INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING VOL. 15 NO. 4 (2023) 329-337

© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Cutting on Existing Bonded Post-Tensioned Slabs: Safety Precautions, Procedures and Execution

Rachmad Irwanto[1*], **Hanif Hanif**[2]

[1]Department of Civil Engineering, Faculty of Engineering,
Universitas Muhammadiyah Jakarta, Jakarta 10510, INDONESIA

[2]PT. Jakarta Propertindo, Thamrin Boulevard, Jakarta 10340, INDONESIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2023.15.04.029
Received 16 October 2022; Accepted 25 May 2023; Available online 28 August 2023

Abstract: Post-formed cut-off or cutting of the post-tensioned slabs is a common practice during post-tensioning work. However, cutting on existing post-tensioned slabs must be done carefully to avoid severe damage to the building. The measurements during the design review are critical in considerations of post-cutting conditions, variations between shop drawings and site, possible grouting failure and excessive deformation. This paper presents a successfully execution of cutting operations on bonded post-tensioned slabs without compromising the structural strength and serviceability. There are procedures and requirements that need to be considered prior to cutting at the design stage, prior to cutting at the site and at slab cutting stage. The safety precautions are necessary for unintentional scenarios that require immediate action. Cutting the slab creates potential hazards. It was found that the grouting material plays an important role not only in solidifying the concrete but also in forming a secondary anchorage mechanism. Therefore, selection of suitable grouting material should be based on the dimension of the locking area. In contrast to unbonded post-tensioned slabs, bonded post-tensioned slabs do not require de-tensioning and re-tensioning.

Keywords: Post-tensioned slabs, slab cutting, bonded post-tensioning, grouting pockets, safety precautions

1. Introduction

Guyon [1] mentioned that the steel in prestressed concrete beams represents not only reinforcement but also a force. This then leads to the concept of using a prestressing system, later defined as a method of reinforcing concrete or other materials with high-strength steel strands or steel bars, typically referred to as tendons [2]. Suleymanoglu & Arslan [3] stated that the post-tensioned design as part of a sustainable structural design to reduce the use of steel material but the building can be constructed with additional floor number at the same cost investment. The reduction of steel material and the adaption of smaller concrete elements are considered as energy saving. In addition, post-tensioned design is known to offer various advantages, particularly in terms of structural performance.

There are two types of prestressing systems for concrete, called pre-tensioning and post-tensioning. The difference between the two lies in the stressing time. With pre-tensioning, the stressing of the tendons occurs before concreting. Oppositely, with post-tensioning, the stressing of the tendons occurs after concreting. Pre-tensioning is usually done in hollow-core slabs, while post-tensioning usually applies to conventional slabs and raft foundations. Post-tensioning itself is divided into three categories: bonded, unbonded and external tensioning. In bonded post-tensioning, the stressed tendons are grouted along the whole length and monolithically to the slab, while unbonded does not use grouting material. On the other hand, external post-tensioning is usually used to strengthening the existing structures, and the tendons are attached to the bottom of external components.

---

*Corresponding author: rachmad.irwanto@umj.ac.id

2. Comparison of Post-Tensioning Codes

There are several codes that normally have been used for reference in the design of both bonded and unbonded post-tensioned slabs. The first reference is identified as American Standards consists of ACI 318, ACI 209 and Post Tensioning Manual. The second reference is European Technical Standards based on Eurocode 2. The third reference is referring to British Standards in terms of BS8100 and TR43. It was identified from the literature that American Standards and Eurocode 2 agree that post-tensioned slabs should be considered to behave as uncrack structural members. On the other hand, TR43 offers more flexibility of crack definition than BS8100. In TR43, it is clearly mentioned that the long-term crack can reach up 0.2 mm [4]. It affects the stresses limit, which appears to be smaller than at BS8100.

In this study, it was found during the design review that Eurocode 2 is more stringent. However, ACI 318, ACI 209 and Post Tensioning Manual provide the strictest and safest results in all cases due to their concrete properties. For example, the required tensile stresses limit in American Standards shall be less than half of squared root of the cylindrical concrete strength, while Eurocode 2 specifies slightly higher values [5], [6]. The Concrete Society [4] emphasized that TR43 is the most detailed manual that could be helpful in filling the guideline gaps for some absence clauses in the other codes. Importantly, TR43 provides the maximum tendon length for bonded and unbonded post-tensioning in two different situations (single stressing and double stressing). Table 1 summarizes the comparison of various design requirements of post-tensioning slabs. It should be noted that the comparison is based on American Standards, Eurocode, BS8100 and TR43.

Table 1 - Comparison of post-tensioning codes. A compilation of [4]- [8.]

Parameter	American Standards	Eurocode 2	BS8100 (Uncracked)	BS8110 (Cracked	TR43 (Cracked)	Note
Material properties						
E_c (MPa)	$4700f'_c{}^{0.5}$	$9500(f'_c + 8)^{1/3}$	$1000(20 + 0.2f_{cu})$		Not Specified	
Creep	2.35	Table 8.7 EC2	Figure 7.1 BS8110		Not Specified	
Shrinkage strain	0.00078	Table 8.6 EC2	Figure 7.2 BS8110		Not Specified	
Angular friction, μ	0.15 - 0.25	0.25	0.12 - 0.55		Not Specified	
Wobble friction, K	0.0016 - 0.0066	0.003	0.0017 - 0.0033		Not Specified	
Post-tensioning design						
Behaviour	Uncracked	Uncracked	Uncracked	Invisible crack	0.1 - 0.2 mm crack	
Pre-compression average (MPa)	$0.9 < P/A < 2$	Not specified	Not Specified		$0.7 < P/A < 2.5$	
Compressive and tensile stresses at transfer load, DL + PT	$C < 0.60f'_{ci}$	$C < 0.6*0.75f'_{ci}$	$C < 0.5f_{cu}$		$C < 0.24\,f_{cu}$	SP
					$C < 0.33\,f_{cu}$	MS
	$T < 0.55f'_{ci}{}^{0.5}$	$T = 0$ (zero tension)	$T < 1$	$T < 0.36f_{cu}{}^{0.5}$	$T < 0.45f_{cu}{}^{0.5}$	SP
	$T < 0.25f'_{ci}{}^{0.5}$				$T < 0.45f_{cu}{}^{0.5}$	MS
Compressive and tensile stresses at service load, DL + LL + PT	$C < 0.60f'_{ci}$	$C < 0.60f'_{ci}$	$C < 0.33f_{cu}$		$C < 0.24f_{cu}$	SP
			$C < 0.40f_{cu}$		$C < 0.33f_{cu}$	MS
	$T < 0.50f'_{ci}{}^{0.5}$	$T < 0.30f'_{ci}{}^{0.5}$	$T = 0$	$T < 0.36f_{cu}{}^{0.5}$	$T < 0.45f_{cu}{}^{0.5}$	SP
					$T < 0.45f_{cu}{}^{0.5}$	MS
Tendon spacing, s	$s < 8*t_{slab}$	$s > h_{agg}+5$ mm	$s > h_{agg}+5$ mm		$s < 8*t_{slab}$	
	$s < 1.5$ m	$s > 20$ mm			$s < 75$ mm	
L/h (normal slab)	45	36	Not Specified		36	(i)
L/h (flat slab)	50	42	Not specified		40	(ii)
Tendon maximum length	Not Specified	Not Specified	Not Specified		25 m	(iii)
	Not Specified	Not Specified	Not Specified		50 m	(iv)

	Not Specified	Not Specified	Not Specified	35 m	(v)
	Not Specified	Not Specified	Not Specified	70 m	(vi)
Inflection ratio	0.1	Not specified	Not specified	0.1	
Balancing load	60% - 80% SW	50% (DL + LL)	Not specified	75% SW	Slab
	80% - 110% SW		Not Specified		Beam
Reinforcement					
Minimum tension reinforcement	$0.00075A_c$, $L_{min} = 1/6L$	$0.0015A_c$	Not Specified	$0.00075A_c$, $L_{min} = 0.2L$	
	From column face	Or A_c/f_y	Not Specified	From column face	

Note:
SP = At support, MS = At mid-span, (i) Without drop panel, (ii) With drop panel, (iii) End-live (bonded), (iv) Live-Live (bonded), (v) End-live (unbonded), (iv) Live-live (unbonded)

3. Problem of Statement

A common practice in post-tensioning is post-formed cut-off through post-tensioned slabs. This cutting is typical of architectural changes (also a common practice in reinforced concrete structures). Therefore, every construction project presents unique challenges. In this study for bonded post-tensioned slabs, there is a requirement for a change to the front facade. The discussion to alter the cutting with re-layout on space design failed, and the attempt to limit the cutting so that it would not touch the tendon lines was also unfavorable. Therefore, cutting on already installed bonded post-tensioned slabs is the final option. This ultimately results in the tendons being severed.

The slab itself was designed according to American Standards, with load configuration taking into account gravitational loads (selfweight, dead load and live load), lateral loads (wind and seismic) and stressing loads. The tendons are attached to the slab by laying perpendicularly. Since the slab is a two-way, the arrangement of tensons was adjusted to the required tension stress distribution. On certain sections of the slab longer than 30-meter length or on certain sections with more extreme tendon curvature profiles, both ends of the tendons are provided with anchorage blocks to counteract potential friction between the strands and the duct. Therefore, anchorage blocks were installed at both ends of the tendons and stressing was applied to the anchorage assemblies. The tendons have a single live-end (same as anchorage blocks) at one end and a dead-end with an onion-like assembly at the other end. This is to ensure that the hydraulic jack would stress effectively considering friction force exists among the strands. After installing the anchorage blocks, the wedges were fixed to hold the strands during and after stressing.

Grout vents were provided at both ends to allocate the flow of grouting material. This is able to protect the tendons from possible corrosion and to solidified the slab [9]. According to Wood et al. [10], the use of grouting material could counteract the risk as corrosion reduces tensile capacity. Faria et al. [11] stated that grouting material could help bond the tendons to the surrounding concrete. The push-in and pull-out tests demonstrated that providing grouting material is important to improve the bonding mechanism. In this study, it is of utmost importance to consider safety precautions due to potential hazards when cutting the tendons. Cutting of the already grouted tendons could impair the anchoring function. In addition, ensuring sufficient bonding and protecting the stands from corrosion after cutting are additional crucial tasks.

4. Procedures and Execution

Greater precautions are required when cutting post-tensioned slabs than when cutting reinforced concrete slabs. The strands follow ASTM A416 [12], which specified a nominal diameter of 12.7 mm at a grade of 1860 MPa. In this study, the nominal breaking load was determined to be 183.7 kN per 98.71 mm^2 cross sectional area. For further handling of the strands, reference was made to ASTM A700 [13]. For bonded post-tensioning, galvanized duct (sheath) with specified properties was used to ensure the isolation of strands during concrete casting and to leave sufficient clearance for grouting. It is estimated to be at least 2.5 times the net area of all the strands contained within it. The galvanized duct was mainly adopted to prevent corrosion of the cables, especially on the anchorage assemblies. The duct is corrugated to provide enough friction to hold the slab and flexibility when bending. The grouting itself complies with ASTM C109 [14], ASTM C827 [15], ASTM C940 [16] and ASTM C942 [17].

4.1 Prior to Cutting at The Design Stage

The first step before cutting is to check the area of the slab. The check should focus on the presence of special loads, such as the heavy point load and the line load. This ensures that these loads will have no substance impact on the design of the slab after the cutting. In addition, not all newly proposed openings are executable. In certain cases, such as (i) the proposed opening crosses heavy duty tendons, (ii) the tendon spacing is too narrow to create proper pocket locking, and (iii) the spot is in a difficult position to safely perform the cutting operations, the proposed opening would require additional structural strengthening and is therefore not recommended due to cost considerations. Fig. 1 shows the cutting locations, indicated by red clouds. Fig. 2 shows the bonded post-tensioning system used in this study.

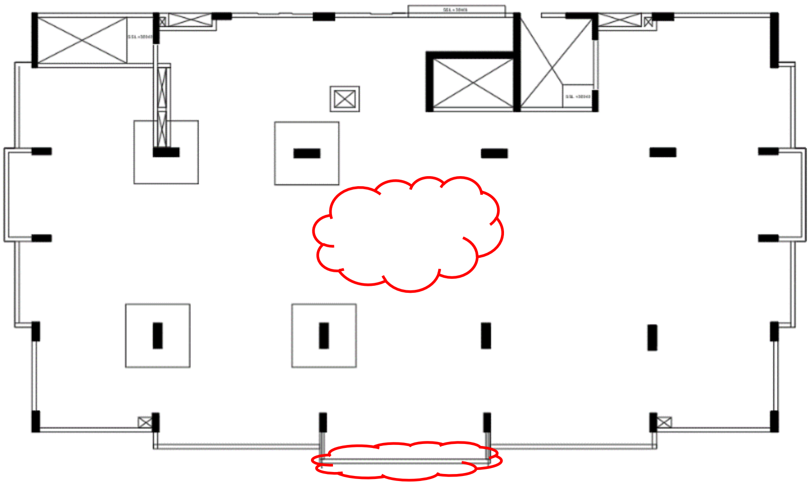


Fig. 1 - Cutting locations, indicated by red clouds

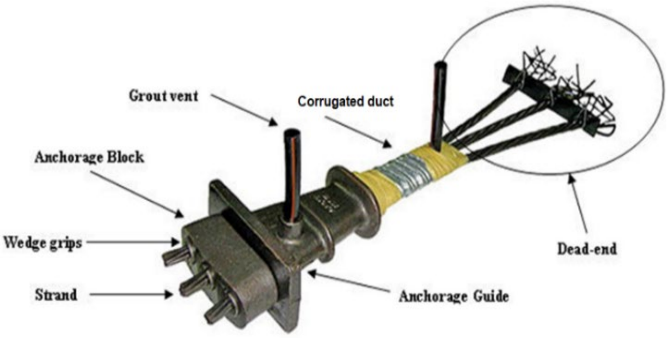


Fig. 2 - Bonded post-tensioning system [18]

A new model and re-analysis of the slab in the post-cutting condition with short tendon were carried out. Short tendon (less than 5 m) generally behaves differently than longer tendon. The Post Tensioning Institute [19] and Bondy [20] does not recommend the use of short tendon as it will not effectively contribute in improving slab strength. If the cutting operations make the tendons shorter than 5 m, the tendons as the prestressing material are neglected and only the steel bars are considered in the analysis.

Though several investigations have proven that the grouted tendon provides good hold, the additional potential stressing losses at the cut-tendon was reviewed for precautions. In terms of concrete serviceability, the pre-compressive stress, compressive and tensile stresses at transfer load and service load, short-term deflection, long-term deflection and shear stress were also checked. The critical stress in the tension should be very low. Since the concrete strength, f'_{ci} = 35 MPa, the actual tensile concrete stress should not be greater than 2.95 MPa as specified by ACI 318 [5]. In the case where the stresses of the slab at post-cutting does not meet the codes, the scenario to include the additional structural strengthening will be taken into account.

In a specific case, if the proposed opening is large enough to reduce the slab diaphragm stiffness, a re-analysis must also be carried out. If the proposed cutting is near a column, careful assessment of punching failure should be deemed necessary. Marinkovic et al. [21] investigated the punching shear effects on post-tensioned slabs through non-linear finite element simulation. The simulation results were found to be in good agreement with the experimental study, confirming that the punching shear failure was initiated by the splitting of the concrete due to a loss of confinement of the high triaxial compressive stress state in localized zones, followed by crushing phenomena. It was observed that a high positioned tendon close to the column was a possible solution to overcome the punching shear failure. By creating a downward force around the column collar, the punching force can be significantly counteracted. The longer the span, the higher the punching force and potentially the higher the tendon force.

Cutting the post-tensioned slabs at the mid-span where the positive moment occurs is easier than at near support, especially where the large negative moment and high shear stress exist. In this situation, the risk of punching shear failure is likely higher without the slab thickening such beam, column head and drop panel around the support. Particularly for long-span slab, the slab-column connection may carry more substantial seismic performance. Therefore, the stresses at the support must be checked carefully. Slab strengthening procedures as reported by Ruiz et al. [22] can also be considered to avoid punching shear failure. The use of fiber reinforced polymer and column jacketing to increase the column collar area or post-installed shear bolt might be required to increase punching shear capacity.

Zhou et al. [23] investigated anchorage failure through an experimental study. Although the assessment relates to the post-tensioned girder beam for a bridge, it is still relevant in this study because cutting of post-tensioned slabs involves removing the anchors (either the live-end or the dead-end) to be replaced by grouting. The anchors act as a longitudinal extrusion from both ends to the mid-span, reducing the contribution of concrete and steel bars. In the case of post-tensioned slabs, after cutting the strands, the effects of longitudinal extrusion may be interrupted. There is a trend of changing in cracking load within the slab. Because the slab is two-way compared to one-way post-tensioned girder beam and it is assumed that only one direction of the tendons is well grouted to provide residual strength, the slab will still have about half the strength capacity when cutting the strands continues.

4.2 Prior to Cutting at The Site

Occupational health and safety assessment (OHSAS) have been referenced, which include personal protective equipment (PPE), securing the area from unauthorized personnel and others. To ensure a smooth cutting operations, a scenario was set up to contain the flying debris. The personnel were instructed to prepare for the incoming of any loose materials due to the cutting of the slab. In order for the concrete stress to reach its design capacity, the slab must be at least 28 days old. The deviations between shop drawings and the actual on-site conditions (e.g. deflection) can be avoided by performing the measurements on site. The data is recorded to compare with the post-cutting condition.

It is a common practice to mark the installed tendon locations after the rear propping has been removed by painting them on the exterior underside of the slab for each completed slab. Fig. 3 shows the marking of tenson locations. This marking of the actual tendon locations is in many cases different from the tendon locations in shop drawings, as the site adjustment is done with plumbing pipes installed within the slab. Therefore, information about this adaptation history was also included in this study. Although the intention was to do this as a precautionary in case further plumbing and piping work required drilling through the slab, this approach proved helpful for the procedures of cutting the slab.

Additionally, for safety reasons, the surrounding area of the proposed cutting must be supported with scaffolding and shuttering beyond the cutting perimeter to adjacent spans. The extended area includes areas beneath high positive moment slab zones (typically in the middle strip) associated with the proposed cut tendon. The installed support under the proposed cutting slab and pocket holes would rest for about 10 days after the entire cutting operations was completed.

Fig. 3 - The marking of tendon locations [24]

4.3 Slab Cutting Stage

Before cutting the slab, the affected tendons should first be secured with high-strength grouting material. Locking the tendons is another precaution that must be taken when cutting bonded post-tensioned slab [25]. This step is usually accomplished by creating grouting pockets at some projected distance from the rim of the proposed opening. The size of the pocket varies depending on the site. In this study, the length of the pocket was set to be at least 500 cm, while the width is usually around 20 cm to 30 cm. This practice typically specified tendon spacing of about 1.5 m, although in certain cases it could be much closer. This would create a comfort space so as not to disturb another tendon routed in different direction. The grouting position can be changed accordingly to avoid crossing the tendons.

A proposed opening would normally have at least two locking pockets, and in some cases none (see Fig. 4). On the other hand, with a change in outline, the number of locking pockets that would replace the anchor or onion could normally be as little as one, or in some cases none at all. This is based on “prior to cutting at the site”. Some possible grouting failure after stressing, immediately after cutting the strands, such as: (i) strands shortening (slipping inside the ducts) and (ii) strands flying out (from the ducts), all of which are due to a loss of grout grip around the strands. In this study, there are neither strands shortening nor strands flying out during the cutting operations. It should be emphasized that in order to increase the safety factor, it is necessary to secure the tendons at the slab vicinity.

Fig. 4 - Cutting zone and locking pockets area

A grouting resin with a minimum bonding capacity greater than the concrete failure stress, which is at least 3 MPa, was used to secure the tendons. The total capacity of the bonding stress for each strand should not be less than the concrete strength itself. Since the cylindrical concrete stress of the slab is 35 MPa or equivalent to a cube concrete stress of 45 MPa, the total length of the locked strand with a diameter of 12.7 mm is about 600 mm. Apart from that, a day is required to apply the grouting material to the locking area. The early strength stresses of the compressive, tensile and flexural must be greater in capacities than the concrete properties of the slab on 28 days. In this study, the grouting material manufactured by Conmix Ltd [26] with a one-day compressive strength of 60 MPa, a bond strength of more than 3 MPa, a flexural strength of 30 MPa and a tensile strength of 20 MPa was used. The grouting material from Master Builders Solutions [27] is also available with different properties, but the dimension of locking area must be adjusted accordingly.

4.3.1 Creating Small Opening for Tendon Grouting Pocket Lock

This procedure was executed with extra precautions. The first step is to grind the slab to a depth of 20 mm. This depth is considered the same depth of the concrete cover. Beyond this depth, the grinder could damage the upper steel bars or tendons, which may be at the height of the high points. After removing the concrete cover, the slab could be carefully knocked out until the tendons are completely exposed. The strands would then be cleared out from the duct and the hardened grouting material using a cutter. After the grouting pockets are formed (see Fig. 5(a)), the residue is removed from the cutting area. The exposed strands are marked, and a short waiting period begins (approximately 10 - 15 minutes). During this duration, any slip movements due to possible friction loss (by partially removing the grouting material) are recorded.

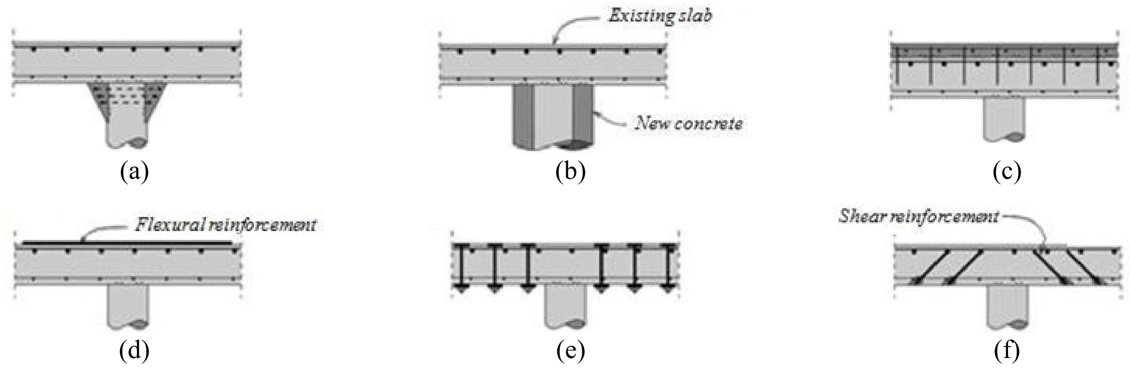
In fact, the slip movements should be anticipated during “prior to cutting at the design stage”. However, there can be various reasons that lead to slip movements after the forming of grouting pockets. One of these is due to incomplete grouting work in the early post-stressing. Should slip movements occur, further confirmation through structural monitoring would be required to initiate the prepared scenario for this fault. In this study, all strands remained in place. In the next step, the grouting resin is poured into the grouting pockets (see Fig. 5(b)). Normally, the grouting material reaches maximum strength at 7 days after pouring. Since this is an open area, the site must be cleared from any activities that could cause vibration or excessive debris.

(a) (b)

Fig. 5 - (a) Grouting pockets and exposed strands, and; (b) grouted locking area

4.3.2 Slab Cutting for The Proposed Opening

The site was instructed to perform the cutting of the slab immediately after confirming that there was no anomaly in the grout lock. The anomaly in this case could take the form of cracks, signs of leakage or a visible rough surface that could indicate strands shortening. Slow and careful cutting operations were carried out, expecting that the cutting operations would meet not only hardened concrete but also grout filled tendon duct and strands which affects the cutting speed. The human body leaning towards the opening side must be avoided. During the cutting operations, the slab is monitored for unintentional deformations. In a particular situation where the deformations are too large, immediate implementation of the prepared scenario for slab strengthening should be initiated. Fig. 6 and Fig. 7 illustrate several approaches that can be considered for slab strengthening.



(a) (b) (c)

(d) (e) (f)

Fig. 6 - Slab strengthening: (a) creating column head; (b) column jacketing; (c) thickening the slab; (d) adding flexural reinforcement; (e) post-installed shear bolt, and; (f) post-installed shear reinforcement [22]

Fig. 7 - Slab strengthening with fiber-reinforced polymer [28]

5. Conclusion

Cutting operations on bonded post-tensioned slabs such as those performed in this study were successfully completed by Ichsan Post Tensioning [29]. In contrast to unbonded post-tensioning, which requires de-tensioning before cutting and re-tensioning at the post-cutting involving strands coupler, this is not necessary with bonded post-tensioning. Krauser [30] discussed in detail the cutting of unbonded post-tensioned slabs. The presence of grouting material that bonds the strands with the duct essentially ensures that the tendons are monolithically integrated with the slab. The grout filled ducts that accommodate the strands are believed to form a secondary anchorage mechanism to the slab. However, for safety reasons, some measurements in the design review are still required before cutting the slab, such as: (i) post-cutting conditions, (ii) variations between shop drawings and site, (iii) possible grouting failure, and (iv) excessive deformation.

Acknowledgement

This study would not have been possible without the permission from Ichsan Post Tensioning to release its technical manuals (including Table 1). The authors are also grateful for the insightful comments offered by the anonymous peer reviewers from Ichsan Post Tensioning. Their experience and expertise in post-tensioning have improved this study in countless ways.

References

[1] Guyon Y. (1963). Béton précontraint étude théorique et expérimentale. Eyrolles/ITBTP.
[2] American Concrete Institute (2013). Concrete terminology.
[3] Suleymanoglu H. & Arslan G. (2017). Use of post-tensioned concrete slabs for sustainable design of buildings. High tech concrete: Where technology and engineering meet. Maastricht.
[4] The Concrete Society (2005). Technical report no. 43 - post-tensioned concrete floors design handbook.
[5] ACI 318-19 (2022). Building code requirements for structural concrete and commentary. American Concrete Institute.
[6] EN 1992-1-1 (2004). Design of concrete structures. general rules and rules for buildings. European Committee for Standardization.
[7] BS 8110 (1997). Structural use of concrete - code of practice for design and construction. British Standard Institution.
[8] American Concrete Institute (1992). Prediction of creep, shrinkage, and temperature effects in concrete structures.
[9] Schokker A. J., Breen J. & Kreger M. E. (2001). Grouts for bonded post-tensioning in corrosive environment. ACI Materials Journal, 98(4), 296-305.
[10] Wood S. L., McKinstry C. A. & Ki Lee J. (2013). Residual tensile capacity of grouted post-tensioned tendons. Structural Journal, 110(6), 1099-1108.
[11] Faria D. M., Lucio V. & Ramos A. P. (2009). Strengthening of reinforced concrete slabs using post-tensioning with anchorages by bonding. Symposium Concrete: 21st Century Superhero, London.
[12] ASTM A416/A416M-06 (2006). Standard Specification for steel strand, uncoated seven-wire for prestressed concrete. ASTM International.
[13] ASTM A700-14 (2014). Standard guide for packaging, marking, and loading methods for steel products for shipment. ASTM International.

[14] ASTM C109/C109M-20 (2020). Standard test method for compressive strength of hydraulic cement mortars (using 2-in. or 50-mm cube specimens). ASTM International.
[15] ASTM C827/C827M-16 (2016). Standard test method for change in height at early ages of cylindrical specimens of cementitious mixtures. ASTM International.
[16] ASTM C940-16 (2016). Standard test method for expansion and bleeding of freshly mixed grouts for preplaced-aggregate concrete in the laboratory. ASTM International.
[17] ASTM C942-15 (2015). Standard test method for compressive strength of grouts for preplaced-aggregate concrete in the laboratory. ASTM International.
[18] Ergon Infra (2018). Components of bonded post tensioning. http://ergoninfra.com/wp-content/uploads/2018/08/components-of-bonded-post-tensioned-system.jpg.
[19] Post-Tensioning Institute (2006). Post tensioning manual.
[20] Bondy K. (2012). Technical notes no. 16 - short tendon elongation. Post-Tensioning Institute.
[21] Marinkovic S. B. & Alendar V. H. (2008). Punching failure mechanism at edge columns of post-tensioned lift slabs. Engineering Structures, 30(8), 2752-2761.
[22] Ruiz M. F., Muttoni A. & Kunz J. (2010). Strengthening of flat slabs against punching shear using post-installed shear reinforcement. Structural Journal, 107(4), 434-442.
[23] Zhou L., Mahunon A. D. G., Yin G. & Xue X. (2020). Experimental investigation of simply-supported post-tensioned beam after anchorage system failure. Engineering Structures, 212, 110507.
[24] The Concrete Society (2022). Post-tensioned suspended floors. https://www.concrete.org.uk/fingertips-nuggets.asp?cmd=display&id=623
[25] Post-Tensioning Institute (20140. A guidance note GN06/v.2 - post cut holes through post-tensioned slabs.
[26] Conmix Ltd (2012). NanoGrout EG - high early strength free flowing epoxy resin grout.
[27] Master Builders Solutions (2017). MasterFlow® 400 - high strength, free flowing epoxy grout.
[28] CTech-LLC (2022). Slab strengthening and repair with FibraOne™ system. https://ctech-llc.com/en/wikitech/slab-strengthening-and-repair-with-frp-composite-system.
[29] Ichsan Post Tensioning (2014). Bonded post-tensioning.
[30] Krauser L. (2006). Repairs, modifications, and strengthening with post-tensioning. PTI Journal, 4 (1), 24-40.