
ÇELİK YAPILAR


YÜKSEK BİNALAR

- Birleşik Devletler'de yüksek binaların diğer deyişle gökdelenlerin (Skyscraper) en düşük yüksekliği 153 m olarak kabul edilmektedir.
- Gökdelen kelimesi gemicilikte geminin en uzun direğine verilen isimdir.
- 305 m 'den daha yüksek binalara İngilizce'de "Supertall" isminin verildiğini görüyoruz.
- Yüksek binalar genellikle büro, konut, otel, hastane amaçlı olarak kullanılmaktadır.
- Yüksek binaların çevre ile iletişimleri önemlidir.
- Yüksek binaların analiz ve tasarımında özel yöntemler kullanılması gerekmektedir.

Yüksek Binaların Yapılmalarının Nedenleri

TEKNOLOJİK NEDENLER

- Çeliğin yapılarda taşıyıcı sistem malzemesi olarak kullanımı
- Yüksek dayanımlı beton teknolojisindeki ilerlemeler
- Asansörün ve hidroforun geliştirilmesi
- Havalandırma sistemlerinin geliştirilmesi
- Kalıp teknolojisindeki gelişimler
- Yatay yüklere göre analiz ve tasarım yöntemlerinin gelişimi

SOSYAL NEDENLER

- Şehir arazilerinin değerlerinin artışı
- Ekonomik büyüme
- Büyük şirketlerin gücünü simgeleyen anıtsal yapılar yapma ihtiyacı
- Yüksek yapıların politik bir yatırım amacı olarak görülmesi

Yüksek Binalara Etkiyen Yükler

- Düşey Yükler

-Sabit Yükler

-Hareketli Yükler

- Yatay Yükler

-Rüzgar Yükleri

-Deprem Yükleri

- Özel Yükleme Halleri

-Patlama Yükleri

-Çarpma Yükleri

Yüksek binalarda Yangın önemli bir sorundur.

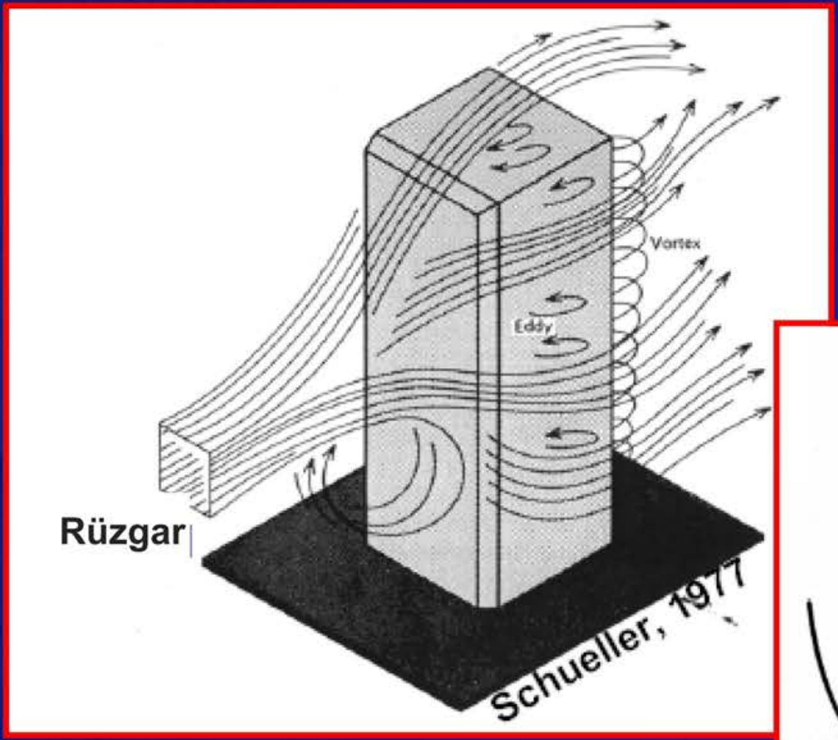
- Binanın ağırlığı ve maliyeti artan yüksekliğe etkiyen yatay yüklerden dolayı lineer olmayan bir şekilde artar.
- Optimum malzeme ve taşıyıcı sistem seçimi ile ağırlık ve maliyet azaltılabilir.
- Rüzgar Yükleri:

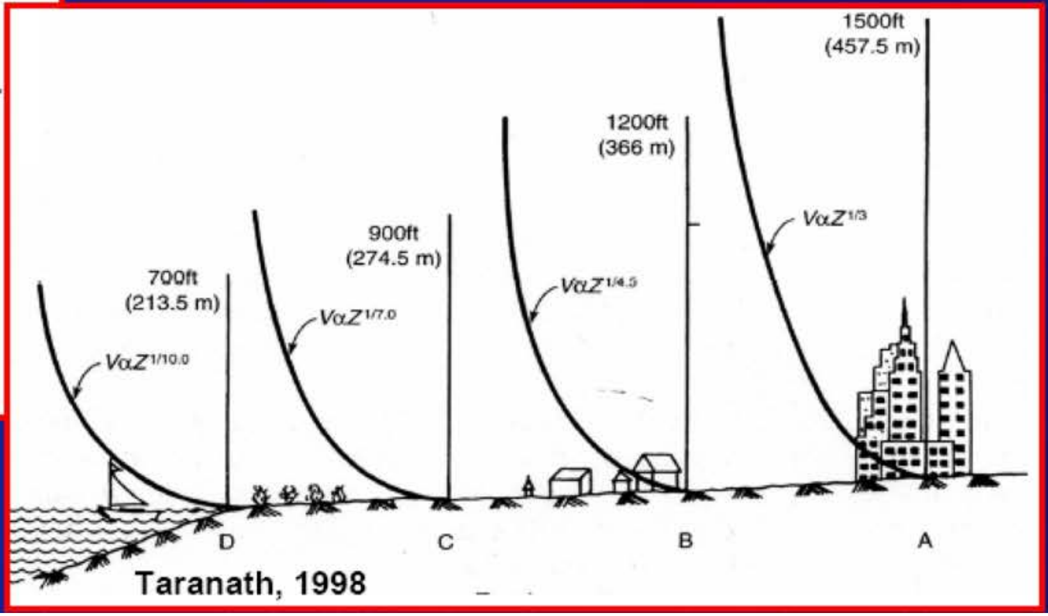
  Çelik binalarda 150 m

  Betonarme binalarda 250 m

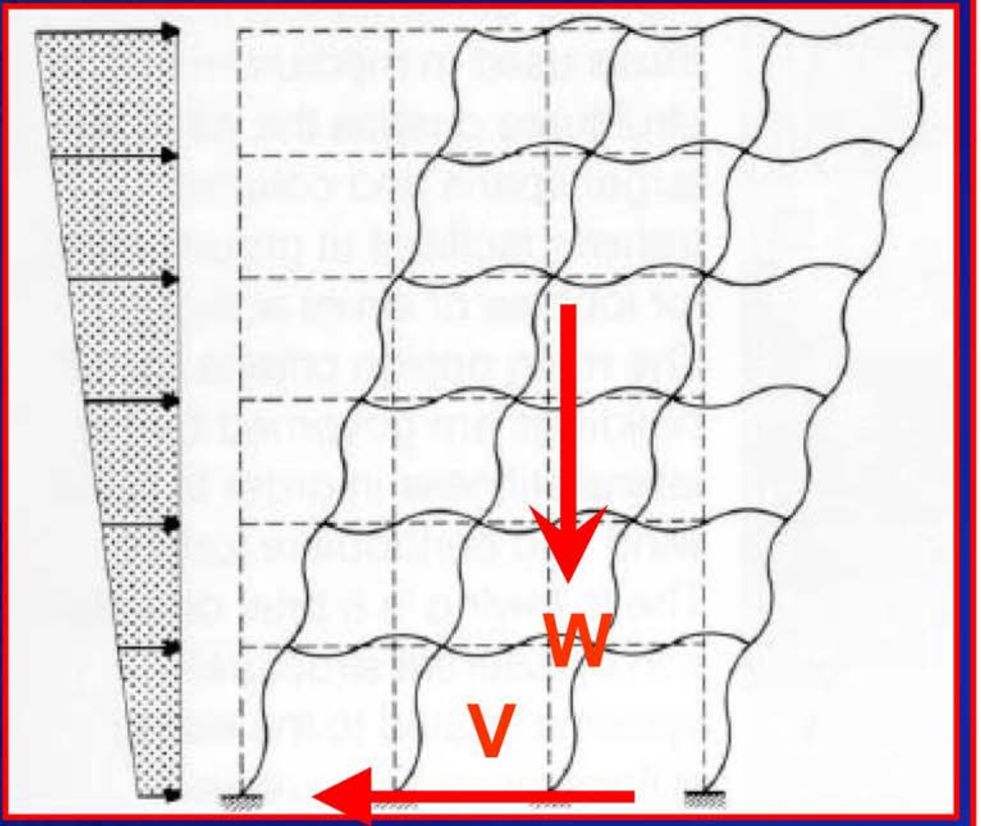
  den sonra birinci dereceden etkilidir.

Rüzgar Yükleri

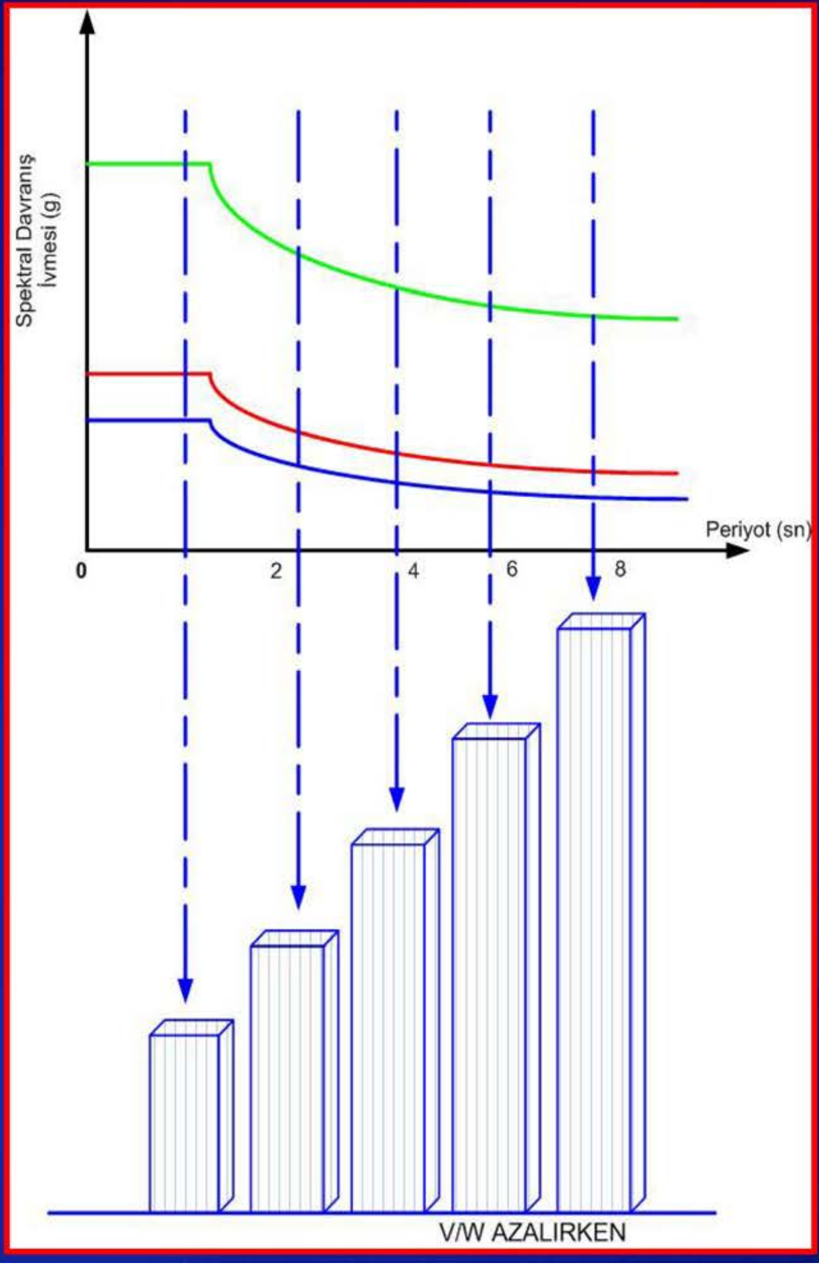




Deprem Yükleri



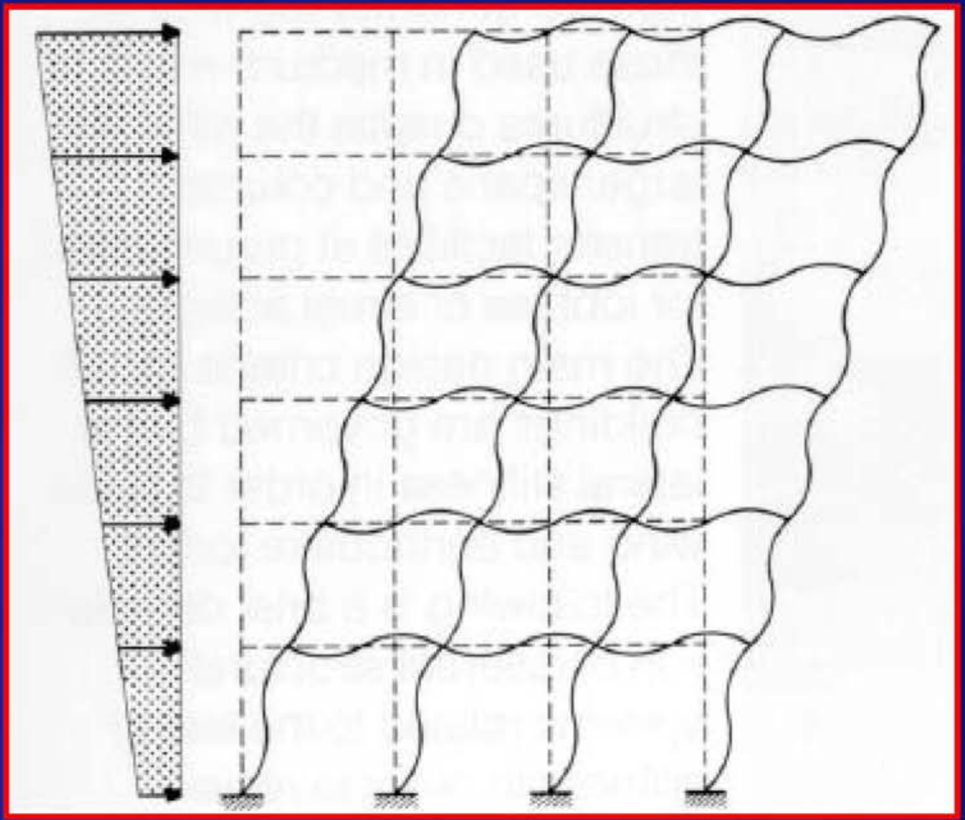
Yapı yükseldikçe Periyot artar



İstanbul Teknik Üniversitesi Mimarlık Fakültesi
Yapı ve Deprem Mühendisliği Çalışma Grubu

Çerçeve Sistemler

- Yatay yer değiştirmelere düğüm noktalarının dönmesi ile karşı koyar.
- Kolon ve kiriş elemanlarının yüksek eğilme rijitliğine sahip olmaları gerekir.
- Rijit düğüm noktaları stabilite için gereklidir.
- 30 kattan sonra etkin değildir.



Döşemeler

- Döşemeler düşey yükleri taşıyan en önemli sistem elemanlarıdır.
- Döşeme sisteminin seçimi binanın davranışını ve dayanımını önemli ölçüde etkiler.
- Binanın kullanım amacı döşeme sisteminin seçiminde önemli rol oynar.

  - Büro binalarında büyük açıklıklı basit kirişlerin kullanımı yaygındır.

  - Otel ve konut tipi yüksek binalarda ise küçük açıklıklı sürekli kirişlerin kullanımı yaygındır.
- Döşeme Tipleri:

  - Betonarme (plak, kirişli, düz, kaset)
  - Öngerilmeli Beton
  - Kompozit

KOMPOZİT DÖŞEMELER

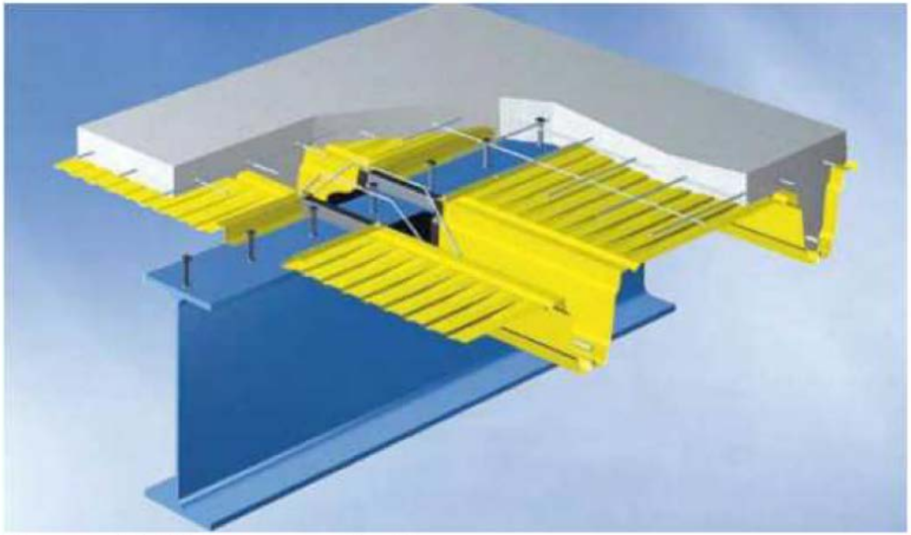
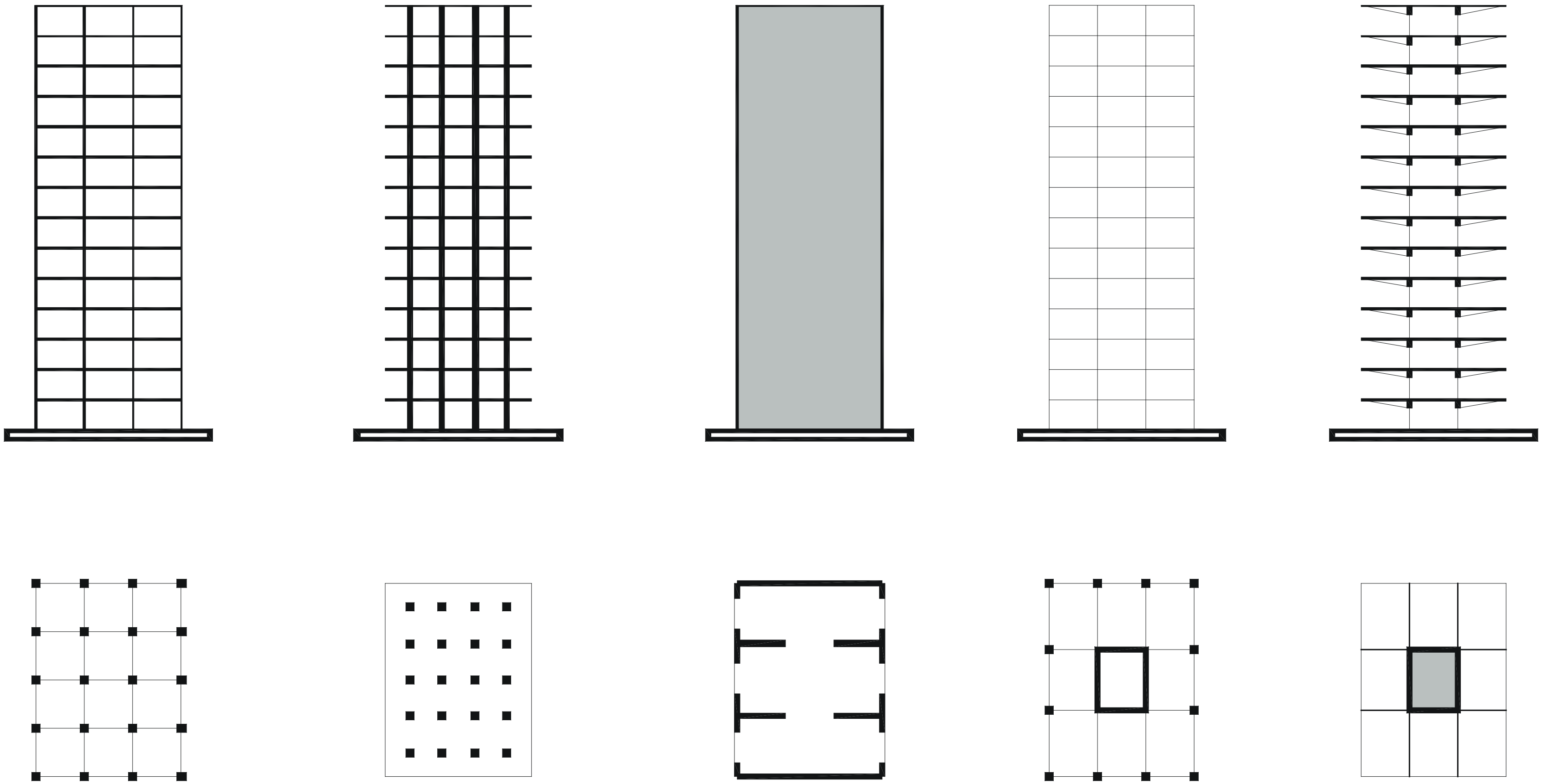


Figure 3-40 composite floor

Figure 3-41 composite floor

Öğr. Gör. Dr. Haluk Sesigür



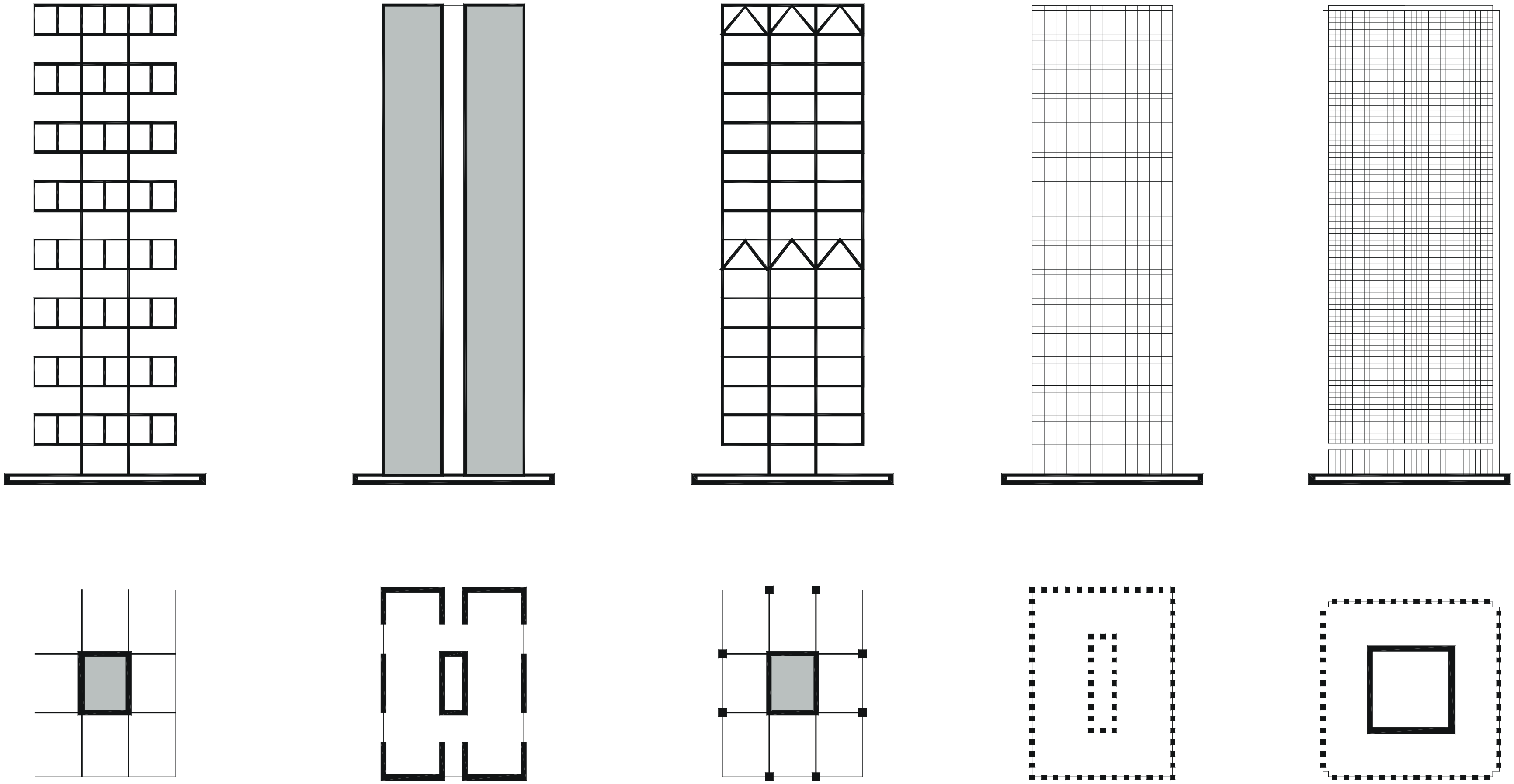
(a_1) Çerçeve (kirişli)

(a_2) Çerçeve (kirişsiz)

(b) Perdeli

(c_1) Çekirdek+ çerçeve

(c_2) Çekirdek+ konsol döşemeli



(c_3) Çekirdek (Vierendeel Kirişli)

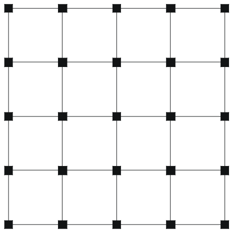
(c_4) Çekirdek+ perde

(c_5) Çekirdek+yatay kafes kiriş

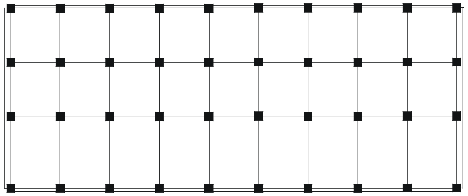
(d_1) İç içe tüp

(d_2) Çekirdek +dış tüp

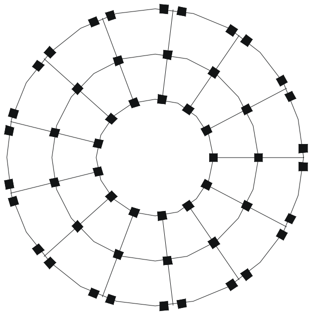
Çerçeve Sistemler



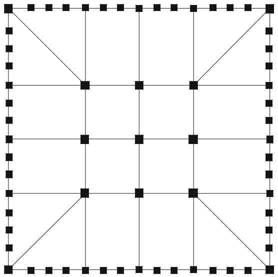
(a) Eksen aralıkları eşit



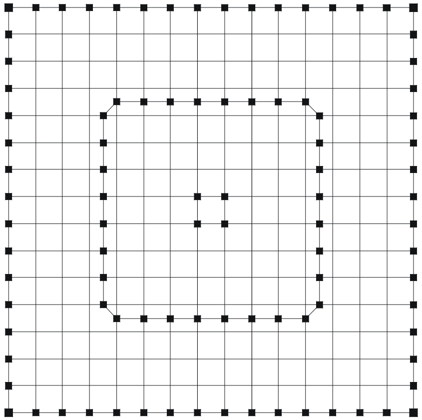
(b) Eksen aralıkları farklı



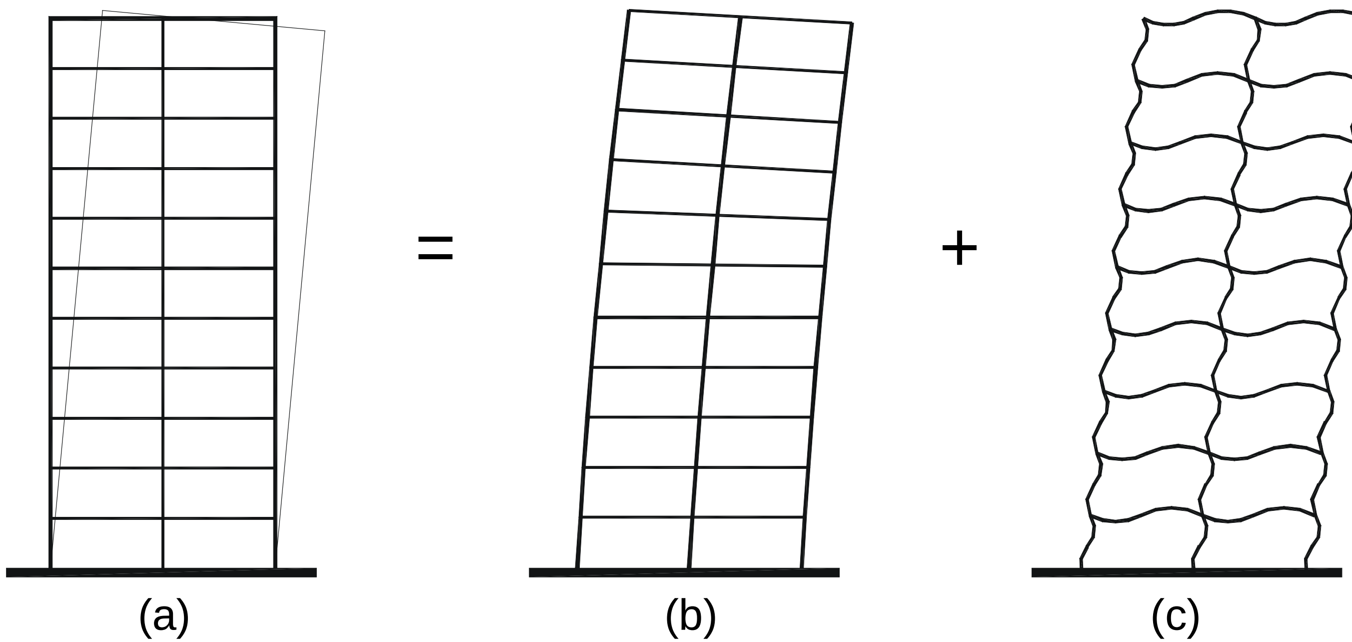
(c) Dairesel ve ışınsal eksenli



(d) iç çekirdek+ dış zarflı



(e) iç ve dış zarflı

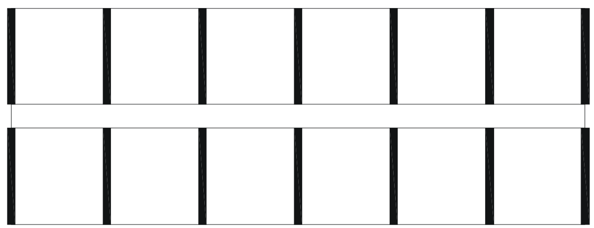


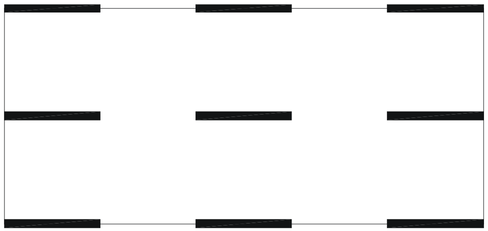
Şekil 1. Çerçeve sistemlerin yatay yükler altındaki davranışı

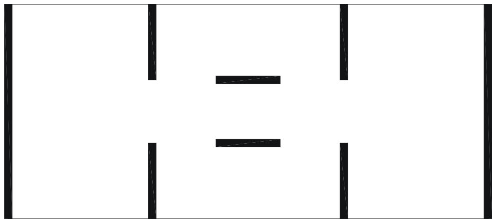
Kiriş ve kolonların yerdeğiştirmeleri, kayma ötelemesi olarak isimlendirilir (Şekil 1.b))

Bu elemanlar eğildiğinde bütün çerçevede yerdeğiştirmeler oluşur; yerdeğiştirmeler, yaklaşık olarak, binanın yatay ötelemesinin % 80'i mertebesindedir; bunun % 65'i kiriş, % 15'i ise kolon eğilmelerindendir.

Perdeli Sistemler

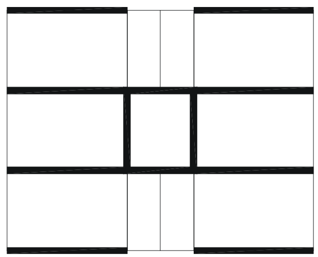
(a) 

 (b)

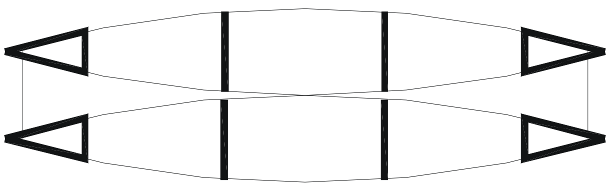
 (c)

Paralel perdeli sistemlere bazı örnekler
(a) Enine doğrultuda perdeli sistem
(b) Boyuna doğrultuda perdeli sistem
(c) İki doğrultuda perdeli sistem

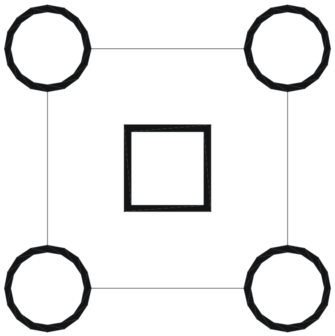
Çekirdek Sistemler



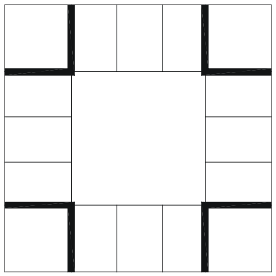
(a) Boyuna perde merkezi çekirdek



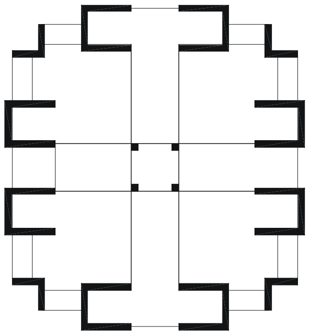
(b) Enine perde+köşe çekirdekleri



(c) Kapalı köşe çekirdekleri+ merkezi çekirdek

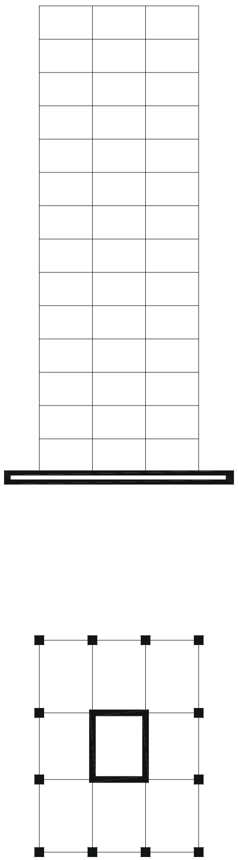


(d) Açık köşe çekirdekler



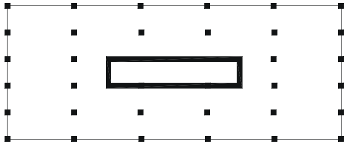
(e) Açık ve kapalı çevre çekirdekler

Çekirdek+Çerçeve Sistemler

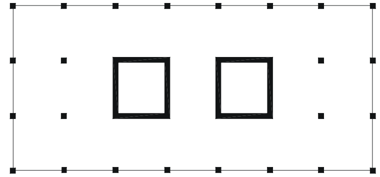


(c_1) Çekirdek+ çerçeve

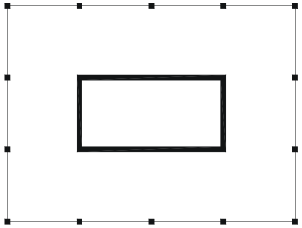
Yalın rijit çerçeve sistemler 20 kattan yüksek betonarme binalarda ekonomik değildir; 150 m'den yüksek binalarda yatay yüklerin taşınması için yalnız perde ya da çekirdek kullanılması uygun olmaz. Çekirdeklerin yeterli güçte olmaları için boyutlarının büyük olması gerekir; bu ise bunların asansör ve tesisat boşluğu olarak kullanılabilme işlevleri ile bağdaşmaz. Ayrıca yerdeğiştirmeler, bölme duvarlarının ve pencerelerin çatlamasına neden olabilecek, hatta bina kullanıcılarında psikolojik etkiler doğurabilecek kadar büyük olabilir. Bu nedenlerle yatay rijitliğin, çekirdek/perde ile birlikte çerçeve kullanılarak büyük ölçüde arttırılması, diğer bir deyişle, çerçeveler ve çekirdekler/perdeler uygun biçimde düzenlenerek oluşturulan çekirdek+çerçeve türü taşıyıcı sistemlerin kullanılması yoluna gidilir.



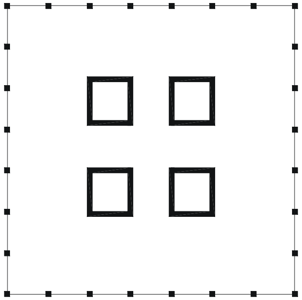
(a_1) Kapalı çekirdek
+ iç çerçeve



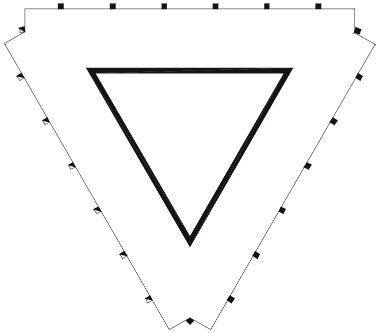
(a_2) Kapalı çekirdekler
+ çerçeve



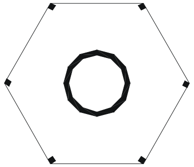
(b_1) Kapalı çekirdek
+ çevre çerçeve



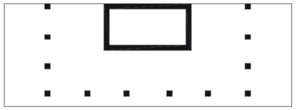
(b_2) Kapalı çekirdekler
+ çevre çerçeve



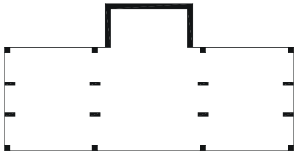
(b_3) Kapalı çekirdek
+ çevre çerçeve



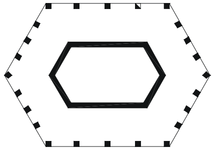
(b_4) Kapalı çekirdek
+ çevre çerçeve



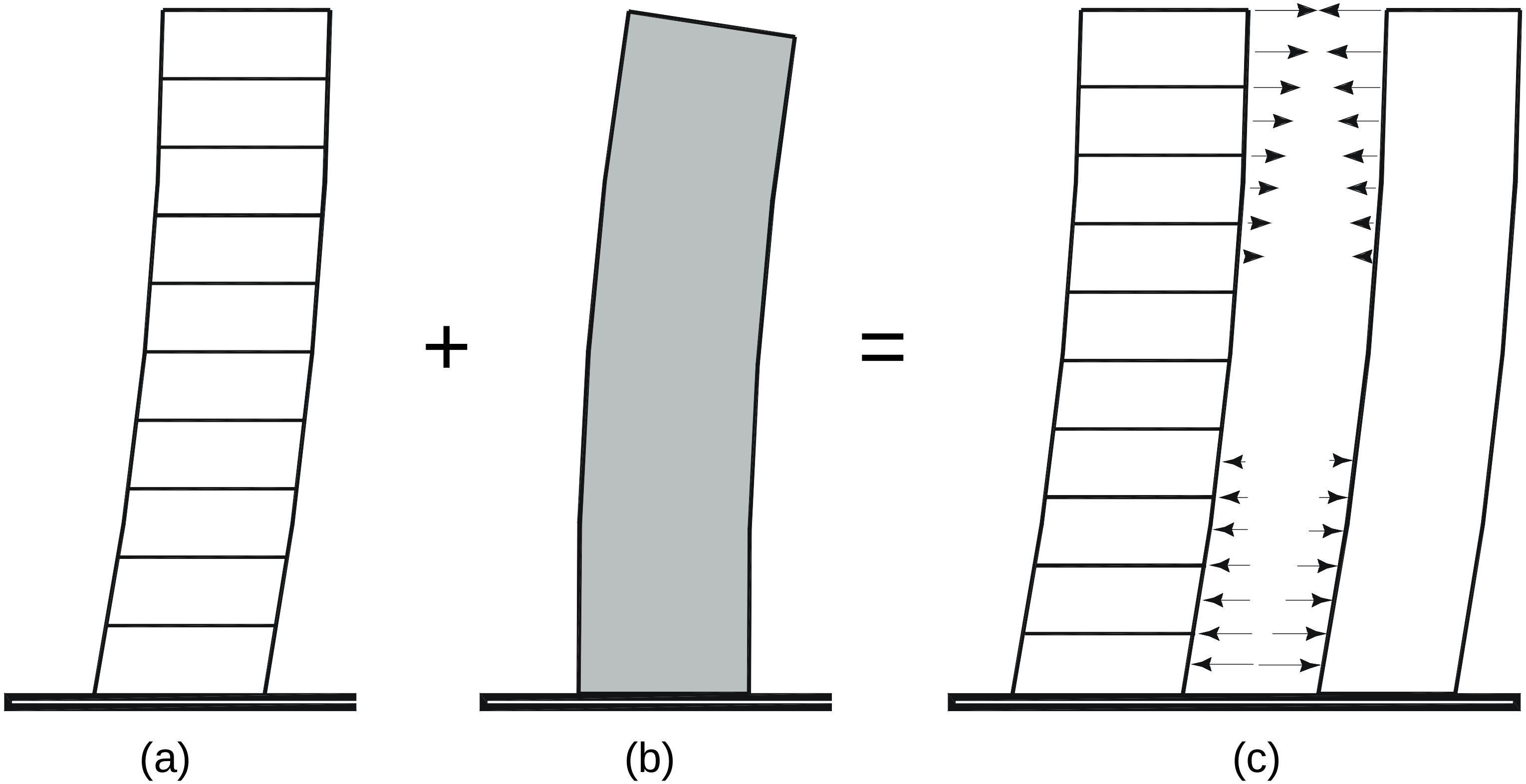
(c) Kapalı iç cephe
çekirdek+iç çerçeve



(d) Açık dış çekirdek
+çevre çerçeve



(b_5) Kapalı çekirdek
+ çevre çerçeve



Şekil 2. Perde/ çekirdek + rijit çerçeve sistemlerin yatay yükler etkisindeki davranışı

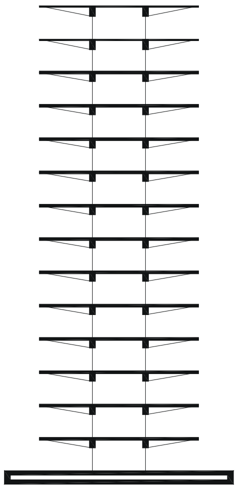
(a) Rijit çerçeve davranışı
(b) Perde/çekirdek davranışı
(c) Perde/çekirdek + rijit çerçevede karşılıklı etkileşim

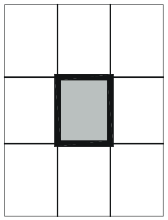
Rijit çerçeve yerdeğiştirme durumunda (Şekil 2.a), taşıyıcı sistem tabanında en büyük kesme kuvveti ve dönme oluşur. Perde yerdeğiştirme durumunda ise (Şekil 2.b), sistem bir düşey konsol kiriş gibi davranır; binanın en üstünde perde/çekirdek sisteminin tüm taşıyıcı sisteme rijitlik katkısı minimumdur ve burada en büyük dönme olur.

Perde/çekirdek ve rijit çerçeve sistemlerinin farklı yerdeğiştirme özellikleri nedeniyle, bina üst kısmında perde/çekirdek rijit çerçeve tarafından çekilir; bina alt kısmında ise ileri itilir (Şekil c). Bu nedenle yatay yükler bina üst kısımlarında daha çok çerçeve, alt kısımlarında ise perde/çekirdek tarafından taşınır.

Çekirdek+Konsol Döşemeli Sistemler.

Kolonsuz bir kullanım hacmi elde edilir, bina boyutu sınırını döşeme dayanımı belirler. Öngerilme tekniklerinden yararlanarak döşeme rijitliği artırılabilir. Düşey yükler üstte sıfırdan başlayarak tabanda maksimum değerine ulaşır. Merkezi çekirdek yatay yük etkisi altında bir konsol kiriş gibi davranır. Genelde çok kullanılan bir yüksek bina taşıyıcı sistemi değildir; çünkü negatif plak momentlerini karşılamak için çok miktarda çelik donatı kullanmak gerekir ve konsollarda büyük düşey yerdeğiştirmeler ve duvarlarda çatlaklar oluşabilir.

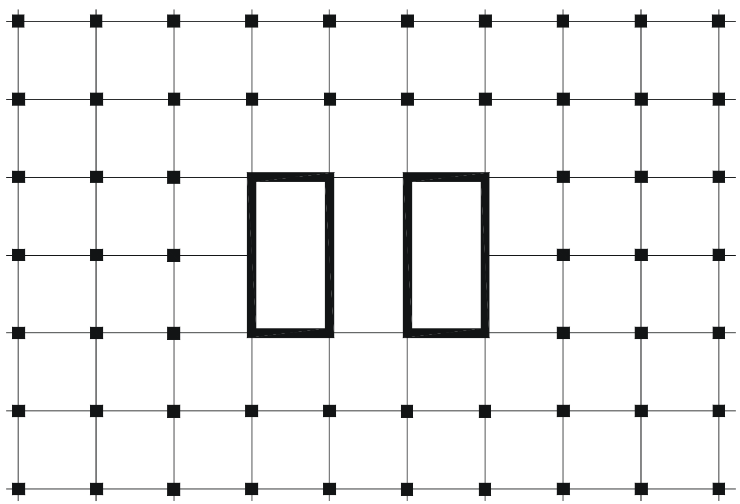


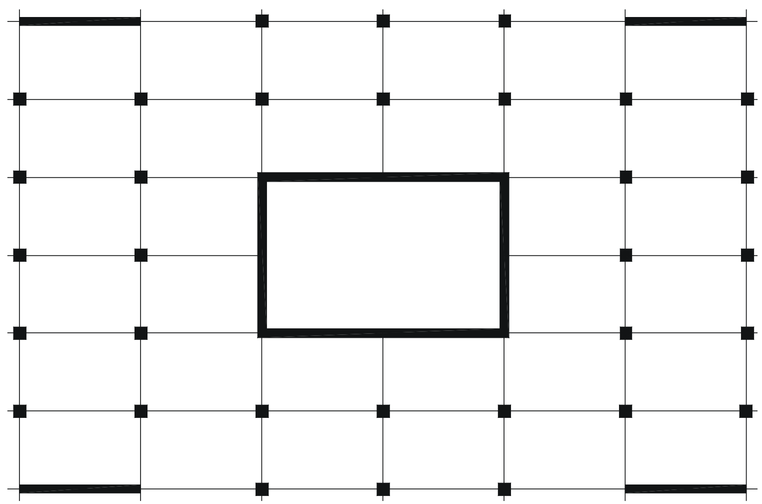


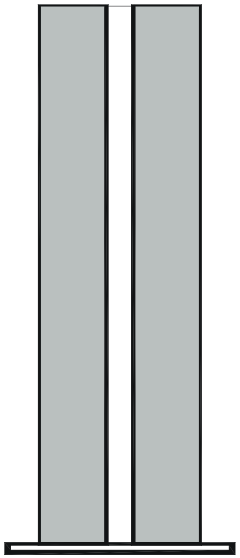
(c_2) Çekirdek+ konsol döşemeli

Çekirdek/Perde+Kirişsiz Döşeme Sistemler.

Betonarme taşıyıcı sistemin monolitik özelliğinden ötürü tüm yapı yatay yüklere bir bütün olarak karşı koyar. Yatay yüklerin yalnız rijit çekirdek ya da perdelerce karşılandığı, döşeme ve kolonların hiçbir katkısı bulunmadığını varsaymak gerçekçi değildir. Sistemin üst kısmında yatay yükler çerçeve etkisi ile, alt kısmında ise perde ya da çekirdek sistemi ile karşılanır.

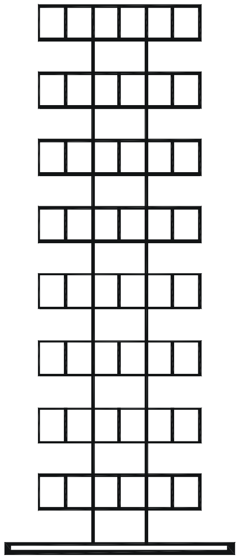




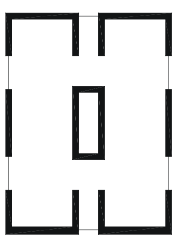


Çekirdek+Vierendeel Kirişli Sistemler.

Kat yüksekliğince konsollu çerçeve taşıyıcı sistemler birer kat atlayarak kullanılır, böylece çerçeve içinde ve üzerinde kullanılabilir hacim yaratılır. Çerçeveli döşeme içindeki hacimler sabit eylemler için kullanılır; çerçeve üstündeki tamamen serbest hacim ise her tür eylem için uygundur.

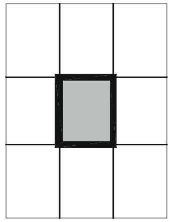


Çekirdek+Dış Perde Sistemler.



(c_4) Çekirdek+ perde

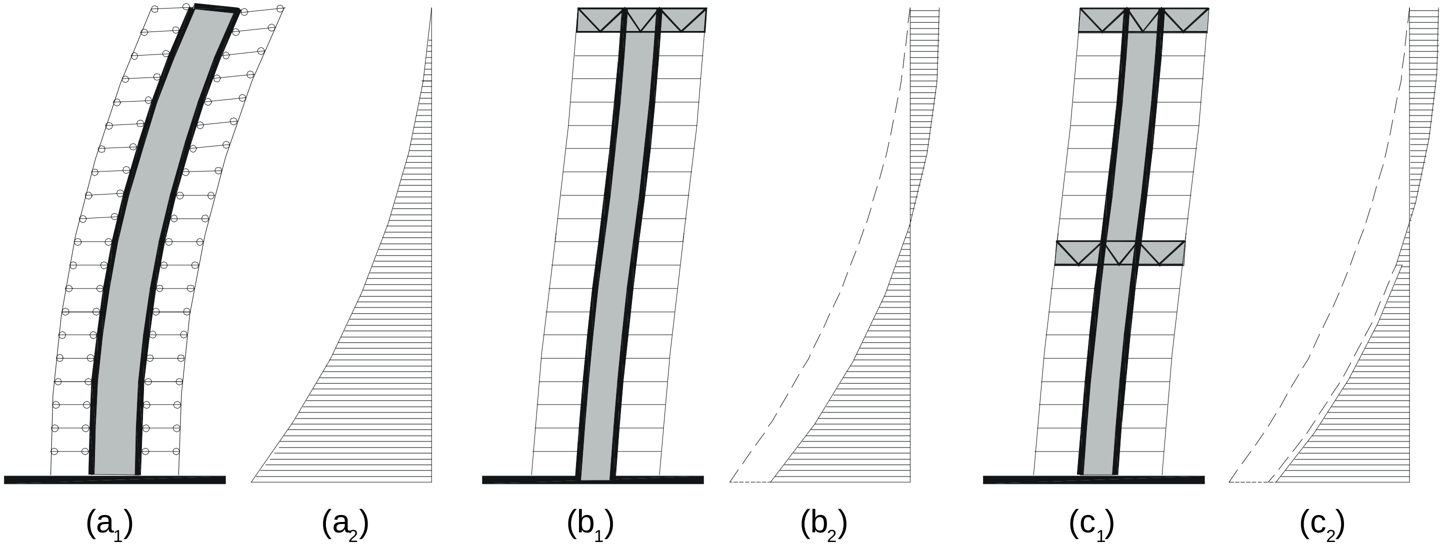
Bu taşıyıcı sistem bir merkezi çekirdek etrafında yer alan düşey dış perde elemanlarından oluşur. Bu düzen, döşeme sisteminin açıklık sınırlarına bağlı olan, iç açık hacimler sağlar. Çekirdek binanın rijitliğine katkıda bulunur; buraya binanın tesisat ve düşey ulaşım sistemleri yerleştirilebilir.



(c_3) Çekirdek (Vierendeel Kirişli)

Çekirdek + Yatay Kafes Kiriş Sistemler. (Core + outrigger)

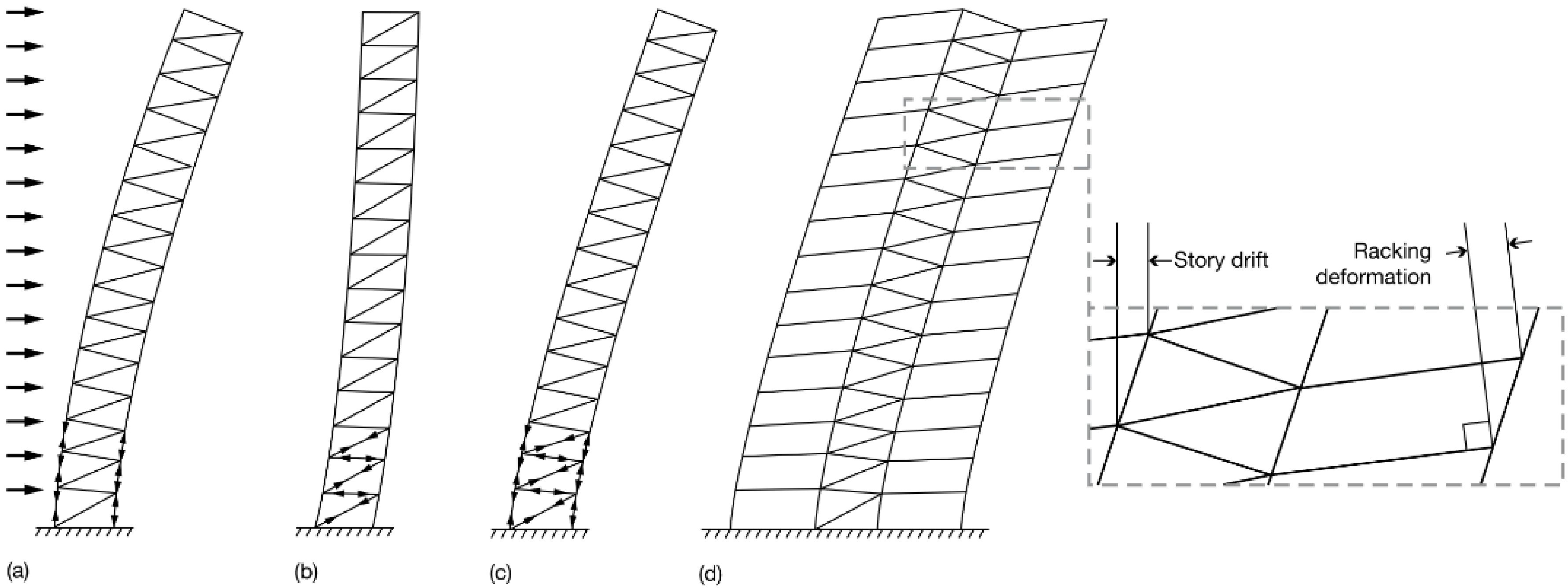
Çerçeve + perde sistemleri 40 kat yüksekliğinden sonra yetersiz kalır. Bina taşıyıcı sisteminin etkinliği, rijit çerçeveyi çekirdeğe bağlamak için, ardışık iki kat kirişlerinin alt ve üst başlıklarını oluşturduğu yatay kafes kirişler kullanılarak yaklaşık %30 arttırılabilir. Kafes kirişler çekirdeğe rijit, dış kolonlara ise basit mafsallı bağlanır.

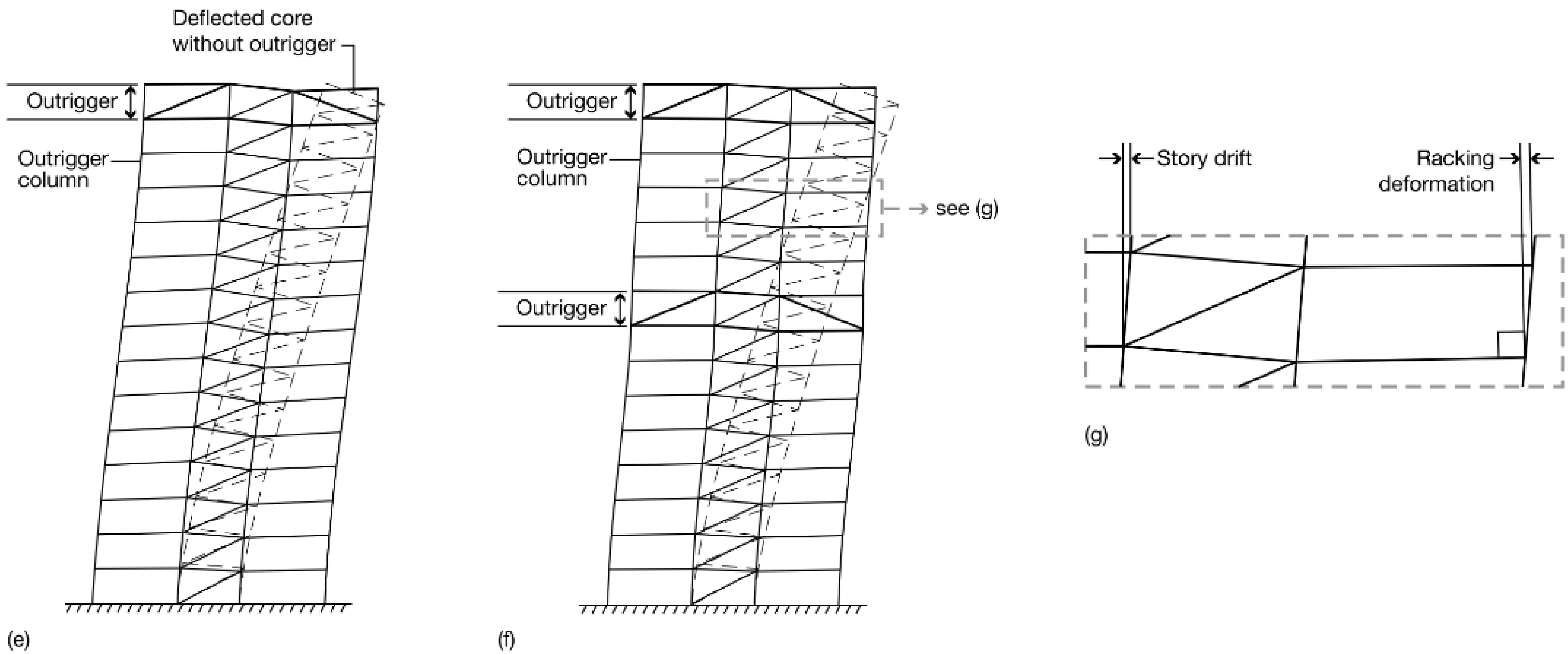


Çekirdek + yatay kafes kiriş sistemlerin yatay yük altında davranışları
(a) Çekirdek+çekirdeğe mafsallı bağlı rijit çerçeve
(b) Çekirdek+bir yatay kafes sistem durumu
(c) Çekirdek+iki yatay kafes sistem durumu

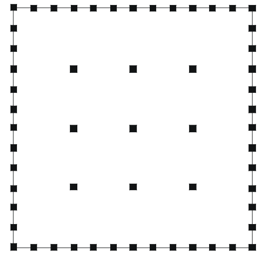
Yaklaşık 60 kat yüksekliğe kadar bina tepesinde ve ortasında yatay kafes sistem kullanmak ekonomik olmaktadır. Kafes kirişler yerine betonarme perdeler de düzenlenebilir.

Taşıyıcı sistemin yatay yüklere karşı dayanım ve rijitliği araya ek yatay kafes sistemler koyarak daha da arttırılabilir (Şekil c_1). Her yatay kafes kiriş düzeyinde taşıyıcı sistemde dönmeler olmaz; eğilme momenti diyagramında, azalma olacak biçimde, süreksizlikler olur.

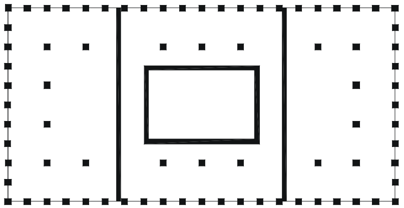

Story drift
Racking deformation
(a)
(b)
(c)
(d)


Deflected core
without outrigger
Outrigger
Outrigger
column
(e)
Outrigger
Outrigger
column
see (g)
Outrigger
(f)
Story drift
Racking
deformation
(g)

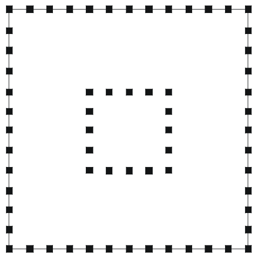
Tüp Sistemler



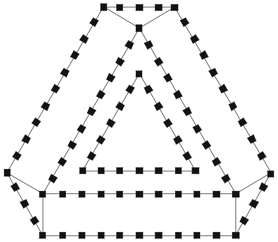
(a) Dış tüp+çerçeve



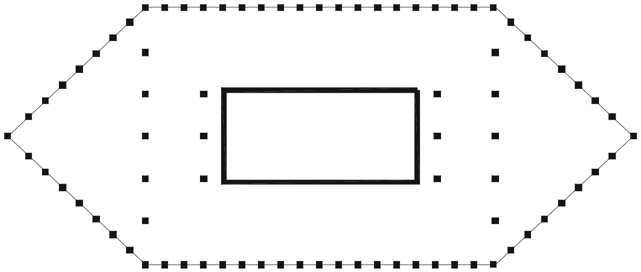
(b) Dış tüp+paralel perde



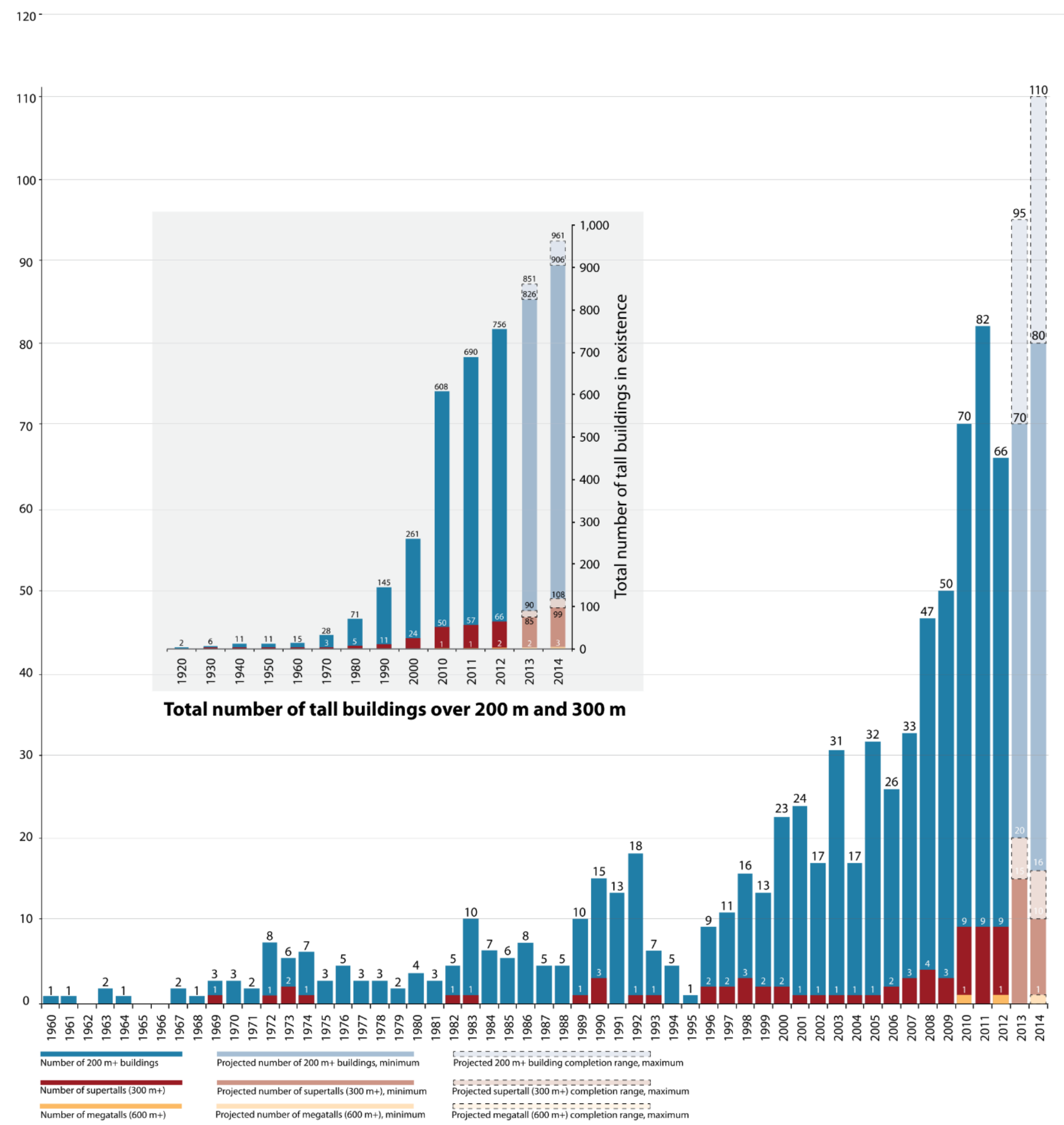
(c) İç içe tüp

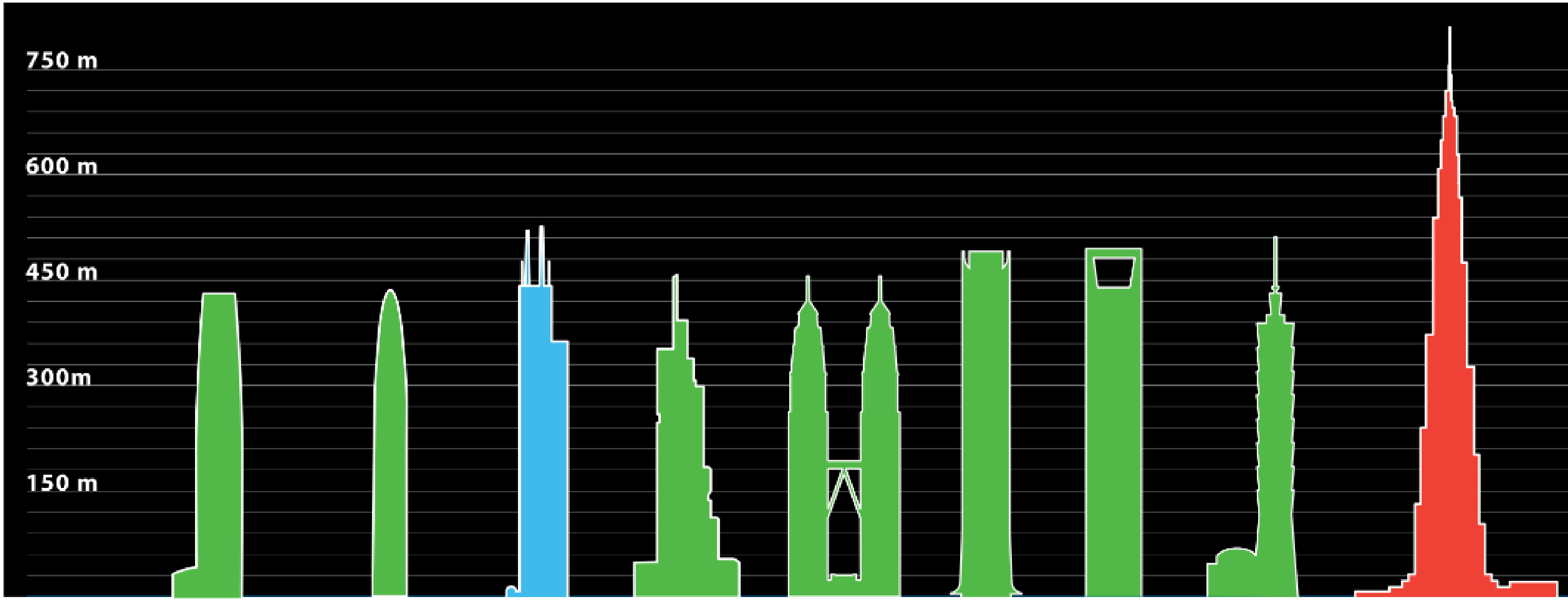


(d) Üçlü iç içe tüp



(e) Dış tüp+çekirdek+çerçeve


Total number of tall buildings over 200 m and 300 m
Total number of tall buildings in existence
Number of 200 m+ buildings
Number of supertalls (300 m+)
Number of megatalls (600 m+)
Projected number of 200 m+ buildings, minimum
Projected number of supertalls (300 m+), minimum
Projected number of megatalls (600 m+), minimum
Projected 200 m+ building completion range, maximum
Projected supertall (300 m+) completion range, maximum
Projected megatall (600 m+) completion range, maximum

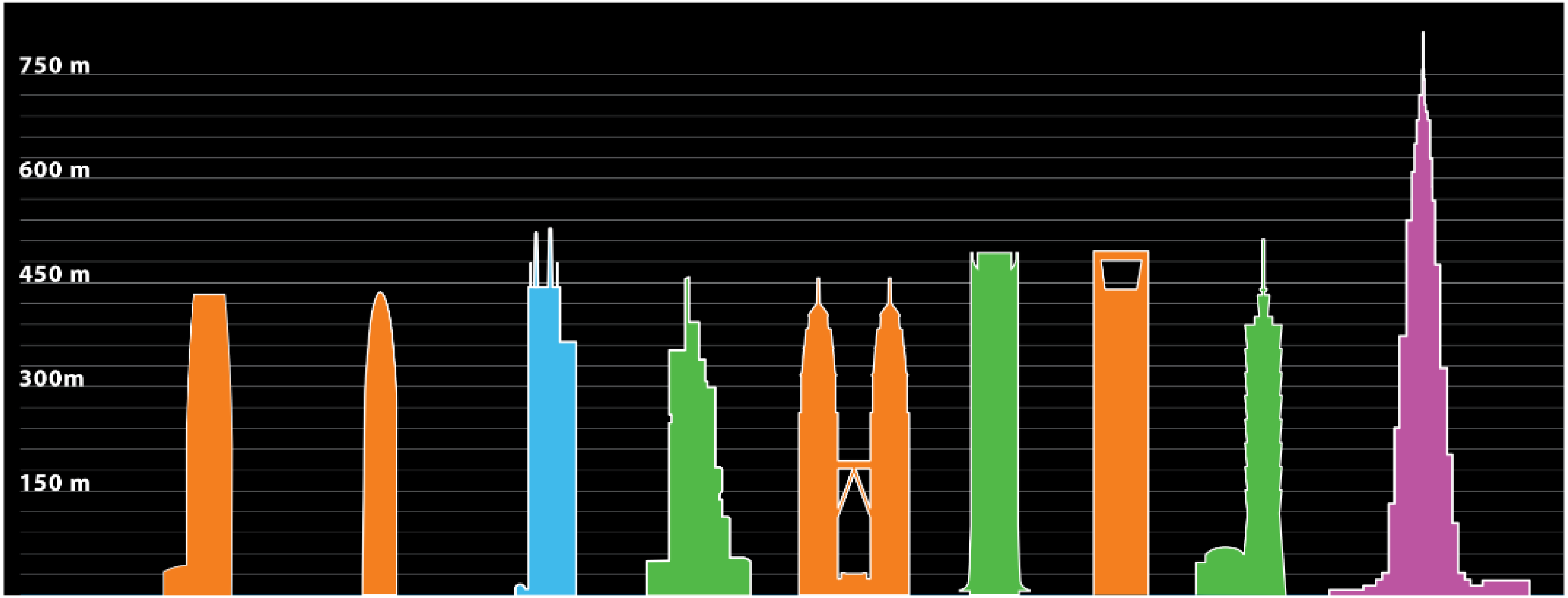


	GUANGZHOU INTERNATIONAL FINANCE CENTER	KK100 DEVELOPMENT	WILLIS TOWER (FORMERLY SEARS TOWER)	ZIFENG TOWER	PETRONAS TOWER 1 AND 2	INTERNATIONAL COMMERCE CENTRE	SHANGHAI WORLD FINANCIAL CENTER	TAIPEI 101	BURJ KHALIFA
Location	Guangzhou	Shenzhen	Chicago	Nanjing	Kuala Lumpur	Hong Kong	Shanghai	Taipei	Dubai
Year Built	2010	2011	1974	2010	1998	2010	2008	2004	2010
Height	439 m	442 m	*442 m	450 m	452 m	484 m	492 m	508 m	828 m

STEEL **CONCRETE** **COMPOSITE**

* BUILDING HEIGHT DOES NOT INCLUDE BROADCAST ANTENNAS

17.6 Structural materials of the world's tallest buildings
Graphic: Skidmore, Owings & Merrill LLP



	GUANGZHOU INTERNATIONAL FINANCE CENTER	KK100 DEVELOPMENT	WILLIS TOWER (FORMERLY SEARS TOWER)	ZIFENG TOWER	PETRONAS TOWER 1 AND 2	INTERNATIONAL COMMERCE CENTRE	SHANGHAI WORLD FINANCIAL CENTER	TAIPEI 101	BURJ KHALIFA
Location	Guangzhou	Shenzhen	Chicago	Nanjing	Kuala Lumpur	Hong Kong	Shanghai	Taipei	Dubai
Year Built	2010	2011	1974	2010	1998	2010	2008	2004	2010
Height	439 m	442 m	*442 m	450 m	452 m	484 m	492 m	508 m	828 m

FRAME – OUTRIGGER
CORE PLUS PERIMETER **
CORE – OUTRIGGER
BUNDLED TUBE
BUTTRESSED CORE

* BUILDING HEIGHT DOES NOT INCLUDE BROADCAST ANTENNAS
** MAY ALSO INCLUDE OUTRIGGER

17.8 Structural systems of the world's tallest buildings
Graphic: Skidmore, Owings & Merrill LLP

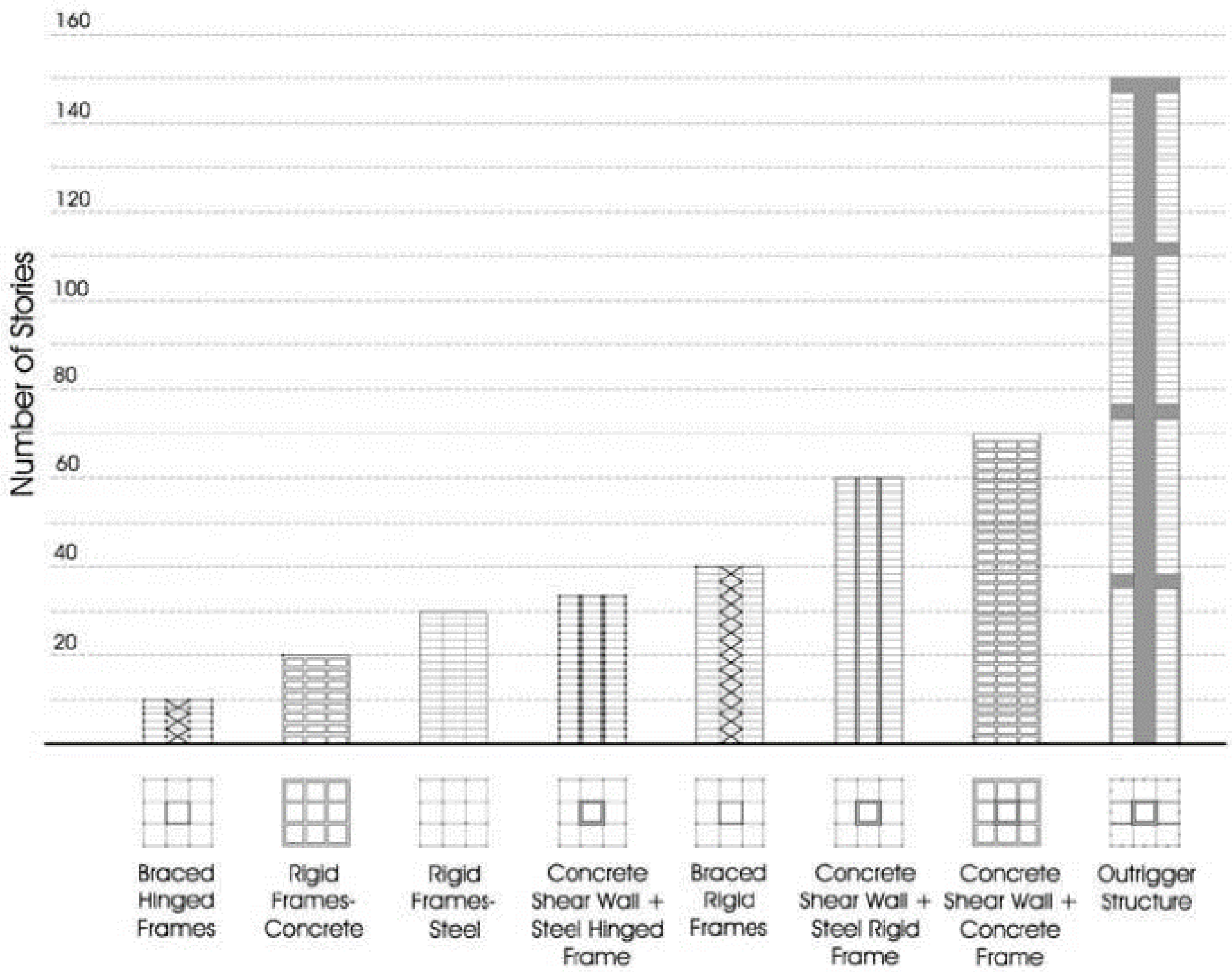
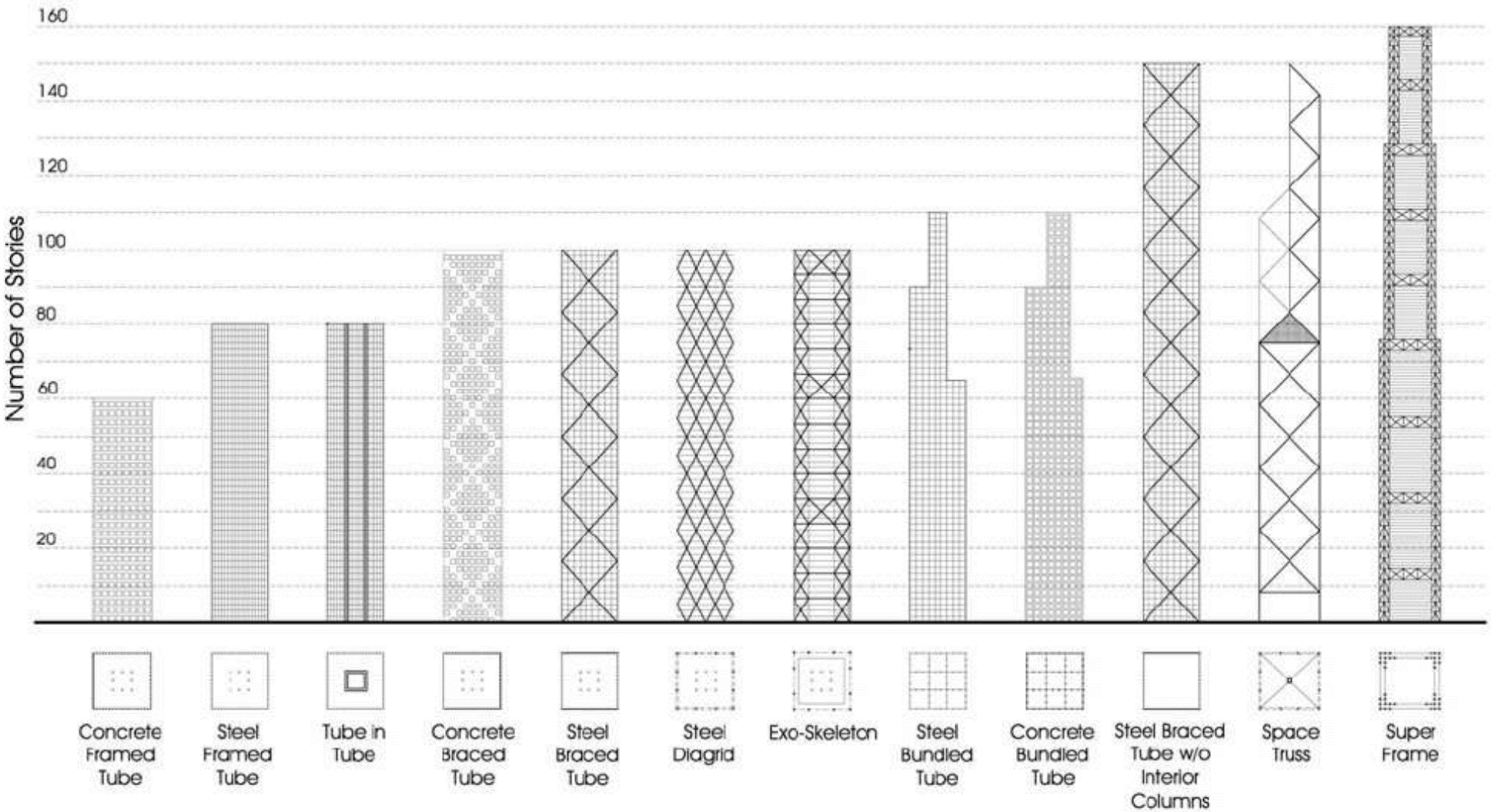


Figure 3-8 Interior structures [8]



ure 3-9 Exterior structure [8]

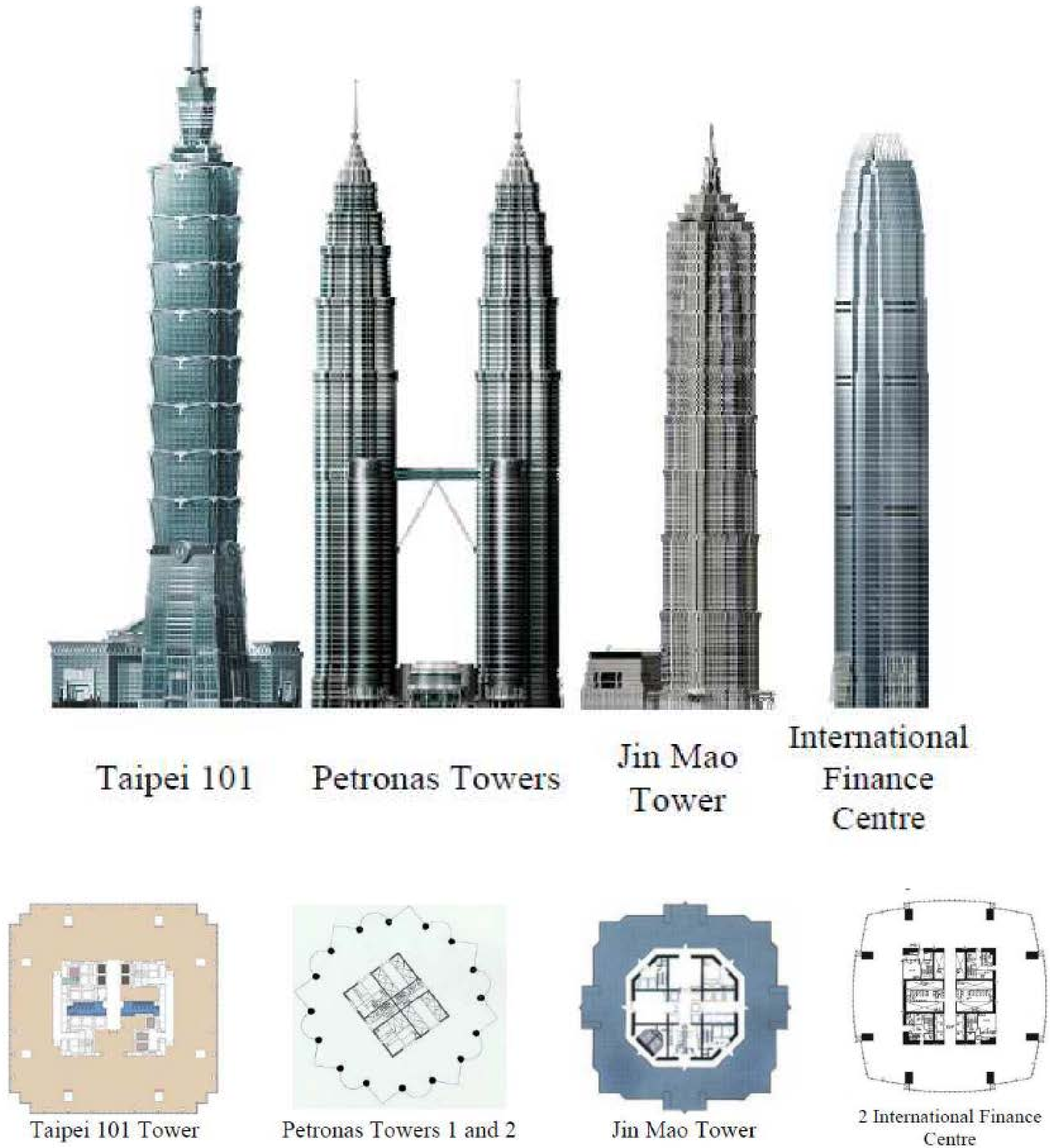
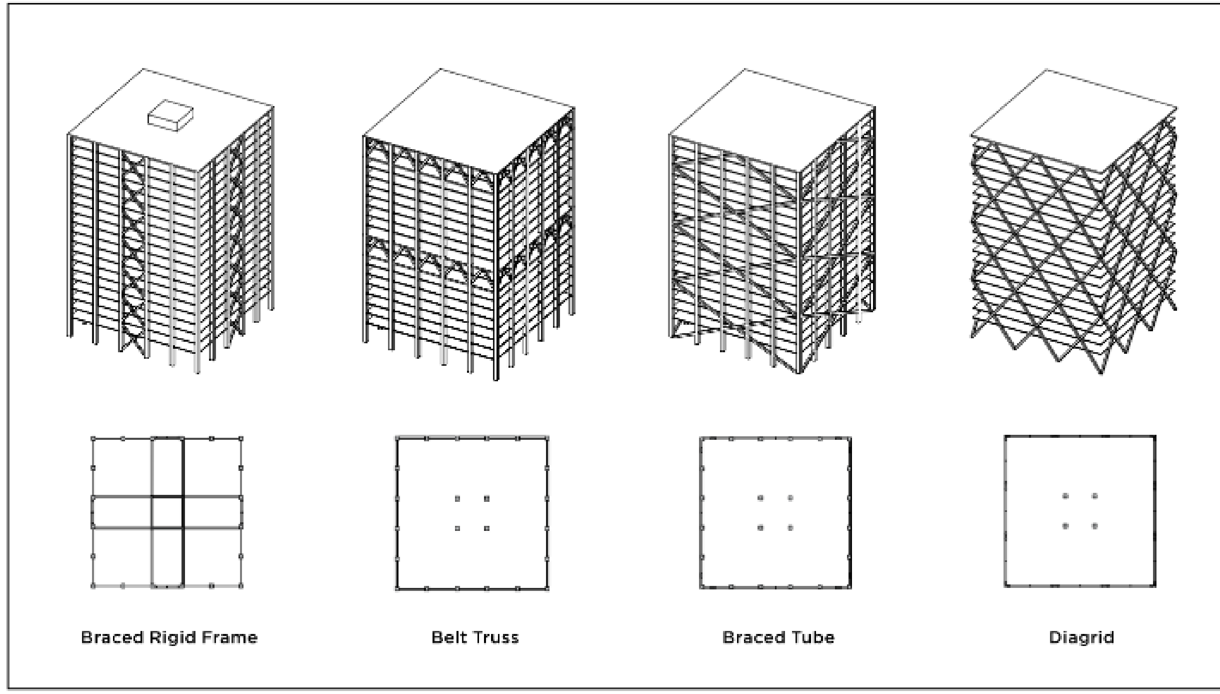
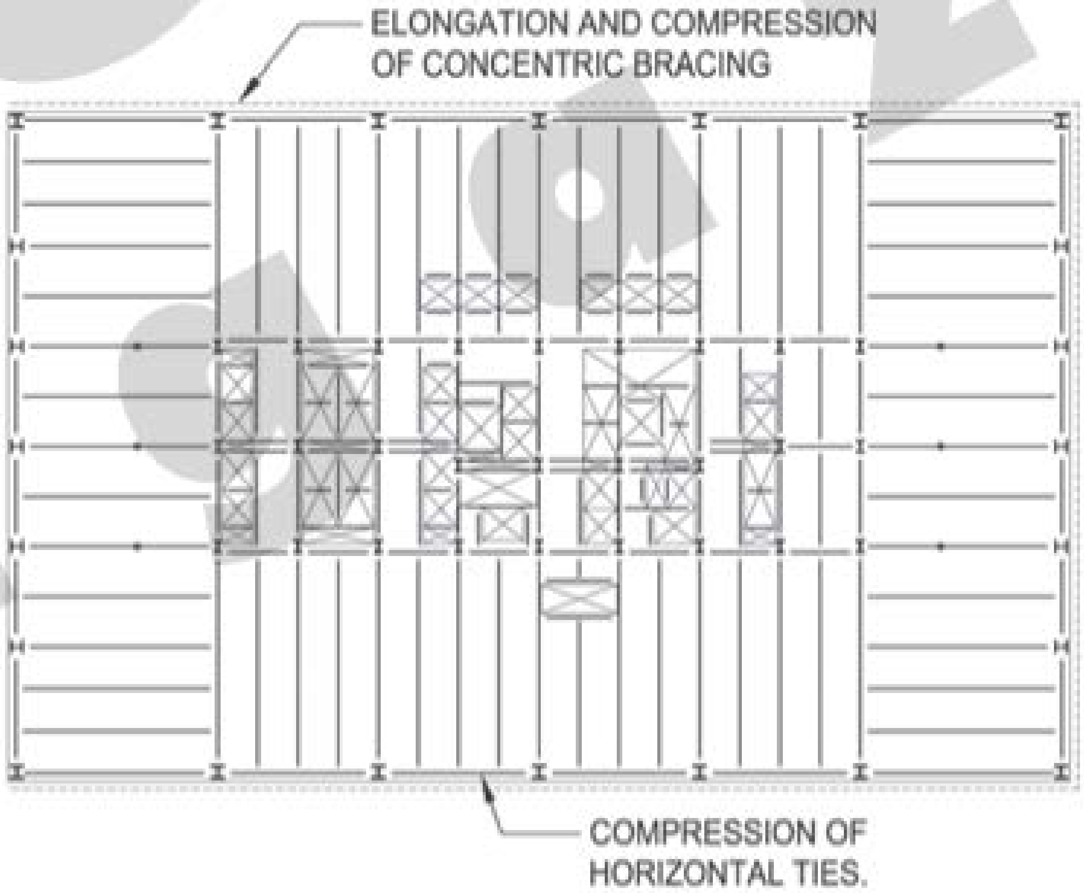


Figure 3-25 Core outrigger cross-sections of supertall buildings

The diagonal braces of the John Hancock Center in Chicago, IL, USA, designed by SOM and completed in 1969, clearly express the lateral bracing system as part of the aesthetic of the façade.

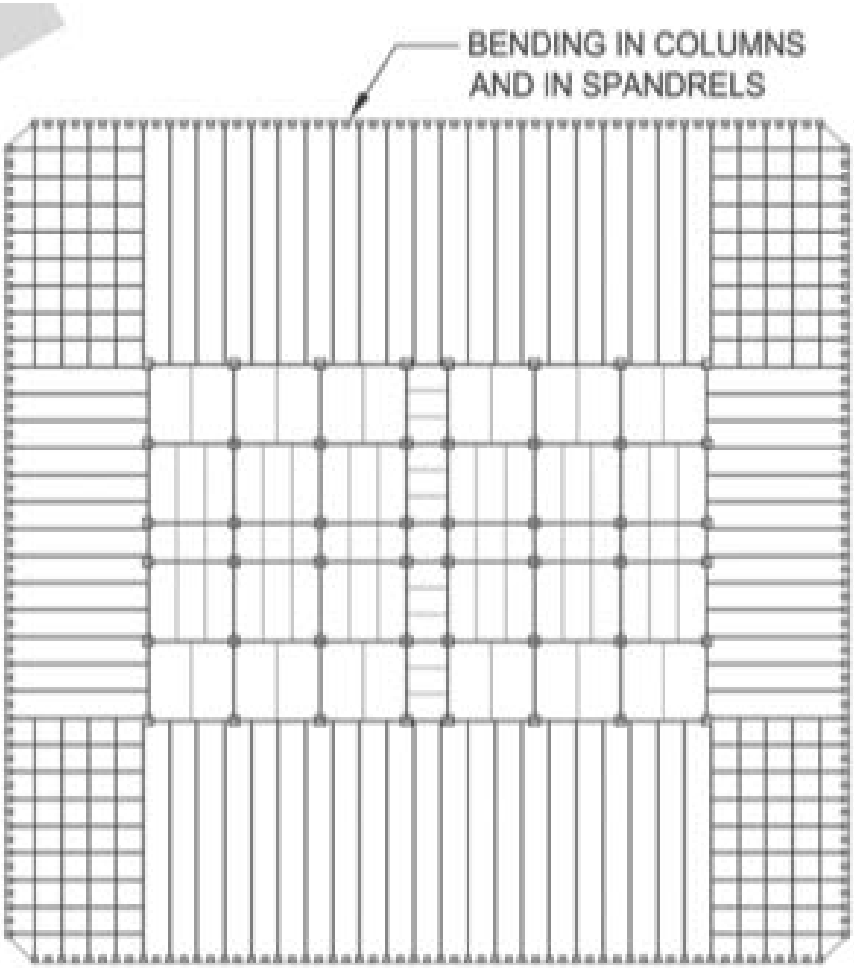


This drawing shows the use of diagonal bracing systems in the high-rise building type. Where the braced rigid frame and the belt truss diagonals are often integrated into a traditional curtain wall framing pattern, both the braced tube system and the diagrid use their scale to transform the design to acknowledge their presence.



JOHN HANCOCK BUILDING (BRACED TUBE)

Figure 3-14 John Hancock



WTC (TUBE STRUCTURE)

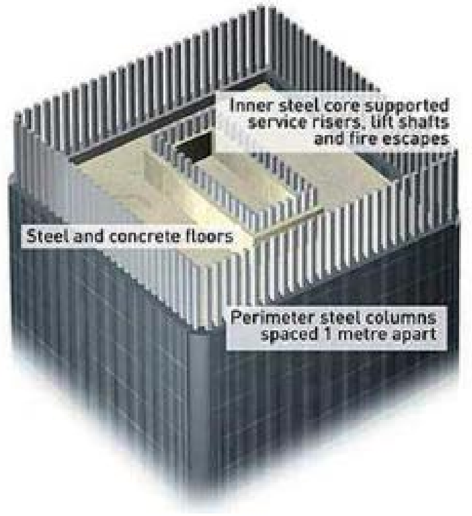
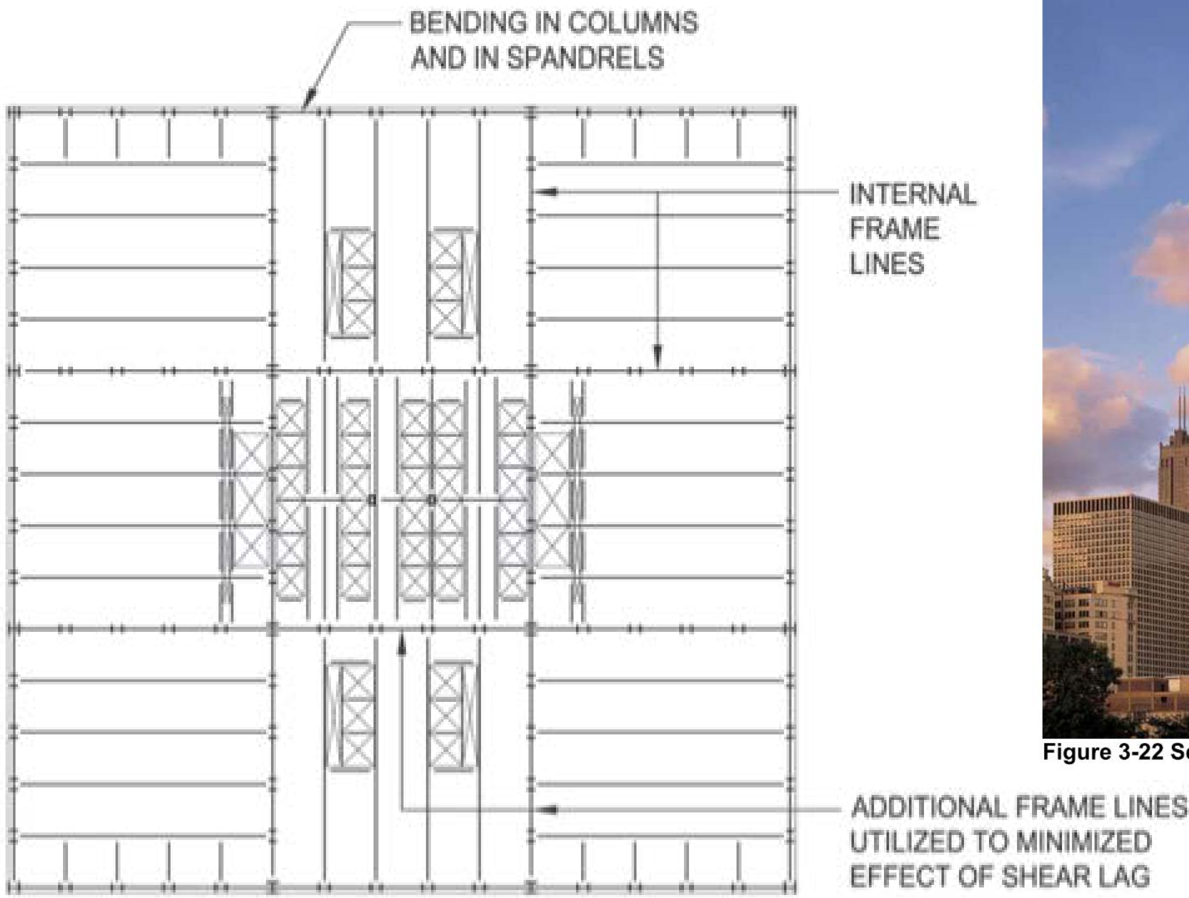


Figure 3-15 World trade center



SEARS TOWER (BUNDLED TUBE)

Figure 3-22 Sears Towers

Figure 3-22 Sears Towers

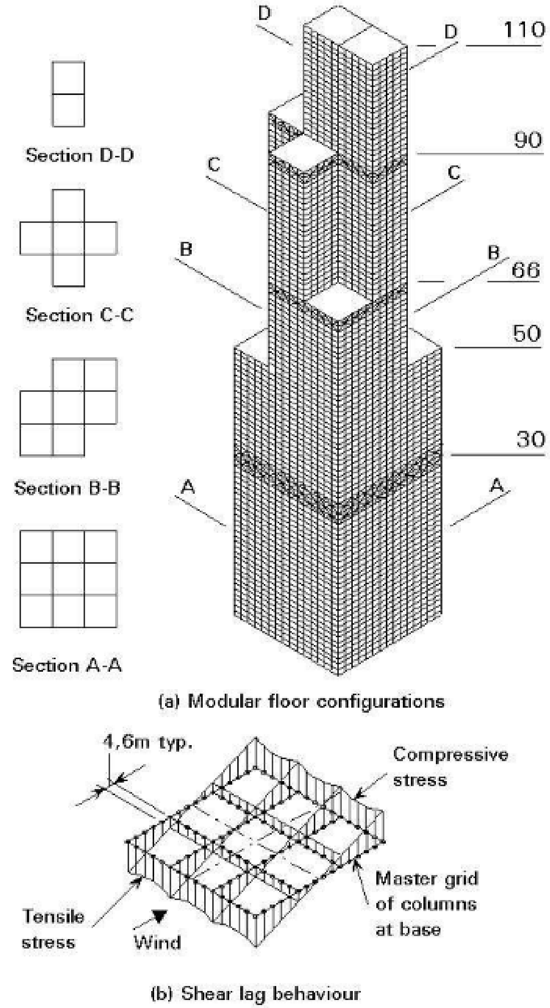
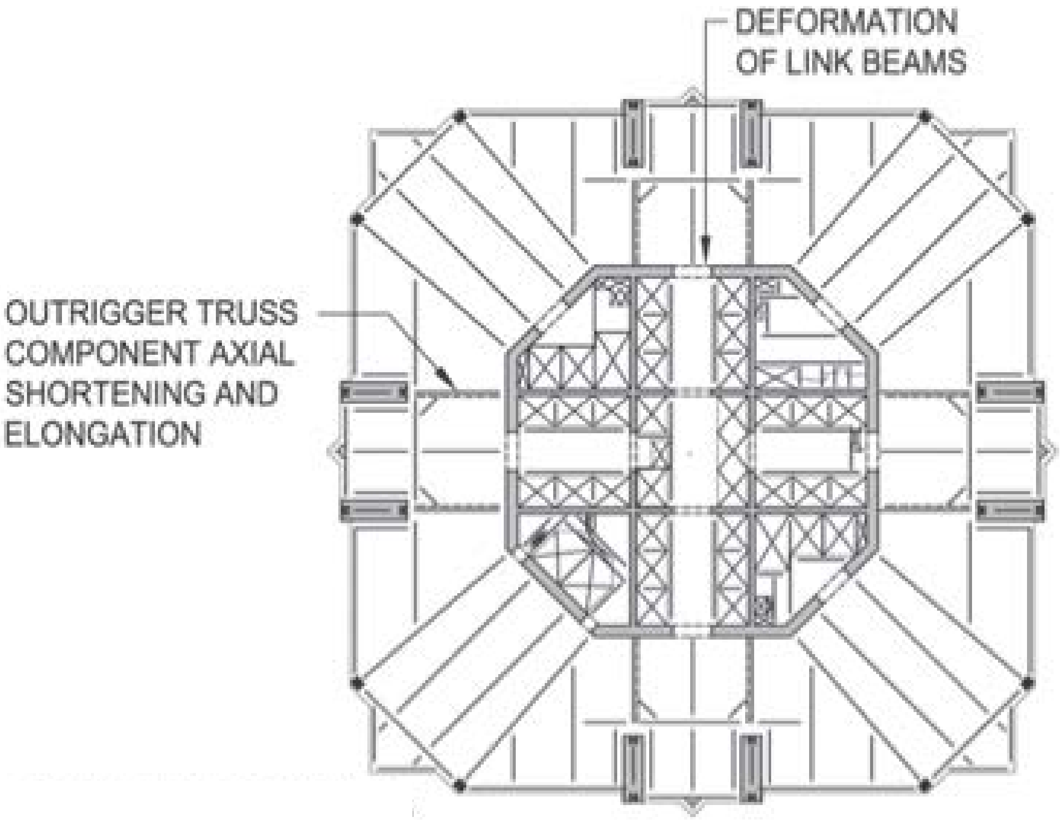


Figure 3-23 Bundled tube concept



JIN MAO TOWER (COMPOSITE STAYED MAST)

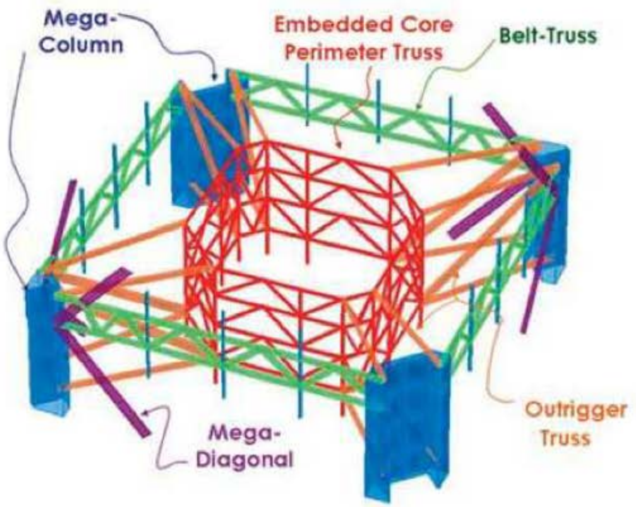


Figure 3-11 Megacolumn (top left) and structural system Shanghai World Financial (down left) and(right)

Photo 1. Perspective of Mode Gakuen Spiral Tower

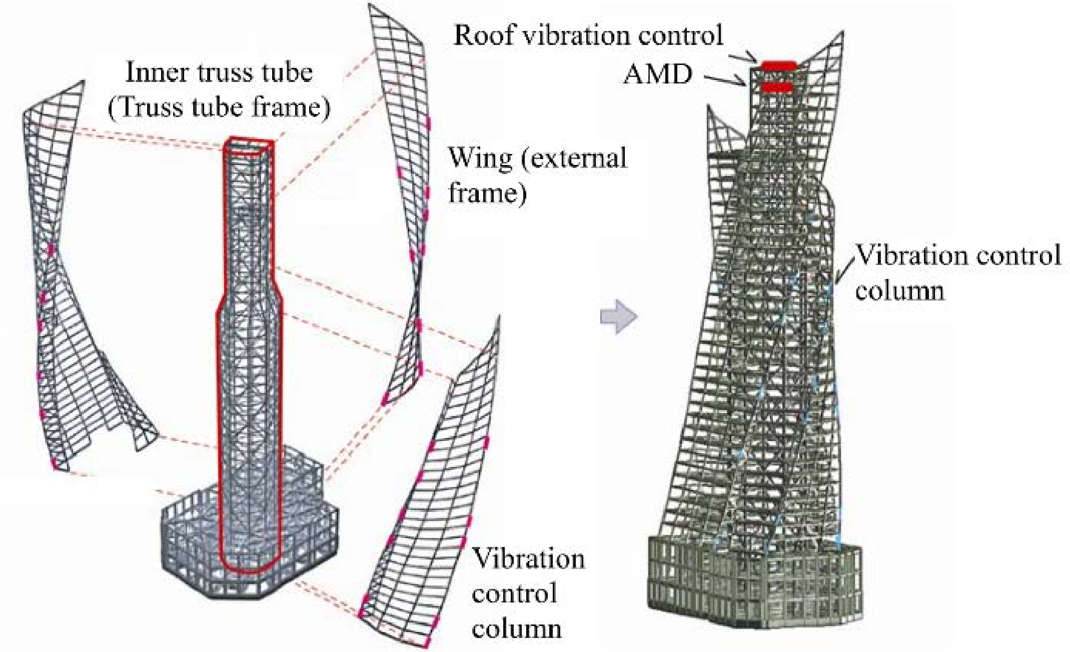


Figure 2. Conceptual system of framing

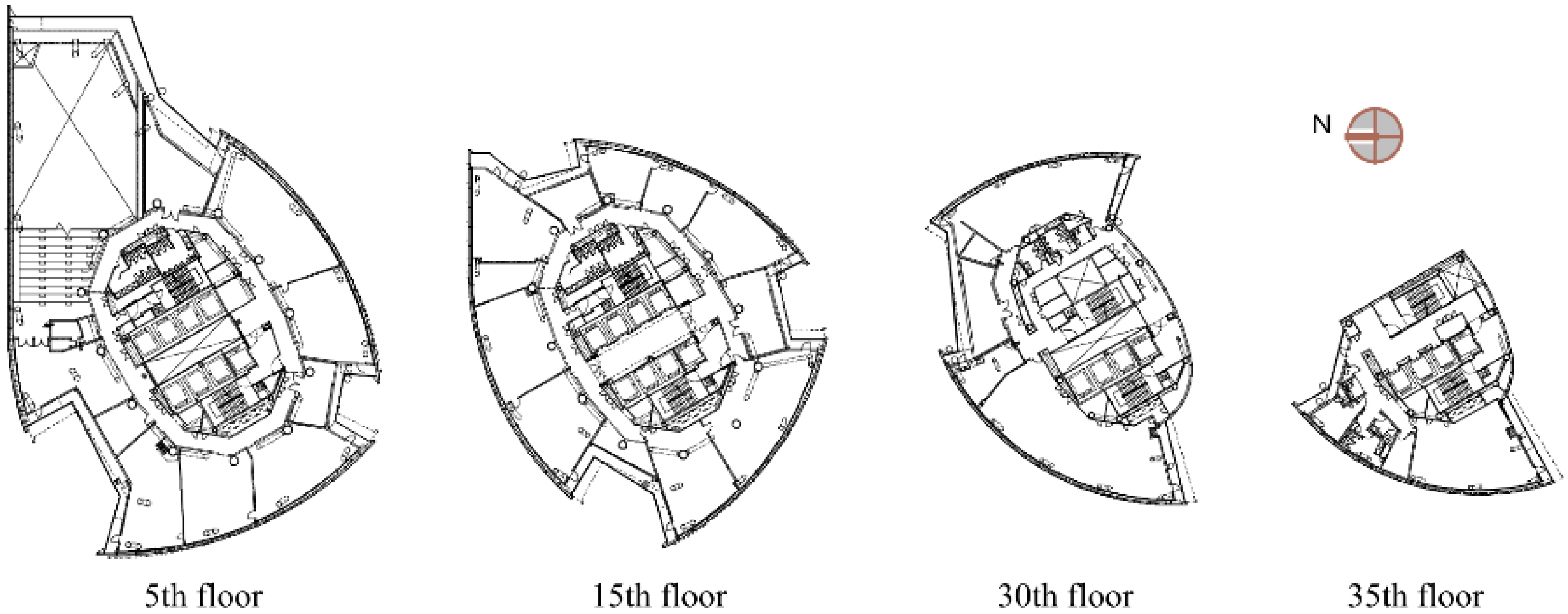


Figure 1. Floor plans of Mode Gakuen Spiral Tower

DIAGRID SYSTEMS

Figure 3-21 Guangzhou East Tower

Figure 3-20 Lotte - early design by SOM

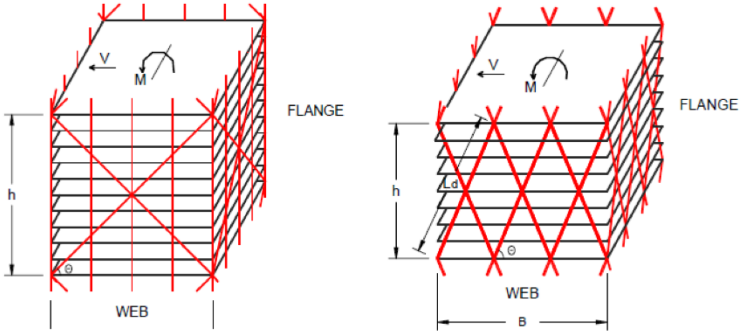


Figure 3-19 Braced module(left) , diagrid module (right)

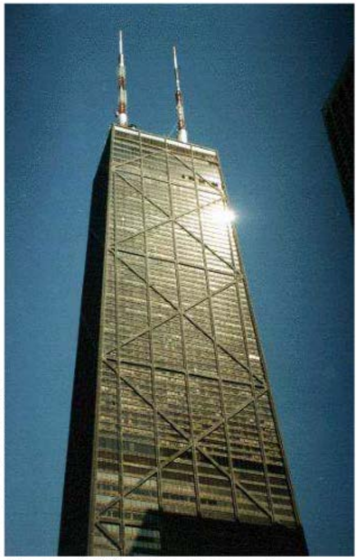


Figure 3-14 John Hancock

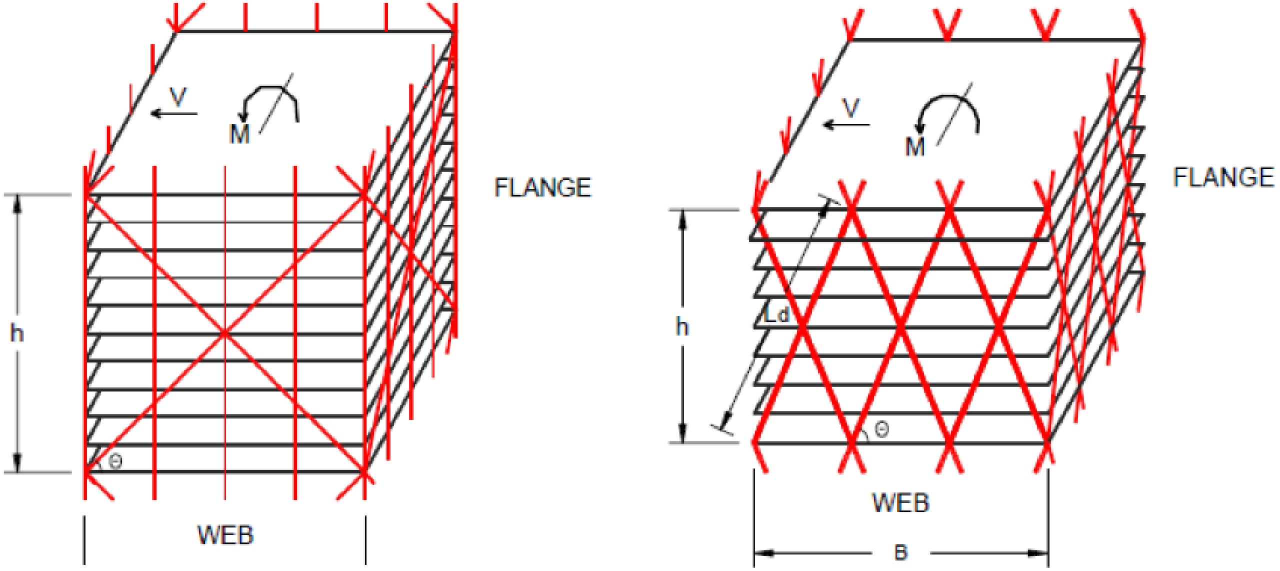
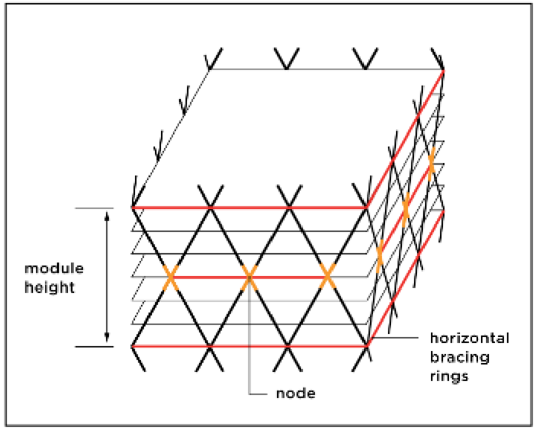
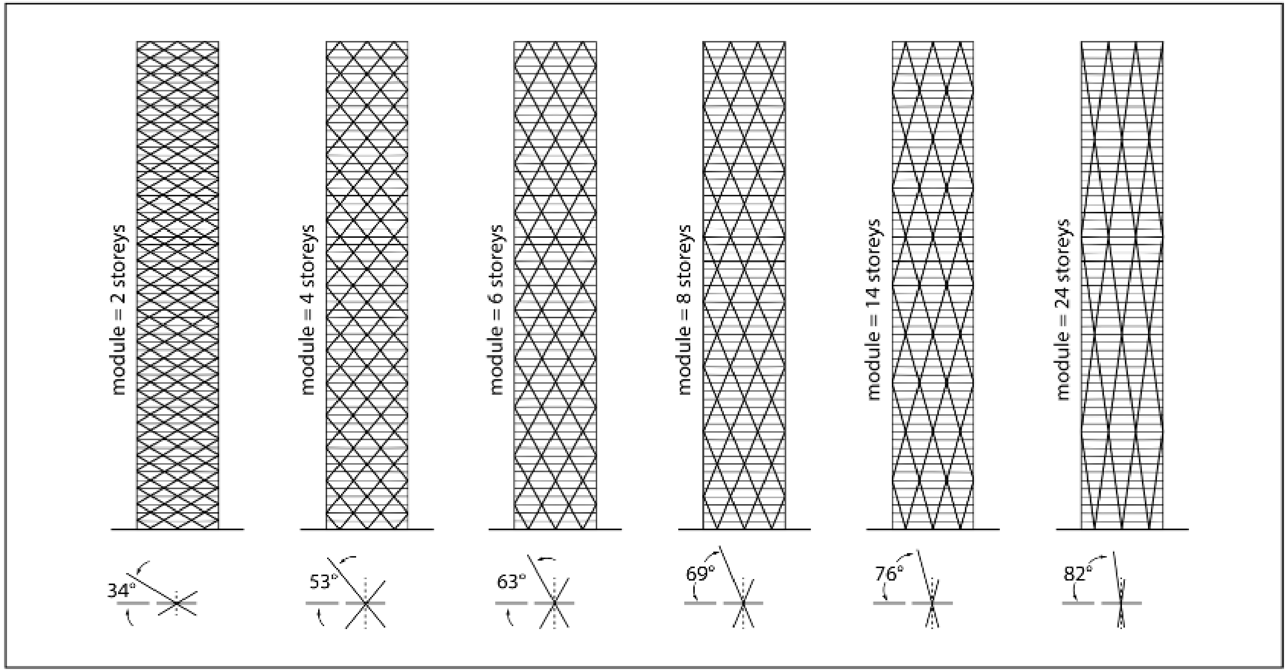


Figure 3-19 Braced module(left) , diagrid module (right)



Basic terminology for structural diagrids as applied to regular geometries, typically for tower structures of varying height. The module height for this example would be six storeys.

Many diagrid buildings, such as the Addition to the Royal Ontario Museum in Toronto, ON, Canada, designed by Daniel Libeskind, use non-regular modules. Here the faces of the "Crystal" are subdivided to suit the geometry. The spans and the roofing or wall-support structure is sized to suit the resulting spans.



This image, modeled after the diagrid research work of Kyoung Sun Moon, shows the visual impact of the change in the inclination of the diagonals on this sample 60-storey tower. All sample schemes maintain the same plan dimensions in order to minimize impact of the variation on the design and span considerations of the floor structure.

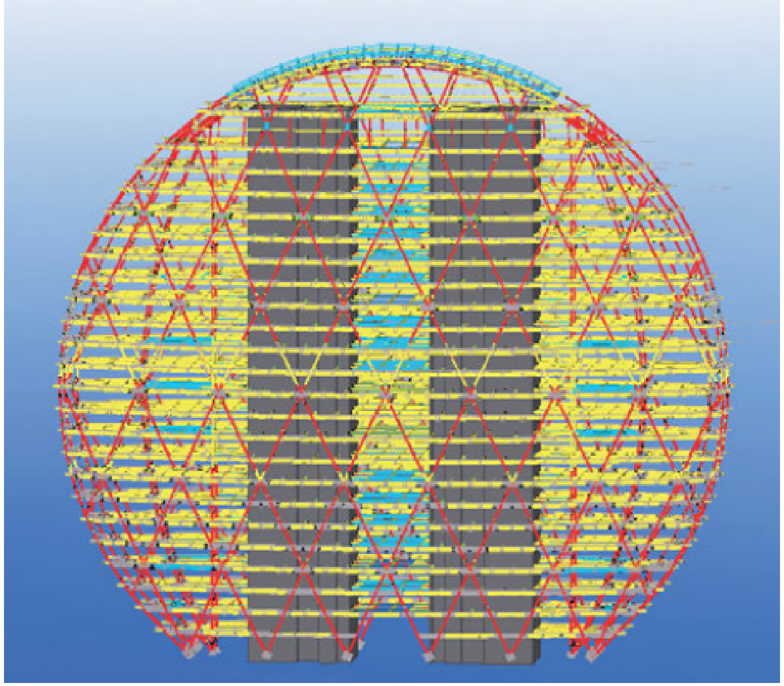
Small Modules: Two to Four Storeys

Smaller-sized modules of two to four storeys of height tend to be applied either to buildings with a small height or those with very unusual geometries or load eccentricities.

In the Swiss Re Tower (30 St. Mary Axe) in London, England, designed by Foster + Partners with Arup, the different functions of the members are reflected in the structural sections. The diagonal diagrid members are fabricated from round tubular steel as these need to be heavier in order to resist compression and tension. The diagonals span two storeys node-to-node so that some are braced by the floors at the mid-point. The diagonals that cross the ventilation shaft are unbraced yet have been kept to the same exterior dimensions as the braced members in order to permit the use of the same details for the cladding and create a more uniform set of connections to the node. The "hoops" that create the tension bracing system around the circumference of the tower are formed by connecting the more slender edge pieces to the nodes. These are connected in a different manner than the primary diagonals to the node.

Midrange Modules: Six to Eight Storeys

The middle range of module size is suitable for larger buildings and those whose geometry is more uniform. As the length of the diagrid member will range from three to four storeys, transportation and erection is usually not a great issue. This length is often assembled in the staging area, with the node to create an assembly in the shape of an inverted V for erection. This minimizes the connection work of the ironworkers high on the building, saving time and cost.



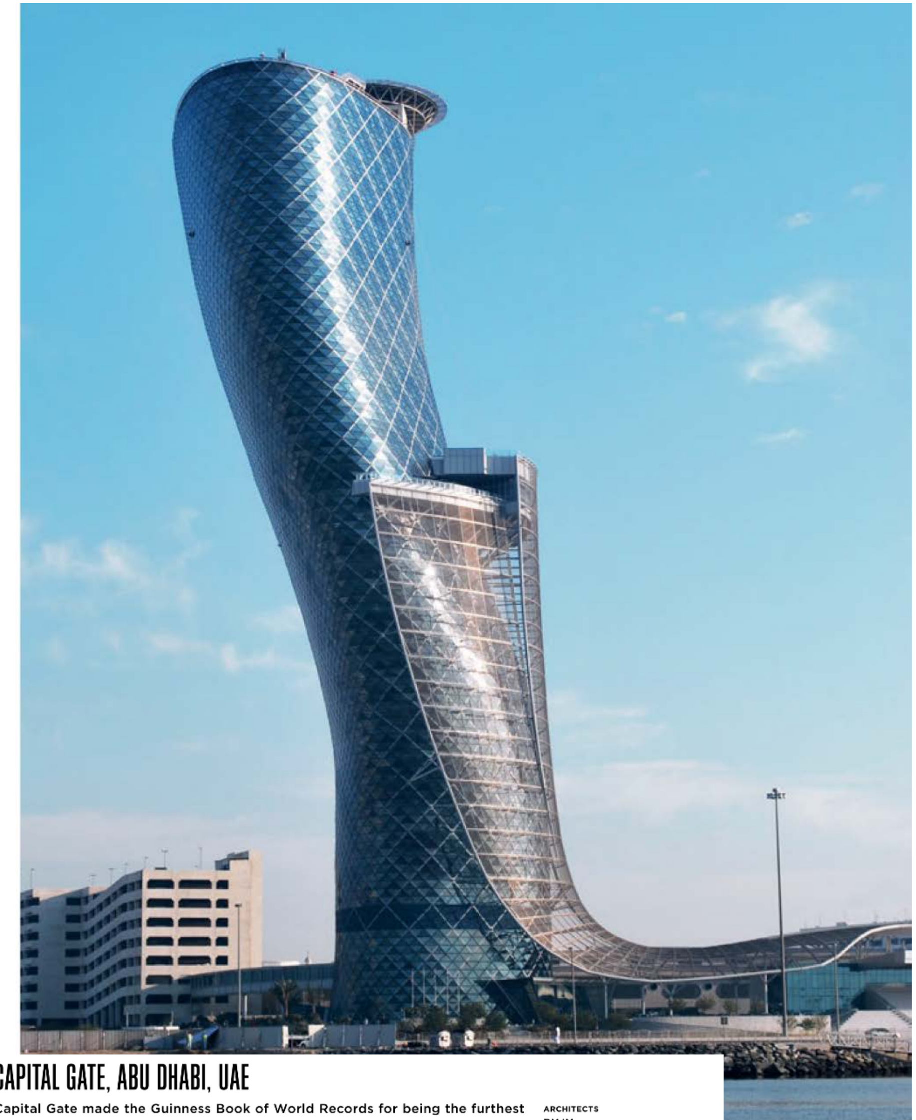
An eight-storey module has been used on the Aldar Headquarters. Although this is a comparatively large module for a 23-storey building, and the angle that the diagonals make with the floor is steep, the very thin floor plates minimize the load on the diagrid structure. The horizontal ring beams that occur at the level of the floor slabs have been down-played in the façade, leaving a diamond pattern.

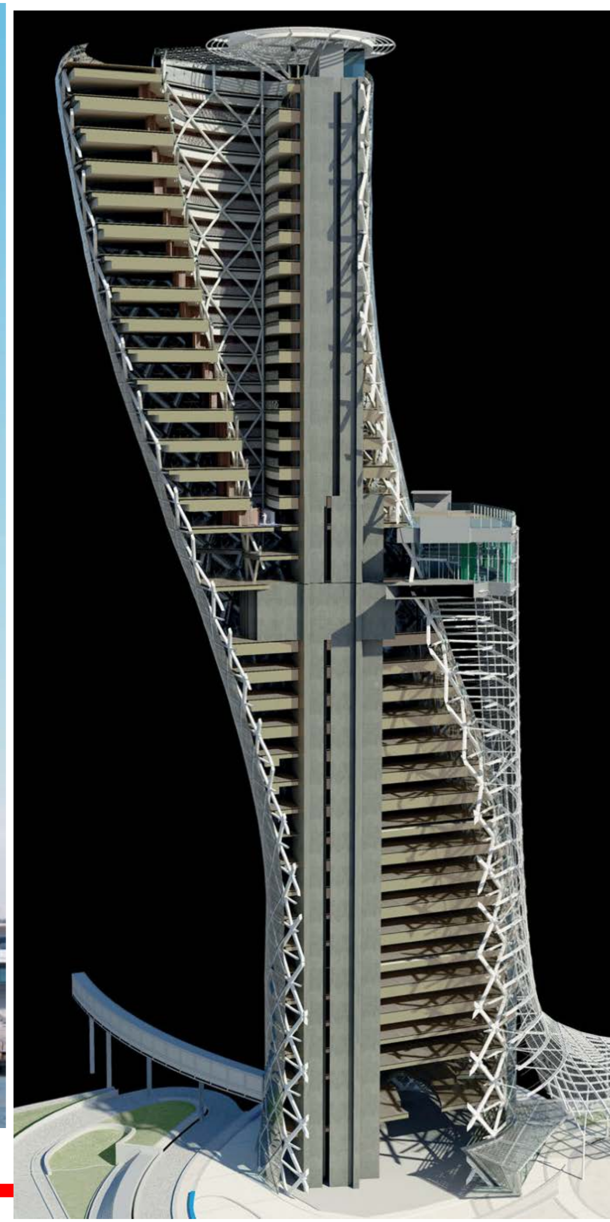
Large Modules: 10+ Storeys

Modules that measure 10 storeys or higher are only appropriate for use on very tall buildings out of considerations of scale. As the support points for the connection of the nodes to the floor edge beams (horizontal rings) cannot be excessively large, having to relate to the spanning capabilities of the floor beam and slab system, this naturally creates a diagrid module that is proportionately much taller than it is wide. The height of tall buildings is thereby accentuated, making them look even more slender than they may be. The overall length of the diagonal members will require special coordination regarding shipping-related issues. It is always desirable to minimize on-site welded connections; if these members are oversized due to their module length, one may incur extra costs on site for assembling.

The use of concrete-filled steel tubes that is becoming common in China and parts of the Middle East will always require significant site welding as the connections must be sealed. This system is becoming a common choice for large module diagrids constructed in these regions as can be seen in the Guangzhou IFC and the Doha Tower.

The selection of the module on The Leadenhall Building in London, England, designed by Rogers Stirk Harbour + Partners with engineering by Arup, had to work with the "cheesegrater" shape of the building that was created to maintain the required visual sightlines to St. Paul's Cathedral. The 14-storey module has been incorporated into the design, based on its seven-storey coordination with the overall building form. The diagonals are braced at each floor level. The ring beam between the nodes has been brought forward and accentuated as it plays a role in the design of the double façade system.





CAPITAL GATE, ABU DHABI, UAE

Capital Gate made the Guinness Book of World Records for being the furthest leaning man-made tower for its 18° lean. The design team for the 165m/541.4ft, 35-storey tower undertook an innovative and exploratory approach to tackling a number of issues associated with the iconic design that was desired by the client. In the words of Jeff Schofield, formerly of RMJM and one of the designers of the building: "It was the right time in history and we had the right technology to make this project happen." The use of a steel diagrid was critical to the success of the structural stability of the building as well as to its visual appearance. 18 diagrid triangles encircle each level of the building. With its shell-like behavior, the diagrid provides a perimeter structure that is adept at conforming to the varying vertical geometry. This has eliminated the need for columns that would otherwise have had to change positions and intrude in the interior spaces. Conventional framing would not have been suitable.

ARCHITECTS
RMJM

STRUCTURAL ENGINEERS
RMJM

PROJECT DEVELOPER
ADNEC (ABU DHABI NATIONAL EXHIBITIONS COMPANY)

PROJECT MANAGERS
MACE

MAIN CONTRACTOR
AL HABTOOR ENGINEERING ENTERPRISES

STEEL CONTRACTOR
EVERSENDAI

FAÇADE CONSULTANT
HYDER CONSULTING

FAÇADE CONTRACTOR
WAAGNER BIRO

COMPLETED
2011

alışma Grubu

Öğr. Gör. Dr. Haluk Sesigür

Custom-fabricated metal covers are used to hide the bolted connection between the horizontal tension hoops and the nodes. The covers will be filled and sanded and when finished will blend in with the appearance of the node. Not all of the diagrid members are fabricated purely "square". As can be seen here, some of the diagonals that must resist high loads have been reinforced with additional material. The use of plates to connect the incoming members assists greatly in solving the varying geometries of the connections as well as making an attractive detail.

This detail of one of the base nodes indicates the method of attaching the node to the diagrid member. Temporary plates are used to secure the members with bolts. These must be removed as well as the weld marks, if the structure is to be exposed as AESS. If the splice welds remain visible, they will be ground smooth. The diagrid structure is ultimately coated with an intumescent material for fire protection, which can also help to mask some imperfections.

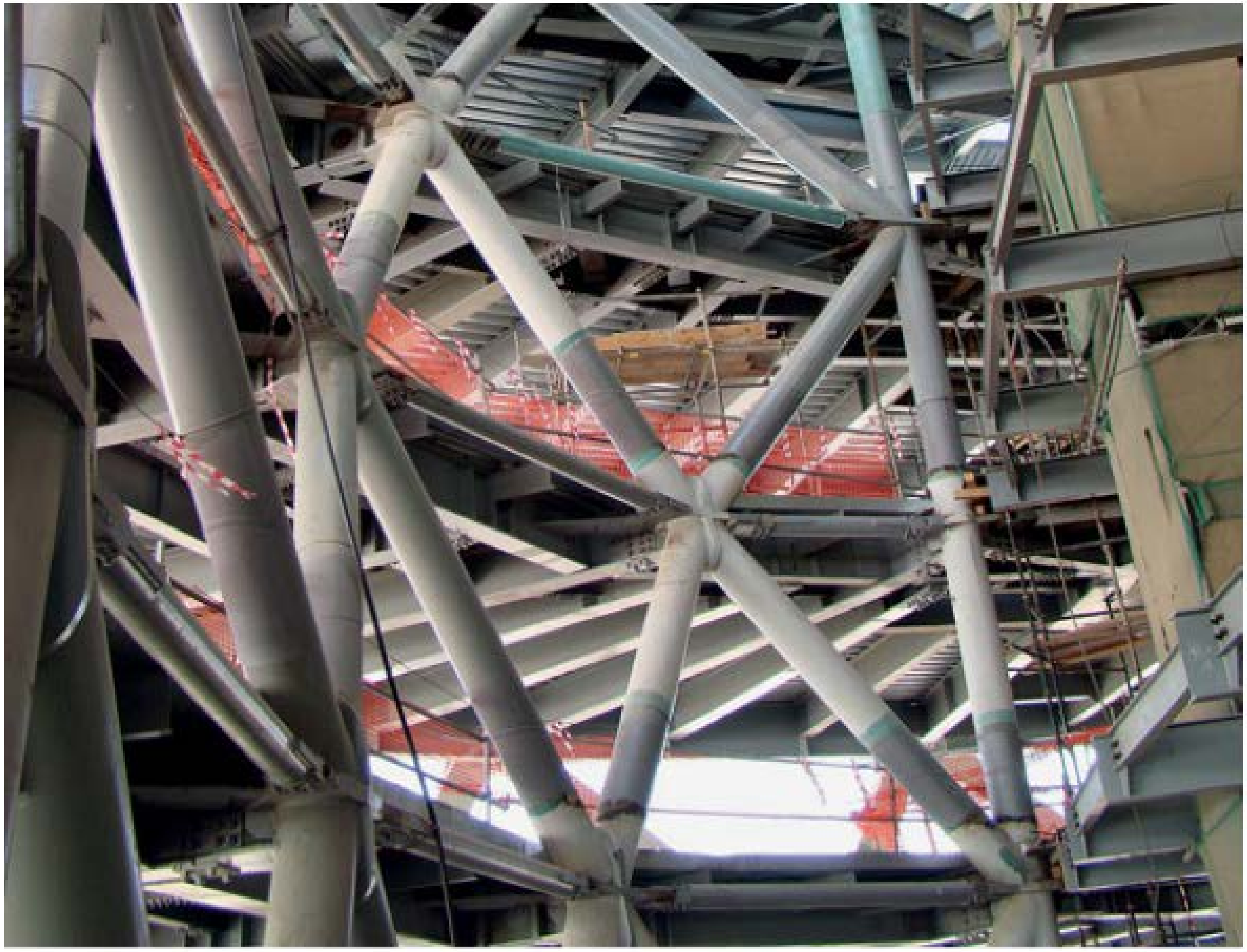
The diagrid elements were fabricated by Eversendai at plants in Sharjah and Dubai with steel mainly from Europe. The actual cut-to-length measures of the members were taken from the preliminary model developed at the initial stage of the project to procure the material. This helped in reducing material wastage. To maintain the required curved surface profile, every panel surface is slightly deviating with respect to the adjacent panel surfaces. External diagrid members are fabricated as hollow sections that measure 600mm x 600mm/2ft x 2ft. The steel thickness of the diagrids varies from 80mm/3.2in at the base of the tower to 40mm/1.6in at the top where the loads are lighter. Custom-welded sections are used at the base of the building where the loads are high and thickness requirements exceed standard material. Standard HSS tubes are used toward the top where the loads are lighter and the section requirements can be met more economically with standard material.

The diagrid that frames the double-height lobby at the ground floor clearly expresses the differentiation in the member shape of the horizontal hoop, or tension tie, that is used to triangulate the diagonal grid.

The most severely leaning diagrid is located on the 18th floor at the restaurant level. The diagonal members are visibly reinforced. The façade cladding system has already been installed and work is proceeding to clean up the welded connections.

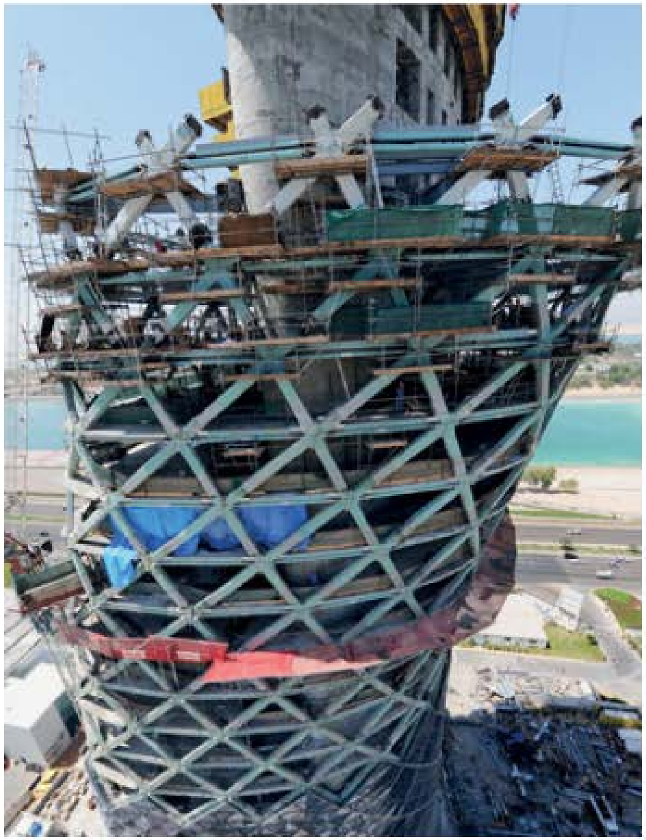
Wide flange or Universal members frame into the beams that tie the diagrid to the core. This system will be fire-protected using spray fireproofing as it will be concealed.

Custom-fabricated beams are used to tie the diagrid back to the concrete core. The ends of the beams employ a pin connection.



The hotel atrium uses a different structural language for its diagrid. Round HSS material is joined using cruciform steel plates to create the geometric transition. This detail adds interest as well as alleviates the difficulty of joining four tubes of varying angles at one connection. The grey zones visible on the tubes denote the splice zone for the X-shaped diagrid elements. Using a system of X-shaped elements comprised of nodes and diagonals significantly reduced the number of on-site welds.

On a highly complex project, construction sequencing is carefully staged to allow the construction to progress at a reasonable pace. Here, the cladding installation is several levels behind the finish welding on the diagrid, which in turn is several floors behind the pouring of the concrete core.



Each node for the building was unique as it had to accommodate ever-changing geometries. Here a node is still attached to the crane after a lift. Such extensive welded connections required the construction of scaffolding at each connection to provide a safe condition for working at height.