UF Center for Infrastructure Protection and Physical Security (CIPPS)
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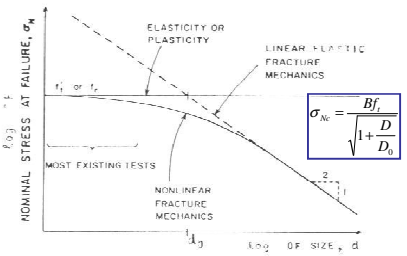
ERDC
US Army Engineer Research and Development Center

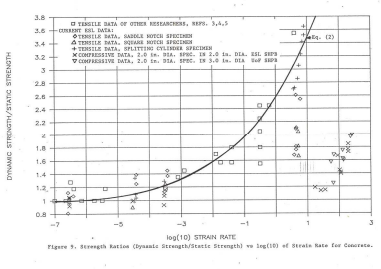
Fracture Based Size and Rate Effects in Concrete Members

Starting Point:

- A known Size Effect in the static domain
- A known strain Rate Effect under dynamic loads
- It was unknown how these effects interact, and how one should address these effects together



Size Effect



Strain Rate Effect

Theoretical and Numerical Study:

- A dynamic crack criterion was formulated by combining:
  - Energy equilibrium
  - Force equilibrium
- A simplified approach was based on Linear Elastic Fracture Mechanics (LEFM) assumptions
- An advanced approach was based on Nonlinear Fracture Mechanics (NMFM) assumptions

LEFM Part

- Adopted Marur's (1996) equivalent mass M_e and stiffness K for the dynamic behavior of a three point bending specimen, simulated as the continuous Timoshenko's beam.
- Derive a dynamic crack criterion by the force and energy equilibrium equations

Crack propagates if: $$2\gamma = \frac{1}{B}\left[-\frac{1}{2}\frac{dK}{da}u^2 + \frac{1}{2}\frac{dM_e}{da}\dot{u}^2\right]$$

or: $$2\gamma - \frac{1}{2B}\frac{dM_e}{da}\dot{u}^2 = -\frac{1}{2B}\frac{dK}{da}u^2$$

NLFM Part

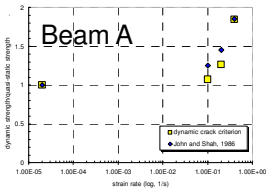
- Numerical FE analysis with the conventional fictitious crack model to show how experimental rate effect data can be derived from structural inertia
- Develop a dynamic crack criterion

$$\frac{dU_{D_f}}{dD_f} = -\frac{1}{2}\frac{dK}{dD_f}u^2 + \frac{1}{2}\frac{dM_e}{dD_f}\dot{u}^2$$

Key Conclusions

- The kinetic energy release rate in the proposed dynamic crack criteria seems to be the main cause of the rate effect
- The size and rate effects are not independent phenomena, but they are coupled
- These unique findings shed new light on the causes for both the size and rate effects

Sample Results



DF_a=15.0 s²

DF_b=16.6 s² from material properties and **DF_a**

$$DF_b = \left(\frac{\text{critical static stress}_a}{\text{critical static stress}_b}\right)^2 \frac{E_b\rho_b}{E_a\rho_a} DF_a$$

Use test data from one beam to derive model parameters, then predict the behavior of another beam