WP4: Structural vulnerability of schools in Nepal

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Picture source: TIME

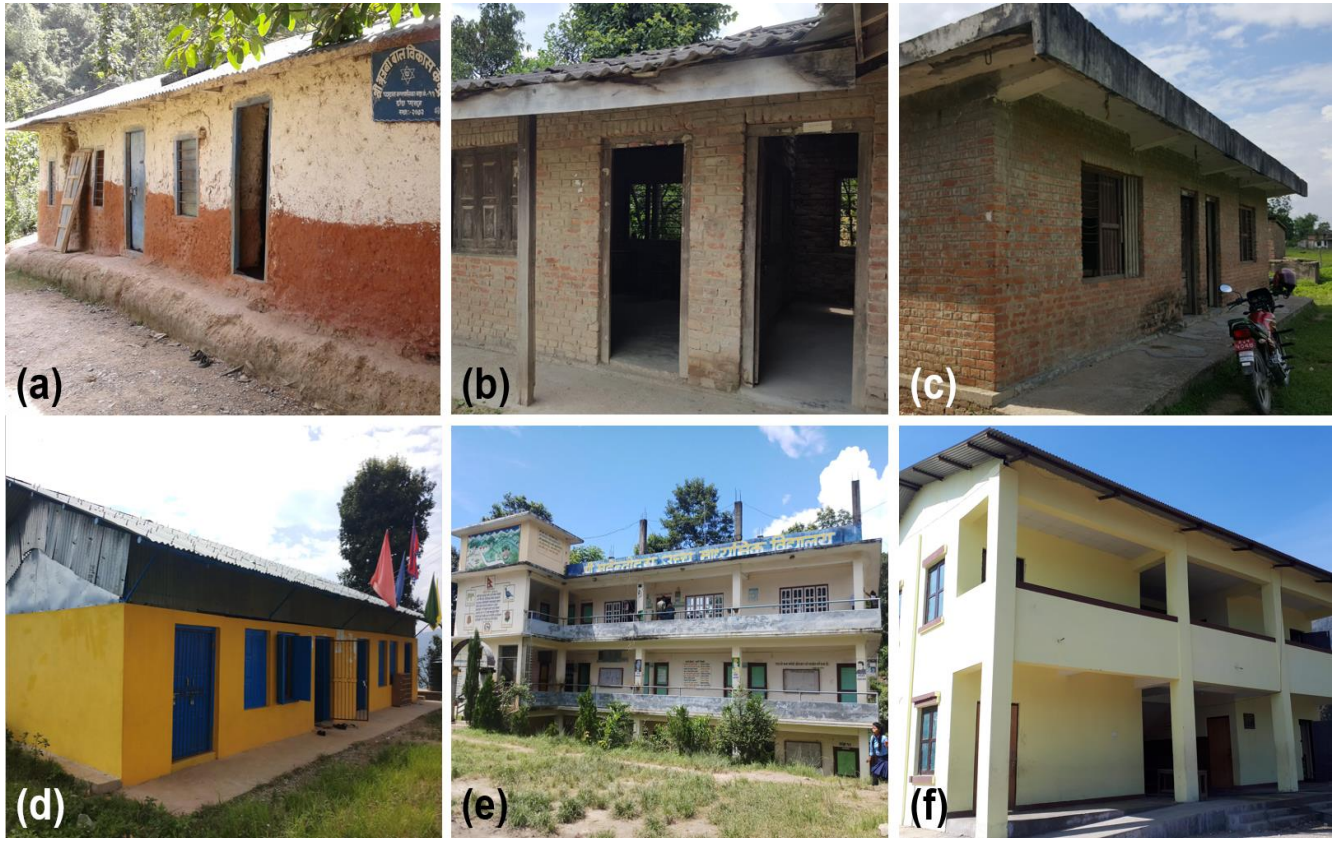
WP4 deliverables

- Fragility curves for URMs: novel closed form solution for out-of-plane assessment
- Fragility curves of RC/infills: Bayesian update of material properties in FAST method

Ongoing:

- Include fragility results in the app (update base-score app)
- Review of damage assessment inspection forms
- Optimum retrofit strategies given damage/vulnerability

Structural typologies



(a) Stone-mud masonry [URM-SM] **(4 App IDs)**
(b) brick-mud masonry [URM-BM] **(4 App IDs)**
(c) brick-cement masonry [URM-BC] **(4 App IDs)**
(d) EAARRP metallic [S] **(4 App IDs)**
(e) non-engineered RC [RC-N] **(12 App IDs)**
(f) engineered RC [RC-E] **(6 App IDs)**

Total: 34/42 IDs

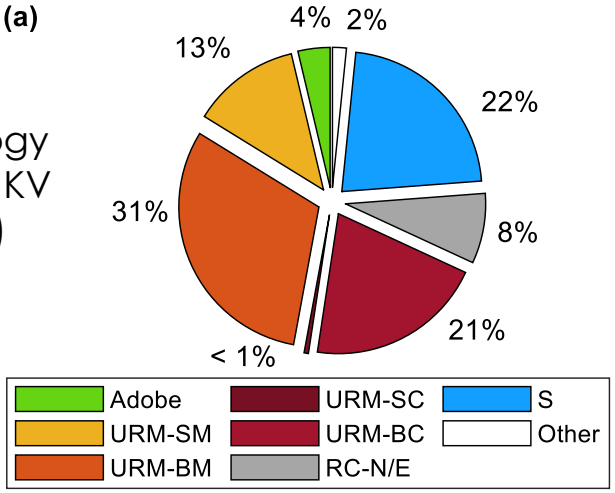
4 IDs - Adobe
2 IDs - Dry-stone
1 ID - Timber
1 ID - Combined system

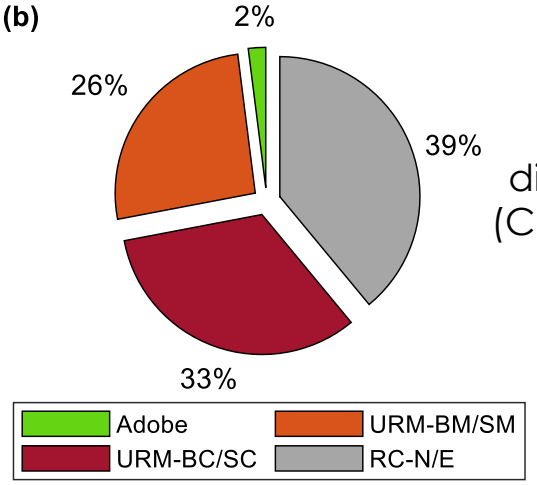
Pictures source: SAFER-App database

Structural typologies

More than 60% are URMs

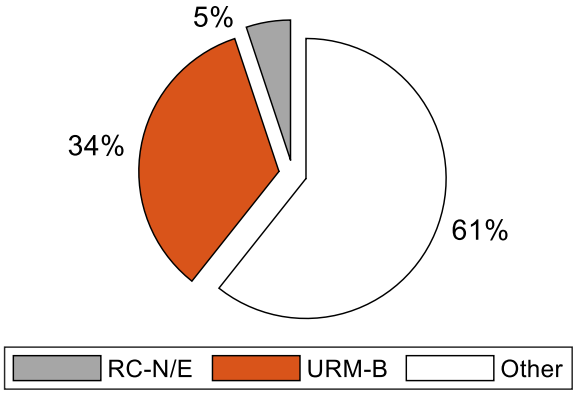
school typology distribution in KV (NSET 2000)

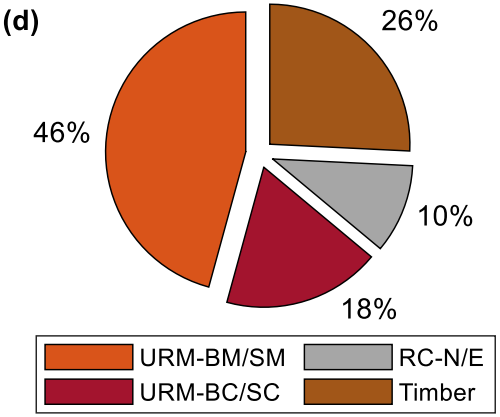




building typology distribution in the KMC (Chaulagain et al. 2016)

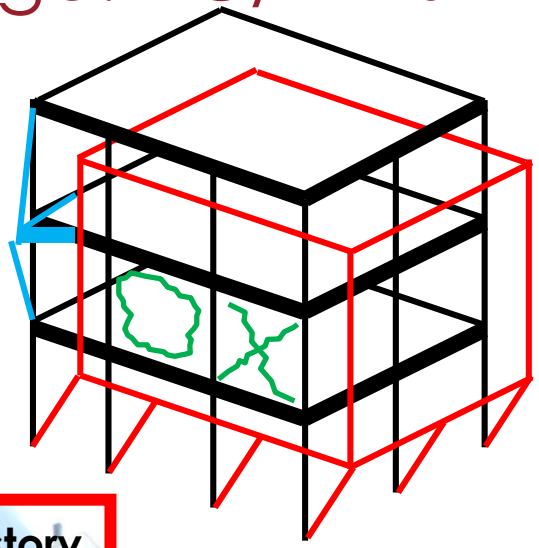
school typology distribution in Nepal (ADB 2014)





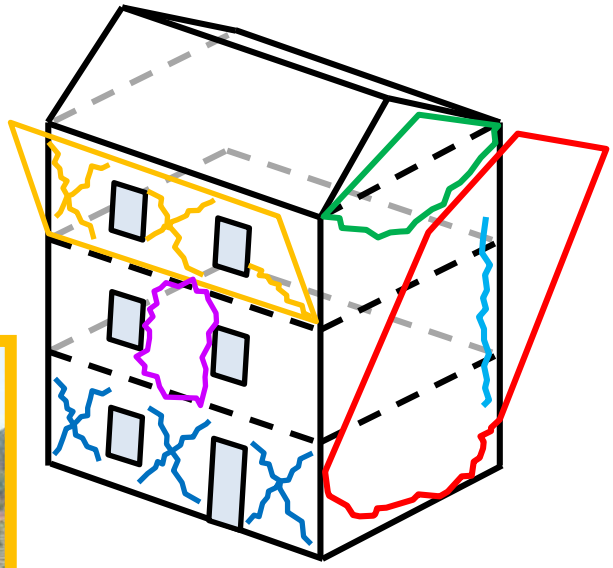
building typology distribution in Nepal by foundation material (Gautam et al. 2018)

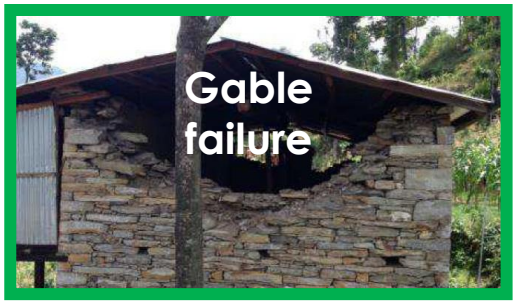
Recurrent damage: RC/infills

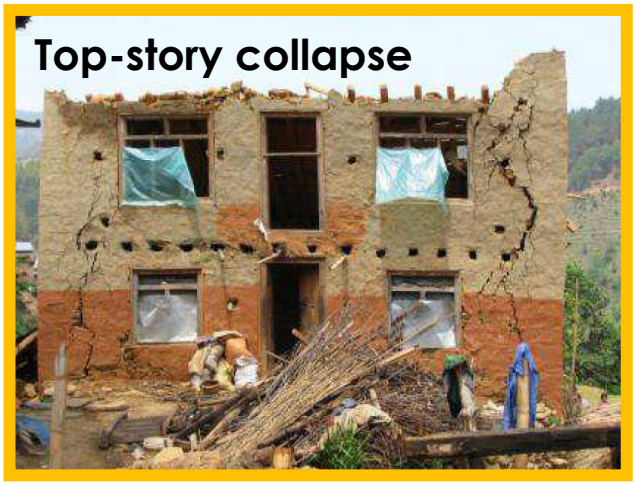


Pictures source: Gautam et al., Build Change, EERI

Recurrent damage: URMs

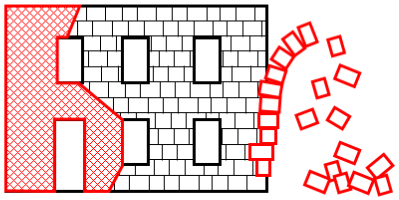
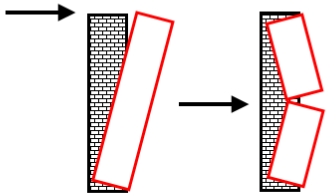
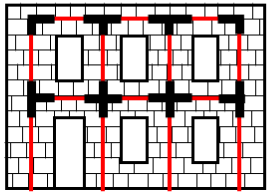
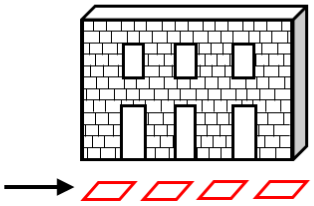
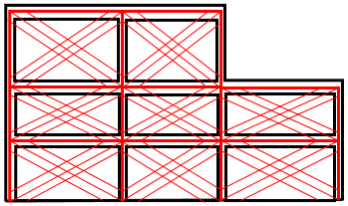
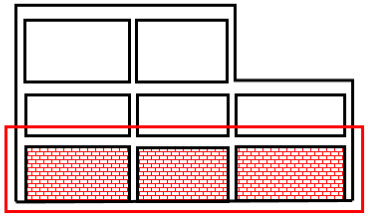






Pictures source: Build Change, AON

Recommendation for the seismic assessment

Structural Type	Detailed assessment	Simplified assessment
Adobe Stone-mud URM Brick-mud URM Metallic (infills)	Finite Element Method (e.g. Lourenço et al. 1998) Discrete Element Method (e.g. Lemos 2007) 	Simplified Rigid block Method (e.g. Doherty et al. 2002) 
Stone cement URM Brick-cement URM	Equivalent Frame Method (e.g. Roca et al. 2004) 	Simplified Mechanical Method (e.g. Lagomarsino et al. 2006) 
RC non-engineered RC engineered	Frame Finite Element Method (e.g. Verderame et al. 2010) 	FAST Method (De Luca et al. 2014) 

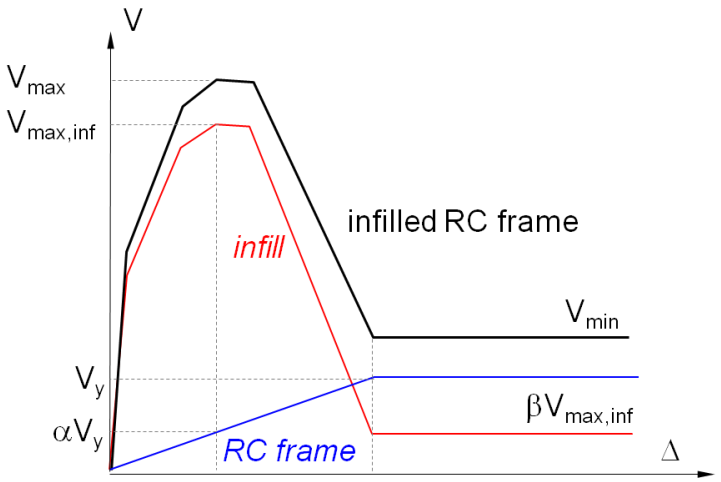
RC/Infills: analytical fragility functions

Approximate definition of the capacity curve → IDA curve defined through proper R-μ-T → Definition of IDR damage thresholds for DS1, DS2, DS3 (EMS 98) → Evaluation of $Sd_{|DSi}$ through approximate deformed shape and Γ → $Sa_{|DSi}$ and $PGA_{|DSi}$ capacity evaluation through the IDA or IN2

CAPACITY CURVE

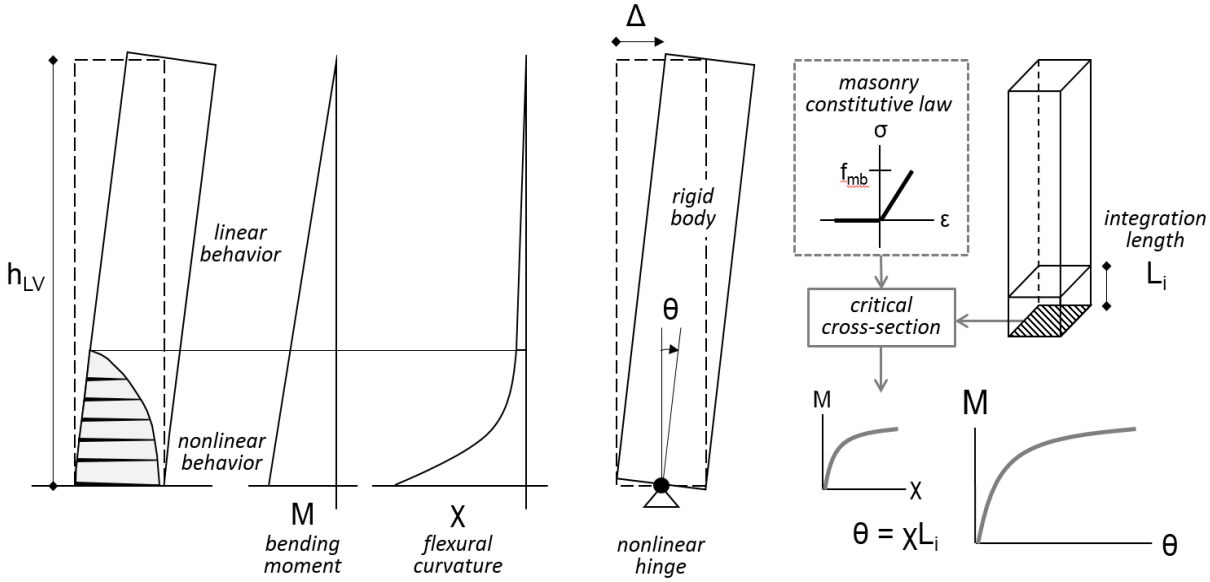
Definition of the quadrilinear backbone of the equivalent SDOF representing a uniformly infilled RC building assuming the hypothesis of first storey plastic mechanism (Dolsek and Fajfar, 2005).

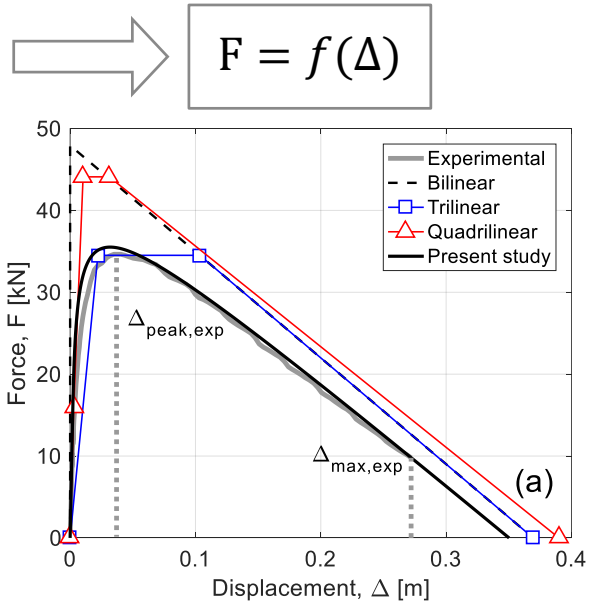
On one hand infill contribution provides an increase of strength and lateral stiffness, on the other hand infills' brittle behaviour causes a strength drop in the capacity curve.



URMs: novel Out-of-Plane assessment method

Out-of-plane failure mode has been recognized as the most recurrent damage for Nepali unreinforced masonry (URM) buildings (Gautam et al. 2016, Sharma et al. 2016, Brando et al. 2017, etc.).

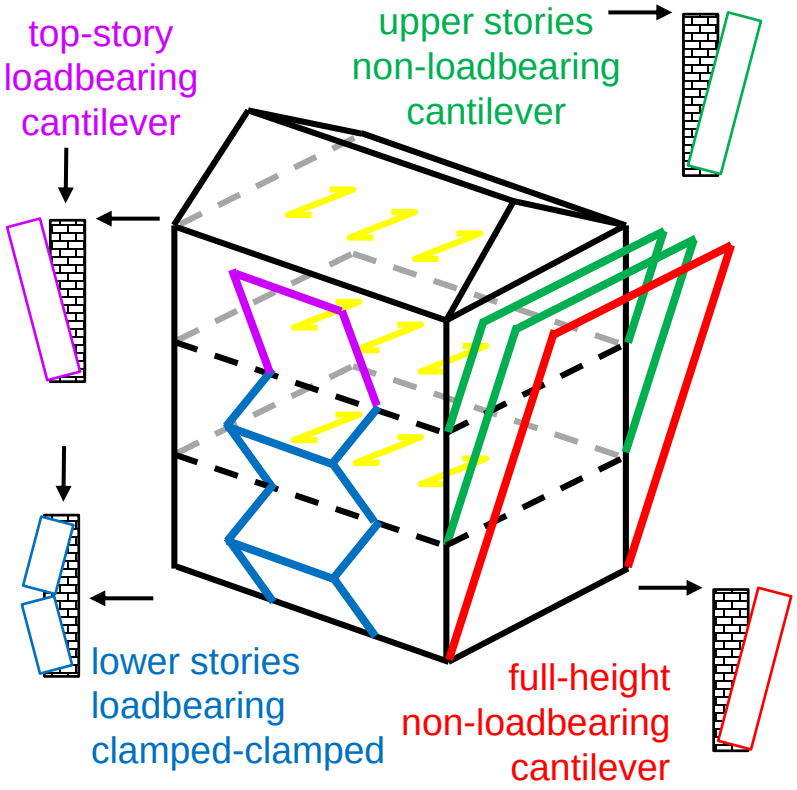




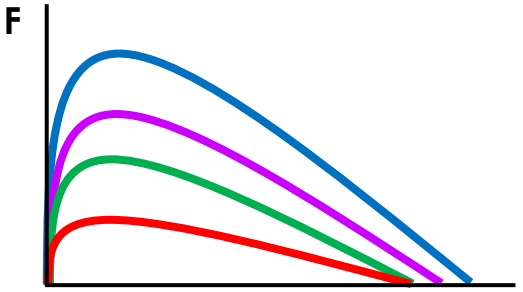
URMs: analytical fragility functions

Out-of-plane damage (OOP) assessment

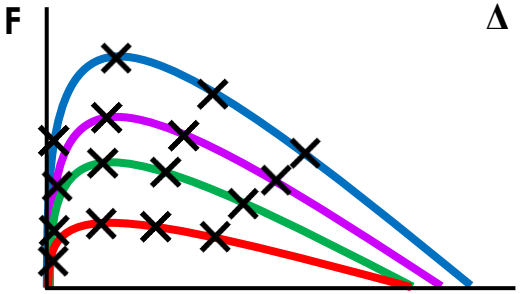
(1) walls classification



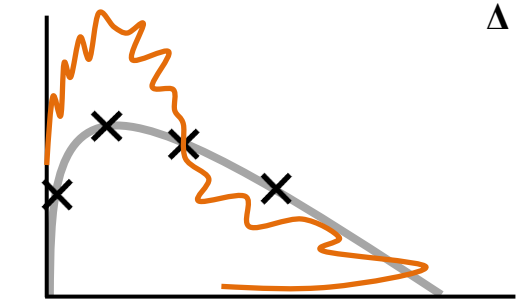
(2) capacity curves



(3) damage states



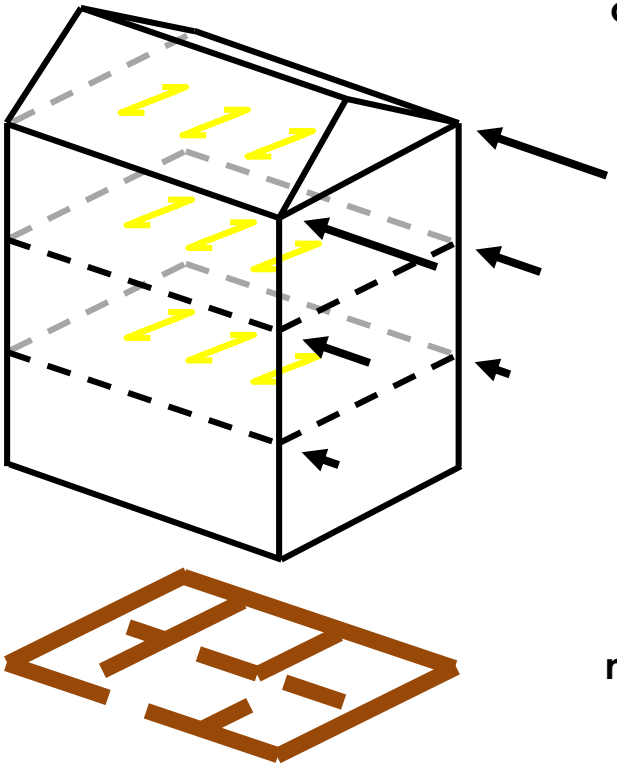
(4) Intensity measures (PGA)



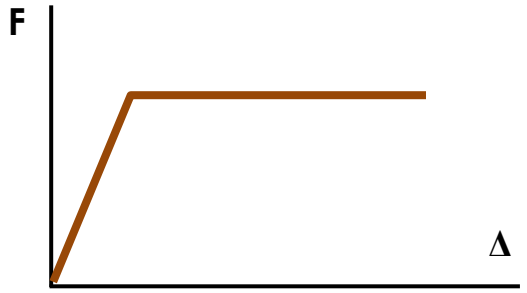
URMs: analytical fragility functions

In-plane damage (IP) assessment (Lagomarsino 2006)

(1) resisting area of the building



(2) capacity curve



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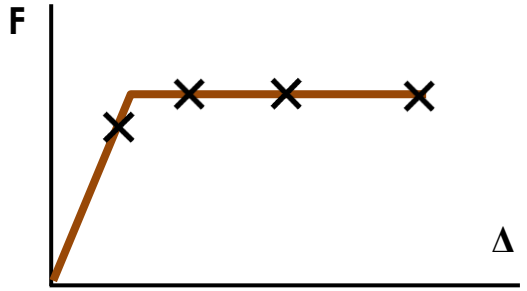

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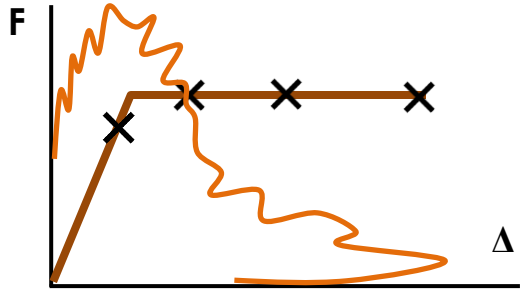

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Thanks!

Questions?

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