



1. YÜKSEK YAPILAR SEMPOZYUMU
04 – 05 MAYIS 2023 İSTANBUL

TMMOB
İNŞAAT MÜHENDİSLERİ ODASI



ÖZEL BİR YÜKSEK YAPI ÖRNEĞİ: KÜÇÜK ÇAMLICA TV KULESİ
YAPI-DEPREM-RÜZGAR TASARIMI

İnş. Yük. Müh. Raşit Çömlek
Balkar Yapısal Tasarım ve Danışmanlık A.Ş.



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YAPI BİLGİSİ

- Üsküdar Bölgesi, Küçük Çamlıca Tepesi
- Dijital Yayıncılık, Radyo ve GSM
- Temel üst kotu : -18.00
Anten tepe noktası : +365.50
Toplam yükseklik : 383.50 m
- Yapı üç ana bölümden oluşmaktadır;
 - Betonarme Şaft
 - Geçiş Bölgesi
 - Çelik Anten
- 4 bodrum kat ve 3 payanda(podyum) katı bulunmaktadır.(H=4.50 m)





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MALZEME BİLGİSİ

- Beton Sınıfı : C60
 - Donatı Çeliği : B420C
 - Yapısal Çelik : S355JR
S460 (Anten Kolonları)
- Zemin Sınıfı : Z1 (ABYBHY-2007)
- Zemin Em. Ger. : $\sigma_{zem} = 130.0 \text{ kN/m}^2$





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YÖNETMELİKLER

- İstanbul Yüksek Binalar Deprem Yönetmeliği
- İstanbul Yüksek Binalar Rüzgar Yönetmeliği
- Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik
- TS 500 Betonarme Yapıların Tasarım ve Yapım Kuralları
- TS 648 Çelik Yapıların Hesap ve Yapım Kuralları
- ANSI TIA-222 Structural Standard for Antennas
- ACI 318 Building Code Requirements for Structural Concrete
- ASCE 7 Minimum Design Loads for Buildings
- ASCE 41 Seismic Evaluation and Retrofit of Existing Buildings
- AISC Steel Construction Manual





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TASARIM FELSEFESİ

Tablo 4.1. Yüksek Binalar için Performansa Göre Tasarım Aşamaları

Tasarım Aşaması	Tasarım Aşaması I – A	Tasarım Aşaması I – B	Tasarım Aşaması II	Tasarım Aşaması III
Tasarım Türü	Ön Tasarım (Boyutlama)	Tasarım	Gerçekleme [†]	Gerçekleme
Deprem Düzeyi	Normal sınıf binalarda (D2) depremi Özel sınıf binalarda (D3) depremi	Normal sınıf binalarda (D2) depremi Özel sınıf binalarda (D3) depremi	Normal sınıf binalarda (D1) depremi Özel sınıf binalarda (D2) depremi	Normal sınıf binalarda (D3) depremi
Hedef performans	Can Güvenliği	Can Güvenliği	Kesintisiz Kullanım	Göçmeme
Analiz türü	Mod Birleştirme Yöntemi ile Lineer Üç Boyutlu Analiz	Zaman Tanım Alanında Nonlineer Üç Boyutlu Analiz (2*7 çözüm ort)	Mod Birleştirme Yöntemi ile Lineer Üç Boyutlu Analiz	Zaman Tanım Alanında Nonlineer Üç Boyutlu Analiz (2*7 çözüm ort)
Taşıyıcı Sistem Davranış Kats.	$R \leq 7$	–	$R = 1.5$	–
Görelî Kat Öteleme Oranı Limiti	% 2	% 2.5	% 1	% 3.5
B/A çubuk elemanlar da kesit rijitliği	Etkin rijitlik (DBYBHY 2007'den)	Etkin rijitlik (moment-eğrilik eğrisinden)	Etkin rijitlik (moment-eğrilik eğrisinden)	Etkin rijitlik (moment-eğrilik eğrisinden)
Dayanım parametresi	Karakteristik dayanım	Ortalama (Expected) dayanım	Ortalama (Expected) dayanım	Ortalama (Expected) dayanım
Kabul kriteri	Dayanım – Görelî kat öteleme oranı	Birim şekil değiştirme – Görelî kat öteleme oranı	Dayanım – Görelî kat öteleme oranı	Birim şekil değiştirme – Görelî kat öteleme oranı

[†] Yüksekliği 75 m'den fazla olmayan binalarda tasarım bu aşamada sonuçlanacaktır.

*ASCE/SEI 41-06: Seismic Rehabilitation of Existing Buildings, American Society of Civil Engineers, 1. Baskı, 15/05/2007.

Performans Kriterleri

Deprem Düzeyi Hedef Performans	D2 (% 10/50) Hemen Kullanım	D3 (% 2/50) Can Güvenliği
Analiz Yöntemi	Mod Süperpozisyonu	Nonlinear Time History
Taşıyıcı Sistem Davranış K. Kabul Kriteri	1.5	–
Dayanım & Rijitlik Parametreleri Sönüm	Dayanım / Görelî Kat Öteleme Oranı Ortalama Dayanım / Çatlamış Kesit Rijitlikleri %5	Birim Şekil Değiştirme / Görelî Kat Öteleme Oranı Ortalama Dayanım / Çatlamış Kesit Rijitlikleri %2
Görelî Kat Öteleme Limiti	%1	%2.5
Beton için Birim Ş.D. Limiti	–	0.0135
Donatı için Birim Ş.D. Limiti	–	0.04
Çelik Kolon Şekil Değiştirme Limitleri	–	ASCE 41-06 ¹
Çelik Kiriş Şekil Değiştirme Limitleri	–	ASCE 41-06 ¹
Bag Kiriş Şekil Değiştirme Limitleri	–	Naish (2013) ²



İSTANBUL BÜYÜKŞEHİR BELEDİYESİ
İMAR MÜDÜRLÜĞÜ

İSTANBUL YÜKSEK BİNALAR DEPREM YÖNETMELİĞİ

Deprem Mühendisliği Anabilim Dalı
Kandilli Rasathanesi ve Deprem Araştırma Enstitüsü
Boğaziçi Üniversitesi
Çengelköy, İstanbul

Versiyon – IV

Mayıs 2008

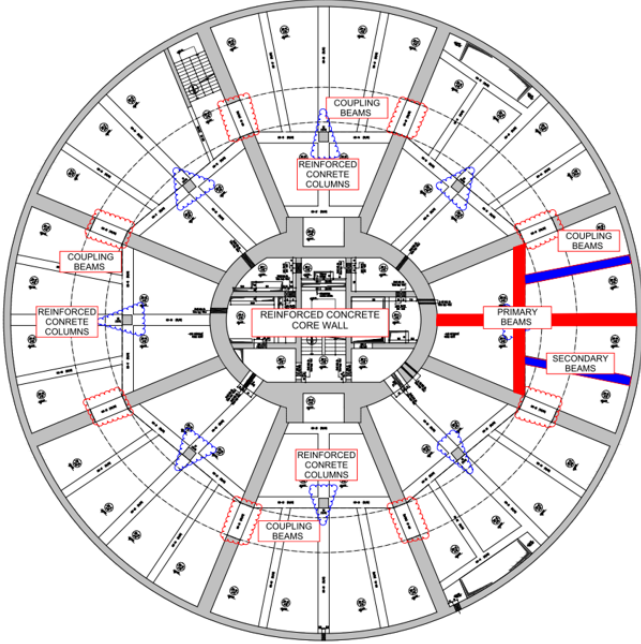


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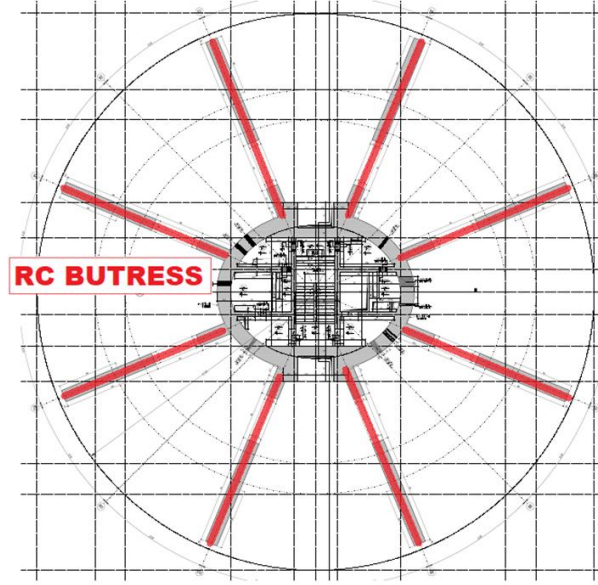
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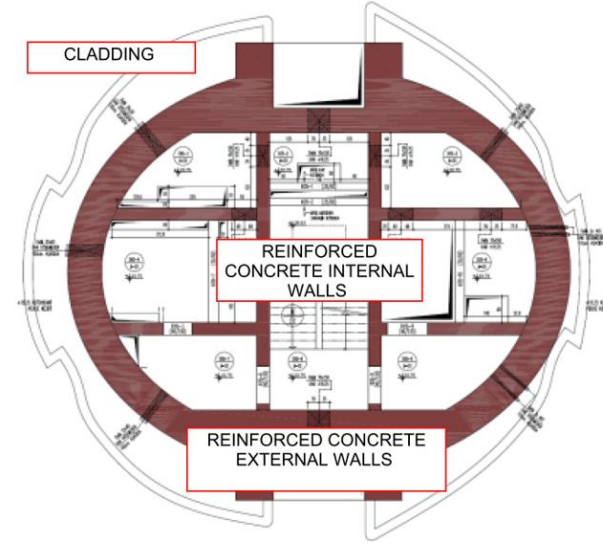
BETONARME TAŞIYICI SİSTEM



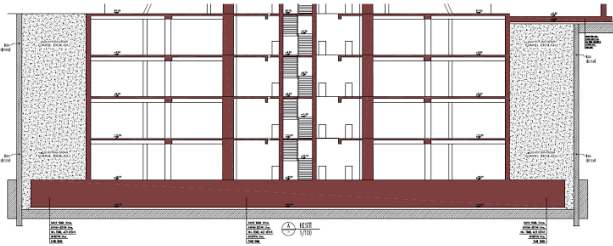
Basement Plan



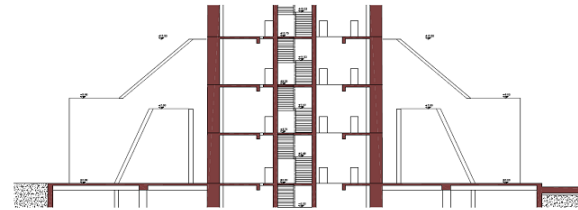
Podium Plan



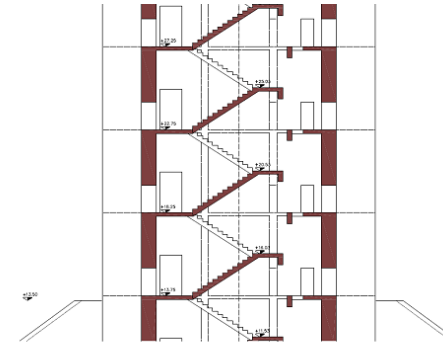
Tower Plan



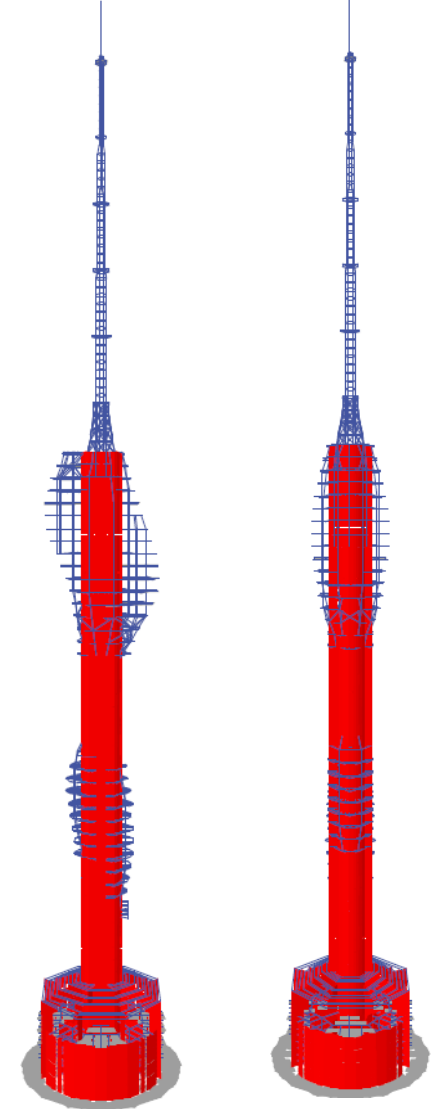
Basement Section



Podium Section



Tower Section



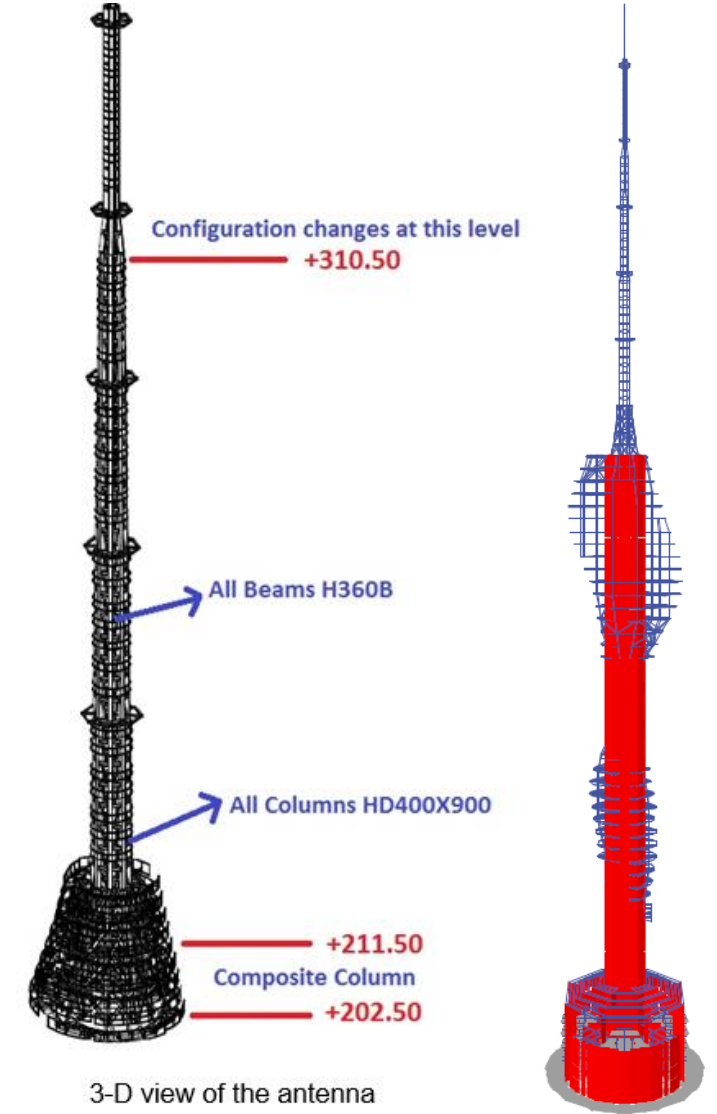
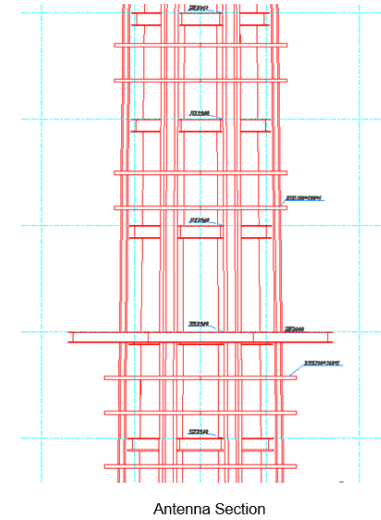
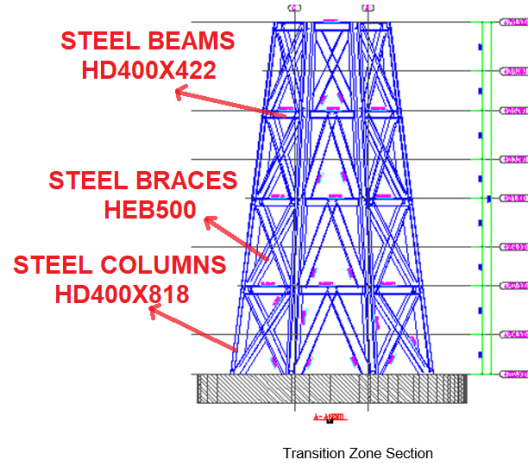
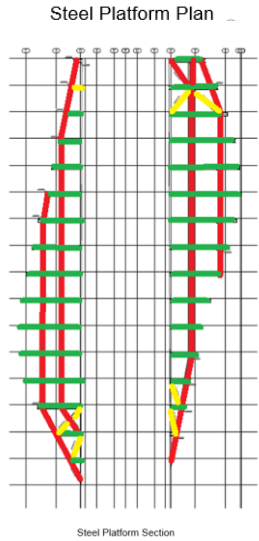
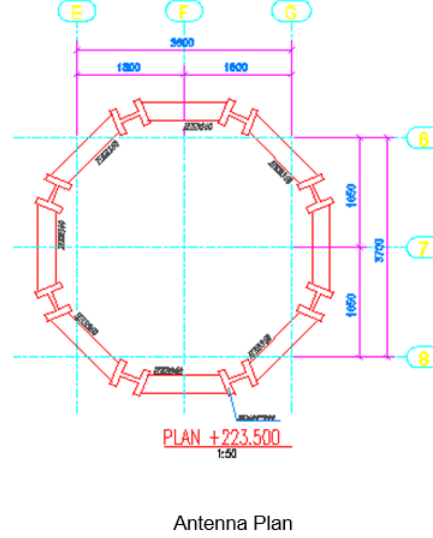
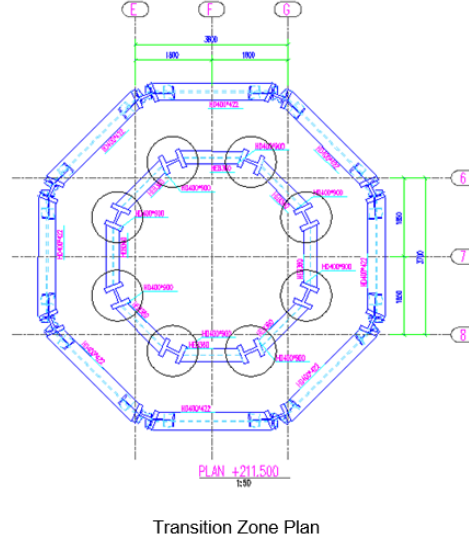
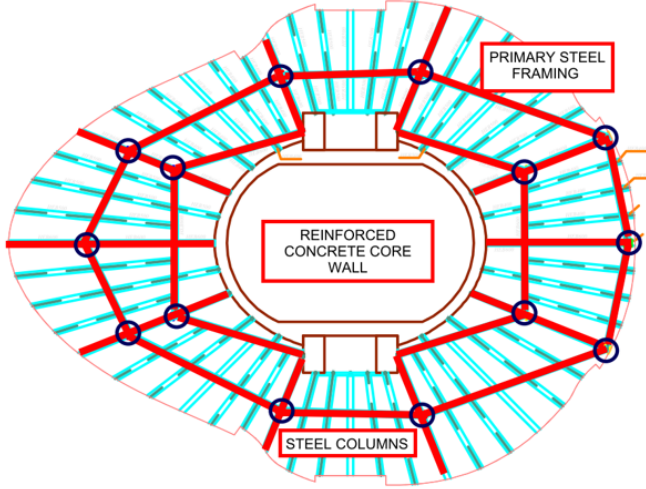


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ÇELİK TAŞIYICI SİSTEM



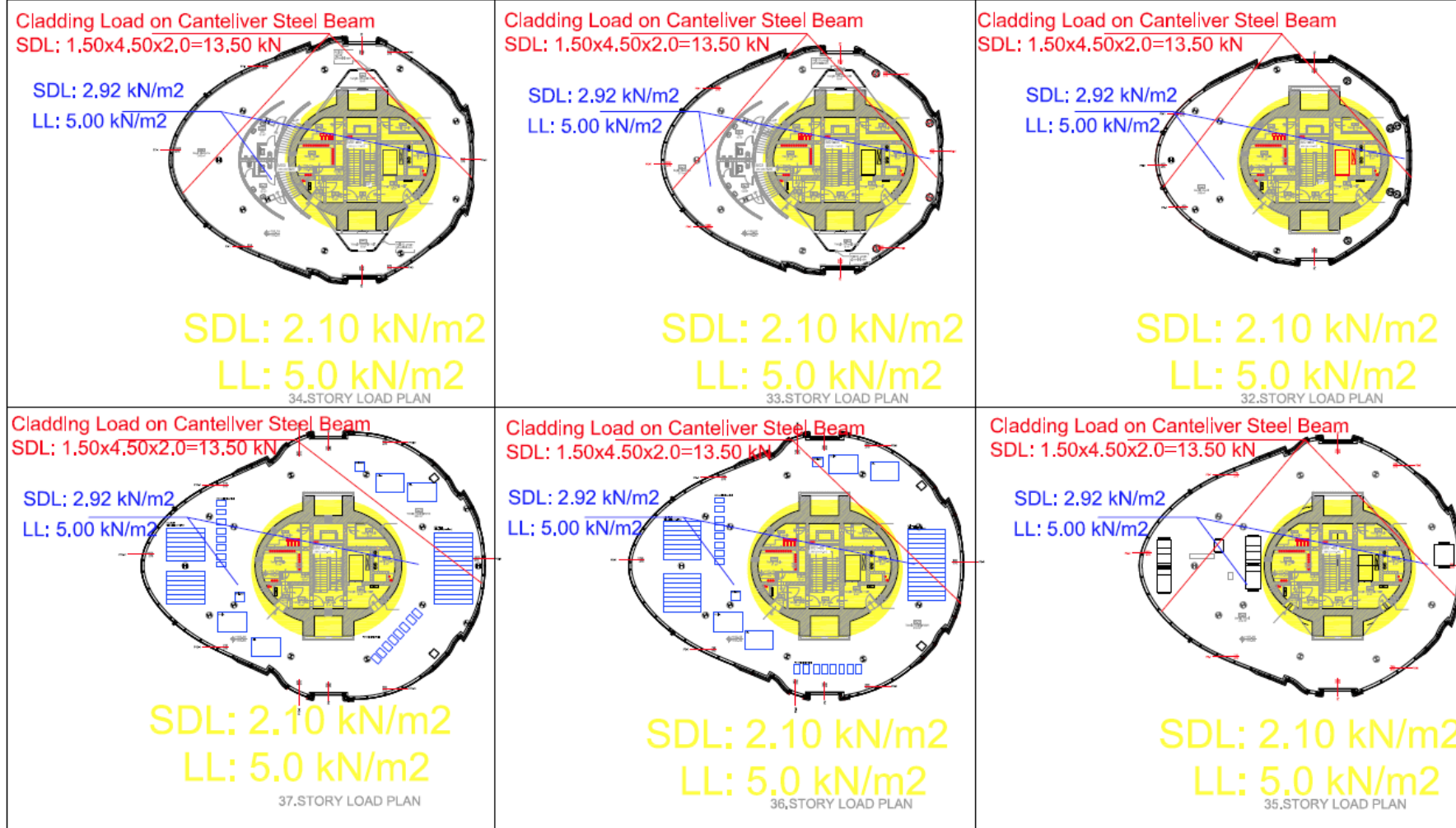


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DÜŞEY YÜKLER





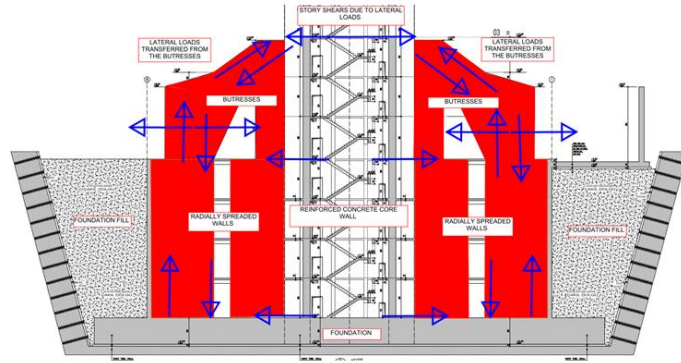
1. YÜKSEK YAPILAR SEMPOZYUMU

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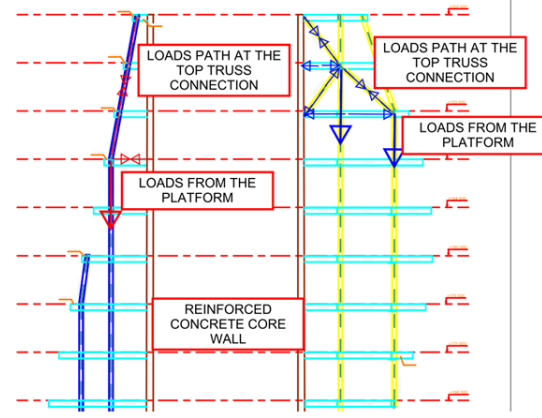
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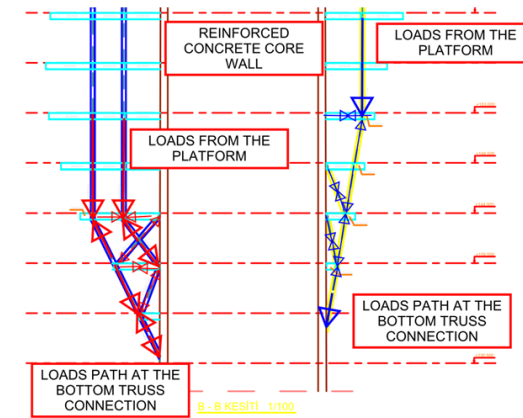
YÜK AKIŞ DİYAGRAMLARI



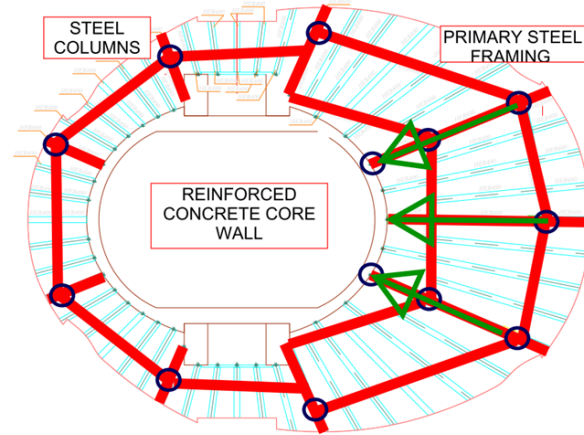
Foundation, basement and podium load paths



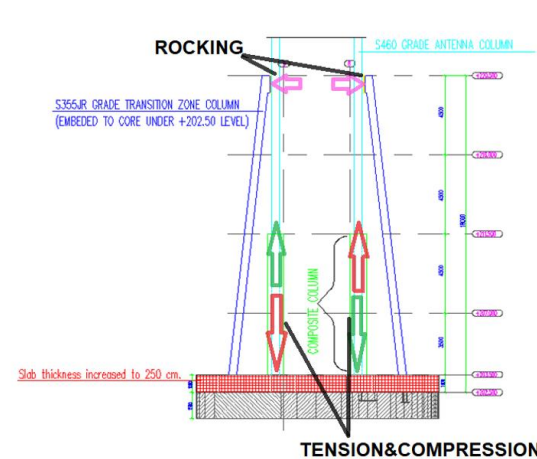
A Typical section through platforms at the top floor and the load path



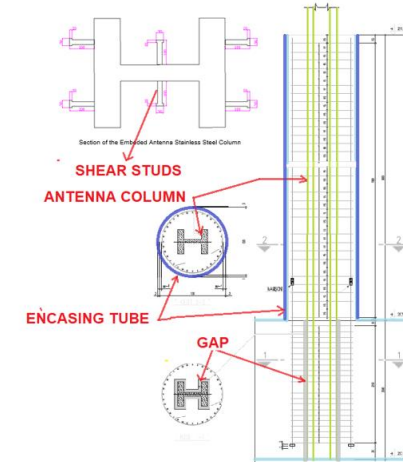
A Typical section through platforms at the bottom floors and the load path



A typical steel framing plan where large in-plane forces are transferred



Transferred lateral and vertical load of antenna to the transition zone and RC slab



Transferred lateral and vertical load of antenna to the composite column and slab



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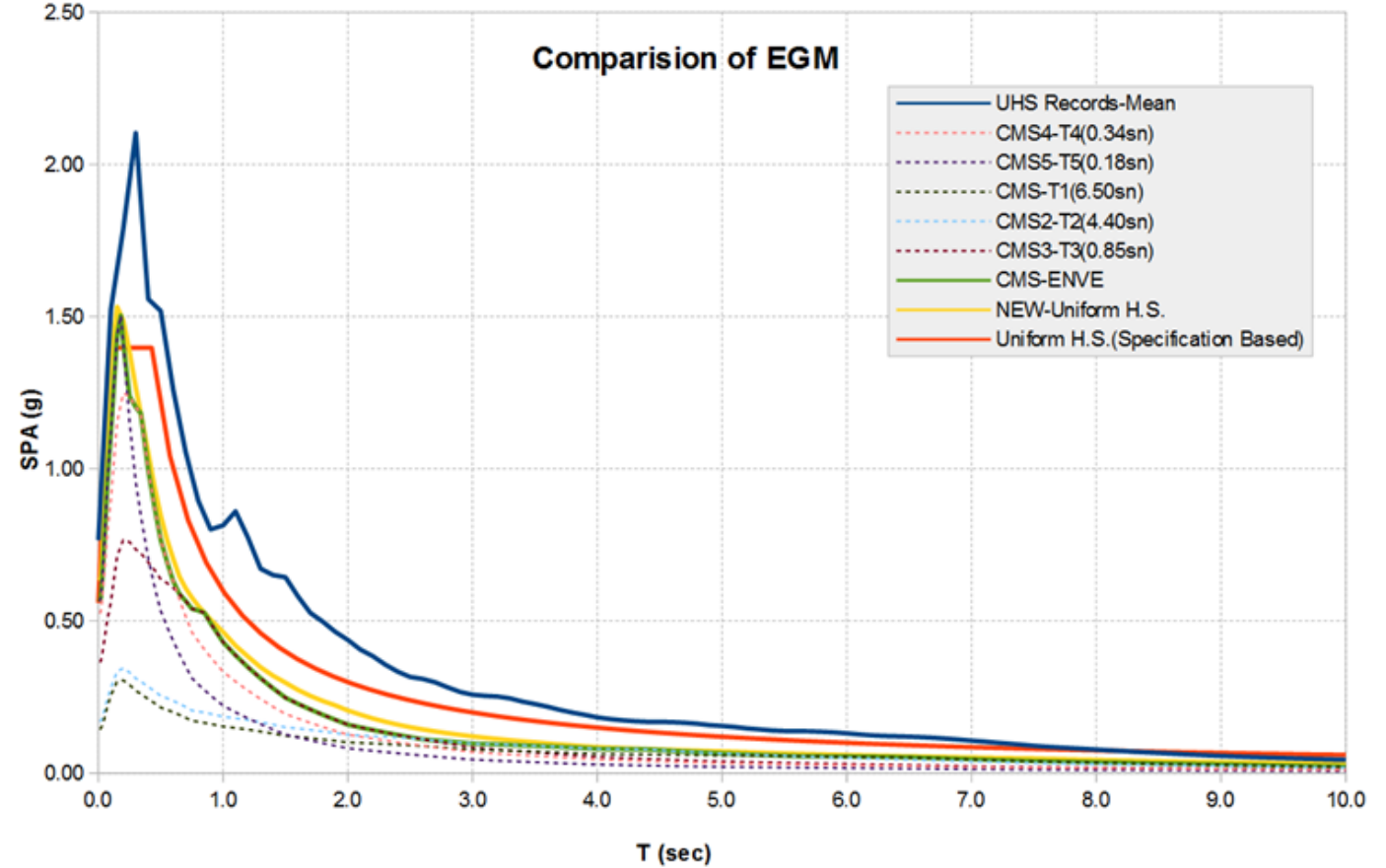


DEPREMSELLİK

- Olasılıksal sismik tehlike analizi ve sahaya özel deprem yer hareketlerinin seçimi.
- Eşit tehlike(Uniform hazard) spektrumu
- Koşullu ortalama(Conditional mean) spektrum

Table 6. Modal Characteristics of the Structure (Participating Mass Ratios)

T*	Mode	Period sec	UX %	UY %	Sum UX %	Sum UY %
T ₁ *=6.6	1	6.80	44.98	0.00	44.98	0.00
	2	6.40	0.00	39.90	44.98	39.90
T ₂ *=4.4	3	4.47	14.72	0.10	59.70	39.99
	4	4.39	0.06	19.61	59.76	59.60
T ₃ *=0.85	5	1.22	0.59	1.41	60.34	61.01
	6	1.21	1.64	0.51	61.98	61.52
	7	0.86	14.18	0.00	76.16	61.52
	8	0.83	0.00	14.74	76.16	76.26
	9	0.67	0.27	0.00	76.43	76.26
	10	0.56	0.03	0.67	76.46	76.93
T ₄ *=0.34	11	0.56	0.60	0.04	77.06	76.96
	12	0.56	0.01	0.00	77.07	76.96
	13	0.35	4.25	0.05	81.32	77.02
	14	0.34	0.07	3.67	81.39	80.69
	15	0.31	2.23	0.06	83.62	80.75
	16	0.31	0.04	3.13	83.66	83.88
	17	0.29	0.00	0.00	83.66	83.88
	18	0.21	0.12	0.48	83.78	84.36
T ₅ *=0.18	19	0.21	0.59	0.09	84.37	84.45
	20	0.19	0.00	0.00	84.37	84.45
	21	0.18	4.36	0.00	88.74	84.45
	22	0.18	0.04	0.65	88.78	85.10
	23	0.18	0.02	4.08	88.79	89.18
	24	0.16	0.03	0.31	88.82	89.49
	25	0.16	0.24	0.01	89.06	89.50
	26	0.14	0.05	0.06	89.12	89.56
	27	0.13	0.38	0.41	89.50	89.97





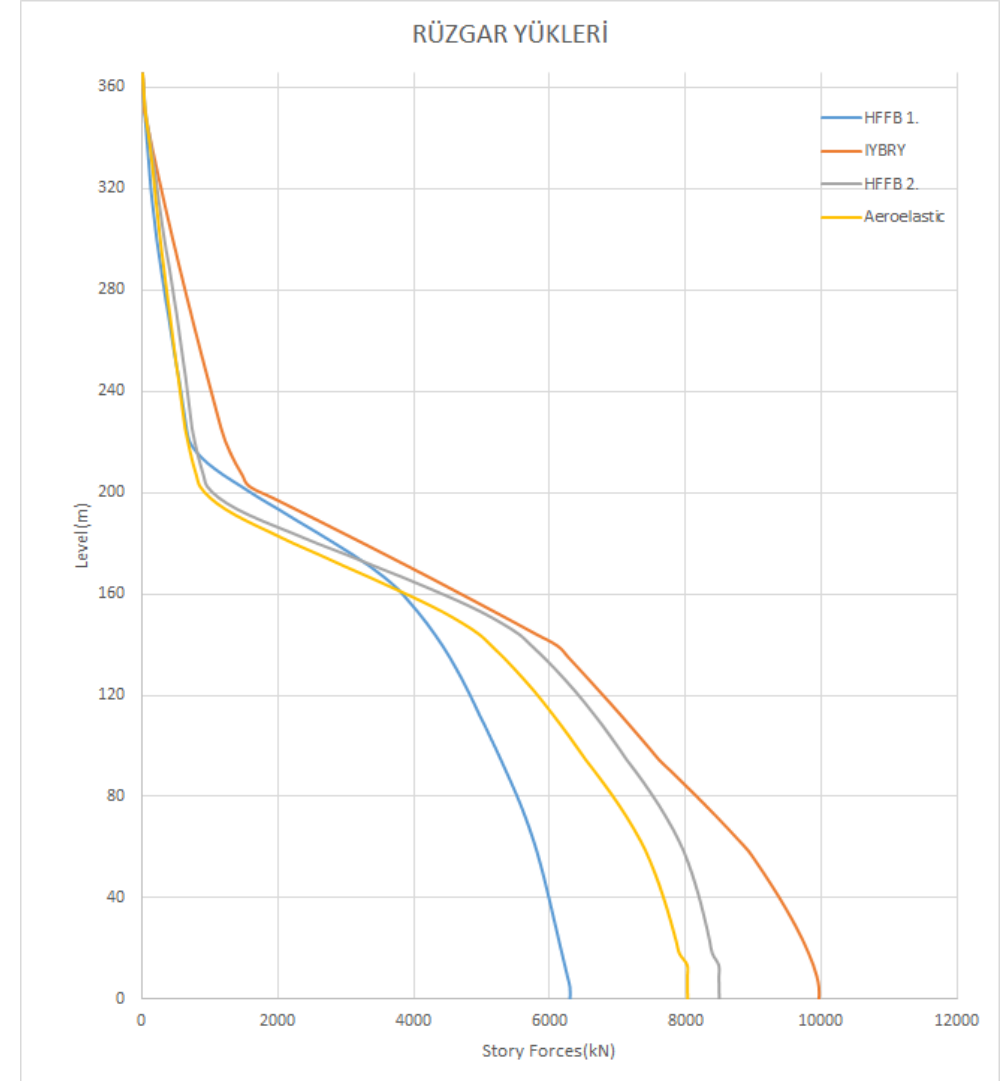
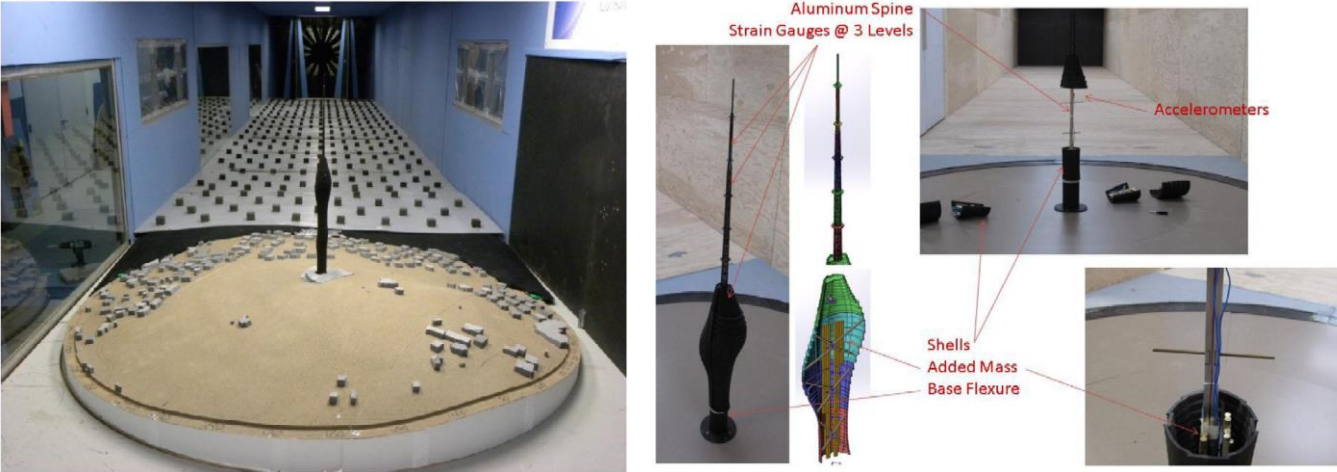
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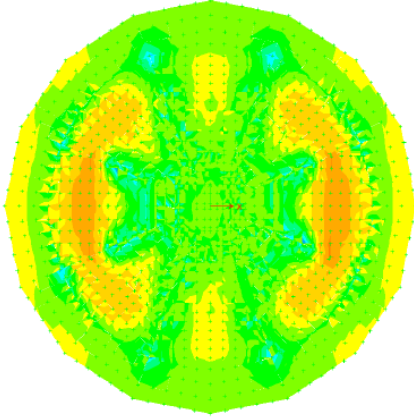
RÜZGAR ETKİLERİ

- İstanbul Yüksek Binalar Rüzgar Yönetmeliği(Ağustos 2008)
- Yüksek Frekans-Kuvvet Dengesi Testi (High Frequency Force Balanced)
- Aeroelastik Rüzgar Testi

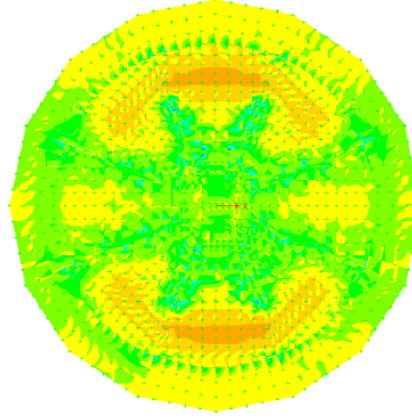




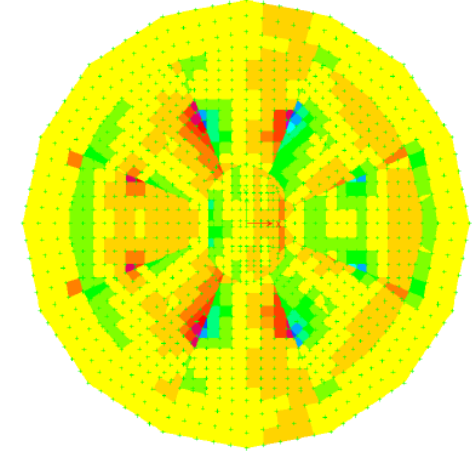
TEMEL TASARIMI



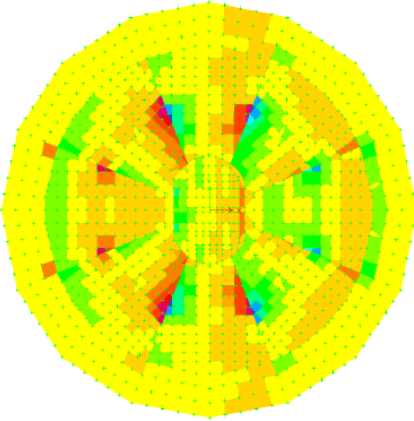
FOUNDATION, ENVELOPE-ABS MAX, M11 MOMENT DIAGRAM(kNm/m)



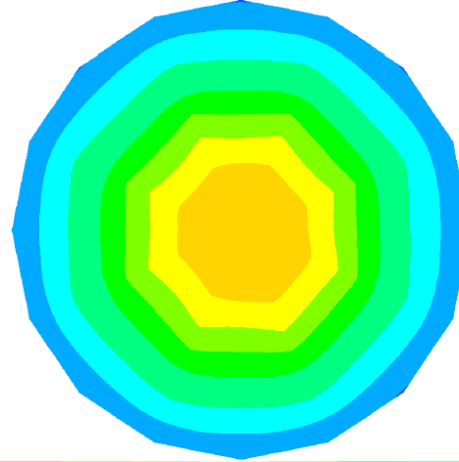
FOUNDATION, ENVELOPE-ABS MAX, M22 MOMENT DIAGRAM(kNm/m)



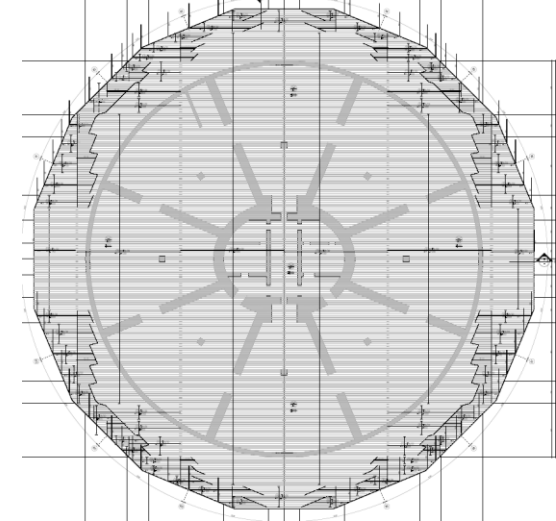
FOUNDATION, ENVELOPE-ABS MAX, DIRECTION-13 SHEAR STRESS(MPa)



FOUNDATION, ENVELOPE-ABS MAX, DIRECTION-23 SHEAR STRESS(MPa)

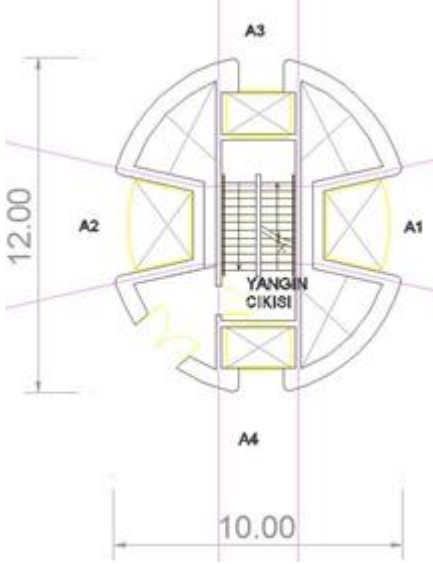


FOUNDATION, SOIL PRESSURE(DL+SDL+LL)(t/m²) < 130 t/m²

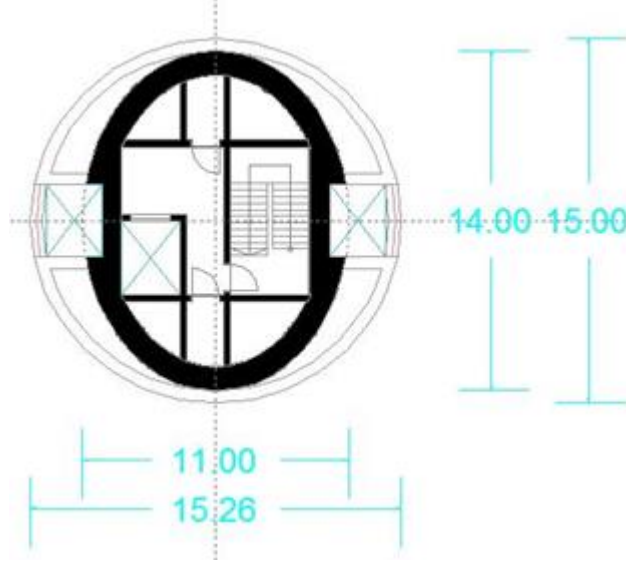




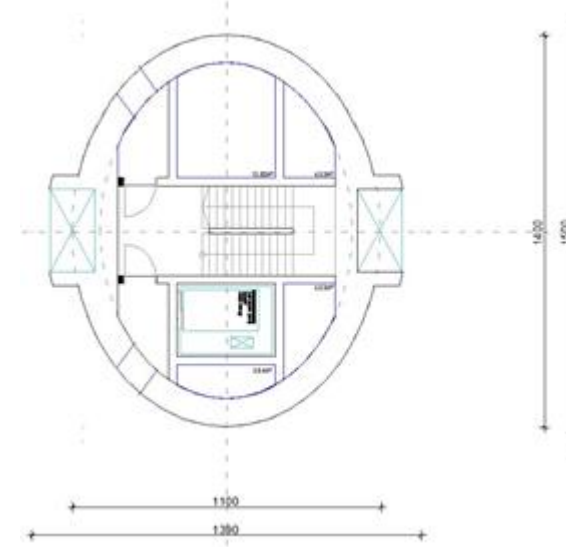
ÇEKİRDEK PERDESİ(B.A. ŞAFT) TASARIMI - NİHAİ FORMUN EVRELERİ



ORJİNAL FORM



ARA FORM



NİHAİ FORM



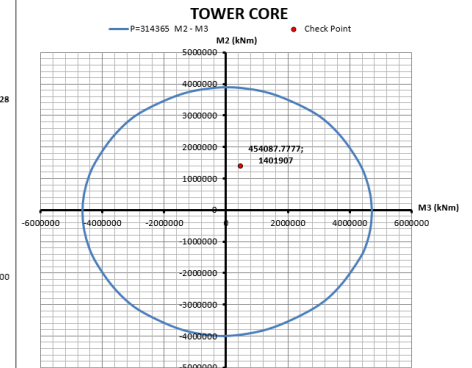
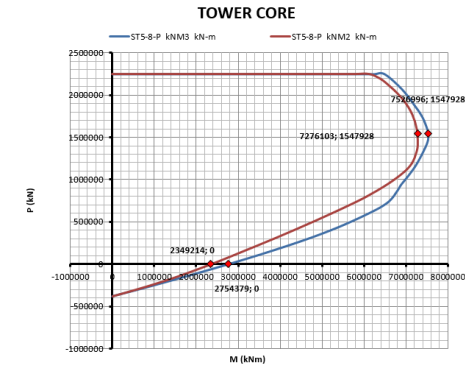
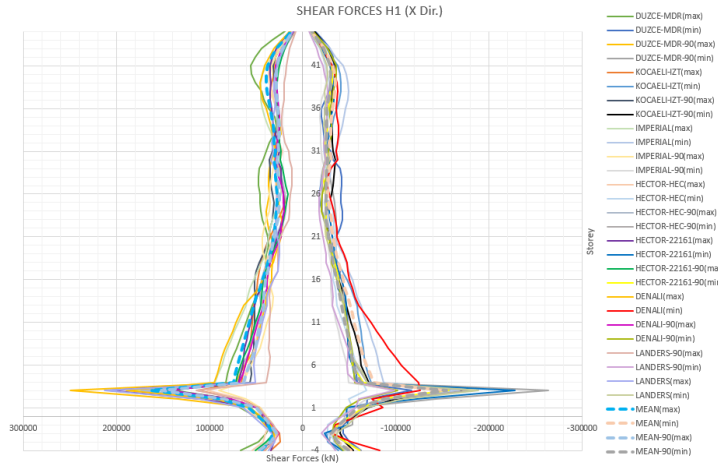
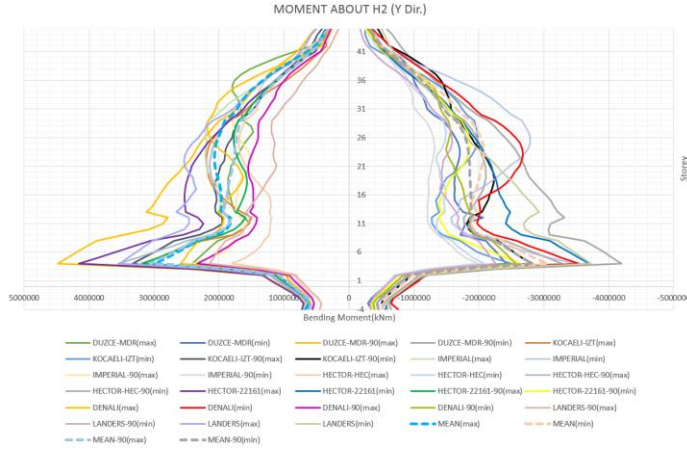
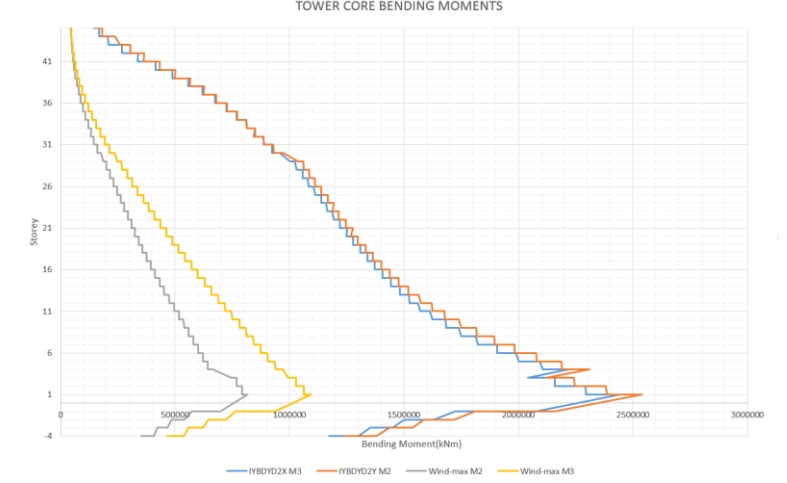
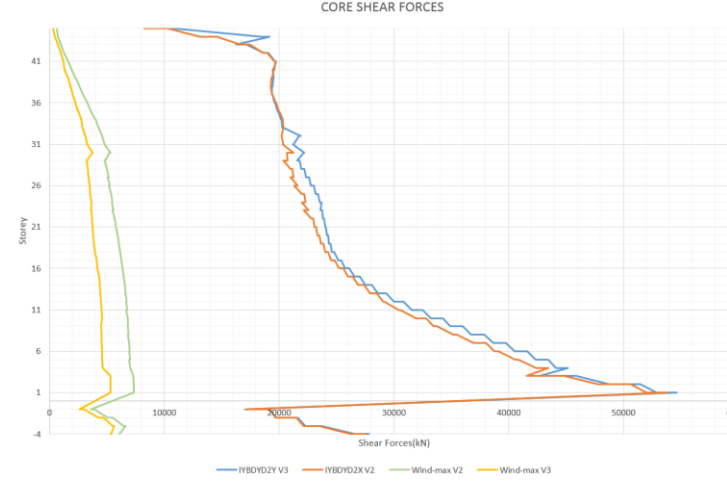
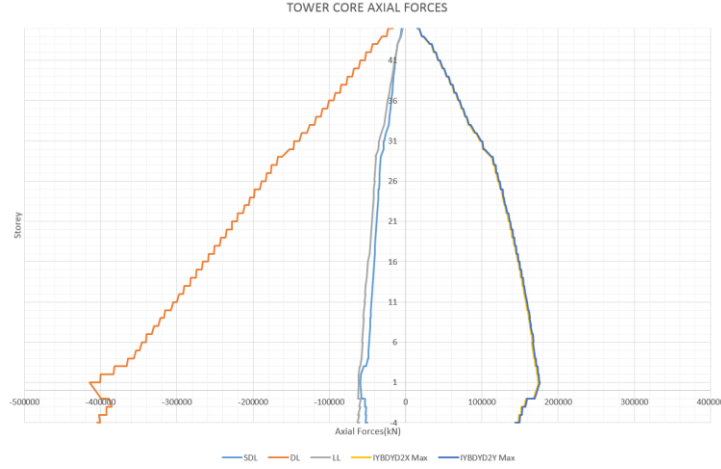
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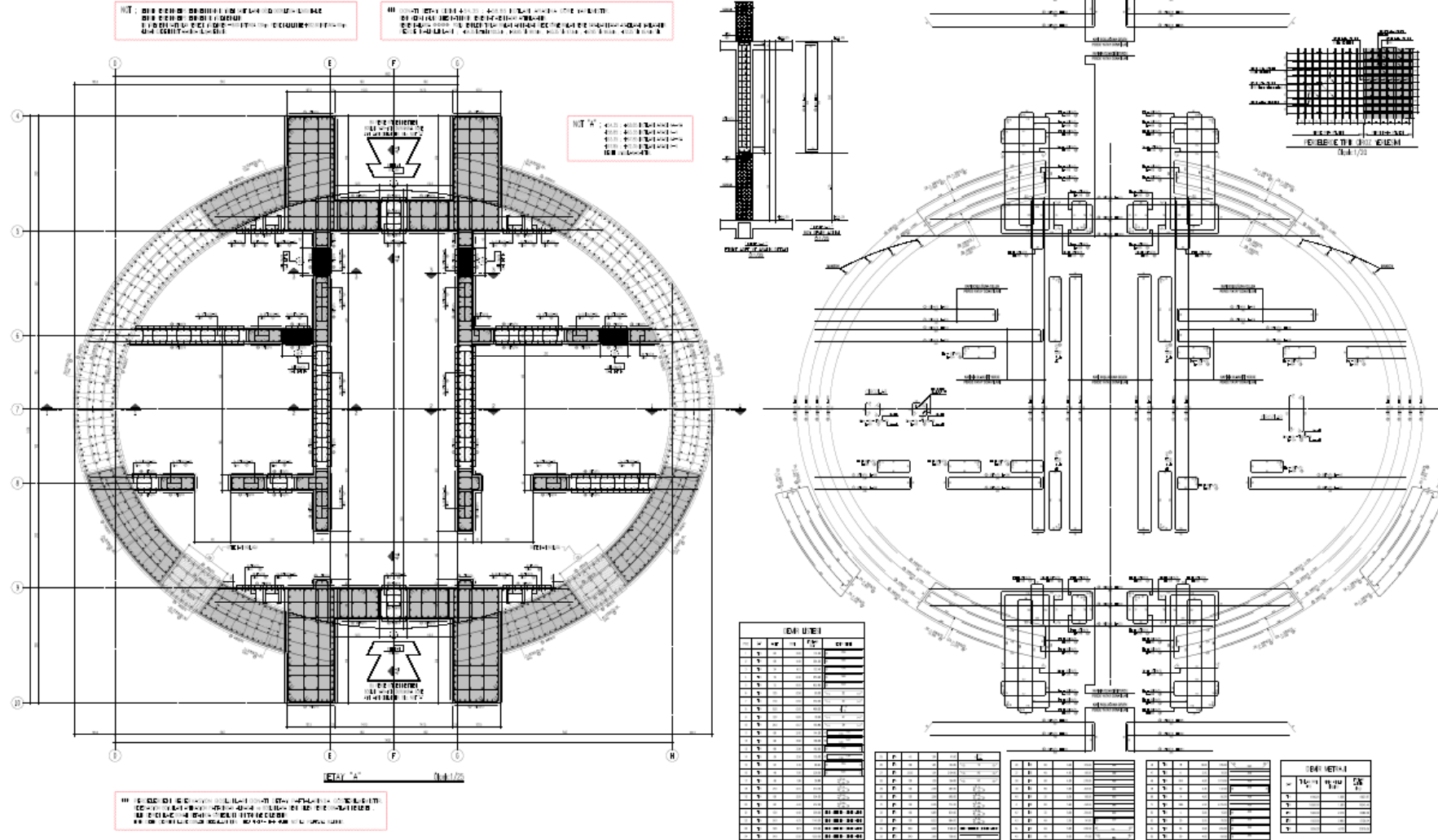


ÇEKİRDEK PERDESİ(B.A. ŞAFT) TASARIMI - İÇ KUVVETLER





ÇEKİRDEK PERDESİ(ŞAFT) TASARIMI - UYGULAMA ÇİZİMLERİ



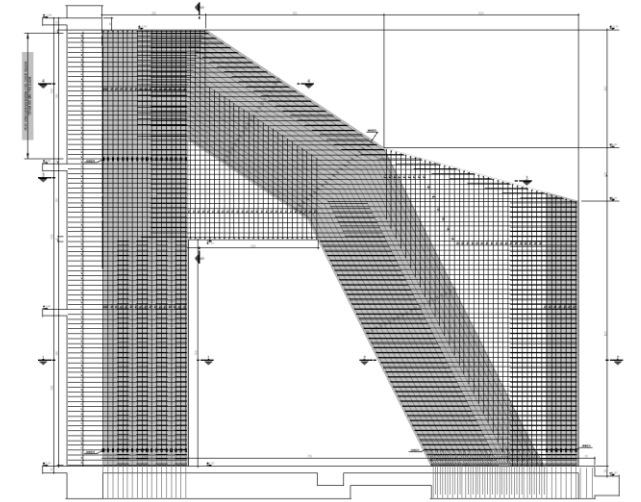
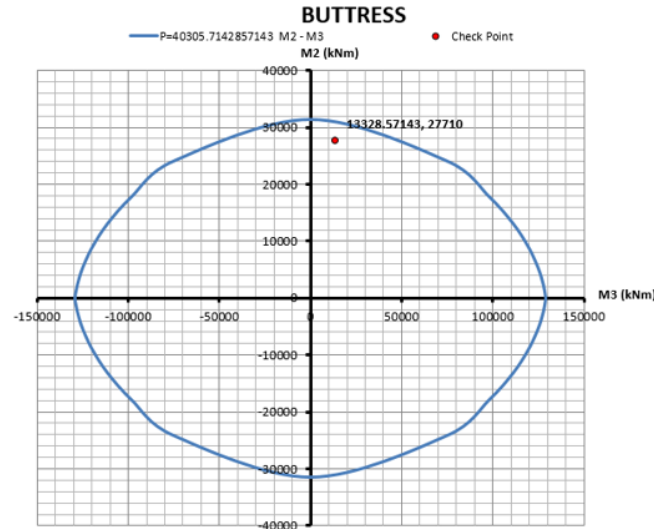
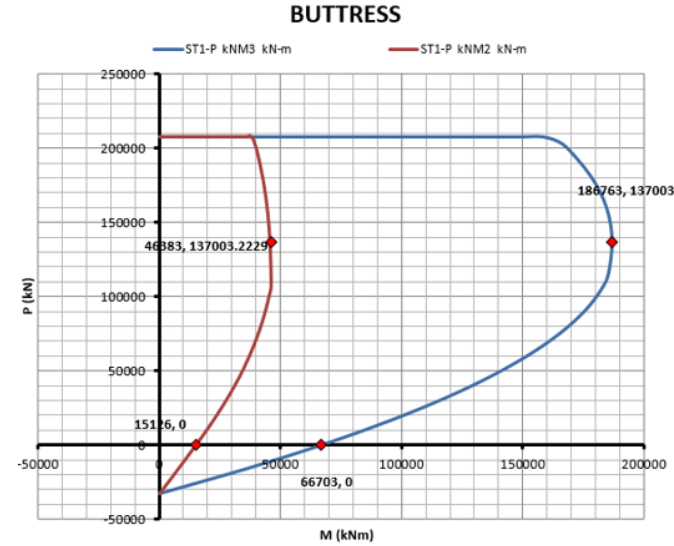
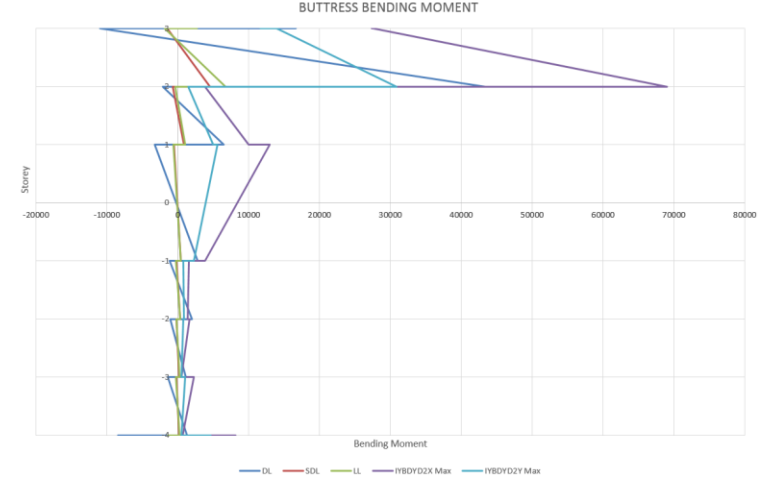
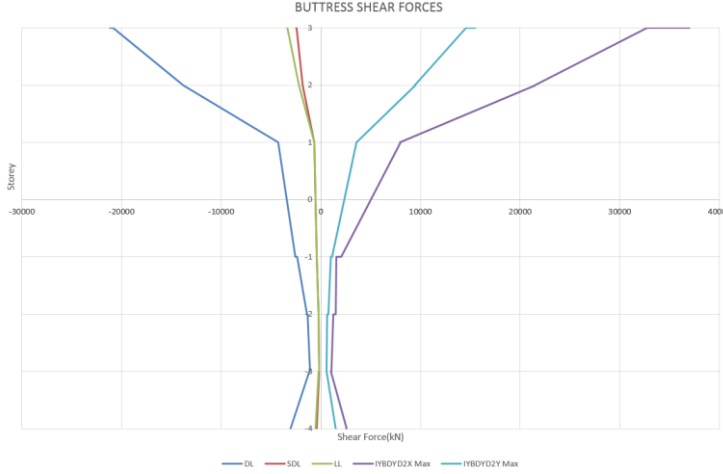
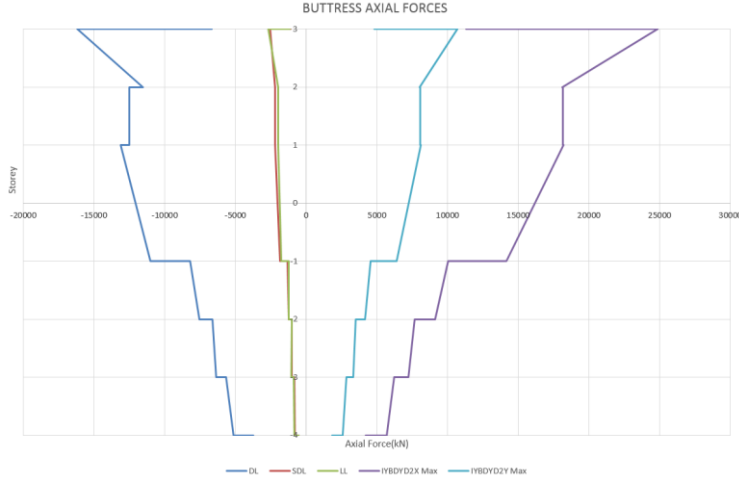


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PAYANDA TASARIMI



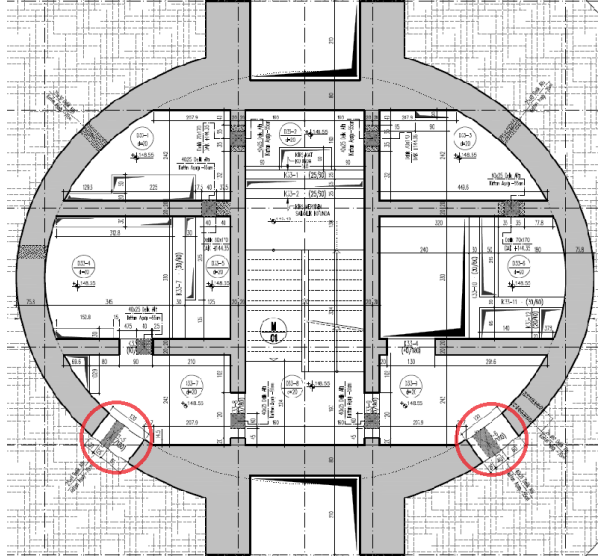


1. YÜKSEK YAPILAR SEMPOZYUMU 04 – 05 MAYIS 2023 İSTANBUL

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BAĞ KİRİŞİ TASARIMI



Story	Spandrel	$b_w(m)$	$d(m)$	$l_n(m)$	$V_d(kN)$	$<1.5b_wdf_{ctde}$	Check	A_{sw}/s (cm^2/m)	$M_p(kNm)$	$V_e=2M_p/l_n$ (kN)	$<0.22b_wdf_{ctde}$	Check	$V_w(kN)$	Check
STORY45	S1-S2	0.40	2.10	1.20	927.47	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY44	S1-S2	0.40	2.10	1.20	1609.25	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY43	S1-S2	0.40	2.10	1.20	1560.73	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY42	S1-S2	0.40	2.10	1.20	1477.21	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY41	S1-S2	0.40	2.10	1.20	1421.78	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY40	S1-S2	0.40	2.10	1.20	1354.03	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY39	S1-S2	0.40	2.10	1.20	1322.70	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY38	S1-S2	0.40	2.10	1.20	1283.98	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY37	S1-S2	0.40	2.10	1.20	1249.23	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY36	S1-S2	0.40	2.10	1.20	1248.36	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY35	S1-S2	0.40	2.10	1.20	1232.35	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY34	S1-S2	0.40	2.10	1.20	1203.94	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY33	S1-S2	0.40	2.10	1.20	1147.75	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY32	S1-S2	0.40	2.10	1.20	882.93	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY31	S1-S2	0.40	2.10	1.20	722.16	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY21	S1-S2	0.40	2.10	1.20	1086.34	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY20	S1-S2	0.40	2.10	1.20	1254.01	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY19	S1-S2	0.40	2.10	1.20	1343.12	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY18	S1-S2	0.40	2.10	1.20	1460.28	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY17	S1-S2	0.40	2.10	1.20	1482.71	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY16	S1-S2	0.40	2.10	1.20	1465.11	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY15	S1-S2	0.40	2.10	1.20	1513.29	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY14	S1-S2	0.40	2.10	1.20	1455.63	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
STORY13	S1-S2	0.40	2.10	1.20	1175.82	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
BASE1	S1-S2	0.40	2.10	1.20	2253.92	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
BASE2	S1-S2	0.40	2.10	1.20	2184.94	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
BASE3	S1-S2	0.40	2.10	1.20	1829.12	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK
BASE4	S1-S2	0.40	2.10	1.20	1617.69	4154.46	OK	76.00	3600.00	6000.00	9609.60	OK	6800.3	OK



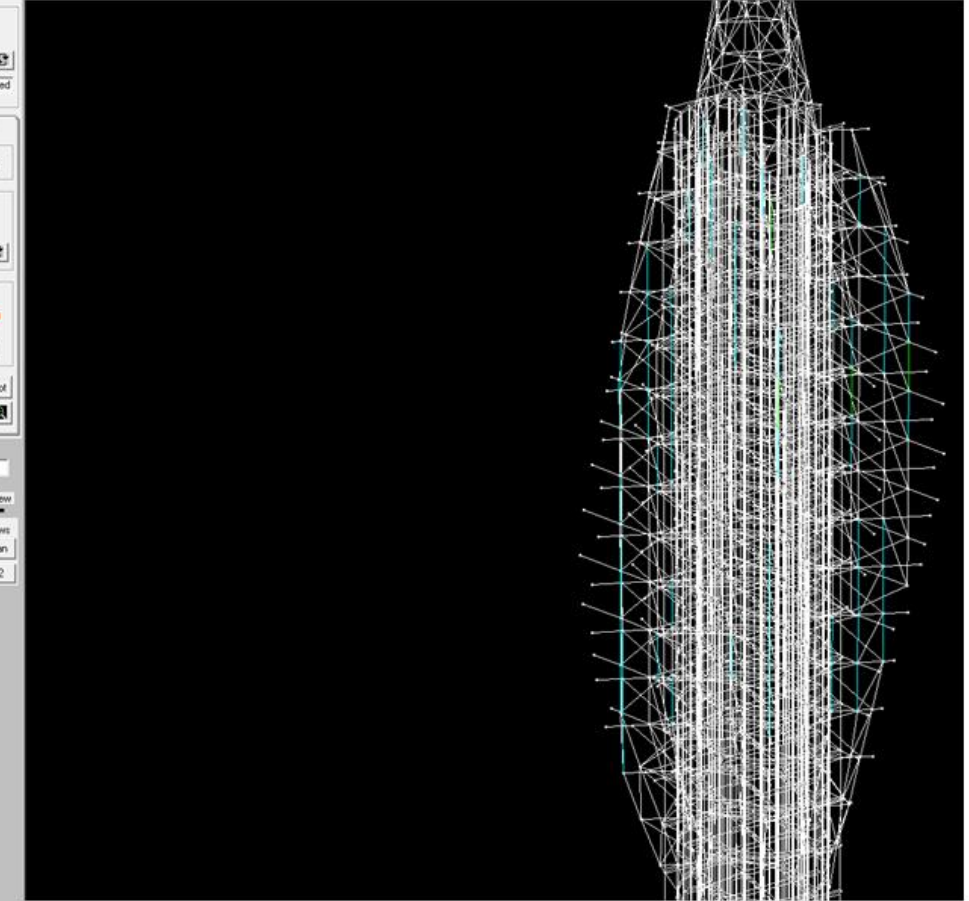
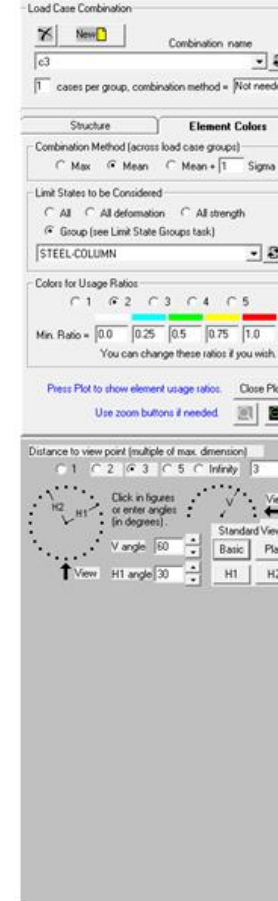
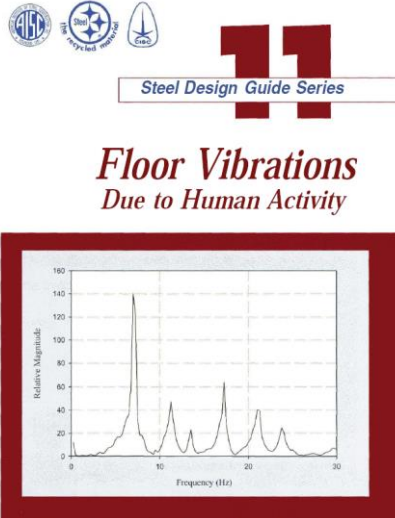
1. YÜKSEK YAPILAR SEMPOZYUMU 04 – 05 MAYIS 2023 İSTANBUL

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PODYUM, PLATFORM VE SEYİR TERASI ÇELİKLERİ

- Podyum : +8.00;+13.50 kotları arası çelik çatı
- Platform: +40.50;+99.00 kotları arası çelik döşemeleri
- Seyir Terası: +144.00;+202.50 kotları arası çelik döşemeleri
- Lineer kabul edilerek, non-lineer analizler sonucu dayanım limitleri kontrol edildi.(Strength Section Limit)
- Servis durumları kontrolü AISC'ye göre yapıldı.

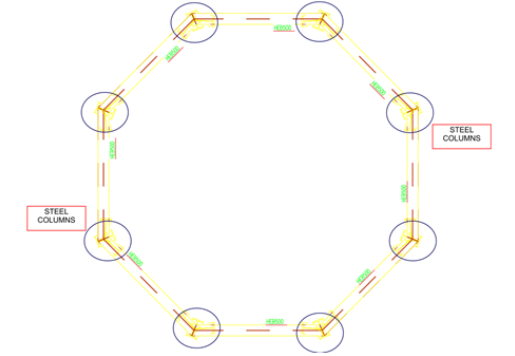


Observation Level Steel Column Strength Section Limits

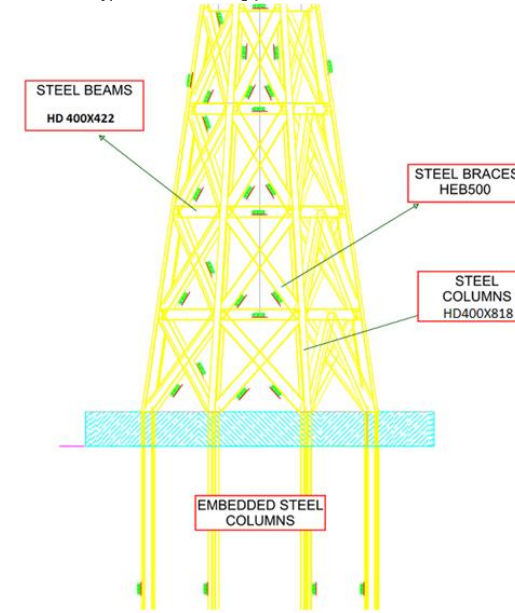


GEÇİŞ BÖLGESİ ÇELİKLERİ - TANIMLAR

- +202.50;+220.50 kotları arasında yer alır.
- Merkezi çaprazlı çelik çerçevelerle teşkil edilmiştir.
- Sekizgen formdaki eğimli kolonlar iki kat boyunca(9.00 m) betonarme çekirdeğe gömülmüştür.
- Çelik anten ile betonarme çekirdek arasında rijit bir bağlantı sağlayarak güvenilir bir yük akışı sağlar.
- Kolonlar lineer elastik modellendi ve PMM dayanım limitleri(Strength Section Limit) ile kontrol edildi.
- Kirişler iki ucunda kesme mafsallı kabulü ile inelastik modellendi.
- Çaprazlar ise eksenel mafsallı kabulü ile inelastik modellendi.



A typical steel framing plan of the transition zone



Transition Zone Section

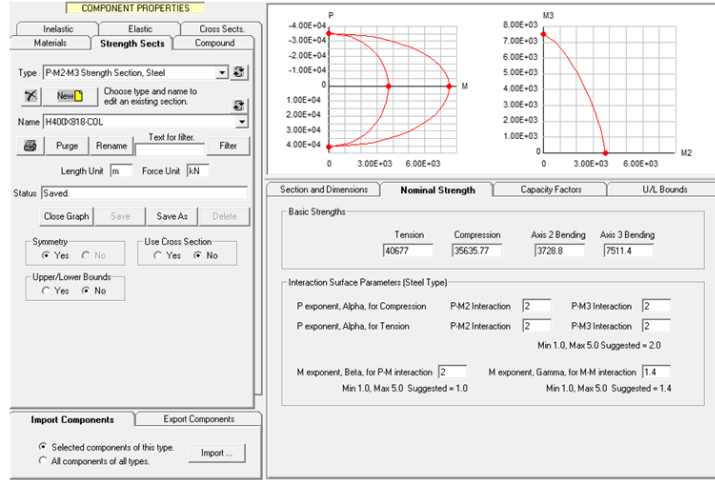


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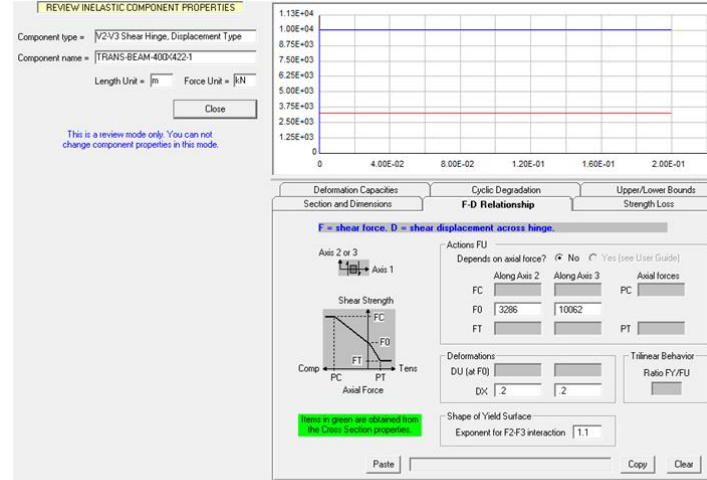
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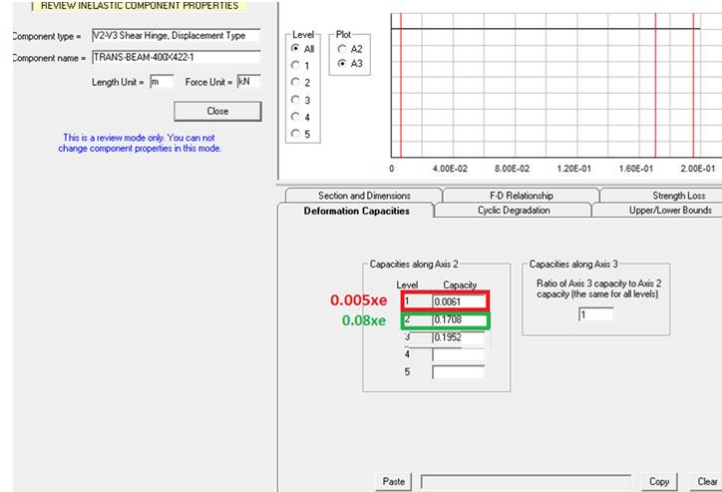
GEÇİŞ BÖLGESİ ÇELİKLERİ - N.L. MODELLEME



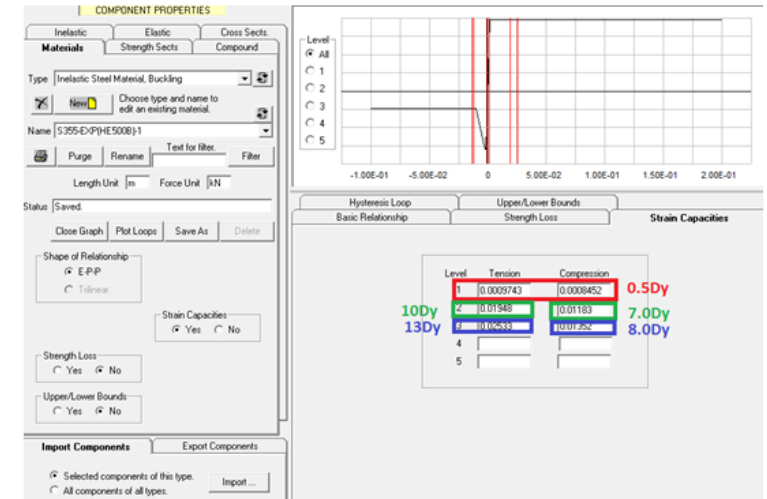
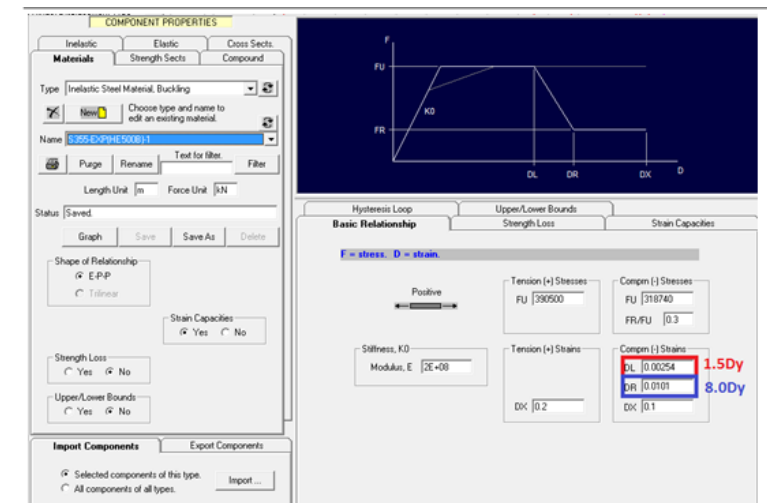
Typical Strength Section Definitions for Columns in Transition Zone



A typical Shear Hinge F-D Relationship for Beams in Transition Zone



Acceptance Criteria for Beams in Transition Zone



Definitions and Acceptance Criteria of the inelastic buckling steel material

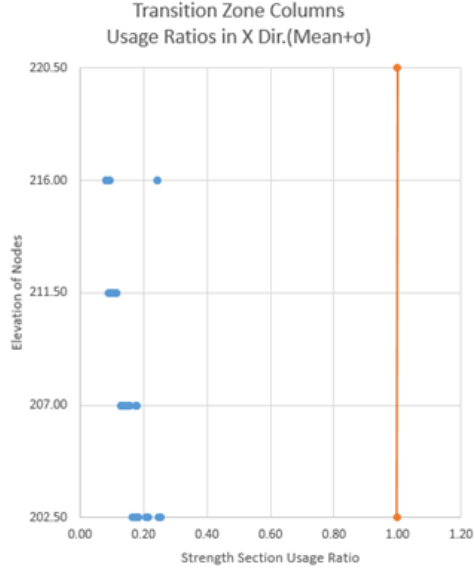


1. YÜKSEK YAPILAR SEMPOZYUMU 04 – 05 MAYIS 2023 İSTANBUL

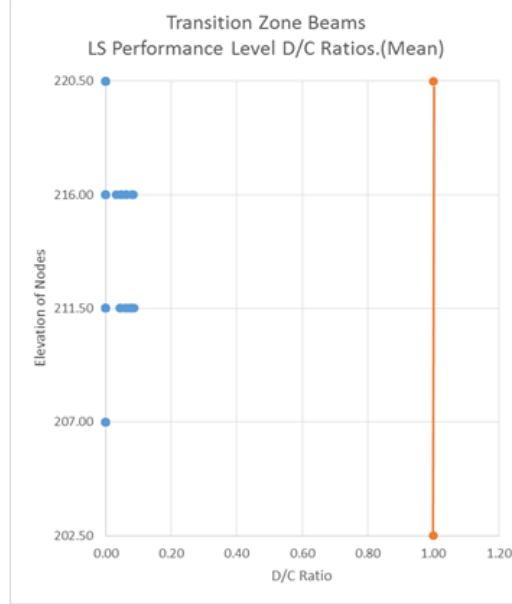
TMMOB
İNŞAAT MÜHENDİSLERİ ODASI



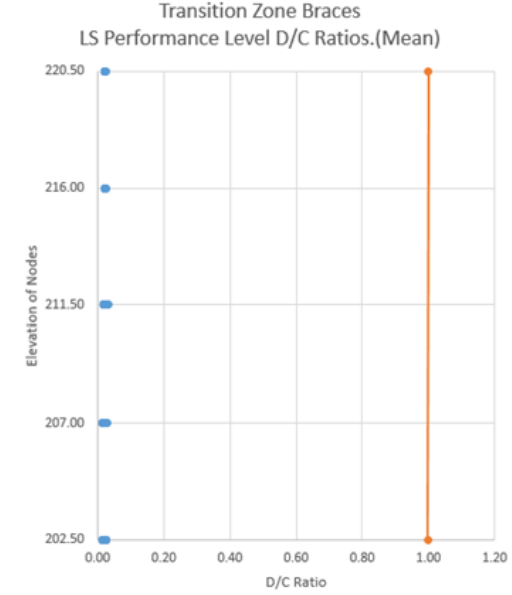
GEÇİŞ BÖLGESİ ÇELİKLERİ – D/C ORANLARI



Steel Columns Strength Section Usage Ratios in Transition Zone at X Direction



Steel Beams LS Performance Level D/C Ratios in Transition Zone



Steel Braces LS Performance Level D/C Ratios in Transition Zone



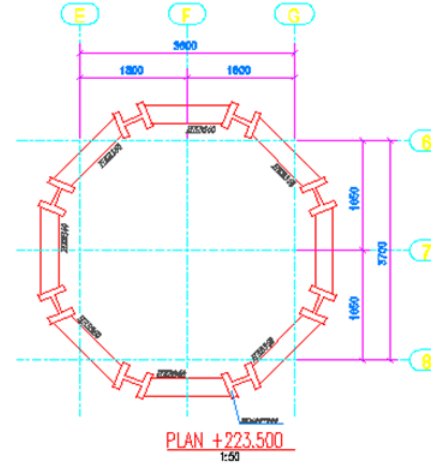
1. YÜKSEK YAPILAR SEMPOZYUMU 04 – 05 MAYIS 2023 İSTANBUL

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İNŞAAT MÜHENDİSLERİ ODASI

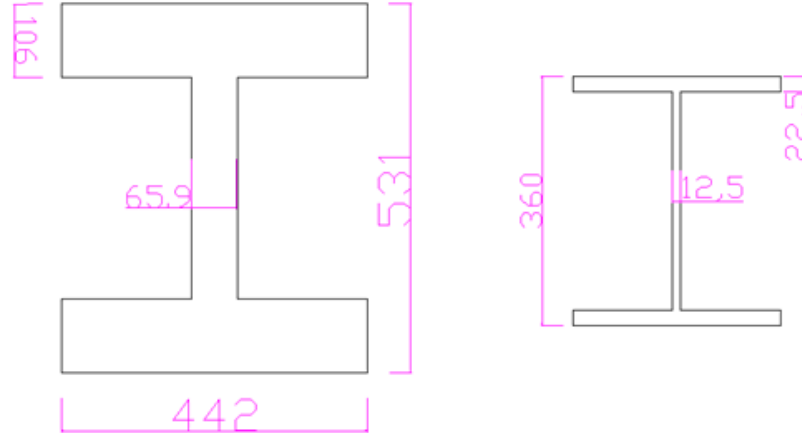


ANTEN ÇELİKLERİ - TANIMLAR

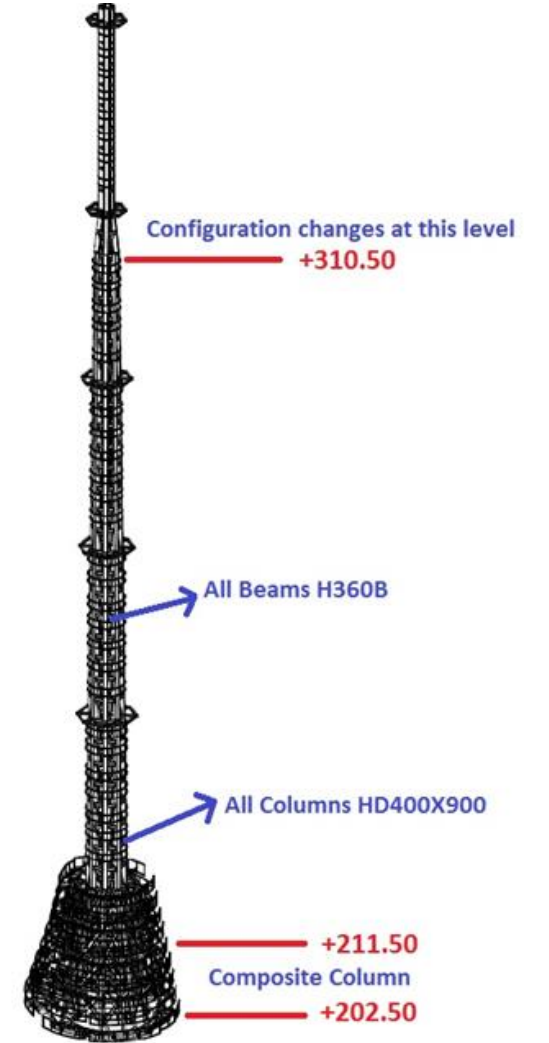
- +220.50;+365.50 kotları arasında yer alır.
- Dışmerkez çaprazlı(Bağ kirişli) çelik çerçevelerle teşkil edilmiştir.
- Kolonlar lineer elastik kalacak şekilde tasarlandı.
- Kirişler iki ucunda kesme mafsallı kabulü ile (çelik bağ kirişi gibi) inelastik modellendi.



Antenna Plan



HD400x900 Column and HE360B Beam Sections of the Antenna



3-D view of the antenna

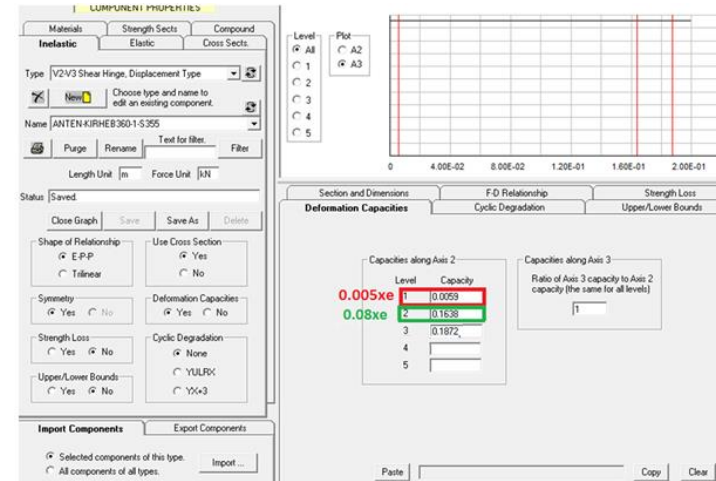
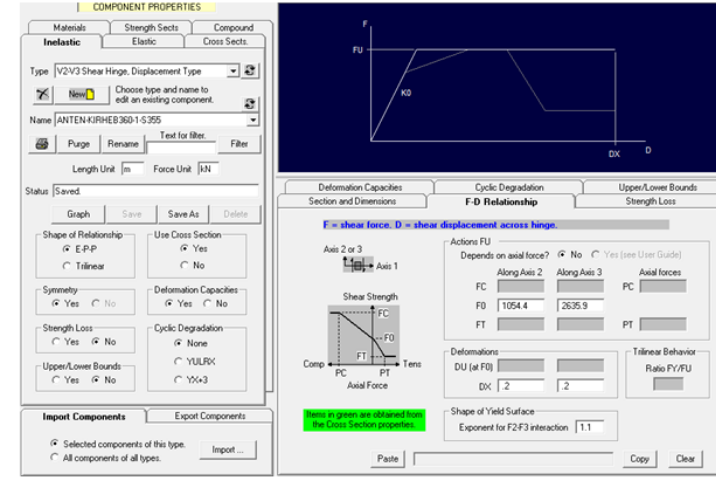
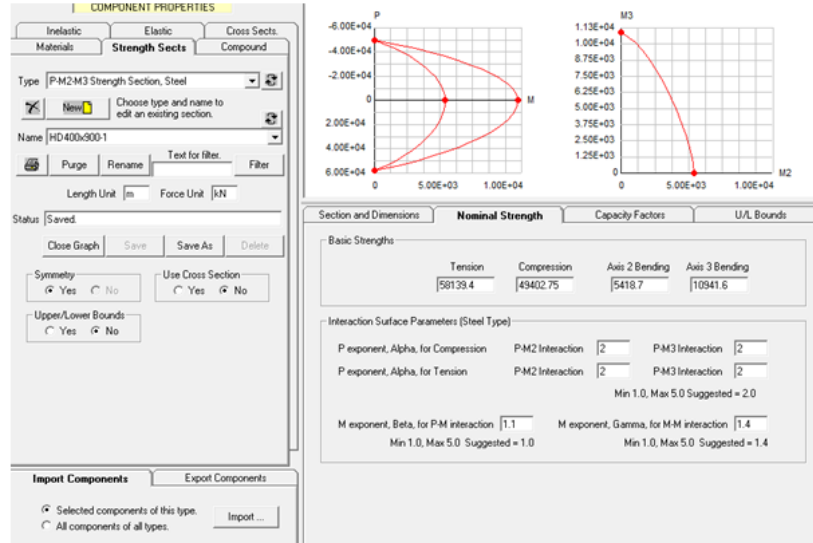


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ANTEN ÇELİKLERİ - N.L. MODELLEME



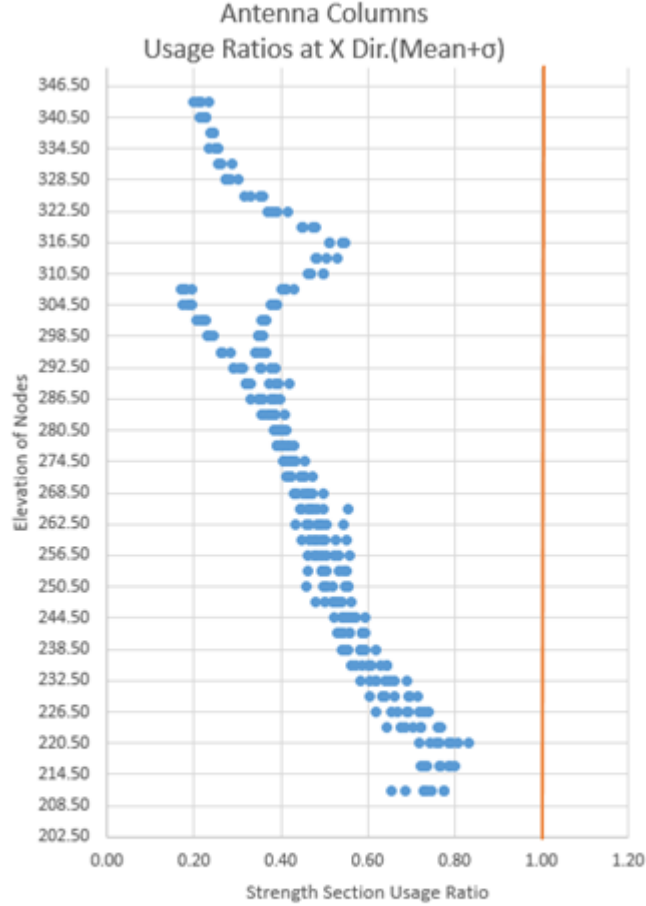


1. YÜKSEK YAPILAR SEMPOZYUMU 04 – 05 MAYIS 2023 İSTANBUL

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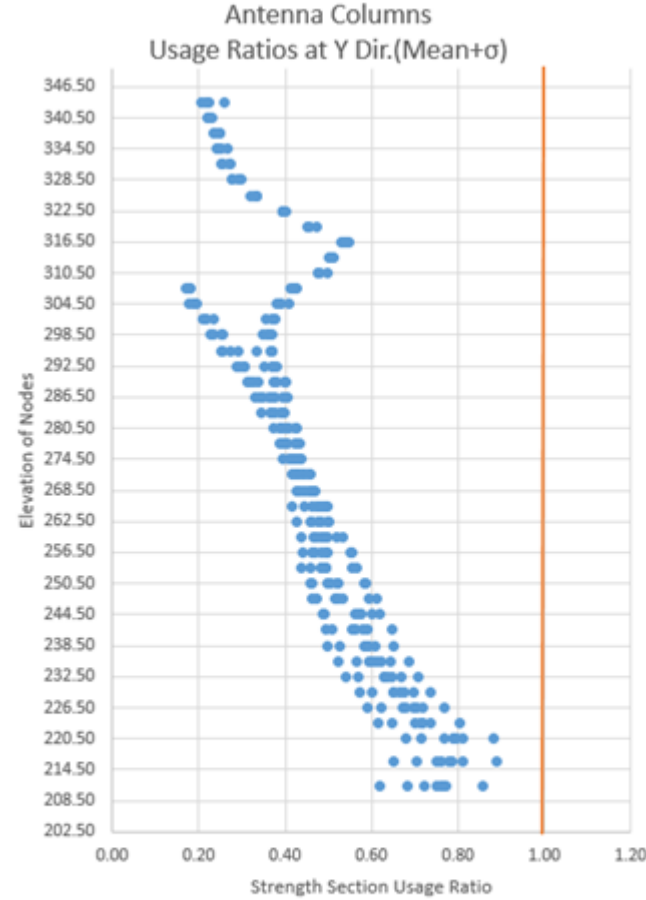


ANTEN ÇELİKLERİ – D/C ORANLARI



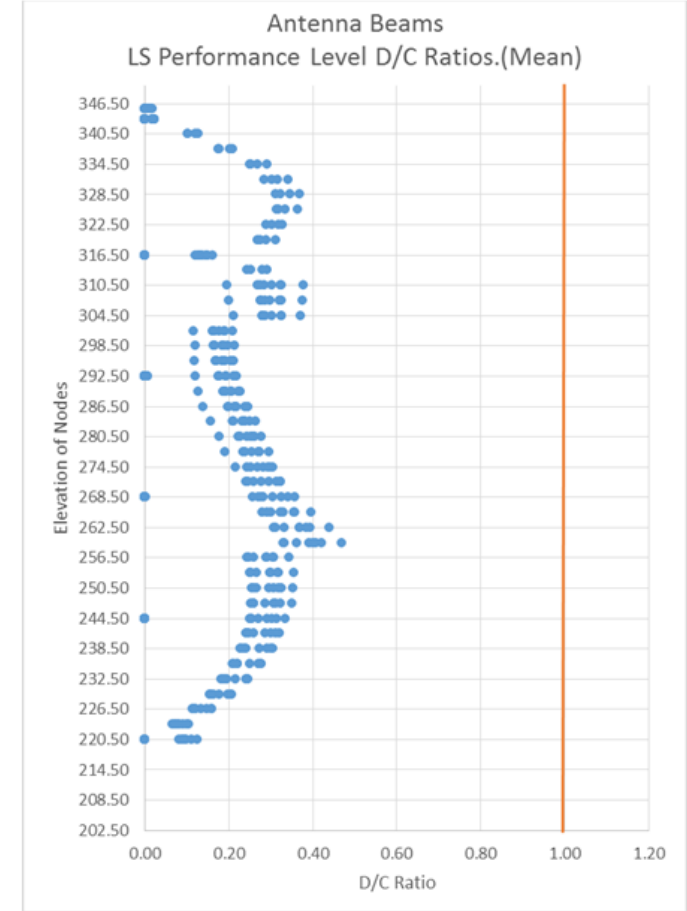
Steel Columns Strength Section Usage Ratios

in Antenna in D3 Events at X Direction



Steel Columns Strength Section Usage Ratios

in Antenna in D3 Events at Y Direction



Steel Beams LS Performance Level D/C Ratios in Antenna



1. YÜKSEK YAPILAR SEMPOZYUMU 04 – 05 MAYIS 2023 İSTANBUL

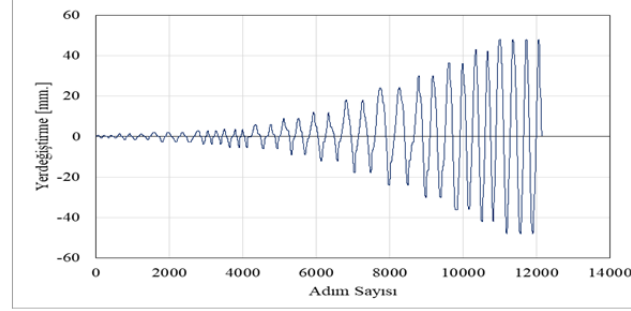
TMMOB
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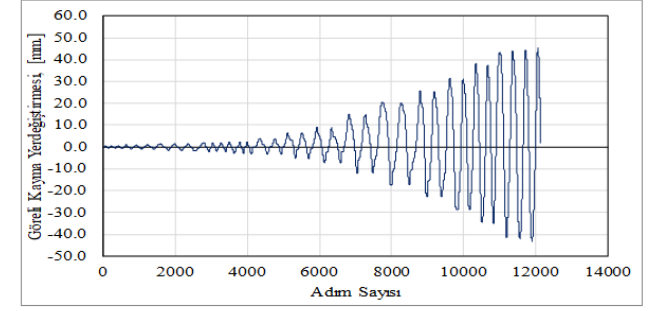
ANTEN ÇELİKLERİ - ÇELİK BAĞ KİRİŞİ TESTİ



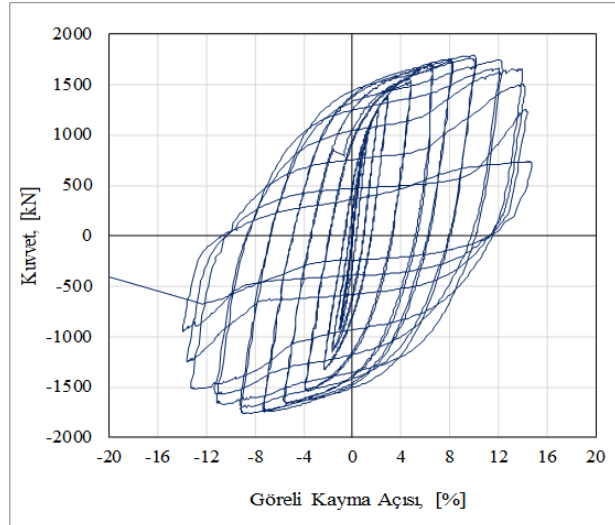
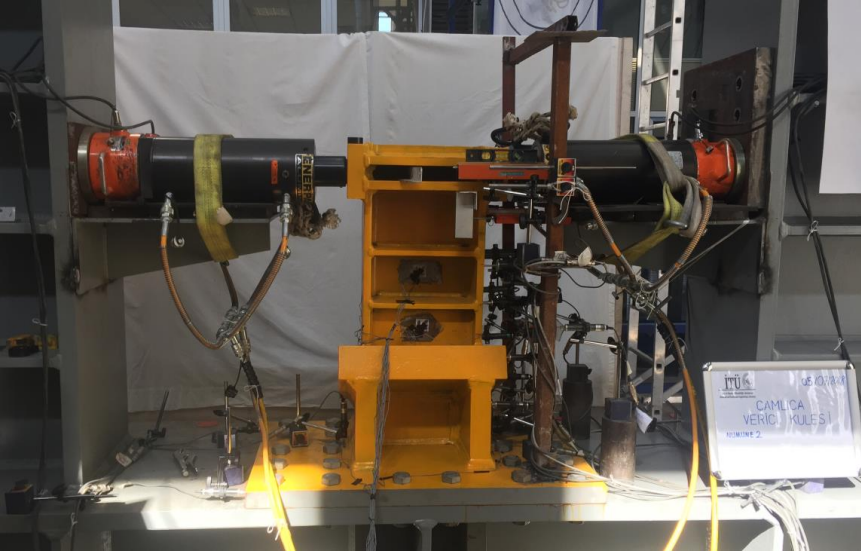
Numune üzerine yerleştirilen şekildeğiştirme ve yerdeğiştirme ölçerler



a) Uygulanan yerdeğiştirme protokolü



b) Bağ kirişi gövdesinde kaydedilen kayma yerdeğiştirme



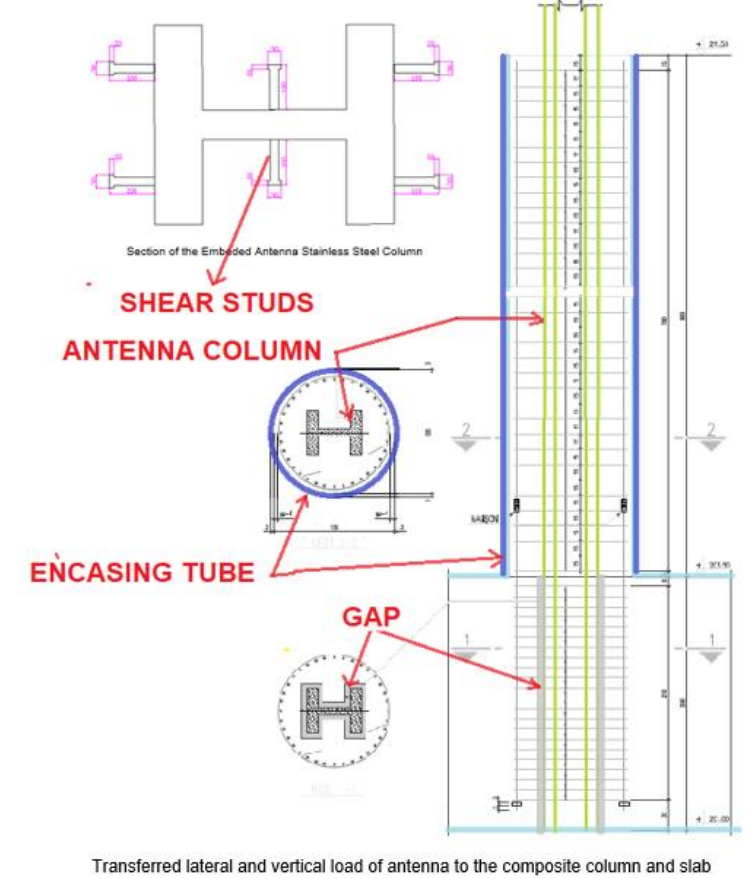
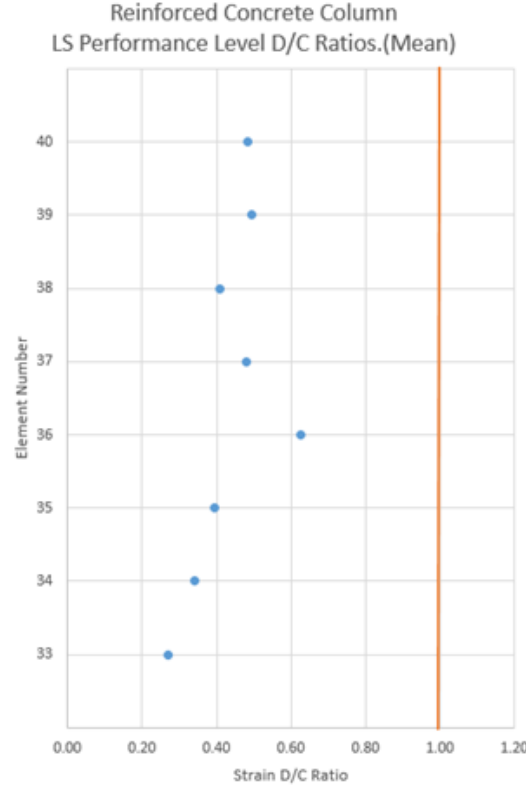
Kuvvet - görel kayma açısı ilişkisi





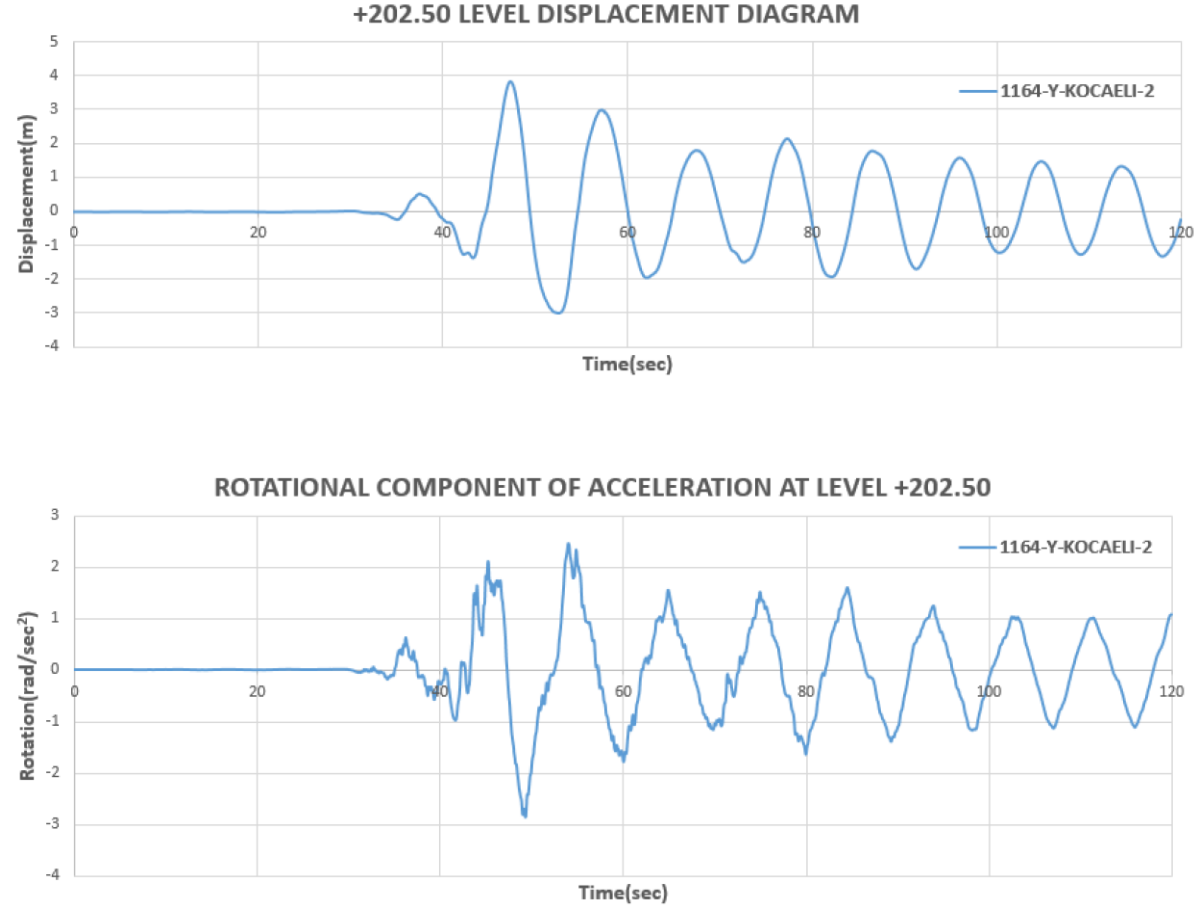
ANTEN ÇELİKLERİ - KOLON-DÖŞEME BAĞLANTISI

- 30 mm kalınlığında çelik tüp ile çevrili 8.00 m yüksekliğindeki kompozit kolon, anten yüklerini güvenli bir şekilde +202.50 kotundaki 250 cm kalınlığında döşemeye aktarmaktadır.
- Çelik anten kolonunun döşeme kotundan itibaren boşluk bırakılarak, betonarme döşemeye ankrajlanması engellenmiştir.
- Döşemeye yük aktarımı sadece betonarme kolon ile sağlanmaktadır.
- Böylece deprem etkilerinde betonarme kolonun akması(lineer ötesi davranışı) sağlanmıştır.



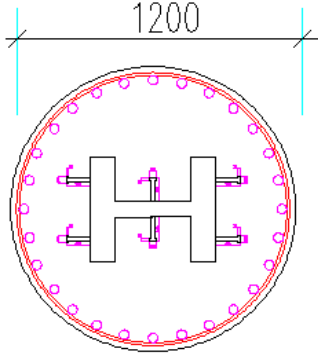


ANTEN ÇELİKLERİ - KOLON-DÖŞEME BAĞLANTISI

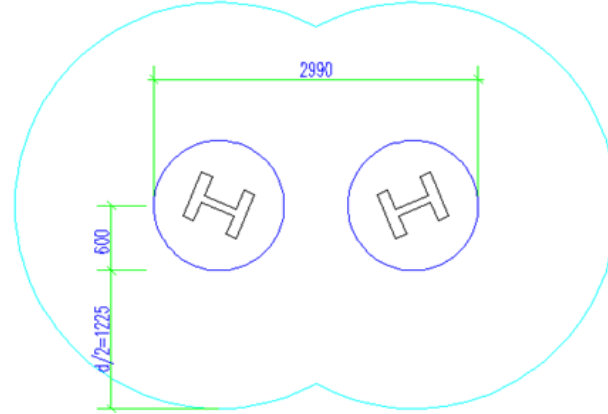




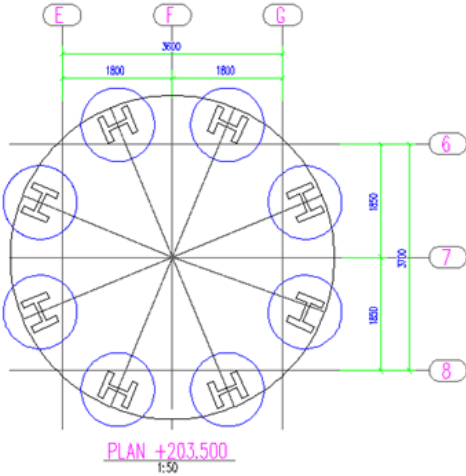
ANTEN ÇELİKLERİ - DİĞER KONTROLLER



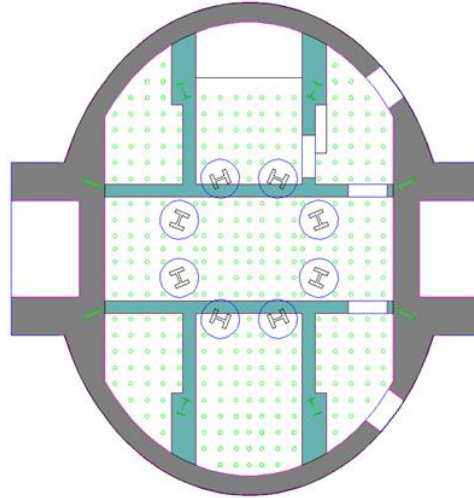
Section of the Antenna Composite Column



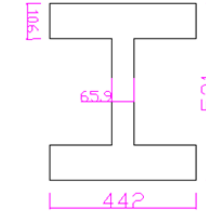
Overlapped Perimeter Length of Two Columns



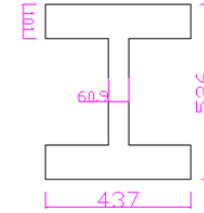
Plan View of the All Antenna Columns



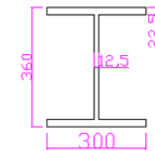
Shear Reinforcement Configurations



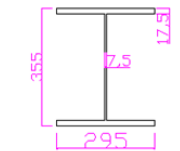
Original Column



Corroded Column

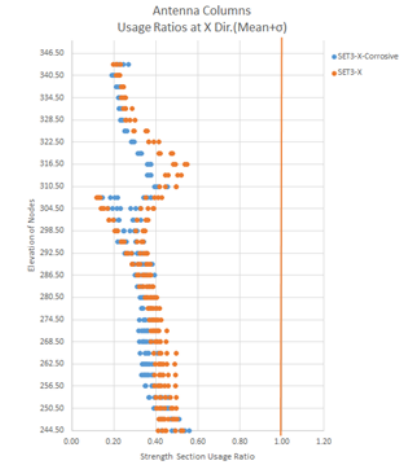
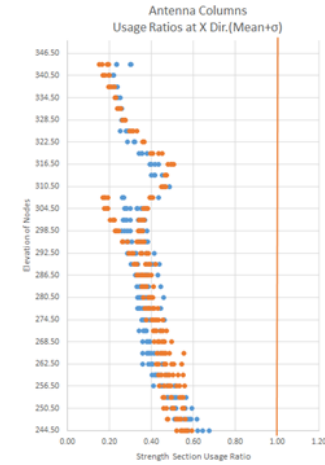


Original Beam



Corroded Beam

Original and Corroded Section of The antenna columns and beams



Performance Evaluation of the Columns Corrosive Section in X dir. under Set-2&Set-3 Event

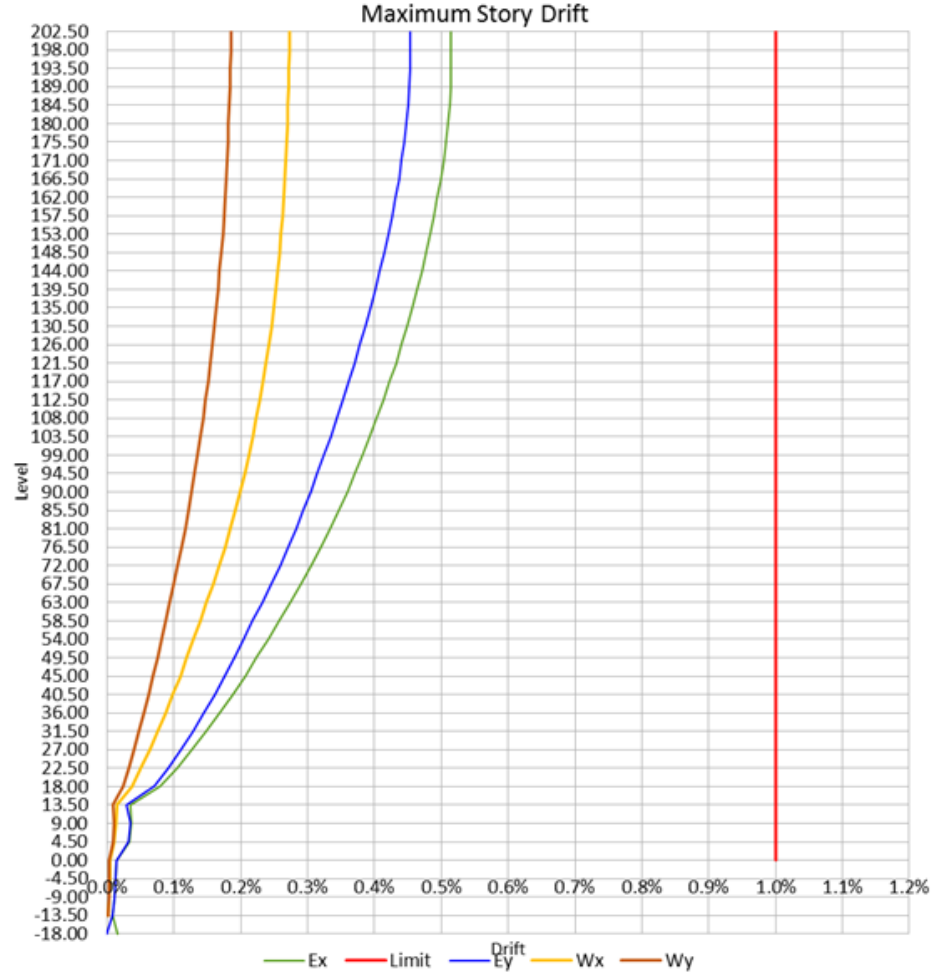


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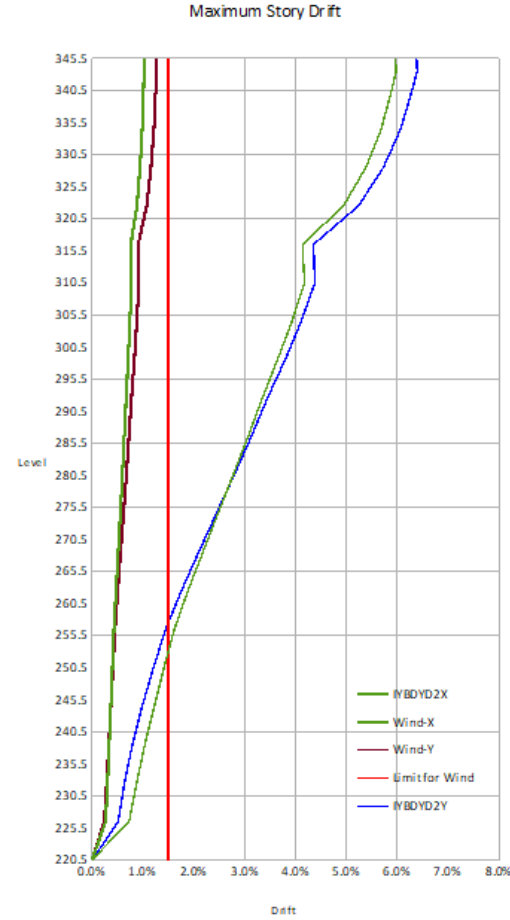
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GÖRELİ KAT ÖTELEMELERİ - TASARIM AŞAMASI-1



Maximum Story Drifts of RC Tower



Maximum Story Drift Ratios of Antenna

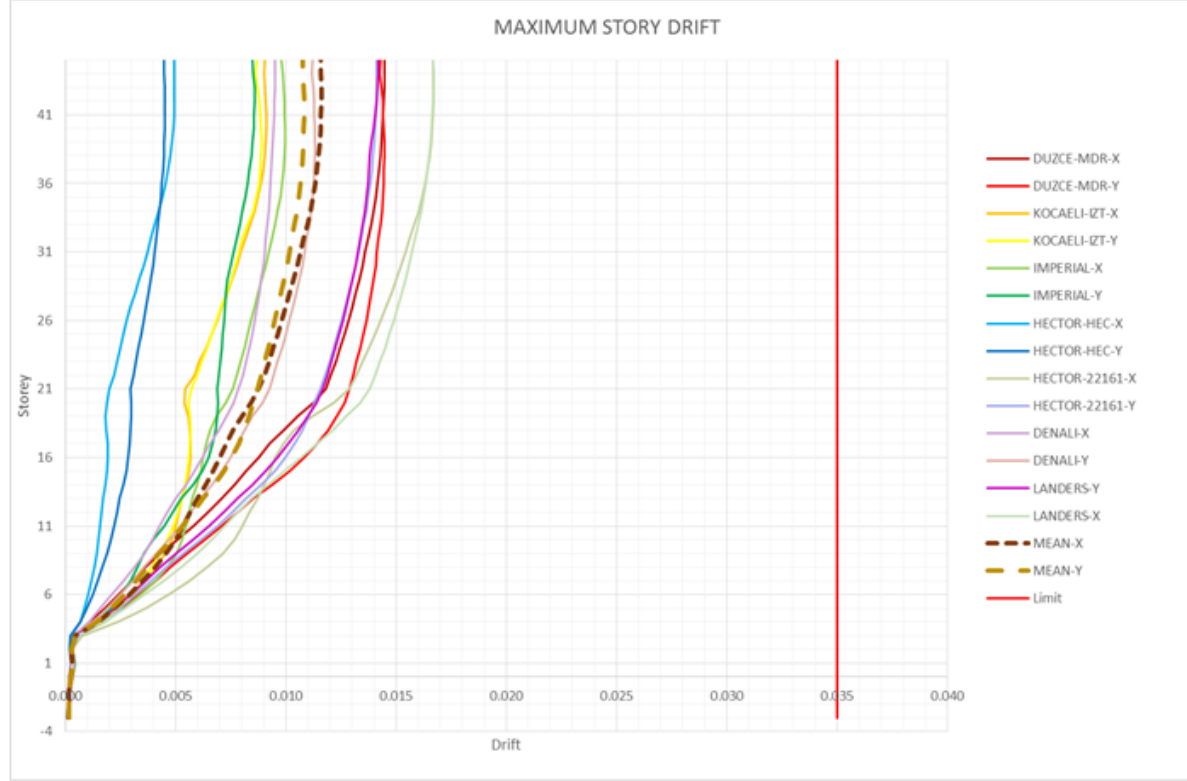


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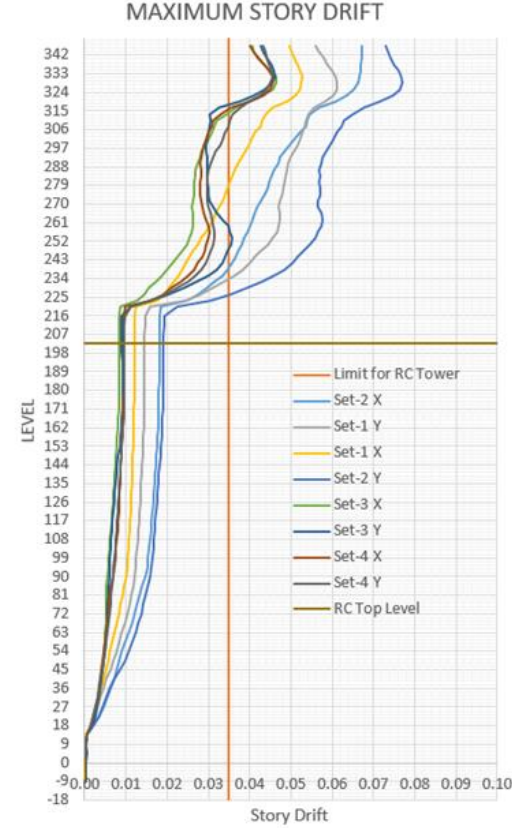
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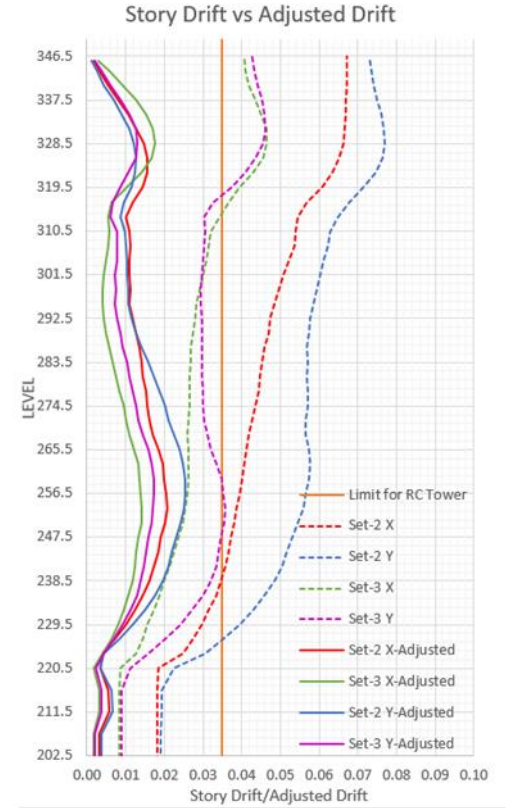
GÖRELİ KAT ÖTELEMELERİ - TASARIM AŞAMASI-2



Maximum Story Drifts



Maximum Story Drifts of Each Sets



Total Drift vs Adjusted Drift of for Set-2 and Set-3



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04 – 05 MAYIS 2023 İSTANBUL

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TEŞEKKÜRLER...