SEISMIC PERFORMANCE EVALUATION OF REINFORCED CONCRETE BUILDING IN TURKEY

Betonarme Binaların Sismik Performans Değerlendirmesi

Prof. Dr. Mehmet INEL

Pamukkale University, Denizli, TURKEY

Outline

- Observed damages in past earthquakes
- Turkish Earthquake Code-2007
- Seismic Evaluation of a Typical School Building
- Field Assessment
- Office Work
- Discussion of Results
- Retrofit Stragies/Examples

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

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
- Kamu Binaları: Hastaneler, okullar ve diğer kamu binaları
- Urban development –Urban transformation law in order to minimize potential earthquake losses.
- Kentsel Dönüşüm –Riskli Binalar Yönetmeliği

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

Tipik Bir Kamu Binasının Değerlendirilmesi

- Sismik Değerlendirme Aşamaları
  - Bina ve eleman geometrik özellikleri
  - Malzeme özellikleri: Beton dayanımı , donatı çeliğinin cinsi ve özellikleri ve zemin özellikleri
  - Betonarme eleman özellikleri; Eleman boyutları, boyuna ve enine donatı yerleşimi ve miktarı
  - Mevcut hasar durumu
- Beton dayanımı ve zemin özelliklerinin belirlenmesi için arazi çalışması ve labratuvar deneyleri
- Binanın modellemesi
  - Performans değerlendirmesi

Evaluation of a Typical Public Building
Tipik Bir Kamu Binasının Değerlendirilmesi

- Seismic Performance Evaluation

  Sismik performans değerlendirmesi
  - Whether the buildings satisfy performance objectives?

    Binanın performans amaçlarını sağlayıp sağlamadığının belirlenmesi
  - Seismic retrofit and strengthening required, economical / not economical, demolish and reconstruct.

    Güçlendirme gerekli, ekonomik/ekonomik değil, yıkım ve yeniden yapım kararlarının verilmesi

Typical School Building
Tipik Bir Okul Binası

Foundation Details and Soil Properties
Temel ve zemin özelliklerinin belirlenmesi

Reinforcement Details
Donatı Detayları

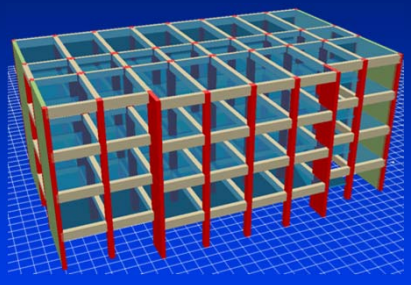
Reinforcement Details
Donatı Detayları

Concrete Strength: Core Samples
Beton Dayanımı: Karot Numuneleri

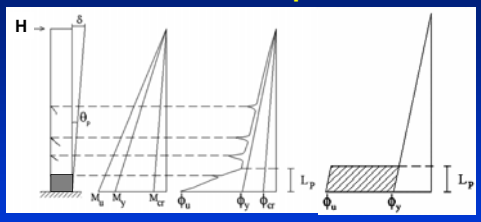
Finishing-Reparing Mortar
Tamir Harcı Doldurulması

Laboratory Testing of Core Samples
Karotların Labratuvarda Kırılması

Modelling
Modelleme

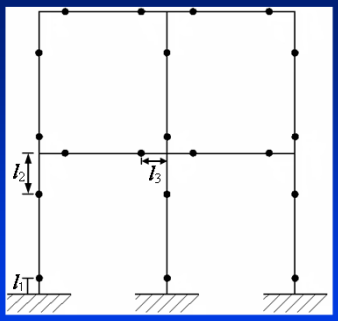


Eğrilik Yoğunlaşması: Yığılı Plastik Mafsal Hipotezi



- Kiriş ve kolon ekseni boyunca dağılı olan plastik şekil değiştirmelerin, deprem etkisinde en çok zorlanan kolon ve kirişlerin uçlarında toplandığı kabul edilir.

Mafsal atanması



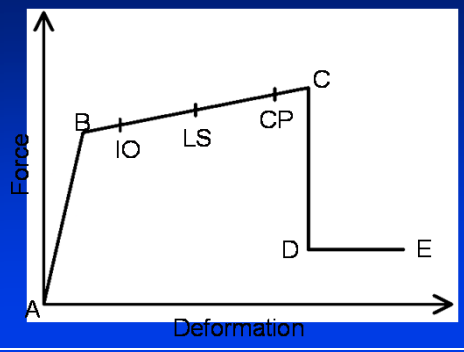
$$\ell_1 = \frac{\ell_p}{2}$$

$$\ell_2 = H_{beam} + \frac{\ell_p}{2}$$

$$\ell_3 = \frac{H_{column}}{2} + \frac{\ell_p}{2}$$

- **Plastik mafsal ataması, dayanımına ulaşması ve plastik deformasyon yapması beklenen kısımlarda mafsal bölgesinin orta noktasına yapılır.**

Performance Evaluation
Performans Değerlendirmesi



Performance Evaluation
Performans Değerlendirmesi

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.

Decision for Building Performance
Bina Performans Kararı

- Adequate

  Yeterli
- Inadequate –Retrofit is possible

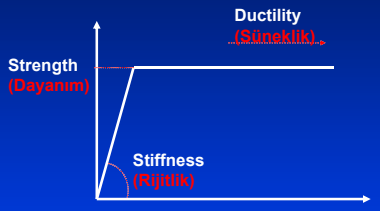
  Yetersiz –Güçlendirme mümkün

  ➔Retrofit (Güçlendirme)

  ➔Retrofit not economical (Güçlendirme ekonomik değil)
- Demolish –Retrofit is not techically possible

  Yıkım – Teknik olarak güçlendirme mümkün değil

RETROFIT
GÜÇLENDİRME



Source(s) of problem ? (Problemin Kaynağı?)

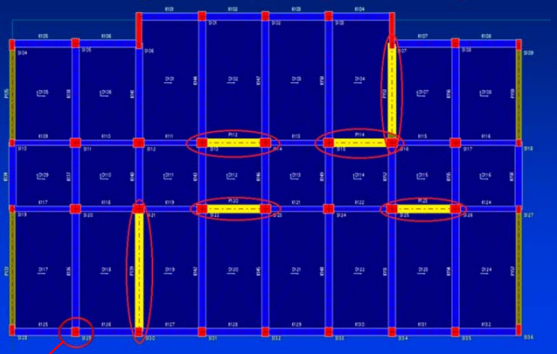
- **Insufficient stiffness ? (Yetersiz rijitlik?)**
- **Insufficient strength ? (Yetersiz dayanım?)**
- **Insufficient ductility ? (Yetersiz süneklik?)**

Typical Retrofit Applications for RC Buildings
Betonarme Binalarda Tipik Güçlendirme Uygulamaları

- Adding / strengthening of shear walls

  Eklenen veya güçlendirilen perde duvarlar
- Strengthening of columns (Kolon mantolama)
- Strengthening of beams (Kiriş güçlendirmesi)
- Strengthening of foundations (Temel güçlendirmesi)

Story Plan View (Kat Planı)



FRP

Adding / Strengthening Shear Walls

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

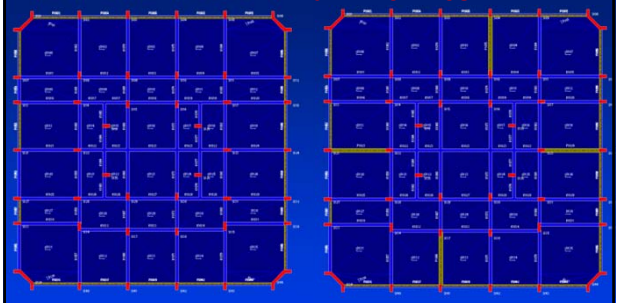
- To increase stiffness capacity
- To increase strength capacity
- To decrease displacement demand

Perde Duvar Eklenmesi

- Mevcut dolgu duvarlar yerine perde duvar eklenmesi

- Rijitlik artışı
- Dayanım artışı
- Deplasman talebinde azalma

Adding / Strengthening Shear Walls
Perde Duvar Eklenmesi



Before After

Replacing the partition walls with RC shear walls

Adding / Strengthening Shear Walls
Perde Duvar Eklenmesi

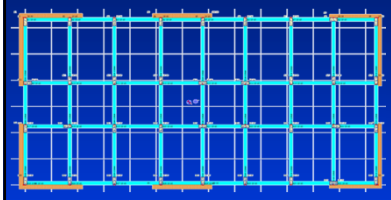
Before After

Replacing the partition walls with RC shear walls

Adding / Strengthening Shear Walls
Perde Duvar Eklenmesi

Replacing the partition walls with RC shear walls

Strengthening by using external shear walls
Dış Perde Duvar



Strengthening by using external shear walls
Dış Perde Duvar

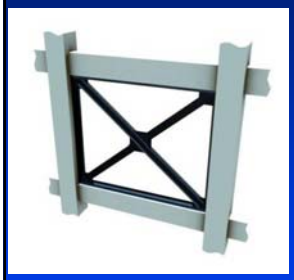
Strengthening by using external shear walls
Dış Perde Duvar

Same building after strengthening

Strengthening by using external precast panels
Dış Panel Uygulaması

Strengthening by using external precast panels
Dış Panel Uygulaması

Strengthening by using Steel Diagonals
Çelik Çaprazlarla Güçlendirme



External application of steel diagonals
Dış Çelik Çapraz Uygulaması

Strengthening of Columns
Kolon Mantolama

Strengthening of Columns
Kolon Mantolama

Strengthening of Columns
Kolon Mantolama

Strengthening of Columns
Kolon Mantolama

Strengthening of Columns by steel jacketing
Çelik Sargılama ile Kolon Güçlendirmesi

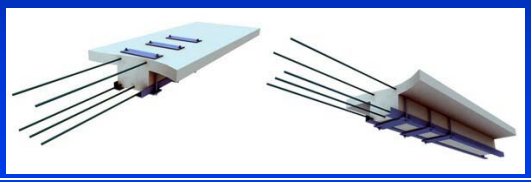
Strengthening of Columns by steel jacketing
Çelik Sargılama ile Kolon Güçlendirmesi

Strengthening of Columns by using FRP
FRP Sargılama ile Kolon Güçlendirme



Strengthening of Columns by using FRP
FRP Sargılama ile Kolon Güçlendirme


Strengthening of RC Beams
Kiriş Güçlendirme

Strengthening of RC Beams
Kiriş Güçlendirme




Strengthening of RC Beams
Kiriş Güçlendirme

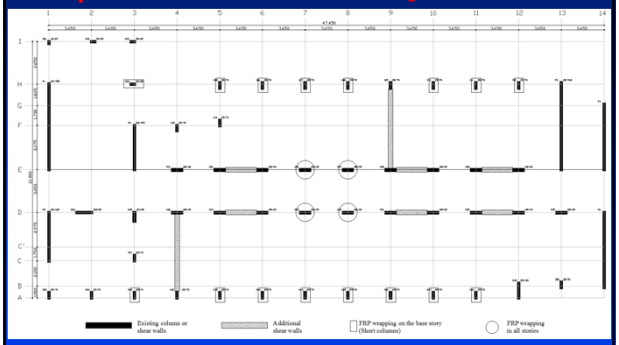


Strengthening of Foundations
Temel Güçlendirme


Strengthening of Foundations
Temel Güçlendirme


Strengthening of Foundations
Temel Güçlendirme


Strengthening of Typical School Building
Tipik Bir Okul Binasının Güçlendirmesi



Strengthening of Typical School Building
Tipik Bir Okul Binasının Güçlendirmesi