Fragility Analysis of Steel Buildings in Fire

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MOTIVATION

Fires in buildings have long been a public safety concern for occupants and first-responders. The World Trade Center building collapses on September 11, 2001 motivated a focus on understanding structural behavior in fires.

This work will help to better understand building behavior to fire, thereby minimizing damage and prolonging the time of collapse in order to permit occupants and first-responders to safely exit the building.

This project aims to provide recommendations and guidance on performance-based fire analysis that can be implemented in the design industry.

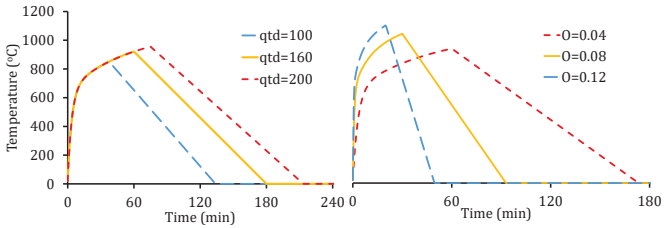
BACKGROUND

Structural engineers in the United States do not currently design structures to withstand fire loads. The amount of fireproofing on a structure and the fire rating of the structure is based on furnace testing of select components and assemblies by testing agencies such as Underwriter's Laboratory.

A performance-based approach for analyzing structures subjected to fires has been developed, which considers not only the time of failure but also the extent of damage. Instead of relying on empirical data from testing that may not translate well into building behavior, system behavior can be evaluated using finite element method (FEM) modeling. This approach, however, tends to considers one design-basis fire and does not adequately consider the possible variability in fire loading.

Incremental Dynamic Analysis (IDA) is a procedure used to create parametric analyses of building behavior to seismic loads through modeling. Earthquakes are scaled by an intensity measure (i.e. - peak ground acceleration or spectral acceleration) and the damage parameter (i.e. – story drift ratio) is recorded at each intensity level. This research will apply the IDA approach to fire through Incremental Fire Analysis (IFA) and providing recommendations for effective intensity measures and damage parameters for overall building behavior.

Eurocode Parametric Time-Temperature Curves

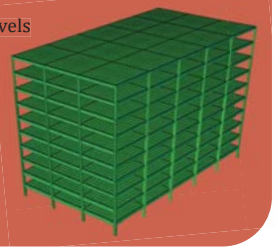


TASK DESCRIPTION

Selection & Design of Prototype Buildings and Fires

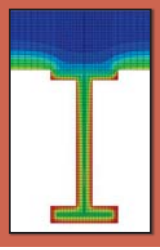
Select prototype buildings of varying hazard levels and number of stories
- 3, 9, and 20-story buildings
- Located in Boston (low seismic), Seattle, and Los Angeles (high seismic)
- Perimeter moment resisting frames

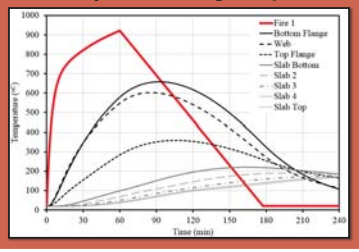
Design buildings using current building codes
Select Eurocode time-temperature fire curve



Determine Primary Failure Modes for Each Building

Use heat transfer analyses to determine internal temperatures of structural members subjected to selected time-temperature fire curve
Model building behavior at elevated temperatures using ABAQUS

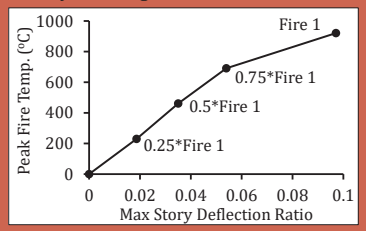




Conduct Parametric Study

The overall building response will be analyzed using Incremental Fire Analysis (IFA).
- Intensity Measure: peak fire temperature, fuel load density, fire duration, etc.
- Damage Measure: deformation, bending moment, etc.

Most useful intensity measure will be chosen.

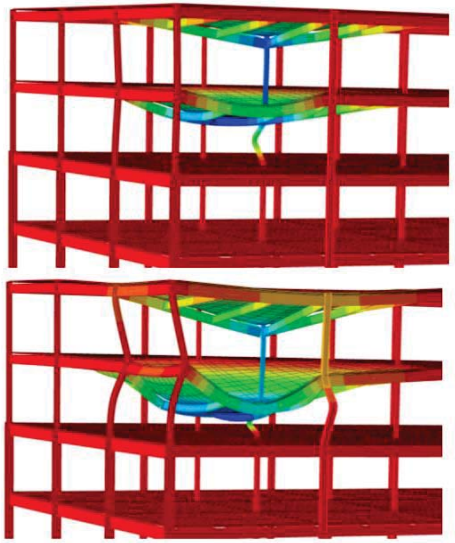


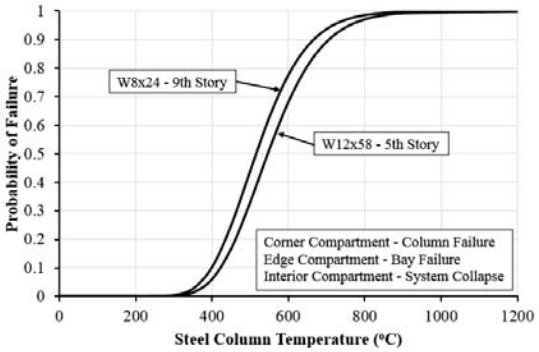
Generation of Fragility Functions

Calculate probability of failure of the structures at different fire intensity levels.
Compare for each building to identify trends amongst buildings.

EXPECTED RESULTS

Primary focus will be on the fire response of gravity columns, as this is the anticipated initiating failure mode. The internal temperatures of the columns will be evaluated to generate fragility curves that capture probability of failure (i.e. – column buckling load) at different fire intensities.





Acknowledgements

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References

Vamvatsikos, D. and Cornell, C.A. (2002). *Incremental dynamic analysis.* Earthquake Engineering & Structural Dynamics, 31 (3): p. 491-514.

EN1991-1-2. (2002). *Eurocode 1: Actions of structures, Part 1-2: General actions – Actions on structures exposed to fire.* European Committee for Standardization: Brussels, Belgium.

Gupta, A. and Krawinkler, H. (1999). *Seismic Demands for Performance Evaluation of Steel Moment Resisting Frame Structures.* Report No. 132, The SAC Joint Venture.

UL Online Certifications Directory (2016): Fire-Resistance Ratings – ANSI/UL263. Available from: http://database.ul.com/

University of Cincinnati
19th Annual
Pilot Research Project
Symposium
October 11-12, 2018

Pilot Research Training Program (PRP) Overview

Welcome to the University of Cincinnati Education and Research Center's (ERC) 19th Annual Pilot Research Project (PRP) Symposium on October 11-12, 2018, held in the Kowalewski Hall Auditorium. The purpose of the PRP is to increase the research capacity of research trainees and young investigators in occupational health and safety and to encourage those in related disciplines to pursue occupational health and safety research.

Under the administrative direction of Dr. Amit Bhattacharya and Dr. Gordon Gillespie, research proposals are solicited and peer-reviewed annually by qualifying faculty and graduate students from the University of Cincinnati and the following PRP partnering institutions – Air Force Institute of Technology, Bowling Green State University, University of Toledo – Health Science Campus, Central State University, Purdue University, University of Kentucky, Western Kentucky University, Eastern Kentucky University, Murray State University, Ohio University and Kentucky State University.

At this symposium, the 2017-18 awardees will be presenting the results of their research and the 2018-19 awardees will make poster presentations of their proposed work. The keynote speaker on Thursday, October 11, 2018 is Captain Lauralynn McKernan from the CDC/NIOSH Division of Surveillance, Hazard Evaluation and Field Studies, presenting on "Listen to the Music: How Rock 'n' Roll Provides Touchstones for the Evolution of Occupational Health."

The University of Cincinnati's Education and Research Center is one of 18 national centers funded by the National Institute for Occupational Safety and Health (NIOSH). Dr. Tiina Reponen serves as the director of the ERC, which is based in the University's Department of Environmental Health within the College of Medicine. The purpose of the ERC is to train professionals in the didactic and research skills necessary to lead in occupational safety and health disciplines. Results of research are translated into action through an outreach program and shared with professionals and practitioners in the region via continuing education.

Since 1999, the PRP program has allocated over $1.4 million to support 239 pilot research projects. These projects have served as a catalyst in bringing over $41 million in additional research support to the region from sources independent of the PRP program, such as, the National Institute for Occupational Safety and Health (NIOSH), National Institutes of Health (NIH), United States Department of Agriculture (USDA), National Science Foundation (NSF), and the Centers for Disease Control and Prevention (CDC). Additionally, the PRP has brought 55 new investigators from other fields of expertise to the area of occupational safety and health research.

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