

Seismic Retrofit of Reinforced Concrete Buildings in Myanmar

Assessment, strategy and techniques
for existing RC buildings
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Scope and objectives

Part I: Context and Damage Patterns in Myanmar

Part II: Understanding Seismic Risk

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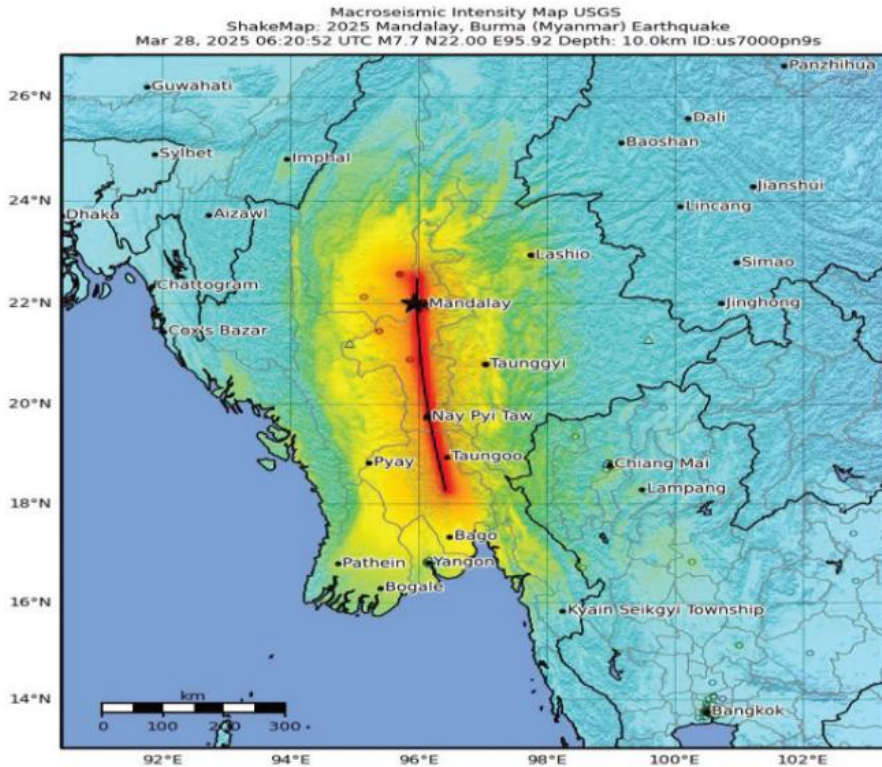
Part IV: Retrofit Design

Part V: Retrofit Techniques and Delivery

Key Takeaways

References

Part I: Seismicity of Myanmar



- Myanmar has a long record of damaging earthquakes, including 1839, 1912, 1930, 1956 and 2016.
- On 28 March 2025, a Mw 7.7 earthquake struck near Mandalay. Rare event: “Supershear” fault rupture, faster than shear waves.

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X-X+

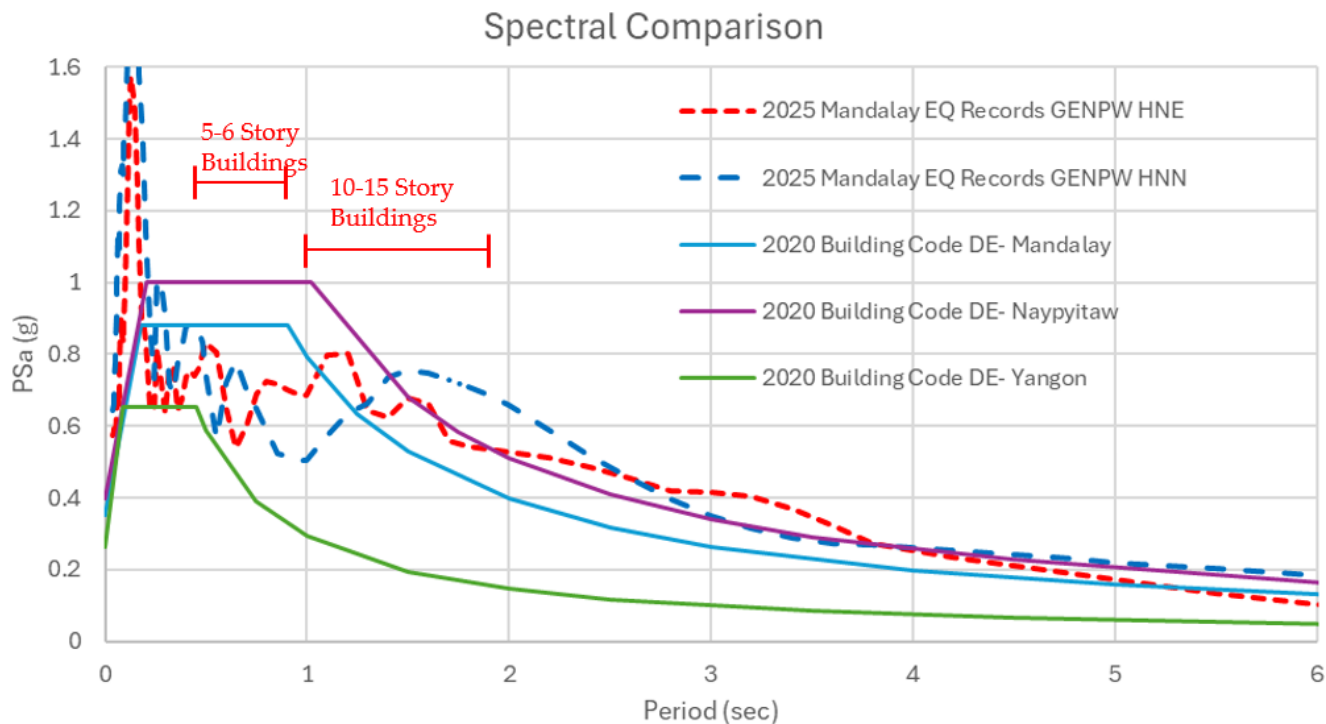
Scale based on Worden et al. (2012)
 △ Seismic Instrument ○ Reported Intensity ★ Epicenter □ Rupture
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USGS ShakeMap, Mw 7.7 Mandalay earthquake (28 March 2025)

(Kassem et al., 2026)

Spectral Demand

Recorded ground motion compared with code design spectra



(Myanmar Earthquake Committee, 2025)

- Recorded demand broadly matched the MNBC (Myanmar National Building Code) 2020 design spectra for Mandalay
- High demand in the 0.3–1.5 s range affected low- to mid-rise buildings
- Severe damage was concentrated in pre-code and non-compliant building stock
- Code-compliant buildings were expected to perform better

Building Vulnerability

Damage driven by hazard and fragility

- About 500,000 buildings exposed
- 100,000 to 150,000 severely damaged or collapsed
- Large share of unreinforced masonry and older reinforced concrete stock
- Many buildings unsafe or restricted

Table 16. Correlation between building typologies and dominant failure mechanisms.

Building Typology	Total Buildings	Dominant Failure Mechanism	Approx. Share of Total Damage (%)
R1-LS	44	Minor non-structural damage	3
R2-MS	78	Minor cracking	5
2 U-2 L	84	Slight column shear	5
2 U-3 L	145	Soft-story deformation	9
4 U-4 L-2B	64	Foundation settlement	4
4 U-4 L-3B	292	Column/joint failure	19
6 U-4 L-2B	541	Soft-story and joint failure	35
6 U-4 L-3B	122	Pounding/infill separation	8
RH-20S-1 L	50	Minor cracking	3
RH-20S-2 L	62	Minor cracking	4
RH-24S-2 L	72	Façade damage	5
DO	2	Total collapse	<1
Total	1556	—	100

Building typologies and dominant failure mechanisms from a post-earthquake field survey of 1,556 buildings

Observed Failure Modes



Damage concentrated in the lower storeys, with progressive collapse of floor and frame elements

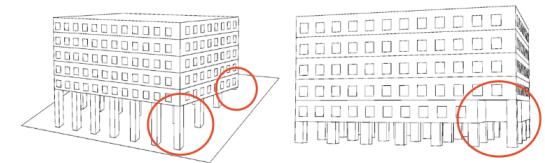
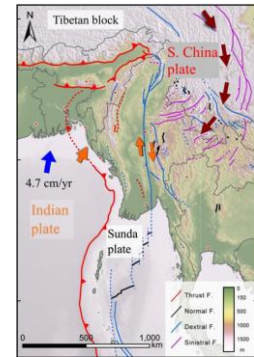
(Kassem et al., 2026)

- Collapses ranged from **lower-storey failure** to **full pancake collapse**
- **Partial collapse** often left upper floors relatively intact
- **Pancake collapse** resulted from **progressive failure** of columns or floors
- These are signs of poor global structural behaviour
- Main causes were **weak lateral systems**, **poor detailing**, and **discontinuous load paths**

Part II: Understanding Seismic Risk

Seismic risk = *hazard* × *vulnerability* × *consequence*

- ▶ **Hazard** is how often and how strongly the ground shakes
 - ▶ ..cannot be changed
- ▶ **Vulnerability** is how much damage the building suffers at that shaking
 - ▶ .. governed by strength, stiffness, configuration, detailing etc.
- ▶ **Consequence** is what the damage costs in repair, casualties and lost function.

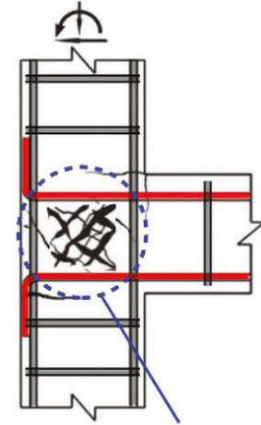


Role of assessment

- ▶ Assessment defines **vulnerability**
- ▶ Provides **a documented basis** for the strengthening

Objectives

- Establish how the **building performs** as it stands
- Identify the **deficiencies in detailing or condition** that point to what needs strengthening



no effective node point for
compression strut

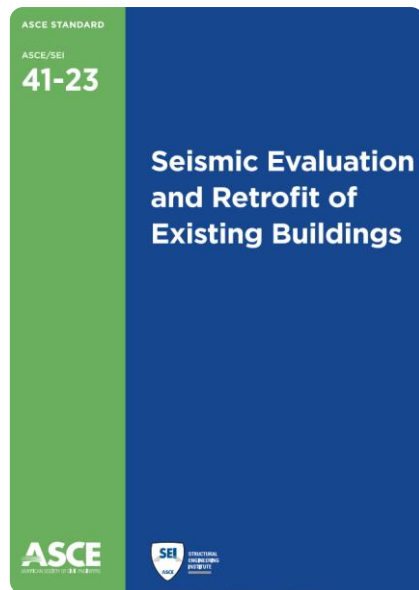
Joint shear damage with
typical 1970s detailing

(Akguzel, 2019)

Considerations & Risks

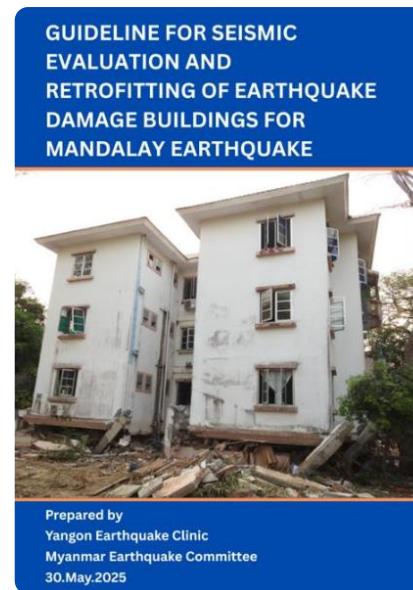
- ▶ The as-built condition should be **measured and tested, not assumed**
- ▶ Reinforcement and detailing are **hidden**; testing reaches a few locations
- ▶ The **original design intent is unknown**, and may not match behaviour
- ▶ More analysis can be **justified** if it shows less retrofit is needed

Which Guidance to Use



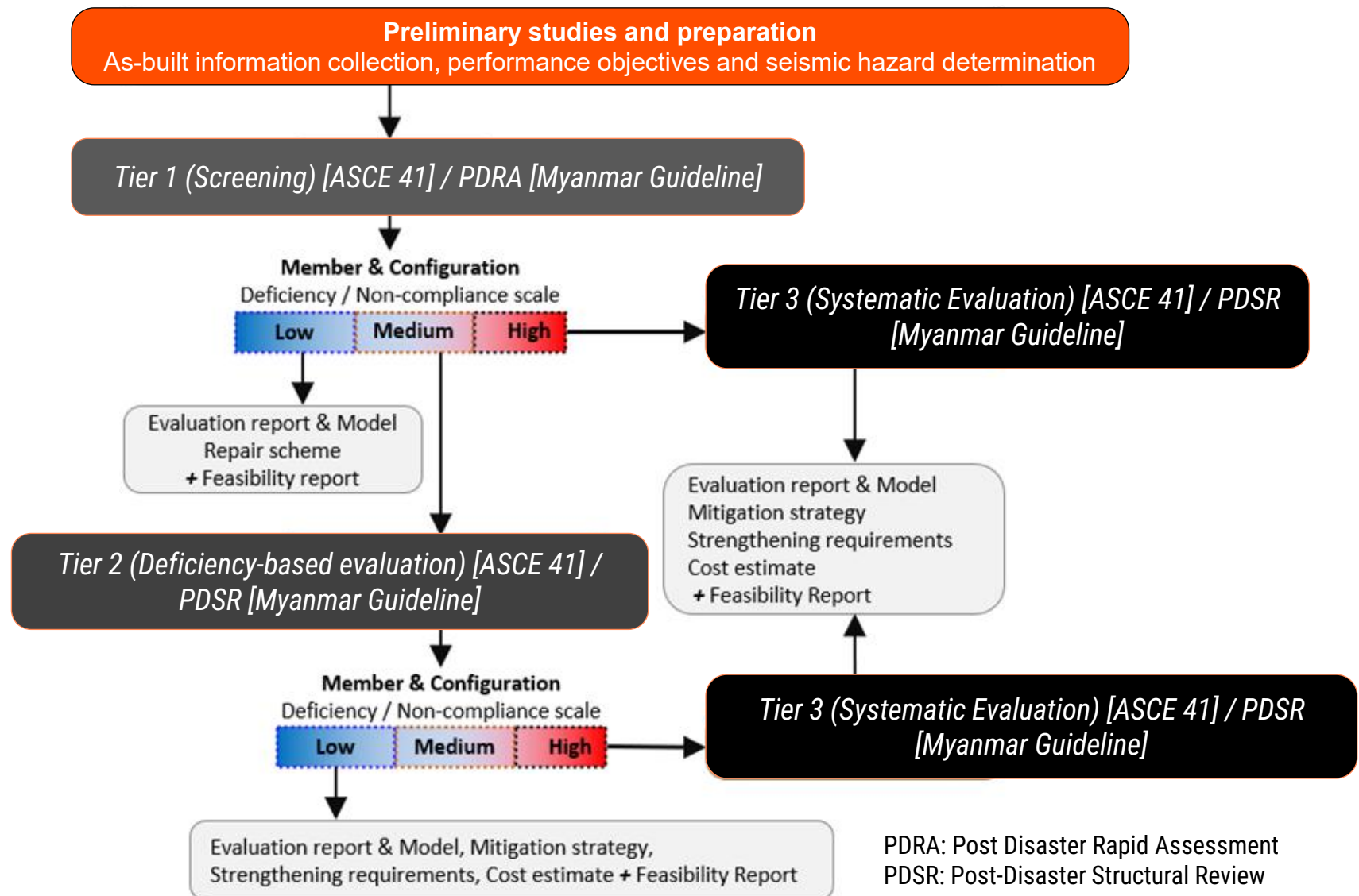
Guidelines for Post-Earthquake Repair and Retrofit of Buildings Based on Assessment of Performance-Critical Damage

FEMA P-2335 / May 2025



Document	Scope	Basis
ASCE 41-23	Undamaged buildings, all types	Deficiency-based
FEMA P-2335	Damaged buildings, concrete only	Damage-based
Myanmar, May 2025	Both. Follows the two above	PDRA and PDSR
NZSEE 2017, Eurocode 8-3	Alternative frameworks	Alternative national approaches

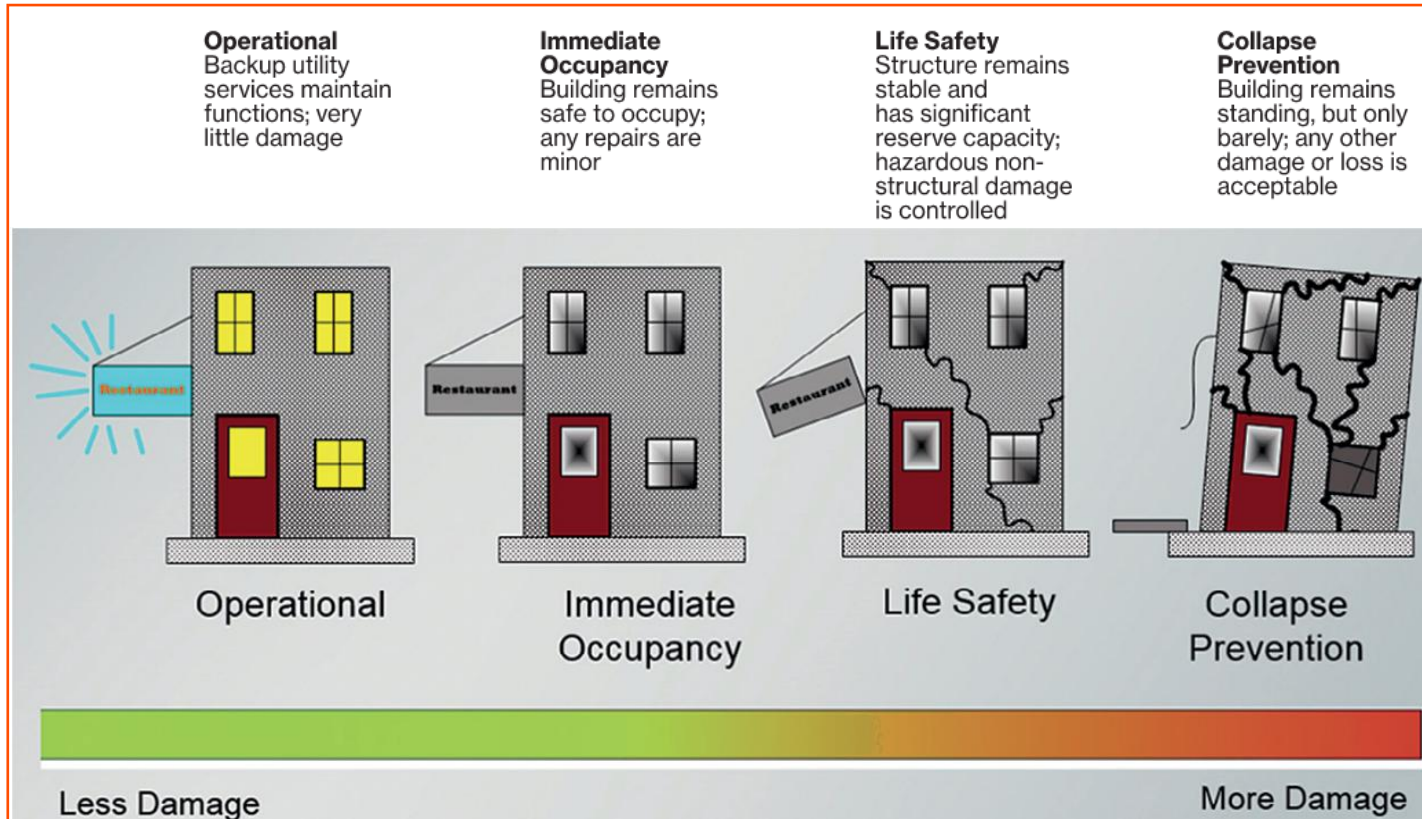
Assessment to ASCE 41



Part III: Retrofit Strategy

Performance objective

A *performance objective* is a *performance level* paired with a *hazard level*



(Silva and Calabrese, 2018)

Performance levels (FEMA 451)

Assessment lets the *client choose the performance and the hazard*

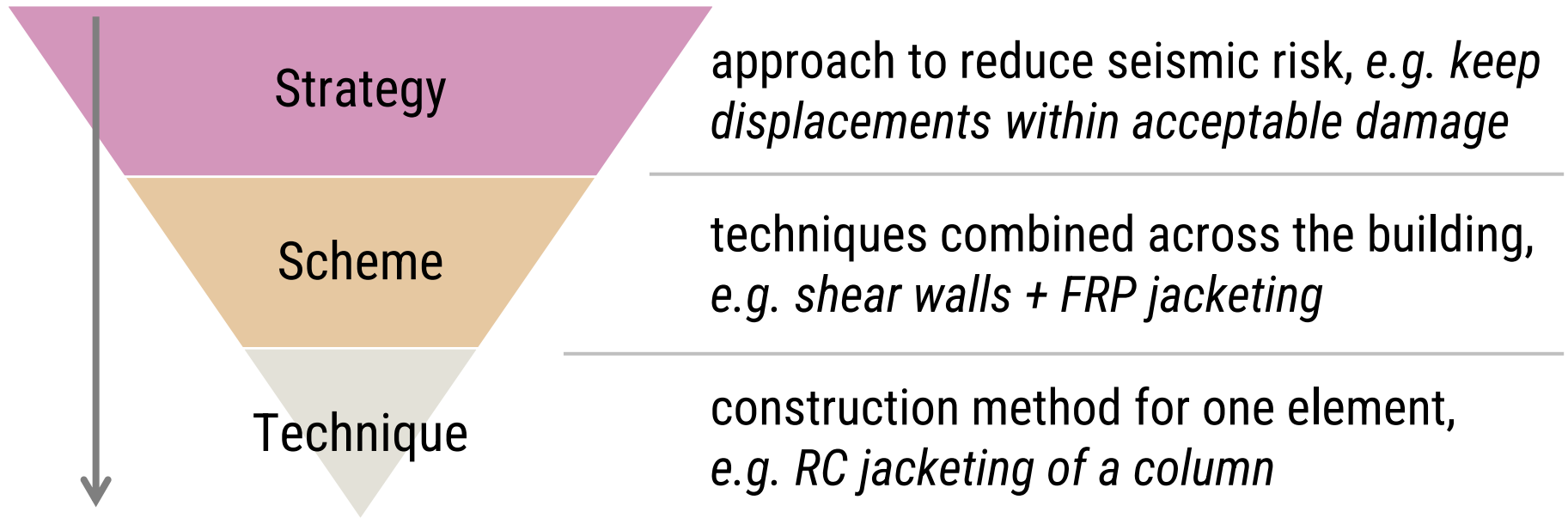
From Assessment Result to Decision

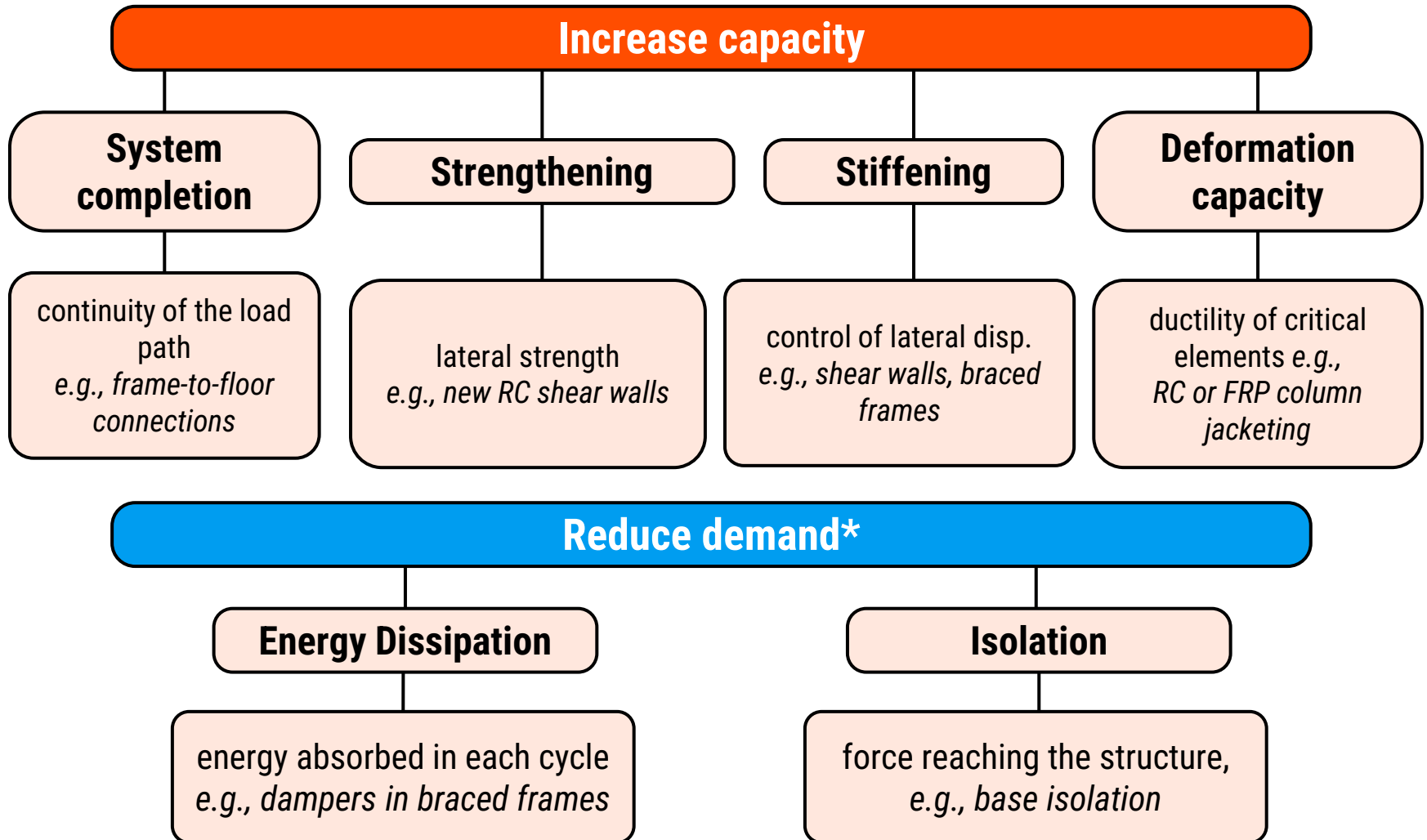
- ▶ **Meets the objective** → accept as is, or repair the damage only
- ▶ **Below the objective** → repair and retrofit together

Option	Action
Accept the shortfall	Owner accepts risk; decision recorded
Refine the assessment	Detailed analysis may change scope
Reduce the objective	Lower occupancy may reduce target
<i>Modify the building</i>	<i>Retrofit structural and non-structural components</i> → STRATEGY

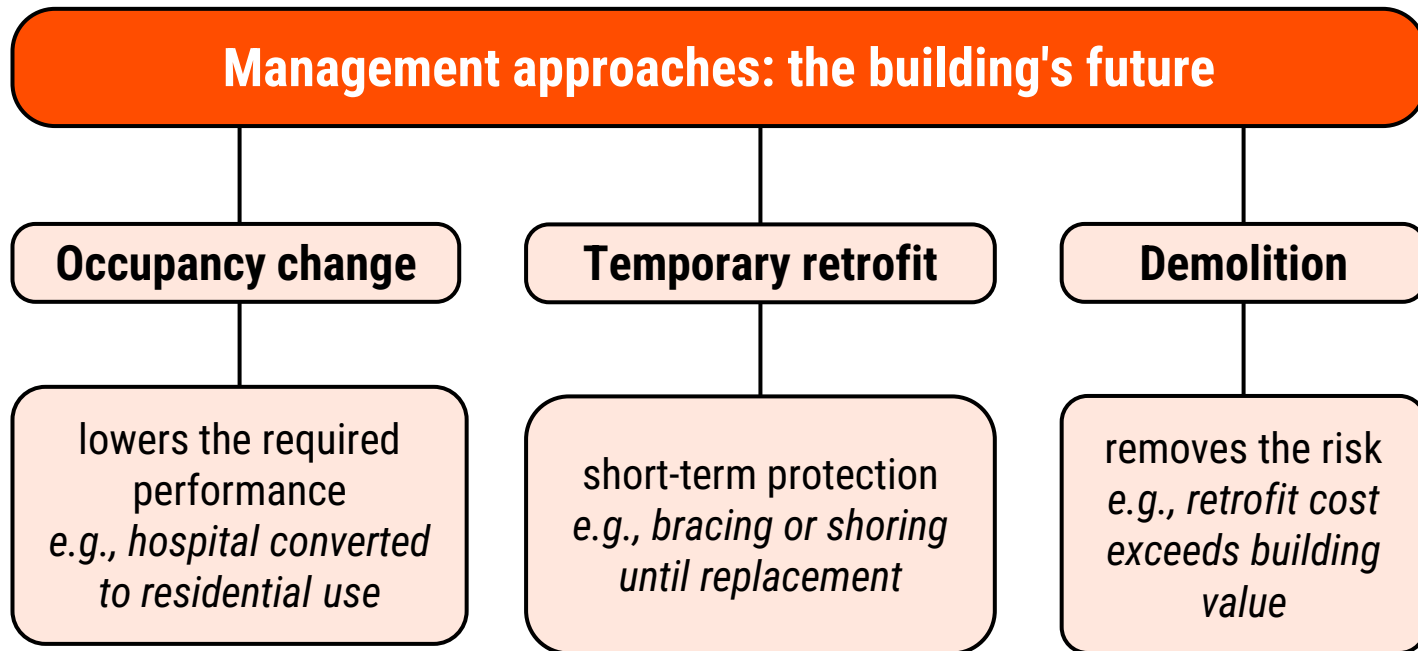
- ▶ **Retrofit not viable** → change the use, or replace

Decision Sequence





**Not covered in this webinar*



Defining the brief

Objective

Performance level and hazard level
e.g., Life Safety at the design earthquake

Scope

Whole building or part?
e.g., ground storey and damaged columns

Legal requirements

What the authority requires
e.g., full upgrade if major work is done

Client constraints

Use, budget, programme
e.g., school must reopen for the new term

Roles

Who designs, checks and approves
e.g., structural, geotechnical, architect, authority

Understanding the existing building

Geometry and loads

Establish the actual load path

Reinforcement and detailing

Identify likely failure modes

Concrete and steel properties

Establish realistic capacity

Damage and deterioration

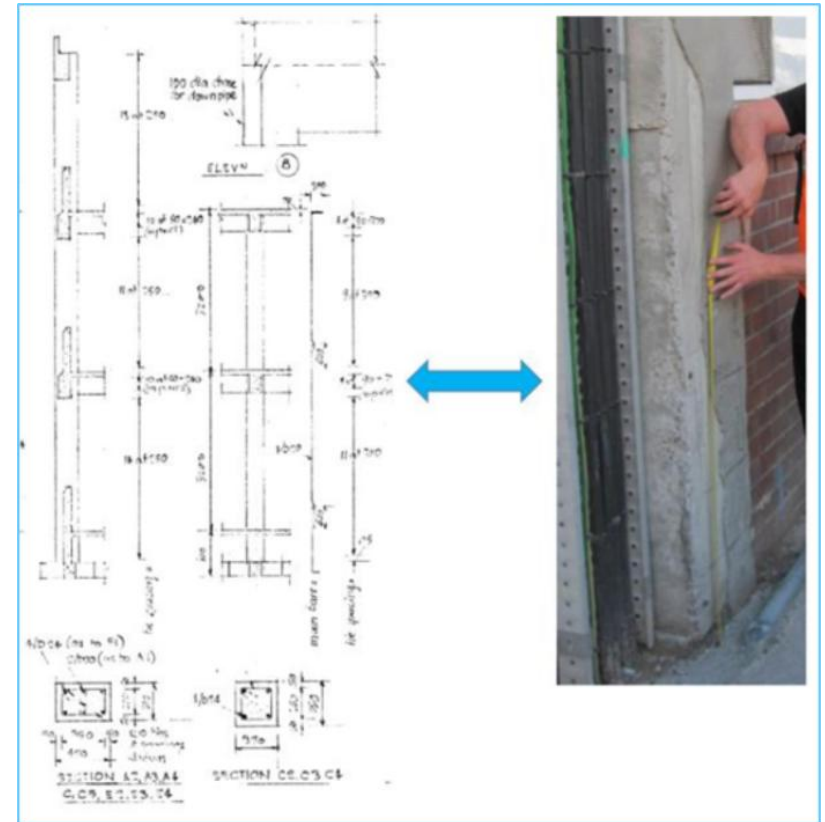
Separate repair from retrofit

Infill and alterations

Identify changes to stiffness and demand

Foundations

Check whether new actions can be transferred



Rebar scanners reveal layout and cover, but
not deformations or 135° hooks

(© Umut Akguzel)

Concept scheme

Develop two or three schemes

Size and locate the major new elements

Use the existing-building assessment procedure

Do not use new-build ductility factors

Protect force-controlled actions and establish the correct strength hierarchy

Ensure ductile yielding occurs before any brittle failure mechanism



Joint failure → shear hinge mechanism



*Better
strength
hierarchy*



Beam hinge → joint remains protected



(© Umut Akguzel)

Part IV: Retrofit Design

Design constraints

Budget

What is the total cost?

Fees, construction, relocation

Function

What space is lost permanently?

Walls affect circulation

Aesthetics

What can be exposed?

Visible bracing or jackets

Uncertainty

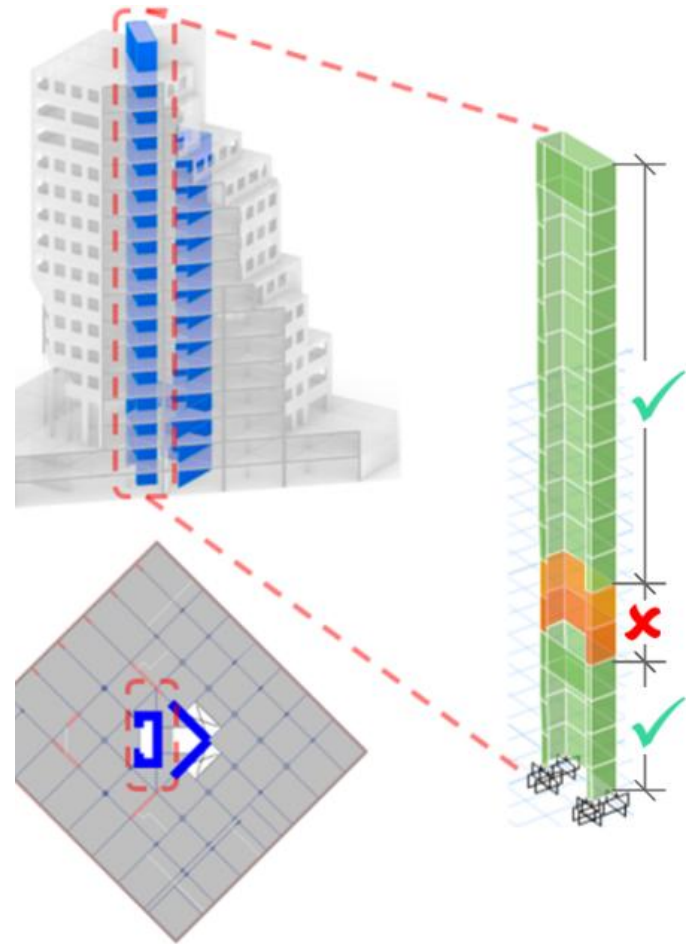
What needs checking?

Rebar, concrete, foundation

Delivery

Can the building stay in use?

Access, phasing, occupied site



Project example for *delivery*: core wall strengthening would block access to upper floors during construction

(© Umut Akguzel)

Part V: Retrofit Techniques and Delivery

Local or global retrofit

Local Retrofit

Fixes specific weak components within a stable structure



(© Umut Akguzel)

Global Retrofit

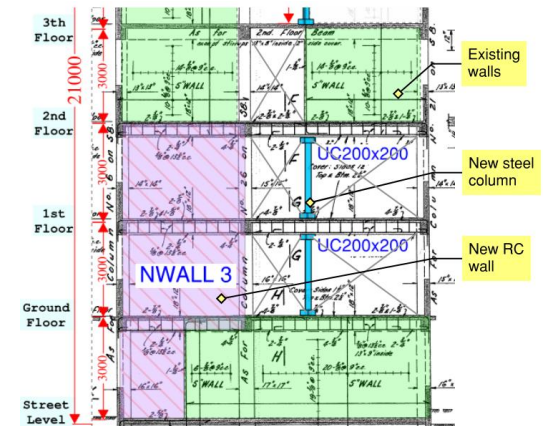
Targets the *whole building system* to alter how the structure handles lateral forces



(Stepinac et al., 2022)

Combined

Addresses both member and system-wide deficiencies.



(© Umut Akguzel)

Example of a building-level problem

- **Plan and vertical irregularities** likely increased vulnerability
- **Open lower levels** likely reduced stiffness and strength
 - Likely **torsional effects** and **soft-storey response**
- **Collapse concentrated in the front wing and lower storeys**
 - Indicates **poor global structural behaviour**



This points to a building-level problem, not only a local defect!

Collapse of an irregular RC hotel building
Jade City Hotel, Nay Pyi Taw, Myanmar

(DesignSafe-CI, 2025)



Before

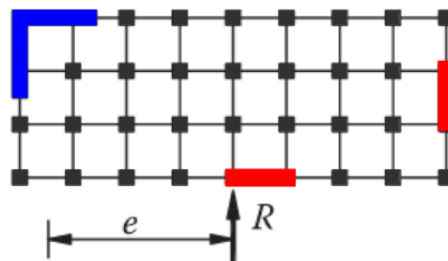
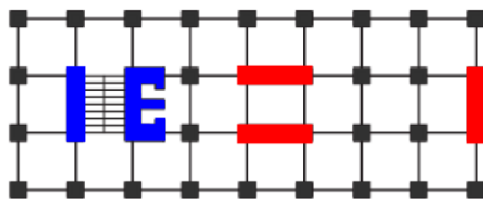


After

Addition of new RC walls

Placement is as important as added capacity

- Distribute new elements to reduce torsion and drift concentration
- Check compatibility between existing and new elements
- Reanalyse the building, including connections and foundations



- Existing shear walls
- Added shear walls

Improvement of stiffness eccentricities with new R/C walls
(Penelis & Penelis, 2014)



External retrofitted concrete shear walls
(Charleson, 2008)

Steel bracing

Options include:

► Braces in frame bay

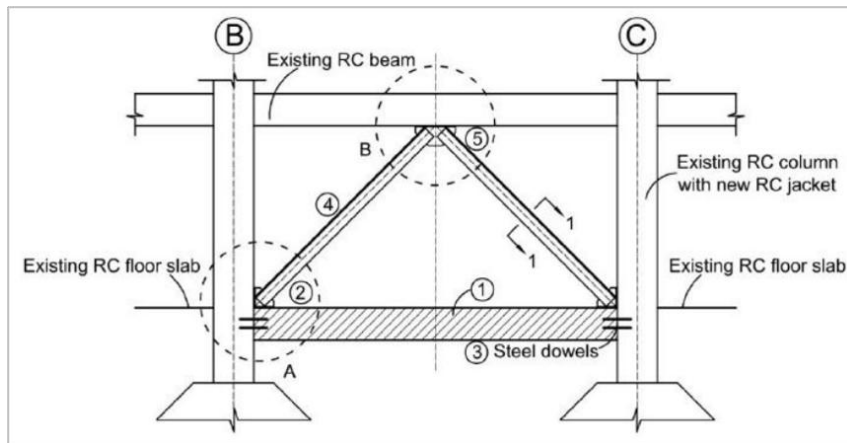
Frame can take brace forces

Higher local forces; tie beam or collectors may be needed

► Braced bay beside or outside frame

Frame too weak for direct bracing

New foundations, anchors, diaphragm connection



Eccentrically braced frames strengthen a reinforced concrete building

(Charleson, 2008)

Added steel bracing in an RC frame: 1 tie-beam; 2 brace-to-column gusset; 3 dowels; 4 double-angle braces; 5 brace-to-beam gusset
(World Bank, 2018)

Existing infill walls

Options include:

► Stiff primary system / new RC walls

Limits adverse infill effects

Major intervention

► Deformable joints

Less in-plane infill action

Gaps needed; still restrain out-of-plane

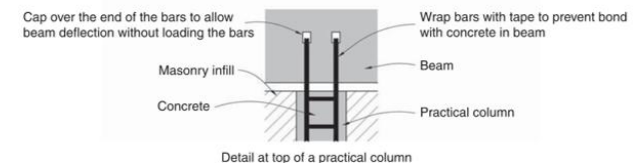
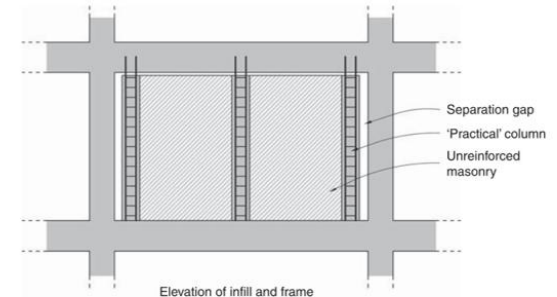
► Out-of-plane restraint

Restrain the wall, not the frame

► FRP strips + anchors

Infill acts structurally

Bond, anchors, specialist work



Separated infill with practical columns for out-of-plane restraint (Charleson, 2008)

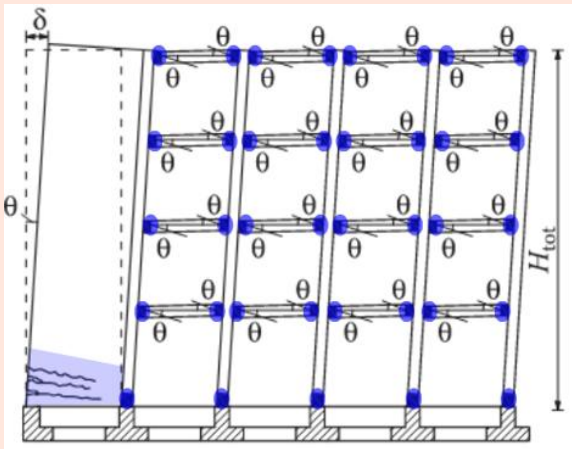


FRP-strengthened infill frame, Istanbul
(Courtesy of OTS Eng. & Consultancy)

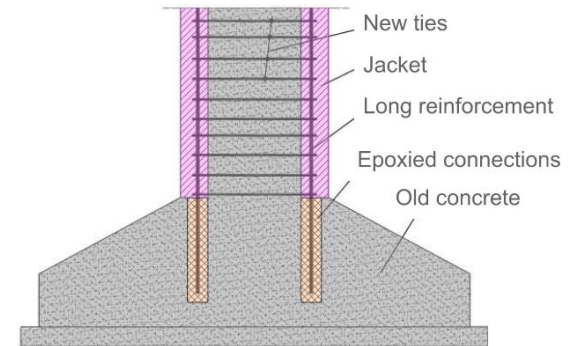
Foundation retrofit

The building must transfer the new forces to the ground

- Foundation design is **part** of the retrofit strategy
- Prefer **yielding above the foundation**



- Check **added** base shear, moment and uplift
- **Reanalyse** foundations when new walls are added
- Foundation damage is **difficult** to repair



Column jacket reinforcement extended and anchored into an enlarged footing to resist increased demand (Penelis & Penelis, 2014)



New wall founded on foundation beam encapsulating footings of nearby columns (Fardis, 2009)

RC columns

Options include:

► RC Jacket

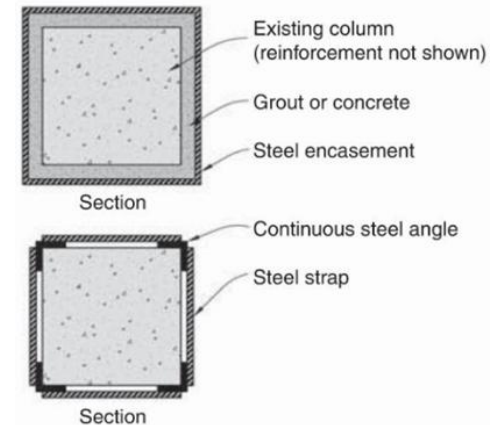
Strength, stiffness and ductility; moment increase only if continuous
Large footprint; check foundation for revised demand

► Steel Jacket

Shear, confinement and lap-splice improvement
Corrosion and weld quality govern; fill all voids with grout

► FRP wraps

Confinement and shear; horizontal fibres for column jacketing
Elastic to sudden rupture; round corners; skilled installation



Steel-jacketed concrete column strengthening (Charleson, 2008)



Connection of jackets to existing columns using dowels and bent-down bars (fib Bulletin 103, 2023)

RC beams

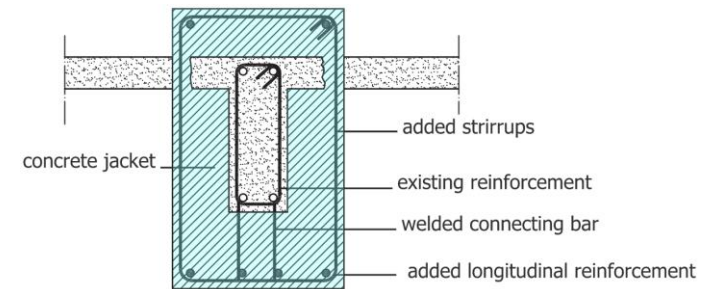
Options include:

► RC jacket

Shear, flexure and confinement; three or four sides
Slab access required; check columns and joints for revised demand

► FRP U-wrap or strips

Shear strengthening without slab drilling; flexural strips where justified
Anchorage and bond govern; check the strength hierarchy



Jacket on four sides of a beam

(Penelis & Penelis, 2014)



FRP for flexural and shear strengthening

(Courtesy of OTS Eng. & Consultancy)

RC beam-column joints

Options include:

- **X-shaped prestressed collars**

External confinement of accessible exterior joints

Not feasible where four beams frame into the joint

- **RC jacketing**

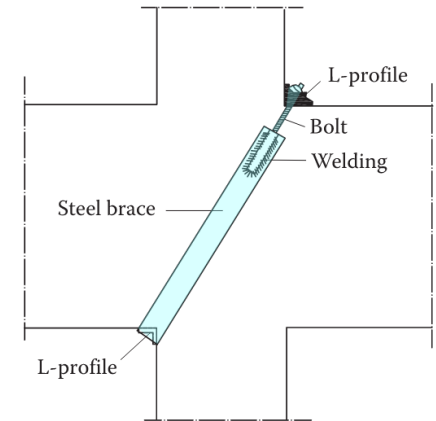
Strengthens and confines the joint and framing members

Slab access required; jacket must engage all framing members

- **FRP with anchors**

Joint confinement and shear strengthening

Slab access required; debonding may govern; check the slab flange effect on the strength hierarchy



X-shaped prestressed collar for an accessible exterior joint. (Penelis & Penelis, 2014)



Installation of an FRP dowel through the bonded sheet into the beam.

(Quintana Gallo et al., 2022)

RC walls

Options include:

► RC jacket

Overlay for shear; end thickening for confinement and bending

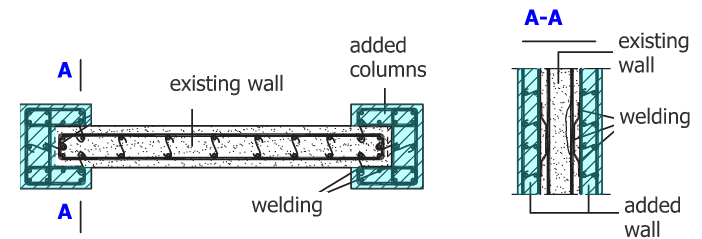
Connection and foundation govern the retrofit

► FRP sheets with anchors

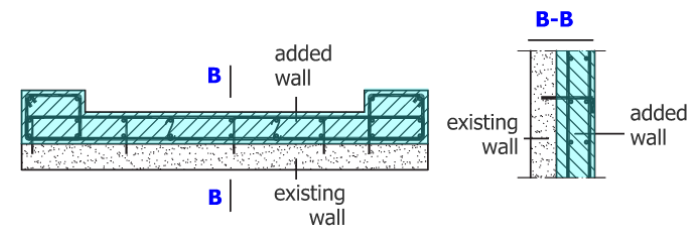
Shear strengthening with minimal added thickness

Anchorage, fire protection and specialist installation*

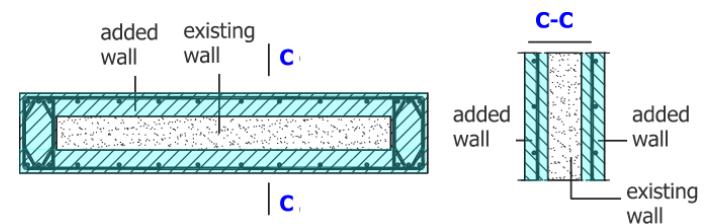
** Resin and adhesive may deteriorate early; protect or verify the unstrengthened member*



thickenings at the ends of the existing wall



one sided jacket with end-thickenings



jackets, on both sides of the existing wall

RC wall jacket options

(Penelis & Penelis, 2014)

RC slabs

Options include:

► **Thickening**

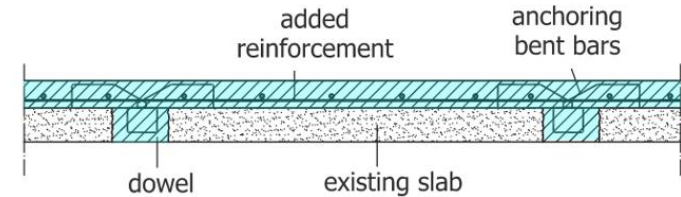
Adds flexural capacity with new concrete and bars
Connect new to old; top-face raises floor level

► **FRP strips or sheets**

Flexural or shear strengthening with minimal added thickness
Bond and anchorage govern; fire protection required

► **Punching shear reinforcement**

Post-installed shear bolts or FRP anchors around slab-column connections
Locate existing bars before drilling



Top-face strengthening
(Penelis & Penelis, 2014)



Slab strengthening with FRP
(© Umut Akguzel)

Quality checks by stage

Stage/Area	What to do	Why
Design	Independent review	Catches errors early
Before construction	Confirm site conditions	Drawings may not match
During construction	Designer stays involved; prop and sequence	Hidden damage; temporary weakness
Materials	Test special materials e.g., FRP, resins	Behave differently from ordinary concrete
Handover	Record and mark	Protect from future works



Site inspection of FRP slab
strengthening
(© Umut Akguzel)

Retrofit is engineering judgement, not a recipe Every building is different

1. Understand the building first

Diagnose damage and deficiency before choosing a technique.

2. Fix the mechanism, not just the strength

Beams yield first; columns and joints stay protected.

3. Think system, not member

Every change moves demand somewhere else.

4. Choose what can be built well

A simple, well-built fix beats an advanced, poorly built one.

5. Stay safe and flexible on site

Prop during the works. Expect surprises.

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Thank you

Questions and discussion