# Advanced Component Method (ACM™) for Earthquake Vulnerability Assessment

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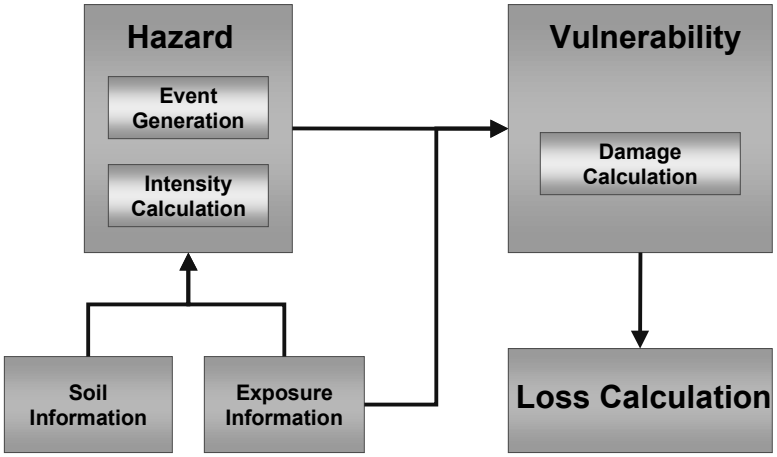
BETTER TECHNOLOGY
BETTER DATA
BETTER DECISIONS


## Discussion Agenda

- Objective versus subjective vulnerability assessment techniques
- Development of physical and monetary damage functions using ACM
- How ACM improves loss estimates




## Fundamental Earthquake Model Components

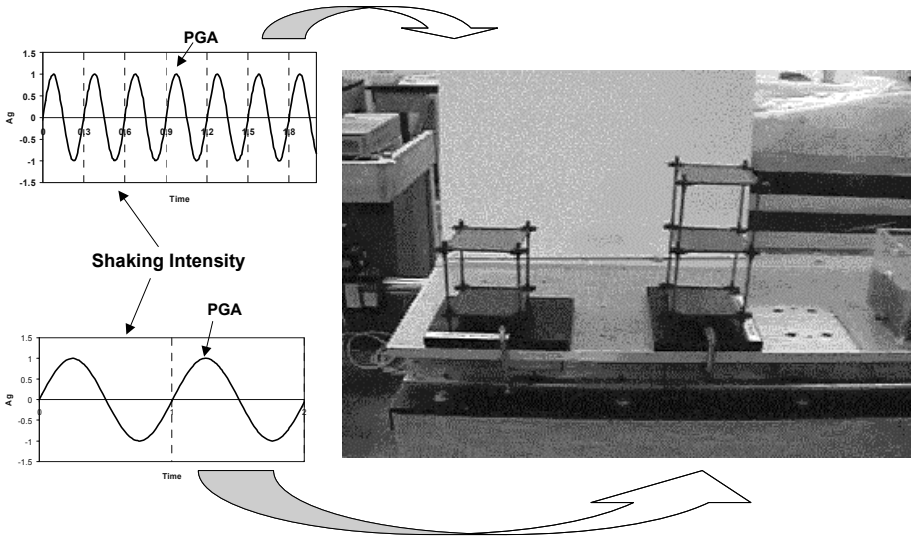






## Typical Earthquake Damage Observation

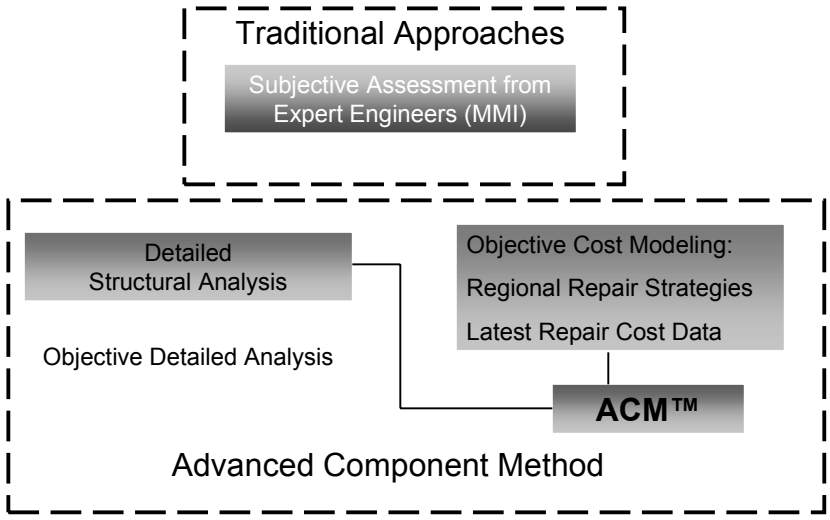
## Response of Different Buildings to Same PGA







## Objective versus Subjective Vulnerability Assessment



## Procedure for the Development of Damage Functions Using ACM

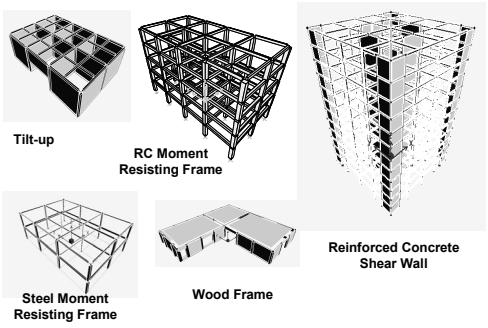
- Detailed design drawings of typical buildings in every modeled region
- Seismic analysis performed on each building type
- Component damage curves estimated for each building type
- Repair strategies and costs determined for each region
- Objective estimate of damage obtained for each building type



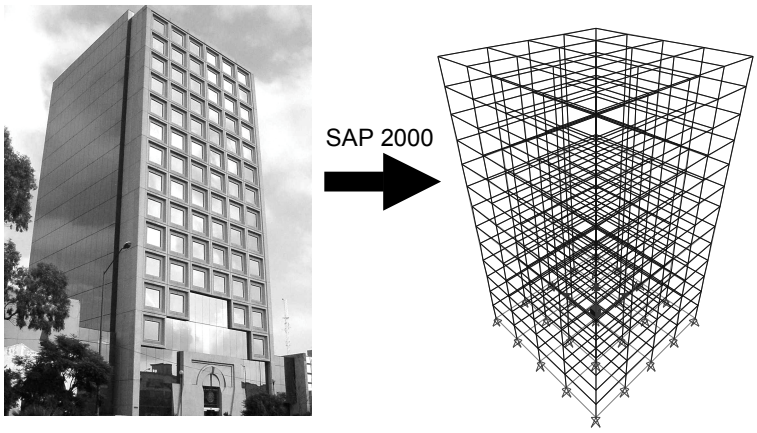

## ACM-US: Building Designs

- Steel
  - Moment Resisting Frame
  - Braced Frame
- Reinforced Concrete
  - Moment Resisting Frame
  - Shear Wall
- Pre-Cast Concrete
  - Moment Resisting Frame
  - Shear Wall
  - Tilt-Up

**35 Building Types**



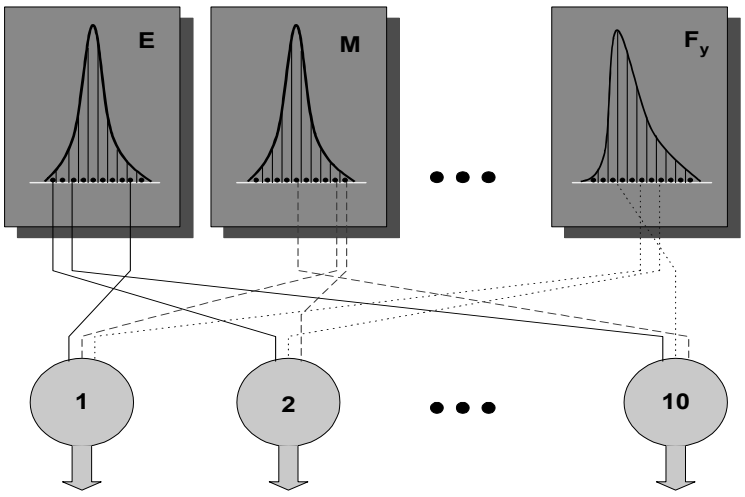
## Applying ACM to the Structure



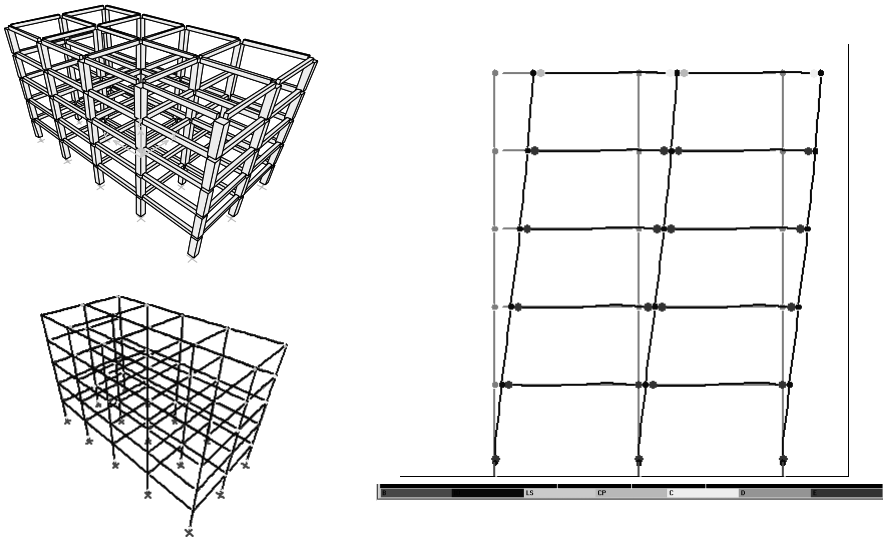




## Capturing the Variability in Actual Buildings



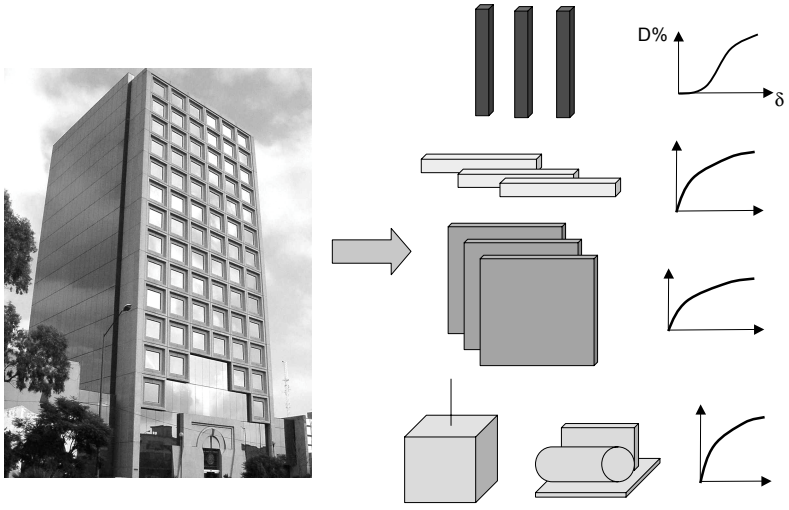
## Push-over Analysis



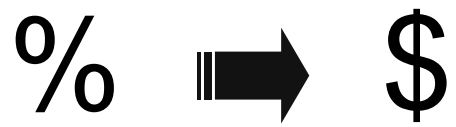




## Vulnerability Assessment at the Component Level



## Translation of Physical Damage Ratio to Monetary Damage Estimate Using ACM



With ACM:

- For *each component* there is a damage state that corresponds to each level of building deformation
- For *each component and at each damage state*, there is an associated repair strategy
- For *each repair strategy*, there is a repair cost




## Typical Component Repair Strategies

**RC Columns:**

**Slight:**
*Damage*: Local hairline cracks.
*Action*: Epoxy injection.

**Moderate:**
*Damage*: Extensive large cracks. Spalling of concrete in weaker elements.
*Action*: Epoxy injection, grouting and jacketing.

**Extensive:**
*Damage*: Extensive crushing of concrete. Disclosure of buckled reinforcement.
*Action*: Jacketing or replacement of affected members.

**Complete:**
*Damage*: Large amounts of concrete fallen. Large tensile strain in hoops. Fracture of hoops leading to loss of confinement. Some longitudinal bars are fractured.
*Action*: Replace members.




## Cost by Component by Floor

Replacement Cost

| | Column | Beam | Floor | Partition | Cladding | Glazing | Ceiling | MEP |
|---|---|---|---|---|---|---|---|---|
| 1st Floor | 88320 | 54148 | 228865 | 38595 | 20730 | 232018 | 42439 | 281160 |
| 2nd Floor | 77288 | 54148 | 228865 | 38595 | 11000 | 232018 | 42439 | 281160 |
| 3rd Floor | 77288 | 54148 | 228865 | 38595 | 11000 | 232018 | 42439 | 281160 |
| . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . |

Repair/Replacement

| | | Column | Beam | Floor | Partition | Cladding | Glazing | Ceiling | MEP |
|---|---|---|---|---|---|---|---|---|---|
| 1st Floor | Negligible | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Slight | 0.000 | 0.000 | 0.048 | 0.031 | 0.000 | 0.101 | 0.065 | 0.031 |
| | Moderate | 0.057 | 0.000 | 0.150 | 0.147 | 0.067 | 0.304 | 0.229 | 0.080 |
| | Extensive | 0.622 | 0.746 | 1.204 | 0.631 | 0.532 | 0.421 | 0.797 | 0.840 |
| | Complete | 1.055 | 1.186 | 1.204 | 0.950 | 0.920 | 0.842 | 1.056 | 1.052 |
| 2nd Floor | Negligible | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Slight | 0.000 | 0.000 | 0.048 | 0.031 | 0.000 | 0.101 | 0.065 | 0.031 |
| | Moderate | 0.066 | 0.000 | 0.150 | 0.147 | 0.058 | 0.304 | 0.229 | 0.080 |
| | Extensive | 0.653 | 0.746 | 1.204 | 0.631 | 0.500 | 0.421 | 0.797 | 0.840 |
| | Complete | 1.078 | 1.186 | 1.204 | 0.950 | 0.870 | 0.842 | 1.056 | 1.052 |
| 3rd Floor | Negligible | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Slight | 0.000 | 0.000 | 0.048 | 0.031 | 0.000 | 0.101 | 0.065 | 0.031 |
| | Moderate | 0.066 | 0.000 | 0.150 | 0.147 | 0.058 | 0.304 | 0.229 | 0.080 |
| | Extensive | 0.653 | 0.746 | 1.204 | 0.631 | 0.500 | 0.421 | 0.797 | 0.840 |
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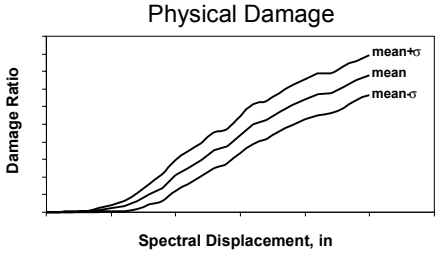
| . | . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . | . |

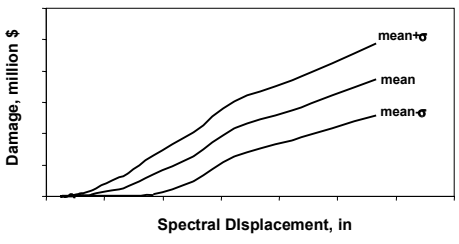



## Final Damage Curves (Physical and Monetary)

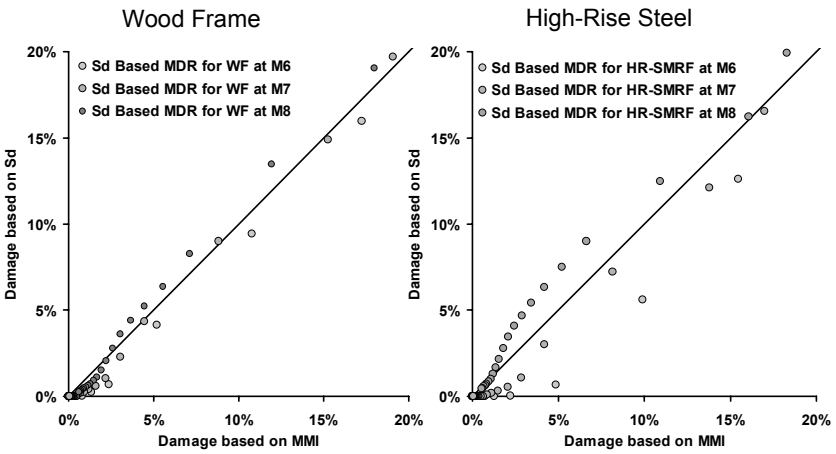
Physical Damage




Monetary Damage



## Comparison Between MMI and ACM







## How ACM Improves Loss Estimates

- Traditional approach generally
  - Underestimates building damage for large earthquakes (M>7.5)
  - Overestimates building damage for small earthquakes (M<6.5)
- Traditional MMI approach generally
  - Overestimates the contents damage in high-rise buildings
  - Underestimates the contents damage in low-rise buildings