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

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 (NLFM) 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

\[
\frac{dU_{in}}{dD_f} = -\frac{1}{B} \frac{dK}{2 \, da} \frac{1}{2} \frac{dM}{da} \frac{1}{2}
\]

or:

\[
2\gamma = \frac{1}{B} \frac{dK}{2 \, da} \frac{1}{2} \frac{dM}{da} \frac{1}{2}
\]

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

\[
\frac{dU_{in}}{dD_f} = -\frac{1}{B} \frac{dK}{2 \, da} \frac{1}{2} \frac{dM}{da} \frac{1}{2}
\]

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