Design of the Double Step Joint to account the Shear Crack with Cohesive Surfaces

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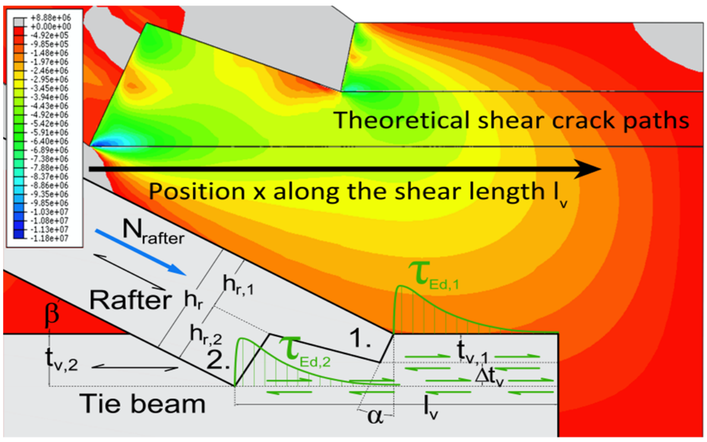
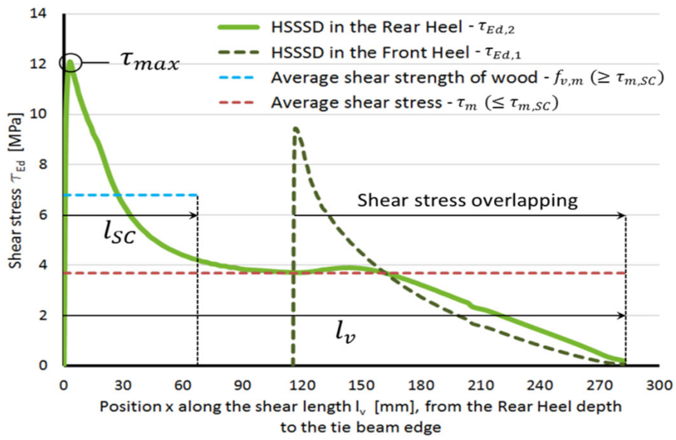
With low rafter skew angles β, the Double Step Joint (DSJ) can be subject to high horizontal thrust, alike the Single Step Joint (SSJ), resulting in the shear crack at the heel depth t_v over the shear length l_v in the tie beam. In order to prevent this brittle failure mode, design equations (1)-(2) from the literature review [1] must be checked in both DSJ heels (i.e. *i*=1 for the Front Heel; *i*=2 for the Rear Heel).

$$N_{rafter,i} \leq k_{v,red,i} \cdot f_{v,m} \cdot \frac{b\,.\ \min(l_{v,i},\ 8.t_{v,i})}{\cos\beta} \quad (1)$$

$$N_{rafter,1} \leq N_{rafter,tot} \leq N_{rafter,1} + N_{rafter,2} \quad (2)$$

Being conditioned by the geometry of both DSJ heels, the total rafter load-bearing capacity ($N_{rafter,tot}$) of the connection should vary between the rafter load-bearing capacity in the Front Heel ($N_{rafter,1}$) and the sum of rafter load-bearing capacities related to both heels ($N_{rafter,1}$+$N_{rafter,2}$). The present numerical research aims at investigating which DSJ geometrical parameters may trigger the shear crack in the tie beam (Figure 1), over the shear lengths along the grain $l_{v,i}$ at the Front and/or Rear Heel depths $t_{v,i}$. Alike previous numerical studies [2, 3], the Cohesive Surfaces method has been chosen to simulate the emergence of shear crack in both DSJ heels through modifying their geometry. Furthermore, their two respective non-uniform shear stress distributions, called Hammock Shape Shear Stress Distributions (HSSSD), have been assessed through several parameters (Figure 2).





Figures 1 and 2: Shear stress along the grain in the tie beam (left). Pattern and parameters of the HSSSD in the Rear Heel (right).

As outcomes from this numerical research, different scenarios of shear crack emergence in both DSJ heels as well as their design equation variants related to (2) have been determined, through modifying two geometrical parameters: (i) Difference of heel depths Δt_v=$t_{v,2}$-$t_{v,1}$; (ii) Ratio between the Rear Heel and rafter heights $h_{r,2}/h_r$. Based on empirical relationships already established for the SSJ design [3], the reducer coefficients $k_{v,red,i}$, which take into account the presence of HSSSD in the Front and Rear Heels, have been checked and adjusted to enhance the reliability of the DSJ design equations (1) against the shear crack in both heels.

References

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