Research Project: Nano particle reinforced composites for critical infrastructure protection

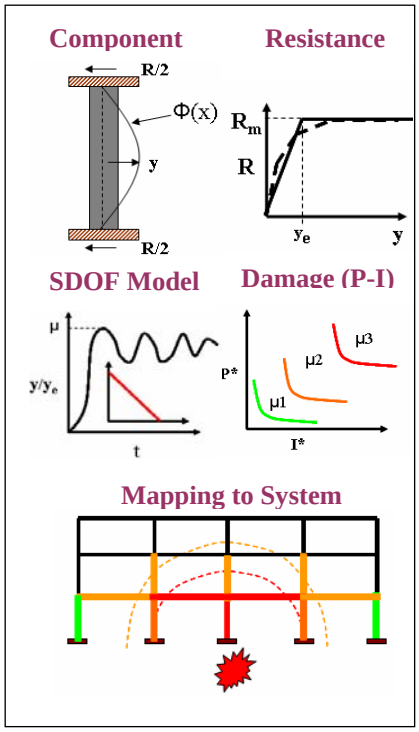
Research Topic: Component vulnerability to blast and extreme environmental loading

Problem

Evaluate strength and deformation capacity of components subject to blast and extreme loading. As a baseline case, an un-retrofitted, reinforced concrete (RC) column is considered whose gross section has been designed to carry the dead and live loads prescribed in the International Building Code 2006 (and, by reference, the American Concrete Institute 318-05 provisions). The reinforcement represents the minimum longitudinal steel ratio recommended in practice and the transverse steel ratio represents the minimum called for in ACI 318-05.

Approach

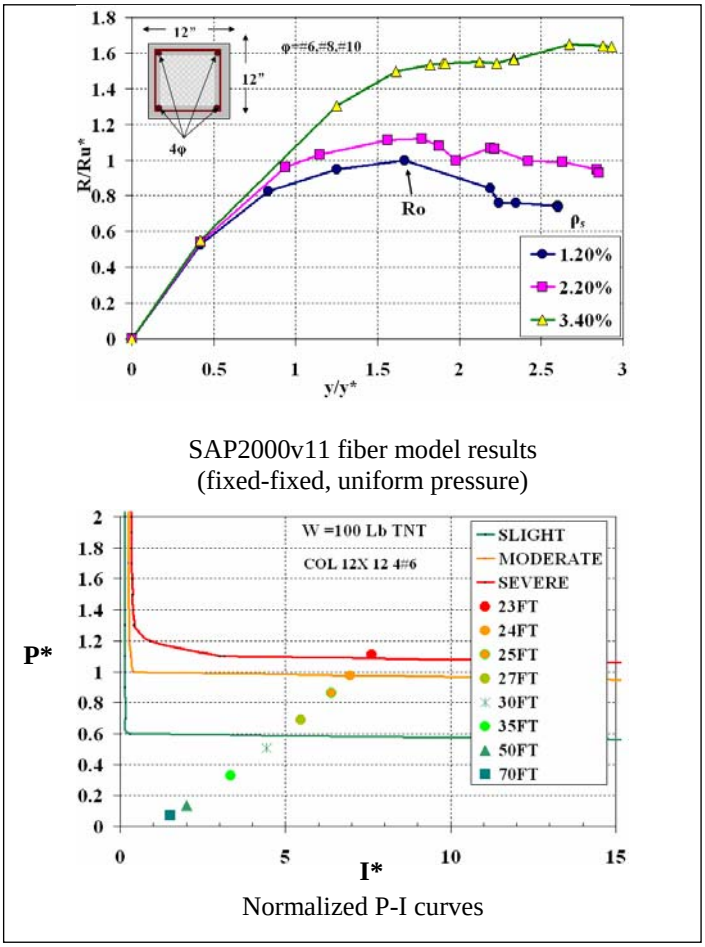
Pressure versus impulse (P-I) curves are used to represent estimated damage levels in components subjected to blast or shock loadings. The procedure and reflected blast pressure versus distance relation follow the TM 5-1300 Joint Forces military guidance. A component (column) is idealized as a single-degree-of-freedom (SDOF) bilinear oscillator per Biggs (1956) where the peak resistance is computed using a SAP2000 fiber hinge model of a fixed-fixed beam. Peak response is obtained by nonlinear time history analysis (NTHA) of the SDOF system using the implicit generalized Newmark method of time integration in Matlab.



A family of P-I curves is obtained by repeating NTHA over a wide range of loads idealized as a triangular impulse and the maximum displacement (y_{max}) is associated with a physically-based damage level: 1) first significant stiffness change 2) peak resistance, and 3) first major post-peak strength degradation (not collapse). P-I parameters are normalized as follows:

$$p^* = \frac{p_r}{p_o} \qquad I^* = \frac{I}{R_m \cdot T_0} \qquad \mu = \frac{y}{y_0}$$

where p_r p_o R_m T_0 y_0 are, respectively, peak reflected pressure at building wall location, pressure on the exposed column face, peak resistance for the minimum steel ratio case, natural period of SDOF oscillator, and effective yield displacement for SDOF oscillator.



SAP2000v11 fiber model results (fixed-fixed, uniform pressure)

Normalized P-I curves

Findings

The work is in progress. A database of P-I curves for reinforced concrete components of various cross sections and reinforcement ratios is being developed including the benefit of nano-particle reinforcement.

Impact

The simulations allow the planner to determine the likely location and extent of damage in building structures subject to blast loadings. The simplified methodology can be used for rapid vulnerability and damage assessment of critical infrastructure.

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(Approved for public release by SERRI. Last update: July 2007)

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