Program celoživotního učení

Národní agentura pro evropské vzdělávací programy

SEISMIC PERFORMANCE EVALUATION OF REINFORCED CONCRETE BUILDING IN TURKEY

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Outline

- Observed damages in past earthquakes
- Turkish Earthquake Code-2007
- Seismic Evaluation of a Typical School Building
- Field Assessment
- Office Work
- Typical Retrofit Examples in RC Structures

Destructive Earthquakes in Turkey

Date (dd/mm/yy)	Magnitude	Location	# of deaths	# of injured	# of heavily damaged buildings	Latitude (N)	Longitude (E)	Depth (km)
13.03.1992	M_s = 6.8	Erzincan	653	3 850	6 702	39.68	39.56	27
01.10.1995	M_s = 5.9	Dinar	94	240	4 909	38.18	30.02	24
27.06.1998	M_s = 5.9	Adana Ceyhan	146	940	4 000	36.85	35.55	23
17.08.1999	M_s = 7.4	Kocaeli	15 000	32 000	50 000 or 100 000 residences	40.70	29.91	20
12.11.1999	M_w = 7.2	Duzce	845	4 948	15 389	40.79	31.21	11
03.02.2002	M_w = 6.5	Afyon-Sultandagi	42	325	4 401	38.46	31.30	6
01.05.2003	M_w = 6.4	Bingol	176	521	1 351	38.94	40.51	6

General Observations

- Mid-rise RC buildings with low technology engineered residential construction have been responsible for considerable life and property losses during seismic events
- Structural damages were mostly due to repetition of well known mistakes of the past in the design and construction of reinforced concrete buildings
- Damaged buildings generally had irregular structural framing, poor detailing, and no shear walls
- Turkey has a modern seismic code that is compatible with the codes in other seismic countries of the world

General Observations (Cont'd)

- Altering the member sizes from what is foreseen in the design drawings
- Poor detailing which do not comply with the design drawings
- Inferior material quality and improper mix-design
- Changes in structural system by adding/removing components
- Reducing quantity of steel from what is required and shown in the design
- Poor construction practice

Assessment of Existing Buildings

- Improved design requirements can reduce damage in newer buildings. However, more than 50% of construction activities concern existing buildings as stated in Handbook 1.
- ISO 13822 provides general principals for the assessment of existing structures.
- In recent years, a lot studies were arried out for assessment and retrofit of existing buildings.

Turkish Earthquake Code-2007

- Following 1999 Kocaeli Earthquake, many strengthening and retrofit of damaged buildings are carried out without any fundamental document.
- TEC-2007 includes a chapter for performance assessment and seismic retrofit of existing structures adapted from FEMA-356.

Seismic Retrofit in Turkey- Current Stage

- Public Buildings: Hospitals, School and other public buildings
- Urban development –Urban transformation law in order to minimize potential earthquake losses.

Assessment of a Typical Public Building

- Seismic Assessment Steps
  - Building properties: geometry and element size
  - Material properties: concrete strength and steel properties, soil properties
  - RC element properties; amount of longitudinal and lateral reinforcement
  - Existing damage state
- Laboratory work to determine concrete strength and soil properties
- Modeling of building
  - Performance assessment

Evaluation of a Typical Public Building

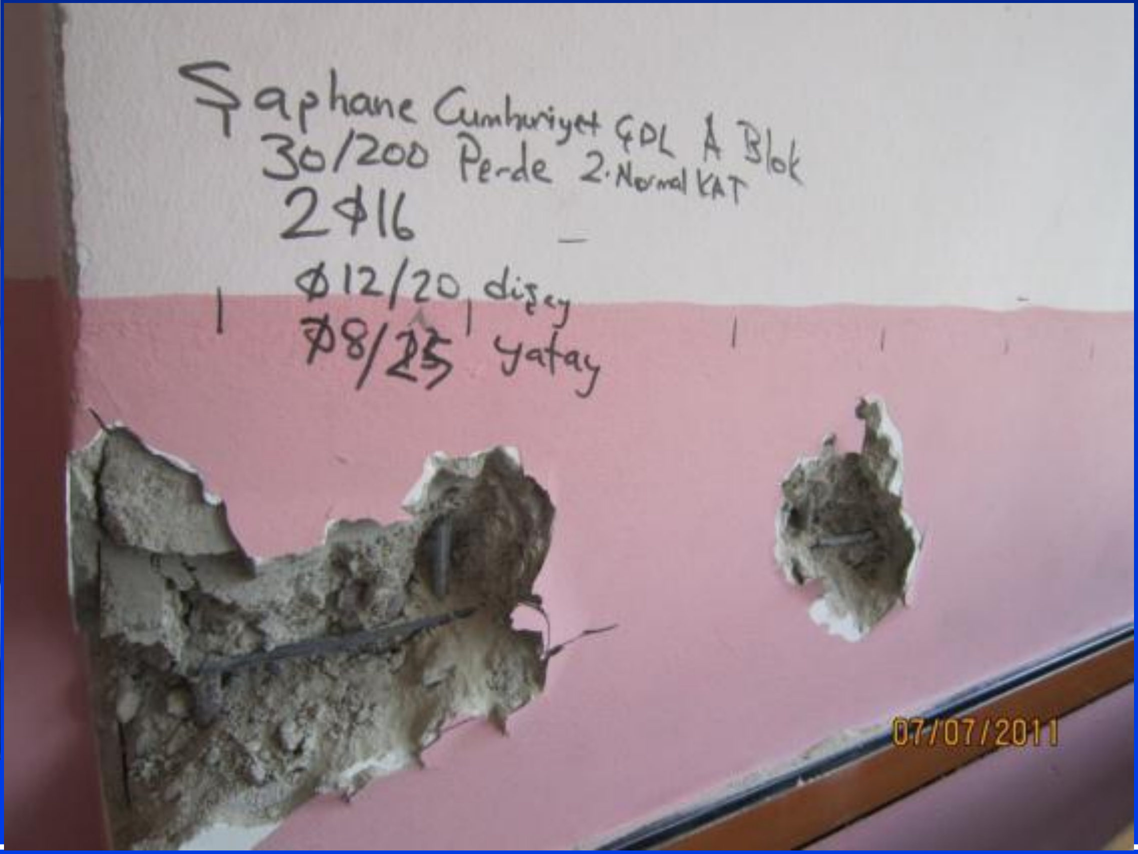
- Seismic Performance Evaluation
  - Whether the buildings satisfy performance objectives?
  - Seismic retrofit and strengthening required, economical / not economical, demolish and reconstruct.

Typical School Building

Foundation Details and Soil Properties

Reinforcement Details

Reinforcement Details

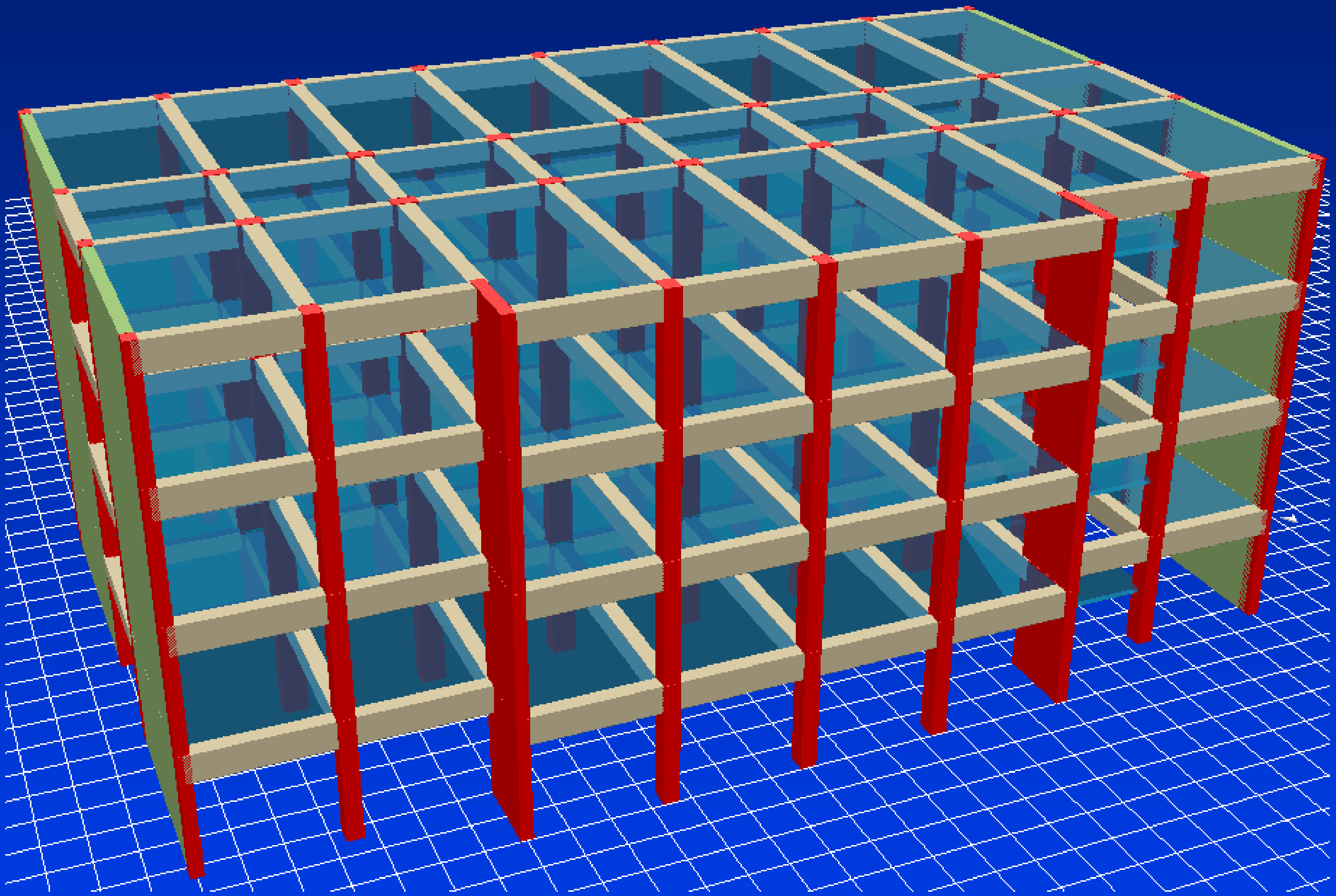


Concrete Strength: Core Samples

Finishing-Reparing Mortar

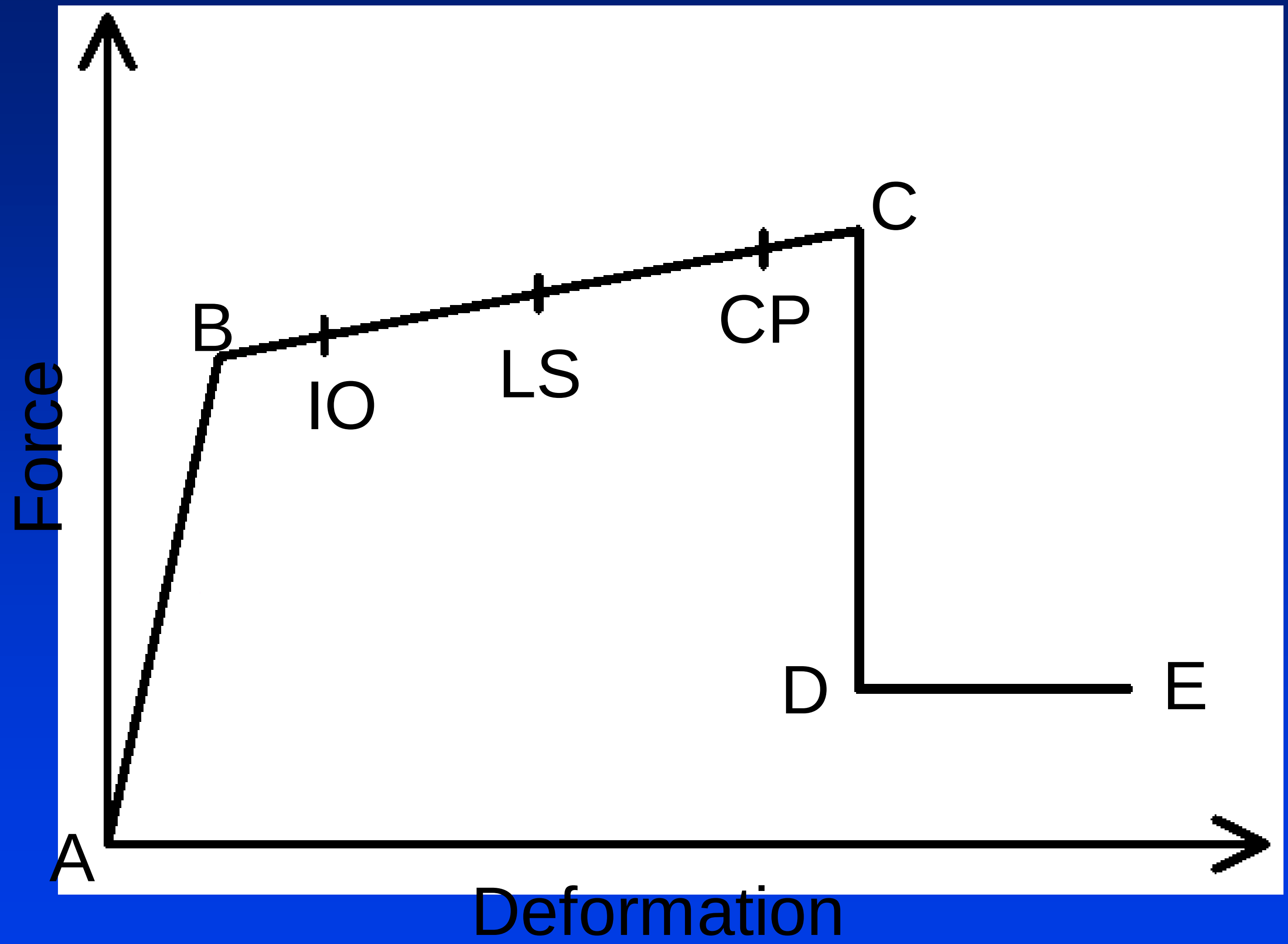
Laboratory Testing of Core Samples

Modelling



- Modelling details can be found in Chapter 3 of Handbook 2

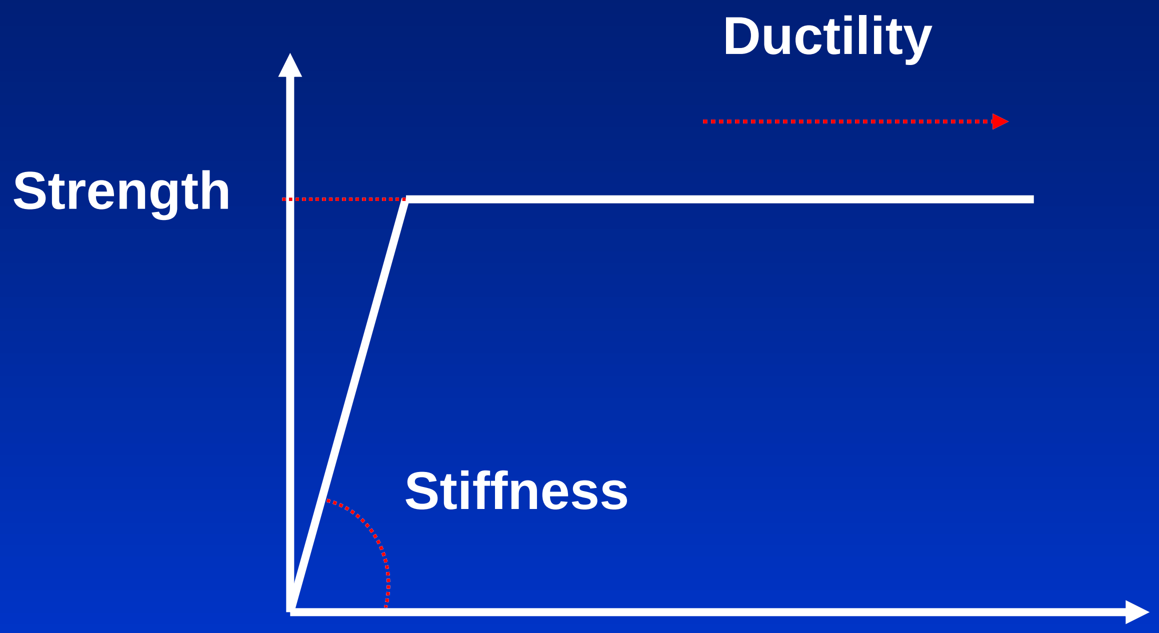
Performance Assessment



Performance Evaluation

Performance Level	Performance Criteria
Immediate Occupancy (IO)	1.There shall not be any column or shear walls beyond IO level. 2.The ratio of beams in IO-LS region shall not exceed 10% in any story. 3.There shall not be any beams beyond LS. 4.Story drift ratio shall not exceed 0.8% in any story.
Life Safety (LS)	1.In any story, the shear carried by columns or shear walls in LS-CP region shall not exceed 20% of story shear. This ratio can be taken as 40% for roof story. 2.In any story, the shear carried by columns or shear walls yielded at both ends shall not exceed 30% of story shear. 3.The ratio of beams in LS-CP region shall not exceed 20% in any story. 4.Story drift ratio shall not exceed 2% in any story.
Collapse Prevention (CP)	1.In any story, the shear carried by columns or shear walls beyond CP region shall not exceed 20% of story shear. This ratio can be taken as 40% for roof story. 2.In any story, the shear carried by columns or shear walls yielded at both ends shall not exceed 30% of story shear. 3.The ratio of beams beyond CP region shall not exceed 20% in any story. 4.Story drift ratio shall not exceed 3% in any story.

RETROFIT



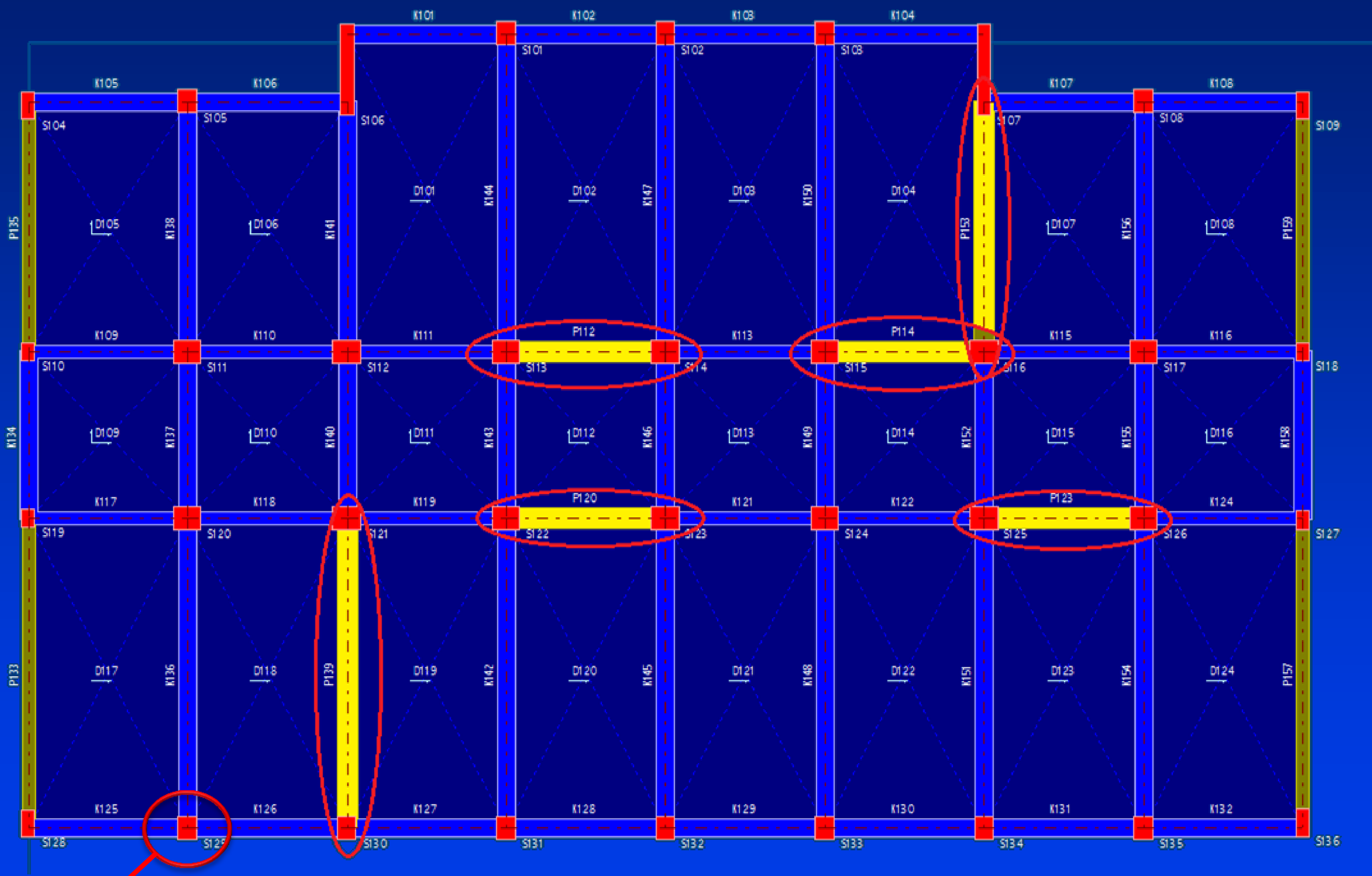
Source(s) of problem ?

- **Insufficient stiffness ?**
- **Insufficient strength ?**
- **Insufficient ductility ?**

Typical Retrofit Applications for RC Buildings

- Adding / strengthening of shear walls
- Strengthening of columns
- Strengthening of beams
- Strengthening of foundations

Story Plan View



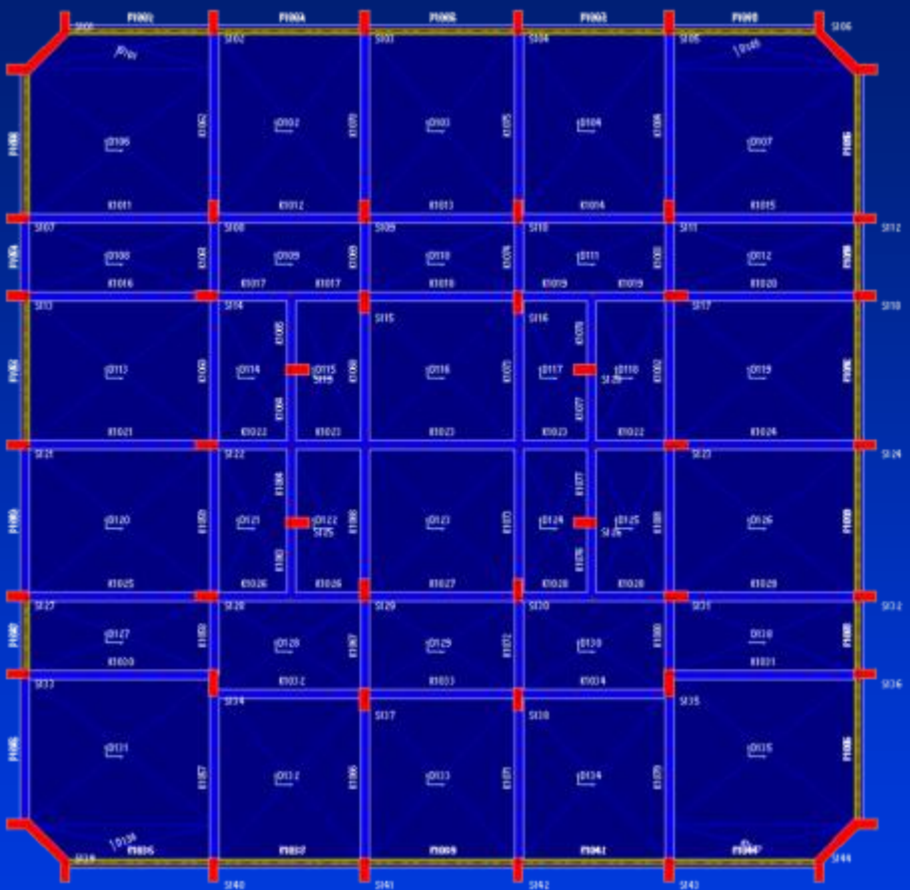
FRP

Adding / Strengthening Shear Walls

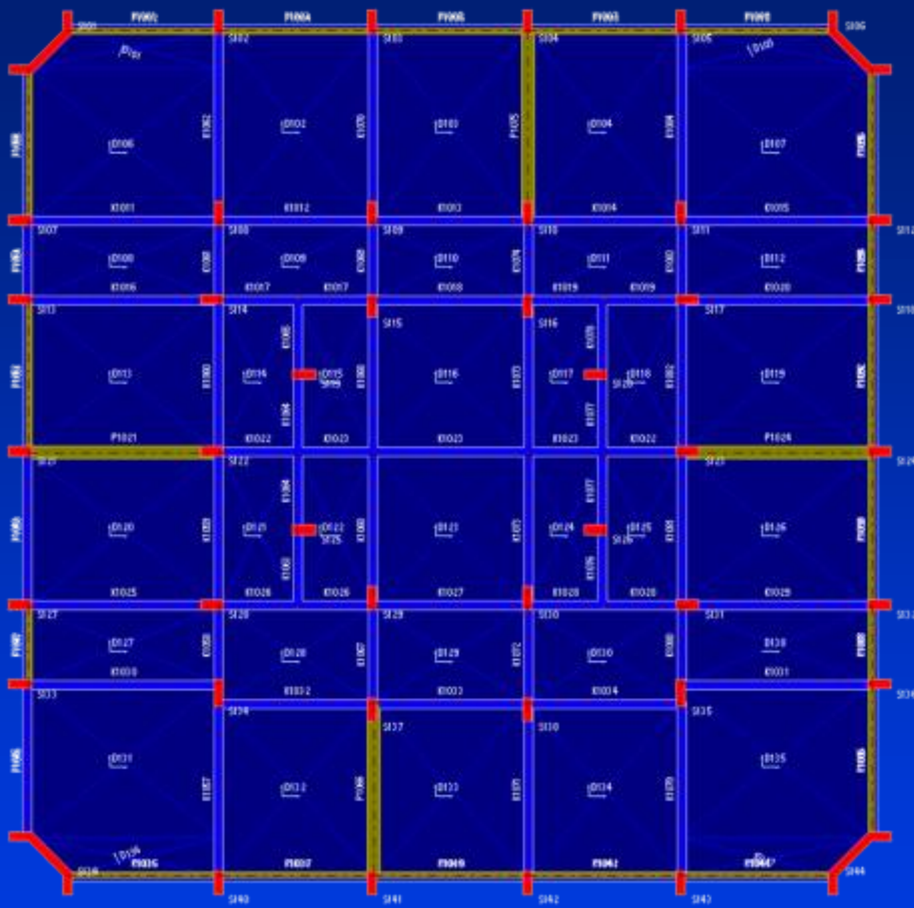
- Adding new R/C shear walls by replacing the partition walls

- To increase stiffness capacity
- To increase strength capacity
- To decrease displacement demand

Adding / Strengthening Shear Walls



Before



After

Replacing the partition walls with RC shear walls

Adding / Strengthening Shear Walls

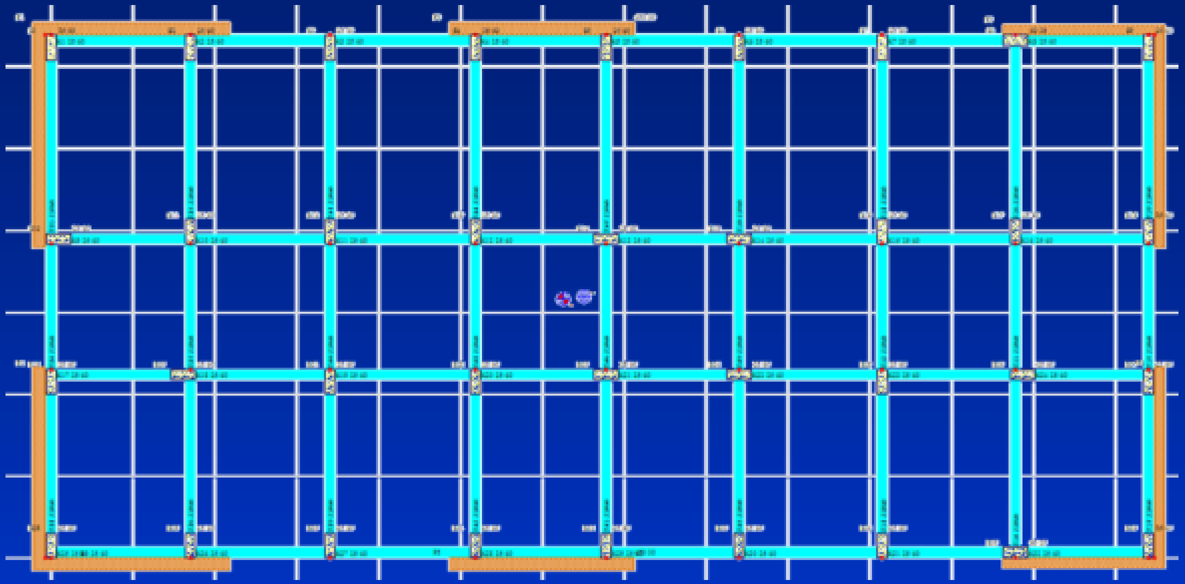
Before **After**

Replacing the partition walls with RC shear walls

Adding / Strengthening Shear Walls

Replacing the partition walls with RC shear walls

Strengthening by using external shear walls



Strengthening by using external shear walls

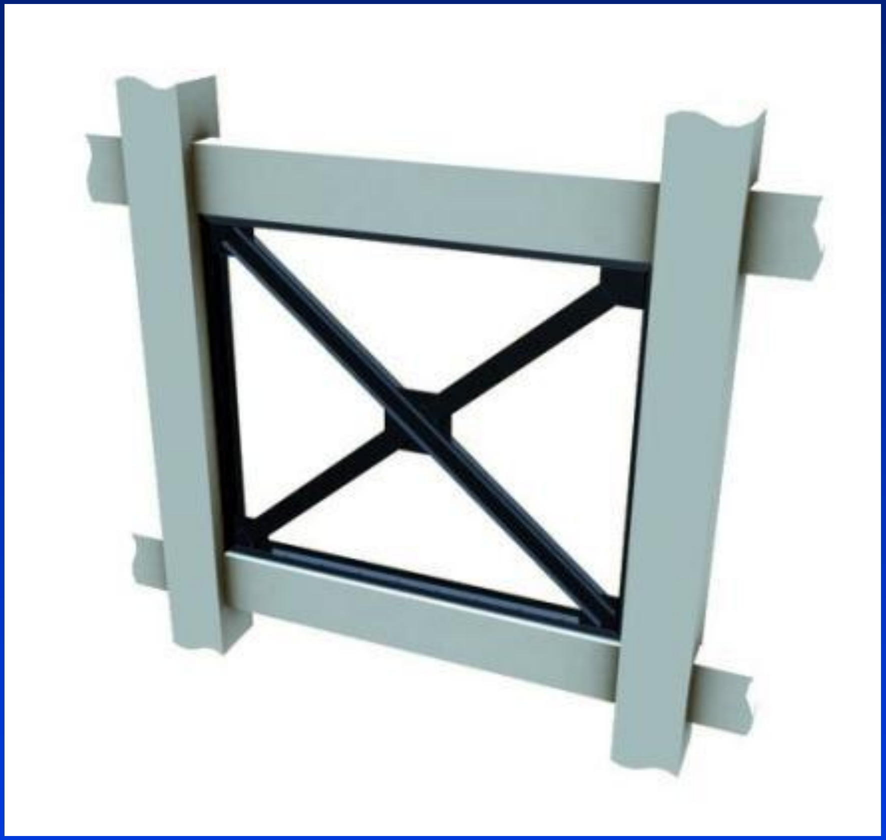
Strengthening by using external shear walls

Same building after strengthening

Strengthening by using external precast panels

Strengthening by using external precast panels

Strengthening by using Steel Diagonals



External application of steel diagonals

Strengthening of Columns

Strengthening of Columns

Strengthening of Columns

Strengthening of Columns

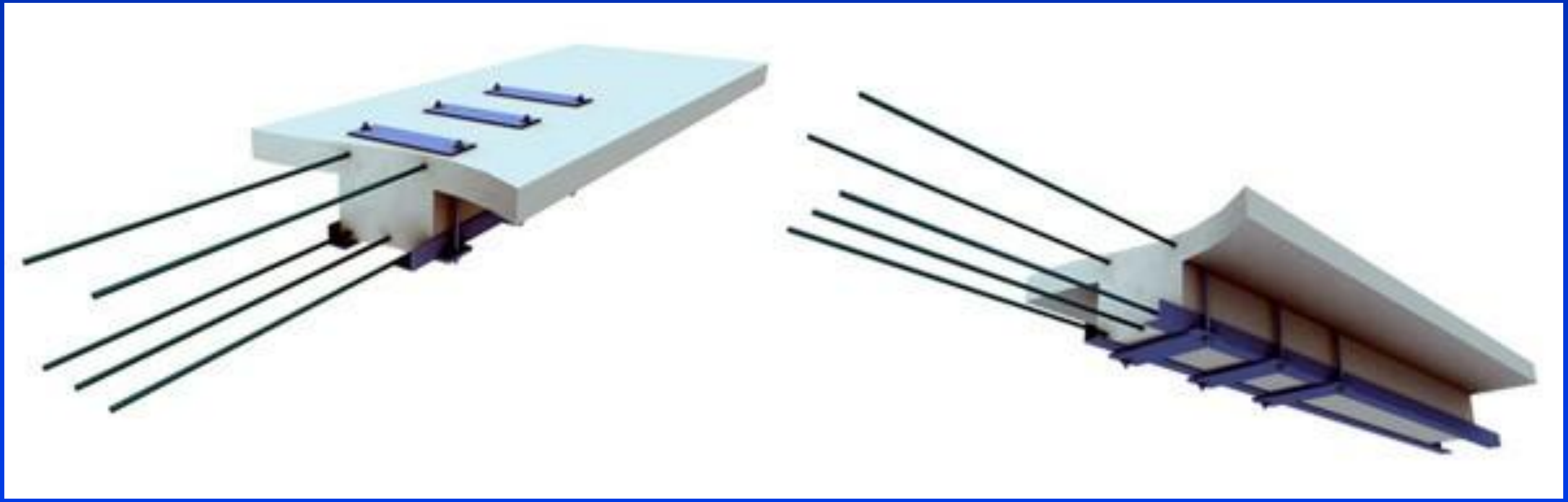
Strengthening of Columns by steel jacketing

Strengthening of Columns by steel jacketing

Strengthening of Columns by using FRP

Strengthening of Columns by using FRP

Strengthening of RC Beams



Strengthening of RC Beams

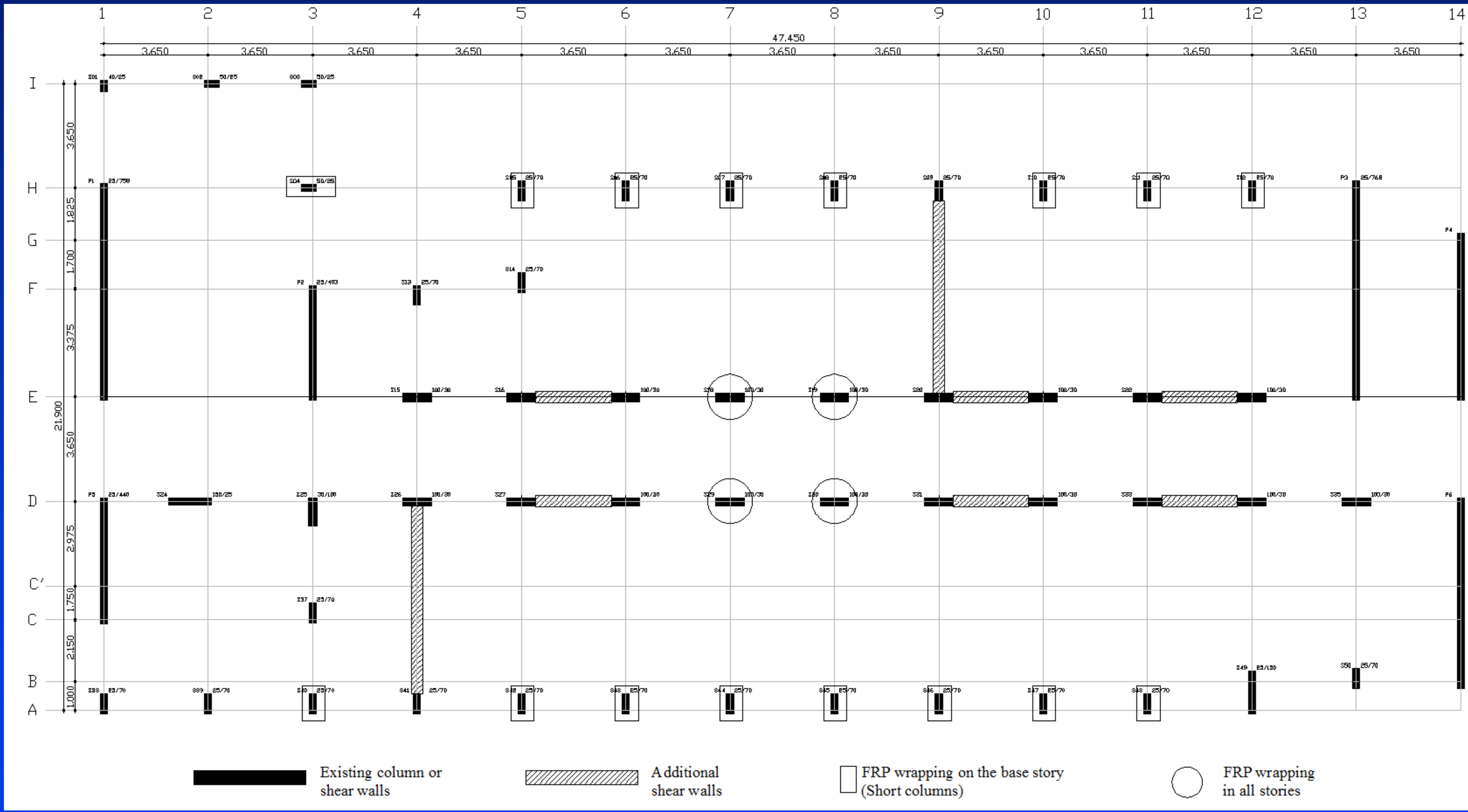
Strengthening of RC Beams

Strengthening of Foundations

Strengthening of Foundations

Strengthening of Foundations

Strengthening of Typical School Building



Strengthening of Typical School Building