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Exploring the design and construction techniques of post-tensioned slabs

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ABSTRACT

This research aims to: 1. Study the post-tension concrete floor type. 2. Study the case study of the building construction process using post-tension concrete floors by studying the plans and construction steps of post-tension concrete floors from studying the manuals and documents for the construction of prestressed concrete floors, applying the knowledge gained from working and learning on-site to understand the characteristics, types, and plans of prestressed concrete floors and the construction steps of prestressed concrete floors. The results of this research provide information on the plans and steps in the construction of post-tension concrete floors, construction supervision, management to meet the specified time frame, various construction problems and solutions, and the development of knowledge and skills in construction supervision for future use. In conclusion, understanding the work process, construction process control methods, and inspection of various post-tension concrete floor constructions can increase work efficiency and reduce labor costs, time, and damage costs, such as contracting parties for breaches of contract. It was found that the advantages of the post-tension floor system are more floors at the same building height and less wind load at the same number of floors because it can improve long-term performance compared to traditional reinforced concrete and beam-slab systems. In addition, factors that affect the useful labor utilization ratio consist of 4 factors: complexity of building design, work items or work steps that make work difficult; use of appropriate tools and machinery to facilitate work and reduce labor waiting time; use of various innovations or substitute materials to help reduce time in work steps; arranging a team of workers that is appropriate for the size and type of work. These factors directly affect the ratio of useful workers. Results from this research Can be used to improve construction processes and inspection, Including selecting concrete materials to increase efficiency.

Keywords: Construction, Control, Plan, Post-tension, Process

INTRODUCTION

Post-tensioned slabs are popular in construction in countries with low-seismic zones, especially Thailand, because they are more economical than construction with traditional structures. There is no need for structural beams to support the floor. The structural floor has a small thickness, which makes it lightweight. The overall weight of the building is reduced, reducing the foundation's size and the number of piles. Fast and easy construction. Increased building space due to increased column-to-column span. The height between buildings' floors is reduced. (Get more floors at the same height) Light weight can reduce dead load by up to 20 - 30%, which results in less weight being transferred to the foundation. Reduce the size of the foundation and the number of pillars [1].

Prestressed concrete technology was first used in Thailand in 1940 to prestress beams. Concrete supports the floor of Preeda Thamrong Bridge, 64 meters long. This technology has been developed throughout the past. Initially, construction was done by foreign companies. Evolution of the development of prestressed concrete technology in the country in the period 40 years ago, by studying prestressed and tensile steel structures [2]. Currently, the construction of high-rise buildings and condominiums has used prestressed concrete floors or post-tension floors in large quantities because this construction takes a short and hassle-free time [3]. Properly studying the plans ensures that the tensioning process is executed correctly, which is critical for the floor's ability to bear loads safely. Missteps in the tensioning process can lead to cracks, excessive deflection, or even catastrophic failure [4]. Understanding the construction steps minimizes the risk of such issues. The placement of tendons must be precise, as incorrect placement can compromise the structural performance of the floor [5]. So, studying the plans ensures that the

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layout of the tendons follows the engineering design accurately.

The timing of when to apply the tension is critical. Applying it too early or too late can weaken the concrete. Understanding the construction schedule ensures that tensioning occurs at the optimal time. Post-tensioned concrete floors often use less concrete and steel than traditional reinforced concrete, saving costs [5]. Proper study of the plans allows for the maximum utilization of these savings by ensuring that materials are used efficiently. By understanding the precise construction steps, contractors can streamline the construction process, reducing overall project time and costs [6].

Non-compliance with standards can result in legal issues or costly repairs. Studying the plans helps avoid these potential problems. Properly constructed post-tensioned floors are highly durable and can handle large spans with minimal cracking and deflection over time [7].

Overall, a deep understanding of the plans and construction steps is vital for ensuring that post-tensioned concrete floors are safe, efficient, and durable, meeting all design and regulatory requirements.

This study seeks to understand post-tension slabs' detailed design and construction process. Following the correct construction steps enhances the long-term performance of the structure. Understanding the construction process helps plan future maintenance, ensuring that the post-tensioned system continues to perform well throughout the building's life. It will help improve construction efficiency, reduce costs, and minimize construction errors.

MATERIALS AND METHODS

1. Materials used in the construction

1.1 Finished floor slab

It is a flat-bottomed prestressed concrete with a cross-section like a board. Whether it is a mold or part of the structure, performing both duties helps bear weight. Generally, the cross-section is 35 cm. wide, 5 cm. thick, and arranged next to each other. The bottom side of the floor is smooth without plastering. Concrete pouring on top (Structural Topping) will work as a composite (Composite) with the finished floor.

1.2 Solid prestressed concrete floor slabs

Prestressed concrete floor slabs have a smooth surface, eliminating the need to plaster or install a ceiling. The long span can be used in various lengths. It's convenient and economical. This is because temporary bracing is not required in construction. Thus, saving both time and labor. (except thickness 6 cm.) They are designed to have different cross-sectional sizes and lengths. To bear the weight of the load. To replace the area for casting in place used for constructing residential buildings and condominiums. Office buildings and industrial factories.

1.3 Solid prestressed concrete floor slabs (Plank)

It is a small prefabricated concrete slab, usually 6 cm thick and 30 or 35 cm wide, used for general small buildings such as residential buildings and condominiums.

1.4 Micropile

It is a small, driven pile with a length of 1.5 meters. It has high density, strength, and durability.

1.5 Driven pile

This type of pile There are concrete piles, steel piles, and wooden piles. Most commonly use concrete piles. Because it is stronger than wooden poles and cheaper than steel poles. Concrete piles can be divided into two types: reinforced concrete and reinforced concrete.

1.5 Cement

1.5.1 Ordinary Portland cement (Type1) is suitable for general concrete work, which complies with TIS 15 cement.

1.5.2 Use the type that gives fast compressive strength (Type 3) following TIS 15. This type of cement will provide high compressive strength in the initial stages. Because it is finer than ordinary Portland cement, it is suitable for making concrete that needs to be used quickly. It can reduce curing time.

1.6 Coarse Aggregate

The stone standard used in producing prestressed precast concrete slabs generally uses 3/8-inch stone, suitable for solid concrete slabs.

1.7 Fine Aggregate

The sand standard that produces prestressed precast concrete slabs should have an FM value. Within the range 2.50-3.50.

1.8 High tensile steel wire (PC Wire)

Steel wire standards are used in the production of prestressed precast concrete slabs. It has a 4 and 5 millimeters diameter and must comply with TIS 95.

2. Tools and machinery used to install tensile floor slabs

2.1 Production platform (Bed)

The production platform for prestressed precast concrete slabs is a form used to cast concrete slab products. It is a steel rail along the length. The length of the production stand may vary according to the area of each factory. It is usually approximately 50-60 meters long to suit the time required for production.

A production platform for solid precast concrete slabs (Plank) is a form used to cast concrete slab products. It looks like a steel rail along its length. by the length and form of the general production platform It will be 0.30-0.35 meters wide and 5 centimeters thick. The length depends on the condition of each factory.

2.2 Wire Stressing Machine

A wire-pulling machine pulls high-tensile steel wire to produce precast concrete slabs. Prestressing can be used with both hollow and solid floors. There are 2 types: used to pull high-tensile steel wire and high-tensile stranded steel wire, Depending on the wire

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drawing cylinder. However, the solid type is used with general high tensile steel wire for prestressed precast concrete slabs and may be used in some prestressed products such as small piles, etc.

2.3 Wire wedge, wire splicing, and high tensile stranded steel wire cylinders

Used for fixing wire at the head-end of the wire mounting panel. Wire wedges used to hold high tensile steel wires are 2-3 pieces with teeth for holding the wire in a wedge wire cylinder.

2.4 Length divider set

Used for dividing the length of floor slabs to be produced. The length must be divided before concrete is poured into the form. There are 2 types: hole type, used by inserting wire into the specified holes according to the quantity produced. The wire height can be set using a comb type. Used to divide by steps between each wire. Nevertheless, we cannot set the wire height distance.

2.5 Concrete Mixing

Pan Type This mixer consists of an important part: a circular pan and a stirring blade attached to the shaft. Furthermore, it will rotate around an axis perpendicular to the Pan Mixer's axis. Some types of Pans will rotate, and some types of mixing blades will rotate. Moreover, some rotate both in opposite directions. The concrete is mixed very well. The Pan Mixer is effective for hard and highly bonded concrete, such as cement-heavy concrete. Therefore, it will be used for prestressed concrete work.

2.6 Concrete vibrating equipment

Used for firmly shaking concrete. with vibration Makes the concrete evenly dense. The surface of the workpiece is smooth. Generally, a vibrator is used. Or you can use a concrete pendant.

3. Engineering standards or regulations that are followed during the design and installation

3.1 Post-Tension Concrete Floor

Post-tension concrete floors are widely used because they are economical and can be constructed quickly [8]. This can be seen in office buildings, parking lots, hotels, shopping malls, etc., which often have long column spans. After bonding forces, the characteristics of post-tensioned concrete floor systems allow them to be designed as flat floors without beams, with long column spans, and to bear more weight than general structural floors.

3.2 Advantages of Post-Tension Concrete Floor Systems [8]

Post-tension concrete floor systems can work quickly. The construction speed is about 7-14 days per floor because it can support the weight of the structure immediately after pulling the prestressing wire and saves on labor costs, scaffolding costs, and formwork costs and reduces construction time because the building can be designed to have a longer column span than the general structure, allowing for a wider variety of usable space designs.

Post-tension concrete floor systems can be designed to have a lower structural thickness than reinforced concrete floors, which can reduce the height between building floors. This allows buildings using post-tension concrete floors to have more floors than general reinforced concrete buildings of the same building height. Because it is a prestressed concrete floor, it has the property of resisting cracking, resulting in a floor that is more watertight than general reinforced concrete floors, reducing the problem of water seepage and rusting of reinforcing steel. In addition, post-tension concrete floors can be designed to have a covering distance sufficient to resist fire according to the standards and requirements of fire-resistant materials according to Ministerial Regulation No. 40 B.E. 2540. The advantages of post-tension concrete floors in various aspects include architectural, structural, and cost-effectiveness.

3.3 Ground Characterization

Most post-tension concrete floors can be designed as flat slabs because they are easy to work with and save material costs, labor costs, and construction time. These are the advantages of post-tension concrete floors compared to general reinforced concrete floors. However, the specification of post-tension concrete floors must also consider other factors. In some cases, post-tension concrete floors require drop panels or band beams to achieve maximum savings, such as in cases where the building has a long column-to-column span, small columns, or 4 large openings. Initially, the characteristics of the post-tension concrete floor can be considered from the length (span), such as flat slab, flat slab with a column span of 6-9 m., drop panel, flat slab with a column span of 9-12 m., and band beam, a floor with a wide beam with a column span of more than 12 m.

3.4 Determination of the distance between the outer span columns and the cantilevered floor

To design post-tension concrete floors with the highest economic value, determining the distance between the edge columns and the free-floating slab that is appropriate and consistent with the spacing between the columns of the inner span will allow to reduce the amount of prestressing wire and the thickness of the post-tension concrete floors. The appropriate distance between the edge columns and the free-floating slab may be considered from the spacing between the columns of the inner span.

3.5 Determination of floor thickness

The thickness of the slab affects the amount of prestressing wire and the amount of reinforcing steel, as well as the deflection and vibration of the post-tension concrete slab. Specifying a slab thickness that is too thin may result in the slab having much prestressing wire, resulting in high and uneconomical construction costs. It may also cause the slab to be unable to withstand

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shear, deflection, and vibration. Consider the example table of design thickness of the post-tension concrete slab, shown in Table 1.

Table 1 Determination of floor thickness. (Source: Siam Cement Company Limited).

Section Type	Loading (LL) kg/m²	Span/depth ration 6m. <=L <=13m.	
1. Flat plate	250	40	
	500	36	
	1,000	30	
2. Flat slab with drop panel	250	44	
	500	40	
	1,000	34	
3. Flat slab with banded beam		SLAB	BEAM
	250	45	25
	500	40	22
	1,000	35	18

3.6 Lowering the ground level

Post-tension concrete floors can have different floor levels (lower floor levels) by either lowering the floor with a flat bottom or lowering the floor with a lower bottom. However, the suitable and economical floor lowering distance for post-tension concrete floors is less than 5 cm.

3.7 Determination of openings in post-tensioned concrete floors

The most suitable opening location on post-tensioned concrete floors should be in the middle of the span. The most avoidable location is the column head or support area because the column head area will have a dense line of prestressed wires. Most importantly, prestressed concrete floors are mainly designed as flat plates. This type of floor requires the concrete around the column to be important in resisting punching shear. Having openings around the column within 10 times the floor thickness (10h) will greatly reduce the punching shear capacity. According to ACI requirements, openings that are no more than 10 times the floor thickness (10h) away from the column will reduce the concrete line that acts as a punching shear force (Critical section), reducing punching shear capacity. If the punching shear capacity is insufficient, it may be necessary to add shear stirrup, increase the floor thickness, and add column capital or beam to help with the force.

3.8 Post-Tension Concrete Floor Installation Procedure

The steps for installing prestressed concrete floors (post-tension) include: 1) setting up supports and floor formwork, 2) placing lower reinforcing bars, 3) inserting PC Strand wire into the corrugated sheath, 4) attaching tendon anchors to side forms 5) placing upper reinforcing bars 6) pouring concrete 7) prestressing the concrete 8) sealing the Anchorage sockets with mortar, and 9) injecting mortar.

3.9 Aggregate and mixed sizes

The elastic modulus of cement-based materials is complex due to the non-homogeneous structure of the material. To predict the behavior of concrete under load, it is necessary to understand the effects of aggregate type, aggregate size, and aggregate volume [9]. The modulus of elasticity is directly proportional to the stiffness of each component in the concrete and the joints [10]. Most static elasticity modulus from normal axial compression only reaches a stress level of approximately 40-50% of the concrete's ultimate compressive strength, which is the level at which the stress does not occur. Small cracks at the interface between the cement and aggregates [11]. Research has shown that compaction to improve the mix ratio is a very effective way to reduce the cement content in the mix [12]. Cement production hurts the environment and improving the compaction of the aggregates can reduce the cement content and increase the elastic modulus. It helps to improve the strength by improving the hydration process in concrete [13]. And the strength of concrete is greatly influenced by the size distribution of aggregates, where the key factor in aggregate compaction is to allow small aggregates to fill the spaces between large aggregate particles by using the right mix size and proportion [14].

RESULTS AND DISCUSSION

Case study of the structural floor of an 8-storey building, a prestressed concrete floor structure. The construction of the prestressed concrete floor can be summarized in Figure 1-8:

1. Steel structure floor plan

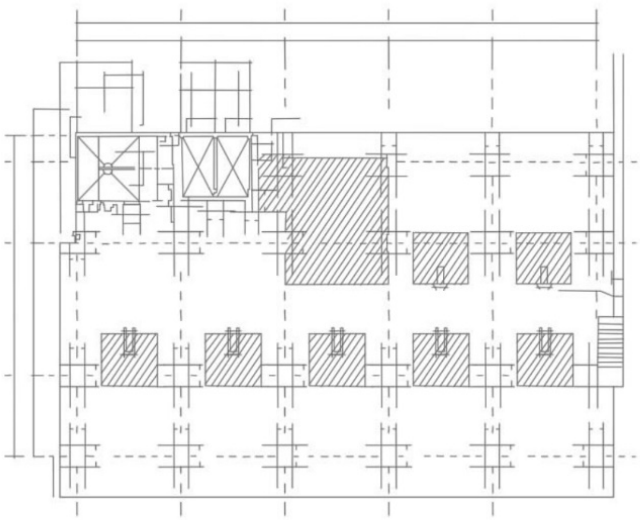

Figure 1 Steel structure floor plan [15].

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2. Expanded shear reinforcement type

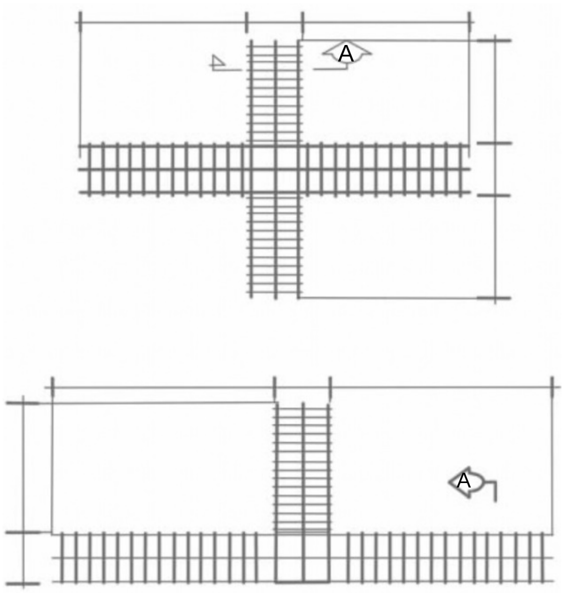

Figure 2 Example Figure [15].

3. Beam A is inside the floor.

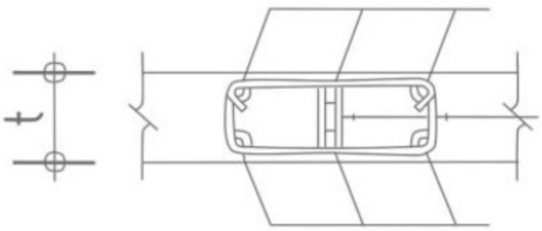

Figure 3 Beam A is inside the floor [15].

4. Shop Drawing (Prestressed Wire)

Shop Drawing (Prestressed Wire Line) shows the number of types of prestressed wire lines and the number of lines for use in laying out the wire ropes and checking before pouring concrete.

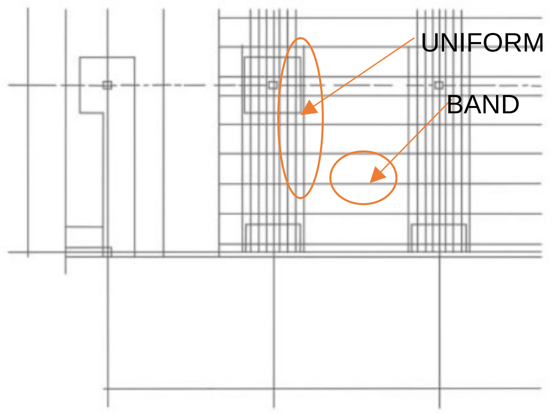

Figure 4 Shop Drawing (Prestressed Wire) [15].

5. Shop Drawing (Prestressed Wire Profile)

Shop Drawing (Prestressed Wire Profile) is a wire rope extension drawing for placing Bar Chairs because each section of the wire rope will not be placed the same in terms of the distance and height of the Bar Chair.

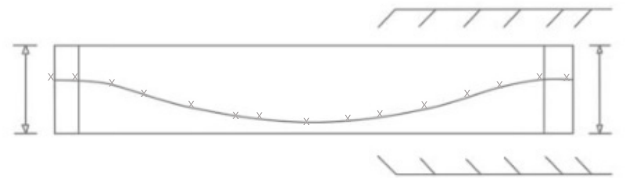

Figure 5 Shop Drawing (Prestressed Wire Profile) [15].

6. More floors at the same building height

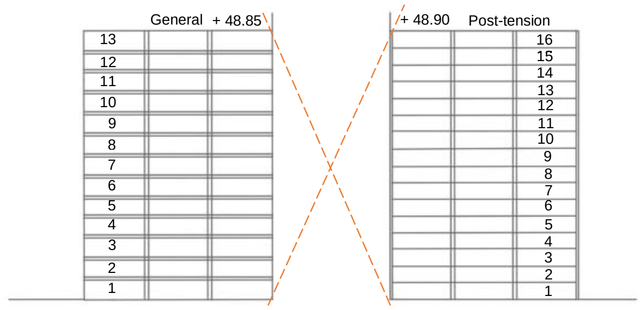

Figure 6 More floors at the same building height [15].

7. Wind Load less than the same number of floors

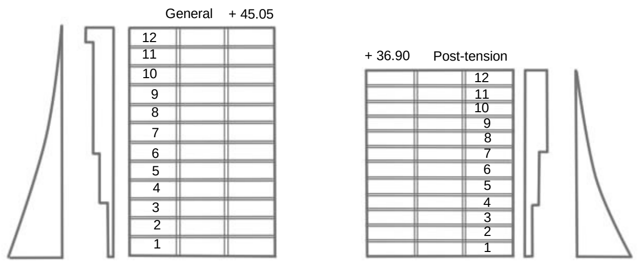

Figure 7 Wind less Load than the same number of floors [15].

8. The construction steps [15]

The construction steps of reinforced concrete floors are following the step according to figure 8.

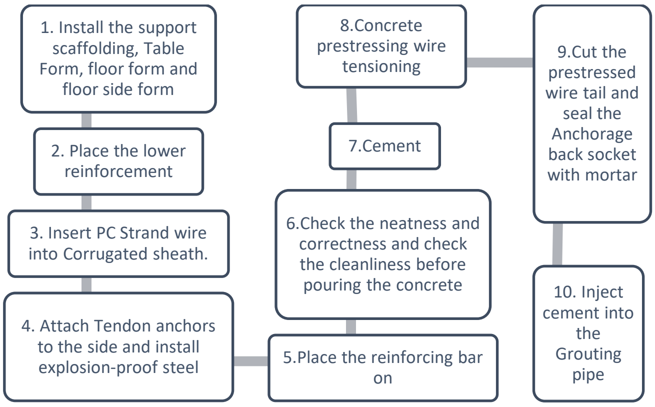

Figure 8 The construction steps of reinforced concrete floors [15].

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9. Factors affecting productivity in construction work of floor work

There are 4 main factors in prestressed concrete: [15]

1. Complexity in building design, work materials, or work procedures that cause difficulty in working.

2. Use appropriate machinery to facilitate work and reduce waiting time for workers in concrete pouring work.

3. Using innovations or alternative materials to help reduce the time in the work process and reduce the difficulty of the work, such as installing steel and reinforcing steel.

4. Arranging the right team of workers for the size and type of work.

CONCLUSIONS

Understanding the work process, construction process control methods and inspection of various post-tension concrete floor constructions can increase work efficiency and reduce labor costs, time, and damage costs, such as contracting parties for breaches of contract.

Table 2 Comparison of various features of Post-Tension Slabs, Reinforced Concrete Slabs, and Beam-Slab Systems.

Feature	Post-Tension Slabs	Reinforced Concrete Slabs	Beam-Slab Systems
Strength	High, better crack control, and load distribution	Lower tensile strength, prone to cracking	High, but requires large beams
Cost	Potentially lower overall due to material savings	Generally higher due to more material needed	Higher due to additional beams and reinforcement
Slab Thickness	Thinner slabs, more space-efficient	Thicker slabs for strength	Thicker slabs with added beam depth
Construction Time	Faster due to reduced slab thickness and complexity	Slower due to thicker slabs and more reinforcement	Slower due to beam complexity
Long Span Capability	Ideal for long spans with fewer supports	Limited span capabilities without beams	Suitable for long spans but with additional material requirements
Durability and Maintenance	Low maintenance, fewer cracks, higher durability	Prone to cracking and maintenance issues	Prone to cracking, additional complexity for repairs
Flexibility and Space	More flexible use of space, open areas	Reduced ceiling height due to thickness	Reduced space flexibility due to beams

This study found that the advantages of the post-tension floor system are more floors at the same building height and less wind load at the same number of floors. Post-tension concrete slabs are a superior choice in many situations, offering cost and time savings, reduced material usage, and improved long-term performance compared to traditional reinforced concrete and beam-slab systems. PT slabs are particularly well-suited for long spans, flexible space usage, and structures that prioritize minimizing slab thickness. While PT systems require higher initial costs due to specialized equipment and materials, their efficiency in construction time, reduced labor costs, and lower long-term maintenance make them a favorable option for many building projects. This is in line with the research of Thanapat Ekphong and Kawin Tantisevi (2021), who studied the construction productivity of prestressed concrete floors in high-rise buildings. This research shows that a lump sum cost based on the weight of wire ropes is 26-37 bath-sq.m. of slabs, while a labor cost based on the number of man-days is 10-12 bath-sq.m. Hence, the difference in labor costs calculated by these two approaches is likely a profit margin for subcontractors. Moreover, the research of Narongchai Paksa and Thotsapon Pinkaew (2020) studied the development of high elastic modulus concrete for ultra-rigid structures. The results are compared with normal concrete specimens using limestone as coarse aggregate. It is found that the proposed concrete using EAF slag can significantly enhance the elastic modulus and is more cost-effective than conventional high-strength concrete.

In addition, factors that affect the useful labor utilization ratio consist of 4 factors: complexity of building design, work items or work steps that make work difficult; use of appropriate tools and machinery to facilitate work and reduce labor waiting time; use of various innovations or substitute materials to help reduce time in work steps; arranging a team of workers that is appropriate for the size and type of work. These factors directly affect the ratio of useful workers. However, if there are indirect factors that may cause an impact on the work, causing the ratio of useful workers to decrease, the researcher believes that this research can be further developed to study such impacts and to be beneficial to projects with similar characteristics in the future.

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Recommendations for use and precautions of post-tension concrete floors include checking the safe load specified in the post-tension concrete floor structure before actual use. Any holes that are dug after construction is complete must be consulted with a design engineer. Renovations and changes to the building's space usage must be consulted with a design engineer. The scaffolding must not be dismantled before the prestressed wire pulling is complete. Also, the integration of new technologies into the post-tensioned concrete slab construction process has the potential to significantly improve efficiency, quality, sustainability, and safety. By embracing innovations in AI, robotics, 3D printing, AR, and advanced materials, the construction industry can develop more innovative, more resilient structures. Further research into the application of these technologies and the development of new materials and construction methods will drive the evolution of post-tensioning techniques, ensuring that they remain a cost-effective, sustainable, and adaptable solution for modern building projects.

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