

Designing Adaptable Architectural Spaces Using Appropriate Structure System to Increase Real Estate Investment Opportunities in Office Buildings: Practical Case Study in New Administrative Capital in Egypt

Faysal Mahmoud Abou El-Azm¹, Fatma Hassan Abd El-Aziz²

Submitted: 02/05/2024 Revised: 15/06/2024 Accepted: 22/06/2024

Abstract: Designing buildings that can be fully sold out within short period of time is master trick in real estate industry. Many buildings may face the problem of finding the suitable tenant. The purpose of real estate industry is to gain satisfied investor and satisfied end user. The investor wants the highest return and minimum risk while the end user wants suitable space with suitable price. The structure system can provide different spans that can suit many tenants so the investor can sell their building faster when using adaptable spans by specific structure system. Adaptability is one of the key words that can solve many problems in the real estate industry. We will study in this research the different types of structure systems that can suit office buildings and get the appropriate ones that provide more adaptable spaces that will increase the opportunities of real estate investment.

Keywords Real Estate Investment, Adaptability, office Buildings, Structure Systems

1. Real estate investment

Investments are assets acquired in order to obtain economic benefits resulting from the increased value of those assets; obtaining income from them in the form of interest, dividends or other profits. It includes commercial transactions and legal rights which are used by the entity. For real estate investment transactions may be buy to let, buy to sell, rent to rent, property crowdfunding and real estate investment trusts. Each transaction has specific legal right to the owner and the tenant.

To choose the suitable real estate for investment, real estate must be classified according to its quality into four categories. Those four categories are core, core-plus, value-added and

opportunistic. The key differentiator between these categories is the risk and return profile. . Core real estate is high-quality building in high quality locations. Core plus real estate is similar to core, but one feature isn't as good as it could be. Value-add properties already exist but need a renovation, a strategy to increase rents, or to enhance occupancy rates. Value-add real estate has the potential for better returns than core properties, but with higher risk. Opportunistic real estate has the highest risk and highest possible return. Opportunistic real estate doesn't have the highest return; it has the highest possibility for return. Investment in opportunistic real estate also provides the highest possibility for no return or even a negative return.

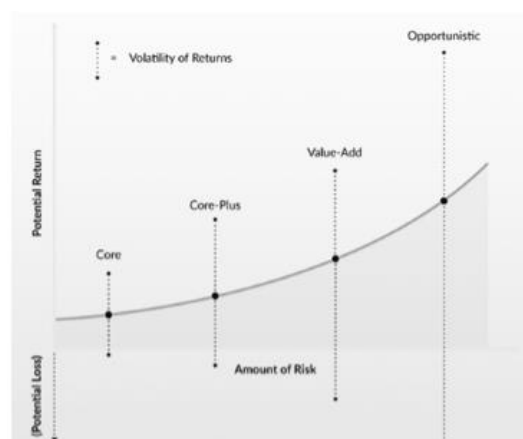


Fig (1): different types of real estate relative to risk and return. Source: <https://www.crowdstreet.com/resources/investment-fundamentals/real-estate-investment-strategy-risk-and-reward>

¹-Associate Professor, Faculty of Engineering, Architecture and Urban Planning Department, Suez Canal University, Al-Ismailia, Egypt

²-Demonstrator at Department of Architecture and urban planning, Faculty of Engineering, Suez Canal University, Ismailia, Egypt

Email: faysal.hussin@eng.suez.edu.eg

The main objective of making investment is either to gain return on that investment in the form of dividend/ interest or appreciation in the investment value. Return is the main motivating force and the reward in the investment.

Risk is a measure of the uncertainty surrounding the return that an investment will gain. Investments whose return is more uncertain are riskier. Risk causes the uncertainty in revenue and cost of real estate investment. Risk in real estate investment can be caused by sponsor, debt, over leverage, debt maturity, cap rate, tenant, leasing, physical asset, entitlement, construction, market or geography.

To assess real estate investment in terms of risk and return, there are many methods, for example, risk-adjusted return on capital,

There are risk-adjusted return calculations to help determine whether investors are extracting the highest possible gains with minimal risk involved. A risk-adjusted return is a measure that puts returns into context based on the amount of risk involved in an investment. Risk free return is the theoretical rate of return for zero risk.

2. Investing in office building

Office is an attractive real estate as it has strong fundamentals, diverse end users that span a variety of industries, and high returns. Office buildings can be classified according to location into central business district (CBD) and suburban. They can also be classified according to quality into class A, B or C based on criteria such as age, quality, amenities, rent and location.

It is valuable for office investors to understand the demand drivers that influence occupancies and rental rate growth. The single largest driver of demand in the office sector is jobs. Traditionally, there has been strong correlation between employment growth and positive absorption of office space. The office sector typically thrives when the economy is growing and companies are expanding, as firms seek more space to accommodate the addition of new workers. Also studying how demographics affect office demand can enable investors to draw asset-based conclusions.

As the main aim of the investor is to minimize risk and maximize return, let's minimize risk using architecture. Adaptable architecture can mitigate risks of design fluidity. Plus using suitable structure system can make spaces suitable for many tenants. So we can widen the range of tenants that can purchase from our asset.

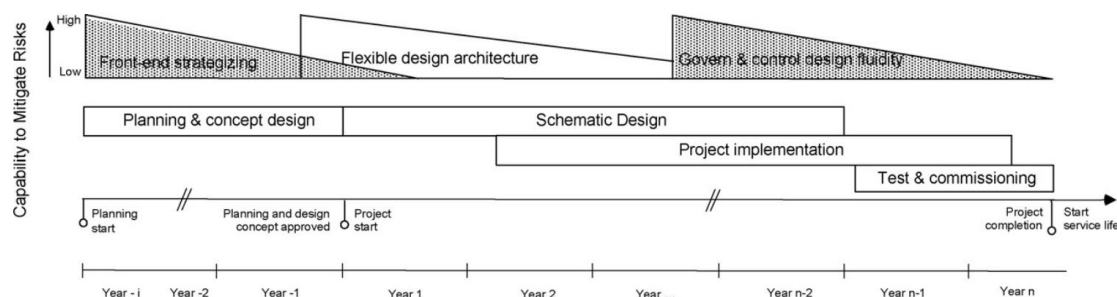


Fig (2): use of design flexibility to mitigate risks of design fluidity. Source:

<https://personalpages.manchester.ac.uk/staff/nuno.gil/Journal%20articles/RESPOL%20Risk%20Management%20and%20Design%20Flexibility.pdf>

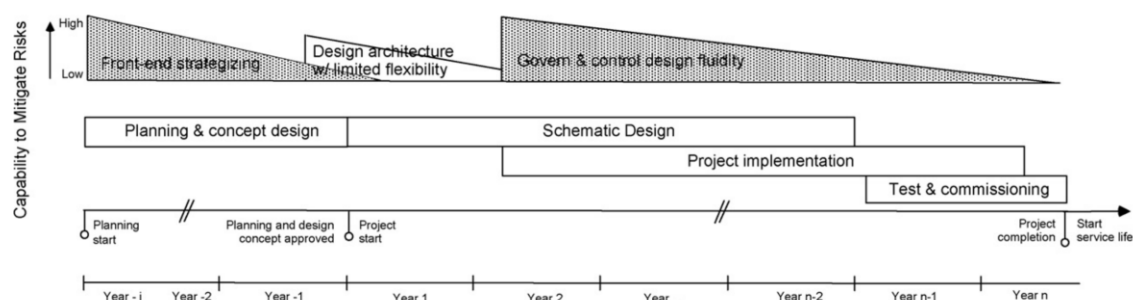


Fig (3): balance of limited flexibility in product design with risk management. Source:

<https://personalpages.manchester.ac.uk/staff/nuno.gil/Journal%20articles/RESPOL%20Risk%20Management%20and%20Design%20Flexibility.pdf>

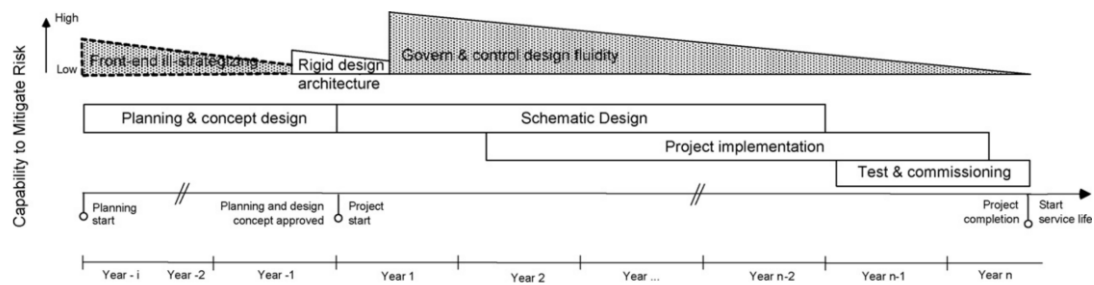


Fig (4): rigid design requires more risk management. Source:

<https://personalpages.manchester.ac.uk/staff/nuno.gil/Journal%20articles/RESPOL%20Risk%20Management%20and%20Design%20Flexibility.pdf>

3. Adaptability in office building

Adaptability is concerned with the capacity to adjust or be adjusted to suit new situations. This can pertain to what changes (e.g. spatial layout, building volume or building

use), the speed or magnitude of the change and whether or not physical alterations are needed. Adaptability can be applied to building layers. The building is a set of layers interacting together. These layers are divided into six layers; stuff, space plan, services, skin, structure and site.

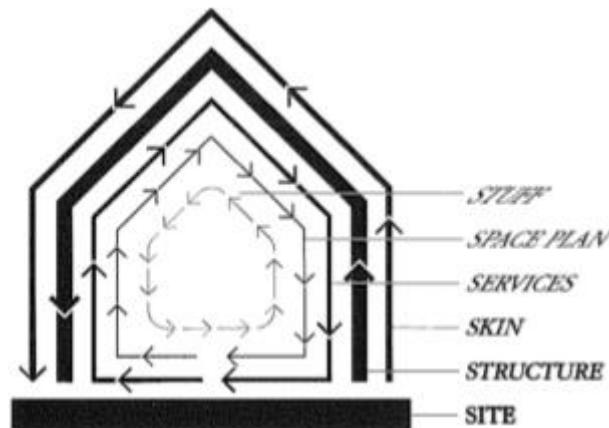


Fig (5): building layers. Source: <https://medium.com/@bhakti1711/how-buildings-learn-wip-619bd89e845e>

Six types of adaptability can control this concept. First type is the change of task/ user. Adjustable solutions provide a more efficient workplace and increased user comfort. It reduces the demand for new equipment and increases the users' control over their environment. Second type is the change of space. Versatility is to change the spatial layout of a room. Spaces can be easily and cheaply rearranged to accommodate different activities, new work patterns, or a change in the number of users. A number of the building's physical parameters can shape the versatility of a space including: the number and location of columns, the plan shape and depth, the overall area, the location of services, and the movability of walls, furniture, and fixtures. Third type is the change of performance. Refitable design strategies involve changing the performance of a building by altering its space, services or skin. Fourth type is the change of function prompted by alterations in the market, social demands, ownership or occupancy for instance. Conversion is easier between similar structural typologies (short span or wide span). Providing a higher than

necessary floor capacity is a simple tactic that can allow for increased loading later. Other critical parameters include storey height, structural grid, plan depth and total usable area. Fifth type is the change of size. Different elements will play a role depending on whether you're adding vertically (e.g. additional load capacity for the slabs and foundation, type of roof structure and building height regulations) or horizontally (plot density, circulation/access points and service capacity). Adding on to a building can benefit from the use of simple shapes or modular components. Sixth type is the change of location. It is the least to occur of all the types. Temporary enclosure of exterior space can provide additional space for an event or fluctuations in occupational capacity. Movable is tied heavily to the structural solution chosen, plot density and scale of components.

The limited discussion of this paper studies the interaction between structure systems and space plan to get more adaptable spaces using appropriate structure system.

3.1 space plan

Office building generally consists of vertical penetration, structure elements, technical services, hygiene areas, circulation areas, amenities, office space and other areas. The most important sector in the office building is the office space, and it includes work space, meeting space and support space.

3.1.1 Work space

Work spaces in an office are typically used for conventional office activities such as reading, writing and computer work. Work space can be classified into six types according to size and dimensions of each office.

Enclosed Type A (22.5m ²)	Enclosed Type B (13.9 m ²)	Enclosed Type C (9.3 m ²)	Open Type D (9.3 m ²)	Open Type E (6.5 m ²)	Open Type F (4.5 m ²)
<ul style="list-style-type: none"> Up to five persons, requiring confidentiality, security, visual and acoustical privacy. 	<ul style="list-style-type: none"> Up to three persons, requiring confidentiality, security, visual and acoustical privacy. Typical assignment for Director, senior position in charge of a regional or district office or equivalent. 	<ul style="list-style-type: none"> Up to two persons, requiring confidentiality, security, visual and acoustical privacy. Typical assignment for position involved with for example human resources management 	<ul style="list-style-type: none"> Concentrated multi-source paperwork. Typical assignment for managerial, professional or technical staff. 	<ul style="list-style-type: none"> Multi-task paper intensive work: telephone work, keyboarding, filing, sorting documents, handling mail, editing, operating equipment, scheduling, receiving visitors. Typical assignment for secretary and administrative support staff. 	<ul style="list-style-type: none"> Specific, task-oriented work, focusing on data input into electronic media. Typical assignment for clerical and data-entry staff.

Table (1): classification of offices according to dimensions, source: Northwest Territories Canada (Feb 2003) office space standards and guidelines

Meeting spaces in an office are typically used interactive. There are three types of meeting space, each supporting different processes, be it quick conversations or intensive brainstorming activities.

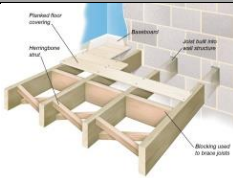


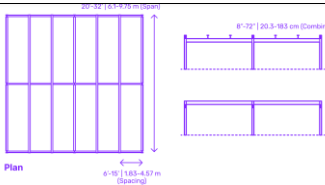

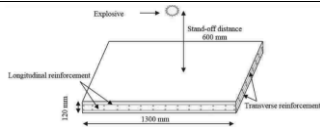
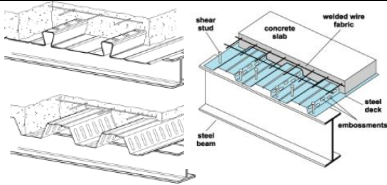
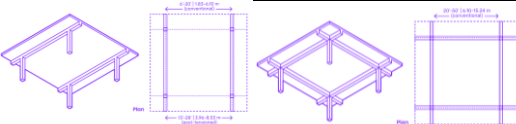
Meeting room 4 to 5 people	Meeting room 6 to 7 people	Meeting room 8 to 12 people

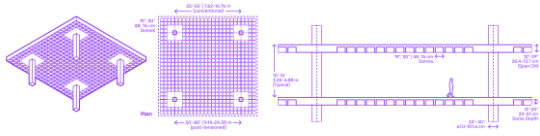
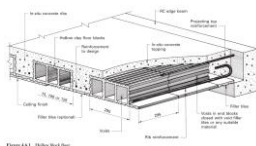
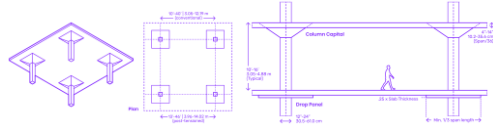
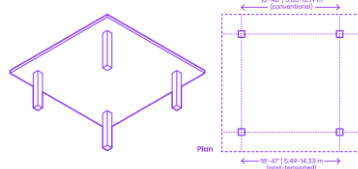

Table (2): classification of meeting rooms according to dimensions, source: Northwest Territories Canada (Feb 2003) office space standards and guidelines


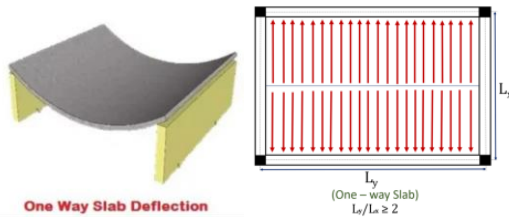
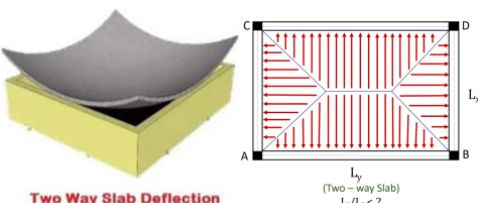


floor slab and foundation. When talking about building spans and adaptability we shall study floor slab that accommodate span

Classifications of slabs

Floor systems can be classified in different ways for instance according to material, presence of beams, location of casting, load path, reinforcement..etc.

			Description	Span	Pros	Cons
Material	Wood		 	Below 4kN/m2 applied load and less than 9m column to column spacing	<ul style="list-style-type: none"> Excellent material at withstanding tensile and compressive stresses Lighter than a concrete slab, allowing for reduced, less expensive section sizes in the construction framework. 	<ul style="list-style-type: none"> Difficulties of fire resistance and Robustness. Because it is a natural material
	Steel		 	Normally up to 15 m	<ul style="list-style-type: none"> excellent at withstanding tensile stresses Lighter Accommodate wide spans 	<ul style="list-style-type: none"> May need to be overdesigned to withstand compressive stresses
	Reinforced concrete		 	Up to 14 m Post tensioned	<ul style="list-style-type: none"> combines the compressive strength of concrete and the tensile strength of steel to allow for efficient and cost-effective design. 	<ul style="list-style-type: none"> Heavy members so it can't accommodate wider spans
	Composite slab			15 ft depending on cross section and the concrete thickness and weight	<ul style="list-style-type: none"> Greater stiffness with less weight Quick installation Cost reduction (labor and materials) lighter structure 	<ul style="list-style-type: none"> Fireproofing of steel members is required Short spans
Presence of beam	Slab on beam	Solid slab		Conventional One way = 1.83 - 6.10 m Post tension one way = 3.96 – 8.53 m Conventional two way = 6.10–15.24 m	<ul style="list-style-type: none"> Cheaper Thinner slab depth 	<ul style="list-style-type: none"> Beams hinder technical installation in ceiling Shorter spans

Location of casting	Beamless slab	Waffle slab	<p>A set of crossing joists, set at small spacings relative to the span, supporting thin slab.</p> 	<p>Conventional two way = 7.62- 16.76 m Post tension two way = 9.14 - 24.38 m</p>	<ul style="list-style-type: none"> Decrease the weight of the slab using large effective depth without the accompanying dead load. 	<ul style="list-style-type: none"> Initial construction cost Requires skilled labor Complex formwork design and construction
		Hollow block	<p>holes are made by placing terra-cotta tiles, precast concrete boxes, or other fillers, placing the reinforcing bars between the filler units, and covering the fillers with cast-in-place concrete.</p> 	<p>Generally used in situations demanding spans larger than about 10 m.</p>	<ul style="list-style-type: none"> Reducing slab weight Ease of construction Economic for spans greater than 5 meters with moderate live load Improved insulation for sound and heat 	<ul style="list-style-type: none"> Not economic for small spans Not suitable for heavy loads or dynamic loads Difficult to repair or strengthen
		Flat slab	<p>Presence of capitals at the tops of the columns and usually also by drop panels or thickened areas of the slab surrounding each column.</p> 	<p>Conventional two way = 3.05 – 12.19 m 10' – 40' Post tension two way = 3.96 – 14.02 m 13' – 46'</p>	<ul style="list-style-type: none"> The column capital and drop panel provide the shear strength necessary for larger loads and spans The flat slab is often the choice for heavily loaded industrial structures and for large spans. 	-
		Flat plates	<p>slab of uniform thickness supported on columns. The choice between the use of flat slabs and flat plates depends on the magnitude of loading and the spans.</p> 	<p>Conventional two way = 3.05 – 12.19 m 10' – 40' Post tension two way = 5.49 – 14.33 m 18' – 47'</p>	<ul style="list-style-type: none"> Free spans without beams or drop panels 	<ul style="list-style-type: none"> The strength of the flat plate structure is often limited by the strength in punching shear at the sections around the columns. Used in light loads, such as are found in residential and some office construction, and relatively short spans.
	Insitu	Casting concrete in position.		Varies	<ul style="list-style-type: none"> High level of strength Limitless flexibility of shape and size Homogenous connections 	<ul style="list-style-type: none"> More labor requirements Consuming time
						

	Precast floor	Precast concrete is manufactured in a factory then delivered to the construction site, where it's assembled.			Varies	<ul style="list-style-type: none">▪ Faster than traditional methods▪ Cost savings▪ Good choice for large structures, such as bridges and water quality systems▪ Strong and durable	<ul style="list-style-type: none">▪ Require specialized equipment for transportation and installation.▪ The manufacturing process for precast concrete can have a significant environmental impact.
Load path	One way				Varies	<ul style="list-style-type: none">▪ Less expensive because they require less concrete and steel reinforcement.▪ simpler and faster to build Because they only require support on two opposed sides▪ Suitable for small spans▪ Reduces the structure's overall weight.	<ul style="list-style-type: none">▪ Limited span capacity▪ Limited design flexibility▪ Susceptible to cracking▪ Poor shear stress resistance
	Two way						<ul style="list-style-type: none">▪ more effective span▪ Adaptable and can be created in various forms and sizes.▪ Made to endure severe loads and strains.
Reinforcement	One layer grid				Varies	Varies	Varies
	Double layer				Varies	Varies	Varies



stressed	Post tension	<p>Corrugated ducts are placed inside the concrete along the centroid axis before casting. After the concrete has hardened and had enough strength, the tendon was placed inside the duct, stressed, and anchored against concrete. Space remains in the duct is filled with mortar.</p> 	Varies according to the presence of beams or ribs	<ul style="list-style-type: none"> • Provide thinner slabs and longer spans • Lower initial cost • Strengthen the structure • Largest possible column free spaces • Lowest possible weight of floor • Quickest possible floor cycle • Less concrete • Reduce floor to floor height • Reduces shrinkage cracking 	<ul style="list-style-type: none"> • Poor workmanship could lead to failure of construction • Quality of construction is very important; failure of any construction could lead serious issues. • Laying of tendons shall be done as specified in the drawings and there is no room for errors
	Pretension	<p>The tendons are tensioned against the abutments before casting the concrete. Once the concrete is hardened, the tension force is released. The tendon tries to shrink back to the initial length but the concrete resists it through the bond between them, thus, compression force is induced in concrete.</p> 	Varies	<ul style="list-style-type: none"> • Section remains uncracked under service loads • Increase in shear capacity • Improved performance under dynamic and fatigue loading • High span-to-depth ratios • Suitable for precast construction • Rapid construction • Reduction of formwork 	<ul style="list-style-type: none"> • Prestressing needs skilled technology. It is not as common as reinforced concrete • High strength materials is costly • Additional cost in auxiliary equipment • Need quality control and inspection

Table (3): classification of structure systems, source: researcher

4. Practical model:

Cloud 7 is a mixed use building located in downtown New Administrative Capital of Egypt. The building includes three floor basements of car parking, four floors of retails and twelve floors of offices.

- The project was sold out on 26th April 2022 according to <https://www.facebook.com/icapitaldevelopmentsegyp/photos/pb.100039953384157.-2207520000>

<https://www.facebook.com/photo/?fbid=305304197738125&set=pb.100039953384157.-2207520000>

- Pre-launch announcement was on 17th May 2021 according to <https://www.facebook.com/photo/?fbid=305304197738125&set=pb.100039953384157.-2207520000>

For more information visit the website <https://icapitaldevelopments.com/#intro>



Fig (6): exterior shot for cloud 7



Fig (7): shot during construction process on 27th Feb 2022

Source:

<https://www.facebook.com/iecegy/posts/pfbid0FpRzJ12mAbTjrd5oqUgeb2asNmr8VqL8ieW1TEUJGaZcorbdbHRQUK3NZv39arBl>

To get more adaptable spaces wider spans should be selected but

- Solid slab is excluded because of the presence of beams that will hinder technical installations

- Hollow block slabs and waffle slabs are excluded because their depth is large and according to the district and its height regulation this may decrease the number of floors and therefore decrease the number of spaces sold and then decrease the return on investment
- Flat plates are excluded because they can't accommodate wide spans without column caps
- Pre-stressed slabs are very expensive and the investor can't accommodate these expenses



Fig (8): Seventh floor



Fig (9): Second basement

Source: CEO of IEC International Engineering Consultancy Co Dr\ Faysal Mahmoud Abou El-Azm

To select the suitable structure system for this design, IEC team shall differentiate between flat slab and post tension slab. From their study they got that time of construction can be reduced to 60% by using post tension and reduce cost by decreasing number of columns and foundations due to decreasing slab thickness. For more information visit the website <https://iecegy.com/>

5. Conclusion

From studying the adaptability we got that to make more adaptable floors, we should make wider spans that can accommodate small and large units using appropriate structure system that provides wider spans. To differentiate between

conventional methods, post tensioned method and pre-tensioned methods to get the wider spans we should consider cost, labor, time, thickness of slab that can affect the total height. So as a developer you should give up one thing in exchange for another. In the practical case of cloud 7 post tension is the preferable structure system according to the studies of IEC team as it can save time and cost.

6. References

- [1] **M. Doss (2023, Jun 23).** *Steel floor two way*. Dimensions.com. Retrieved from <https://www.dimensions.com/element/steel-floor-two-way>

- [2] **T. Gunthel (2023, Mar 22).** *Flat roof hall made of steel.* Dlubal. Retrieved from <https://www.dlubal.com/en/downloads-and-information/examples-and-tutorials/models-to-download/004061>
- [3] **Nyanzi (2022, Jun 06).** *Know the slab type for your project.* New Vision. Retrieved from https://www.newvision.co.ug/category/entertainment/know-the-slab-type-for-your-project-NV_135545
- [4] **K. Taylor and N. Walker (n.d).** *Permissible clear spans for domestic floor joists.* Timber beam calculator. Retrieved from <https://www.timberbeamcalculator.co.uk/en-gb/span-table/floor-joists?load=1.5&class=C24>
- [5] **JK Cement Ltd (2023, Aug 17).** *What is RCC slab?* Retrieved from <https://www.jkcement.com/blog/construction-planning/what-is-rcc-slab/>
- [6] **The free encyclopedia for UK steel construction information steelconstruction.info (n.d).** *Composite construction.* Retrieved from https://www.steelconstruction.info/Composite_construction#:~:text=Composite%20slabs%20comprise%20reinforced%20concrete,reinforcement%20at%20the%20final%20stage.
- [7] **LGW group (2022 Mar 10).** *Guide to Metal Decking.* Retrieved from <https://www.lgwgroup.co.uk/news/guide-to-metal-decking>
- [8] **M. Doss (2023 July 02).** *Concrete floor one way slab.* Dimensions.com. Retrieved from <https://www.dimensions.com/element/concrete-floor-one-way-slab#:~:text=One%2DWay%20Slab%20Concrete%20Floors,depth%20formula%20of%20Span%2F30>
- [9] **Archi Monarch (n.d).** *Difference between one way and two way slab.* Retrieved from <https://archi-monarch.com/difference-between-one-way-and-two-way-slab/>
- [10] **Civilmart (n.d).** *When to use Precast Concrete vs In-Situ Concrete.* Retrieved from <https://civilmart.com.au/blog/the-benefits-of-precast-concrete-vs-in-situ-concrete/#:~:text=Precast%20concrete%20is%20much%20more,way%20it's%20constructed%20and%20poured.>
- [11] **Incoperfil (n.d).** *Advantages of composite slab.* Retrieved from <https://www.incoperfil.com/advantages-of-composite-slabs-cms-1-51-189/>
- [12] **Stewart Perry (n.d).** *Pros and Cons of Three Concrete Structure Methods.* Retrieved from <https://stewartperry.com/tips-from-the-field/pros-and-cons-of-three-concrete-structure-methods/>
- [13] **Testbook (2024 Jan 24).** *Waffle slab- definition, features, advantages and disadvantages.* Retrieved from <https://testbook.com/civil-engineering/waffle-slab>
- [14] **McNeil Engineering (2023 Mar 14).** *The advantages and disadvantages of using precast concrete in structural engineering.* Retrieved from <https://www.mcneilengineering.com/the-advantages-and-disadvantages-of-using-precast-concrete-in-structural-engineering/>
- [15] **E. Decken (n.d).** *Opportunities for precast prestressed concrete floor slabs in building projects.* BFT international. Retrieved from https://www.bft-international.com/en/artikel/bft_Opportunities_for_precast_prestressed_concrete_floor_slabs_in_building-3081839.html
- [16] **Javatpoint (n.d).** *Difference between one way slab and two way slab.* Retrieved from <https://www.javatpoint.com/difference-between-one-way-slab-and-two-way-slab#:~:text=Because%20they%20only%20require%20support,applied%20largely%20in%20one%20direction.>
- [17] **Housing news deck (2023 May 29).** *Slab designs: types and uses.* Retrieved from <https://housing.com/news/slab-designs-types-and-uses/>
- [18] **Moment solution (n.d).** *The difference between pre-tensioning and post-tensioning.* Retrieved from <https://www.moment-solutions.com/the-difference-between-pre-tensioning-and-post-tensioning/>
- [19] **Neumann Monson Architects (2024 Jan 18).** *Pros and Cons of Post-Tensioned Concrete: An Architect's Perspective.* <https://neumannmonson.com/blog/pros-cons-post-tensioned-concrete#:~:text=This%20method%20introduces%20tension%20to,flexibility%20and%20complicate%20future%20modifications.>
- [20] **Schmidt III, R., & Austin, S. (2016).** *Adaptable architecture: Theory and practice.* Google Books. Retrieved from https://books.google.com/books/about/Adaptable_Architecture.html?id=YLWYuAAACAAJ
- [21] **Northwest Territories Canada (Feb 2003).** *Office space standards and guidelines*
- [22] **Sirota, D. (2016).** *Essentials of Real Estate Investment* (11th ed.).