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Multivariable Modeling: Shoring for Critical Stage and Prestress Losses in Composite Slabs

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Abstract - This research analyzes the structural behavior of precast prestressed slabs with composite topping (PPCC) during the casting phase—a critical stage that can compromise structural integrity if temporary shoring is not properly evaluated.
Three slab typologies (6/60:30, 6/60:35, and 6/60:40) were assessed using structural modeling in ETABS and SAP2000, along with multivariable statistical analysis in Python and MATLAB. Key variables considered include span length, steel yield strength (1700–1860 MPa), and concrete modulus of elasticity (25–35 GPa).The results show that span lengths exceeding 5.5 m, when combined with low-stiffness concrete and lower-strength prestressing steel, lead to significant prestress losses, surpassing 13%.
Response surface analysis made it possible to visualize the interactions among variables and optimize the required number of shoring elements. This study proposes technical criteria to enhance safety and efficiency in the construction processes of prestressed composite slabs.

***Keywords*:** Temporary shoring; Prestressed slab; Prestress losses; Structural analysis

1. Introduction

Precast prestressed slabs with composite topping represent an efficient and widely adopted technical solution in multi-story building projects. This structural typology combines the rapid construction and quality control of precast elements with the structural continuity provided by the in-situ casting of the composite topping. This synergy facilitates the reduction of permanent formwork, optimizes execution time, and ensures an adequate transfer of loads between elements [1], [2].

However, during the casting stage of the composite topping, the structural system is in a critical transitional state, as the precast slab has not yet reached its final strength. In this condition, the structure may not be capable of resisting construction loads without additional support. This situation raises a fundamental question in structural engineering: Is temporary shoring required to prevent partial collapse due to flexure, excessive deformation, or shear failure?

Recent studies have emphasized the importance of considering both ultimate limit states (flexural and shear strength) and serviceability limit states (deformations and stresses) during this construction phase, as premature failures are likely to occur if adequate shoring is not provided [3], [4], [5]. Nevertheless, regulatory gaps and a variety of construction practices still persist, justifying the need for specific research depending on the slab type and loading conditions.

In particular, the use of temporary props can significantly increase both costs and construction time, and therefore, the necessity of their implementation must be rigorously evaluated. Research such as [6], [7], and [8] underscores that unnecessary oversizing of the shoring system may reduce the efficiency of the construction process, whereas underestimating its need can lead to progressive failures.

For this reason, this article aims to analyze the structural behavior of prestressed concrete slabs with evolving strength during the casting phase of the composite topping. The objective is to determine how many props are required—and where to place them— to ensure compliance with ultimate and service limit states, avoiding collapse due to flexure, shear, or excessive deformation.

The research is based on structural models developed under the ACI 318 code, evaluating different cross-section typologies (6/60:30, 6/60:35, and 6/60:40), varying span lengths, and mechanical properties of steel and concrete [9], [10].

The structural analysis considers positive and negative bending moments, code-compliant load combinations, verification of limit states, and comparison with allowable values for deflection and stresses. The goal is to generate practical technical criteria to improve structural safety, reduce the risk of failures during construction, and ensure an efficient and safe execution process.

2. Materials and Methods

This study was developed based on the structural modeling of precast prestressed slabs with composite topping (PPCC), using cross-section typologies 6/60:30, 6/60:35, and 6/60:40, commonly applied in floor slabs and roof systems for multi-level buildings. The slabs were evaluated under loading conditions during the casting stage of the topping, a phase in which the system is in a transitional state and has not yet reached its final strength.

To analyze the structural behavior in this critical phase, both ultimate limit states (flexural and shear strength) and serviceability limit states (deflection and stress) were considered. The methodology included the use of structural modeling tools and statistical data processing, integrating specialized software platforms.

Given the range of spans studied, the need for more than two props is considered highly unlikely. Therefore, three shoring variants were defined:

- Variant P0: No shoring required, this $X_0 = l_{pl}$
- Variant P1: Refers to the placement of a single intermediate prop, dividing the precast slab into two equal working spans, each equal to $X_1 = l_{pl}/2$.
- Variant P2: Refers to the placement of two intermediate props, dividing the precast slab into three equal working spans, each equal to $X_2 = l_{pL}/3$.

Figure 1 includes the equations used to evaluate both positive and negative bending moments caused by the load D_{E1} during this stage.

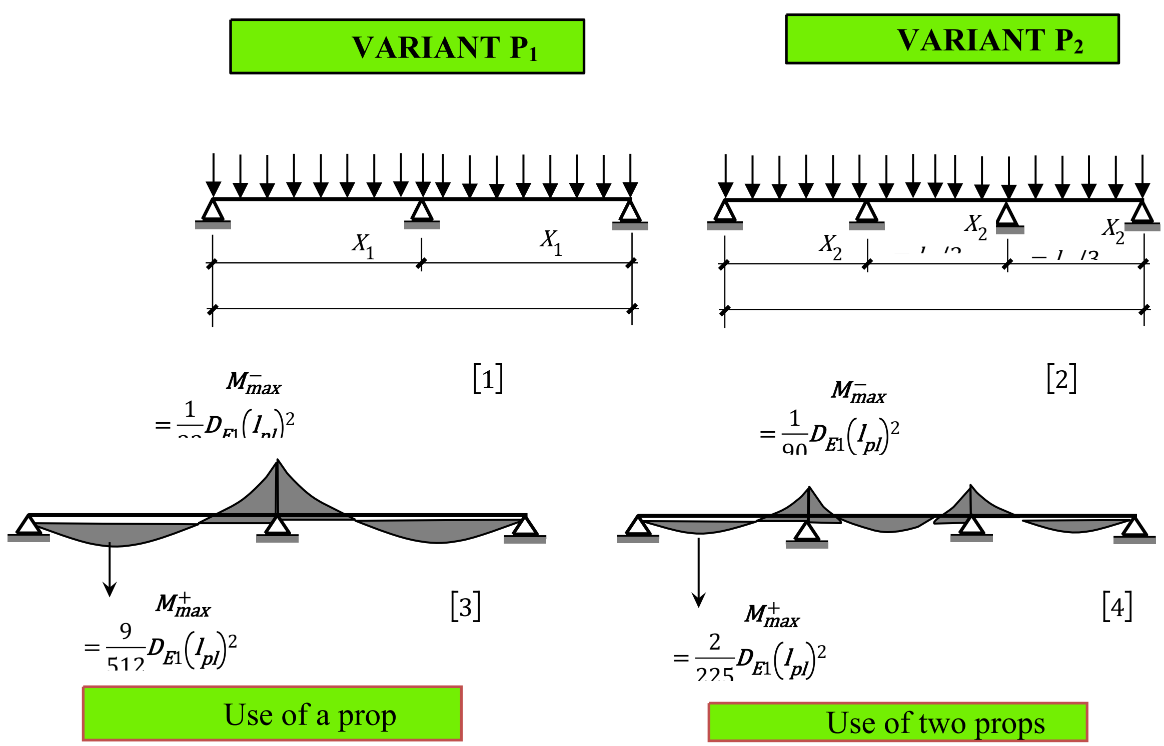

Fig. 1: Shoring variants for the execution stage of the composite topping

When analyzing this stage using a prismatic resistant section and centered prestressing for typologies PPCC: 6/60:35 and PPCC: 6/60:40, or quasi-centered for the case of PPCC: 6/60:30, it is sufficient to consider the positive bending moments acting on the resistant section to determine whether shoring is required.

Table 1: Caption for table goes at the top.

STAGE	SHORING VARIANT	PROP SPACING	ELASTIC MOMENT	M^{+}_{max} , M^{-}_{max}	λ
TOPPING CASTING	NO PROP	l_{pl}	POSITIVE	$M^{+,-}_{max} = \lambda \cdot D_{E1}(l_{pl})^2$	1/8
	ONE PROP	$l_{pl}/2$	POSITIVE		9/512
			NEGATIVE		1/32
	TWO PROPS	$l_{pl}/3$	POSITIVE		2/225
			NEGATIVE		1/90

Determination of the Number of Props to Ensure the Ultimate Limit State of Flexural Resistance

Using equilibrium equations related to ultimate limit states for a rectangular cross-section, as proposed for this stage:

FORCE EQUILIBRIUM::

$$0.85 f'_c \cdot \beta_1 \boldsymbol{c} \cdot b_{virtual} = A_p \cdot f_{ps} \qquad [5]$$

MOMENT EQUILIBRIUM:

$$\boldsymbol{M_n} = 0.85 f'_c \cdot \beta_1 c \cdot b_{virtual}(d - 0.5\beta_1 c) \qquad [6]$$

To estimate the working stress of prestressing steel (fpsf_{ps}fps), the expression defined by the ACI is adopted:

$$f_{ps} = f_{pu}\left[1 - \frac{\gamma_p}{\beta_1}\left(\frac{A_p \cdot}{b_{virtual} \cdot d}\right)\frac{f_{pu}}{f'_c}\right] \qquad [7]$$

Assumptions for calculation::

- Yield-to-ultimate strength ratio:: $\xi = f_{py}/f_{pu} = 0.85 \Longrightarrow \boldsymbol{\gamma_p} = 0.40$
- Concrete strength (same for precast slab and topping): $f'_c = 25\,MPa \;\; \Longrightarrow \boldsymbol{\beta_1} = 0.85$

Design condition: : $M_u \leq \emptyset\, M_n$

If defined as: $M_u = \lambda q l^2_{pl} = \lambda(\gamma_{sD} \cdot D_{E1}) l^2_{pl}$ [8]

Then, for each shoring configuration, defined by the coefficient λ, it must satisfy

$$:\lambda(\gamma_{sD} \cdot D_{E1}) l^2_{pl} \leq \emptyset\, M_n \quad \Longrightarrow \quad \lambda \leq \emptyset\, M_n / \gamma_{sD} \cdot D_{E1} \cdot l^2_{pl} \qquad [9]$$

Procedure to Determine Prop Spacing that Satisfies the Flexural Ultimate Limit State During the Topping Casting Stage.

Table 2: Number of Props Required for the PPCC Slab Typology 6/60:30 During Topping Concrete Casting

DATA: $h_{pl} = 60\,mm$ (Tabla 3.19) $f'_c = 25\,MPa$ $(\beta_1 = 0.85)$			$b_{virtual} = 354\,mm$ $\gamma_{sD} = 1.2$			$d_s = 25\,mm$ (Anexo 3) $k_{bal} = 0.003 / (f_{pu}/E_p - 0.004)$	$(d = h_{pl} - d_s = 35\,mm)$						
PRECAST SLAB DATA						**NUMBER OF PROPS REQUIRED**							
CONCRETE			**STEEL**		**LOAD**	$f_{pu} = 1\,770\,MPa$ $(k_{bal} = 0.619)$				$f_{pu} = 1\,860\,MPa$ $(k_{bal} = 0.566)$			
h_c (mm)	h_t (mm)	d (mm)	TIPOL.	A_p (mm^2)	D_{E1} (N/mm)	PRECAST SLAB (I_{pl})				PRECAST SLAB (I_{pl})			
						3.00 m	3.50m	4.00m	4.50m	3.00m	3.50m	4.00m	4.50m
20	80	35	**T-3^3**	21.21	1.35 (Tabla 3.18)	1	1	1	1	1	1	1	1
			T-5^3	58.89			1	1	1		1	1	1
			T-3^5	35.35		1	1	1	1	1	1	1	1
			T-5^5	98.15			1	1	1		1	1	1
			T-3^2:5^1	33.77		1	1	1	1	1	1	1	1
			T-3^1:5^2	46.33			1	1	1		1	1	1
			T-3^3:5^2	60.47			1	1	1		1	1	1
			T-3^2:5^3	73.03			1	1	1		1	1	1
30	90		**T-3^3**	21.21	1.47 Tabla 3.18)	1	1	1	1	1	1	1	1
			T-5^3	58.89		1	1	1	1	1	1	1	1
			T-3^5	35.35		1	1	1	1	1	1	1	1
			T-5^5	98.15			1	1	1		1	1	1
			T-3^2:5^1	33.77		1	1	1	1	1	1	1	1
			T-3^1:5^2	46.33		1	1	1	1		1	1	1
			T-3^3:5^2	60.47		1	1	1	1		1	1	1
			T-3^2:5^3	73.03			1	1	1		1	1	1
40	100		**T-3^3**	21.21	1.59 (Tabla 3.18)	1	1	1	1	1	1	1	1
			T-5^3	58.89		1	1	1	1	1	1	1	1
			T-3^5	35.35		1	1	1	1	1	1	1	1
			T-5^5	98.15			1	1	1		1	1	1
			T-3^2:5^1	33.77		1	1	1	1	1	1	1	1
			T-3^1:5^2	46.33		1	1	1	1	1	1	1	1
			T-3^3:5^2	60.47		1	1	1	1	1	1	1	1
			T-3^2:5^3	73.03			1	1	1		1	1	1

Table. 3. Number of Props Required for the PPCC Slab Typology 6/60:35 During Topping Concrete Casting

DATA: $h_{pl} = 65\,mm$ **(Tabla 3.19)** $(d = h_{pl} - d_s = 39.6\,mm)$ $f'_c = 25\,MPa$ $(\beta_1 = 0.85)$						$\gamma_{sD} = 1.2$ $b_{virtual} = 364\,mm$		$k_{bal} = 0.003 / (f_{pu}/E_p - 0.004)$		$d_s = 25.4\,mm$ **(Anexo 3)**			
DATOS DE LA PRELOSA						**Slab Typology**							
CONCRETE			**STEEL**		**LOAD**	$f_{pu} = 1\,770\,MPa$ $(k_{bal} = 0.619)$				$f_{pu} = 1\,860\,MPa$ $(k_{bal} = 0.566)$			
			T IPOL.			Slab Typology(I_{pl})				Slab Typology(I_{pl})			
						3 .00m	3 .50m	4 .00m	4 .50m	3 .00m	3 .50 m	4 .00 m	4 .50 m
0	5	39.6	**-3^3**	2 1.21	1.41 (Tabla 3.18)	1	1	1	1	1	1	1	1
			-5^3	5 8.89				1	1			1	1

			-3^5	3 5.35		1	1	1	1		1	1	1
			-5^5	9 8.15				1	1			1	1
			$-3^2:5^1$	3 3.77		1	1	1	1	1	1	1	1
			$-3^1:5^2$	4 6.33			1	1	1		1	1	1
			$-3^3:5^2$	6 0.47				1	1			1	1
			$-3^2:5^3$	7 3.03				1	1			1	1
0	5		**-3^3**	2 1.21	1.53 **Tabla 3.18)**	1	1	1	1	1	1	1	1
			-5^3	5 8.89			1	1	1			1	1
			-3^5	3 5.35		1	1	1	1	1	1	1	1
			-5^5	9 8.15				1	1			1	1
			$-3^2:5^1$	3 3.77		1	1	1	1	1	1	1	1
			$-3^1:5^2$	4 6.33			1	1	1		1	1	1
			$-3^3:5^2$	6 0.47			1	1	1			1	1
			$-3^2:5^3$	7 3.03			1	1	1		1	1	1
0	05		**-3^3**	2 1.21	1.65 **(Tabla 3.18)**	1	1	1	1	1	1	1	1
			-5^3	5 8.89			1	1	1		1	1	1
			-3^5	3 5.35		1	1	1	1	1	1	1	1
			-5^5	9 8.15				1	1			1	1
			$-3^2:5^1$	3 3.77		1	1	1	1	1	1	1	1
			$-3^1:5^2$	4 6.33			1	1	1		1	1	1
			$-3^3:5^2$	6 0.47			1	1	1		1	1	1
			$-3^2:5^3$	7 3.03			1	1	1		1	1	1

Determination of the Number of Shores to Ensure the Ultimate Shear Limit StateBase de cálculo

The evaluation of the ultimate shear limit state is based on verifying that the shear demand VuV_uVu does not exceed the design shear strength ϕVn\phi V_nϕVn, using a strength reduction factor ϕ=0.75\phi = 0.75ϕ=0.75. The shear demand is calculated as: $V_u \leq \emptyset\ V_n$ Siendo $\emptyset = 0.75$

$$V_u = \zeta q l_{pl} = \zeta(\gamma_{sD} \cdot D_{E1}) l_{pl} \qquad [10]$$

The nominal shear strength of the section is estimated using the expression:

$$V_n = 0.17\sqrt{f_c'}(b_{virtual}) d \qquad [11]$$

Thus, to satisfy the structural safety requirements against shear, the following condition must be met:

$$\zeta(\gamma_{sD} \cdot D_{E1}) l_{pl} \leq 0.75\, V_n \quad \Longrightarrow \quad \zeta \leq 0.1275 \frac{(b_{virtual}) d\sqrt{f_c'}}{(\gamma_{sD} \cdot D_{E1}) l_{pl}} \qquad [12]$$

Table 4 presents the values of the coefficient ζ\zetaζ for each shoring scheme, enabling the identification of configurations that require temporary shoring to ensure safety against shear forces during the critical phase of casting the composite topping slab.

Table 4. Coefficients to Evaluate the Maximum Elastic Shear during Topping Casting

STAGE	SHORING VARIANT	SHORE SPACING	V_{max}	ζ
TOPPING CASTING	No Shoring	l_{pl}	$V_{max} = \zeta(D_{E1}) l_{pl}$	1/2
	One Shore	$l_{pl}/2$		3/8
	Two Shores	$l_{pl}/3$		2/5

For the Shear Limit State, the calculations confirm that none of the slab typologies require temporary shoring. For example, consider the verification of the most unfavorable case, corresponding to:

- The slab with the smallest cross-sectio (**PPCC: 6/60:30** $\Longrightarrow$ $b_{virtual} = 354\,mm\,; d = 35\,mm$)
- The maximum span length: ($l_{pl} = 4.50\,m$)
- The thickest topping slab ($h_c = 40\,mm \Longrightarrow D_{e1} = 1.59\,N/mm$)

$$V_u = \zeta(\gamma_{sD} \cdot D_{E1}) l_{pl} = \tfrac{1}{2}(1.2)(1.59\,N/mm)(4500\,mm) = 4\,293\,N \qquad [13]$$

$$V_n = 0.17\sqrt{f_c'}(b_{virtual}) d = 0.17\sqrt{25\,MPa}(354\,mm)(35\,mm) = 10\,532\,N \qquad [14]$$

It is confirmed that even without the use of temporary shoring ($\zeta = 1/2$) he condition for the Shear Limit State is satisfied, i.e. $V_u < 0.75\,V_n$. In fact:: 4 293$\boldsymbol{N} < < 7\,899\boldsymbol{N}$.

The slabs were defined with a modular width of 1.20 m, and a total thickness comprising a 6 cm prestressed precast slab plus a 5 cm cast-in-place composite topping, resulting in a final thickness of 11 cm. The prestressing reinforcement consisted of high-strength steel strands with yield strengths of 1700, 1770, and 1860 MPa. The effective prestress loss was evaluated as a function of three span lengths: 4 m, 5 m, and 6 m.

The independent variables of the analysis were:

s were:

- Span length (L): 4 m, 5 m, and 6 m
- Yield strength of prestressing steel (f_y): 1700, 1770, and 1860 MPa
- Modulus of elasticity of concrete (E_c): 25, 30, and 35 GPa

The dependent variables analyzed were:

- Total prestress loss (%)
- Remaining effective stress in the strands (MPa)

These variables allowed the construction of a response surface that describes the interaction between design parameters and the structural behavior of the slabs during the casting of the topping slab.

Considering that the acting load is of short duration (as the freshly cast concrete begins to set within hours), and neglecting the upward deflection caused by prestress (which is a conservative assumption), and assuming a simply supported beam under a uniformly distributed load, the maximum instantaneous deflection (δ_max**)** occurs at midspan and is evaluated using the following expression:

$$\delta_{max} = \frac{5}{384}\left[\frac{D_{E1}\left(l_{pl}\right)^4}{E_c I}\right] = \frac{5}{384}\frac{(1.59 N/mm)(4\ 500 mm)^4}{\left(4700\sqrt{25 MPa}\right)(6\ 372\ 000 mm^4)} = 56.7 mm \qquad [15]$$

While the maximum allowable deflection is:

$$\Delta_{adm} = \frac{l}{240} = \frac{4\ 500 mm}{240} = 18.9 mm$$

This result ($\delta_{max} > \Delta_{adm}$) onfirms the necessity that, under these conditions — lower stiffness of the precast slab**,** higher acting load**,** and greater span length — the precast slab must be temporarily shored. The next step is to verify whether a single shore is sufficient.

$$\delta_{max} = \frac{1}{3\ 072}\left[\frac{D_{E1}\left(l_{pl}\right)^4}{E_c I}\right] = \frac{1}{3\ 072}\frac{\left(1.59 N/mm\right)\left(4\ 500 mm\right)^4}{\left(4700\sqrt{25 MPa}\right)\left(6\ 372\ 000 mm^4\right)} = 1.41 mm \qquad [13]$$

That is, a single shore placed at mid-span is sufficient to significantly reduce deformation, validating this solution **(**1.41 mm << 18.9 mm**).**

Since these final calculations correspond to the most unfavorable scenario — precast slab with the smallest resistant section**,** subjected to the maximum acting load, and considering the longest span — the analysis for the casting stage of the topping slab can be concluded with the following:

Figure 2 presents a three-dimensional response surface that illustrates the total prestress loss (%**)** in the tendons as a function of two key variables:

- Span length (m): ranging from 4 to 6 meters
- Yield strength of steel (f_y): 1700, 1770, and 1860 MPa

The elastic modulus of concrete was held constant at 30 GPa to isolate the effect of the other two variables.

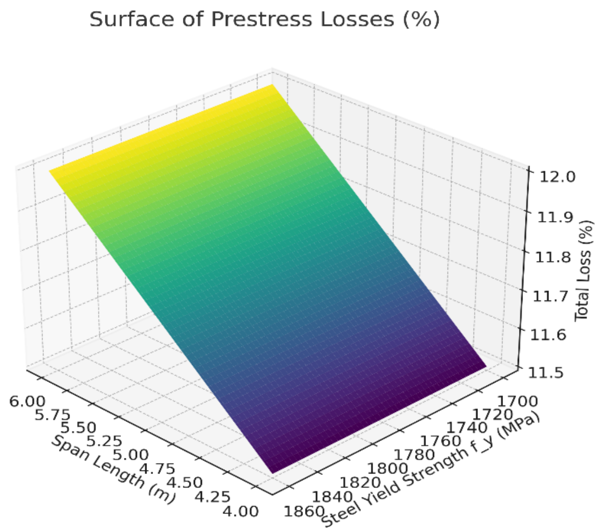

Figure 2. Response surface for total prestress losses as a function of span length and steel yield strength, with concrete modulus of elasticity fixed at 30 GPa.

It is observed that prestress losses increase significantly with span length, which is attributable to greater initial and long-term deformations.
Steels with lower f_y values tend to retain a smaller percentage of prestressing force.
The response surface in Figure 2 helps to identify critical configurations that require temporary shoring to ensure structural safety during the casting of the composite topping slab.
The surface shows a steeper gradient in the span length direction, confirming that span length has a more severe impact than steel type when concrete properties remain constant.
This chart allows the definition of critical zones of prestress loss and justifies the use of temporary shoring for spans longer than 5.5 meters, particularly when high-strength steel is not used.

Figure 3. Effective residual stress (MPa) in the prestressing cable after accounting for all losses, evaluated under the same range of variables:

- Span length (m): from 4 to 6 m
- *Steel yield strength* (f_y)*: from* 1700 *to* 1860 *MPa*
- Concrete modulus of elasticity (E_c): constant at 30 GPa

Bicubic interpolation was used to generate a smoothed surface, which facilitates the interpretation of gradual transitions.

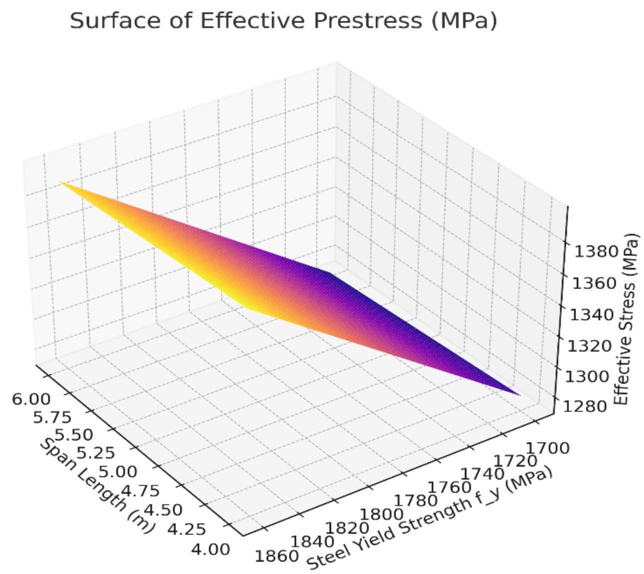

Figure 3. Smoothed response surface of residual effective stress as a function of span length and steel yield strength, with the concrete modulus of elasticity fixed at 30 GPa.

- The effective stress decreases as the slab span increases, particularly when lower-strength prestressing steel is used.
- Using steel with $f_y \geq$ 1860 MPa (high yield strength) helps preserve higher levels of prestress, making it ideal for critical construction stages.
- The smoothed surface enables continuous visualization of variable interactions to evaluate optimal structural alternatives.

The structural models were developed in **ETABS** and **SAP2000** to determine maximum bending moments and vertical reactions under load combinations specified in **ACI 318-19**.
Subsequently, a manual verification of limit states was carried out, considering:

- Critical load combination: **1.2 Dead Load + 1.6 Live Load**
- Deflection limit: **L/360 (ACI 318)**
- Admissible stresses in steel and concrete during the construction phase

The minimum number of required temporary props was validated through successive iterations, using matrix-based methods and comparative analysis with reference models [11], [5].

Finally, **multivariable interpolation** was applied to generate response surfaces, integrating **Python** and **MATLAB** to visualize the combined influence of the three independent variables on stress losses and effective tension.
The graphs were presented in a smoothed format with normalized scales and exported in vector format for technical and academic analysis.

ANÁLISIS ANOVA

Table 5 presents the statistical analysis performed using ANOVA for the two response variables: **total prestress losses (%)** and **residual effective stress (MPa)**. The evaluated factors were **span length (L)**, **steel yield strength** (f_y) and concrete modulus of elasticity (E_c).

Table 5 displays the statistical ANOVA results for both response variables.

Source	Sum sq Loss	Df Loss	F Loss	PR(>F) Loss	Sum sq Stress	Df Stress	F Stress	PR(>F) Stress
C(L)	8.9489	2.0000	251.6875	0.0001	5133.3756	2.0000	299.9246	0.0000
C (f_y)	1.9622	2.0000	55.1875	0.0012	18117.2956	2.0000	1058.5280	0.0000
C (E_c)	8.9489	2.0000	251.6875	0.0001	5133.3756	2.0000	299.9246	0.0000
Residual	0.0711	4.0000	nan	nan	34.2311	4.0000	nan	nan

- In the ANOVA framework, the F-statistic indicates the ratio between the variability explained by a factor and the variability attributed to error.
- An F-value close to 1 suggests that the factor does not significantly contribute to variability; in contrast, much higher F-values indicate that the factor has a statistically significant effect on the dependent variable.
- Statistical significance is formally determined by comparing the observed F-value with the critical values of the F-distribution, and by evaluating the associated p-value.

ANOVA Analysis

The ANOVA results indicate that the three variables (L, f_y y E_c), have statistically significant influence on both prestress losses and the effective residual stress. For prestress losses, span length and concrete elastic modulus had similar contributions (F = 251.69), while the influence of steel yield strength was somewhat lower (F = 55.19). In contrast, effective stress was strongly determined by the steel's yield strength (F = 1058.53), highlighting the critical importance of selecting high-strength prestressing tendons. These findings confirm the multivariable dependence of the structural response and validate the use of response surface models to assess performance during critical construction stages.

Graphical Representation

Figure 4 illustrates the F-statistics derived from the ANOVA analysis for each influencing variable on both responses. It is evident that fy has the most significant influence on effective stress, while L and Ec show comparable influence on prestress losses.

Figure 4 illustrates the F-statistics derived from the ANOVA analysis for each influencing variable on both responses

Resultados y Discusión

Prestress losses in the tendons increase proportionally with the span length of the slab. This behavior is consistent with previous studies that identify a direct relationship between initial deformation of the system and the need for temporary shoring [5], [7], [12]. The magnitude of these losses increases the risk of structural failure if no temporary measures are taken, as highlighted by several researchers emphasizing the importance of considering transient states in precast systems.

The generated response surfaces revealed significant trends. For shorter spans (4 m), total losses remained below 12%, whereas for spans of 6 m, losses exceeded 13.5%, significantly reducing the effective stress available to resist loads [2], [6], [4]. This aligns with findings in hybrid floor systems that emphasize the importance of limiting free span to avoid excessive deflections.

The use of high-strength steel (1860 MPa) showed a clear advantage over 1700 and 1770 MPa steels, allowing for a greater percentage of effective stress retention even under adverse conditions. This is consistent with technical literature recommending high-performance steels for structures under critical construction phases [13], [1], [9]. Moreover, steel quality is confirmed as a determining factor in mitigating initial losses, supported by tensile tests and nonlinear simulations.

Additionally, the elastic modulus of concrete had a measurable impact. Stiffer concretes (E_c = 35 GPa) contributed to reducing shortening losses compared to more deformable concretes (E_c = 25 GPa). This effect has been corroborated by several authors through experimental and numerical analysis of hybrid composites [8], [1], [10].

The smoothed response graphs facilitated a three-dimensional interpretation of the results, revealing nonlinear interactions between variables. These tools enable structural designers to make informed decisions based on clear visualizations of critical service conditions [4], [2], [10].

Based on these findings, the use of temporary shoring is recommended for prestressed slabs with spans greater than 5.5 m, especially when using low-modulus concretes or steels with f_y below 1770 MPa. This preventive measure can reduce the risk of local collapse, avoid excessive deflections, and optimize the efficiency of the construction system [5], [6], [12].

Conclusiones

The structural analysis of prestressed slabs with composite topping (PPCC) during the casting phase confirmed that this stage represents a critical condition in slab performance. Prestress losses in the tendons—mainly influenced by span length, steel type, and concrete stiffness—can compromise the fulfillment of limit states if appropriate preventive actions are not taken.

The response surface results show that spans greater than 5.5 m significantly increase total prestress losses. In such cases, the use of temporary shoring is essential to maintain structural safety, especially when using concrete with low modulus or steel with f_y below 1770 MPa.

Using high-strength steel ($f_y \geq$ 1860 MPa) and higher modulus concrete ($E_c \geq$ 30 GPa) helps mitigate effective stress losses, optimizing slab strength without oversizing the shoring system. This not only improves technical performance but also offers a cost-effective solution for floor and roof systems in mid- and high-rise buildings.

The computational tools used—MATLAB, Python, ETABS, and SAP2000—proved effective in modeling, analyzing, and visualizing multivariable behaviors in the structural system. In particular, response surfaces helped understand the combined effect of structural variables and offer a robust method for decision-making in structural design.

Finally, this research highlights the need to incorporate transient state analysis criteria into design codes for precast slabs, aiming to standardize the rational use of temporary shoring and ensure structural safety from the construction stage.

Based on the calculations, the following conclusions are drawn for the composite slab casting stage:

- For the Shear Strength Limit State, no shoring is required.
- For the Serviceability Limit State related to Normal Stresses, no shoring is needed.
- For the Serviceability Limit State related to Deflection, only one prop is required in the most unfavorable scenario.
- For the Flexural Strength Limit State, shoring is required as proposed in the studied variants, never exceeding one prop.

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