Seismic Rehabilitation of Low-Rise Industrial Buildings

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Low-Rise Industrial Buildings

- **Turkey**
  - Precast concrete frames
  - Large interior spaces
  - Vulnerable to earthquake damage

- **US**
  - Tilt-up walls with timber roof diaphragms
  - Large interior spaces
  - Vulnerable to earthquake damage
  - Rehabilitation strategies were successful in Northridge earthquake
Precast Concrete is the most common structural system for warehouses and light industrial facilities in Turkey.

Most precast industrial buildings are one story in height and are characterized by long roof spans.
Precast Industrial Buildings

- Gutter Beam
- Roof Girder
- Precast Column
- Socket Footing
Precast Industrial Buildings

- Transverse Bay Width: 10 - 25 m
- Longitudinal Bay Width: 6 - 8 m
- Story Height: 6 - 8 m
- Longitudinal Bay Width: 6 - 8 m

Diagram: Purlins
Earthquake Demand

- 11 ground motion records from the Kocaeli earthquake ($M_w = 7.4$)
  - IZT, YPT, SKR, GBZ, ARC, DZC
  - Four records from soft soil sites, five records from stiff soil sites, two records from rock sites

- 4 ground motion records from the Düzce earthquake ($M_w = 7.1$)
  - DZC, BOL
  - Four records from soft soil sites
Parametric Study

Prototype building from Adapazarı

- Four transverse bays at 20 m
- Twenty-six longitudinal bays at 7.5 m
- 7-m story height

Eight column sizes

- 40 x 40 cm
- 80 x 80 cm
Stiff Soil/Rock Sites

Calculated Drift at Yield

- 40x40-cm column
- 50x50-cm column

Drift Ratio, %

Period, sec

Maximum
Mean
Minimum
Soft Soil Sites

- Calculated Capacity
- 40x40-cm column
- 80x80-cm column
- 50x50-cm column
- Maximum
- Mean
- Minimum

Drift Ratio, %

Period, sec

Calculated Capacity

40x40-cm column 80x80-cm column 50x50-cm column
Implications for Rehabilitation

Target performance is highly dependent on soil conditions.

- For stiff soil/rock sites modest increases in strength and stiffness are required.
- Increasing column size may not be sufficient for soft soil sites.
Tilt-Up Industrial Buildings
Tilt-Up Industrial Buildings

Diaphragm flexes

Transverse walls resist In-plane shear

Direction of ground motion

Longitudinal panels are subjected to out-of-plane deformations
Vulnerable Connections

Concrete tilt-up panel

Plywood sheathing

Subpurlin

Ledger

EQ force
1994 Northridge Earthquake

- 400 of 1200 tilt-up structures in the San Fernando Valley sustained significant structural damage.
- City of Los Angeles adopted an ordinance to require repair of vulnerable tilt-up structures in 1994.
- 60 tilt-up structures had been strengthened voluntarily at the time of the Northridge earthquake.
Chatsworth Example

- **Building A**
  - Constructed in 1969
  - 207 by 180 ft
  - Strengthened in 1993
  - No structural damage.

- **Building B**
  - Constructed in 1970
  - 207 by 180 ft
  - Serious structural damage and partial collapse of roof.

- **Building C**
  - Constructed in 1977
  - 200 by 185 ft
  - Serious structural damage and partial collapse of roof.
Structural Rehabilitation

- Installed anchors to transfer diaphragm forces into walls.
- Installed anchors to prevent glulam beams from unseating.
- Strengthened splices in glulam beams.
- Added continuous diaphragm chord.

Diaphragm has been strengthened and relative movement among structural elements has been minimized.
Improved Connections

Concrete tilt-up panel

Plywood sheathing

EQ force

Steel connector

Adhesive Anchor

Ledger

Concrete tilt-up panel
Summary

- The diaphragm is the critical element in older tilt-up structures. Increasing the strength of the diaphragm improves the seismic response dramatically.

- Strengthening the columns alone is not likely to be sufficient for precast industrial structures in regions of soft soil. Providing connections among members at the roof level is critical for these structures.