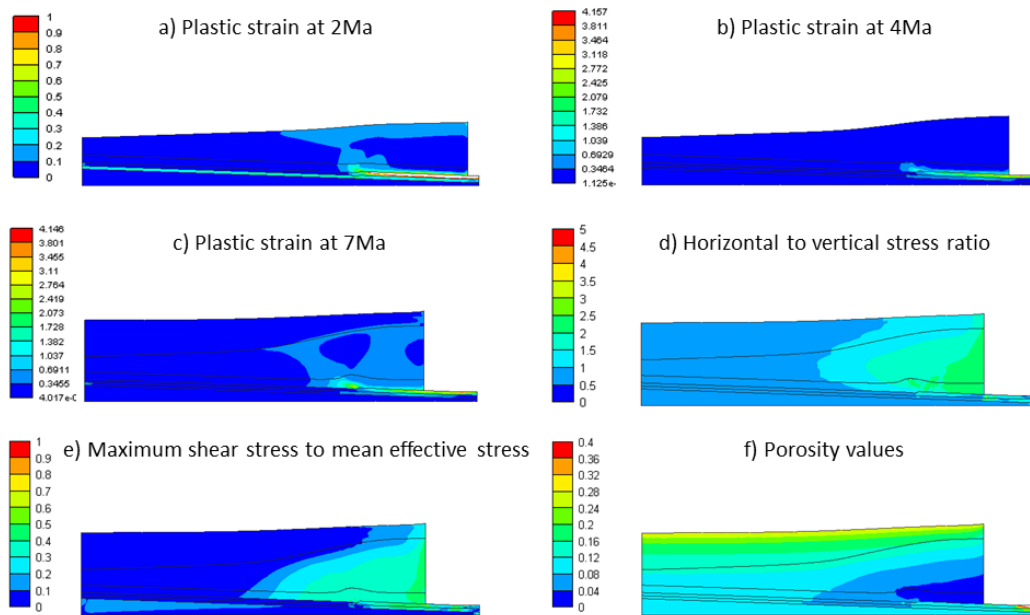
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# Case 28



230

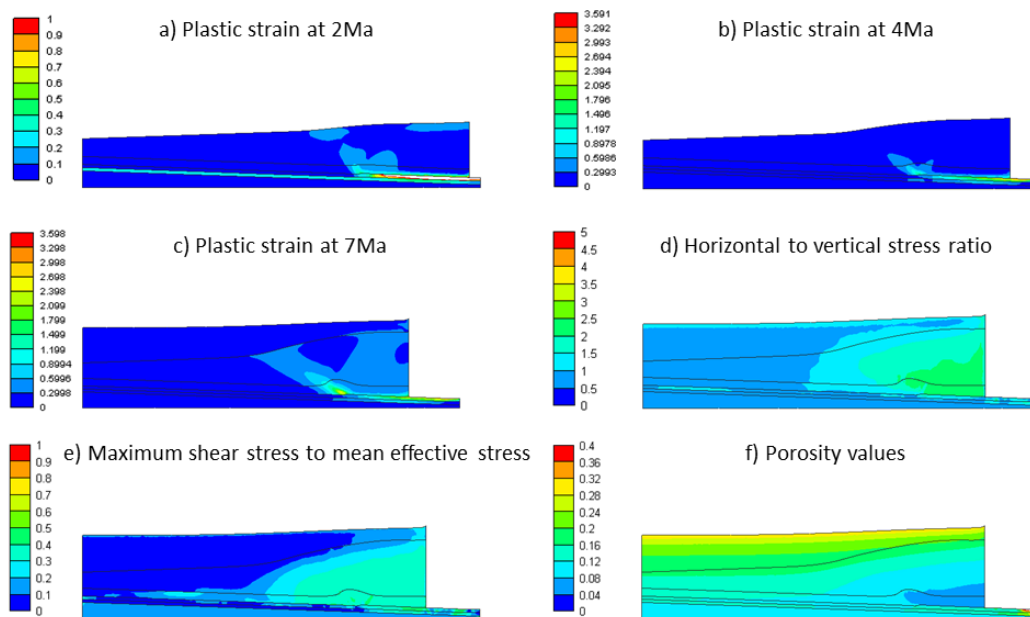
# Case 29



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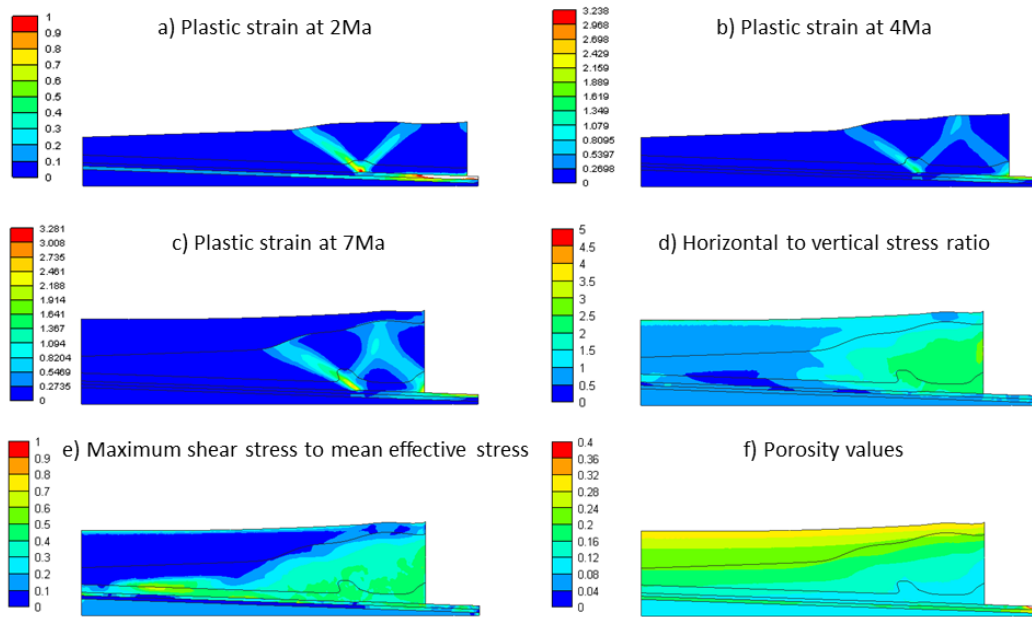
# Case 30



245

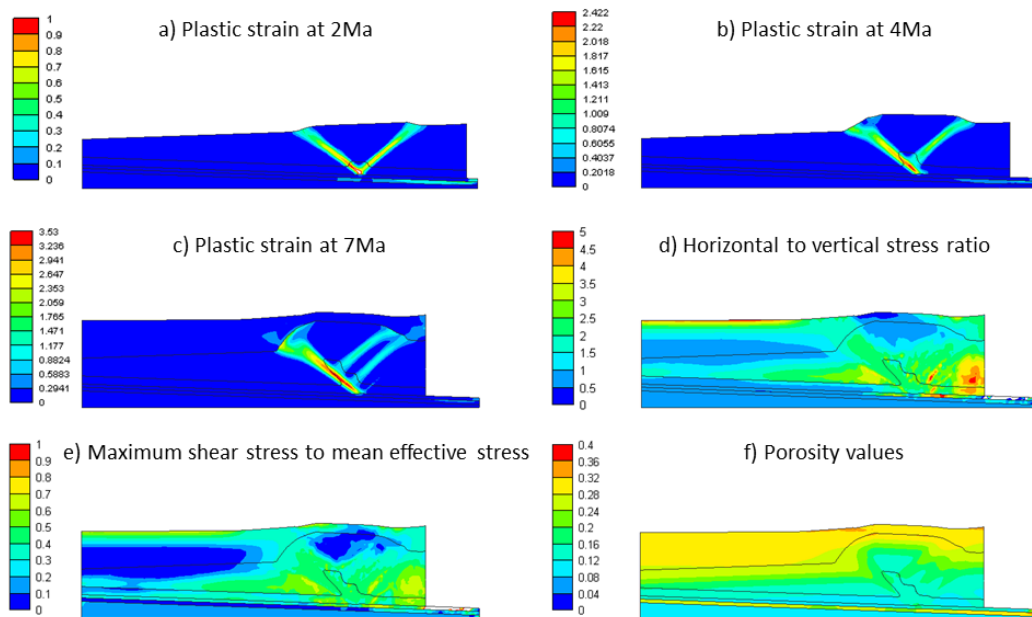


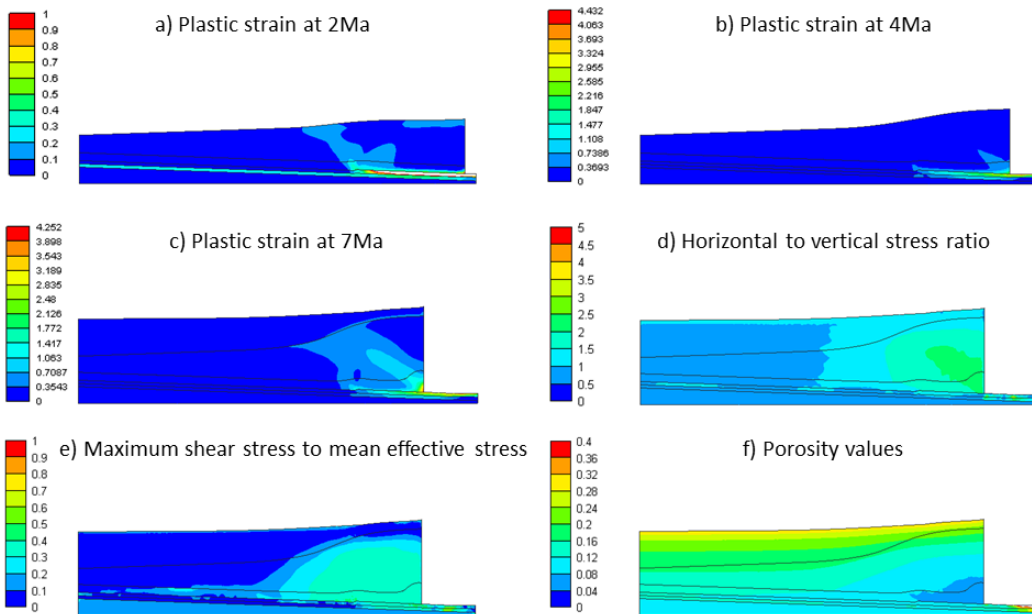
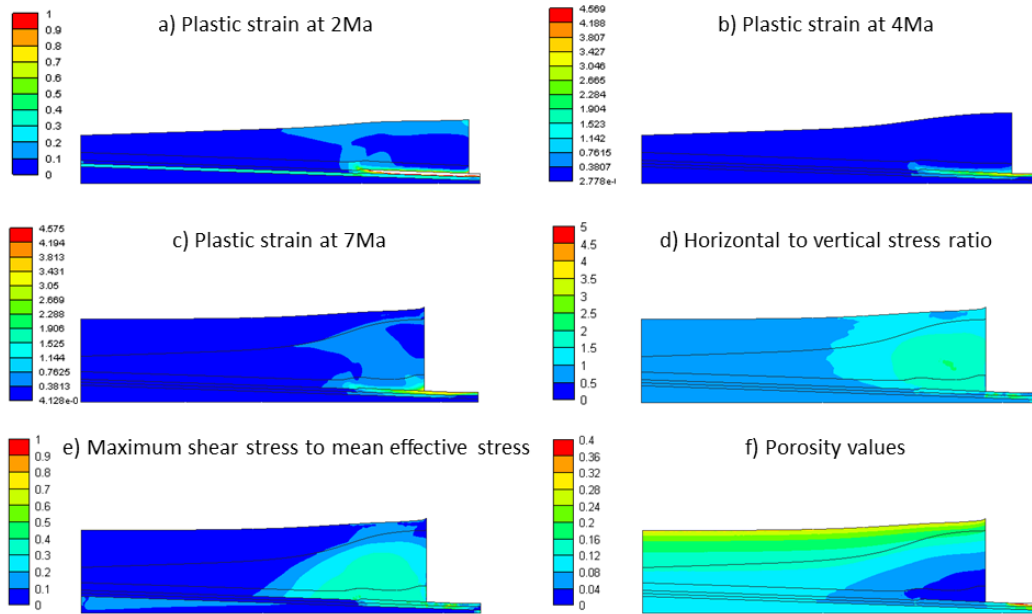
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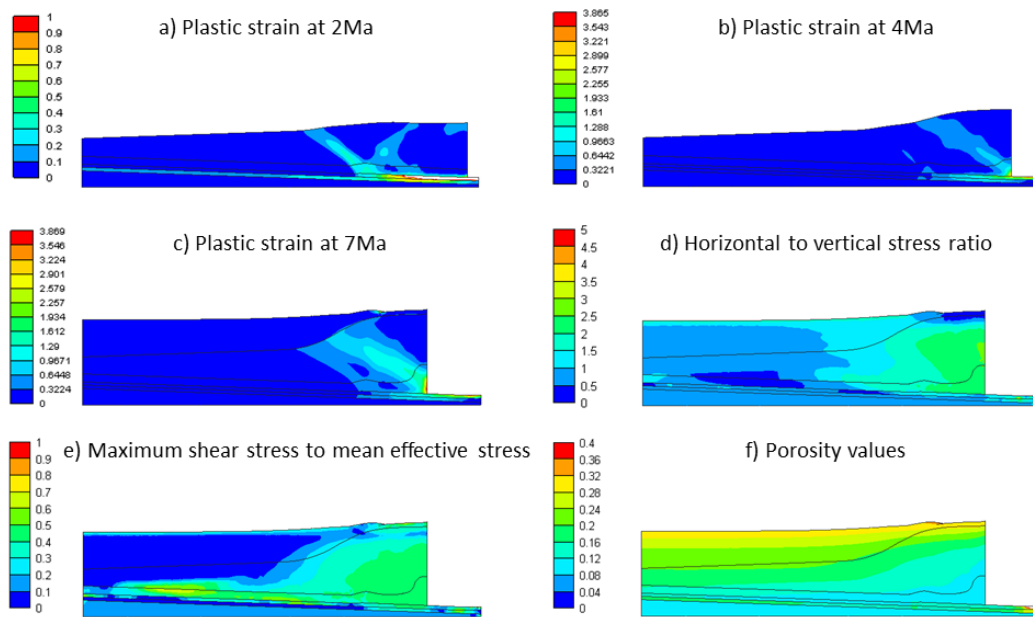
# Case 32





# Case 35

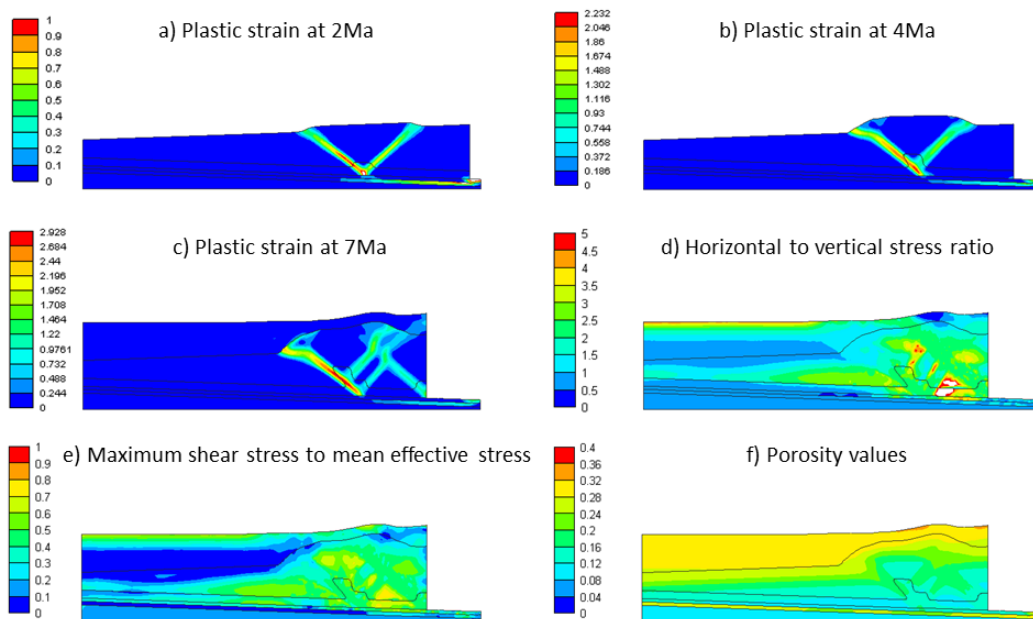
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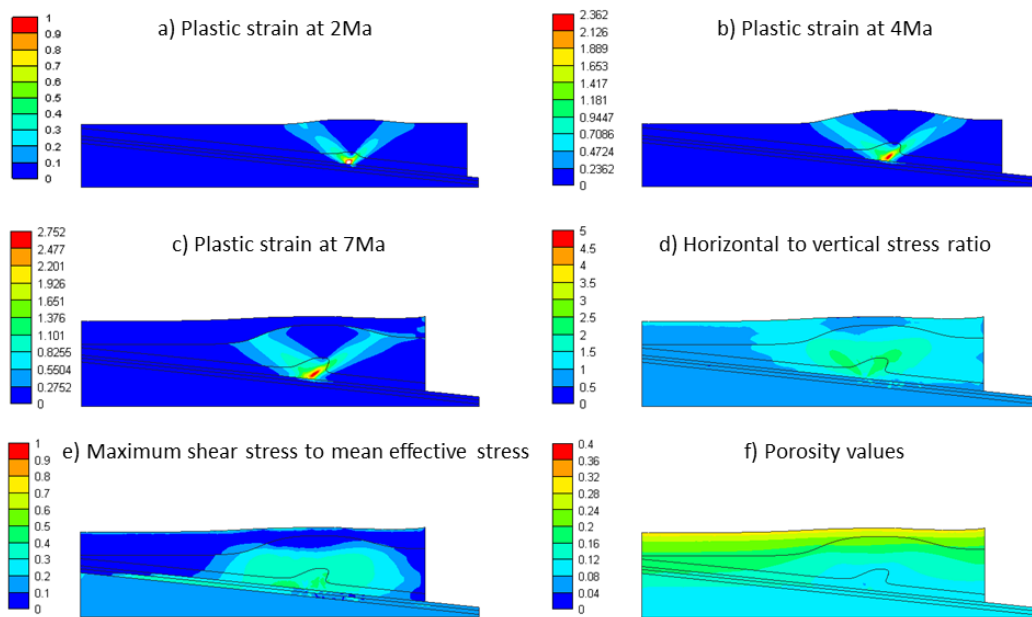
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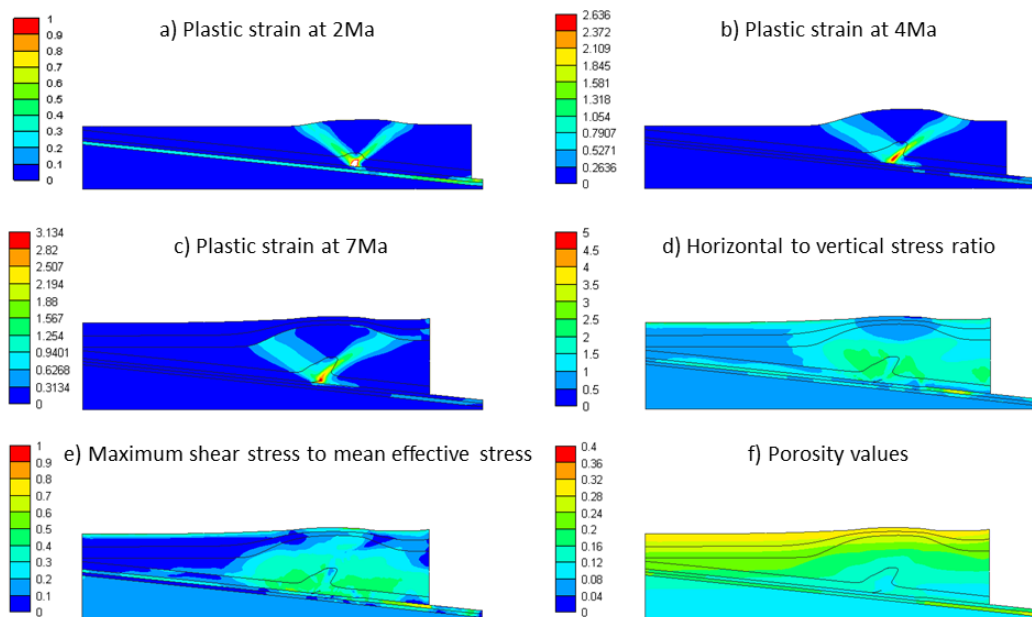
# Case 2\*

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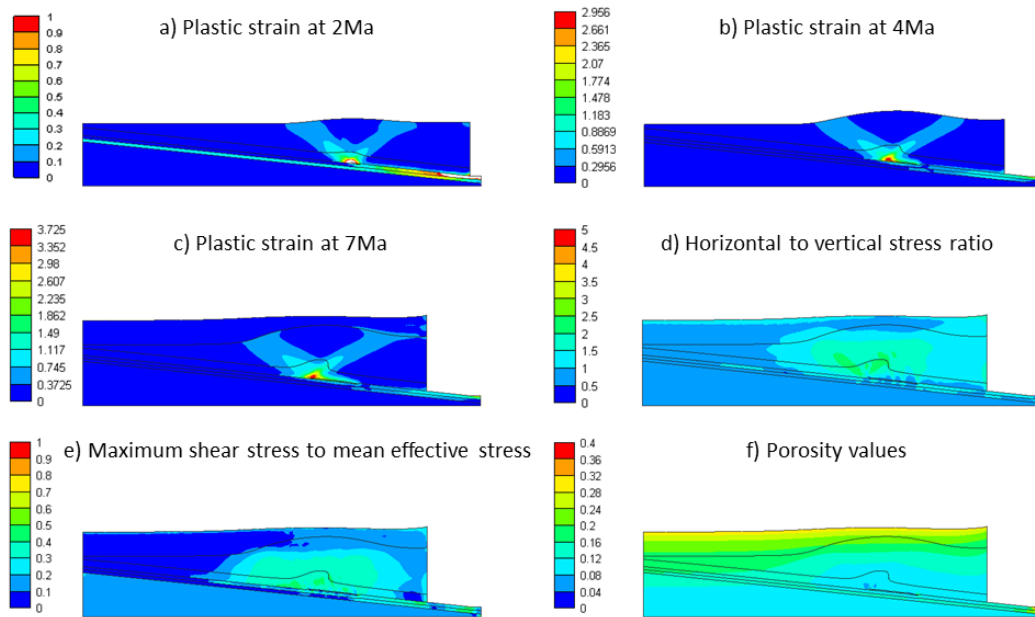
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# Case 3\*



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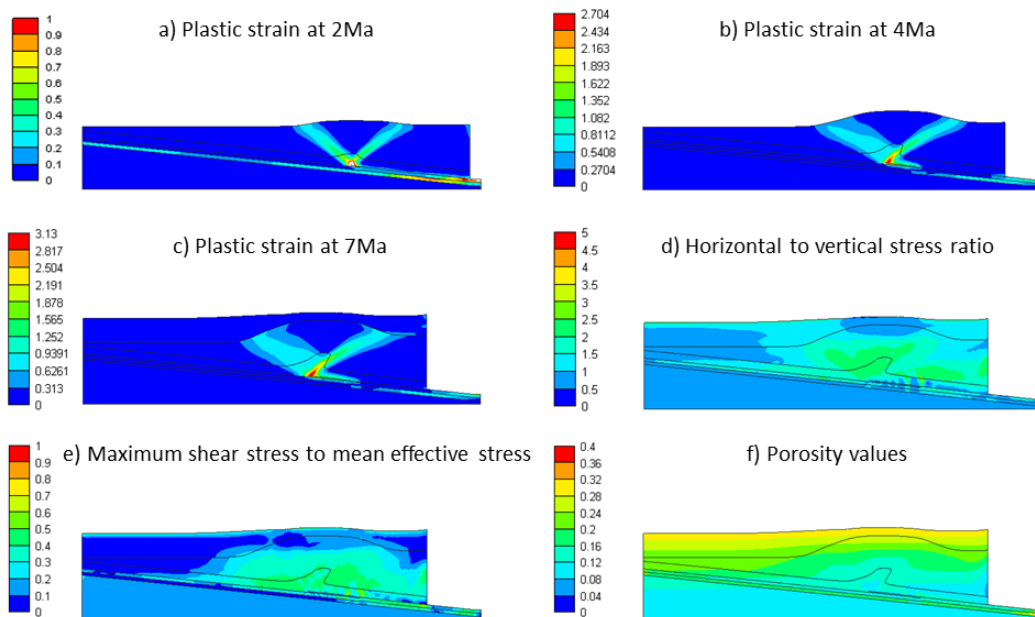
# Case 6\*



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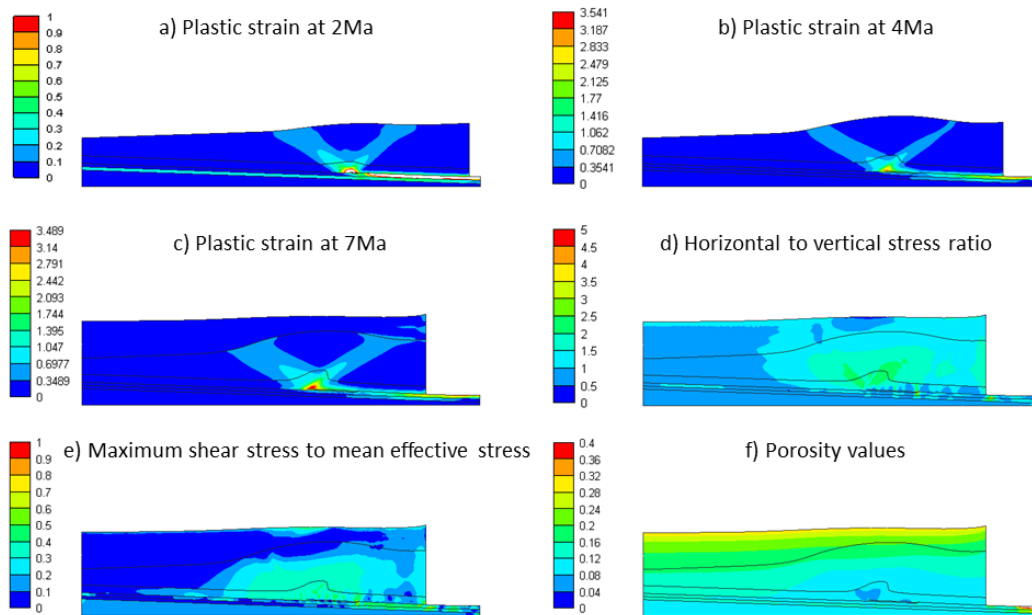
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# Case 7\*



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Case 34\*



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325 Case 35\*

