Ülkemizdeki betonarme binaların deprem performansını etkileyen genel özellikler

General characteristics influencing seismic performance of RC buildings in Turkey

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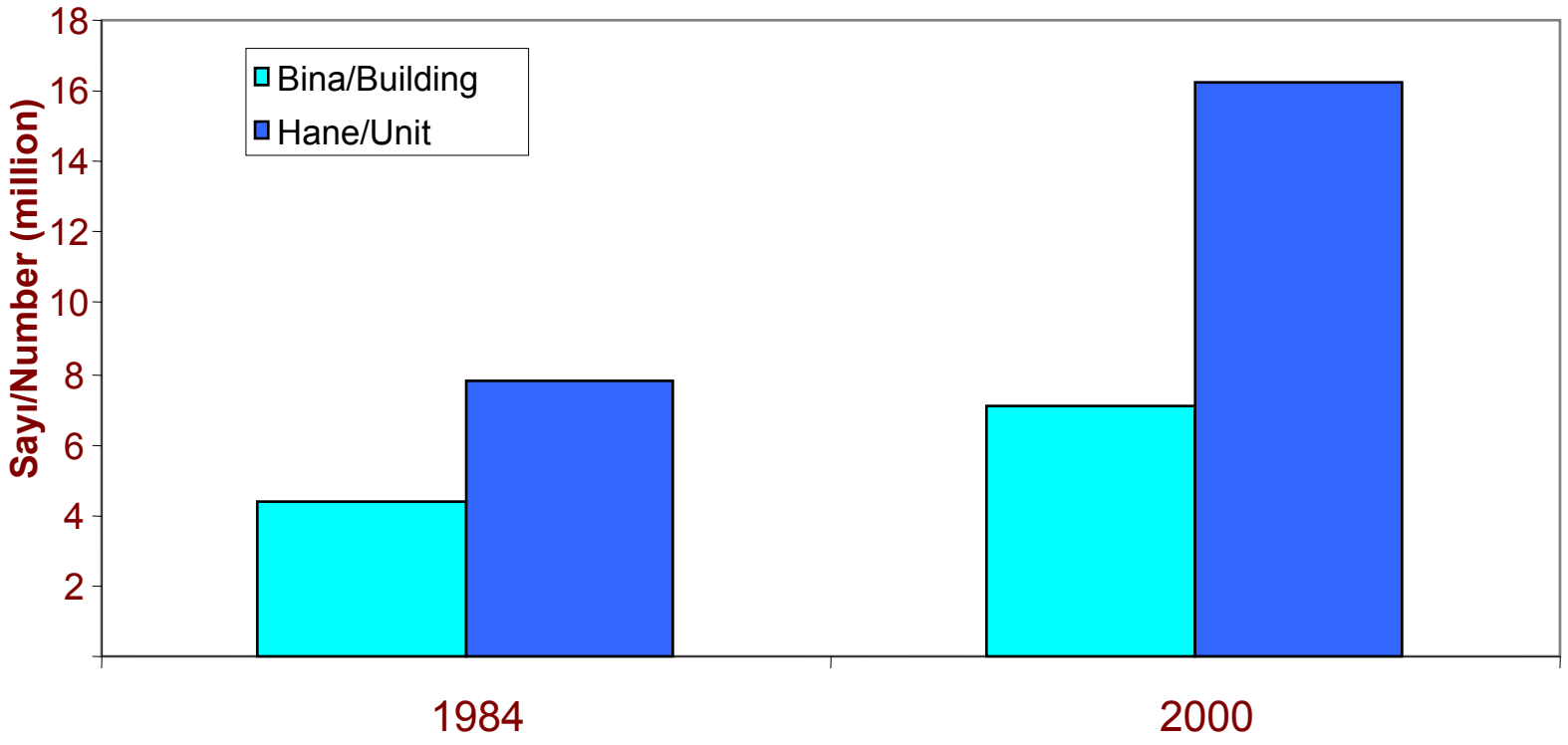
İçerik (Content)

- Bina İstatistikleri
  Building statistics
- BA Binaların Geometrik özellikleri
  Geometrical properties of RC buildings
- Geçmiş depremlerde gözlenen performans
  Observed performance from past earthquakes
- Hasara yol açan faktörler
  Parameters influencing performans
- Kapasiteye ilişkin özellikler
  Capacity related properties)
- Mevcut binaların deprem performans hesapları
  Seismic performance assessment of existing buildings
- Sonuçlar
  Conclusions

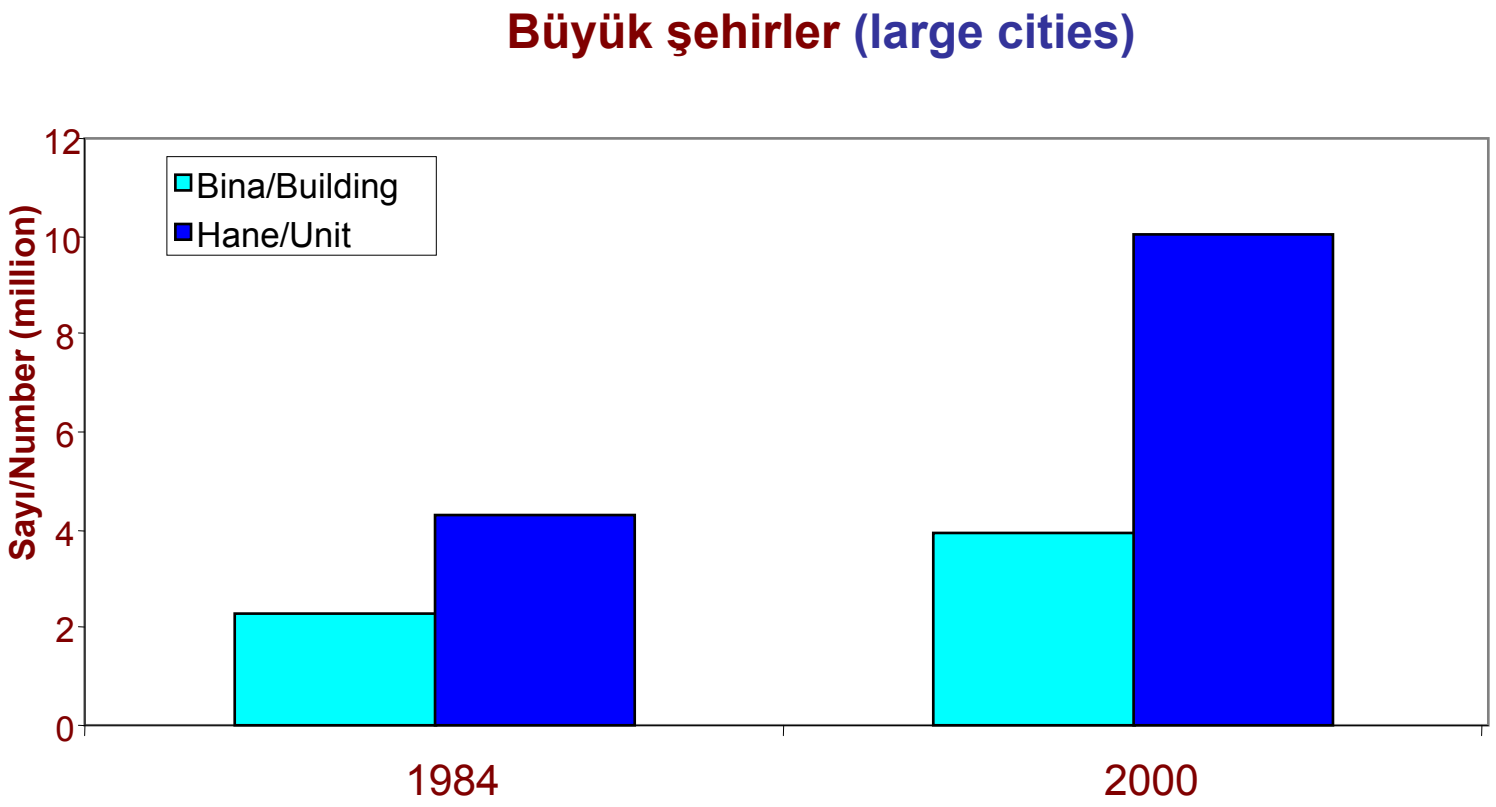
Bina istatistikleri
Building statistics

2000 Bina İstatistikleri
2000 Building statistics

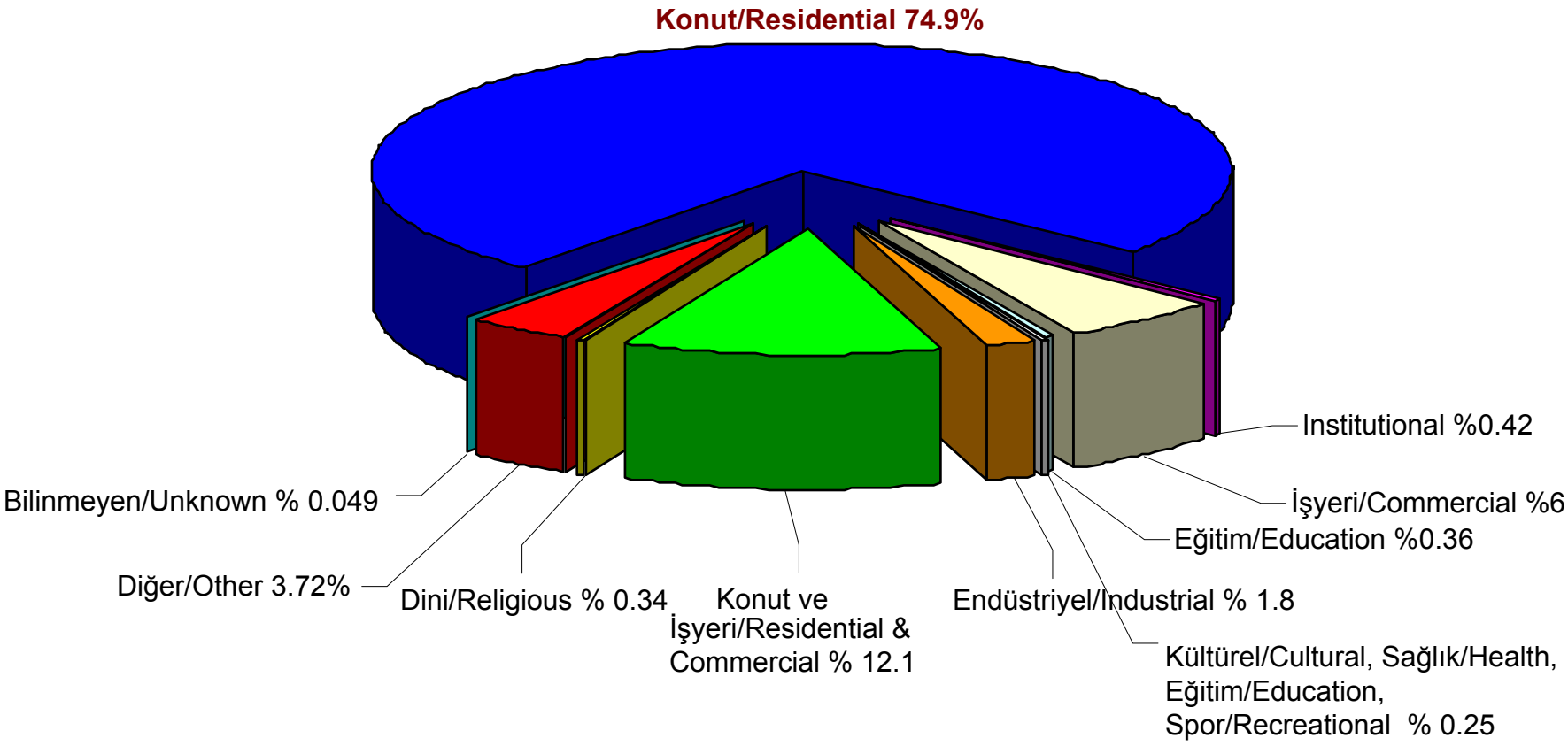
Türkiye Geneli (Nationwide)



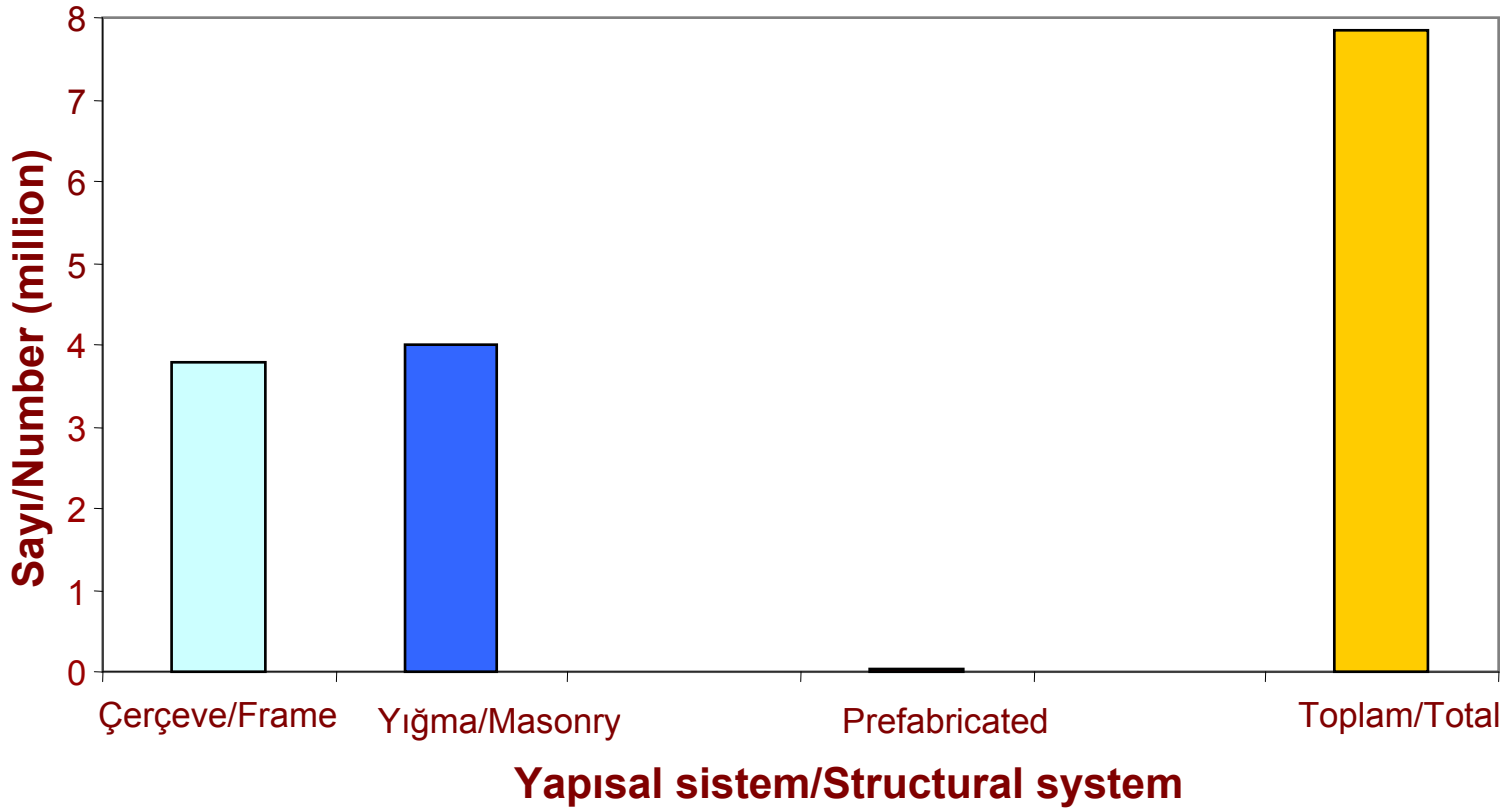
2000 Bina İstatistikleri
2000 Building statistics



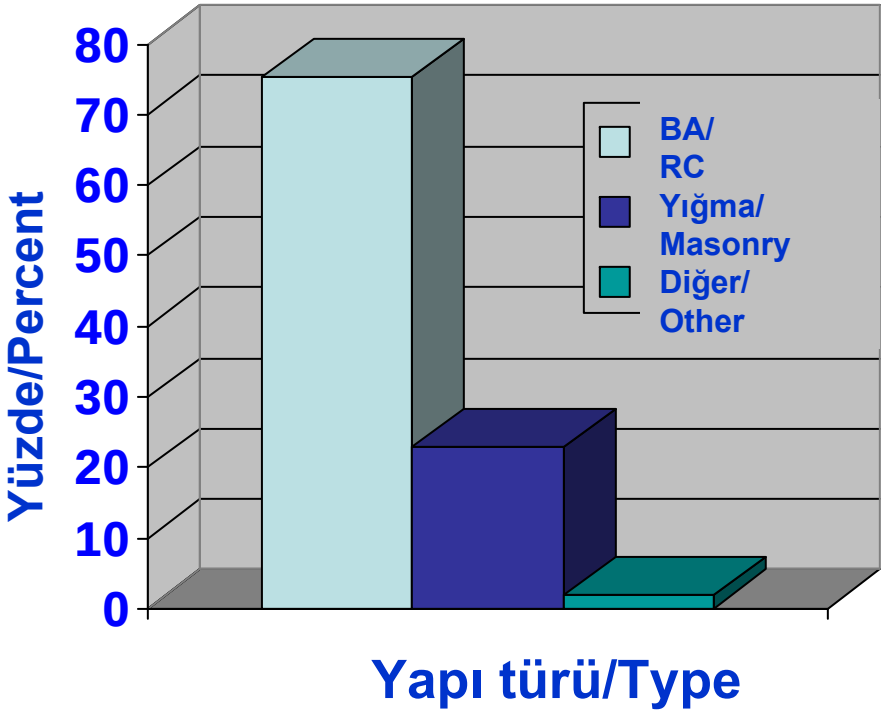
Bina envanteri: Kullanım amacına göre
Building inventory: based on occupancy

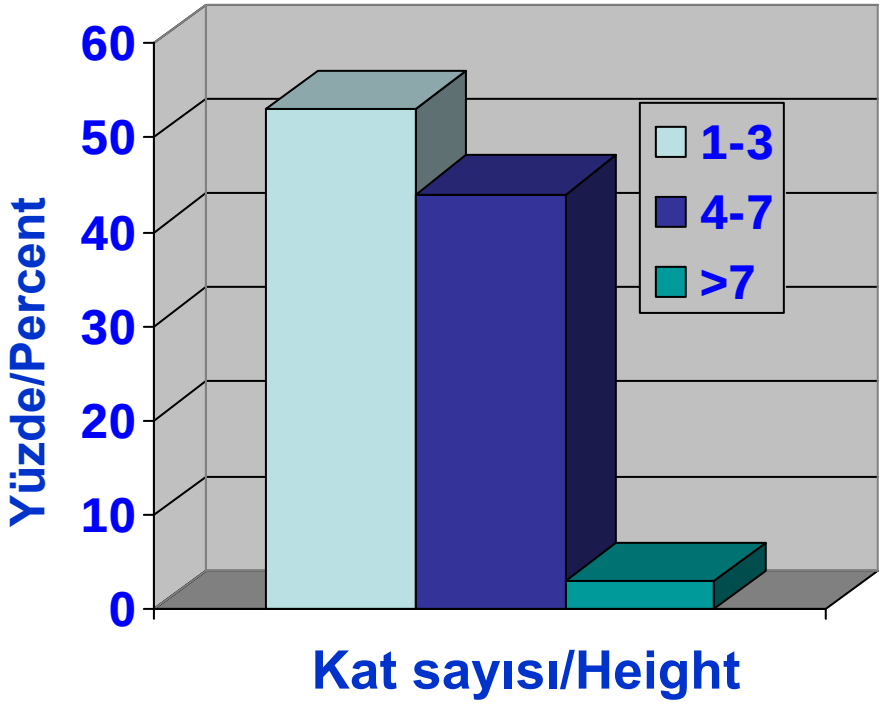


2000 Bina sayımı: yapısal sistem
2000 Building census: structural sistem



Bina envanteri (Şehir): Kat sayısı ve yapı türü
Building Stock (Urban): Per Height and type





Hatay'da
In Hatay

- Bina sayısı/ Number of buildings:
  - 79 098 (1984)- % 80.3 konut/ residential
  - 176 048 (2004)- % 77.7 konut/ residential

- Hane sayısı/ Number of dwellings:
  - 107 508 (1984)
  - 273 294 (2000)

- Çerçeve**/ Frame :** 112 661 (%64.0)
- Yığma/ **Masonry** : 62 729 (%35.6)

BA Binaların geometrik özellikleri
Geometrical characteristics of RC buildings

Özellikler
Characteristics

- **Kat Yüksekliği/Story Height**
  - **Giriş Katı/Ground Story**
  - **Normal Kat/ Regular Story**
- **Sürekli Çerçeve/Continuous Frame**
- **Kısa/Uzun Kenar Oranı (Short/Long Dimension Ratio)**

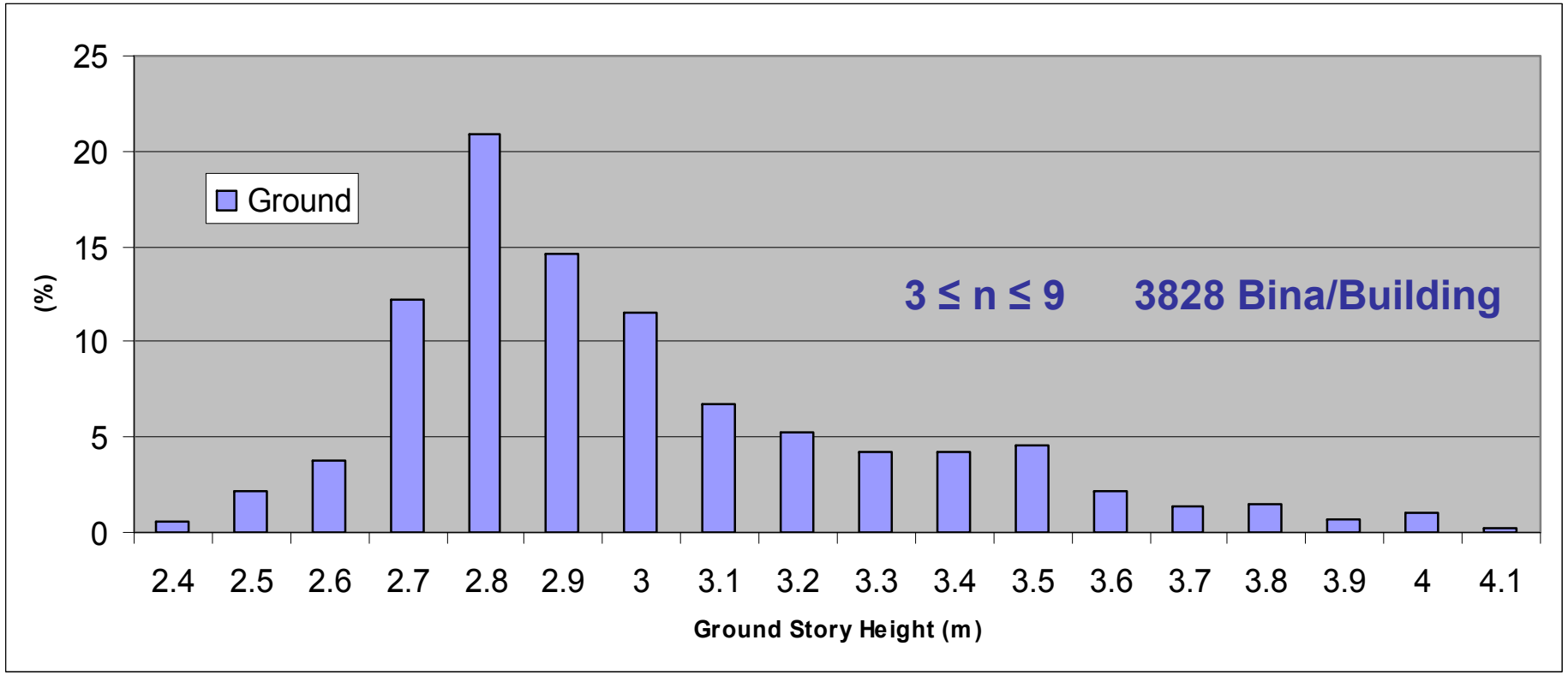
Kat Yüksekliği
Story Height

- **Düzce, Bakırköy and Zeytinburnu Veritabanı/Database**

- **Toplam 3860 Bina $1 \leq n \leq 9$**
  Total of 3860 Buildings
  - **(BA Çerçeve/RC Frame)**

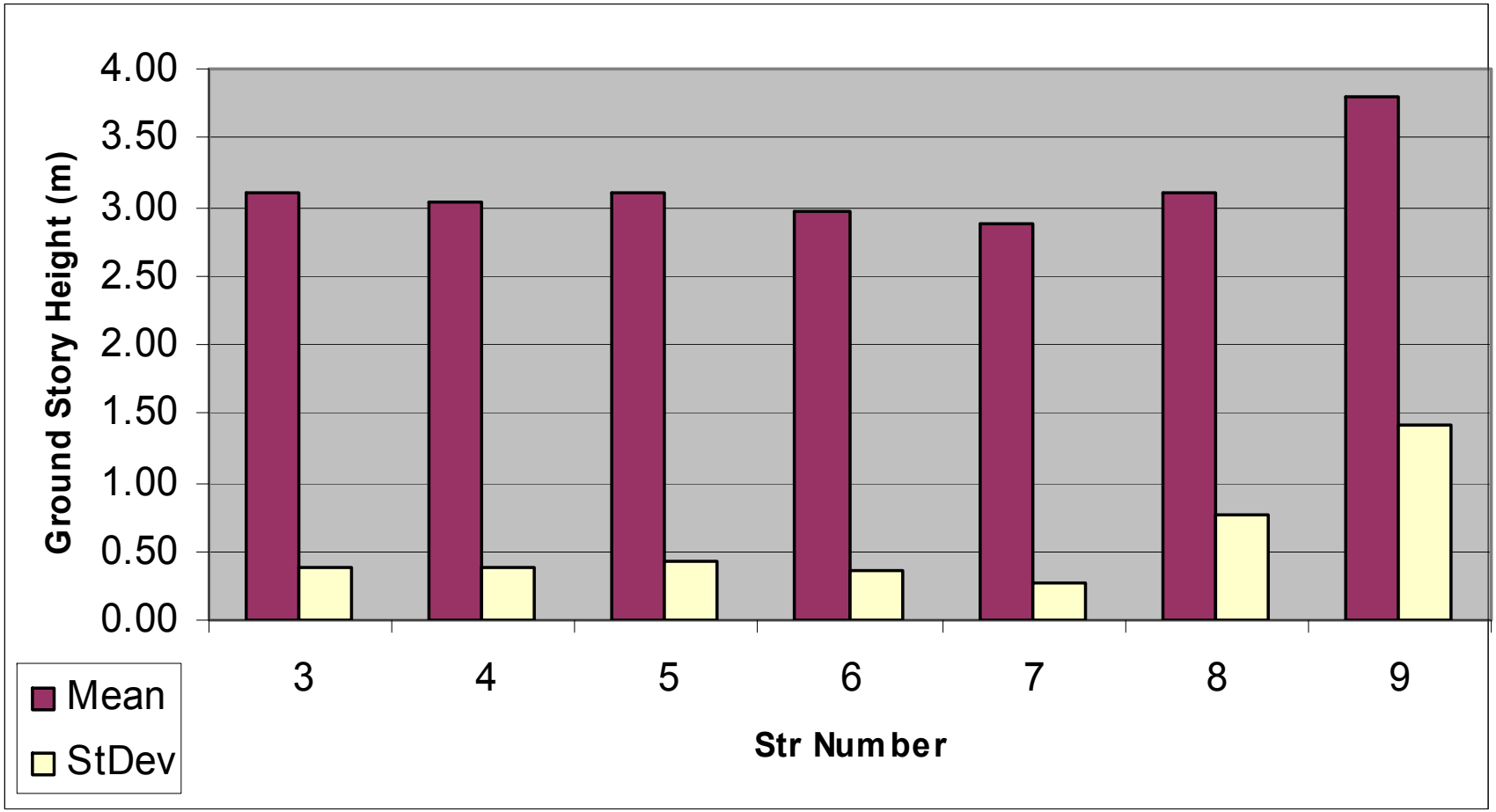
- **Toplam 3828 Bina $3 \leq n \leq 9$**
  Total of 3828 Buildings

Giriş Kat Yüksekliği
Ground Story Height



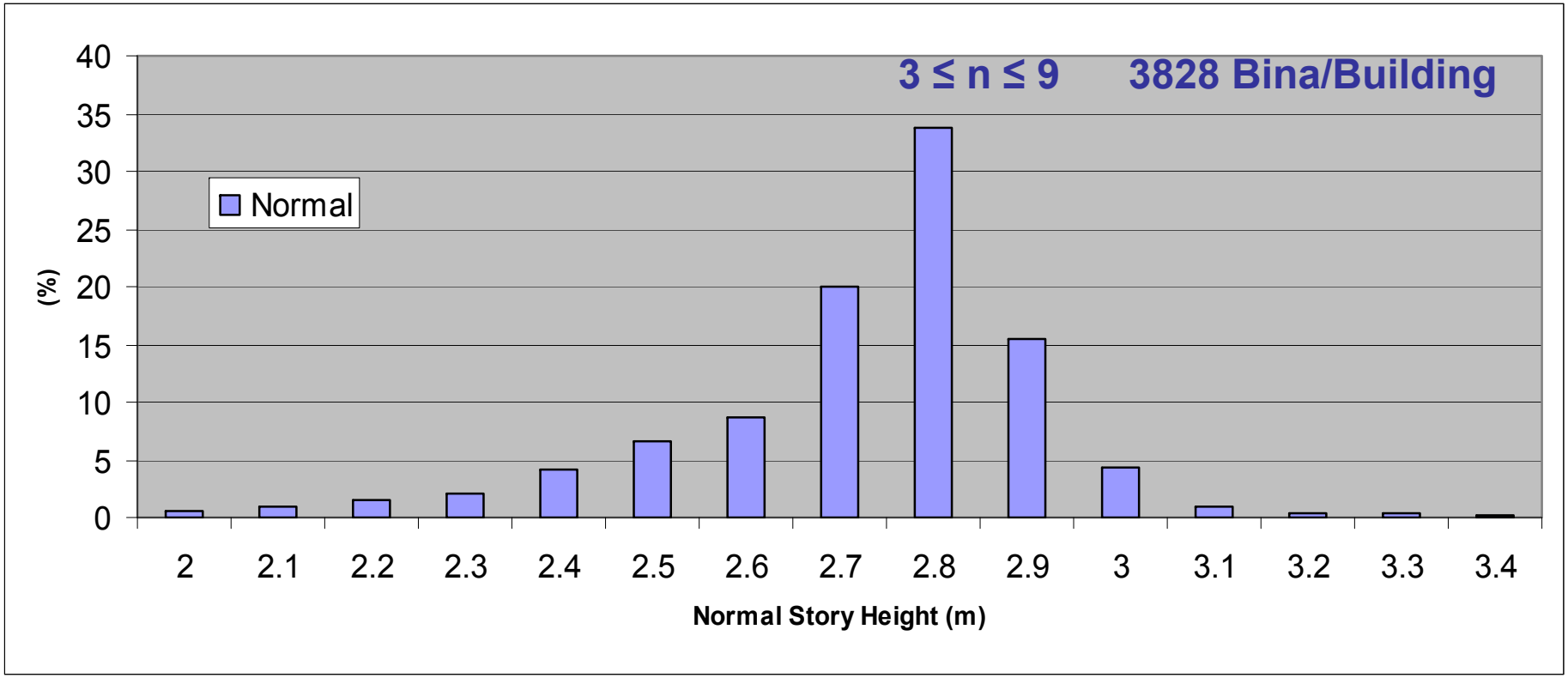
- **Ortalama/Mean = 3.01 m**
- **Standard sapma/STD = 0.40 m**

Giriş Kat Yüksekliği
Ground Story Height



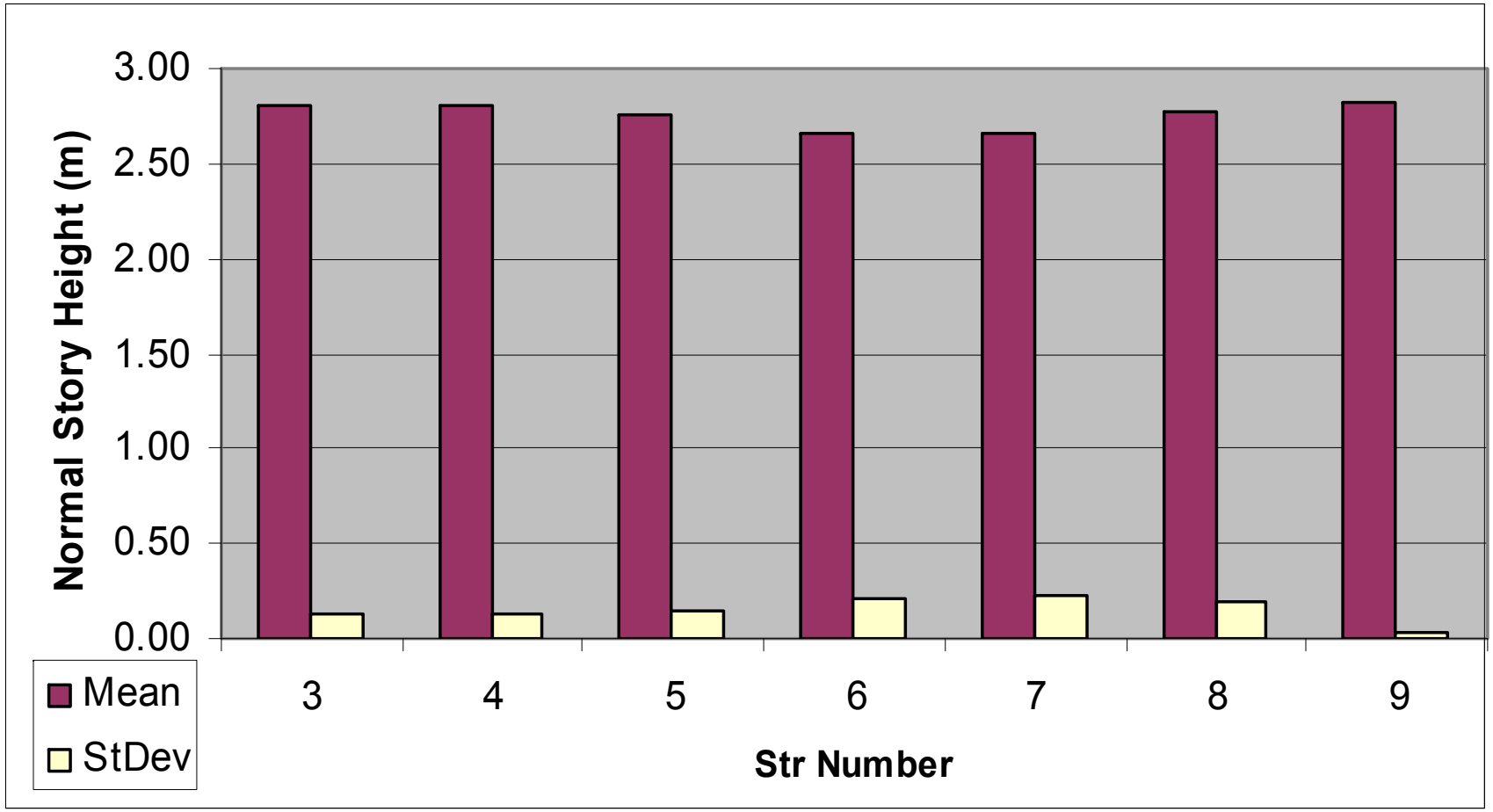
3 ≤ n ≤ 9 **3828 Bina/Building**

Normal Kat Yüksekliği
Regular Story Height



- **Ortalama/Mean = 2.72 m**
- **STD = 0.21 m**

Normal Kat Yüksekliği
Regular Story Height



3 ≤ n ≤ 9 **3828 Bina/Building**

Kısa kenar/Uzun Kenar
Short Dim / Long Dim

- Küçükçekmece, Bakırköy ve Zeytinburnu Veritabanı/Database

- Toplam 54077 Bina

  Total 54077 Building

- 3 ≤ n ≤ 15 42177 Bina/Building

- S/L Ortalama/Mean = 0.73
- S/L Stdev = 0.18

Kısa kenar/Uzun Kenar
(Short Dim / Long Dim)

- **Kısa kenar ortalaması= 9.48 m**

  Mean of Short Dimension = 9.48 m
- **Kısa kenar standard sapma=3.84 m**

  Stdev of Short Dimension = 3.84 m

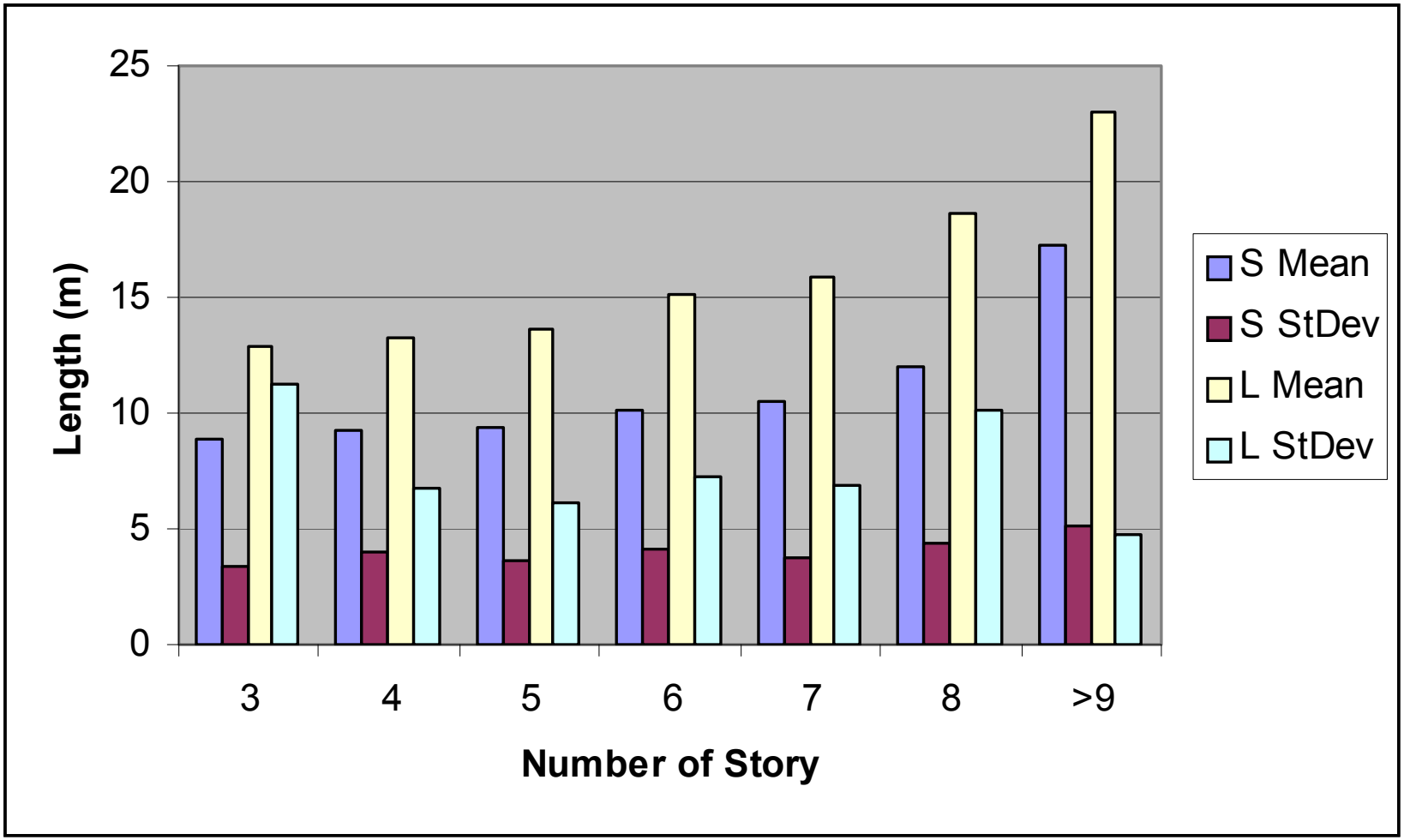
- **Uzun kenar ortalaması= 13.78m**

  (Mean of Long Dimension = 13.78 m)
- **Uzun kenar standard sapma= 8.08 m**

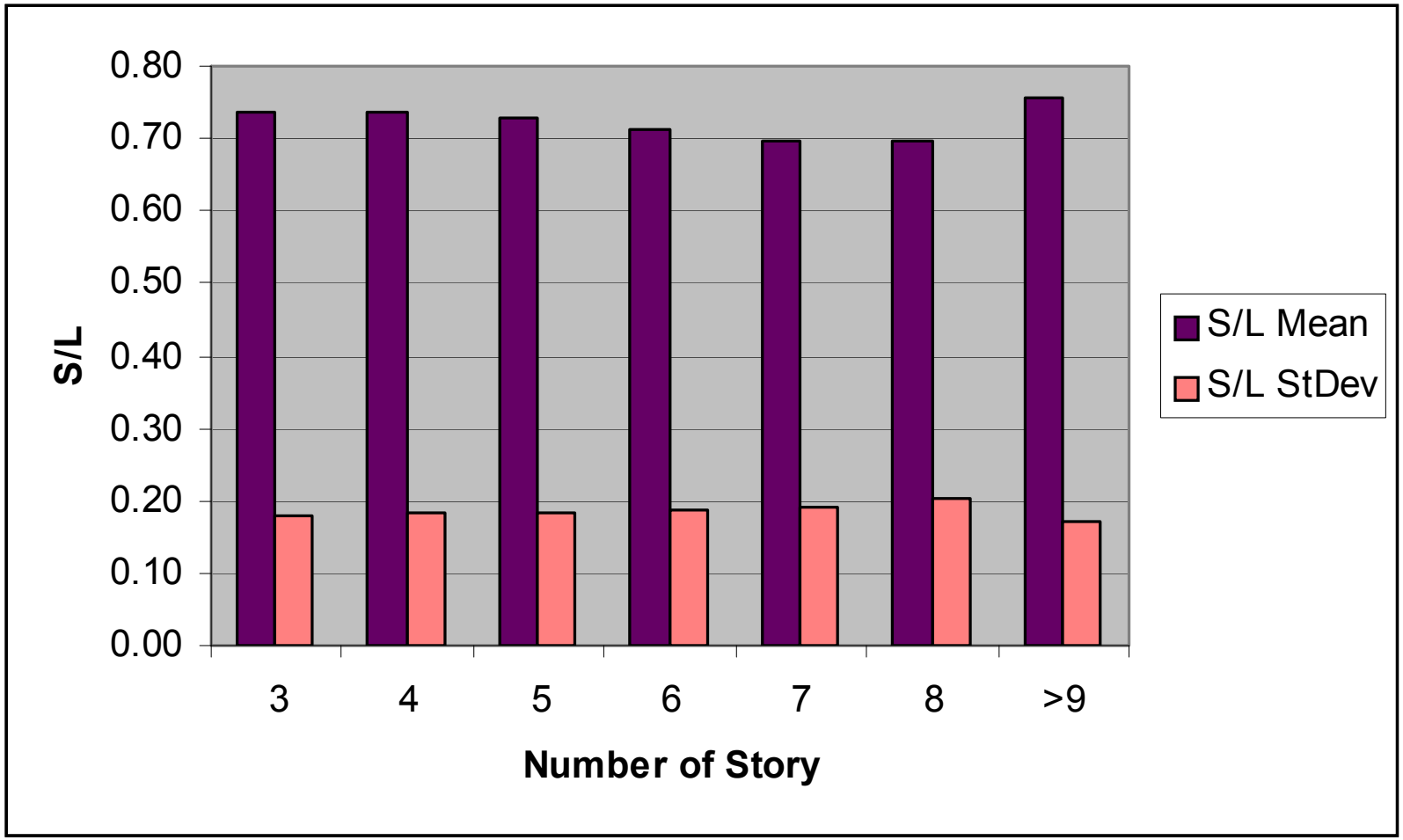
  (Stdev of Long Dimension = 8.08 m)

Kısa kenar/Uzun Kenar
Short Dim / Long Dim

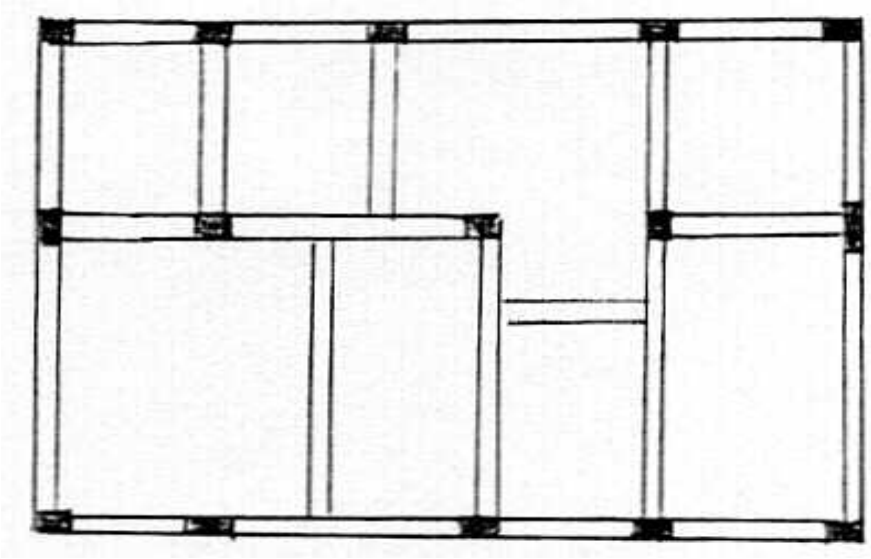
Kısa kenar ortalaması= 9.48 m Mean of Short Dimension = 9.48 m
Uzun kenar ortalaması= 13.78m Mean of Long Dimension = 13.78 m

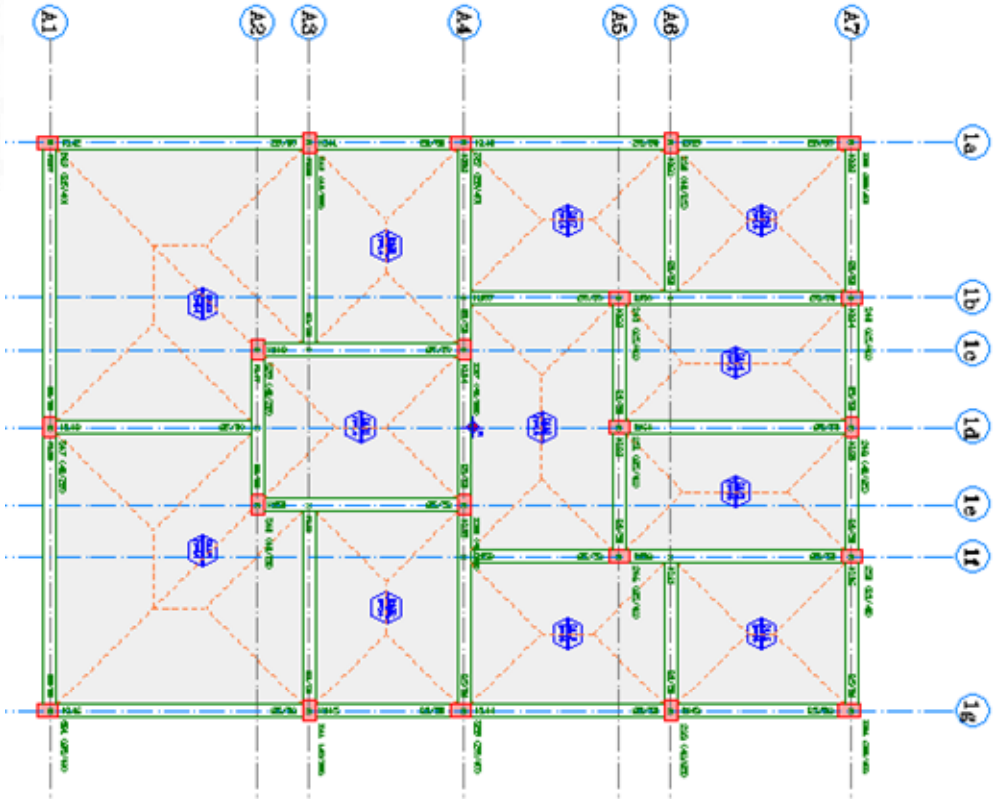


S / L


0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
S/L
3
4
5
6
7
8
>9
Number of Story
S/L Mean
S/L StDev

Çerçeve süreksizliği
Frame discontinuity





Sürekli Çerçeve
Continuous Frame

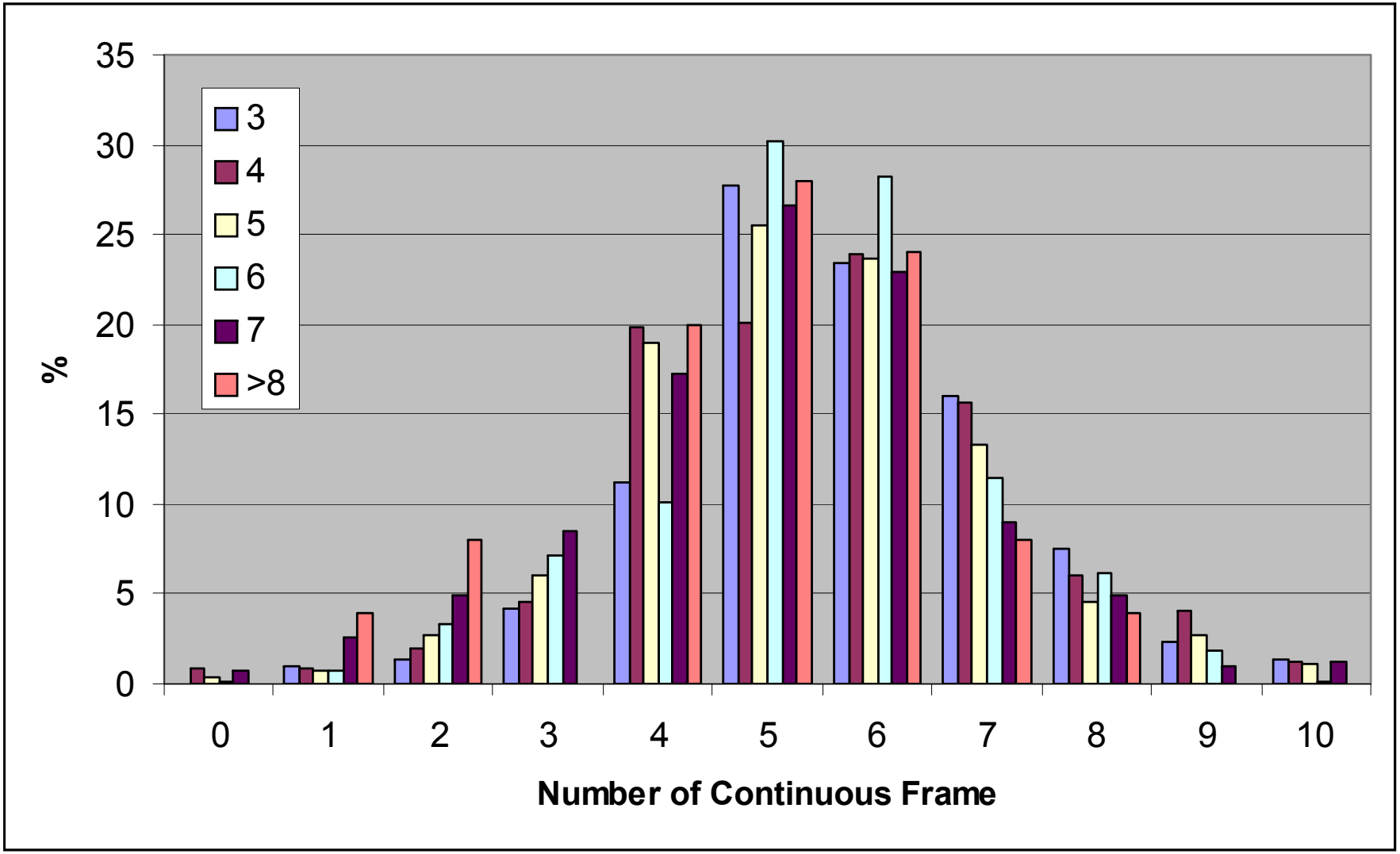
- **Düzce ve Zeytinburnu Veritabanı/ Database**
- **Toplam 3796 Bina $3 \leq n \leq 9$**

  Total of 3796 Buildings
- **Ortalama sürekli çerçeve sayısı=5.38**

  Mean of total continuous frame = 5.38
- **Sürekli çerçeve sayısı standard sapma= 1.73**

  Stdev of total continuous frame = 1.73

Sürekli Çerçeve
Continuous Frame



Beton Dayanımı
Concrete Strength

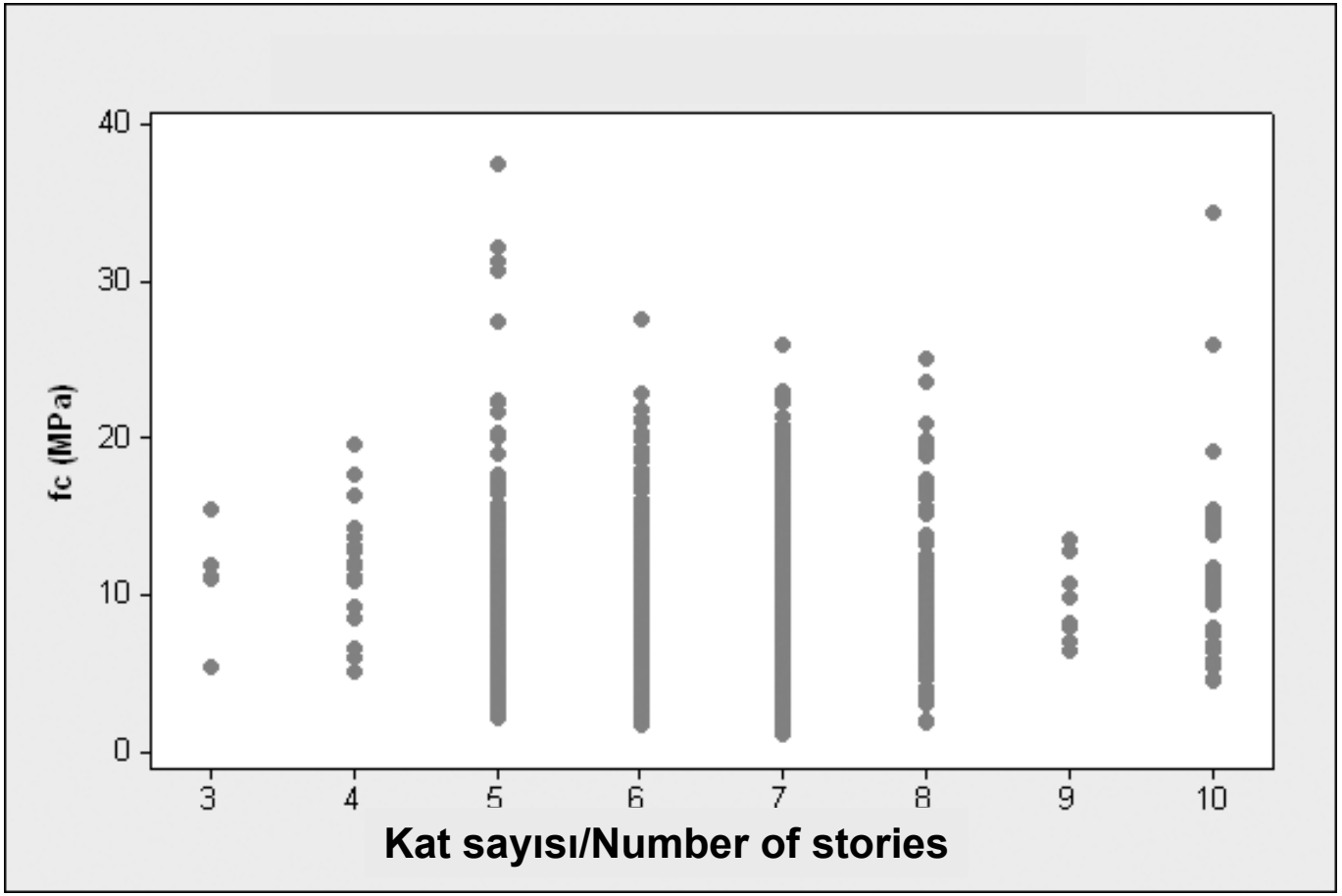
- 693 binadan alınan 4647 karot numunesi

  4647 core specimens taken from 693 buildings
- Yapım yılı ve kat sayısına göre beton dayanımı

  Concrete strength versus construction date and number of stories

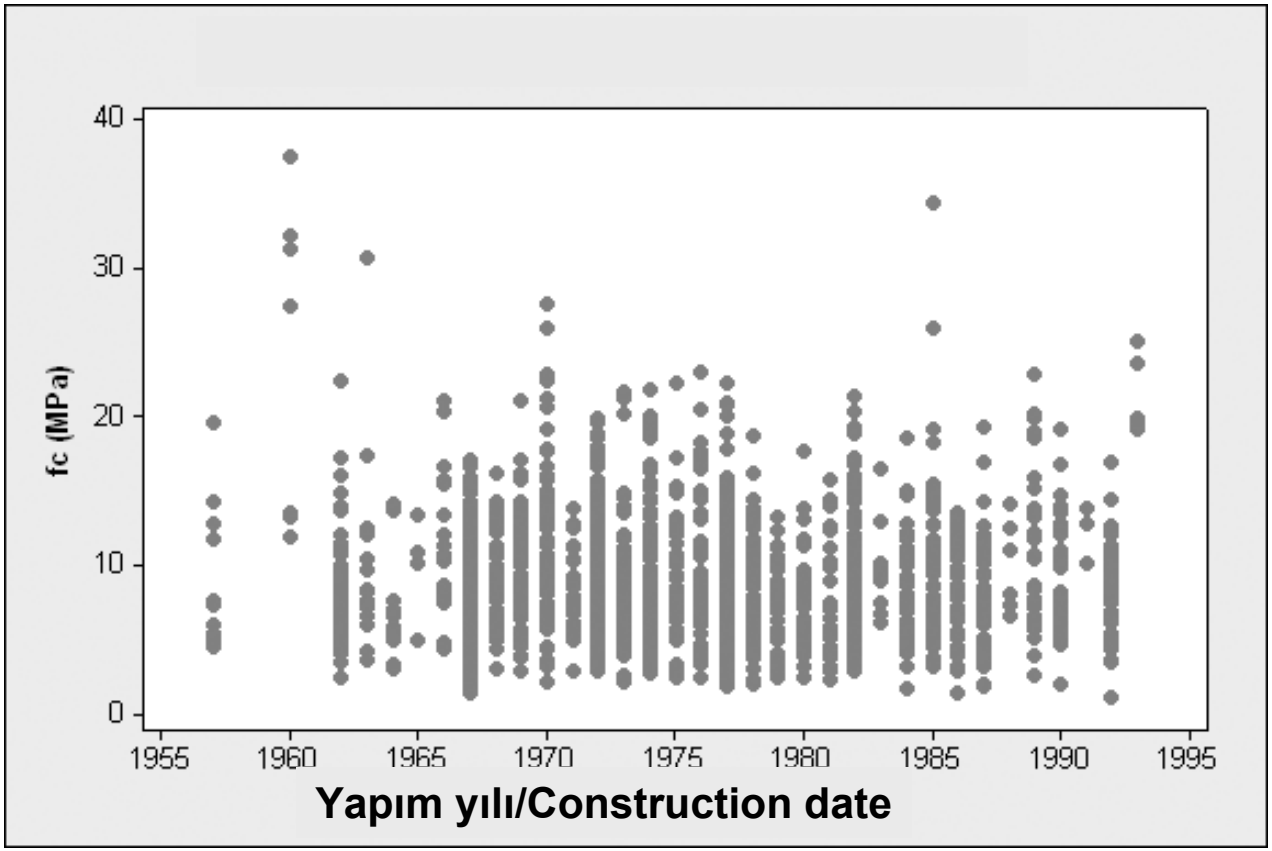
Beton Dayanımı-Kat sayısı
Concrete Strength-Number of stories

Ortalama/Mean= 9 MPa
Standard sapma/standard deviation=4 MPa



Beton Dayanımı-Kat sayısı
Concrete Strength-Number of stories

Ortalama/Mean= 9 MPa
Standard sapma/standard deviation=4 MPa



Geçmiş depremlerde gözlenen performans
Observed performance from past earthquakes

Yetersiz yanal rijitlik
Inadequate lateral rigidity

Yumuşak kat
Soft story

Adapazarı, 1999: Zemin kat göçmesi
Ground floor collapse

Bingöl, 2003 : Zemin kat göçmesi
Ground floor collapse

Kısa kolon
Short column

Kısa kolon, yetersiz sargı
Short column, inadequate confinement

Bingöl, 2003 : Yetersiz sargı
Inadequate confinement

Kötü detaylandırma
Poor detailing

Eksik birleşim bölgesi detayı
Lack of connection zone detailing

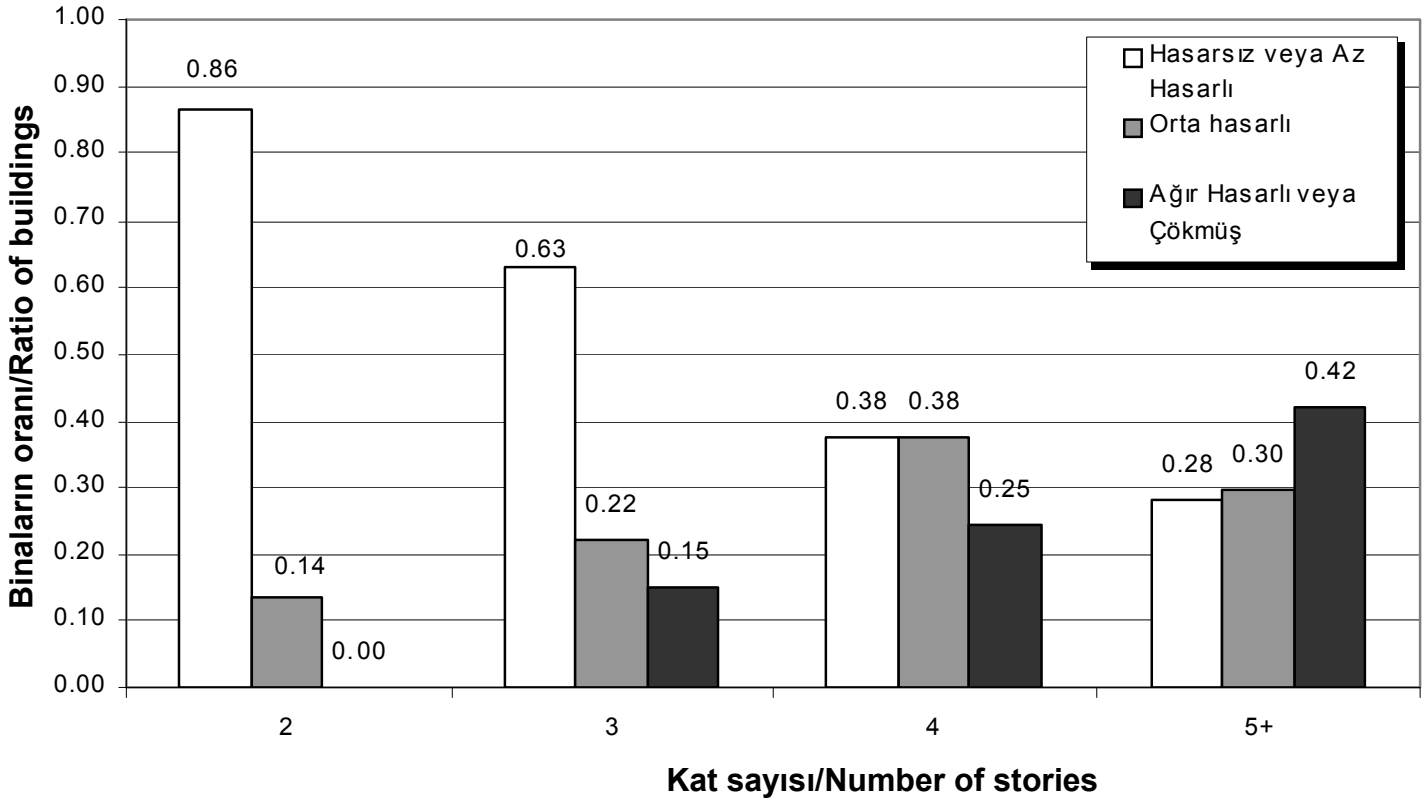
Zayıf tasarım, işçilik ve malzeme
Poor design, workmanship and material

Bitişik binaların çarpışması
Pounding of adjacent buildings

Düzce hasar dağılımı
Damage distribution in Düzce

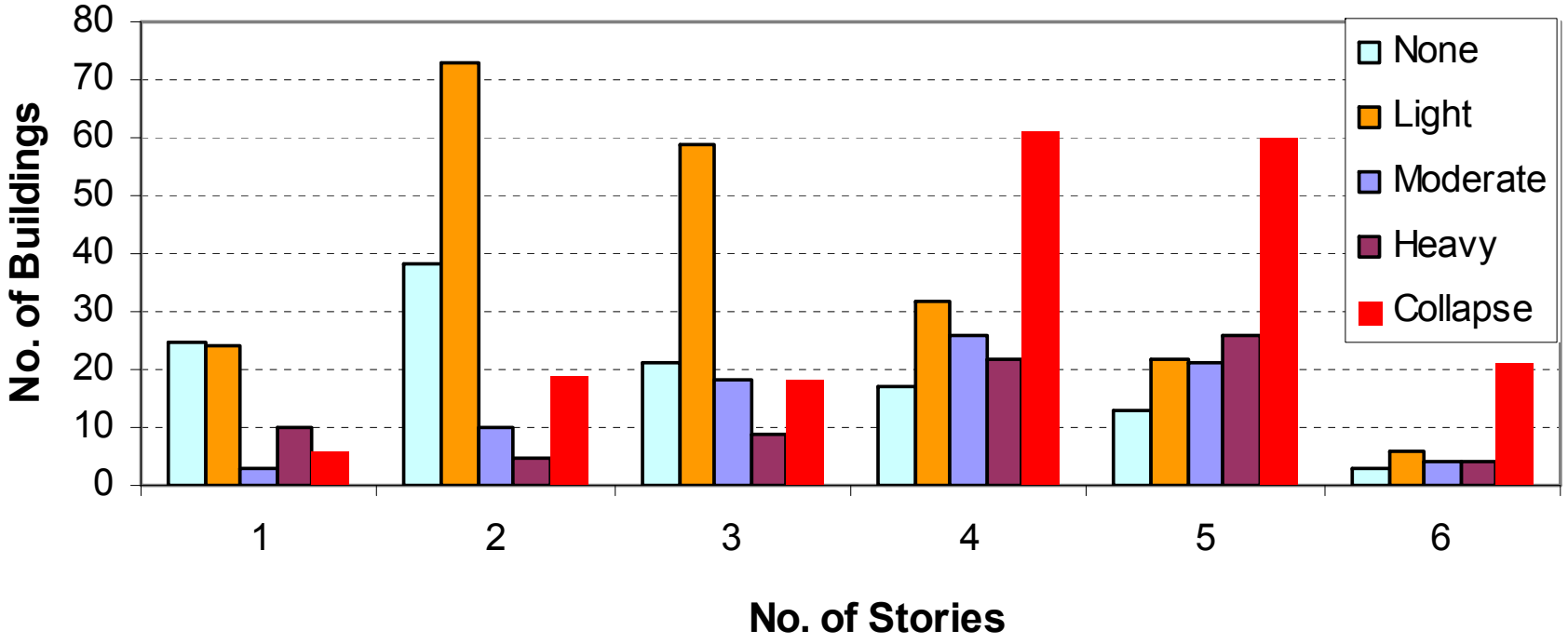
- 1999 depremleri sonrası (477 bina)

After 1999 earthquakes (477 buildings)

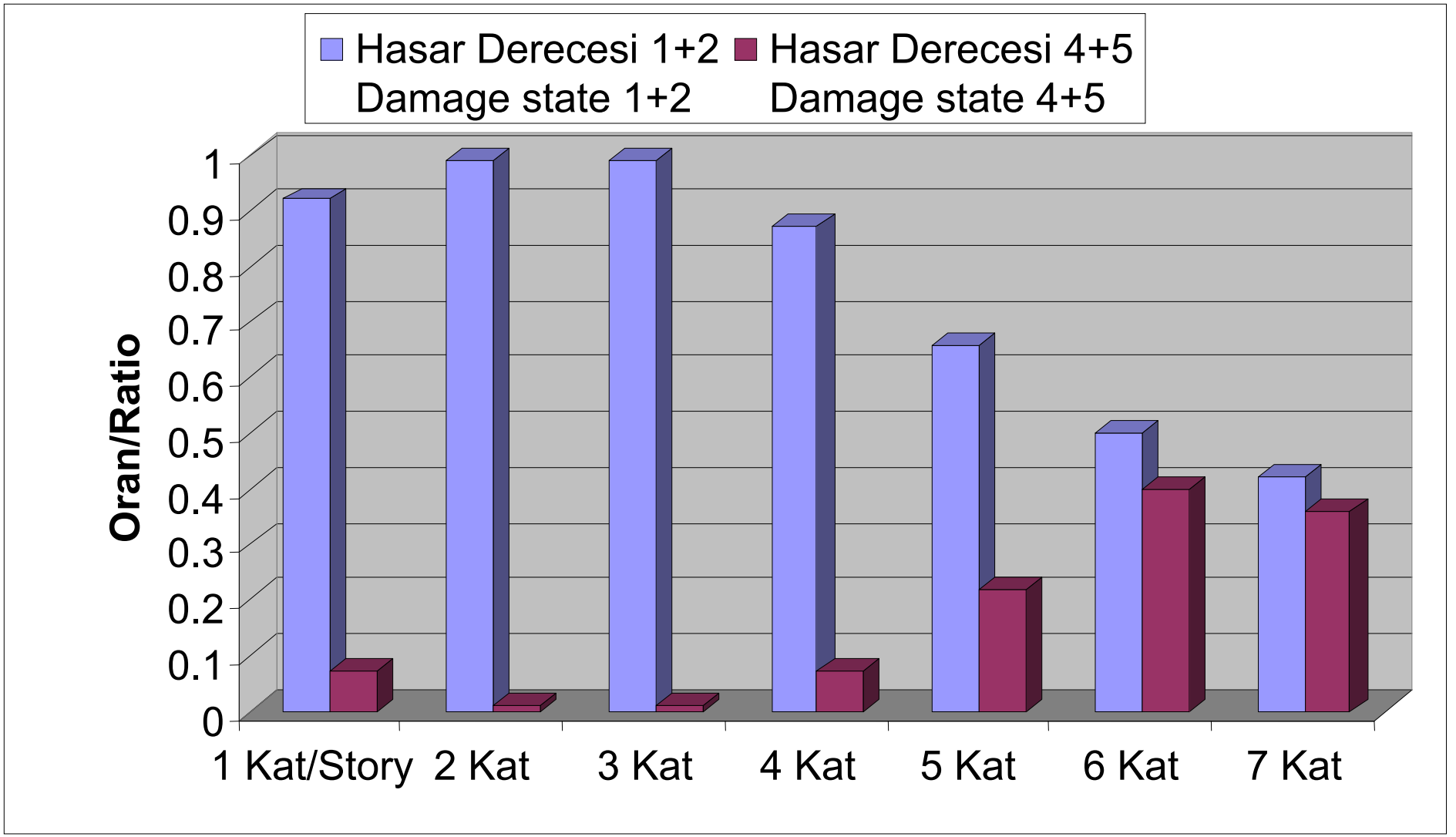


Past Performance

Damage database in Düzce after 1999 Earthquakes



Gölcük hasar dağılımı
Damage distribution in Gölcük



Zayıf performansın nedenleri
Reasons of poor performance

- Yapısal yetersizlikler/ Structural inadequacy
  - Taşıyıcı sistemin yetersiz olması/ Inadequate structural system
  - Eleman yerleşim ve dağılımının uygun olmaması/ Inproper member layout
  - Donatı detayı ve malzeme özelliklerinin yetersiz olması/ Inadequate material and detaling
- Mimari sorunlar/ Architectural features
  - Düzensizlikler/ Irregularities
    - Yumuşak kat/ Soft story, süreksiz çerçeve/ discontinuous frame, çıkma/overhang, burulma/ torsion
  - Yapı nizamı/Adjacency
    - Çarpışma etkisi/ Pounding
    - Konum/ Location
- Kötü İşçilik ve malzeme kalitesi/ Poor workmanship and material
- Yetersiz denetim/ Inadequate supervision

Hasara yol açan faktörler
Parameters leading to damage

En belirgin parametreler
Significant parameters

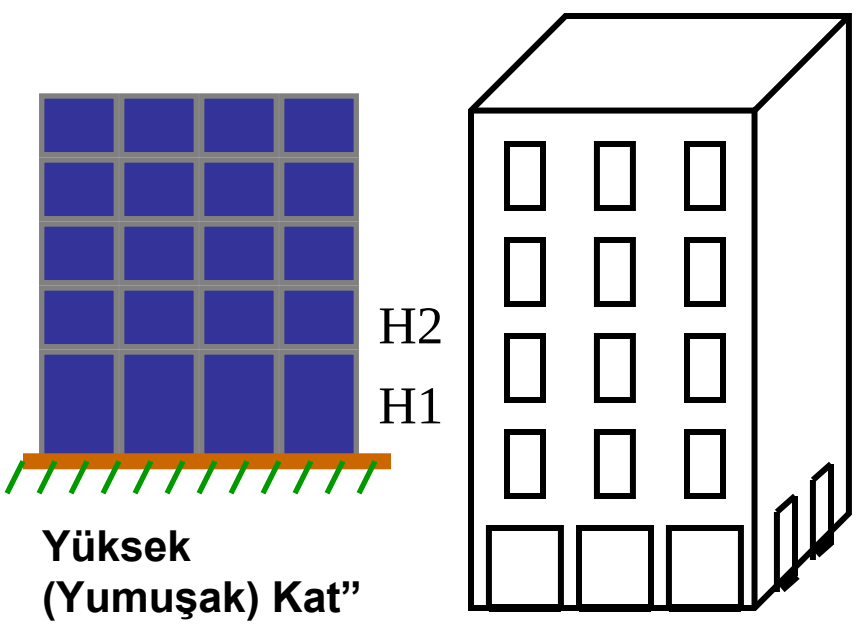
- Kat sayısı/ Number of stories
- Yumuşak kat/ Soft story
- Ağır çıkma/ Heavy overhang
- Görünen kalite/ Apparent quality
- Bitişik nizam/ Adjacency
- Çerçeve sürekliliği/ Frame continuity
- Yetersiz dayanım/ Inadequate lateral rigidity
- Kötü malzeme ve işçilik/ poor material and workmanship
- Yetersiz detaylandırma/ Inadequate detaling

Tipik riskli bina
Typical vulnerable building

- Orta katlı/ Mid-rise
- Betonarme/ RC
- Düşük beton dayanımı/ Low concrete strength
- Çıkmalar/ Overhangs
- Yumuşak kat/ Soft story
- Bitişik nizam/ Adjacent

Yumuşak kat
Soft story

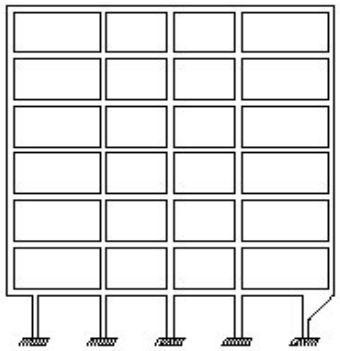
- Farklı giriş kat yüksekliği/ First story height
- Giriş katında boşluk/ Opening on ground floor



Çıkma kat
Heavy overhang

Giriş katı ve bir üst katın alanına bağlıdır

(depends on the areas of ground and upper floor)



Kapasiteye ilişkin özellikler
Capacity related properties

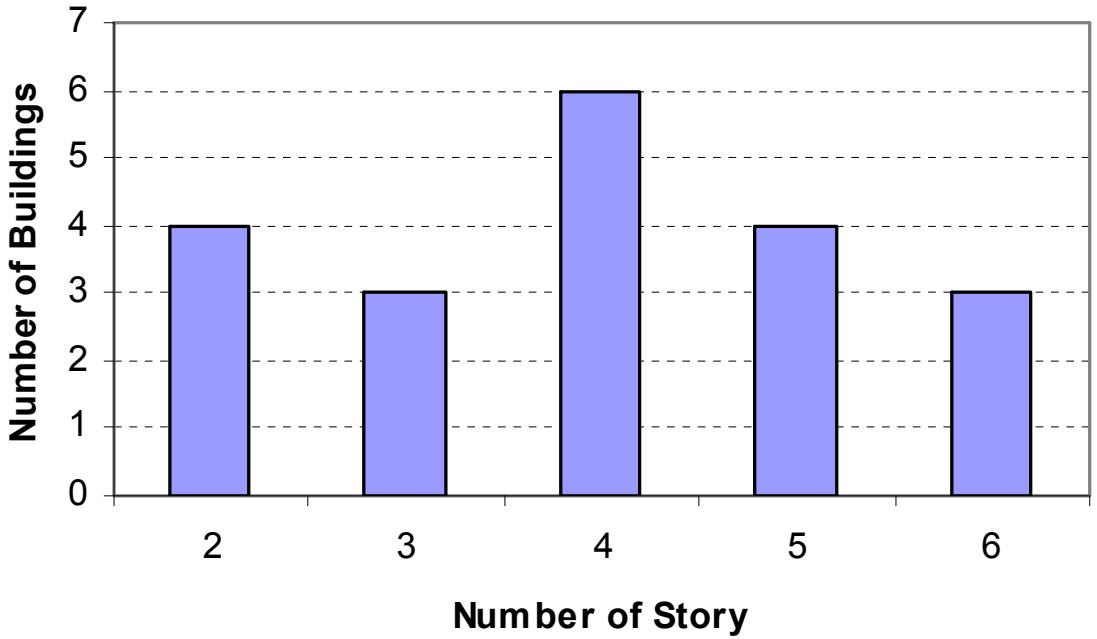
Bina veritabanı ve analiz yöntemi
Building Database and analyses

- Mevcut 2-6 katlı BA binalar
  Existing residential RC buildings (2-6) stories

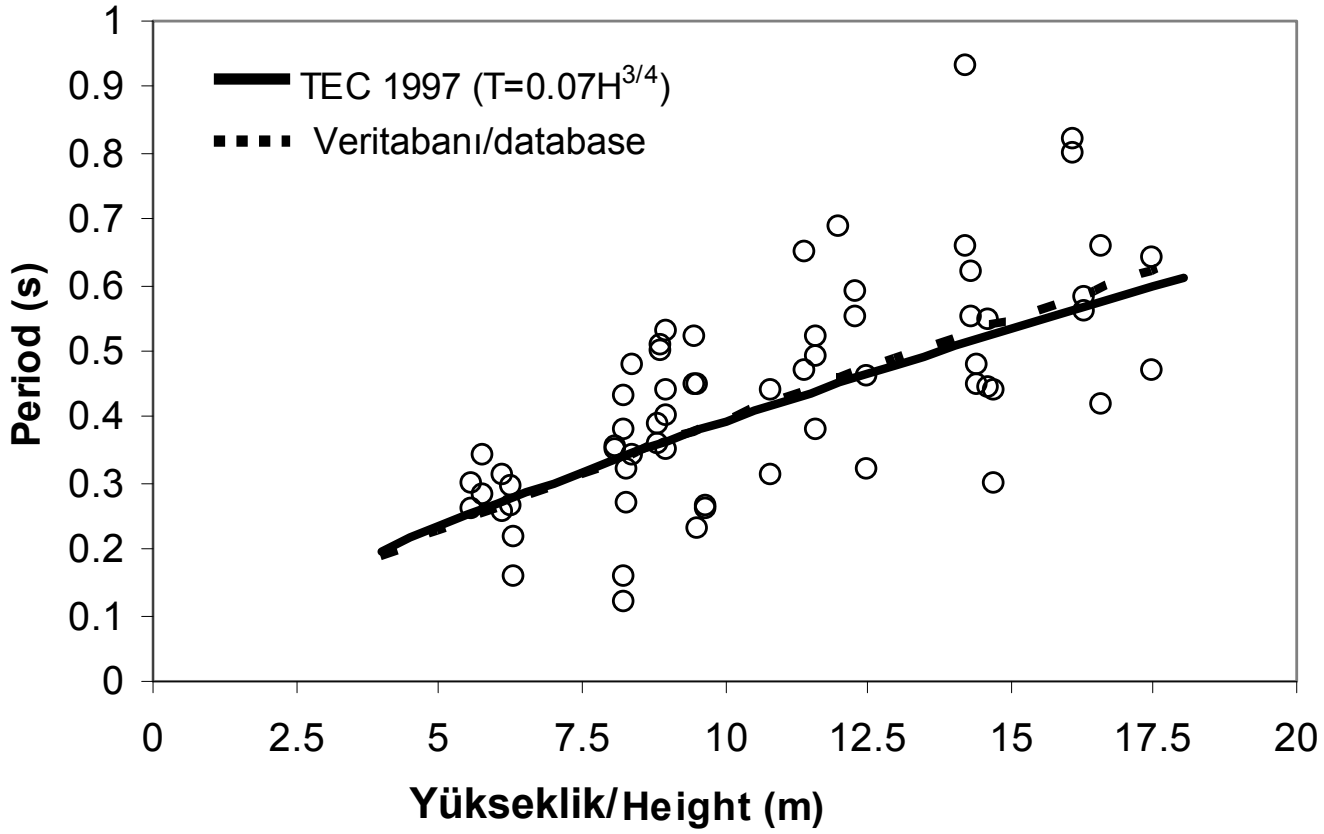
- Kat sayısı, periyot, kat alanı ve krokiye göre seçilmiş tipik binalar
  Typical buildings selected based on their number of stories, fundamental period, floor area and layout

- Üç boyutlu modellerin itme analizi
  Pushover analysis of 3D building models

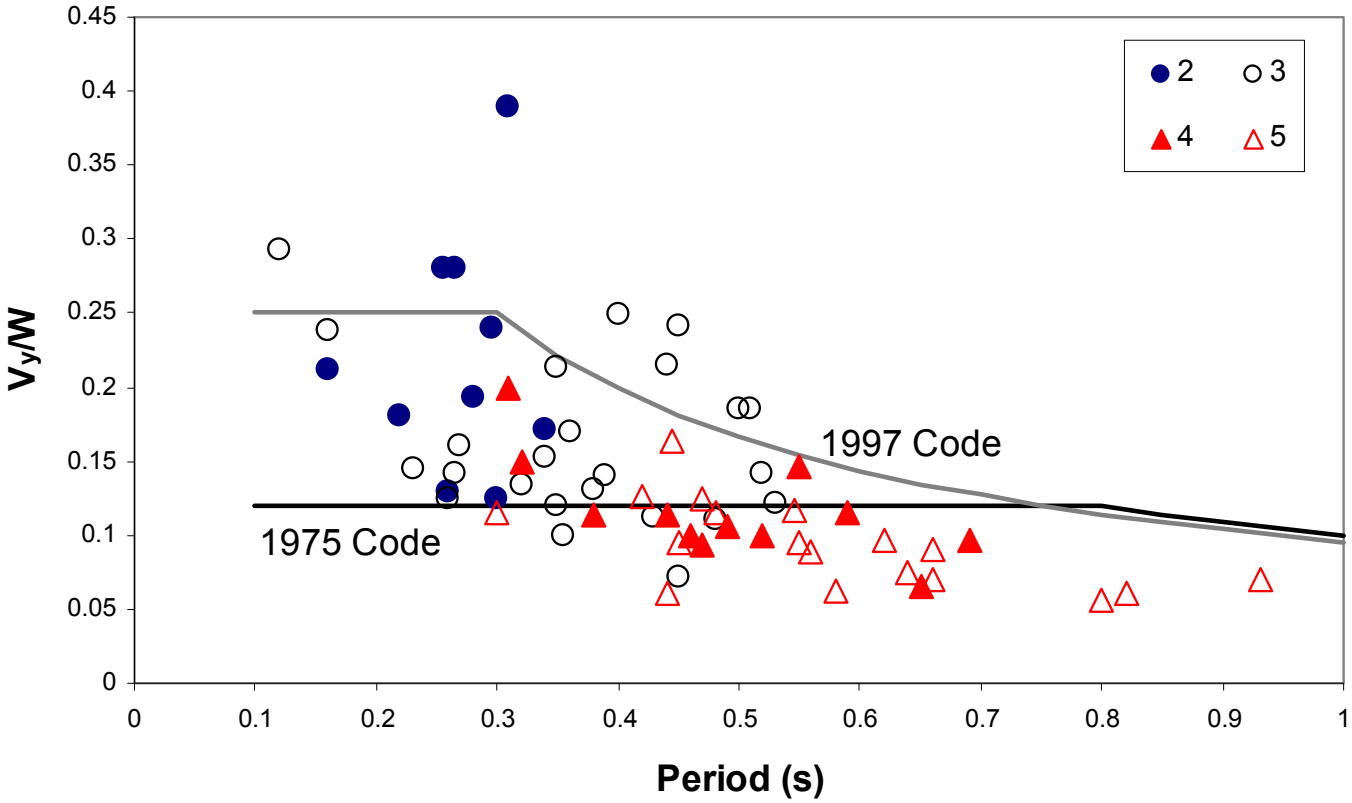
Kat yüksekliği dağılımı
Height Distribution



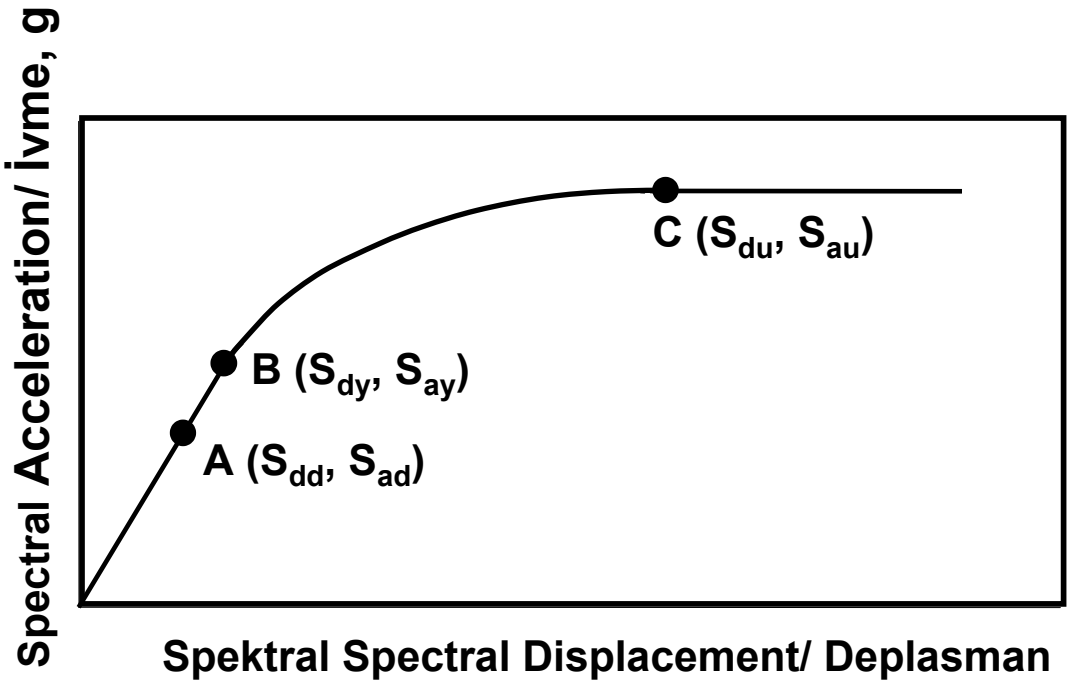
Bina yüksekliği-periyot ilişkisi
Building period versus height



Taban kesme kuvveti katsayısı
Base shear coefficient



Tipik kapasite eğrisi
Typical capacity curve (Hazus)



$$Sa_y = \frac{C_s \gamma}{\alpha_1} \qquad Sd_y = \frac{Sa_y T_e^2 g}{4\pi^2} \qquad Sa_u = \lambda Sa_y \qquad Sd_u = \lambda \mu Sd_y$$

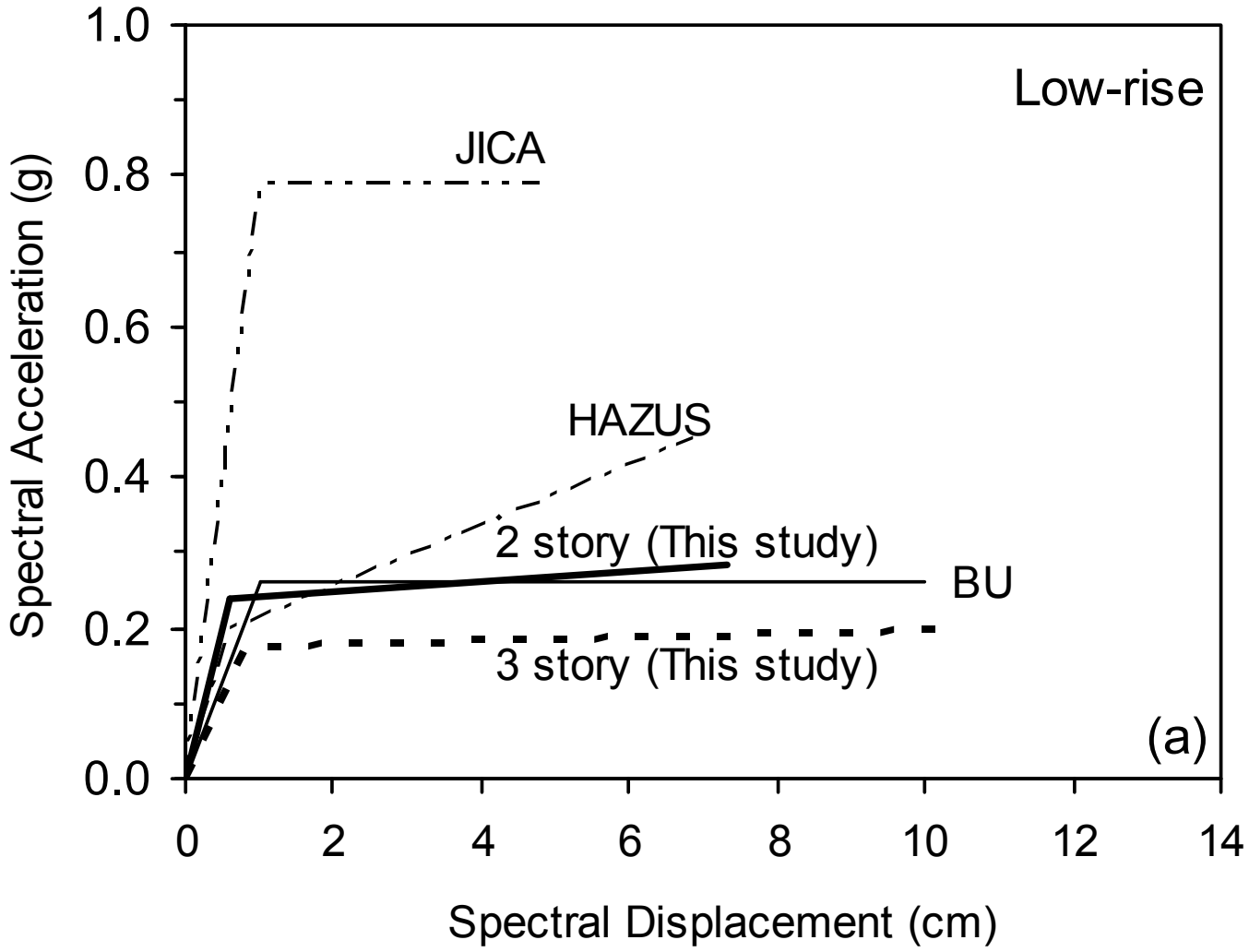
Kapasite eğrisi parametreleri
Capacity Curve Parameters

Parametre/ Parameter		Kat sayısı/ Number of stories			
		2	3	4	5
Sd_y (cm)	mean	0.75	1.06	1.67	1.52
	st. dev	0.25	0.29	0.71	0.35
Sa_y (g)	mean	0.25	0.18	0.16	0.12
	st. dev	0.09	0.07	0.04	0.04
Sd_u (cm)	mean	7.30	10.65	12.84	14.06
	st. dev	1.50	2.95	3.61	5.40
Sa_u (g)	mean	0.28	0.21	0.18	0.14
	st. dev	0.10	0.08	0.05	0.04
Cs	mean	0.10	0.10	0.10	0.10
	st. dev	0.00	0.00	0.00	0.00
Te	mean	0.27	0.34	0.47	0.55
	st. dev	0.05	0.11	0.11	0.14
PF	mean	1.17	1.24	1.28	1.29
	st. dev	0.02	0.04	0.02	0.01
α	mean	0.94	0.88	0.83	0.83
	st. dev	0.02	0.06	0.05	0.03
γ	mean	2.31	1.58	1.30	1.02
	st. dev	0.85	0.52	0.39	0.32
λ	mean	1.13	1.15	1.14	1.16
	st. dev	0.04	0.12	0.03	0.06
μ	mean	9.23	9.26	7.67	7.86
	st. dev	3.03	3.12	3.01	2.22

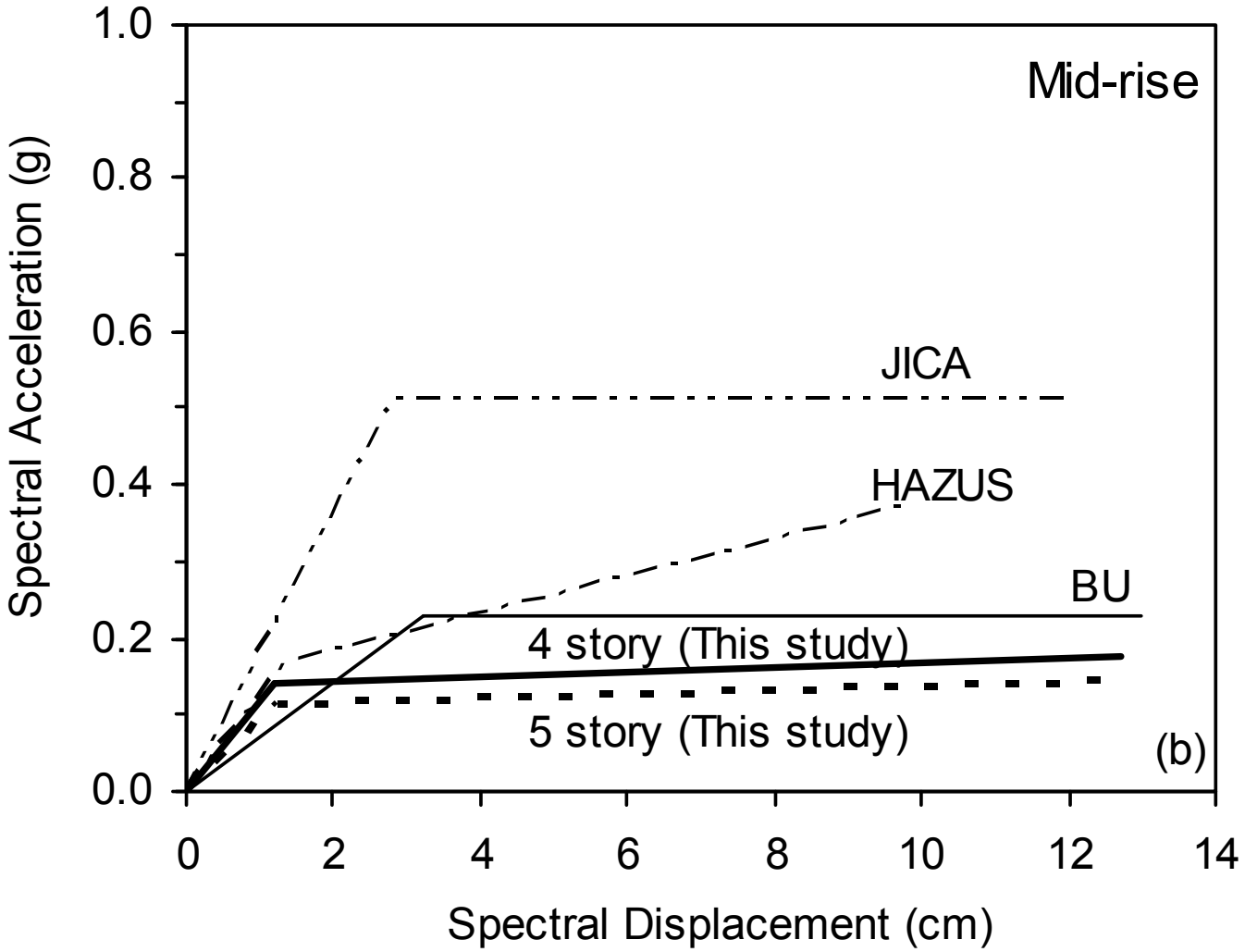
Kapasite eğrisi parametreleri
Capacity Curve Parameters

Parametre/ Parameter	Kat sayısı/ Story Number	Ortalama/ Mean	Standard Sapma/ Standard Deviation
Taban kesme kuvveti katsayısı/ Base shear coefffcient	All	0.14	0.07
	2	0.22	0.08
	3	0.16	0.05
	4	0.12	0.03
	5	0.09	0.03
Akma ötelenme oranı/ Yield drift ratio-%	All	0.12	0.04
	2	0.12	0.05
	3	0.11	0.04
	4	0.13	0.04
	5	0.11	0.03
Göçme Ötelenme oranı/ Ultimate drift ratio-%	All	1.34	0.40
	2	1.46	0.33
	3	1.41	0.46
	4	1.39	0.38
	5	1.13	0.43

Kapasiteye ilişkin çalışmalar – Az katlı
Capacity related studies-Low rise



Kapasiteye ilişkin çalışmalar – Orta katlı
Capacity related studies-Mid rise



Kapasiteye ilişkin özellikler- Okul binaları
Capacity related properties- School buildings

		Kat sayısı/ Number of stories		
Parameter		3	4	5
Sd_y (cm)	mean	1.14	2.36	3.56
	st. dev.	0.84	1.37	1.08
Sa_y (g)	mean	0.19	0.13	0.10
	st. dev.	0.12	0.09	0.05
Sd_u (cm)	mean	3.84	7.27	12.59
	st. dev.	3.09	4.47	2.34
Sa_u (g)	mean	0.27	0.17	0.11
	st. dev.	0.19	0.13	0.06
C_s	mean	0.09	0.07	0.07
	st. dev.	0.04	0.02	0.01
T_e	mean	0.54	0.95	1.28
	st. dev.	0.32	0.45	0.37
PF	mean	1.25	1.24	1.27
	st. dev.	0.13	0.19	0.10
α	mean	0.78	0.71	0.73
	st. dev.	0.10	0.13	0.09
γ	mean	1.83	1.39	1.06
	st. dev.	1.08	0.74	0.48
λ	mean	1.39	1.26	1.15
	st. dev.	0.30	0.26	0.08
μ	mean	3.38	3.09	3.67
	st. dev.	1.14	0.99	0.63

Number of stories		
3	4	5
1.06	1.67	1.52
0.29	0.71	0.35
0.18	0.16	0.12
0.07	0.04	0.04
10.65	12.84	14.06
2.95	3.61	5.40
0.21	0.18	0.14
0.08	0.05	0.04
0.10	0.10	0.10
0.00	0.00	0.00
0.34	0.47	0.55
0.11	0.11	0.14
1.24	1.28	1.29
0.04	0.02	0.01
0.88	0.83	0.83
0.06	0.05	0.03
1.58	1.30	1.02
0.52	0.39	0.32
1.15	1.14	1.16
0.12	0.03	0.06
9.26	7.67	7.86
3.12	3.01	2.22

	st. dev	3.03

Mevcut binaların deprem performans hesapları

Seismic performans assessment of existing buildings

İstanbul'daki Mevcut BA Binaların Performans Değerlendirmesi

Perfomance assessment of existing RC buildings in İstanbul

- Sokak taramasında incelenen ilçeler:

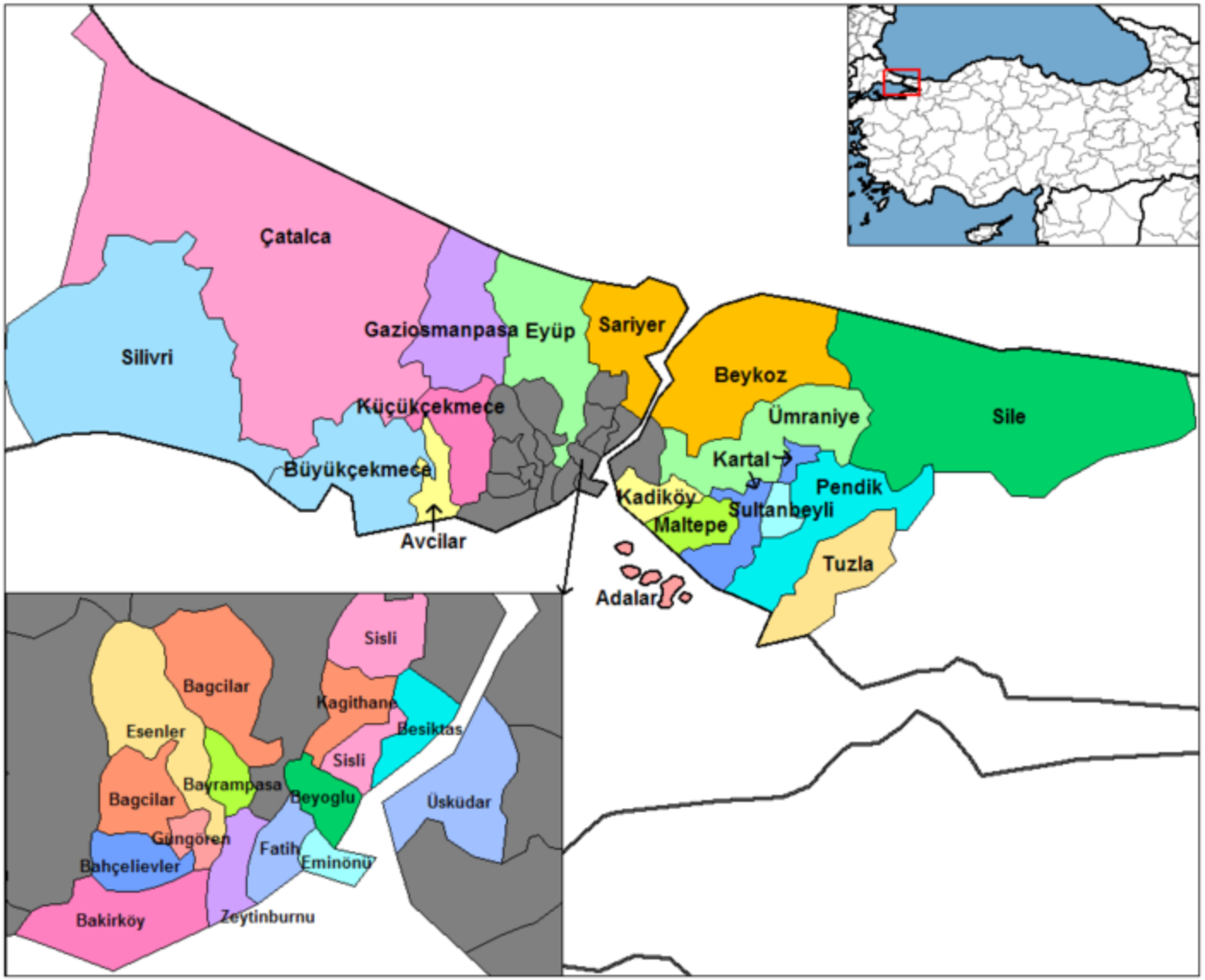
Districts considered in walk-down evaluation

- Zeytinburnu
- Fatih
- Küçükçekmece
- Bayrampaşa
- Güngören
- Bahçelievler

Dikkate alınan parametreler
Parameters considered

- Kat sayısı/ Number of stories
- Yumuşak kat/ Soft story
- Ağır çıkma/ Heavy overhang
- Görünen kalite/ Apparent quality
- Binanın konumu/ Building adjacency
- Kısa kolon/ short column
- Deprem tehlikesi/ Seismic hazard

İlçeler-Districts



Zeytinburnu

	Zeytinburnu	İstanbul	Oran/ Ratio
Nüfus/ Population	239,927	10,018,735	2.39
Alan/ Area (Ha)	1,150	77,054	1.49
Bina sayısı/ Number of buildings	16,030	700,942	2.28

BİNA ENVANTERİ

- İlk Jenerasyon (1960's)

BİNA ENVANTERİ

- İkinci Jenerasyon (1970’s)

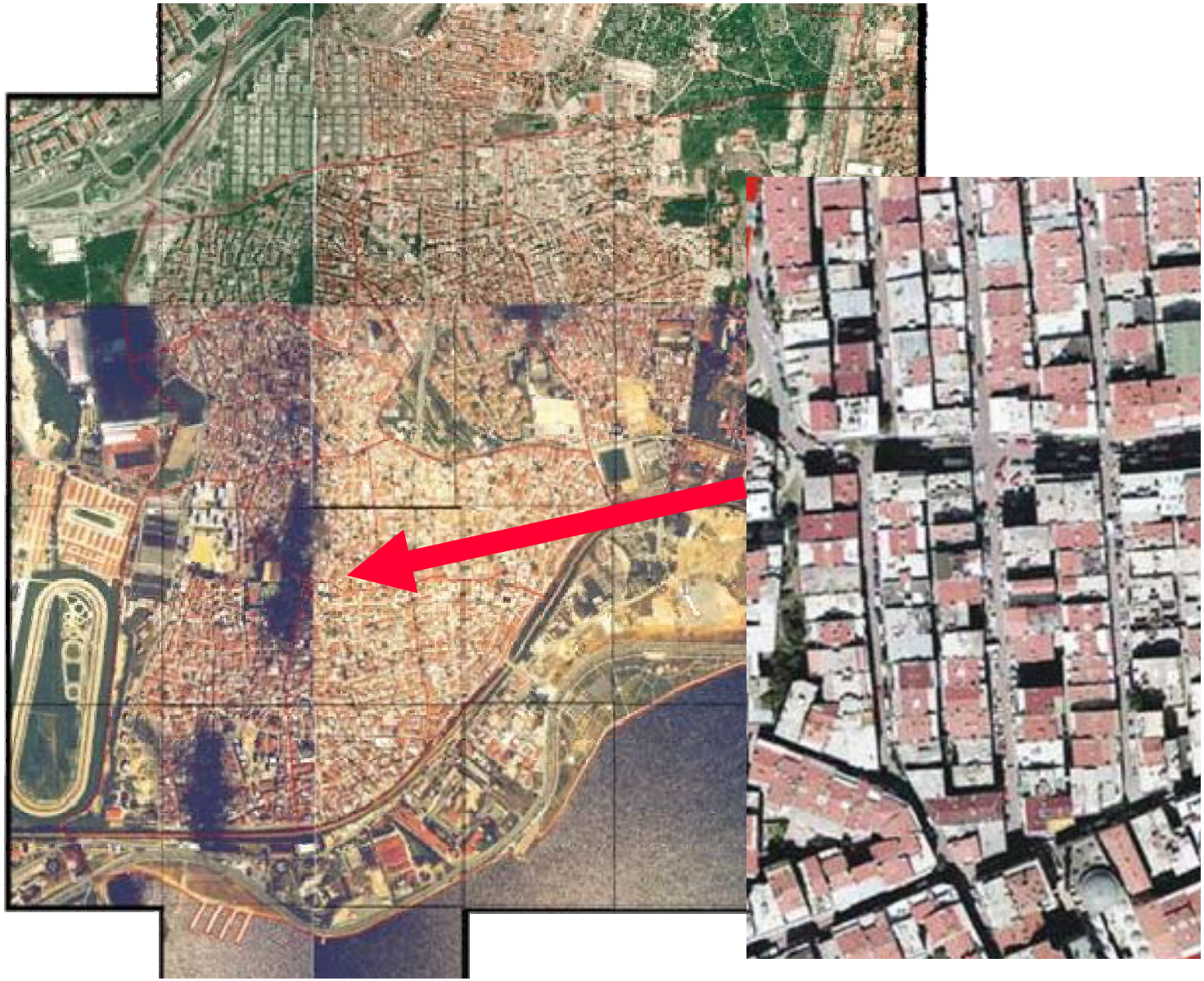
BİNA ENVANTERİ

- Üçüncü Jenerasyon (1980’s)

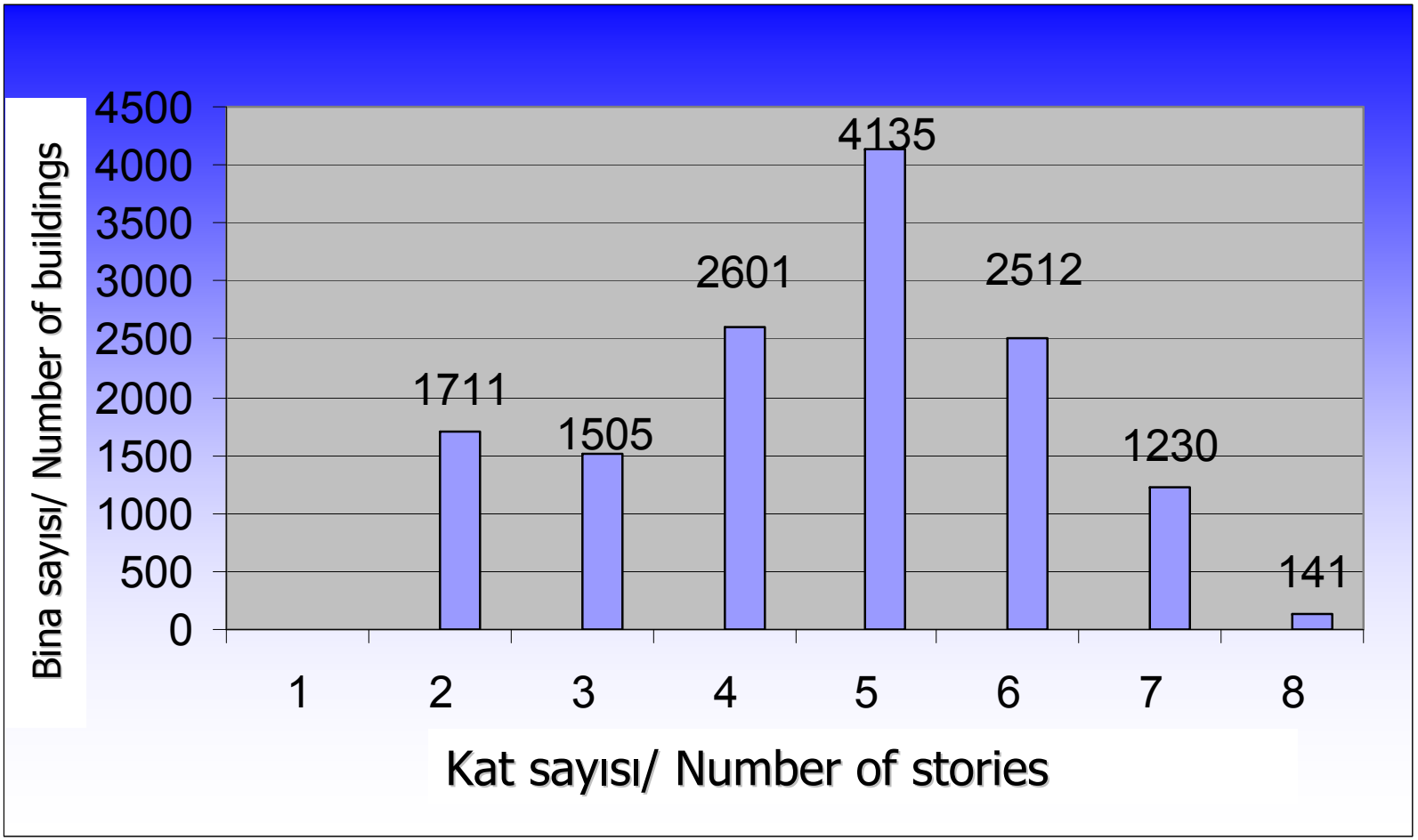
BİNA ENVANTERİ

- Dördüncü Jenerasyon (1990’s)

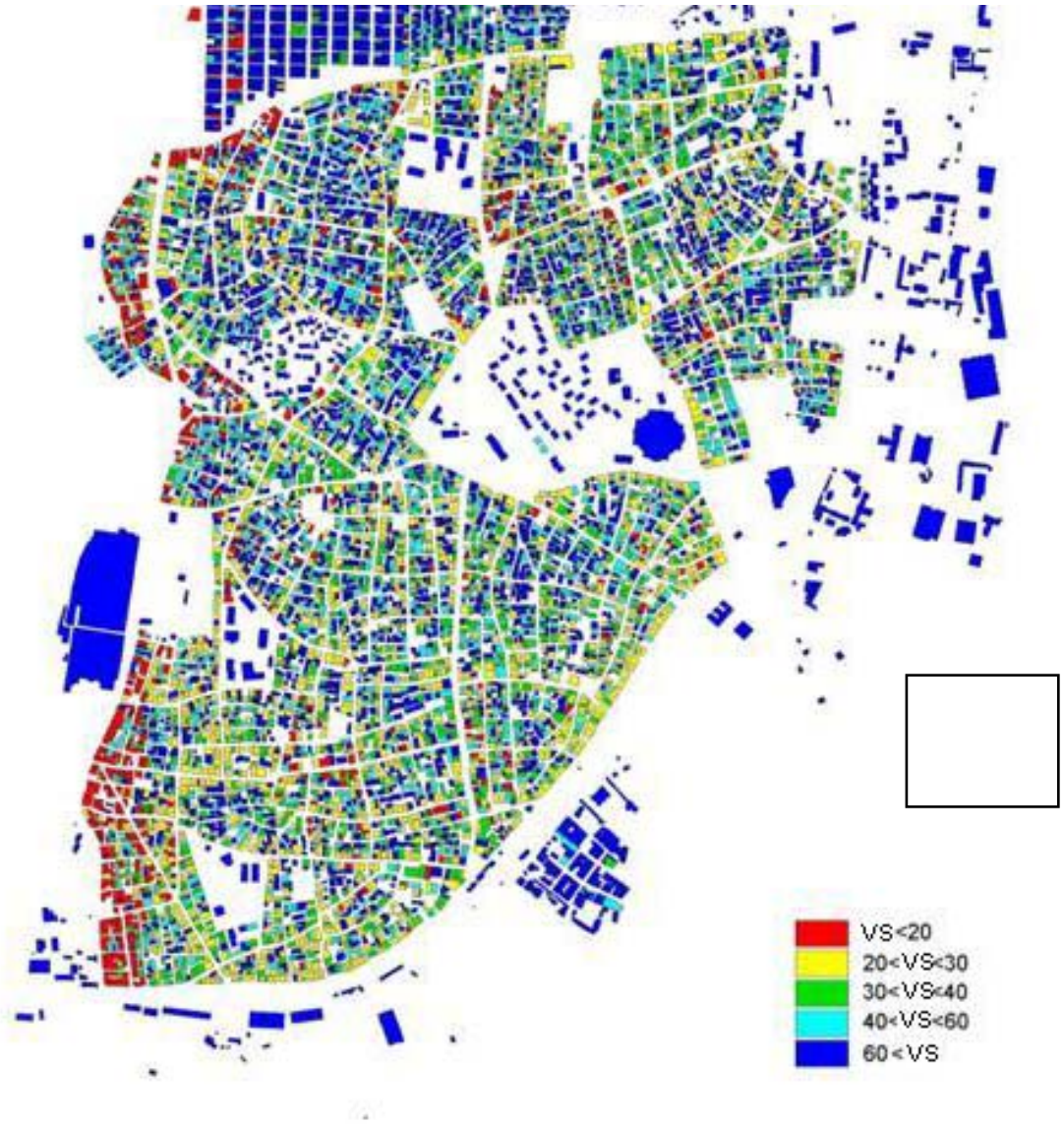
Zeytinburnu Bina Envanteri



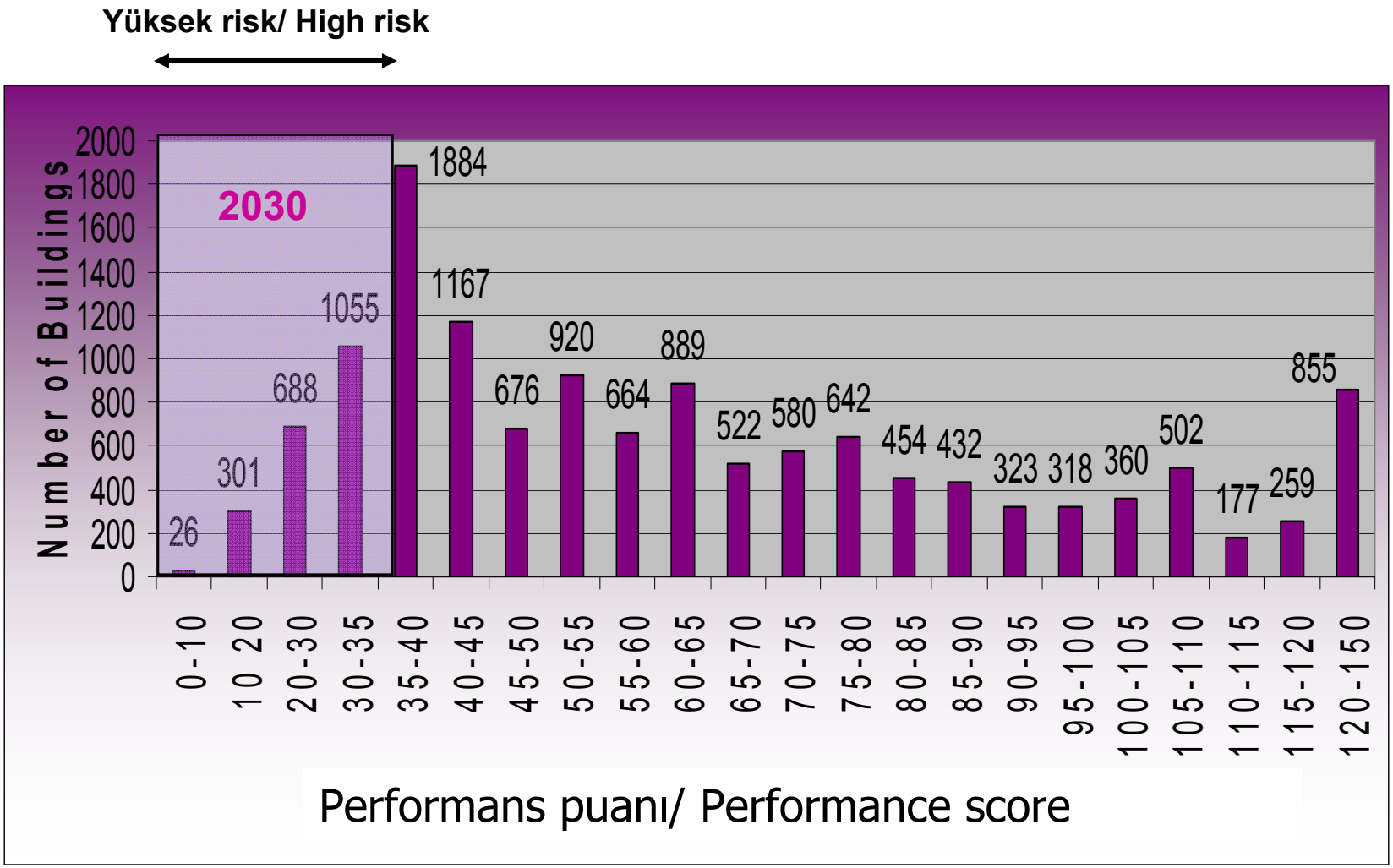
Sokak Taraması-BA Binalar
Street survey-RC buildings



Sokak Taraması (BA Binalar):Performans puanları

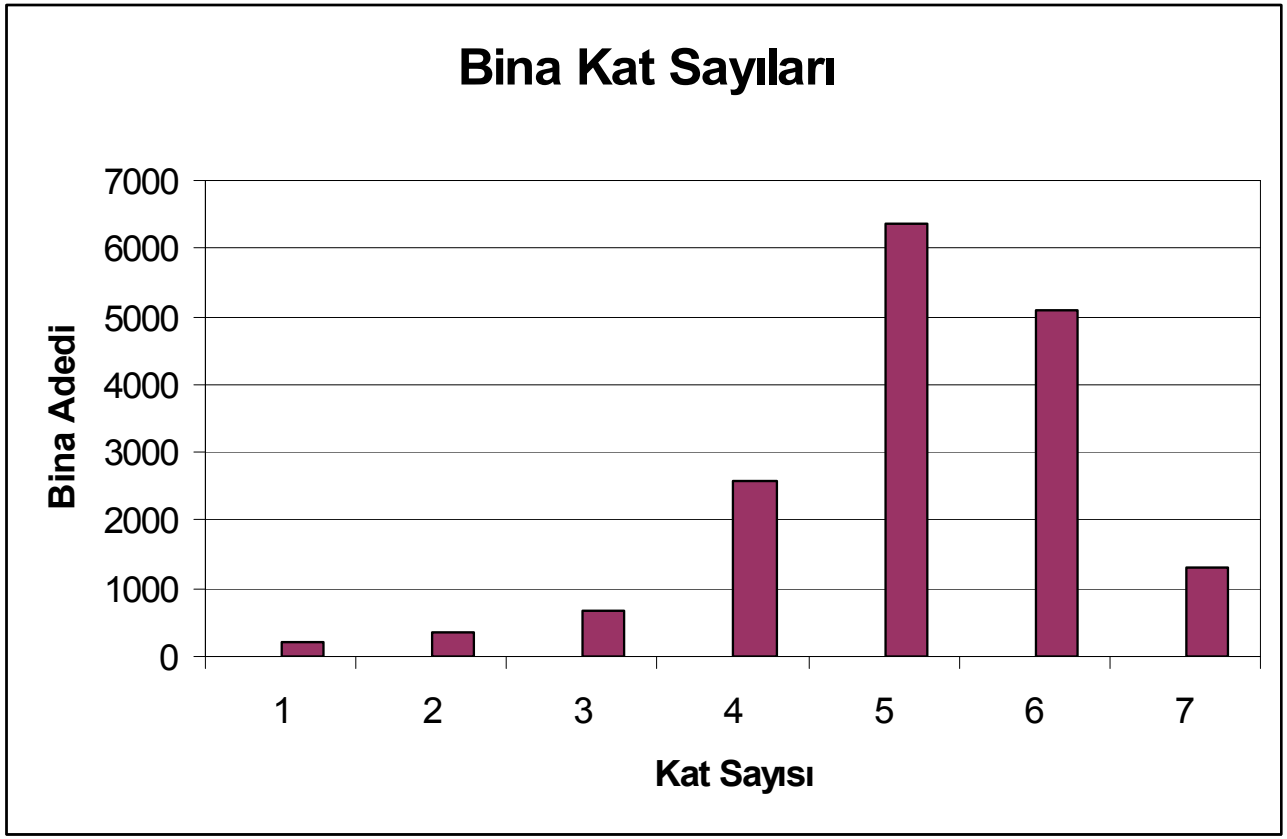


Performans puanları
Performance scores



Uygulama: Fatih, İstanbul

16523 BA Bina



Yapı stoku

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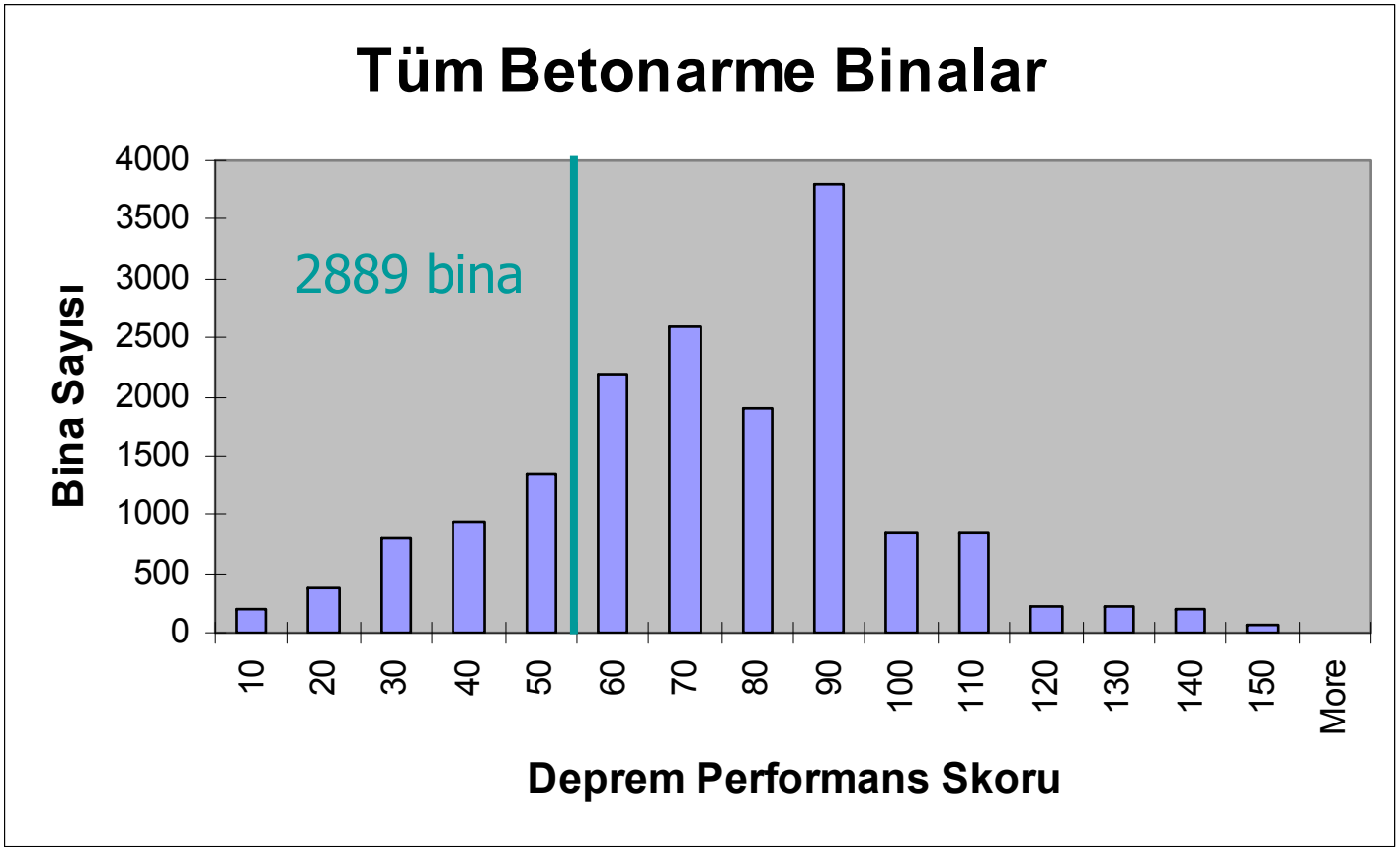
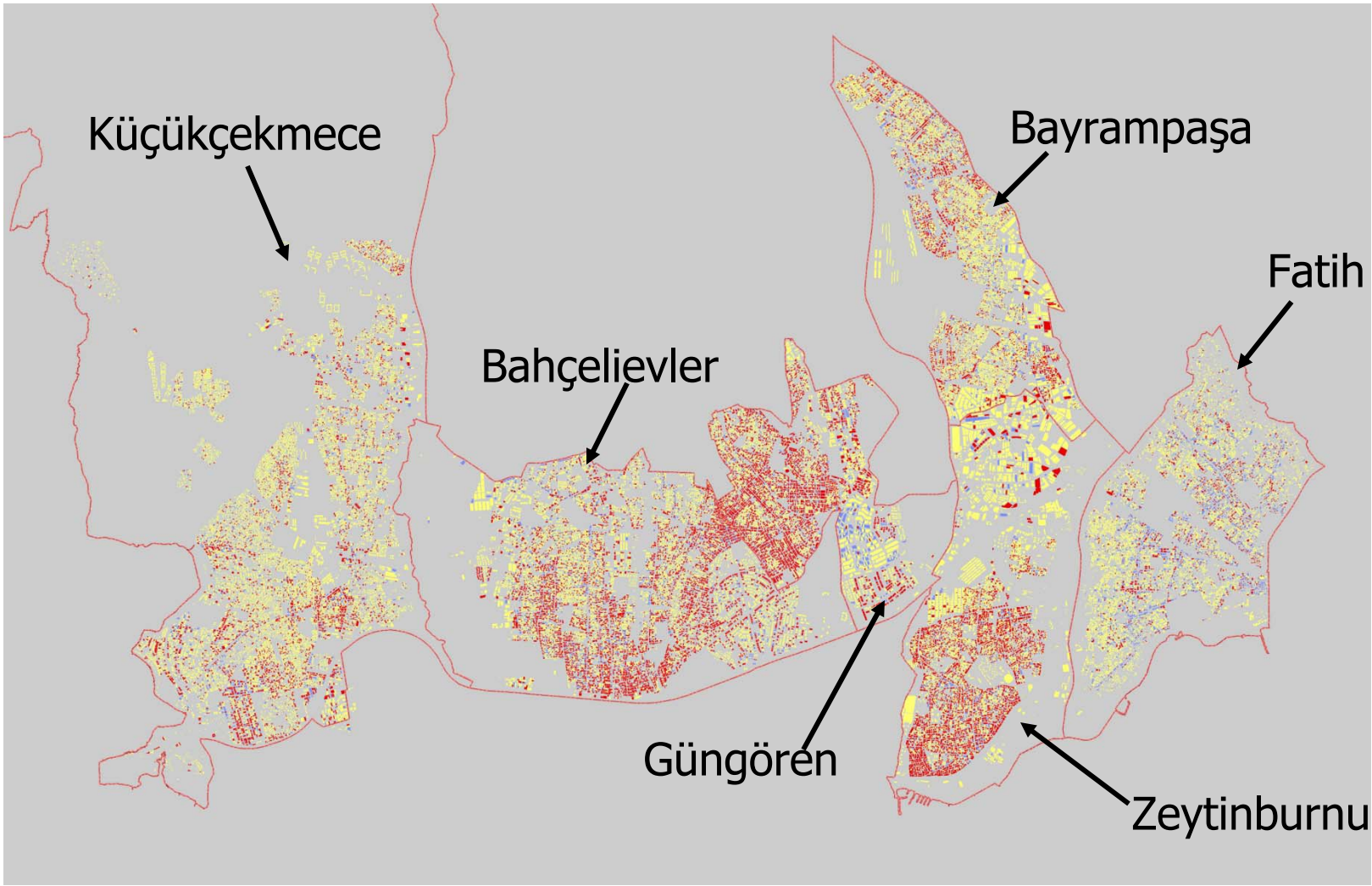
Sokak Taraması: Fatih



Altı ilçe için sonuçlar
Results for six districts

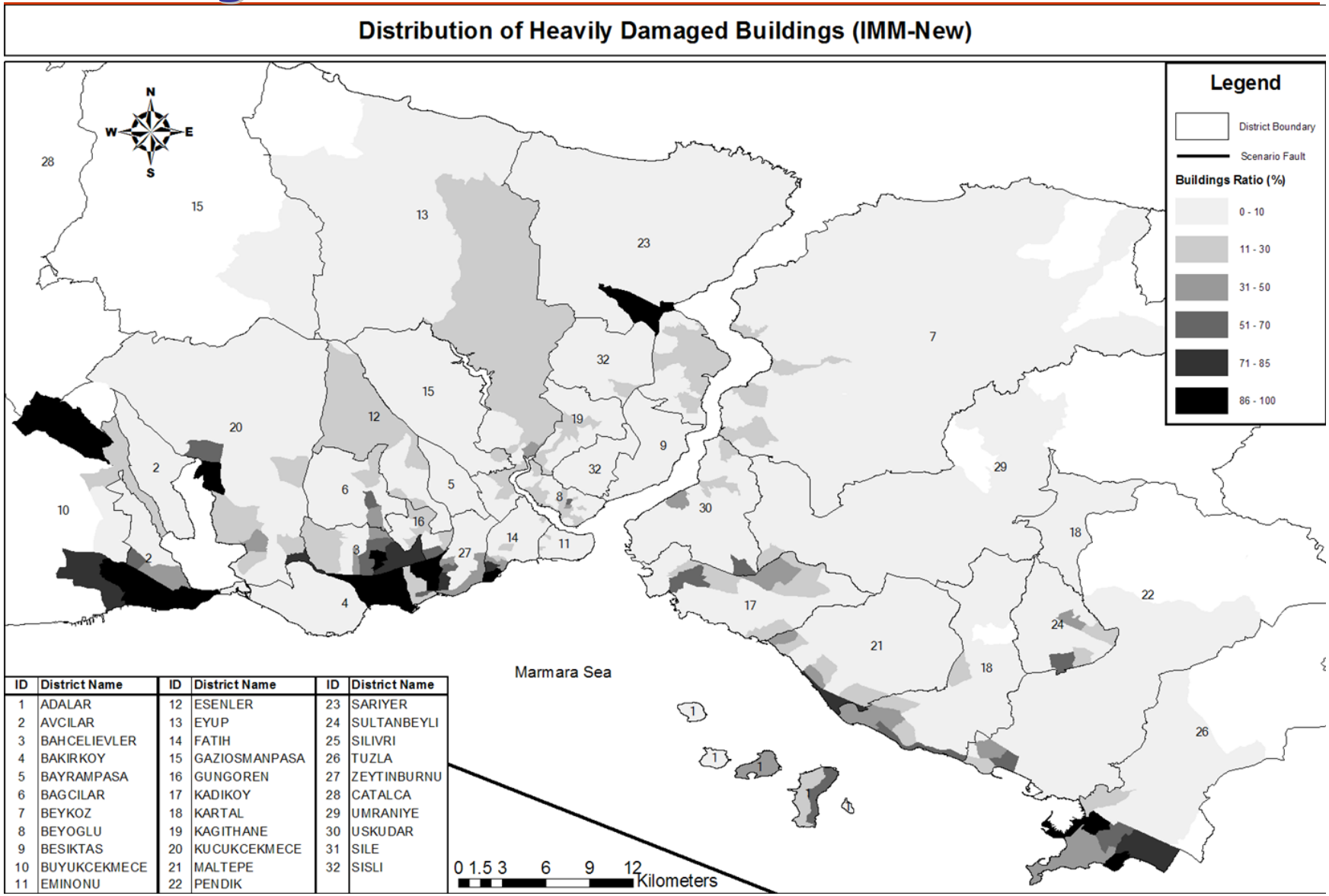
Yüksek risk/ High risk



Değerlendirme özet: Senaryo deprem Mw=7.2
Assessment summary: Scenario EQ Mw=7.2

İlçe/ District	Bina sayısı/ Number of buildings	
	Toplam/ Total	Yüksek risk/ High risk
Zeytinburnu	14 035	5 129 (37 %)
Fatih	16 907	1 713 (10 %)
Küçükçekmece	25 287	3 781 (15 %)
Bayrampaşa-Güngören-Bahçelievler	44 586	13 567 (30 %)

İstanbul için hasar tahmini: Genel model
Damage Prediction in Istanbul: Global models



ID	District Name	ID	District Name	ID	District Name
1	ADALAR	12	ESENLER	23	SARIYER
2	AVCILAR	13	EYUP	24	SULTANBEYLI
3	BAHCELIEVLER	14	FATIH	25	SILIVRI
4	BAKIRKOY	15	GAZIOSMANPASA	26	TUZLA
5	BAYRAMPASA	16	GUNGOREN	27	ZEYTINBURNU
6	BAGCILAR	17	KADIKOY	28	CATALCA
7	BEYKOZ	18	KARTAL	29	UMRANIYE
8	BEYOGLU	19	KAGITHANE	30	USKUDAR
9	BESIKTAS	20	KUCUKCEKMECE	31	SILE
10	BUYUKCEKMECE	21	MALTEPE	32	SISLI
11	EMINONU	22	PENDIK		

Nihai görüşler
Final Remarks

- Kentsel bölgelerdeki mevcut bina envanterinin en önemli bölümünü betonarme yapılar meydana getirmektedir.

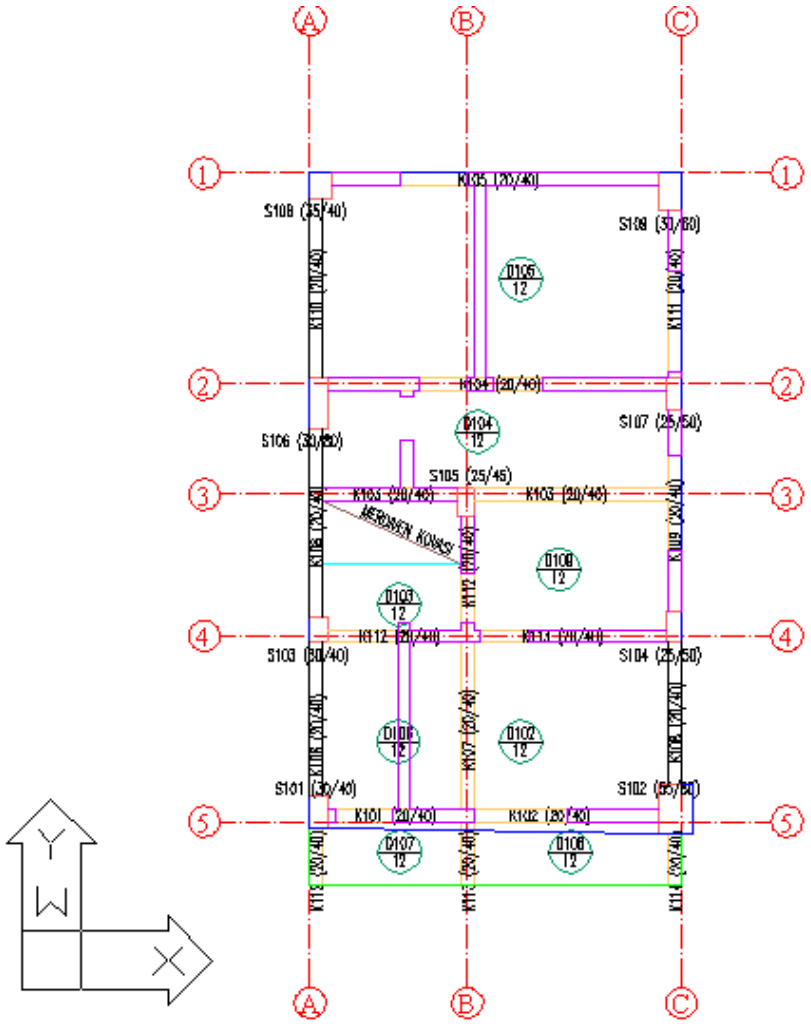
  Majority of urban building stock is comprised of RC buildings
- Mevcut yapıların deprem performansı oldukça zayıftır.

  Seismic perfomance of existing RC buildings is rather poor
- Zayıf performansa yol açan en önemli parametrelerin başında düzensizlikler, yetersiz malzeme ve işçilik kalitesi, ve yapısal yetersizlikler gelmektedir.

  The most significant parameters leading to poor performans are irregularities, inadequate and poor workmanship and material quality, and inadequate structural details.
- Mevcut BA binaların yatay yük kapasiteleri oldukça düşük olduğundan yüksek riskli bina sayısı oldukça fazladır.

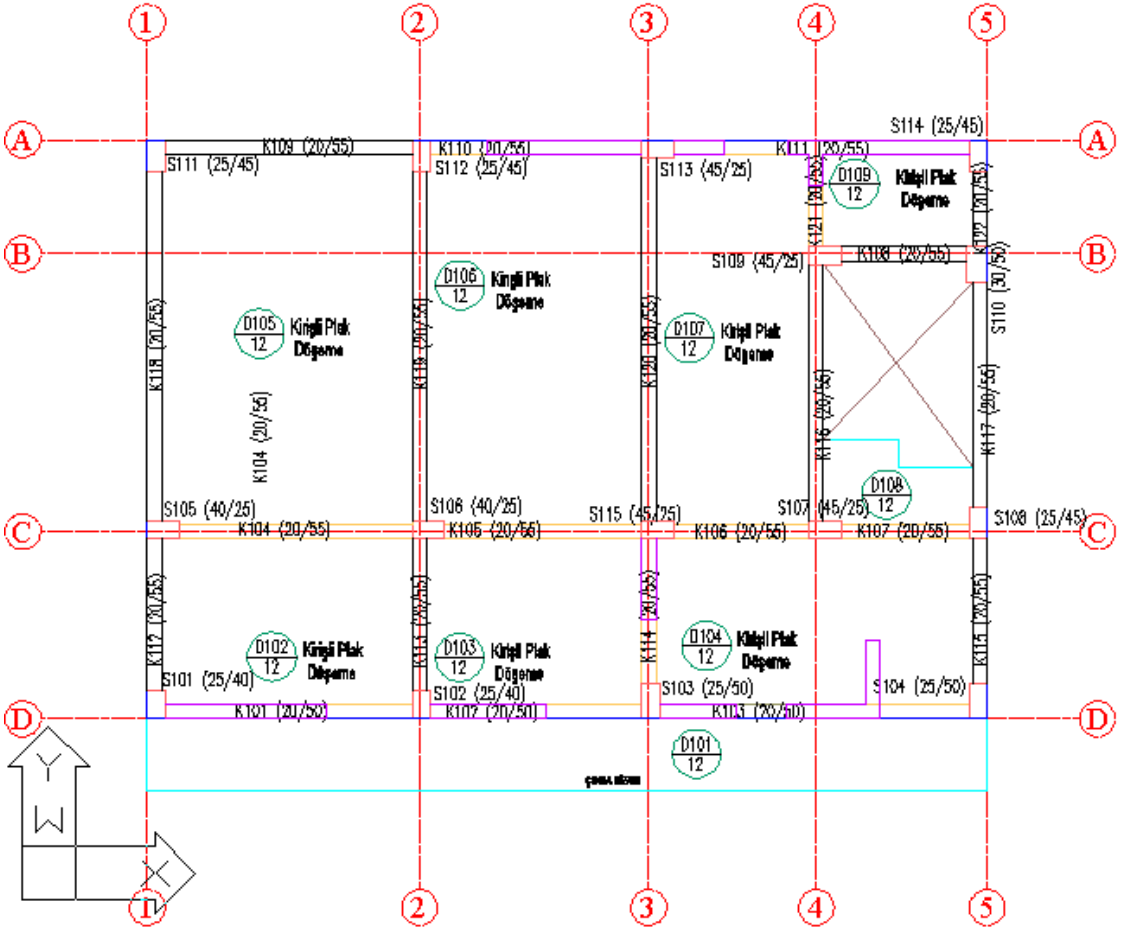
  Overall seismic capacity of existing RC buildings is quite low leading to significantly large number of vulnerable buildings.

Candidate 1



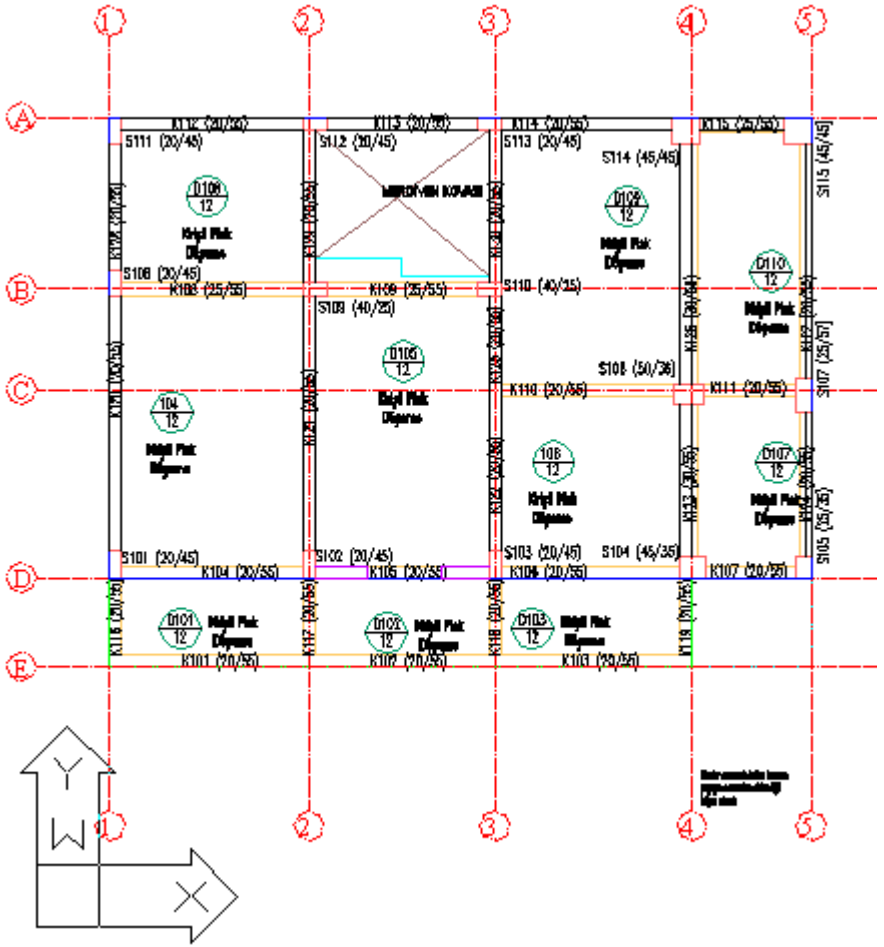
- 4 stories
- Plan: 10mx20 m
- Column density: 0.23%
- RC Wall density:0
- Story height: 2.8 m
- In-fill wall density:0.44%
- Soft story: YES
- Overhang: YES
- Quality: Poor
- Expected Vulnerability: High

Candidate 2



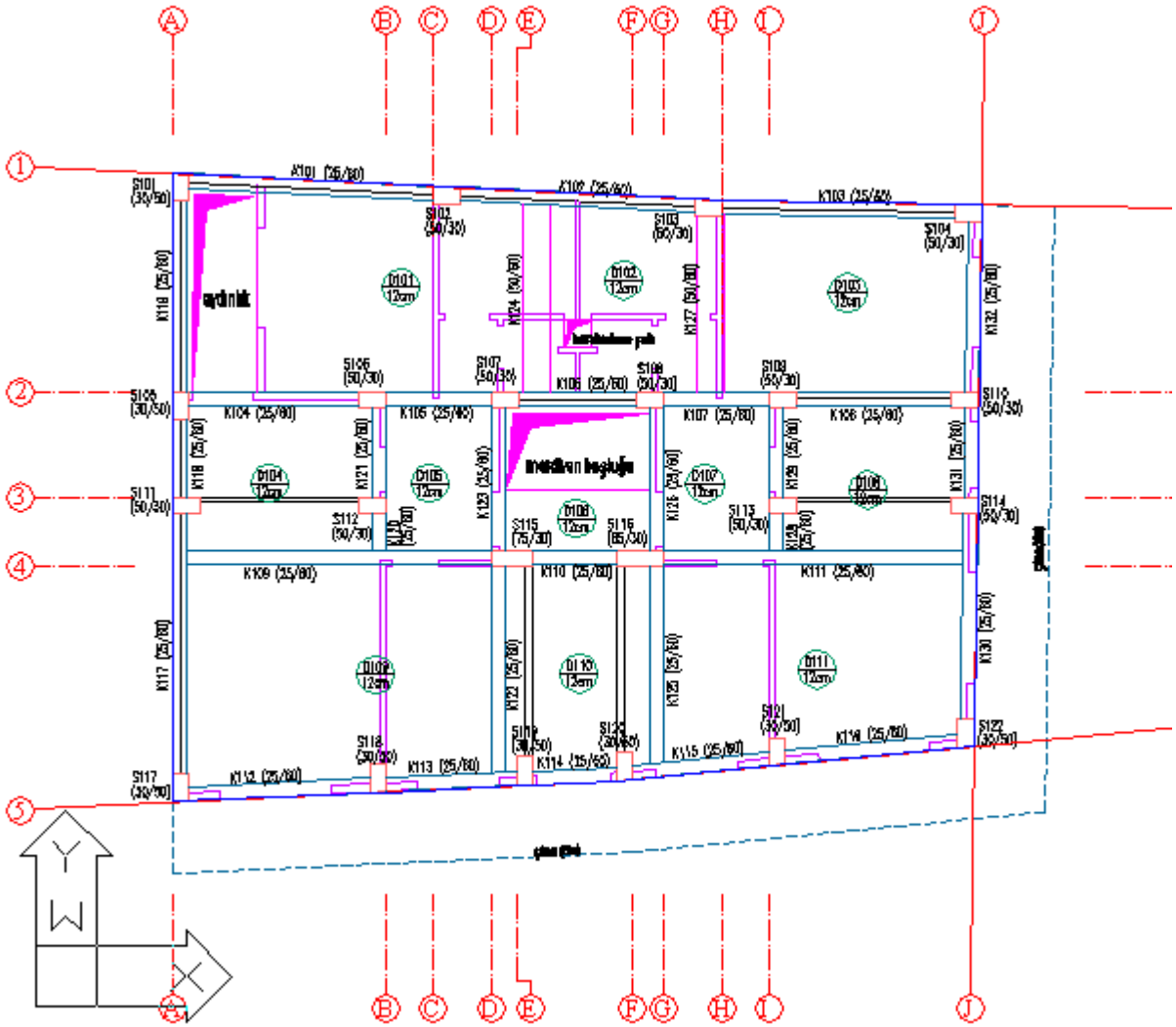
- 4 stories
- Plan: 20mx25 m
- Column density:0.12%
- RC wall density:0
- Story height: 3.0m
- In-fill wall density:0.28%
- Soft story: YES
- Overhang: YES
- Quality: Moderate
- Expected Vulnerability: Medium

Candidate 3



- 5 stories
- Plan: 22mx24 m
- Column density:0.19%
- Story height:3.1m
- In-fill wall density:0
- Soft story: YES
- Overhang: NO
- Quality: Poor
- Expected Vulnerability: High

Candidate 4



- 6 stories
- Plan: 25mx30 m
- Column density:0.12%
- Story height:2.8m
- In-fill wall density:0.07%
- Soft story: YES
- Overhang: NO
- Quality: Poor
- Expected Vulnerability: High

Teşekkürler