



# What does RESILIENCE look like?

Ayşe Hortaçsu  
Applied Technology Council

SCEC Annual Mtg  
September 9, 2024

# Outline

- Resilience (recovery)-based design - the latest and greatest in seismic design of buildings today
- Resilience – one size fits all?
  - Building and infrastructure performance in the February 2023 Turkey earthquake sequence and other events
- The many steps towards resilience – retrofit example

# Resilience-based design

*“The ability to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions” (NIST Community Resilience Planning Guide, 2016)*



1971 San Fernando earthquake



- ATC was established as a non-profit in 1973 to speed up transfer of research to practice
- ATC's mission is to imagine, develop, and promote the advancement of technologies to enhance societal resistance to natural and other hazards

# Timeline of U.S. Seismic Code Development

(from FEMA P-2156, 2021 - slide from R. Kersting)

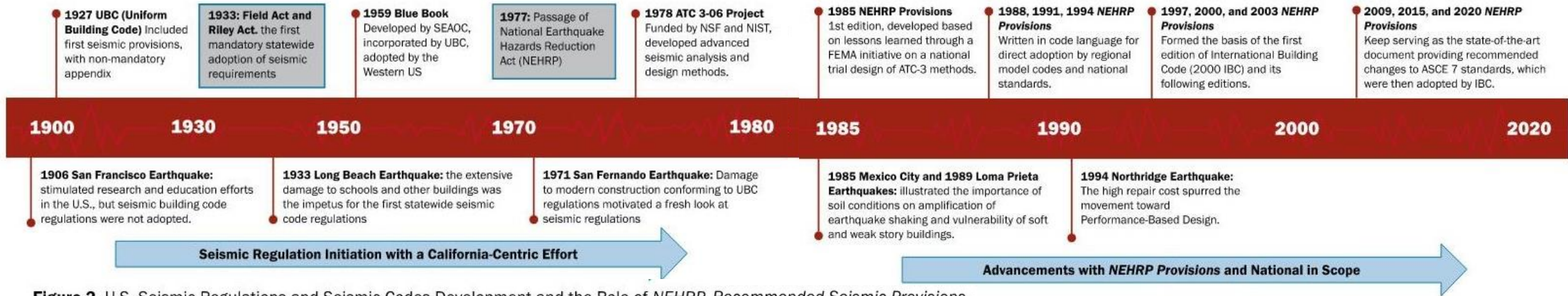
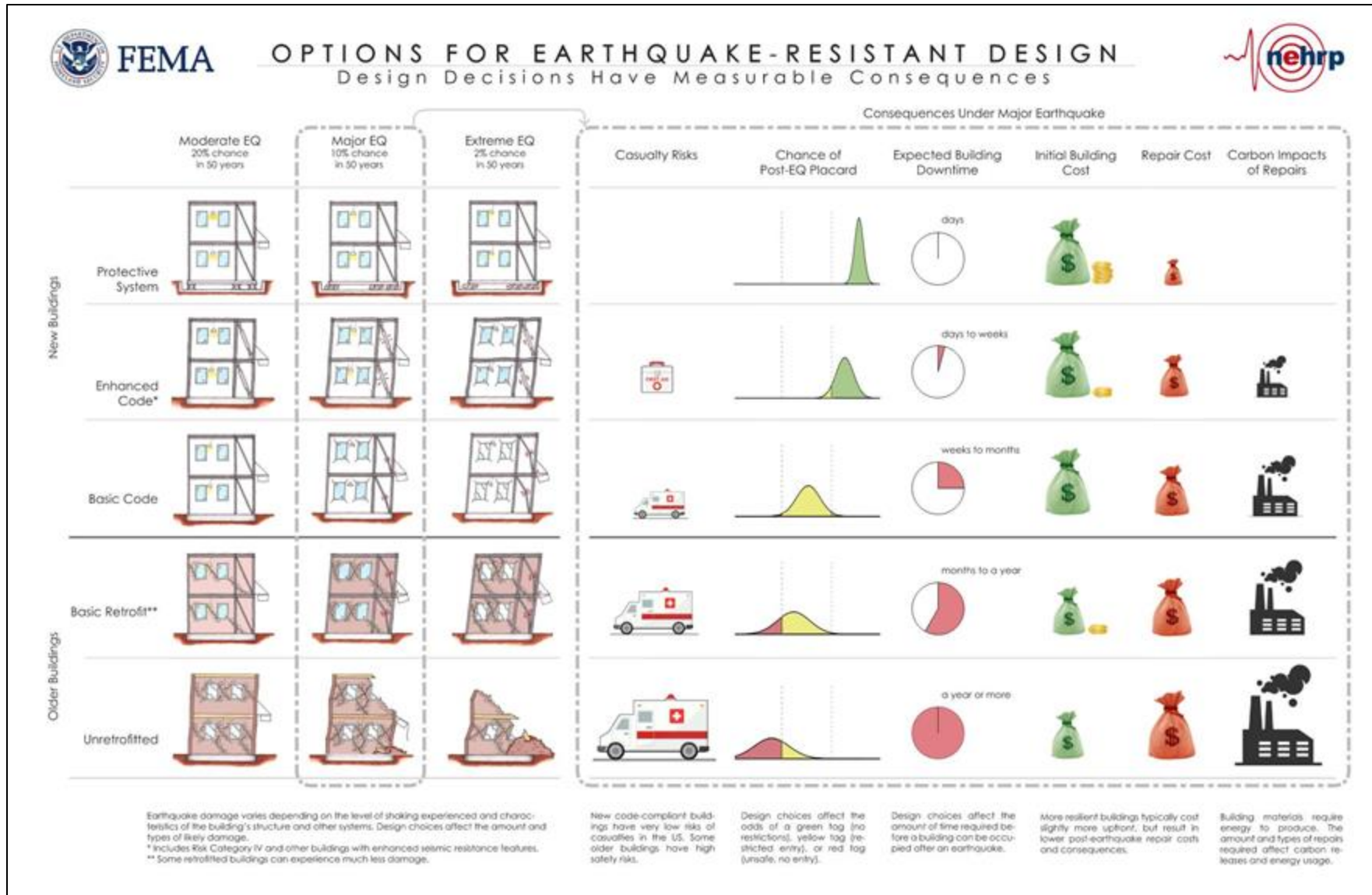


Figure 2. U.S. Seismic Regulations and Seismic Codes Development and the Role of NEHRP Recommended Seismic Provisions.

- URM, Non-ductile Concrete, Precast Concrete, Steel Moment Frames
- Soft story, Diaphragms, Out of plane wall anchorage, Nonstructural components
- Near-Fault effects, Next-Generation Attenuation, Soil-Structure Interaction
- Nonlinear Analysis, Seismic Isolation, Damping Systems

# Performance-based Seismic Design



## Building the Performance You Need

A Guide to State-of-the-Art Tools for Seismic Design and Assessment

FEMA P-58-7 / December 2018

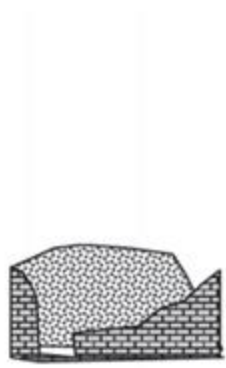


## FEMA P-58-7

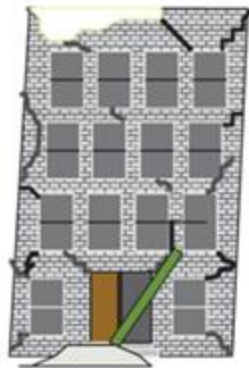


# Recovery-based Seismic Design

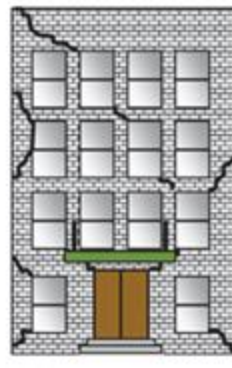
## *Functional Recovery*



Collapse



Safety



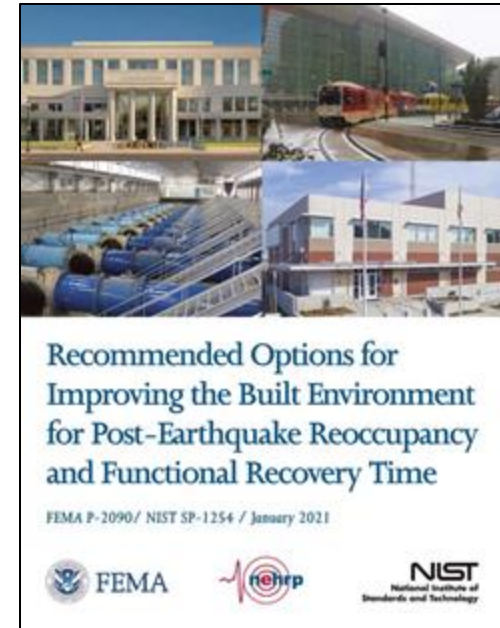
Reoccupancy



Functional Recovery



Full Functionality



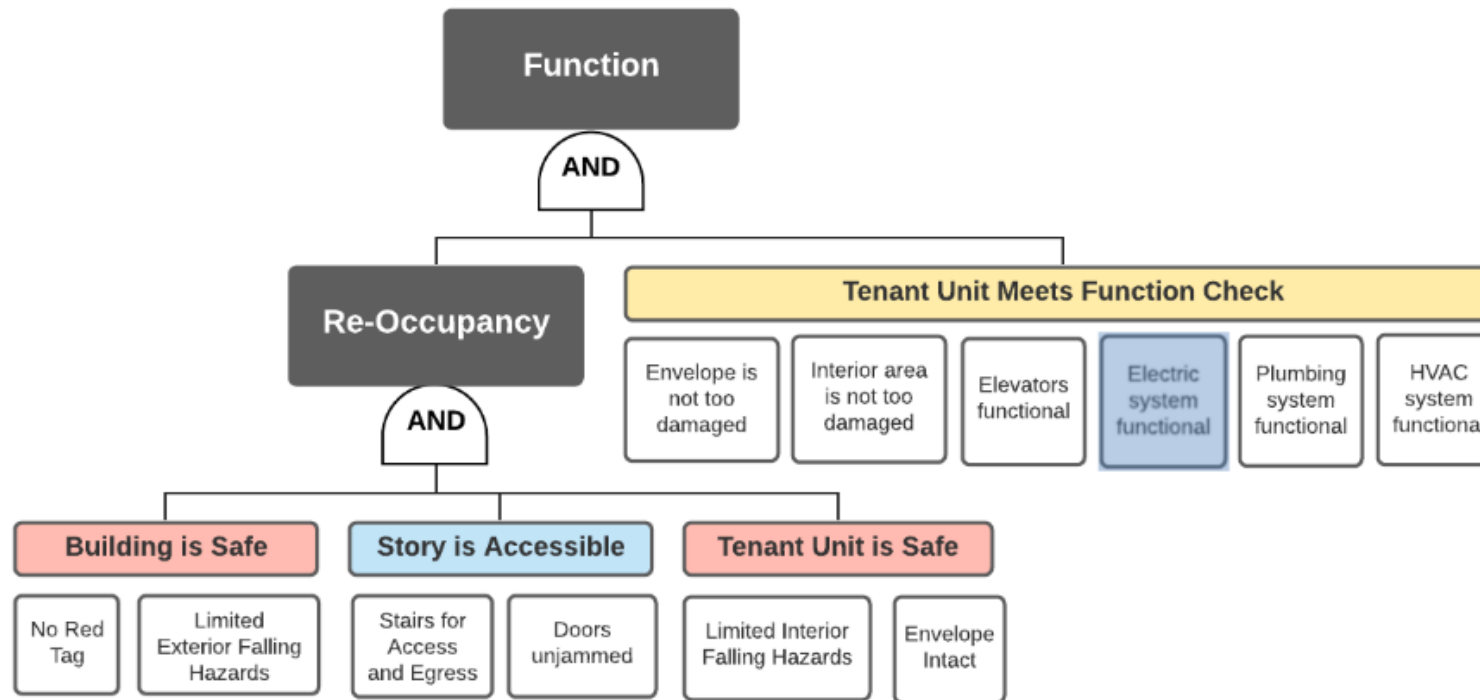
*FEMA P-2090*

*NIST SP-1254*

# Functional Recovery Methodology for Buildings

*FEMA-NEHRP funded ATC-138 project*

- Extending FEMA P-58 to assess function:



(courtesy of A. Liel, D. Cook)



# Potential Next Steps for Seismic Design of Buildings

*2026 NEHRP Recommended Seismic Provisions*

**2026 NEHRP**

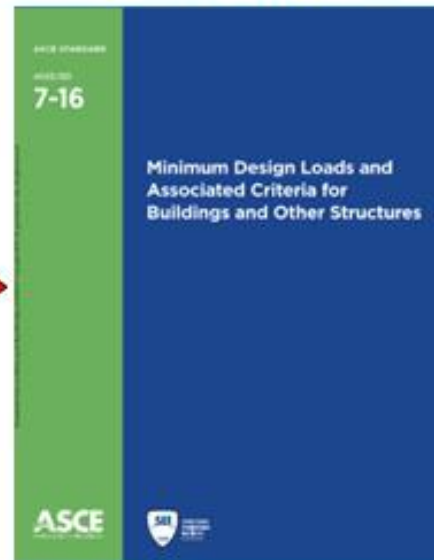


NEHRP Recommended  
Seismic Provisions for  
New Buildings and Other  
Structures

Volume I: Part 1 Provisions, Part 2 Commentary  
FEMA P-1050-1/2015 Edition



**2028 ASCE7**



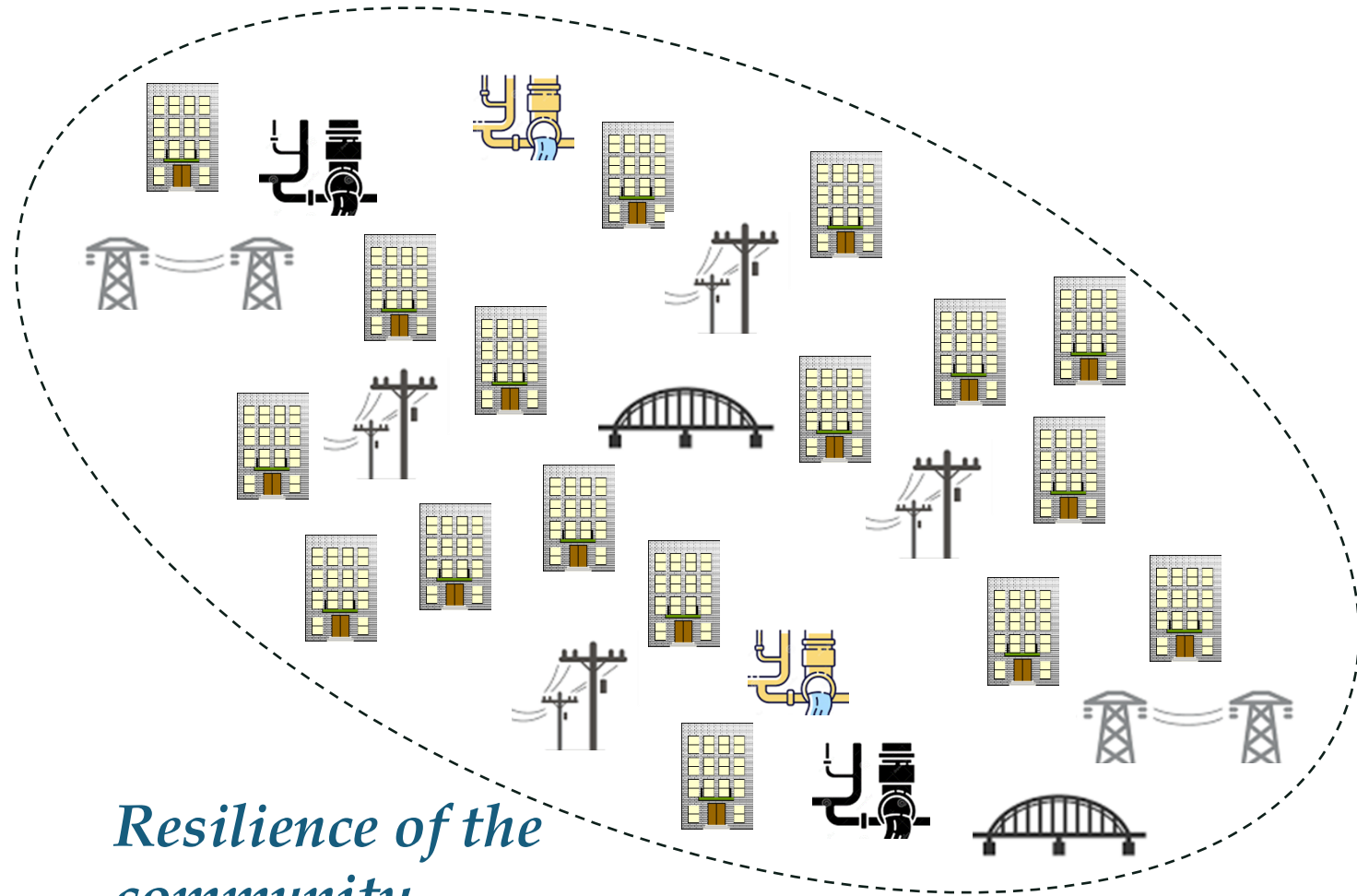
**2030 IBC**



# “ability to withstand and recover rapidly from disruptions”



*Recovery-based design  
of one building*

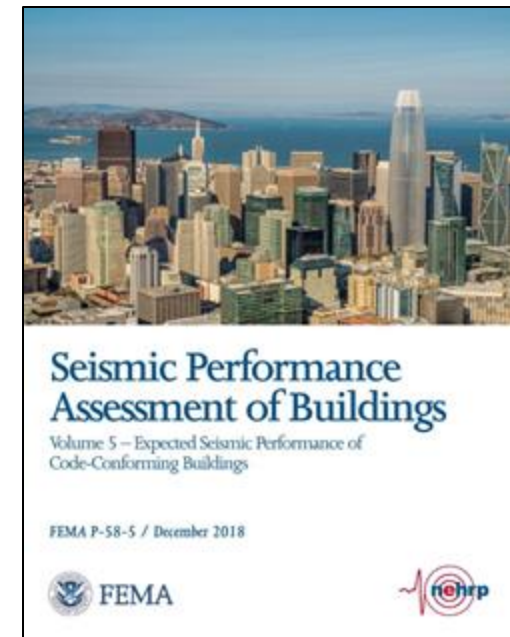


*Resilience of the  
community*

# How about existing buildings?

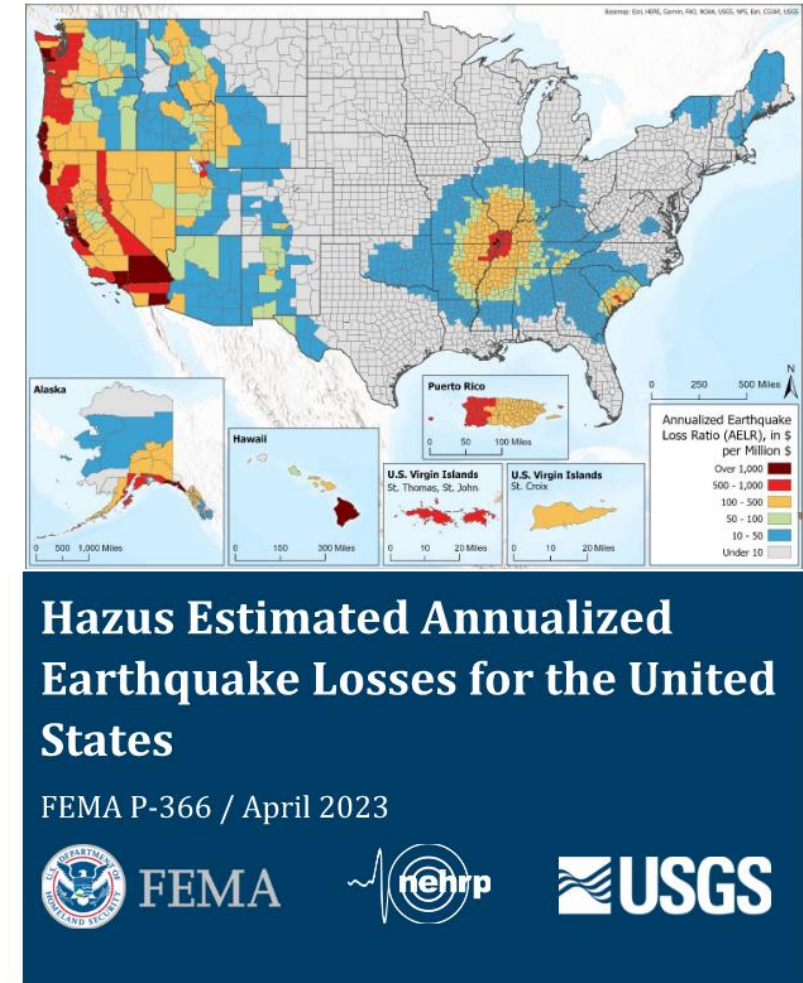
## *FEMA P-58-5: Expected Seismic Performance of Code-Conforming Buildings*

- Current codes and standards do not explicitly protect against economic losses nor target performance in terms of return of function
  - **20-40%** of modern code-conforming buildings projected to be unfit for occupancy following major earthquake for months to years (not days to weeks)
  - **15-20%** economically unreparable
- Older buildings perform even worse



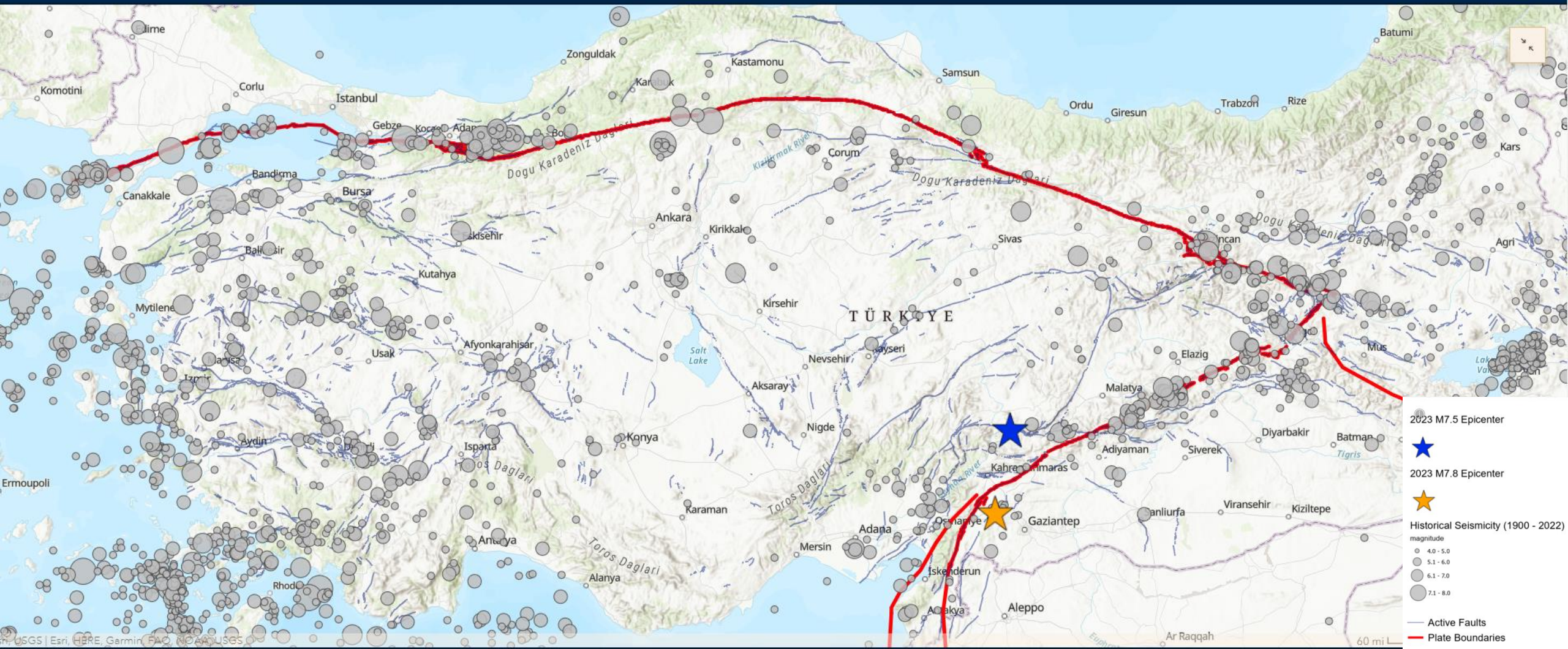
# Annualized Earthquake Losses for U.S.

- Estimated AEL for US = \$14.7B
- Estimated AEL for California = \$9.6B
- Total estimated economic exposure = \$107.8T (more than 29% from California)



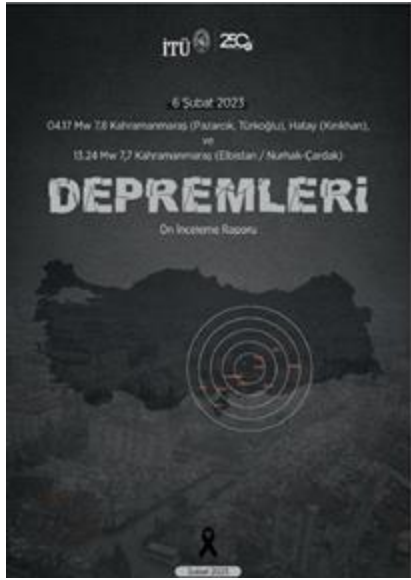
*What does the Public expect?*

**Resilience - one size fits all?**

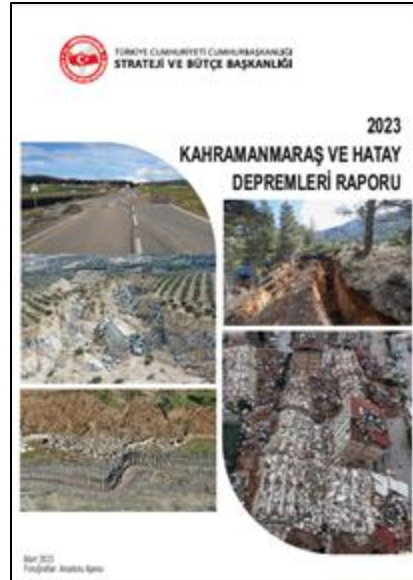


2023 M7.5 Epicenter  
★  
2023 M7.8 Epicenter  
★  
Historical Seismicity (1900 - 2022)  
magnitude  
● 4.0 - 5.0  
● 5.1 - 6.0  
● 6.1 - 7.0  
● 7.1 - 8.0  
— Active Faults  
— Plate Boundaries

Historical seismicity <M5.5 since 1900



Istanbul Technical University



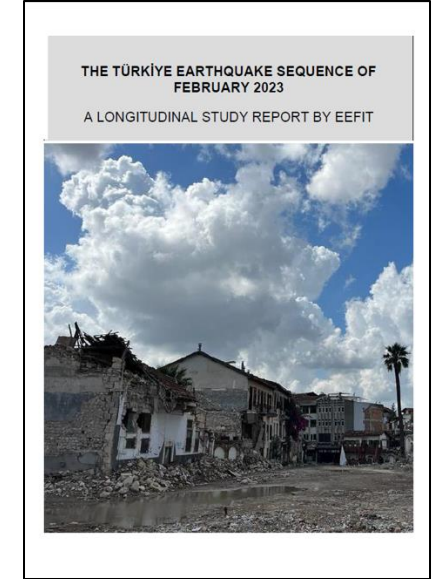
Türkiye Ministry of Strategy



NSF-funded StEER and EERI



NSF-funded GEER and EERI



EEFIT

Special Collection: Seismic hazard and risk in Türkiye and Syria

Turkey

1. [Earthquake Risk and Hazard Mitigation in Turkey](#)
2. [Empirical Attenuation Equations for Vertical Ground Motion in Turkey](#)
3. [Turkey-Adjusted NGA-W1 Horizontal Ground Motion Prediction Models](#)
4. [Site-Dependent Spectra Derived from Ground Motion Records in Turkey](#)
5. [Predictive kappa \(k\) models for Turkey: Regional effects and uncertainty analysis](#)
6. [Provisions for the Seismic Risk Evaluation of Existing Reinforced Concrete Buildings in Turkey under the](#)
7. [The 23 October 2011 MW7.0 Van \(Eastern Turkey\) Earthquake: Interpretations of Recorded Strong Ground Structures](#)
8. [Spatial Distribution of Damage Caused by the 1999 Earthquakes in Turkey](#)
9. [Strong Motion Station Characterization and Site Effects during the 1999 Earthquakes in Turkey](#)
10. [Damage at Sürgü Dam during May 5, 1986, Malatya, Turkey, Earthquake](#)
11. [Monte-Carlo Simulation of the Theoretical Site Response Variability at Turkey Flat, California, Given the L](#)



Papers Related to February 2023 Mw 7.8 Earthquake Sequence in Turkey

As a service to global researchers working on the 5 February 2023 magnitude 7.8 earthquake sequence in Turkey, the Seismological Society of America has created a short list of our journal papers related to the region and faults involved in the seismic events. These papers will be freely available for one week, from 6 February to 14 February 2023.

- Source Process of the 24 January 2020 Mw 6.7 East Anatolian Fault Zone, Turkey, Earthquake
  - DOI: 10.1785/0220200124
- Coseismic Slip Distribution of the 24 January 2020 Mw 6.7 Doganyol Earthquake and in Relation to the Foreshock and Aftershock Activities
  - DOI: 10.1785/0220200152
- Probabilistic Seismic-Hazard Assessment for East Anatolian Fault Zone Using Planar Fault Source Models
  - DOI: 10.1785/0120170009









Kahramanmaraş from Google Street View (by A. İrfanoğlu)



Kahramanmaraş (by A. İrfanoğlu)

# **Building performance**

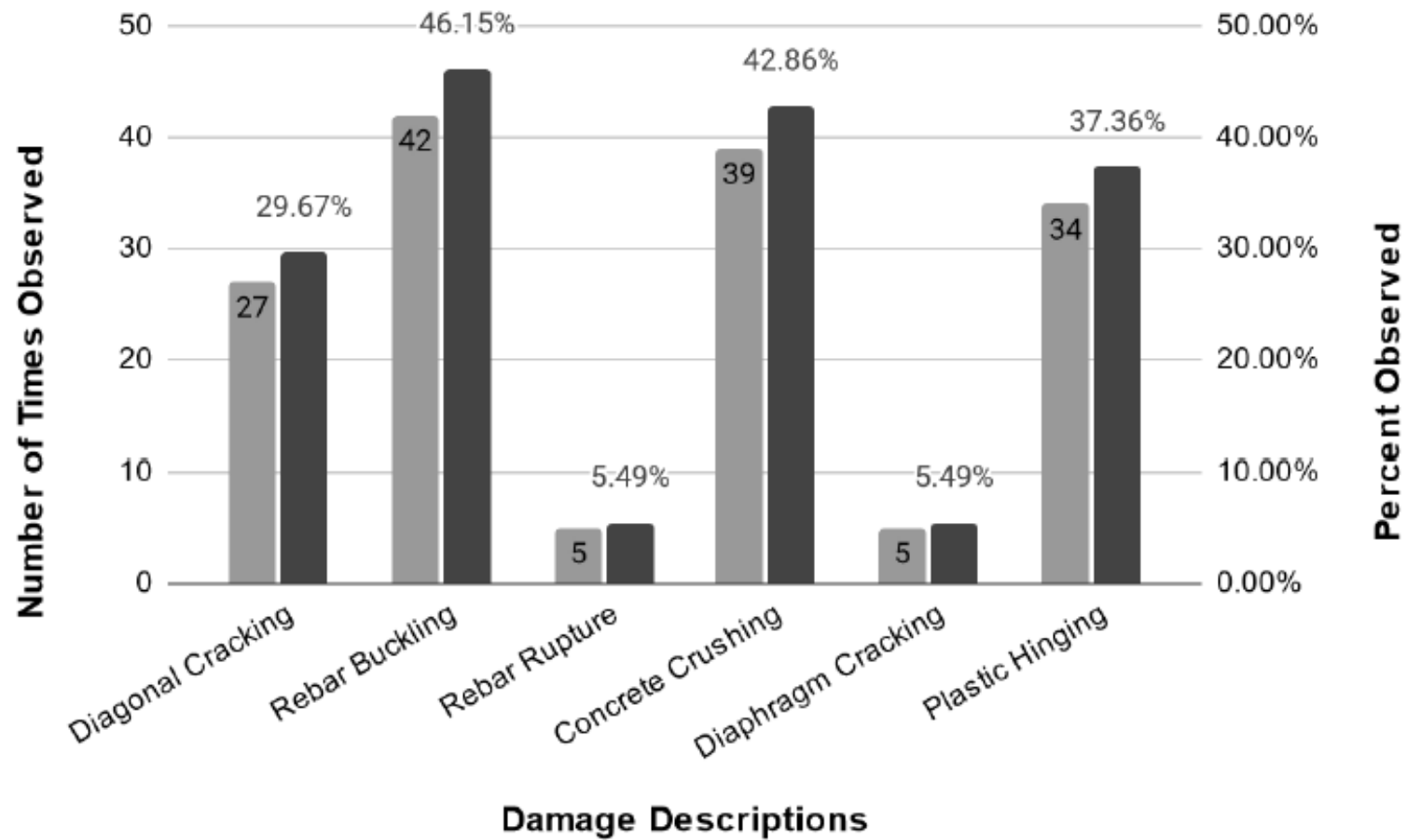
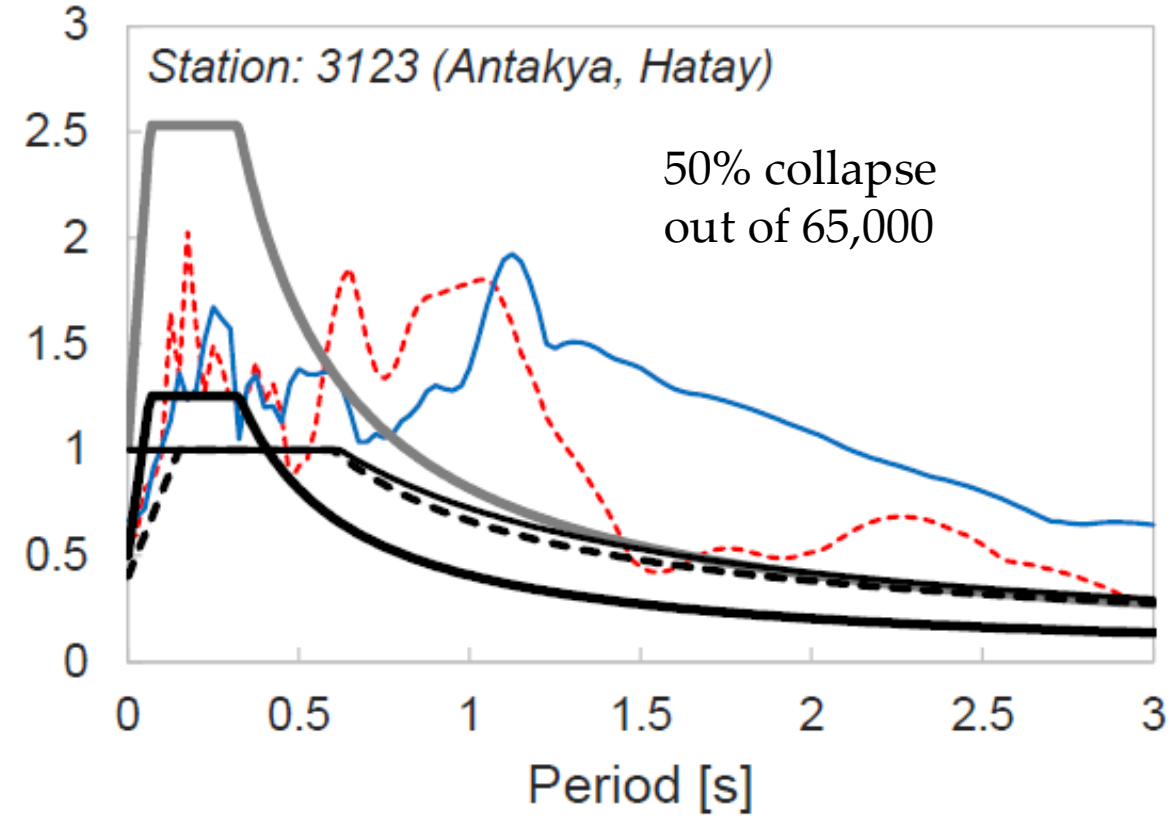
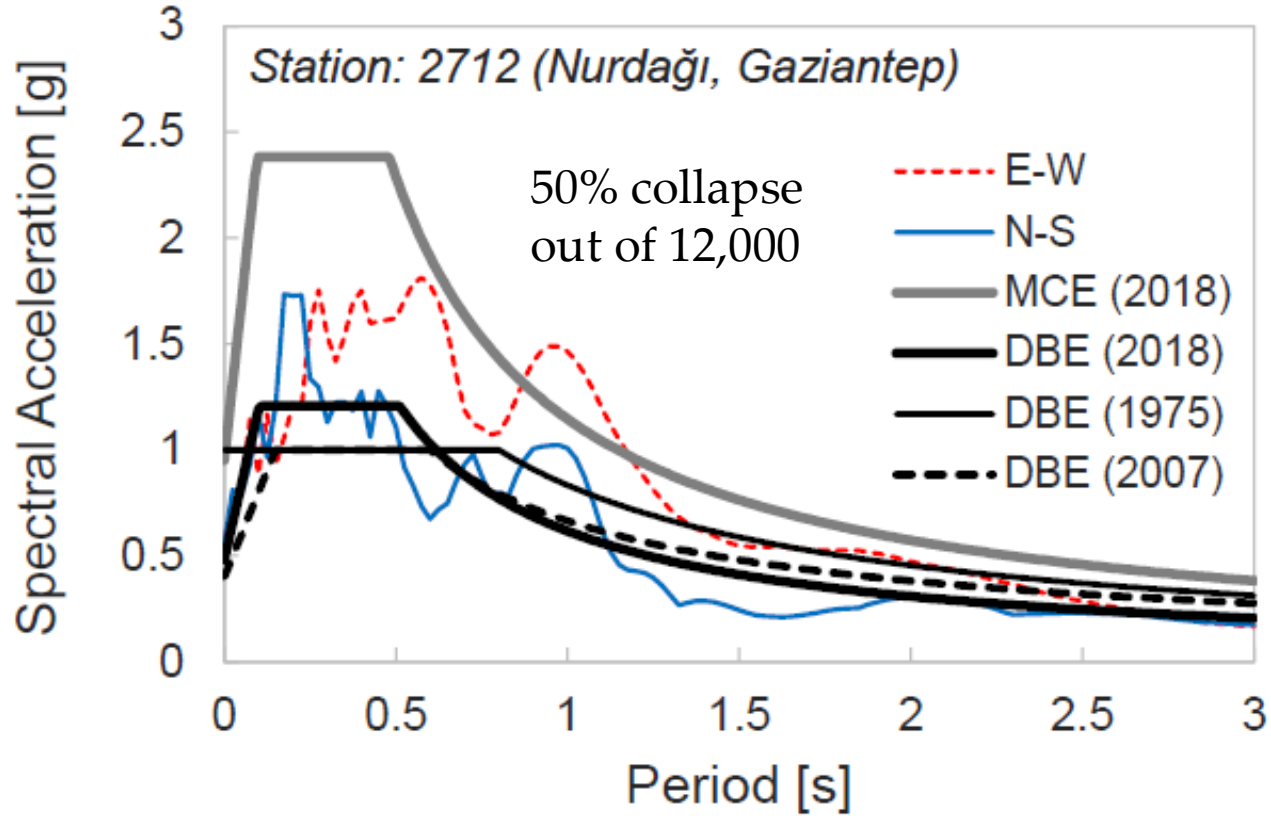
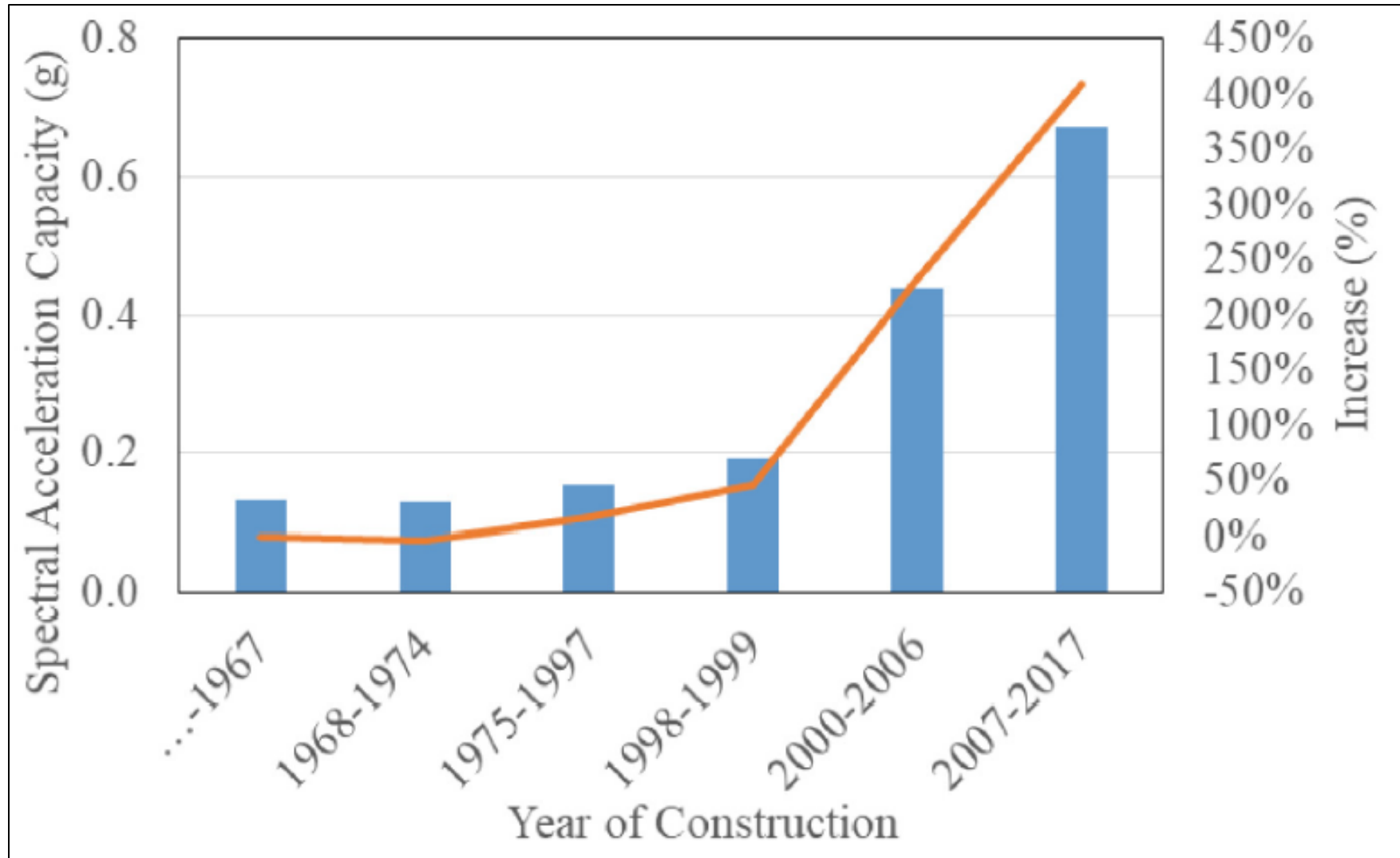


Figure 5.10. Types of damage observed in the residential buildings visited by the EERI Buildings team

<https://learningfromearthquakes.org/2023-02-06-nurdagi-turkey/>







CNN

World

Africa

Americas

Asia

Australia

China

Europe

India

Middle East

United Kingdom

# Turkey arrests nearly 200 people over alleged poor building construction following quake tragedy

By Isil Sariyuce, CNN

Published 11:58 AM EST, Sun February 26, 2023



<https://www.nytimes.com/2023/05/04/world/europe/turkey-earthquake>

**Re-occupancy**





Kahramanmaraş (by A. İrfanoğlu)



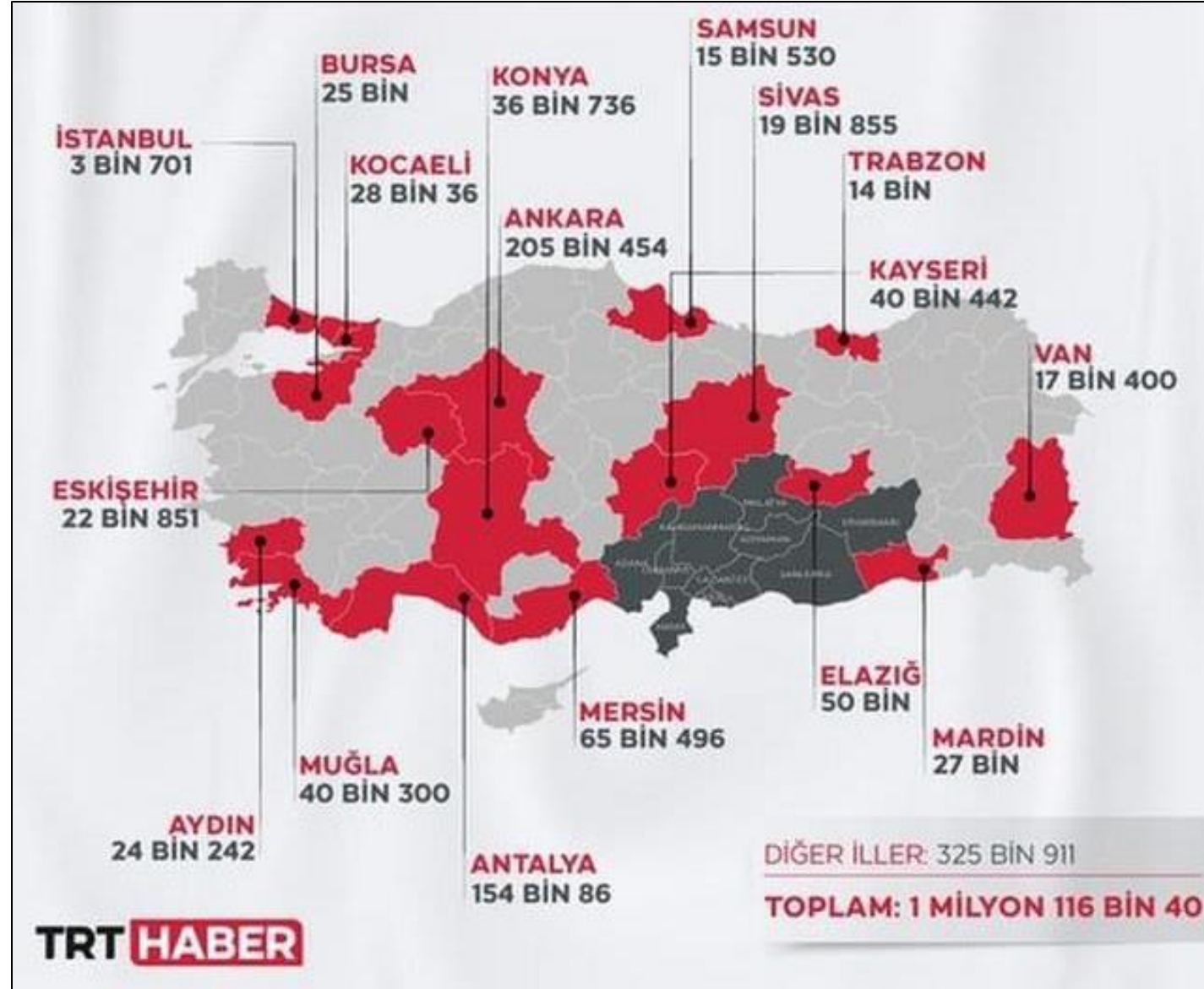
Kahramanmaraş (by A. İrfanoğlu)

# Who occupies the buildings?

Region	Population	Total Buildings	Residential Buildings	Residential Constructed before 2000	Damaged
Kahramanmaraş	1.2M	240k	92%	33%	60%
Hatay	1.7M	410k	88%	45%	48%
EQ Region (11 cities)	14M	2.6M	88%	37%	34%

**Housing for 2.7M people affected in the region**  
(Avg 3.5 persons per household)

# Where did they go?



# Where are they now?

- Tents -> Containers



**Turkish floods inundate two cities  
hit by quakes killing 14**

OMER YASIN ERGIN/ANADOLU AGENCY/GETTY



<https://www.aa.com.tr/tr/asrin-felaketi/adiyamanda-cadir-sinif-kuran-nuran-ogretmen-cocuklara-gonullu-egitim-veriyor/2839082>

# Rebuilding 850,000 residential units

Cost to owners:

- Subsidies
- Credit
- 10 year payment

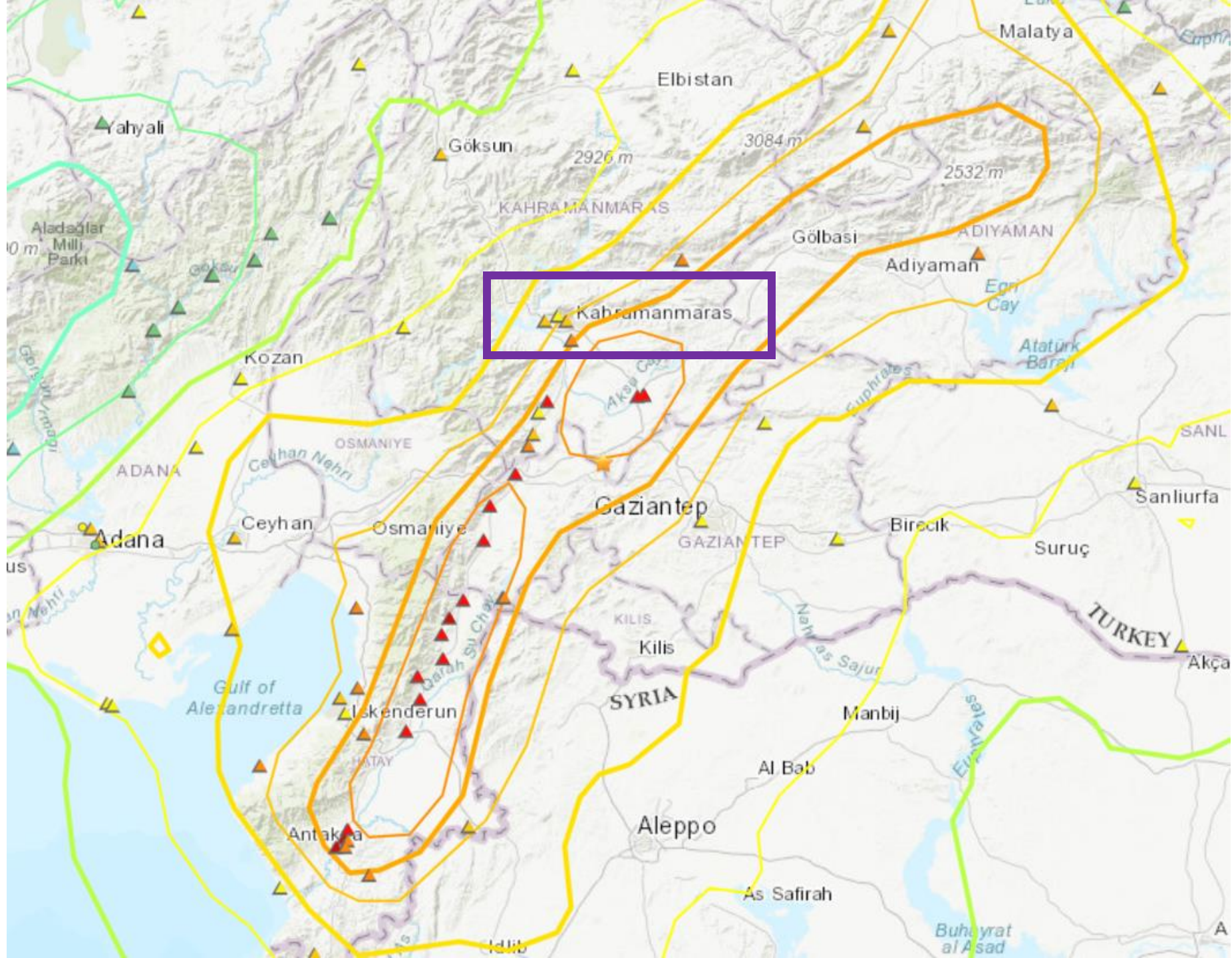
Rebuilding “in situ”

- Preserving the community



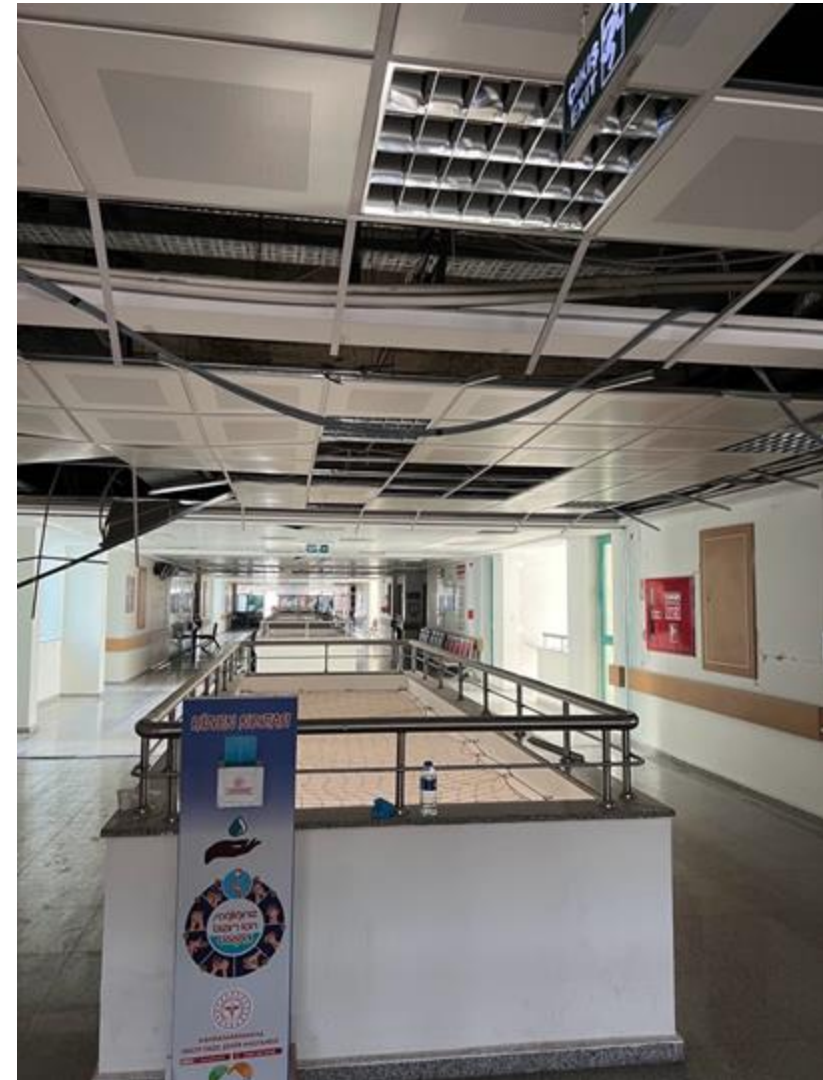
**Function**







City Hospital  
built 2012



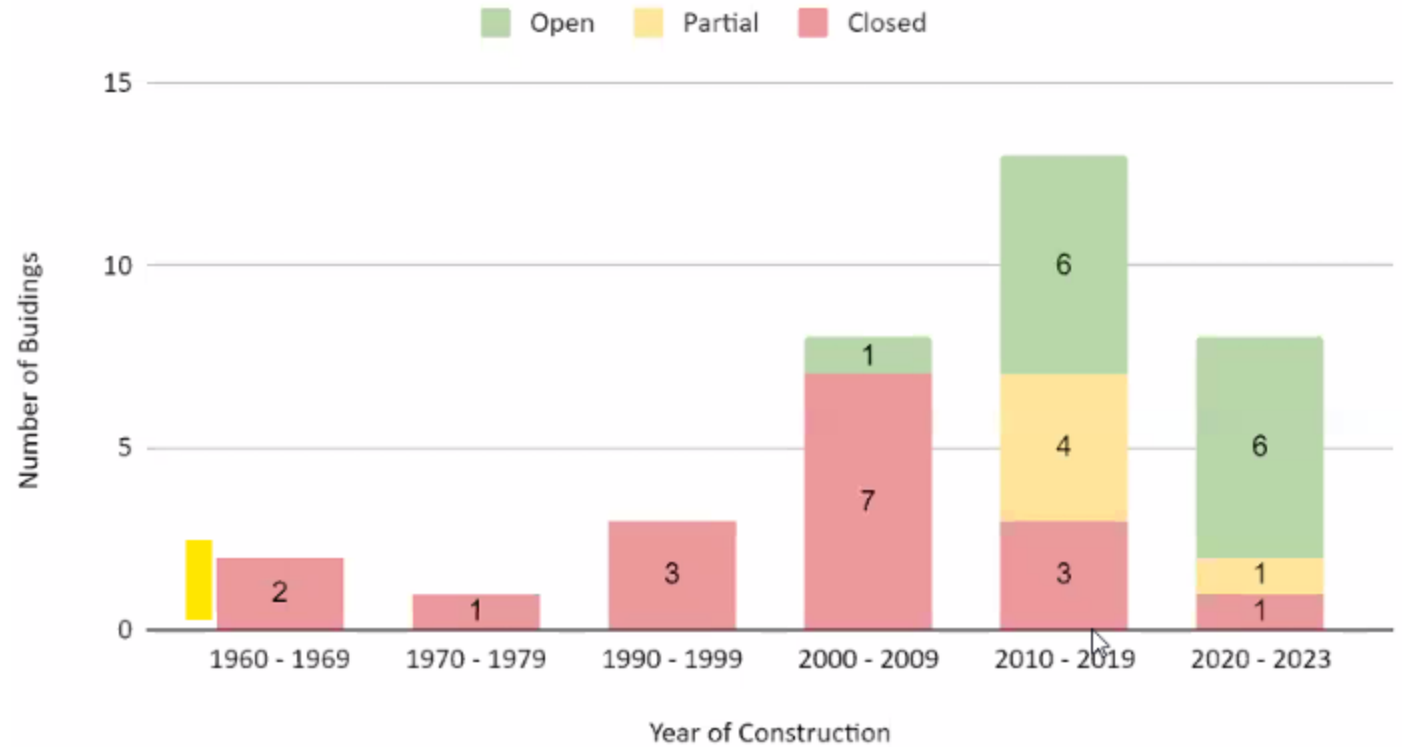




from EERI-GEER report




## Operational Status at 6 weeks by Year of Construction



- There are more hospitals built recently.
- Newer hospitals had better functional recovery.
- Fixed base construction: 1962 to 2023
- Seismically isolated construction: 2017 to 2023

# New Orleans September 1, 2021



A darkened New Orleans skyline on Monday, when most of the city was without power following Hurricane Ida. (Edmund D. Fountain for The New York Times)

A dramatic sunset or sunrise over a city skyline. The sky is filled with dark, heavy clouds, with a bright orange and yellow glow from the sun breaking through near the horizon. The city skyline is silhouetted against the sky, with several tall buildings visible. In the foreground, there is a body of water reflecting the light from the sky.

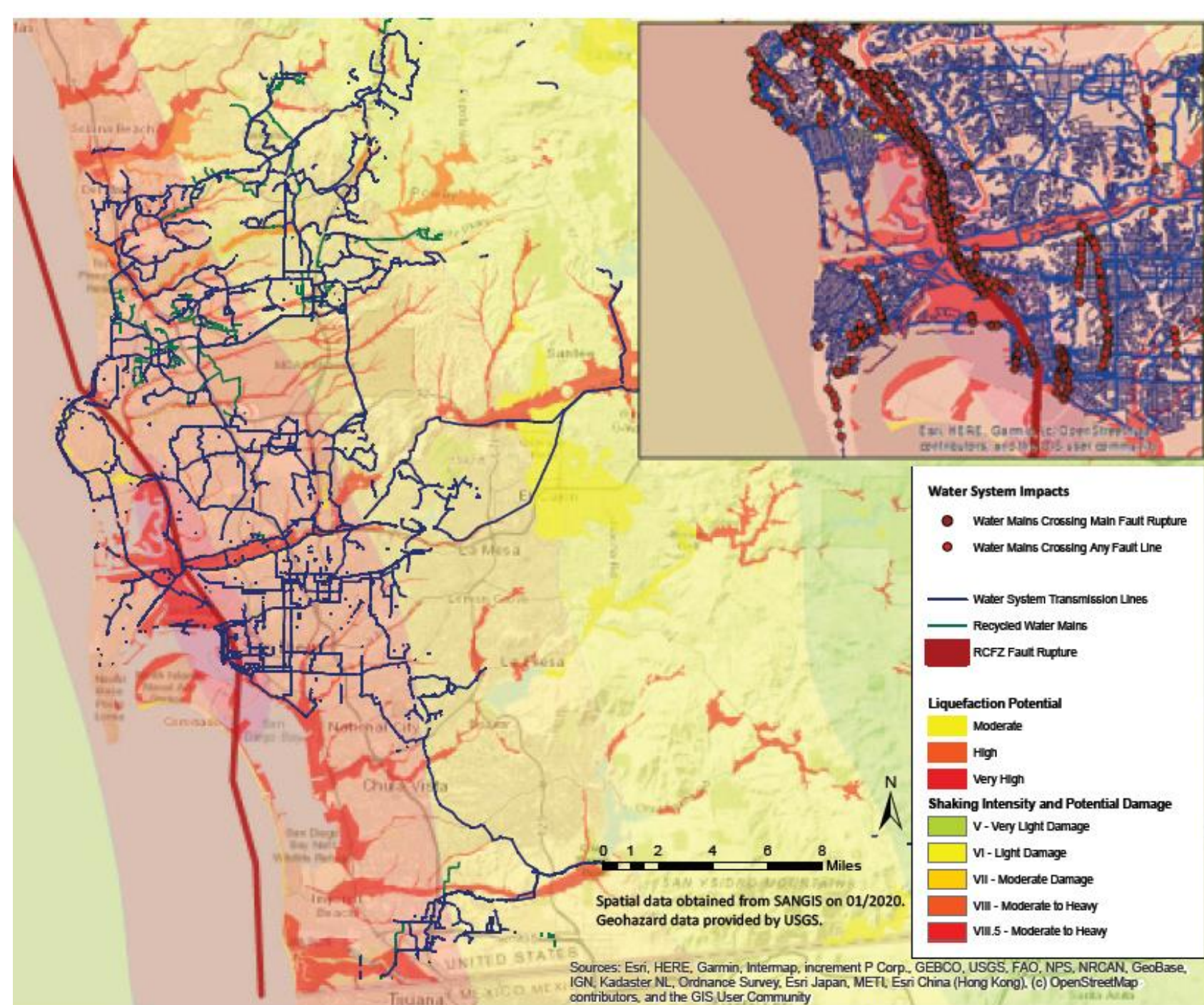
## Louisiana Governor John Bel. Edwards:

“I can’t tell you when the power is going to be restored. I can’t tell you when all debris is going to be cleaned up and repairs made. But I can tell you is we are going to work hard every day to deliver as much assistance as we can.”

“Many of the life-supporting infrastructure elements are not present, they’re not operating right now.  
So, if you have already evacuated, do not return.”

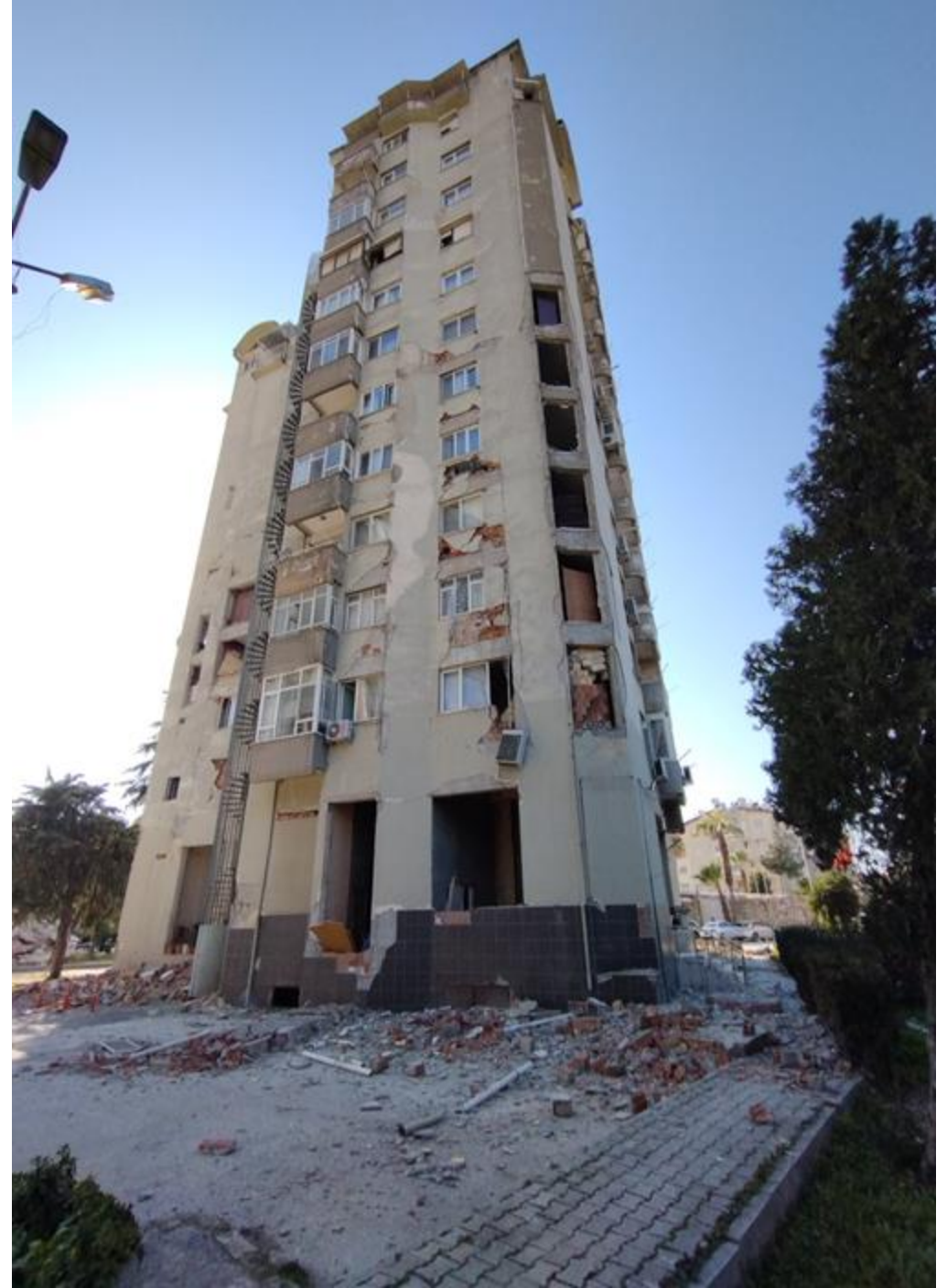
# San Diego Earthquake Planning Scenario (EERI-SD, 2020):

“Major supply pipeline ruptures along the fault are expected to leave the coastal communities west of the fault and south of La Jolla Shores completely without water for **weeks to months.**”





**Retrofits lift all ships**



Antakya

# San Francisco

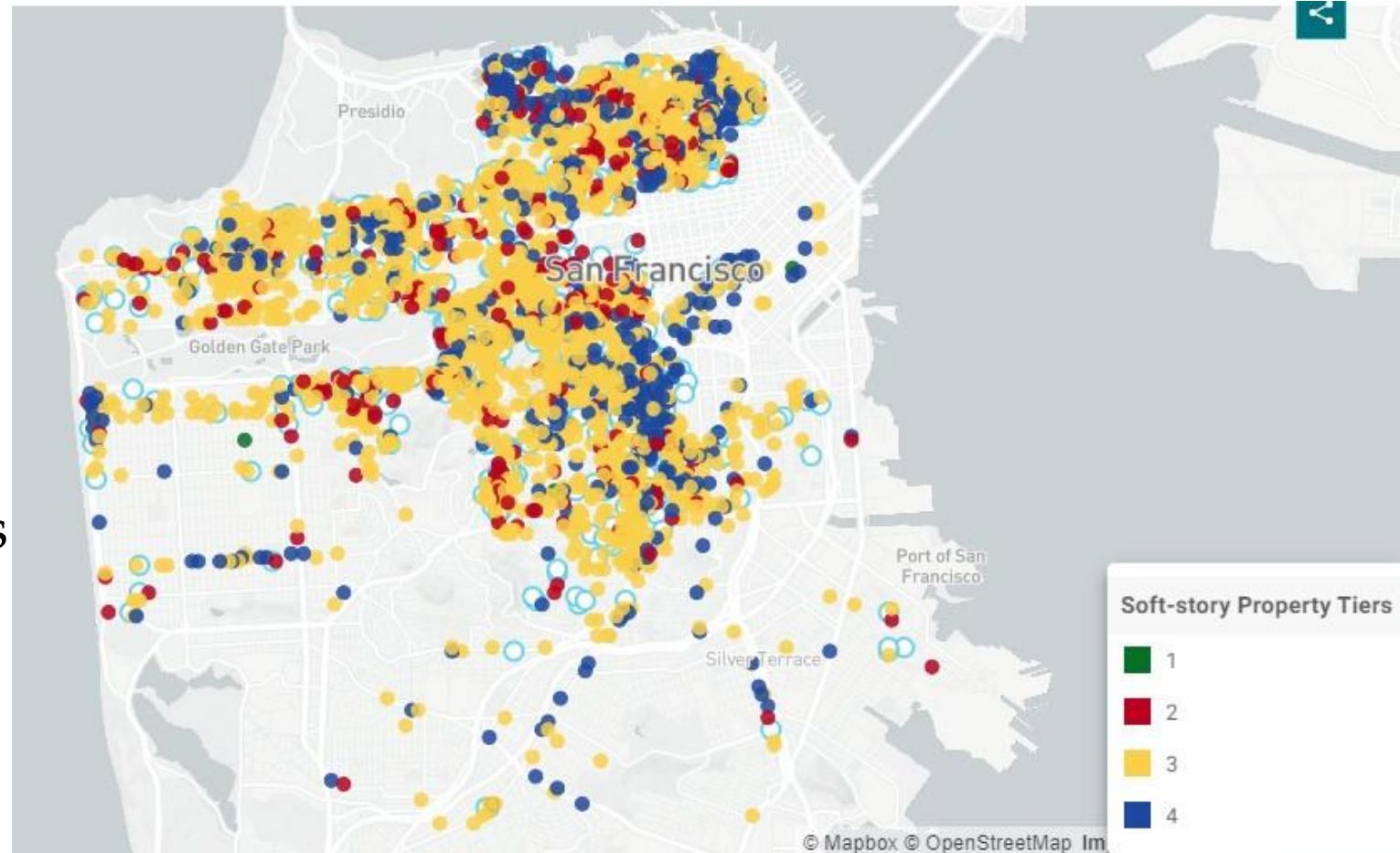
*1989 – soft-story damage*



# San Francisco

*As of November 14, 2023*

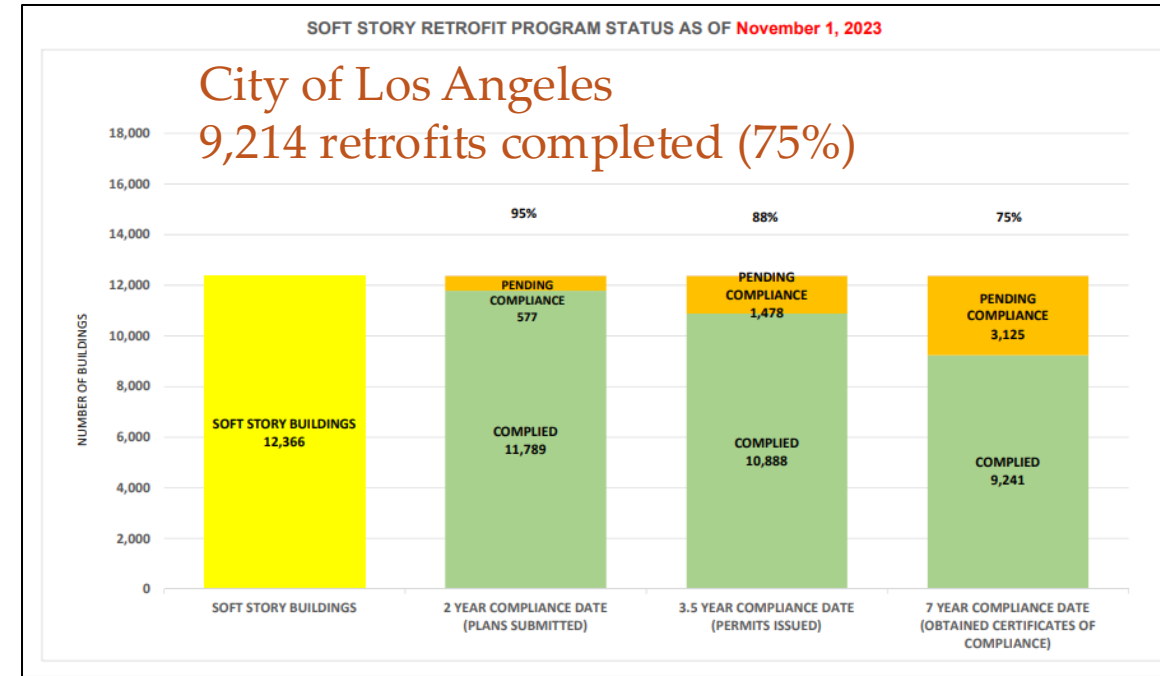
- Over 4,500 soft-story buildings in San Francisco obtained a Certificate of Final Completion and Occupancy (CFC) for their retrofits
  - this is 92% of all buildings subject to the program



completed projects as of 2023 (SFDBI)

# Elsewhere in California

- Alameda
- Albany
- Berkeley
- Beverly Hills
- Burbank
- Fremont
- Hayward
- Los Angeles
- Mountain View
- Oakland
- Pasadena
- San Leandro
- Santa Monica
- West Hollywood



City of Berkeley  
279 retrofits completed (76%)

INVENTORY OF POTENTIALLY HAZARDOUS  
SOFT, WEAK OR OPEN FRONT BUILDINGS, STATUS AS OF 10/24/2023

*For more information about the requirements for properties on the inventory of soft, weak or open front (SWOF) buildings, please see Chapter 19.39 of the Berkeley Municipal Code or contact Galadriel Burr at (510) 981-7475.*

STATUS COUNT AND KEY


COUNT	STATUS	STATUS	DESCRIPTION
279	off, retrofit	Soft Story retrofit	Soft Story retrofit completed This building has been retrofitted to address the SWOF condition and is no longer on the inventory.
62		Removed from inventory	This building was placed on the inventory, but was removed for one of the following reasons:
		Does not contain 5 dwelling units	Owner proved building does not have 5 dwelling units and is not subject to Berkeley Municipal Code Chapter 19.39.
		Not a SWOF building	Owner proved building does not have a SWOF condition.
		Newer building	Reporting requirements of Phase I applied to all buildings permitted for construction prior to adoption of the 1997 Uniform Building Code. Mandatory retrofit requirements for Phase II apply to buildings permitted for construction prior to 1/1/1978.
		Demolished	Building has been demolished.

# ATC-52-2 Project

(2008-2010)

ATC **52-1**

**Here Today—Here Tomorrow:  
The Road to Earthquake Resilience  
in San Francisco**  
Potential Earthquake Impacts




ATC Applied Technology Council

Prepared for  
San Francisco Department of Building Inspection  
under the Community Action Plan for Seismic Safety (CAPSS) Project

ATC **52-3**

**Here Today—Here Tomorrow:  
The Road to Earthquake Resilience  
in San Francisco**  
Earthquake Safety for Soft-Story Buildings

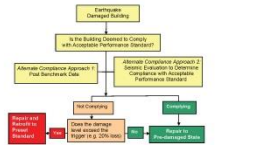


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Prepared for  
San Francisco Department of Building Inspection  
under the Community Action Plan for Seismic Safety (CAPSS) Project

ATC **52-4**

**Here Today—Here Tomorrow:  
The Road to Earthquake Resilience  
in San Francisco**  
Post-Earthquake Repair and Retrofit  
Requirements

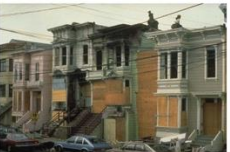


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San Francisco Department of Building Inspection  
under the Community Action Plan for Seismic Safety (CAPSS) Project

ATC **52-1A**

**Here Today—Here Tomorrow:  
The Road to Earthquake Resilience  
in San Francisco**  
Potential Earthquake Impacts:  
Technical Documentation




ATC Applied Technology Council

Prepared for  
San Francisco Department of Building Inspection  
under the Community Action Plan for Seismic Safety (CAPSS) Project

ATC **52-3A**

**Here Today—Here Tomorrow:  
The Road to Earthquake Resilience  
in San Francisco**  
Earthquake Safety for Soft-Story Buildings:  
Documentation Appendices




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San Francisco Department of Building Inspection  
under the Community Action Plan for Seismic Safety (CAPSS) Project

ATC **52-2**

**Here Today – Here Tomorrow:  
The Road to Earthquake Resilience  
in San Francisco**  
A Community Action Plan for Seismic Safety



ATC Applied Technology Council

Prepared for  
San Francisco Department of Building Inspection  
under the Community Action Plan for Seismic Safety (CAPSS) Project

“A study never saved a life or prevented property damage – studies are only effective when their results and recommendations stimulate actions that mitigate the effects and consequences of future disasters.”

Participants:

- SF Department of Building Inspection
- SF Building Inspection Commission
- CAPSS Volunteer Advisory Committee with >40 attendees


# Here Today - Here Tomorrow

## A Community Action Plan for Seismic Safety

ATC **522**

**Here Today - Here Tomorrow:  
The Road to Earthquake Resilience  
in San Francisco**

A Community Action Plan for Seismic Safety



**ATC** Applied Technology Council

Prepared for:  
San Francisco Department of Building Inspection  
under the Community Action Plan for Seismic Safety (CAPSS) Project

Office of the Mayor  
City & County of San Francisco



Gavin Newsom

### Executive Directive 10-02 Earthquake Safety Implementation Committee (ESIC)

December 22, 2010

#### ABOUT CAPSS

The Community Action Plan for Seismic Safety (CAPSS), run by the Department of Building Inspection, is a 9-year, \$1 million effort to catalogue the specific seismic risks San Francisco faces as a result of damage to privately-owned property from future earthquakes, and suggestions on how to best mitigate this loss of life and property damage. The project ends on December 31, 2010, and CAPSS has completed reports describing the scope of vulnerability faced by San Francisco, and recommendations as to what steps the City can take to mitigate these risks.

#### THE CONSEQUENCES

USGS scientists have forecast 63% likelihood of one or more M6.7 or larger earthquakes striking the Bay Area in the next 30 years. Using GPS to measure strain accumulating along the San Andreas fault, scientists report that enough strain has re-accumulated along the Peninsula segment of the San Andreas already to produce a M7.2 earthquake. This event, which seismologists call the "expected" earthquake, would lead to an estimated 300 fatalities, 7,000 injuries requiring medical attention, 27,000 buildings being condemned, 2,700 additional buildings destroyed by fire, 85,000 housing units lost, and up to \$30 billion in property damage.

All told, after shaking and fire, almost a fifth of the City's buildings would be uninhabitable or destroyed, including an estimated 11 million square feet that will burn. More detailed tables on casualties and building damage are attached to this Directive as Appendix A.

#### THE SOLUTIONS

The CAPSS reports present a very grim picture. But they also suggest policies and programs to mitigate as much damage and loss of life as possible. It all begins with requiring owners to evaluate the seismic performance of their buildings at the next sale or by a time-certain deadline. This citywide evaluation would be paired with updated code standards for all common building types in San Francisco, which would be mandatory by different deadlines for different specific retrofits.

CAPSS proposes a set of 17 recommendations to get buildings evaluated and retrofitted. A full outline of recommendations is attached to this Directive as Appendix B. Taken together, CAPSS's suggested policies will save lives and prevent billions of dollars in property damage. CAPSS details prioritized timetables for much of this seismic upgrading, a chart of which is attached as Appendix C.

#### NEXT STEPS

The scientific research is complete: San Francisco faces grave consequences when the next big earthquake hits. CAPSS provides us with actions we need to take to mitigate this damage. The next phase of the CAPSS program must include:

- 1) Raising the public's awareness of the consequences of future earthquakes and what we can do to prevent the resulting loss of life and property damage
- 2) Building a broad base of political will to enact government programs and mandates to get this work accomplished
- 3) Locating resources to assist with the retrofit of private structures

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Office of the Mayor  
City & County of San Francisco



Gavin Newsom

Over the next several decades, billions of dollars must be spent on retrofitting privately owned buildings if we hope to prevent hundreds of deaths, thousands of injuries, and tens of billions of dollars of damage. Some of this money will come from private citizens paying to retrofit their own property. But some funding must be made available through government financing, either in the form of GO Bonds, special assessments, or some other instrument.

San Francisco needs a comprehensive program that links disparate interests together for a common cause. When the ground shakes and buildings fall, the damage and displacement of residents impacts the whole City. Loss of housing, tent camps, economic devastation, fires – these afflictions don't discriminate between neighborhoods or blocks.

Earthquake prevention requires citywide effort to achieve citywide benefit. In order to successfully educate the public on what must be done, the City must outreach to neighborhood councils, building owners, tenant associations, commercial builders, and dozens of other groups. Only with a citywide approach like this can we win support for the comprehensive interventions necessary to reduce the risks that San Francisco faces. Awareness breeds urgency. Urgency paves the way for solutions. The next phase of CAPSS must be widespread awareness, and knowledge of the relative risks posed by each building.

#### Directive Establishing ESIC Under the City Administrator

To that end, I am directing the City Administrator to oversee the process of outreaching to interested parties around the City to build a broad coalition of supporters to implement the CAPSS recommendations. The City Administration is currently tasked with post-disaster planning, coordination and recovery, and ESIC aligns with this existing responsibility. We have scientifically supported conclusions about how the next earthquake will impact San Francisco. We now need to implement.

This Directive establishes the Earthquake Safety Implementation Committee (ESIC), with the main objective being timely implementation of the 17 policy recommendations included in the CAPSS Task 4 report.

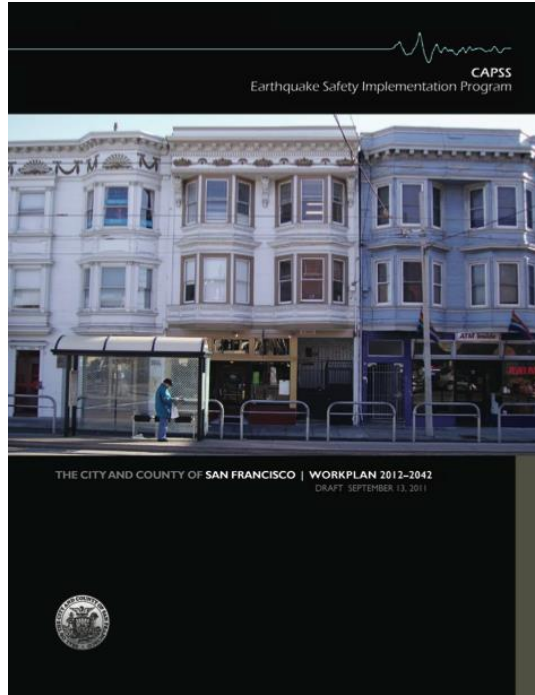
- Coordinating with DBI to create implementation plans and timelines for CAPSS's recommendations and tasking other departments with implementation assignments;
- Performing community outreach to build political support for a comprehensive, long-term earthquake mitigation strategy;
- Clarifying, through stakeholder meetings and further research, the costs associated with the CAPSS recommendations;
- Devising a variety of financial instruments to subsidize for the cost of implementing seismic mitigation activities on private property, through both the legislative process and public-private partnerships with the financial and mortgage sectors; and
- Building consensus around timelines for inspection and retrofit, taking into account CAPSS's recommended time frames and community feedback on feasibility and desire to perform the work.

The City Administrator should work closely with the following entities or their designees: the Controller, the Office of Public Finance, the Director of DBI, the President of the Building Inspection Commission, the Fire Chief, and the Director of the Department of Emergency Management. All other City departments and agencies are directed to cooperate with the City Administrator's requests for information, participation, and action pertaining to ESIC.

  
Gavin Newsom  
Mayor

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# ESIP



The City and County of San Francisco  
Earthquake Safety Implementation Plan  
(2012-2042)

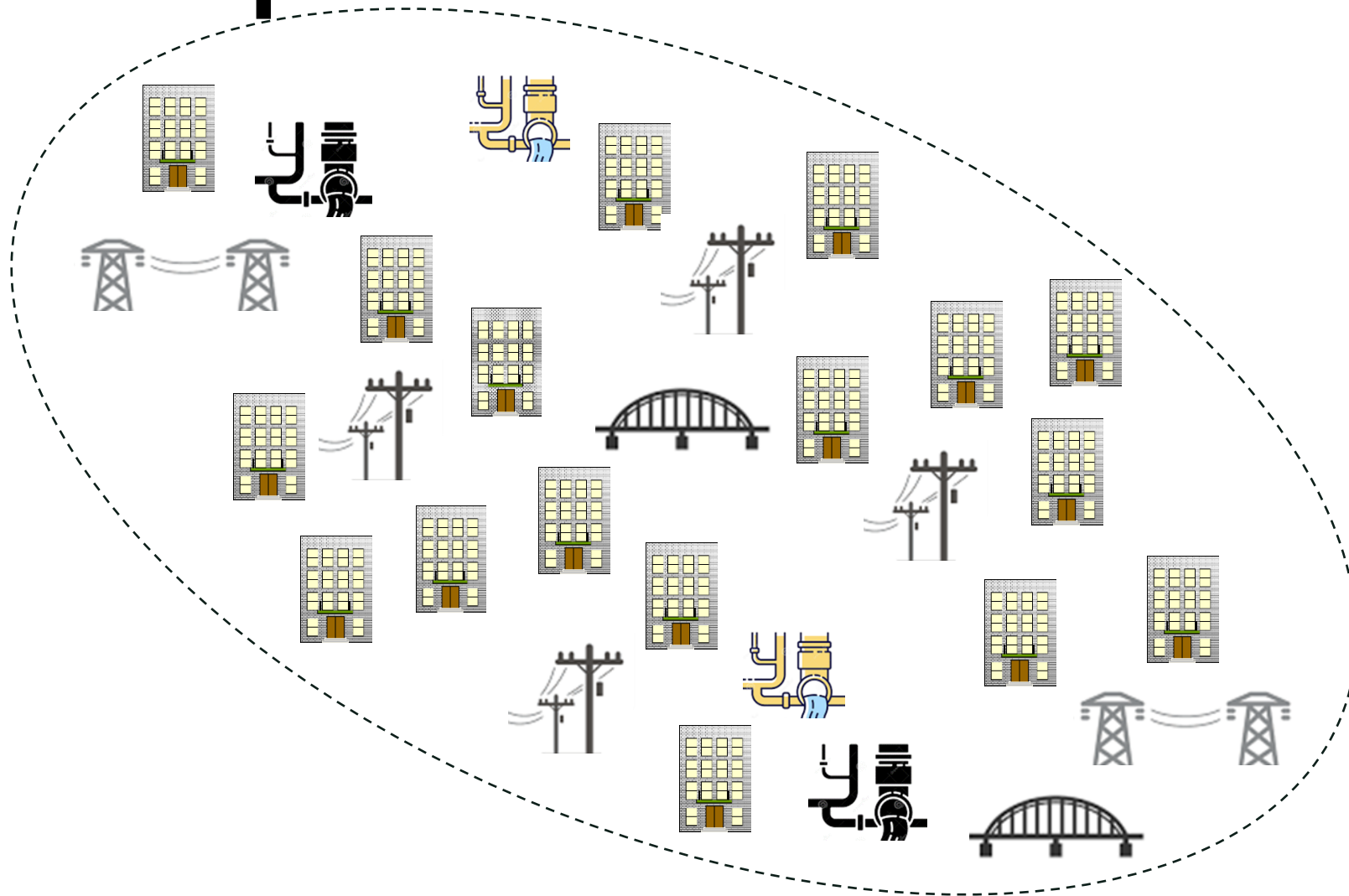


2014-2024; Task A.3.a:  
Mandatory evaluation and retrofit  
of 3+ story, 5+ unit soft-story wood-  
frame residential buildings  
(Department of Building Inspection)





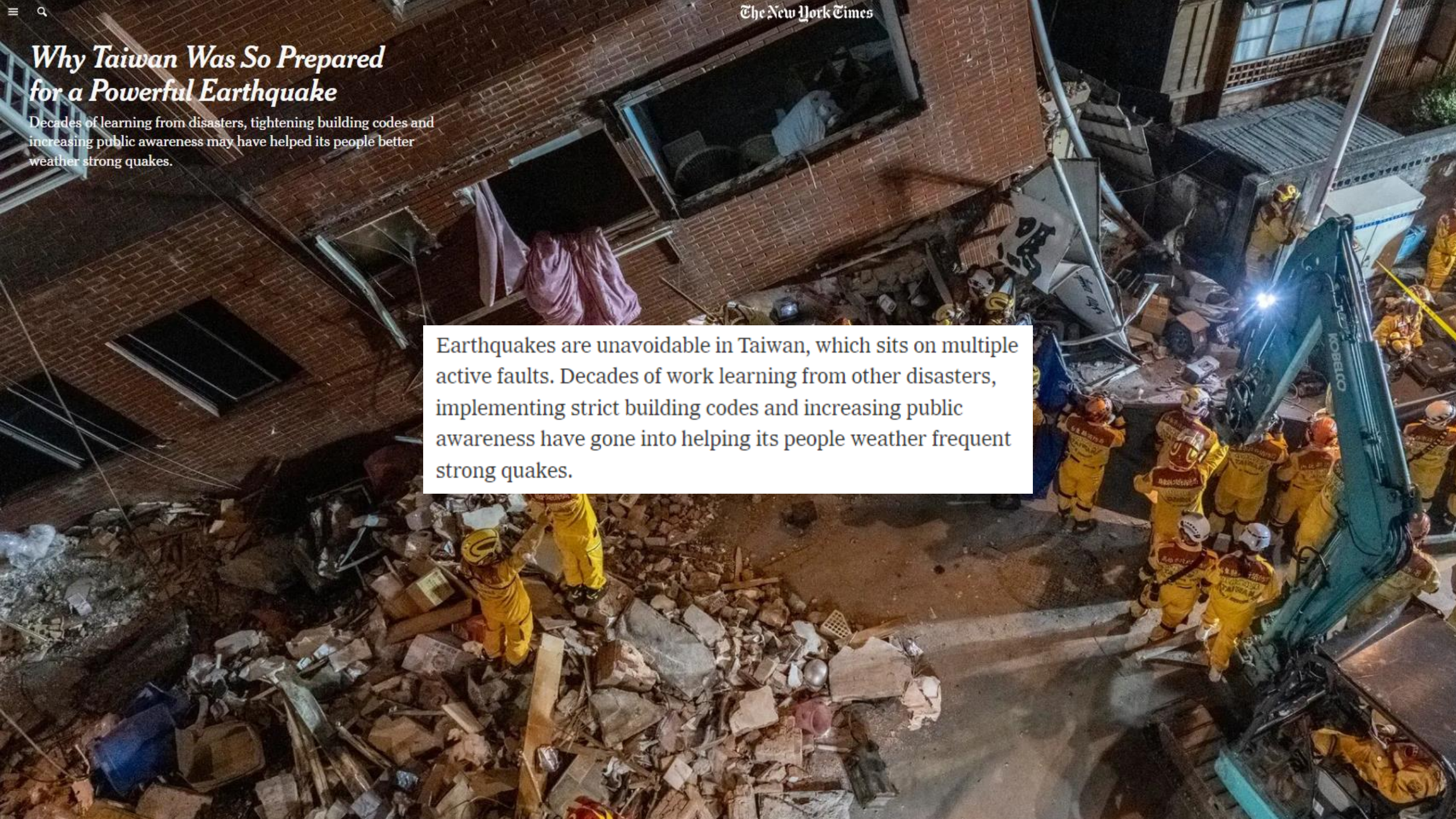
# “ability to withstand and recover rapidly from disruptions”



## Why Taiwan Was So Prepared for a Powerful Earthquake

Decades of learning from disasters, tightening building codes and increasing public awareness may have helped its people better weather strong quakes.

Earthquakes are unavoidable in Taiwan, which sits on multiple active faults. Decades of work learning from other disasters, implementing strict building codes and increasing public awareness have gone into helping its people weather frequent strong quakes.





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[www.ATCouncil.org](http://www.ATCouncil.org)