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
- Discussion of Results
- Observed Concrete Strength in Existing Buildings
## Destructive Earthquakes in Turkey

<table>
<thead>
<tr>
<th>Date (dd/mm/yy)</th>
<th>Magnitude</th>
<th>Location</th>
<th># of deaths</th>
<th># of injured</th>
<th># of heavily damaged buildings</th>
<th>Latitude (N)</th>
<th>Longitude (E)</th>
<th>Depth (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.03.1992 Ms = 6.8</td>
<td>Erzincan</td>
<td>653</td>
<td>3 850</td>
<td>6 792</td>
<td></td>
<td>39.68</td>
<td>39.56</td>
<td>27</td>
</tr>
<tr>
<td>01.10.1995 Mw = 5.9</td>
<td>Dinar</td>
<td>94</td>
<td>240</td>
<td>4 909</td>
<td></td>
<td>38.18</td>
<td>30.02</td>
<td>24</td>
</tr>
<tr>
<td>27.06.1998 Mw = 5.9</td>
<td>Adana Ceyhan</td>
<td>146</td>
<td>940</td>
<td>4 000</td>
<td></td>
<td>36.85</td>
<td>35.55</td>
<td>23</td>
</tr>
<tr>
<td>17.08.1999 Mw = 7.4</td>
<td>Kocaeli</td>
<td>15 000</td>
<td>32 000</td>
<td>50 000 or 100 000 residences</td>
<td>40.70</td>
<td>29.91</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>12.11.1999 Mw = 7.2</td>
<td>Duzce</td>
<td>845</td>
<td>4 948</td>
<td>15 389</td>
<td></td>
<td>40.79</td>
<td>31.21</td>
<td>11</td>
</tr>
<tr>
<td>03.02.2002 Mw = 6.5</td>
<td>Afyon-Sultandagi</td>
<td>42</td>
<td>325</td>
<td>4 401</td>
<td></td>
<td>38.46</td>
<td>31.30</td>
<td>6</td>
</tr>
<tr>
<td>01.05.2003 Mw = 6.4</td>
<td>Bingol</td>
<td>176</td>
<td>521</td>
<td>1 351</td>
<td></td>
<td>38.94</td>
<td>40.51</td>
<td>6</td>
</tr>
</tbody>
</table>

### 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

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 evaluation 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.

Evaluation of a Typical Public Building

- Seismic Evaluation 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-Repairing Mortar

Laboratory Testing of Core Samples
Modelling

Performance Evaluation

<table>
<thead>
<tr>
<th>Force</th>
<th>Deformation</th>
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<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>IO</td>
</tr>
<tr>
<td></td>
<td>LS</td>
</tr>
<tr>
<td></td>
<td>CP</td>
</tr>
<tr>
<td></td>
<td>D</td>
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Performance Evaluation

<table>
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<tr>
<th>Performance Level</th>
<th>Performance Criteria</th>
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</table>
| 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. |

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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

Replacing the partition walls with RC shear walls
Adding / Strengthening Shear Walls

Before
Replacing the partition walls with RC shear walls

After

Replacing the partition walls with RC 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 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 Foundations
Strengthening of Foundations