

DANNEGGIAMENTO E FESSURAZIONE

NEI MATERIALI STRAIN-SOFTENING :

APPLICAZIONE DELLA TEORIA DELLA

DENSITÀ DI ENERGIA DI DEFOR-

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- 1) Legge costitutiva : bi-lineare con softening
- 2) Geometria : three point bending test
- 3) Criterio di danneggiamento e crescita del crack
Strain Energy Density Theory
- 4) Trasformazione delle R-curves al variare della :
 - VELOCITÀ DI CARICO
 - SCALA DELLA STRUTTURA

FRACTURE TEST

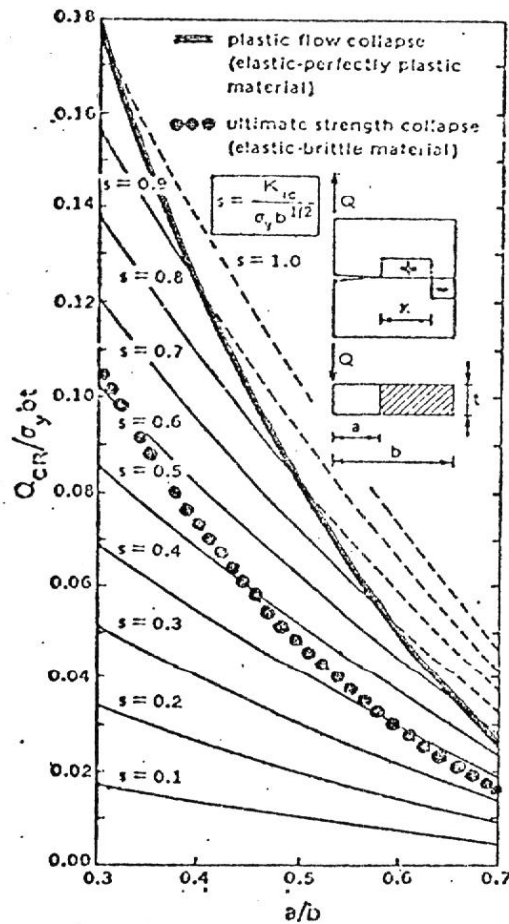
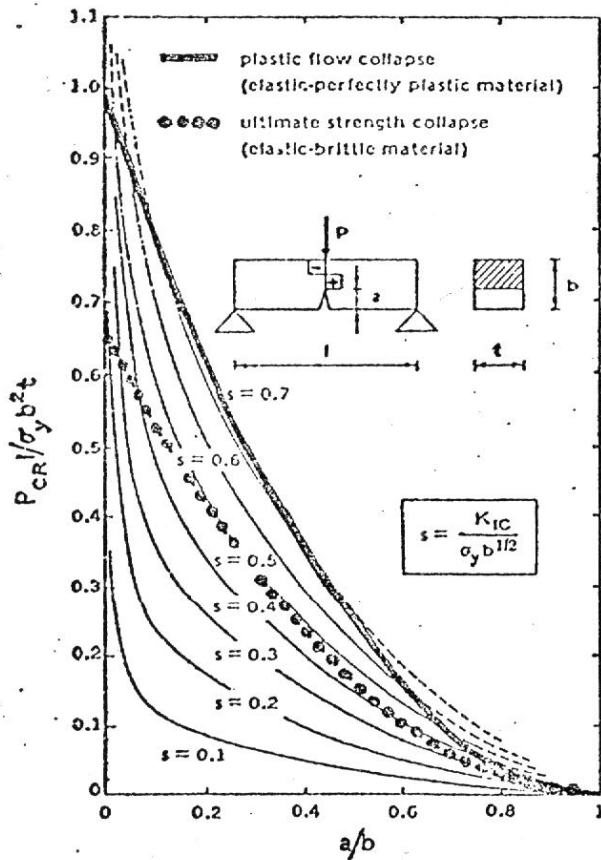
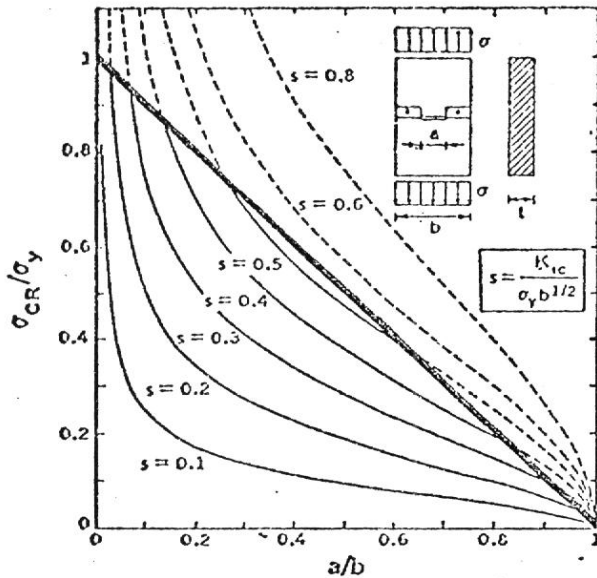
GEOMETRIES

• crack propagation :

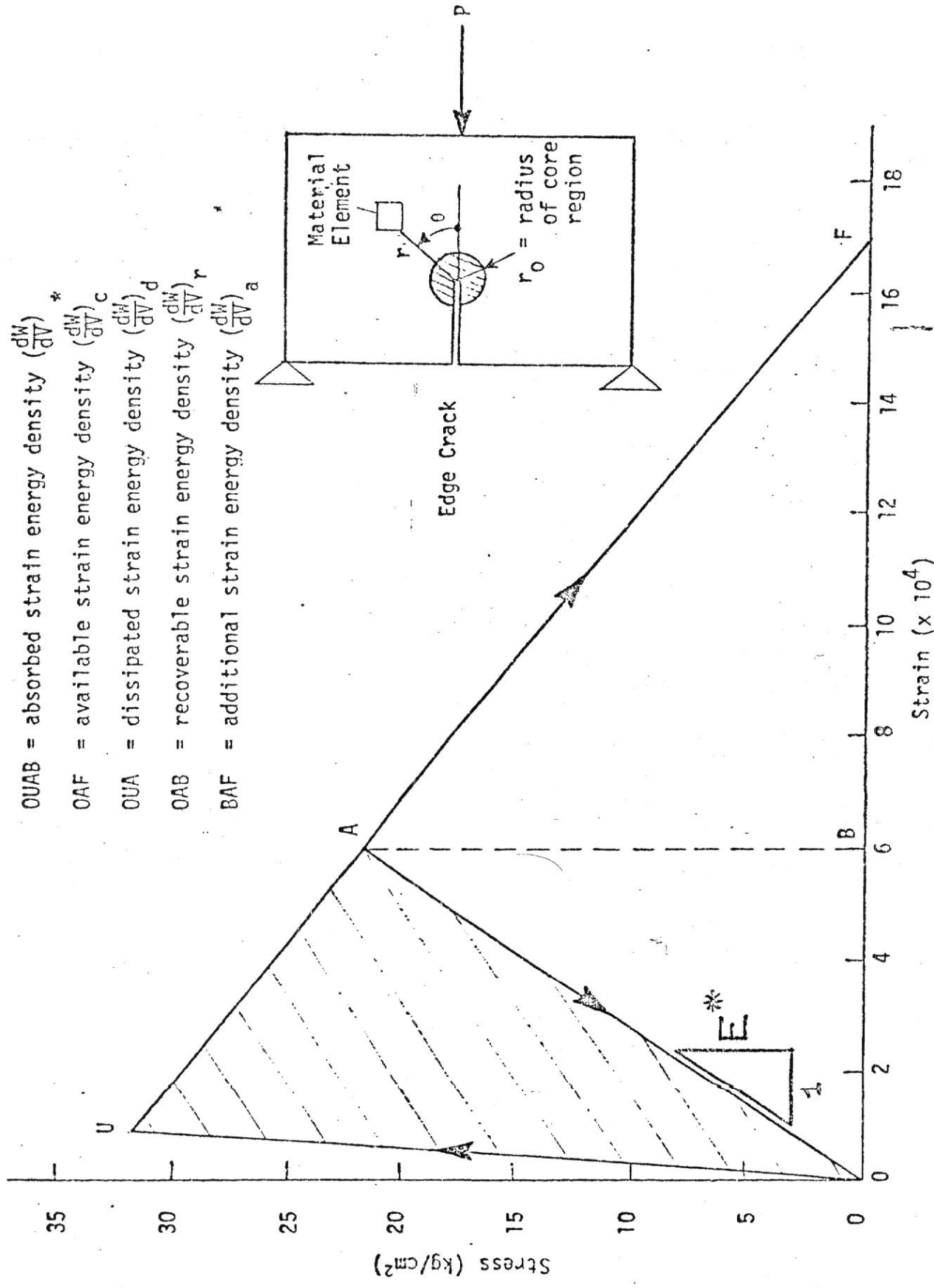
$$\frac{\sigma_{CR}}{\sigma_y} = \left(\frac{\cos \frac{\pi}{2} \frac{a}{b}}{\frac{\pi}{2} \frac{a}{b}} \right)^{1/2}$$

• plastic flow :

$$\frac{\sigma_{CR}}{\sigma_y} = 1 - \frac{a}{b}$$



$$s = \frac{K_{IC}}{\sigma_u b^{1/2}} ; S^* = \frac{S_c}{\left(\frac{dW}{dV}\right)_c b} \Rightarrow S^* = s^2 \frac{(1+\nu)(1-2\nu)}{\pi}$$



- OUAB = absorbed strain energy density $(\frac{dW}{dV})^*$
- OAF = available strain energy density $(\frac{dW}{dV})_c^*$
- OUA = dissipated strain energy density $(\frac{dW}{dV})_d$
- OAB = recoverable strain energy density $(\frac{dW}{dV})_r$
- BAF = additional strain energy density $(\frac{dW}{dV})_a^*$

Figure 1. Uniaxial elastic-softening stress-strain curve

$$E^*(n) = \frac{(26-n)}{25} E, \quad n = 1, 2, \dots, 25$$

52 elements
309 nodes

APE S-program

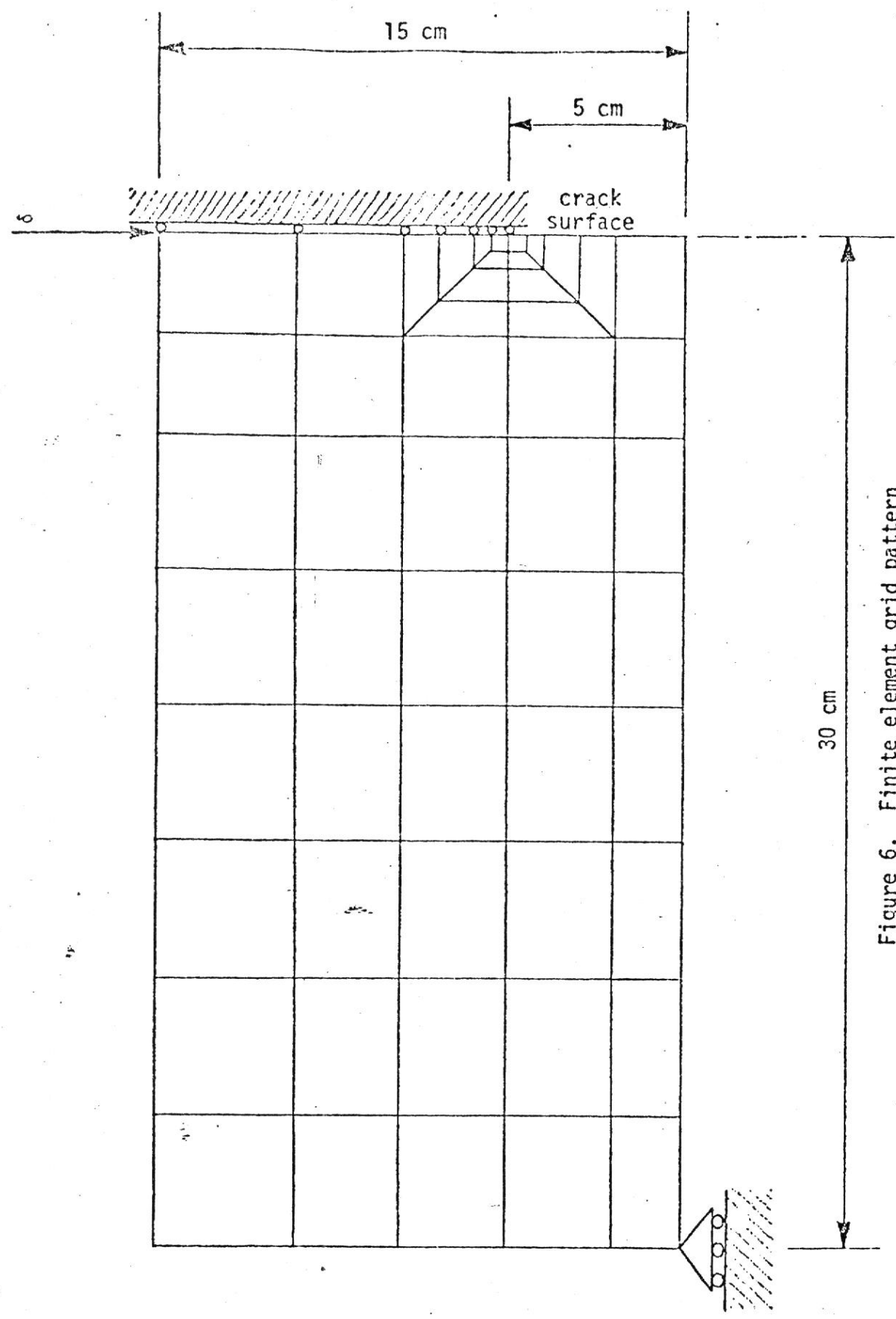


Figure 6. Finite element grid pattern

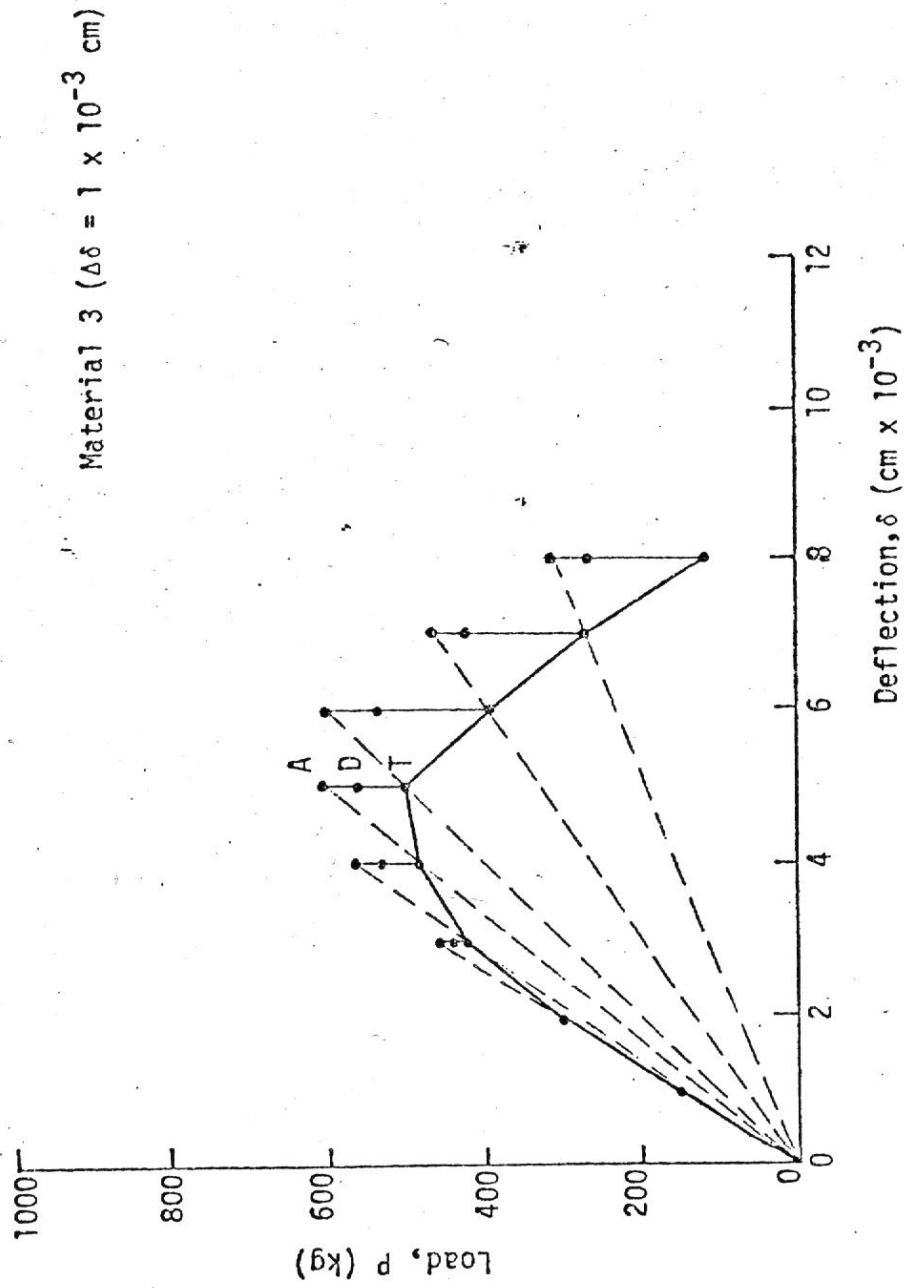


Figure 29. Load-displacement curve for material damage and crack growth:

Material 3 ($\Delta\delta = 1 \times 10^{-3}$ cm)

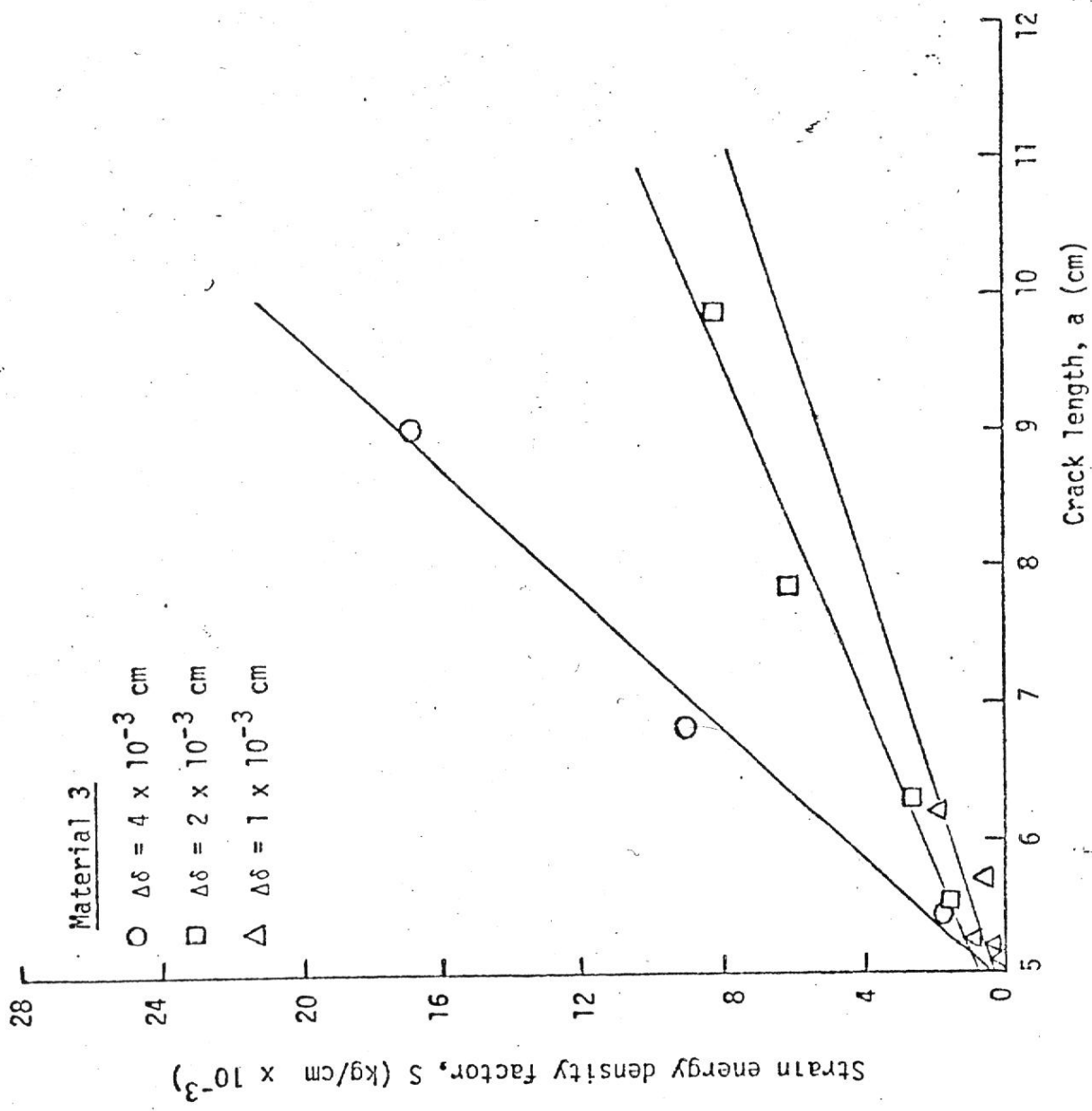
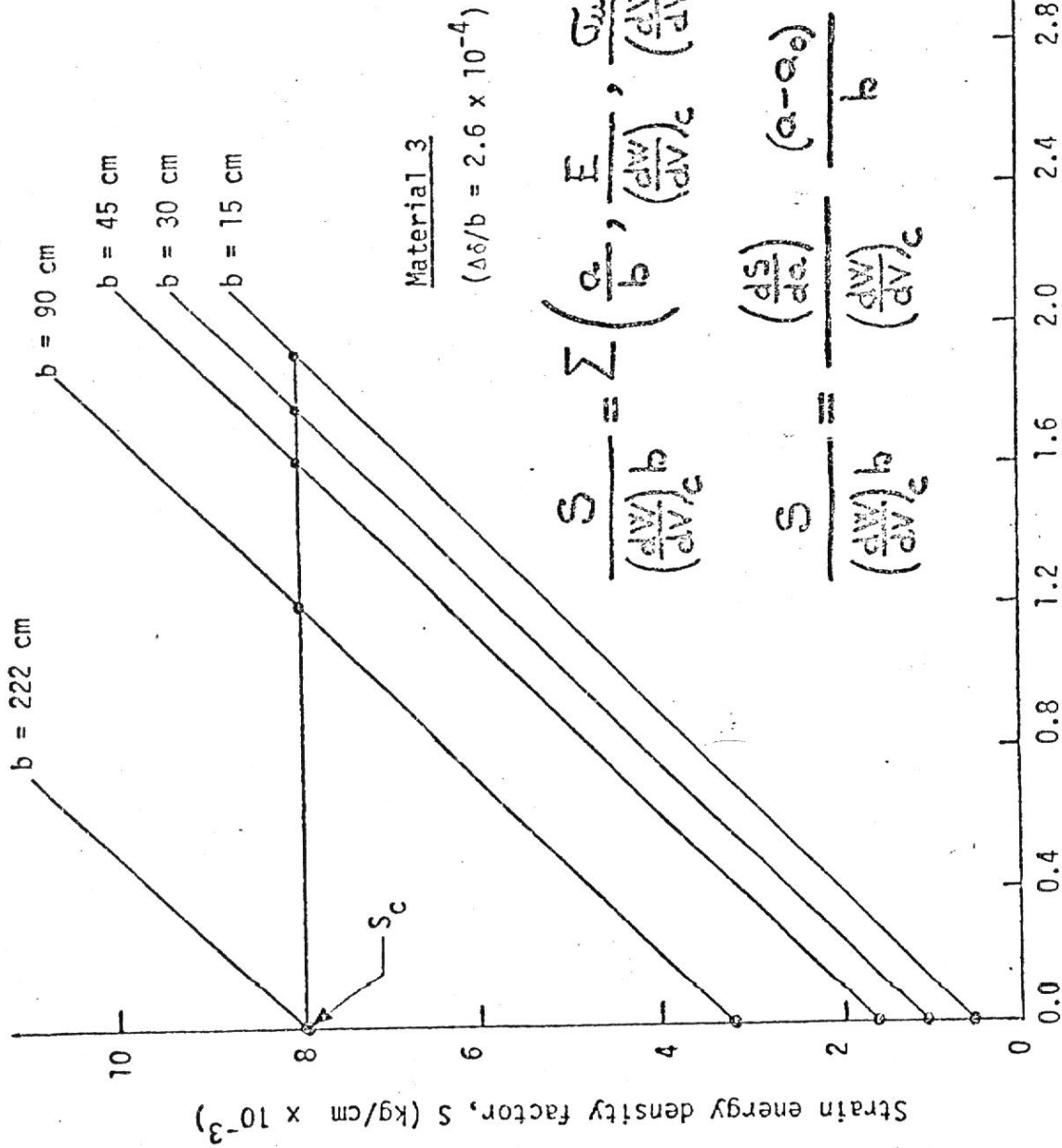


Figure 40. Strain energy density factor versus crack length for Material 3 with three different loading steps

$$S_0 \propto c b$$



$$\frac{S}{\left(\frac{dW}{dV}\right)_c} = \sum \left(\frac{\sigma_c}{b}, \frac{E}{\left(\frac{dW}{dV}\right)_c}, \frac{\sigma_c}{\left(\frac{dW}{dV}\right)_c}, \gamma, \frac{f}{b}, \frac{t}{b}, \frac{\alpha_c}{b} \right)$$

$$\frac{S}{\left(\frac{dW}{dV}\right)_c} = \frac{\left(\frac{dS}{dc}\right)}{\left(\frac{dW}{dV}\right)_c} \cdot \frac{(a-a_0)}{b} + \frac{S_0}{\left(\frac{dW}{dV}\right)_c} b$$

Crack growth, $a-a_0$ (cm)

Figure 43. Strain energy density factor versus crack length for different structural scales and $\Delta\delta/b = 2.6 \times 10^{-4}$

$$\frac{P}{\left(\frac{dW}{dV}\right)_c b^2} = \pi \left(\frac{\delta}{b}, \frac{E}{\left(\frac{dW}{dV}\right)_c}, \frac{\sigma_{th}}{\left(\frac{dW}{dV}\right)_c}, \gamma, \frac{S_c}{\left(\frac{dW}{dV}\right)_c b}, \frac{t}{b}, \frac{a_0}{b} \right)$$

$$\frac{L}{\epsilon} = S^*$$

Material 3

$$(\Delta\delta/b)_c = 2.6 \times 10^{-4}$$

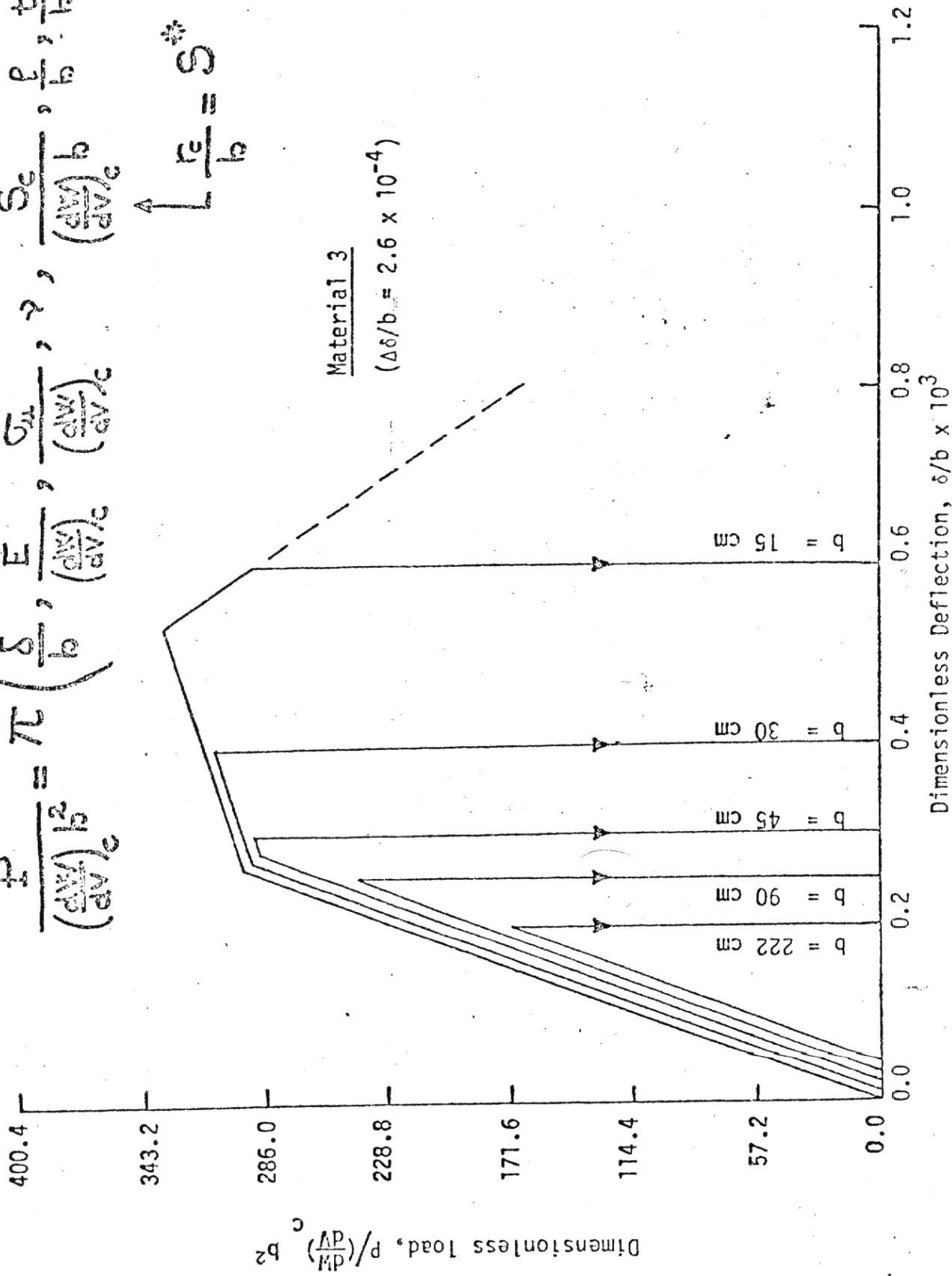


Figure 44. Dimensionless load-deflection for unstable crack propagation and $\Delta\delta/b_c = 2.6 \times 10^{-4}$

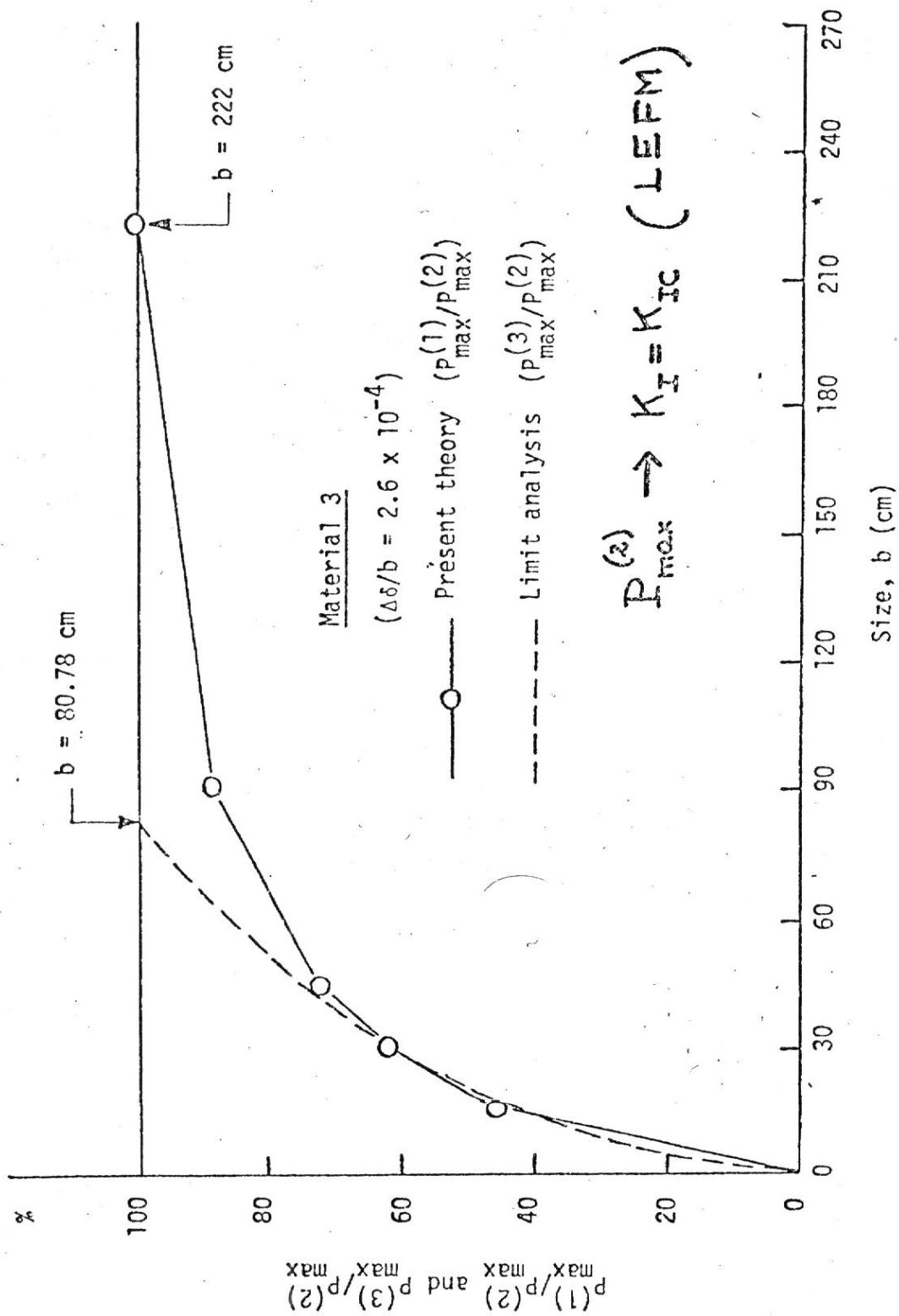


Figure 49. Comparison of normalized maximum load ratio for brittle fracture and present model

R-CURVES DI PARAMETRI ENERGETICI

