Fire Following Earthquakes

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PEER Associate Director

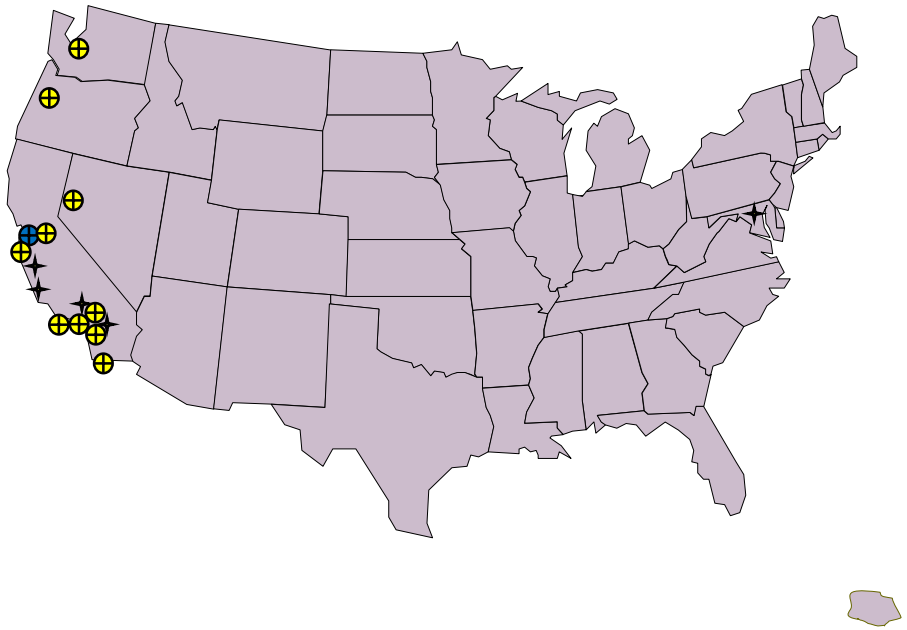
COE-LBNL Fire Research Group Meeting, Oct. 16, 2018, 10:00-12:00, LBNL, Institute for Nuclear & Particle Astrophysics, Conference Room, Bldg. 50, Room 50-5026.

PEER: University, Government, Professional & Industry Alliance

PEER: **The Pacific Earthquake Engineering** Research Center is a multi-institutional research & education center with headquarters at the **University of California, Berkeley**.

6 Educational Affiliates

- California Polytechnic State University, San Luis Obispo
- California State University, Los Angeles
- California State University, Northridge
- San Jose State University
- University of Hawaii
- Johns Hopkins University



11 Core Institutions

- University of California, Berkeley - Lead Institution
- California Institute of Technology
- Oregon State University
- Stanford University
- University of California, Davis
- University of California, Irvine
- University of California, Los Angeles
- University of California, San Diego
- University of Southern California
- University of Nevada, Reno
- University of Washington

PEER combines resources of major research universities in western US where earthquake hazards are largest. PEER is able to represent consensus of many experts. PEER Mission focuses on **Integrated Performance-based Engineering (PBE) Methodology**.

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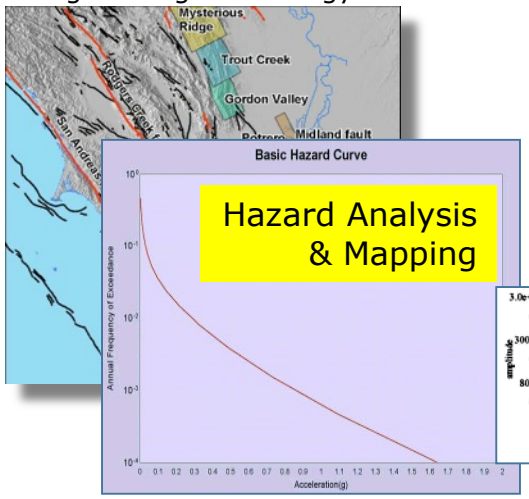
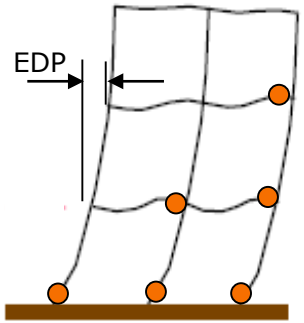
PEER DNA: Integrated PBEE Methodology

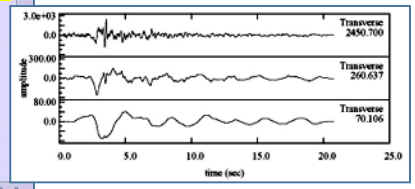
Engineering Seismology



Hazard Analysis & Mapping

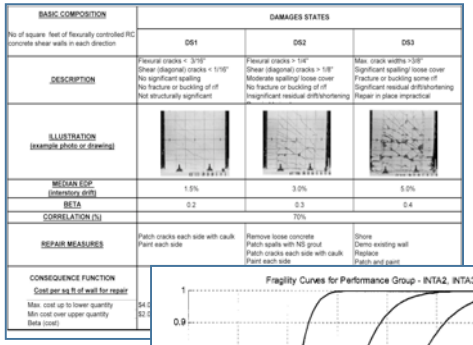
HPC simulation

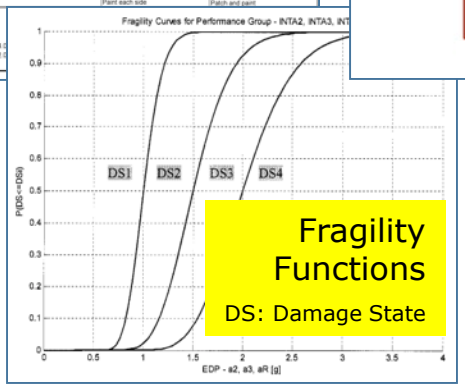




Ground motion selection & scaling

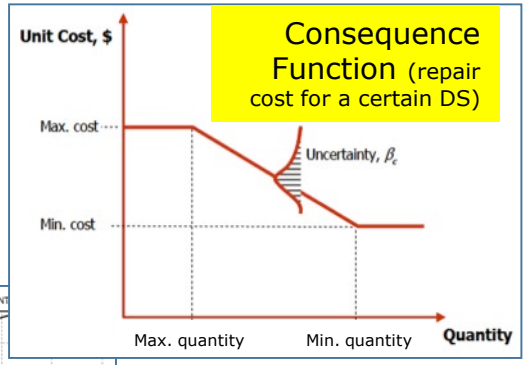
Performance Databases



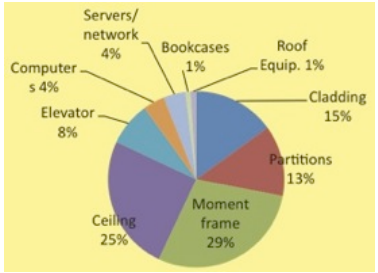


Fragility Functions

DS: Damage State



Consequence Function (repair cost for a certain DS)



Loss Assessment

Seismic Hazard Analysis	Response Analysis	Damage Analysis	Loss Analysis
$\lambda(im)$	$G(edp \mid im)$	$G(dm \mid edp)$	$G(dv \mid dm)$
IM: intensity measure	**EDP**: Engineering Demand Parameter	**DM**: Damage Measure	**DV**: Decision Variable

Probabilistic Assessment of:
- ✓ Cost of repair & Downtime
- ✓ Lifecycle costs
- ✓ Casualties
- ✓ *Embodied energy*

$$\lambda(DV > dv) = \int_{im}\int_{dm}\int_{edp} G(dv \mid dm)\, dG(dm \mid edp)\, dG(edp \mid im) \left| d\lambda(im) \right|$$

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Enabling Technology Development

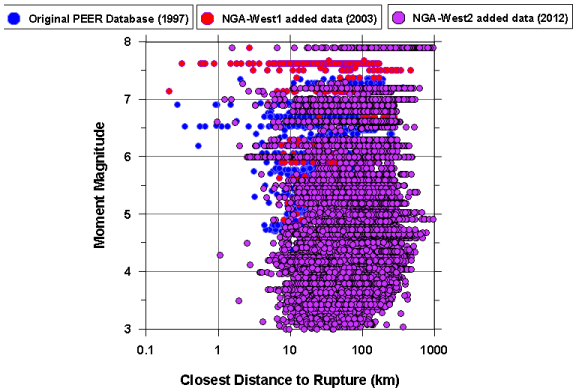
Analytical Simulation → OpenSees

Open System for Earthquake Engineering Simulation, http://opensees.berkeley.edu/

Hybrid Simulation (HS) → OpenFresco

Open-source Framework for Experimental Setup and Control, http://openfresco.berkeley.edu/

Databases:



Next **G**eneration **A**ttenuation (**NGA**) Projects:

http://peer.berkeley.edu/ngawest2/
http://peer.berkeley.edu/ngaeast/

PEER SPD Structural Performance Database

https://nisee.berkeley.edu/spd/

Seismic Performance Observatory
Pacific Earthquake Engineering Research Center

https://peer.berkeley.edu/spo

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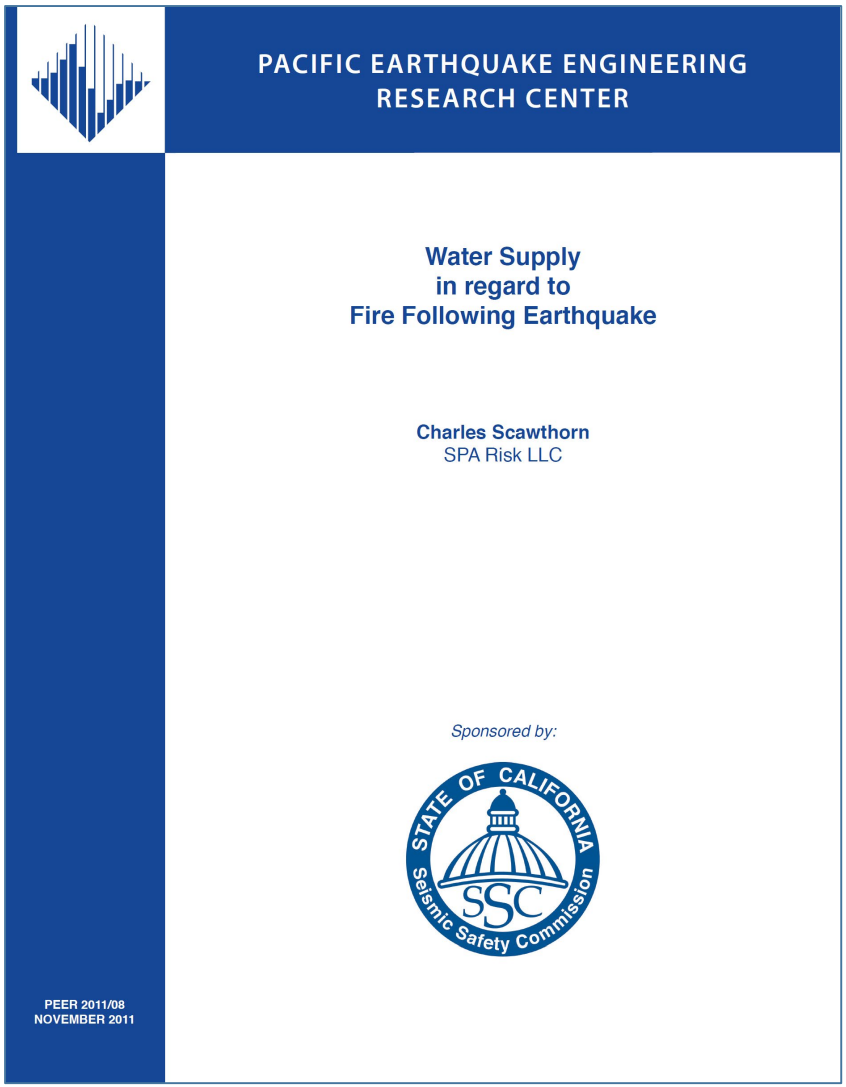
Fire Following Earthquakes: PEER Reports

https://peer.berkeley.edu/node/59/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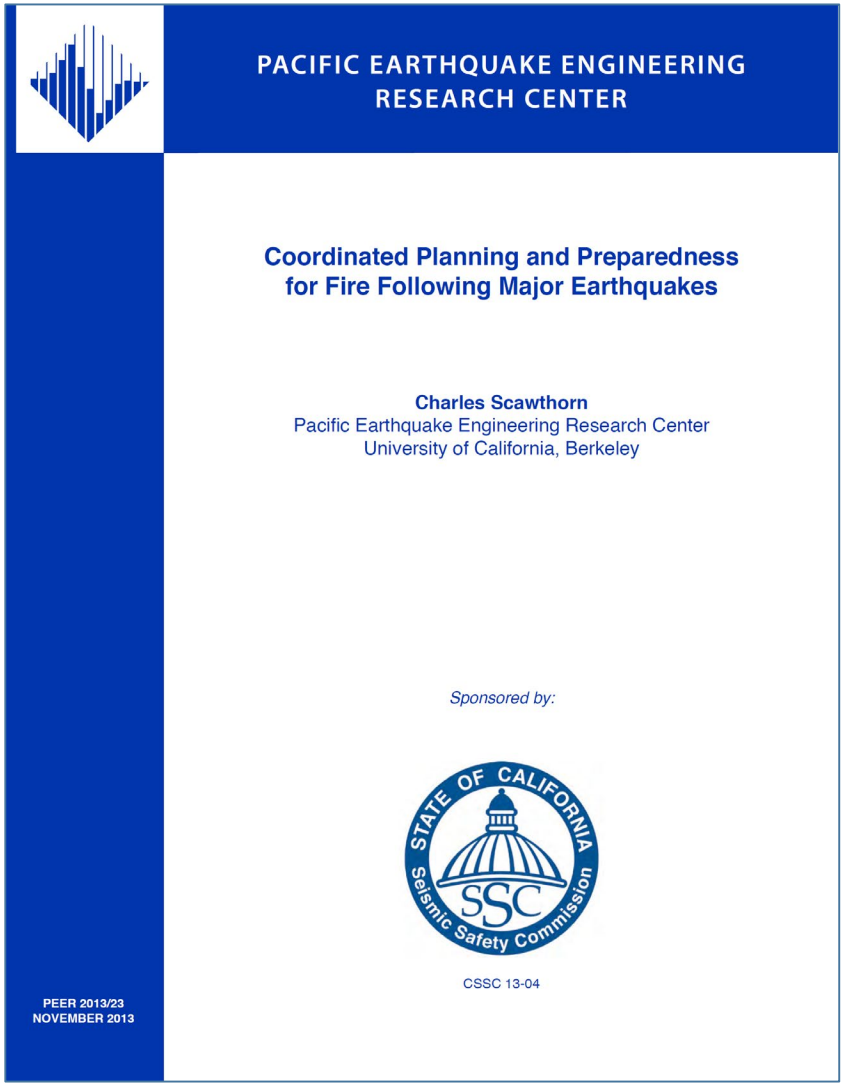
Water Supply
in regard to
Fire Following Earthquake

Charles Scawthorn
SPA Risk LLC

Sponsored by:

STATE OF CALIFORNIA Seismic Safety Commission SSC

PEER 2011/08
NOVEMBER 2011


PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Coordinated Planning and Preparedness
for Fire Following Major Earthquakes

Charles Scawthorn
Pacific Earthquake Engineering Research Center
University of California, Berkeley

Sponsored by:

STATE OF CALIFORNIA Seismic Safety Commission SSC

CSSC 13-04

PEER 2013/23
NOVEMBER 2013

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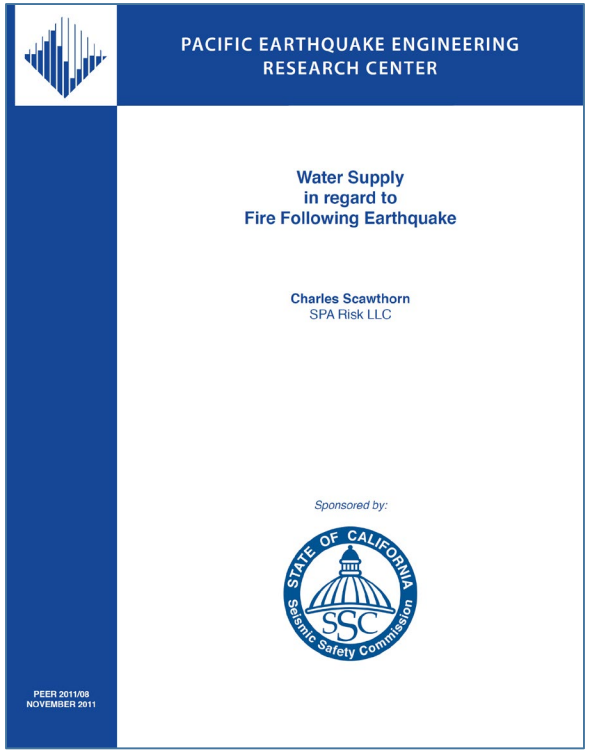
2011 PEER Study

https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf

A major earthquake in LA, SD or the SF Bay Area is expected to result in numerous fires. A survey of fire & water agencies (with responses from those serving ~1/3 of urbanized CA) found poor understanding of the post-earthquake fire issue, and poor communication between fire & water agencies. To mitigate the problem, it is recommended that meetings should be held within the CA fire service and the CA water distribution community, to highlight this problem and enlist both communities in an effort to develop state-wide requirements for post-earthquake firefighting water supply target goals, to be achieved by a given date. Possible ways to assure satisfactory post-earthquake water supply may include development of a standardized CA portable water supply system (PWSS) for use in major urban areas, consideration of a saltwater high pressure system for the LA Metropolitan Area (LA & Orange counties), to be used in conjunction with PWSS, and development and deployment of neighborhood equipment container caches, for use by Neighborhood & Community Emergency Response Team (NERT & CERT), and other volunteers, to enhance their currently very limited post-disaster firefighting capability.



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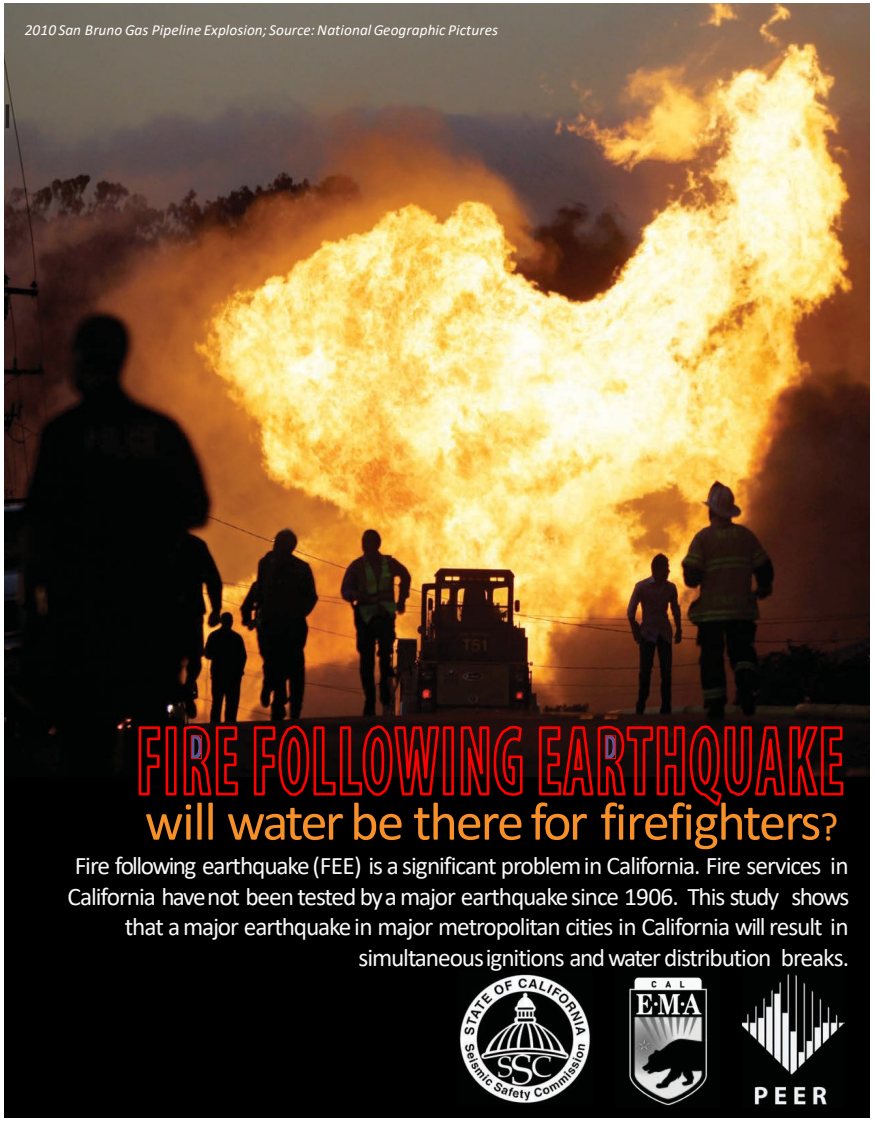
2011 PEER Graphics

https://peer.berkeley.edu/sites/default/files/fire_following_earthquake-online-view-layout-sm.pdf



PEER

2011 PEER Graphics

https://peer.berkeley.edu/sites/default/files/fire_following_earthquake-online-view-layout-sm.pdf

2008 ShakeOut Exercise M_w 7.8 San Andreas earthquake analysis found that

APPROXIMATELY 1,600 IGNITIONS OCCUR IN SOUTHERN CALIFORNIA, WITH THE CENTRAL LA BASIN EXPERIENCING HUNDREDS OF LARGE FIRES.

Los Angeles Basin; Source: johnfund.com

MOST FIRE AND WATER DEPARTMENTS IN CALIFORNIA

could be BETTER INFORMED about the specifics of their earthquake risk

generally believe most municipal water supplies are UNRELIABLE in a major earthquake

do NOT FULLY UNDERSTAND water department system vulnerabilities

Source: Survey of fire and water agencies conducted by PEER, 2011

Tokyo oil refinery following the 2011 Mw 9.0 earthquake; Source: daehanilbo.co.kr

CALIFORNIA IS HIGHLY EXPOSED

there are about **9.5 million** residential properties

1 MILLION commercial property insurance policies in CA

$4.7 trillion is the total value of insured property

guidance provided by the insurance industry for adequacy of public water supplies **DOES NOT** mention or consider **EARTHQUAKES**

Source: Statistics from the CA Department of Insurance, 2009

there is a crucial need for post-earthquake fire fighting water supply in California.

This problem should be **highlighted** in joint meetings between key figures in the California Fire Service and key water agencies. State-wide plans for post-earthquake fire fighting should be developed and implemented.

Recommendations from PEER Report 2011/08 sponsored by the CA SEISMIC SAFETY COMMISSION

THREE STEPS FOR SUGGESTED FURTHER STUDY:

1. Develop a standardized California Portable Water Supply System (PWSS) to be deployed in major urban areas. This PWSS would suffice for the San Francisco Bay Area.

2. Develop a saltwater high pressure system for LA and Orange Counties to be used with the PWSS. This is quite feasible if existing large storm drain channels could be used for pipeline rights-of-way.

3. Develop and deploy neighborhood equipment container caches to enhance post-disaster fire-fighting capabilities. These would be used by NERT, CERT, and other volunteers.

Portable Water Supply System (PWSS); Vallejo FD; Source: Scawthorn

Berkeley FD BAWSS 12 inch Ultra LDH; Source: Berkeley FD

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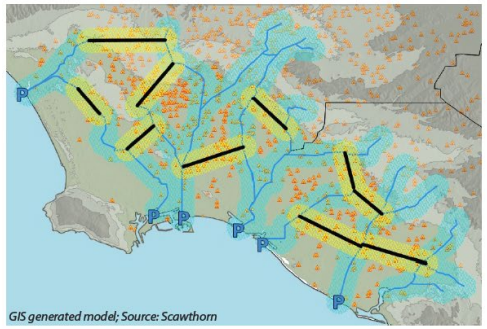
2011 PEER Graphics

https://peer.berkeley.edu/sites/default/files/fire_following_earthquake-online-view-layout-sm.pdf

SALTWATER HIGH PRESSURE SYSTEMS

as alternative sources of water

San Francisco has already developed and maintains a high pressure seawater-supplied Auxiliary Water Supply System (AWSS). SF recently, in June 2010, approved a $412 million bond issue to enhance their system.

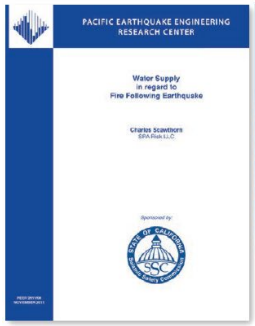


GIS generated model; Source: Scawthorn

Central Los Angeles and Orange County could benefit from building a saltwater high pressure system since they are at great risk due to fire following earthquake.

This map shows Los Angeles and Orange County high pressure salt water system pipe network in storm drain channels (blue lines) with proposed connectors (black lines) overlaid on ShakeOut scenario ignitions. The pipe network is supplied from pump stations (P). Blue and yellow buffer zones around pipelines would be areas reachable by a PWSS.

One of the larger drain channels in LA; Source: hcn.org



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Pacific Earthquake Engineering Research Center

for more information, download PEER Report 2011/08

Water Supply in regard to Fire Following Earthquake
by Charles Scawthorn

at:

www.seismic.ca.gov

OR

http://peer.berkeley.edu/publications/peer_reports_complete.html

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Berkeley, CA 94720 -1792

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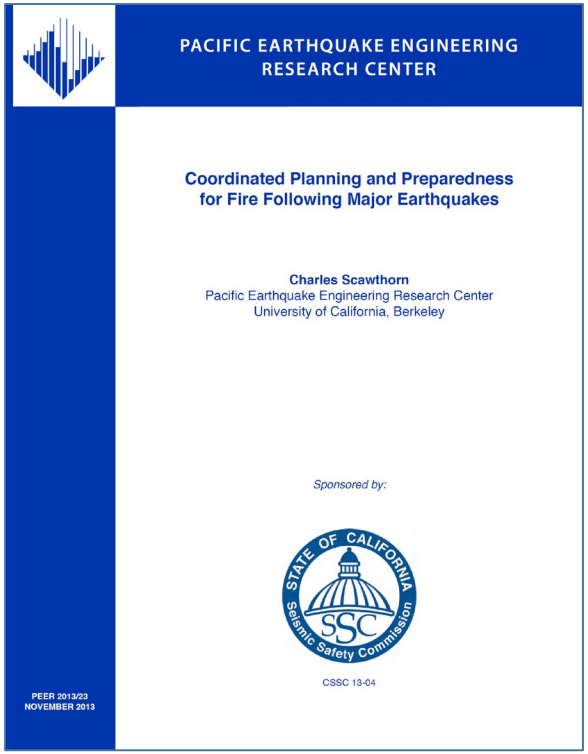
2013 PEER Study

https://peer.berkeley.edu/sites/default/files/webpeer-2013-23-charles_scawthorn.pdf

Activities of a project entitled "Coordinated Planning & Preparedness for Fire Following Major Earthquakes" built on a previous project entitled "Water Supply in regard to Fire Following Earthquake". Voluntary Performance Guidelines for post-earthquake reliability of water supply for firefighting were developed to focus the attention of high-risk urban regions on this problem while placing little demand on fire or other agencies. The Guidelines recommend that incorporated jurisdictions of population exceeding 100,000 and having significant seismic hazard to develop quantitative estimates of the number and locations of fires that are likely to occur given the same pattern of earthquake shaking hazard used in CA Building Code. The Guidelines also recommend that jurisdictions should also develop and maintain a written plan for reducing, responding to and fighting such fires, with particular attention to supply of water from normal & alternative sources of firefighting water taking into account earthquake damage to such supplies. Several interactions with the fire service were undertaken to highlight and disseminate the Guidelines – working with FIRESCOPE has proven most effective, and FIRESCOPE has taken this issue on as a task, with this project

FIRESCOPE: FIrefighting **RES**ources of **C**alifornia **O**rganized for **P**otential **E**mergencies) Program



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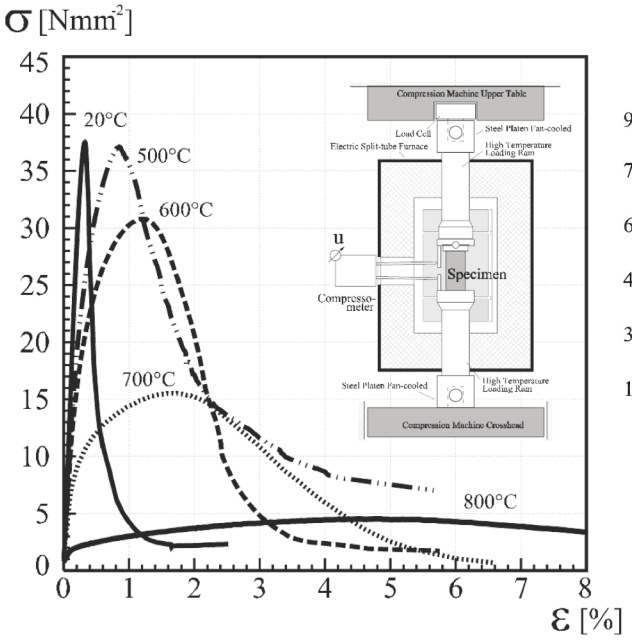
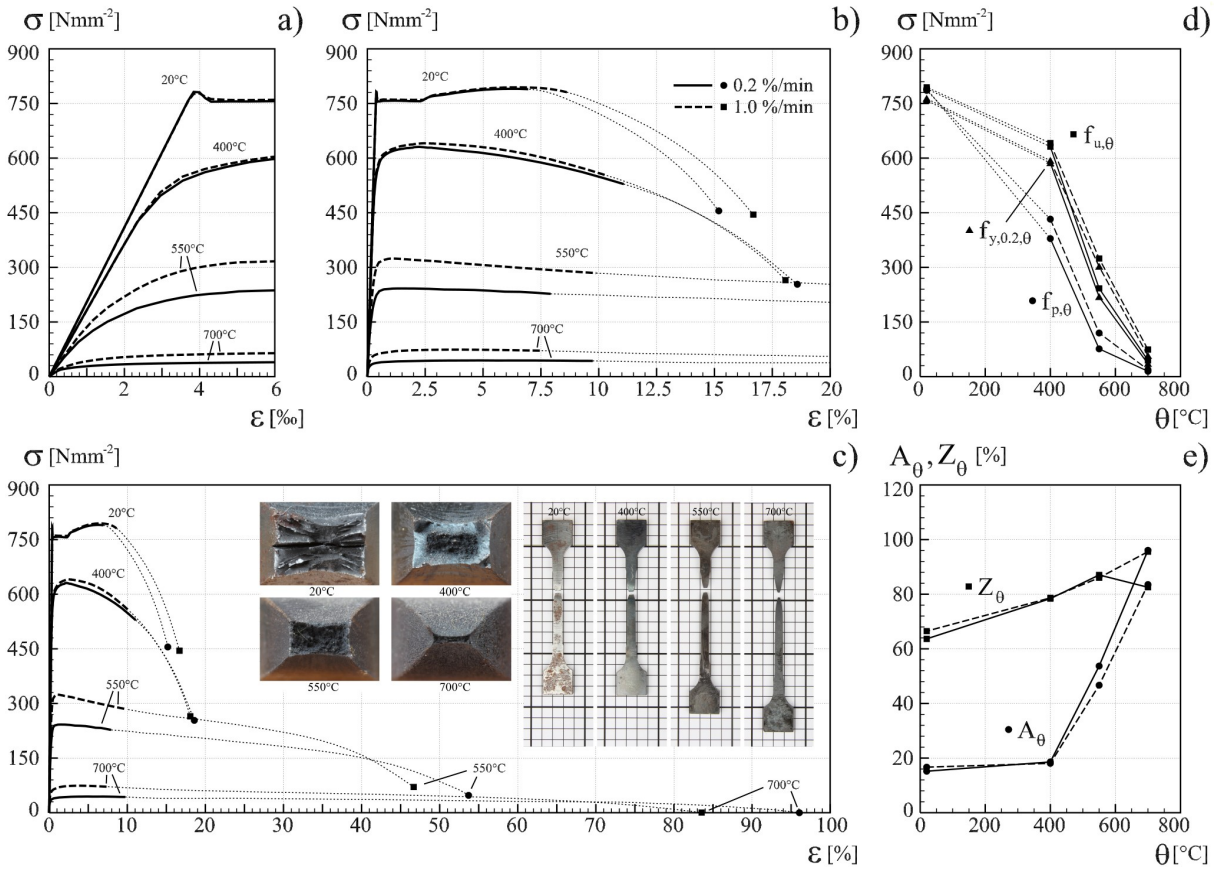
Temperature–Dependent Construction Material Properties

- **Thermal Expansion**
- **Stiffness and Strength Degradation**
- **Time-Dependent (Creep/Strain Rate Sensitivity)**



Concrete



High-Strength Steel

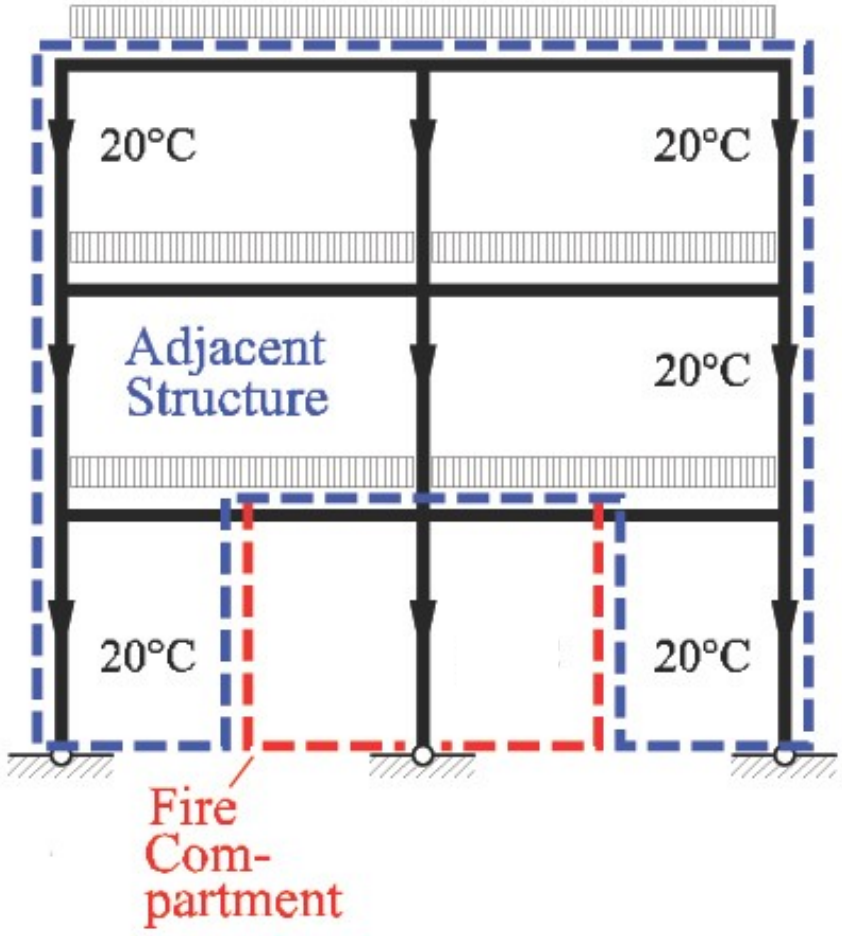
Objectives of Fire Designs for Entire Structural Systems

- **Prevent Fire From Spreading**

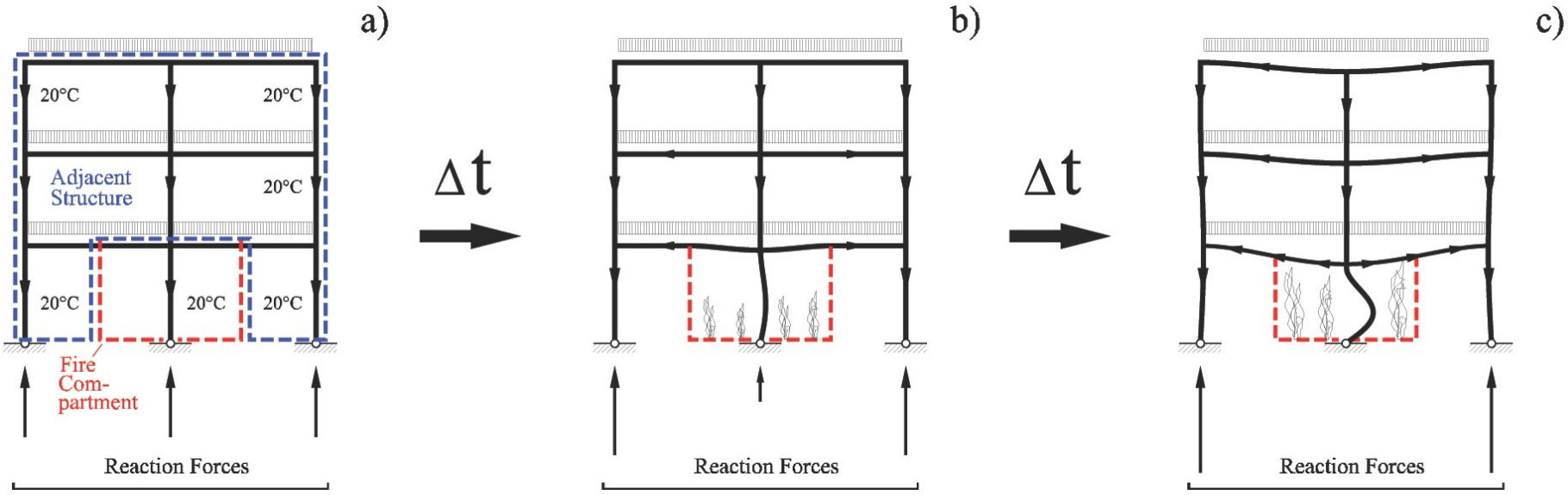
  ➡ **Fire Compartment Design Principle**

- **Prevent Structural Collapse**

  ➡ **Fire Protection Design Principle**



Performance of Entire Structural System in Fire: Beneficial Interaction Mechanisms



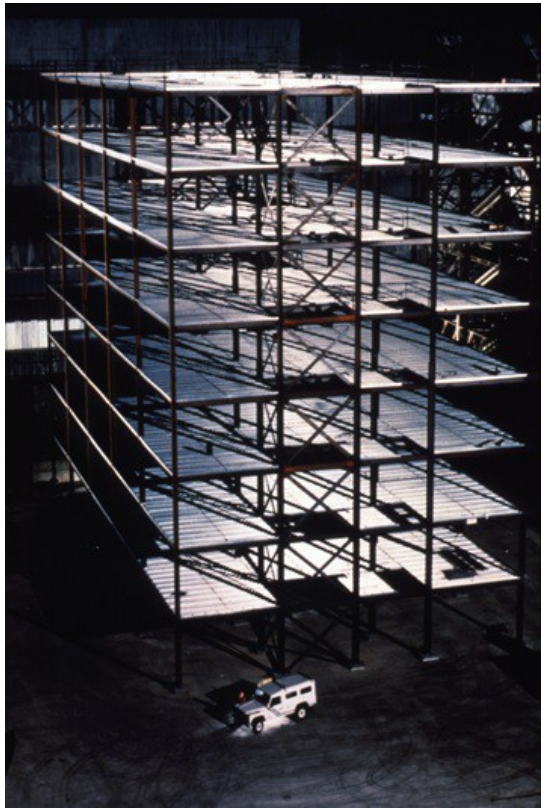
Configuration Before Fire Exposure

Development of Alternate Load Paths

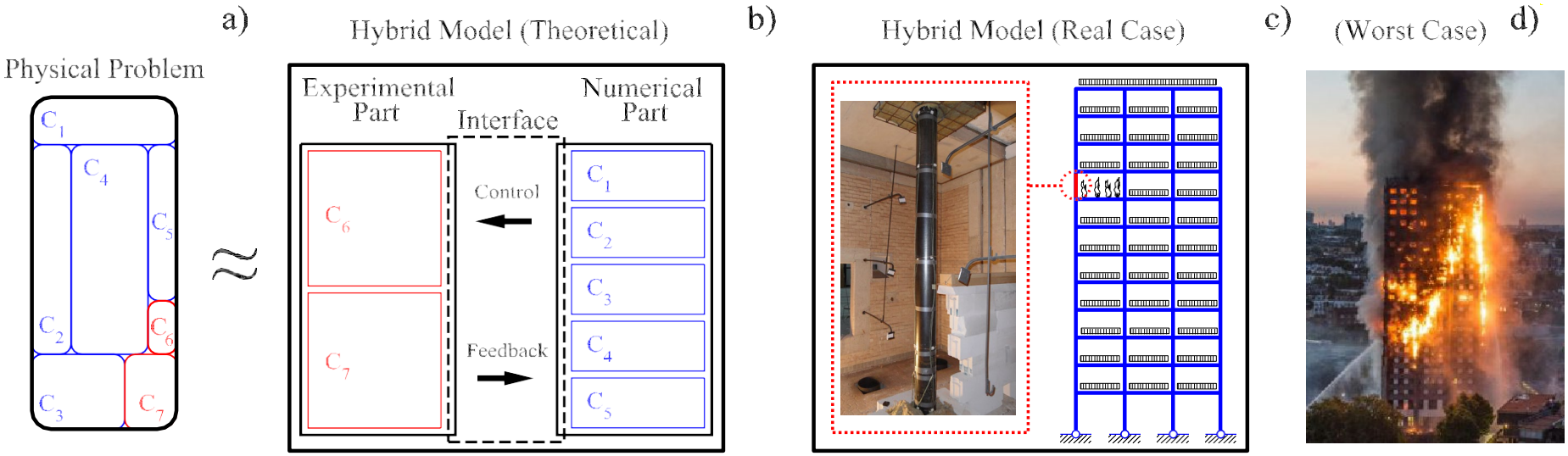
Change of Structural System

Performance of Entire Structural System in Fire: Empirical Evidence

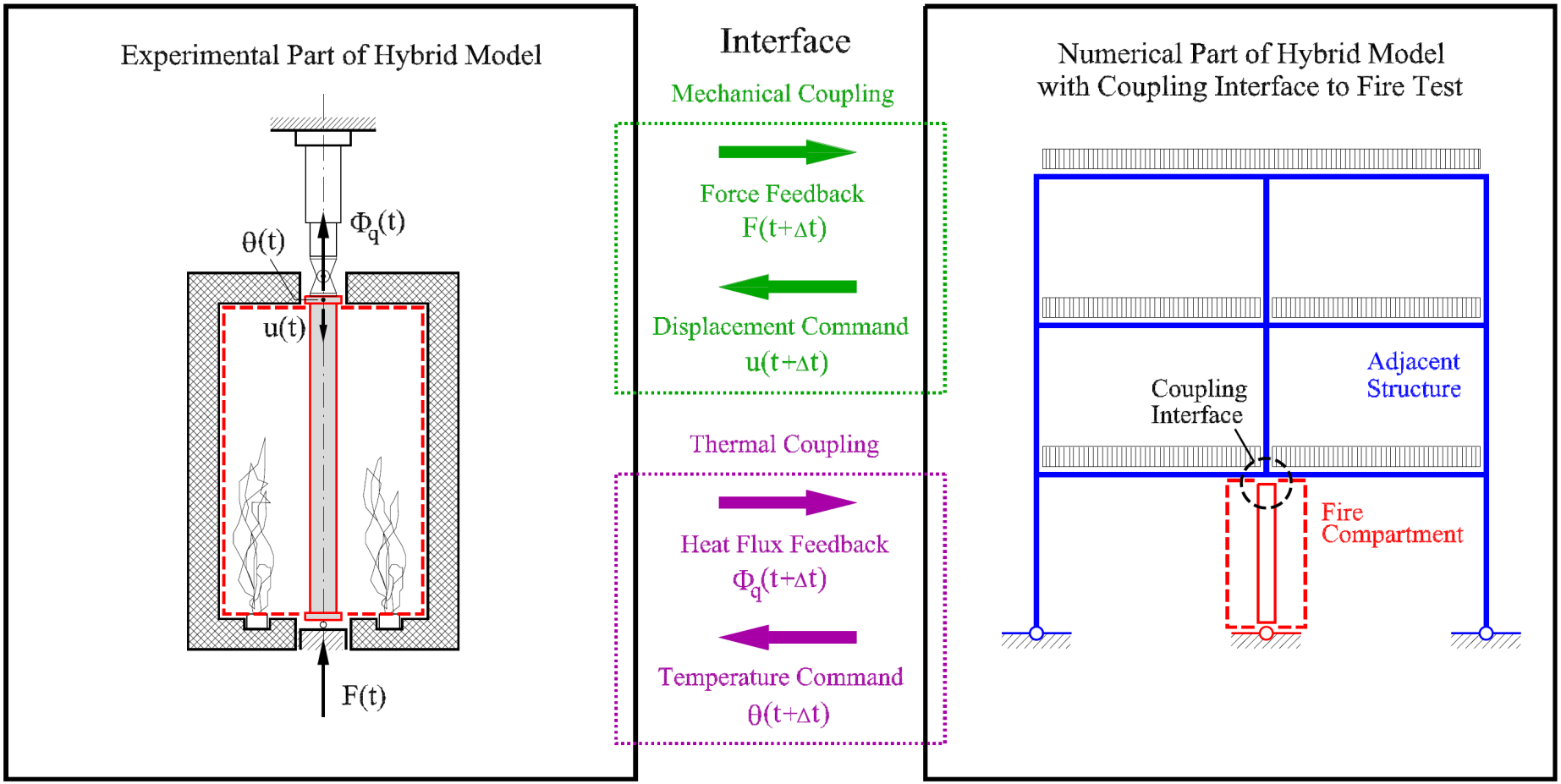
- **Real Fire Incidences (Broadgate Fire 1990)**
- **Full–Scale Fire Tests (D 1987, UK 1999)**
- **Fire Tests Structural Sub-Assemblies (AUS 1992)**
- **Isolated Structural Member Tests**



Hybrid Modeling—Best Way to Assess the Performance of Large Scale Engineering Structures in Fire



Performance of Entire Structural System in Fire: Unlock Potential with Hybrid Testing



Other PEER Projects

How the Water/Binder Ratio and Voids Affect the Performance of Hardened Concrete Subjected to Fire	**PI**: Kamran Nemati	**Institute**: University of Washington

https://peer.berkeley.edu/research/transportation-systems/request-proposals

PEER Request for Proposal:
Solicitation TSRP-PEER 18-01

Introduction

The Pacific Earthquake Engineering Research (PEER) is a multi-campus center that has continuing funding from the State of California related to the seismic performance of transportation systems. This funding supports the Transportation Systems Research Program (TSRP), the purpose of which is to lessen the impacts of earthquakes on the transportation systems of California, including highways and bridges, port facilities, high-speed rail, and airports.

Funding from the TSRP supports transportation-related research that uses and extends PEER's performance-based earthquake engineering (PBEE) methodologies, and integrates fundamental knowledge, enabling technologies and systems. The program also aims to integrate seismological, geotechnical, structural, hydrodynamic and socio-economical aspects of earthquake engineering, and involve theoretical, computational, experimental and field investigations. The program encourages vigorous interactions between practitioners and researchers.

The PEER TSRP is coordinated by a Research Committee (PEER-RC) consisting of Pedro Arduino (University of Washington), Jack Baker (Stanford University), Judy Liu (Oregon State University), Khalid Mosalam (ex-officio, University of California, Berkeley), Gilberto Mosqueda (University of California, San Diego), and Tom Shantz (ex-officio, Caltrans). Proposals will be reviewed by external reviewers, who will be determined by this committee, among experts who have not submitted proposals.

Post-earthquake Fire Performance of Industrial Facilities

Project # 1139-NCTREF

Principal Investigator
Erica C. Fischer, Assistant Professor, Oregon State University

Research Team

Start-End Dates:
8/1/2018-8/1/2019

Abstract
This project is a seed project that will produce results necessary for a much larger scope project on performance-based earthquake and fire engineering. The scope of the project includes evaluation and investigation of the post-earthquake fire performance of industrial facilities. The investigation will use OpenSees. Previous researchers have demonstrated good results using OpenSees for multi-hazard evaluation of buildings. Post-earthquake fires tend to cause more damage than the earthquake itself. In the case of the 1906 San Francisco and the 1923 Tokyo earthquake, 80% of the damage was caused by post-earthquake fires. A variety of ground accelerations will be used and combined design fire scenarios developed using performance-based fire engineering approaches. The varying ground accelerations will cause varying degrees of damage to the building during the earthquake phase of the simulations. Varying ground accelerations will allow the researchers to quantify how much additional damage is caused by the fire versus the earthquake ground motion. This work will integrate seismological, multi-hazard, and socio-economical aspects of earthquake and fire engineering to improve emergency management and the resilience of communities. Cities on the west coast of the United States are quantifying the economic impacts of post-earthquake fires on their communities. The proposed research project would work with practitioners to communicate the results and develop retrofit strategies that improve the performance of buildings in post-earthquake fires and are able to be implemented by contractors.

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Thank You!
Questions?

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