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ED APPLICATA

Enhanced beam models for delamination toughness tests: mixed-mode fracture tests

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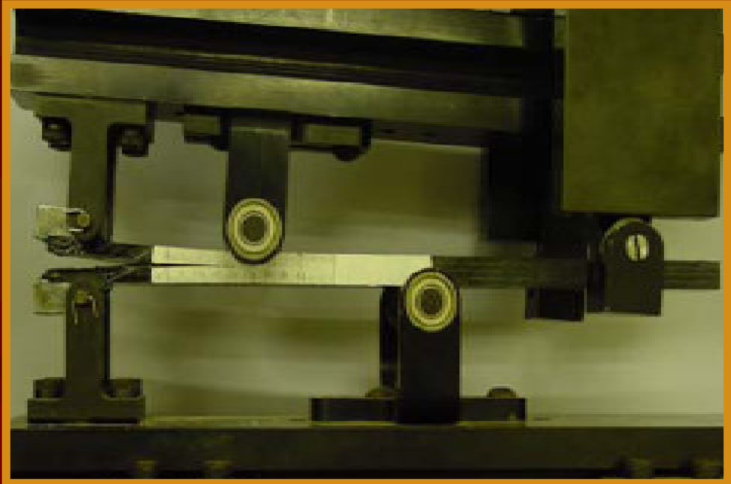
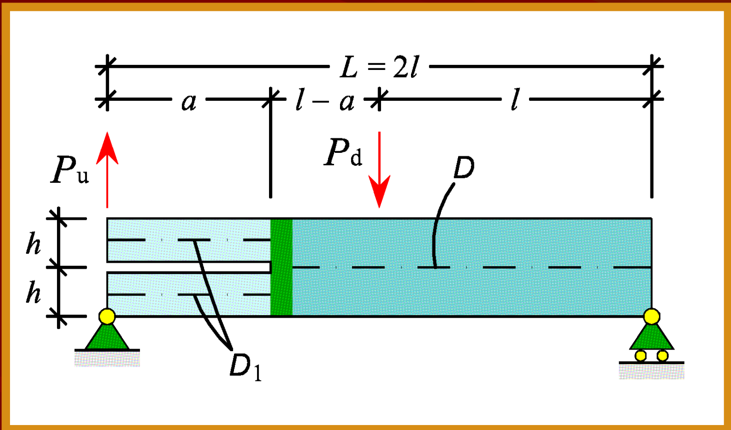
Mixed-mode delamination tests

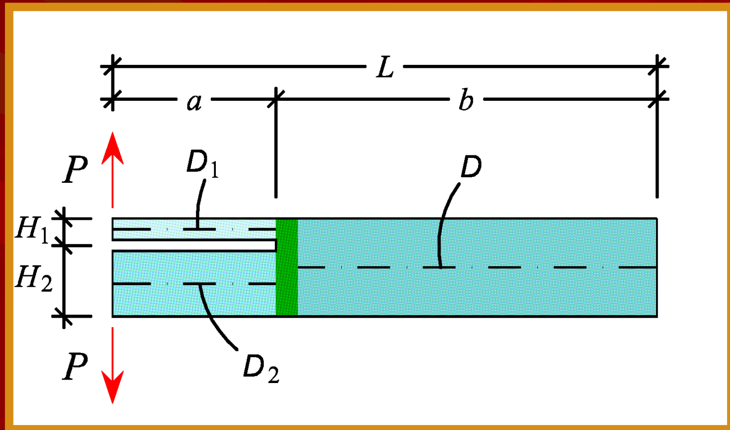
Mixed-mode bending (MMB) | Asymmetric double cantilever beam (ADCB)

Experimental setup



Simple beam theory model



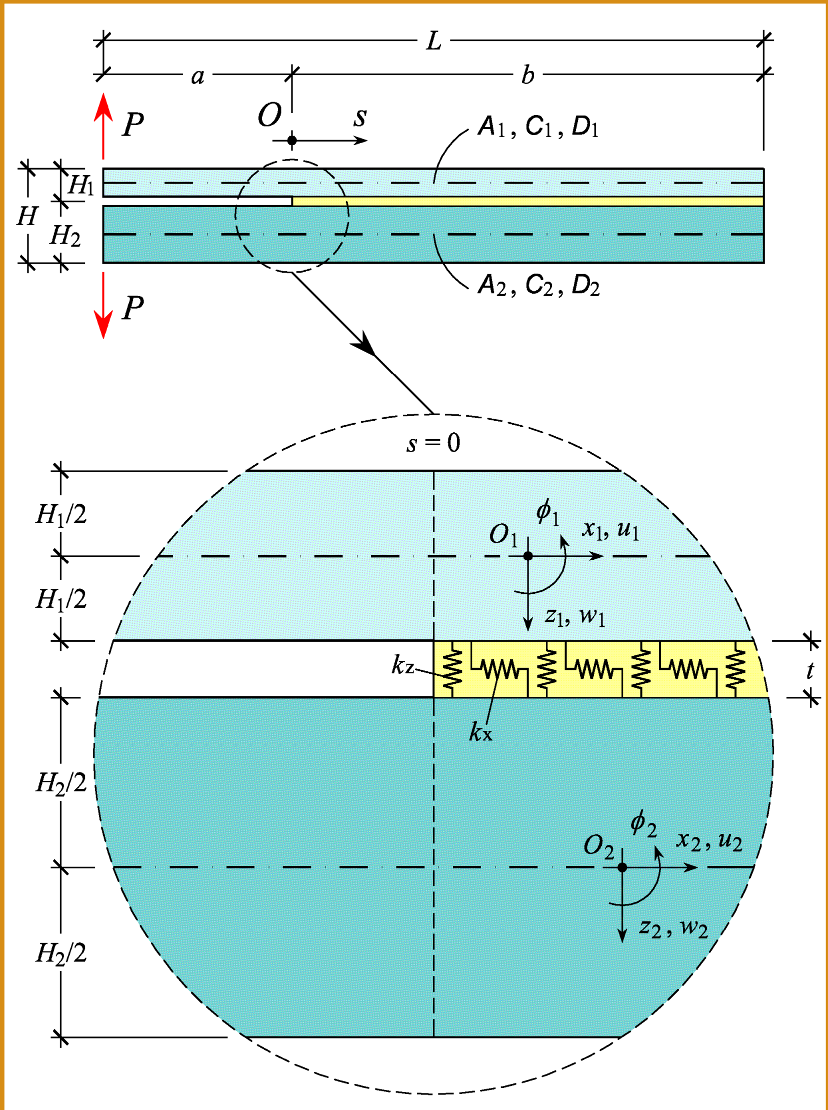


$$G_{\mathrm{I}}^{\mathrm{SBT}} = \frac{8(P_{\mathrm{u}} - P_{\mathrm{d}}/4)^2 a^2}{B^2 D}, \quad G_{\mathrm{II}}^{\mathrm{SBT}} = \frac{3P_{\mathrm{d}}^2 a^2}{8B^2 D}$$

$$G^{\mathrm{SBT}} = G_{\mathrm{I}}^{\mathrm{SBT}} + G_{\mathrm{II}}^{\mathrm{SBT}} = \frac{P^2 a^2}{2B^2}\left(\frac{1}{D_1} + \frac{1}{D_2}\right)$$

Enhanced BT model of ADCB test

Mechanical model



Interfacial stresses

$$\begin{cases} \sigma(s) = \dfrac{P}{B}\displaystyle\sum_{i=1}^{6} c_i \exp(\lambda_i s) \\ \tau(s) = -2\dfrac{P}{B}\dfrac{\displaystyle\sum_{i=1}^{6} c_i\left[\dfrac{\lambda_i^3}{k_x} - \left(\dfrac{1}{C_1}+\dfrac{1}{C_2}\right)\lambda_i + \left(\dfrac{1}{D_1}+\dfrac{1}{D_2}\right)\dfrac{1}{\lambda_i}\right]\exp(\lambda_i s)}{\dfrac{H_1}{D_1}-\dfrac{H_2}{D_2}} \end{cases}$$

Modal contributions to Energy release rate

$$\begin{cases} G_{\mathrm{I}}^{\mathrm{EBT}} = \dfrac{1}{2}\dfrac{(\sigma|_{s=0})^2}{k_z} = \dfrac{P^2}{2k_z B^2}\left(\displaystyle\sum_{i=1}^{6} c_i\right)^2 \\ G_{\mathrm{II}}^{\mathrm{EBT}} = \dfrac{1}{2}\dfrac{(\tau|_{s=0})^2}{k_x} = \dfrac{2P^2}{k_x B^2}\left[\dfrac{\dfrac{1}{D_1}+\dfrac{1}{D_2}+\displaystyle\sum_{i=1}^{6} c_i\lambda_i\left(\dfrac{1}{C_1}+\dfrac{1}{C_2}-\dfrac{\lambda_i^2}{k_x}\right)}{\dfrac{H_1}{D_1}-\dfrac{H_2}{D_2}}\right]^2 \end{cases}$$

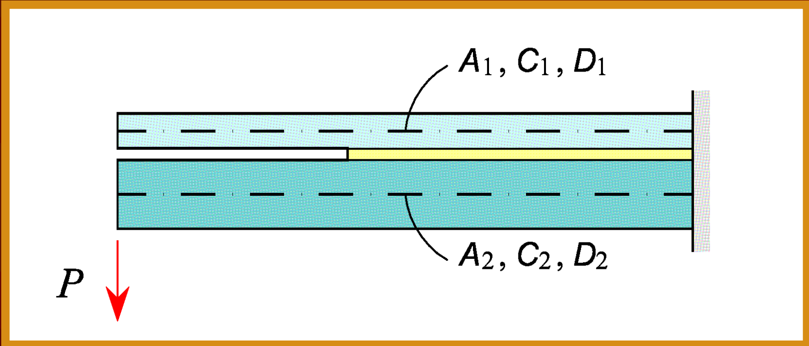
Constants

λ_i = roots of characteristic equation

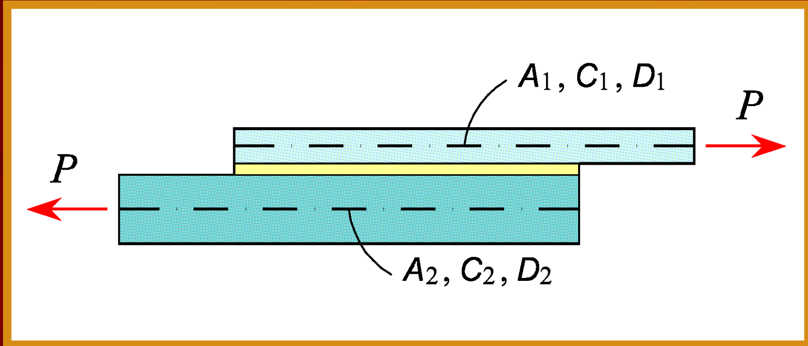
c_i = integration constants $\qquad (i = 1, 2, \dots, 6)$

Developing new EBT models

Asymmetric end loaded split (AELS)

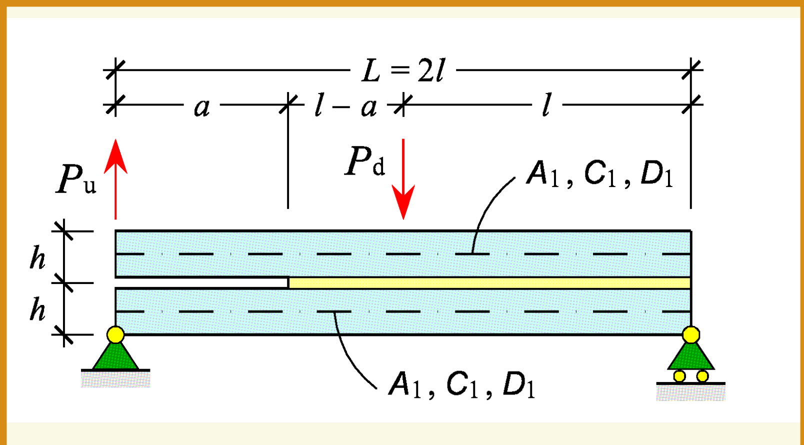


Asymmetric single lap joint (ASLJ)



Enhanced BT model of MMB test

Mechanical model



Correction factors

$$\begin{cases} \mu_{\mathrm{I}} = \dfrac{G_{\mathrm{I}}^{\mathrm{EBT}}}{G_{\mathrm{I}}^{\mathrm{SBT}}} = [1 + \dfrac{(\lambda_1+\lambda_2)^2(1-Z_1Z_2-T_1T_2) + \dfrac{\lambda_1^2-\lambda_2^2}{\lambda_1\lambda_2 a}(\lambda_1T_2-\lambda_2T_1)}{(\lambda_1^2+\lambda_2^2)T_1T_2 - 2\lambda_1\lambda_2(1-Z_1Z_2)}]^2 \\ \mu_{\mathrm{II}} = \dfrac{G_{\mathrm{II}}^{\mathrm{EBT}}}{G_{\mathrm{II}}^{\mathrm{SBT}}} = \{\coth\lambda_5(L-a) + \dfrac{1}{\lambda_5 a}[1 - 2\dfrac{\sinh\lambda_5(L/2)}{\sinh\lambda_5(L-a)}]\}^2 \end{cases}$$

where $Z_j = \operatorname{sech}\lambda_j(L-a)$, $T_j = \tanh\lambda_j(L-a)$, $j = 1, 2,$

and $\lambda_1, \lambda_2, \lambda_5$ = roots of characteristic equations