



University of Wales

Trinity Saint David

Iestyn Wynne Thomas

Student Number: 2404365

Subject: Construction Materials

Lecturer: Allan Nantel

Module Code: ACBA4016

Table of content

- Introduction
- Analysis of habitable concrete frame
- Analysis of habitable steel frame
- Methods of construction
- Analysis of framing material for each building
- Summary comparison -Table of advantages and disadvantages
- Conclusion
- References

Introduction:

In this analysis, I will be analyzing and reporting on two existing habitable buildings from around the world, constructed with one from a concrete frame and another

constructed with a steel frame. I will investigate by comparing two designs and also the material of frame and its properties and how they will affect the environment, the performance of the buildings, and its structural components and their material properties.

Analysis of habitable concrete frame:

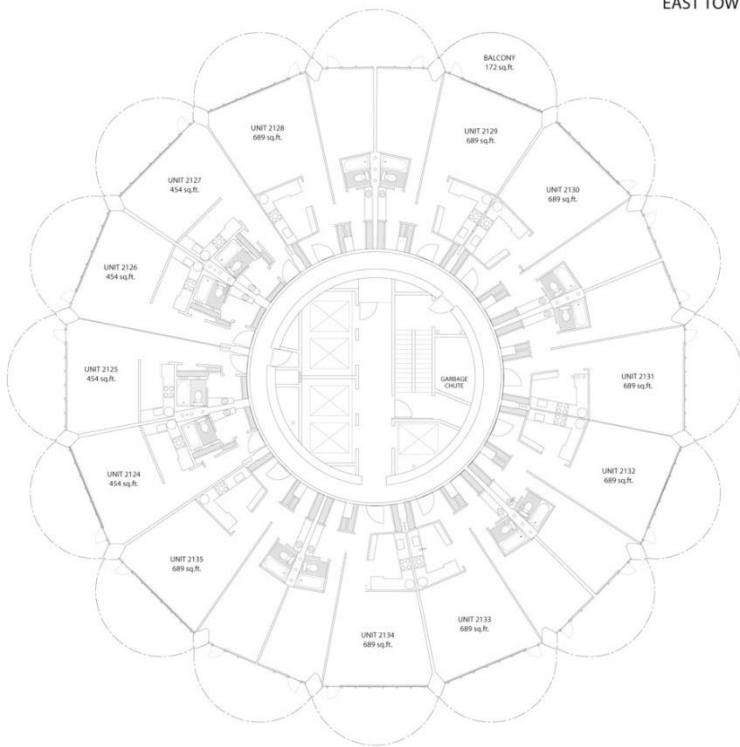
The concrete frame habitable building I have chosen is Marina city. Marina city is an innovative and unique construction, as most skyscrapers were developed and constructed using a skeletal iron frame, however in this construction this building was innovative towards the history of skyscrapers development as this building used a concrete frame. The development and techniques used in this building construction are now the same techniques used on this building is regarding as a competing material with a steel frame. Concrete used as a frame in this method of construction includes properties such as flexibility and being a solid structure allows for unique designs, it can be used with steel which is ideal for high rise buildings. However, its also strong enough to support skyscrapers on its own. (*Skyscraper Museum - Tue, Jun 13, 2023*)

Marina city was constructed after World War II, many people were leaving Chicago's downtown for the suburbs. Marina City aimed to bring people back to city living by offering a "city within a city" concept. This meant within this building features residential apartments, offices, retail spaces, a theatre, restaurants, and a marina in one location. Bertrand Goldberg was the architect for marina city he envisioned a new way of living and community and innovative way of living with resources and facilities in the same building as the residents. it has been said that the marina city and Golberg was "ahead of their time". (Britannica)

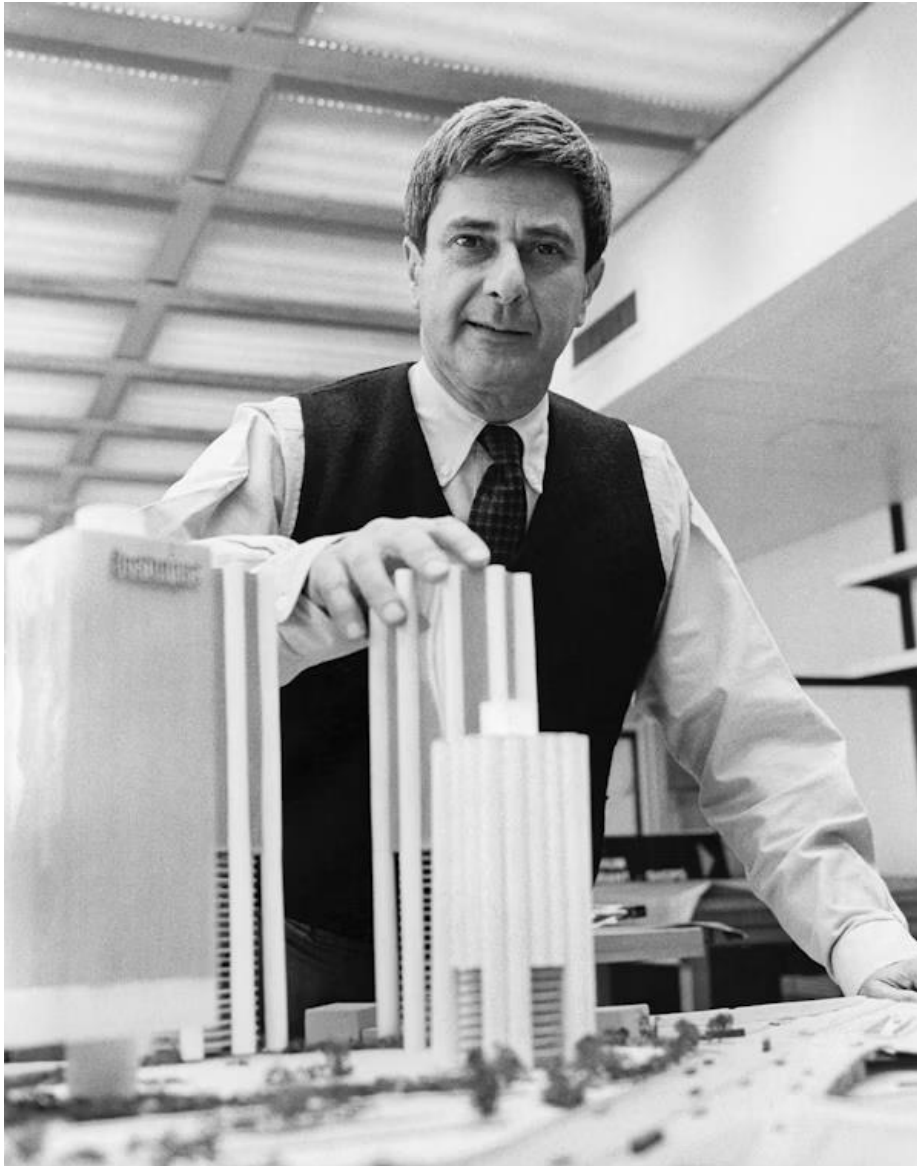
In 1962 Marina City was completed construction and was one of the first residential and commercial mixed-use buildings built in the United States. In addition, it was also the tallest reinforced concrete building in the world. The Marina City was probably Goldberg's most important project as it was remarkable and innovative for its sculptural use of precast reinforced concrete forms attached to a central mechanical core. (Art Intuitive Chicago). A mechanical core usage in a high-rise concrete frame building such as this, the core employs deep beams that are placed along the heavy reinforced concrete shaft that accumulated across the height of the building. The outrigger beam is a horizontal beam that connect from the core to the exterior columns or walls this helps to resist to wind loads that the building faces. This aids with forces on the either sides of the building facades. (*The construction wiki*)



(photo by Angie Mcmonigal)
EAST TOWER 21ST - 52ND FLOOR



(Archdaily)



(Goldberg Family Archive-1967)

Analysis of habitable steel frame :

The steel frame habitable construction I have chosen is the *John Hancock Center* but now known as *875 North Michigan Avenue* in Chicago, United states. This building stands at 1,128 feet tall, and construction was completed in 1969. The architects who designed this building were Skidmore, Owings & Merrill, an architect firm, but was designed by Bruce Graham. (Archeyes- March 15, 2021).

The reason I chose this building as an example is due to its significance as it's the most recognizable feature is the Steel-framed skyscraper with an exterior X-bracing system. The engineering is a "Braced tube" structural system, which was devised by structural engineer Fazlur Khan and architect Bruce Graham, this was innovative towards the designs of tall buildings. The braced tube structural system began with the initial concept design of the Tube Frame structural system which was used by Khan at the

Chestnut-Dewitt apartment building in Chicago and that construction was completed in 1966. (Aaron Mazeika-June 2, 2024)

Fazlur Khan found by placing closely spaced columns around the perimeter of the construction, Khan designed the structure to act like a thin-walled tube anchored to the ground. This increased structural strength without affecting the building's functionality, allowing interior columns to focus on the weight loads and be spaced further apart, creating a wider interior space. Khan found whilst working on the John Hancock construction a diagonalized truss on the John Hancock Centre's perimeter made the structure more efficient and required less material, just like how diagonal trusses are stronger than Vierendeel trusses in bridges and spans. (Aaron Mazeika-June 2, 2024). The X-shaped bracing on the building's exterior is a diagonalized truss system. It allows the structure to resist wind, and gravity loads without needing as many interior columns as possible. This design made the John Hancock Center one of the strongest and most material efficient skyscrapers of its time. (civil engineering practice journal)



(International Database and Gallery of Structures)



(Bruce Graham-1925)



(Fazlur Rahman Khan)

Methods of construction:

Concrete frame construction method (marina city)-

Marina city used a concrete frame construction rather than a steel frame one, which would be a widely used method during the time of construction. Many methods were used due to Goldbergs choice and design of using reinforced concrete as the primary material of the frame. Marina city construction methods use reinforced concrete instead of steel, enabling the towers to be unique, and allow a curved design. The central core accommodates elevators and utilities, while circular floor layouts maximized space. Cantilevered balconies extended living spaces outward without compromising structure. (Archeyes). Cantered balconies are a common choice for modern architecture. These balconies can create sleek and minimalist designs. These balconies extend outward from the building concealing the supports required, which creates a cleaner appearance overall. These balconies rely on structural components within the building, such as reinforced concrete beams or brackets, to provide structural support and balance. (*Types of Balcony Structures*) Marina city consists of two cylindrical residential towers. The two reinforced concrete towers are designed around structural and vertical circulation core that allows for an equal distribution of residential units on each floor. This serves as a structural stabilizer against the strong Chicago winds. (Andrew Kroll)

Steel frame construction methods (875 North Michigan Avenue)-

875 North Michigan Avenue also known as John Hancock centre. Construction of this building began in 1965 but was at a standstill in 1967 because the building kept sinking. For the reason of the building's location is near a lakeside location. To prevent sinking 57 concrete caissons had to be sunk into 10 ft wide holes drilled 197-feet below grade into bedrock. Because of this method of construction, the John Hancock Centre having the deepest foundation of any building at the time. (How Did They Build That)

Concrete caissons were used within the foundation of the John Hancock centre 57 due to the type of ground the building was placed on. Concrete cassions structure is a type of foundation used in deep water or soft soil. It's manufactured from a number of big, impermeable concrete cylinders that are placed in the ground within the foundation. The base creates a solid foundation for the building to be built on top. The benefits of having concrete caissons in the case of John Hancock building, Caisson foundations are less expensive than common practice methods and are a cost-effective solution for building on land that holds water or near water. This construction method also generates much lower noise levels and a reduction on vibration, which makes it a more suitable method in high populated areas such as Chicago with the john Hancock building. (*What is Caisson Foundation? -October 28, 2024*)

Analysis of framing material for each building-

Concrete frame analysis-

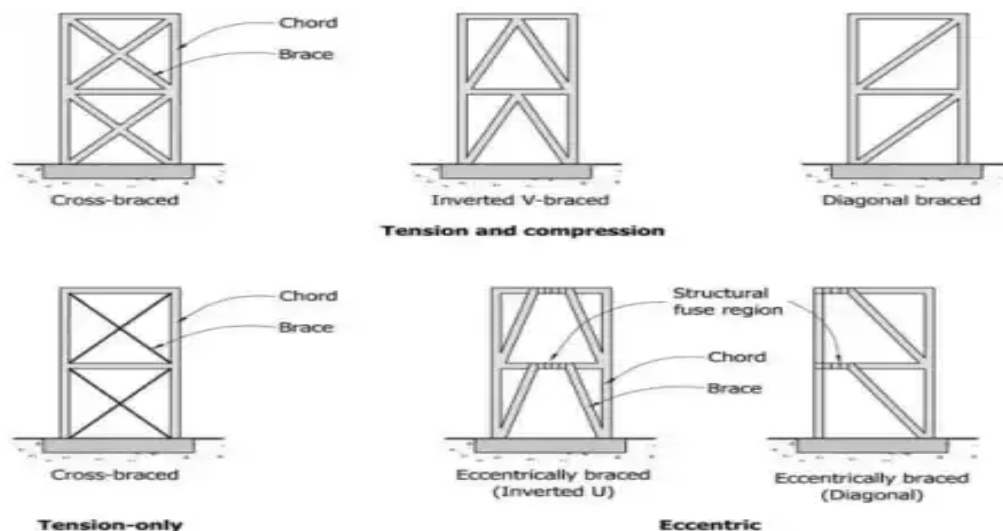
Concrete frame construction comprises of a network of columns and connecting beams that forms the structure of a building. These beams and column are commonly constructed on a concrete foundation and is used to support the building's floors, roof, and walls. There are various types of beams that have different roles for each in the frame.

The main beam's role is to transmit the floor and secondary beam loads to the columns or for the secondary beams to transmit floor loads to the main beams. Columns are the vertical components of the concrete frame and are the construction main load-bearing element. They transmit the beam loads down to the foundations, ensuring the load is equal across the foundation.

The materials that can be constructed with a concrete frame structure varies, as masonry options would include brick, blockwork, stone and other options for example drywall and timber. Additionally, any kind of cladding materials can be used for concrete frame structures. (*Designing Buildings- 11 Mar 2025*)

Steel frame analysis-

The benefits of using steel frame whilst construction the frame components can hastily manufactured off-site and then transported to the site. Although this increases the carbon footprint of the project, costs and relies upon transportation of the components for the construction. With reliance upon the transportation of the frame manufacturing offsite delays such as traffic or road closures can delay the build and increases costs such as transportation costs. However offsite manufacturing minimises onsite labour requirements and can reduce factors of site conditions such as weather that can cause delays. (*Structural Steel Fabrication*)



(the constructor)

The type of steel frame that was used on the John Hancock centre is a braced frames this is a cantilevered vertical truss that resist lateral loads are mainly carried by diagonal components, with the girders this creates a structure of the vertical truss. Bracing members eliminate bending in beams and columns. (the constructor)

The benefit and downfall of steel as a material it can soften at high temperatures, which if the right criteria are met could cause structural collapse, and this is a huge downfall and the method of reducing this risk is if the frame is ever in contact with high temperatures.

The steel frame would have a form of fire protection, which would reflect the heat away from the frame to reduce the risk of it softening. This protection of the frame might consist of encased the frame masonry, concrete or plasterboard or sprayed with an insulating coating. Another downfall of using steel as a material for a frame it's open to corrosion or oxidation in humid climates or marine environments this means that when constructing with a steel frame it needs to be encased with fireproofing methods and also may need to be painted or coated to form a carrier for water or humidity or oxygen to prevent corrosion. (Design and build- 03 Nov 2021)

Summary comparison -Table of advantages and disadvantages-

Concrete frame-

ADVANTAGES	DISADVANTAGES
- Concrete is a good material that handles compression well and better than other materials. Besides. - Concrete handles tension well. - Concrete is a great fire-resistant material and holds fire longer than steel	- It needs meticulous care when making concrete with the mixing, casting and curing, this will affect the final. - The cost of Molds to cast concrete is relatively high.

• Cost effective as its low cost and low service. • In large structure like sky rise and dams it's the most cost-efficient material. • Concrete is very malleable as it can be cast into any shape, and this is the best option of material when there is complex shape that are needed. • Less expert labour is needed to use concrete • Concrete can be used with steel such as reinforcement with putting rebar into concrete foundations to strengthen it further (theconstructor.org)	• It has low compressive strength when compared to steel this is shown in large sections of beams in multistorey buildings, cracks development in concrete due to shrinkage. • If reinforced concrete not done properly the steel starts to corrode the steel this will reduce its strength. • repairs are then very expensive and difficult. (theconstructor.org)
---	---

Steel frame-

ADVANTAGES	DISADVANTAGES
• Strength & Durability - steel is stronger and has a lower mass than wood or concrete products. The average weight-bearing steel component is 30%- 50% lighter than other equivalent such as wood • steel can have good weather resistance, depending on its carbon content. coating and extra powder treatments will prevent rust, and this will increase steels resistant to moisture (Structural Steel Fabrication)	• Thermal Conductivity-Steel is not known for its insulating properties, due to its high efficiency in conducting heat. • Supporting Structures-Steel frame constructions rarely work on their own. They commonly require masonry or sheathing, insulation. • Cost-steel frames and components are very expensive and in the case of a high-rise building would come at an extreme cost • Environmental factors-steel fabrication has a high carbon footprint which isn't a sustainable option (Structural Steel Fabrication)

Conclusion-

To conclude both concrete and steel frames offer advantages and disadvantages. Concrete allows durability, a certain fire resistance. However is a costly method as for the need for Molds. Although with steel everything can be fabricated offsite but in consideration of this material is harsher to environment and isn't as cost effective. To

finalise these two material frames all depends on environment for example the type of land and weather conditions. The main consideration for one or the other would all come down to budget and timescale.

References:

Skyscraper Museum - Tue, Jun 13, 2023- [Marina City: A Virtual Lecture by Geoffrey Goldberg - The Skyscraper Museum](#)

Britannica- [Marina City, a complex for revitalizing downtown Chicago | Britannica](#)

Art Intuitive Chicago, library exhibitions - [Case 4: Marina City, 1959-1967 | The Art Institute of Chicago](#)

Designing Buildings-the construction wiki-[Structural systems for high-rise reinforced concrete buildings - Designing Buildings](#)

Angie McMonigal- [Marina City | Chicago Architecture Center](#)

Archeyes- March 15, 2021- [John Hancock Center in Chicago by Skidmore, Owings & Merrill](#)

Aaron Mazeika-June 2, 2024- [Evolution of the Braced Tube](#)

civil engineering practice journal- [The Trussed Tube John Hancock Center](#)

International Database and Gallery of Structures- [John Hancock Center \(Chicago, 1969\) | Structurae](#)

Archeyes- [Marina City: Bertrand Goldberg's Vertical Vision for Urban Living | ArchEyes](#)

Types of Balcony Structures- [Types of Balcony Structures | Balcony Systems](#)

Andrew Kroll -[AD Classics: Marina City / Bertrand Goldberg | ArchDaily](#)

How Did They Build That-[How Did They Build That? John Hancock Center, Chicago](#)

What is Caisson Foundation? -October 28, 2024- [What is Caisson Foundation? Its Types, Process, and Advantages](#)

Arch daily- [AD Classics: Marina City / Bertrand Goldberg | ArchDaily](#)

Goldberg Family Archive-1967- [Bertrand Goldberg | The Art Institute of Chicago](#)

Bruce Graham-1925- [Bruce Graham | Architectuul](#)

Fazlur Rahman Khan- [Fazlur Rahman Khan: The Man Behind Every Modern Skyscraper](#)

Designing Buildings-The construction wiki- 11 Mar 2025- [Concrete frame - Designing Buildings](#)

Structural Steel Fabrication- [The Advantages & Disadvantages Of Steel Frame Construction](#)

Theconstructor- [Types of High-Rise Buildings Structural Systems – theconstructor.org](#)

Design and build- 03 Nov 2021- [Steel frame - Designing Buildings](#)

theconstructor.org- [Concrete Frame Construction – Types and Major Components – theconstructor.org](#)