

Standard Requirements for Design of Shallow Post-Tensioned Concrete Foundations on Expansive Soils

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1.0 – SCOPE

This standard provides minimum requirements for design of shallow post-tensioned concrete foundations built on expansive soils.

1.1 – Design shall be based upon controlling moments (M_L and M_S), shears (V_S and V_L), and differential deflections (Δ_o) for edge lift and center lift swell modes as determined by “*Standard Requirements for Analysis of Shallow Concrete Foundations on Expansive Soils*”, 3rd Edition, Post-Tensioning Institute, Phoenix, Arizona, May 2008.³ Alternatively, if soil parameters e_m and γ_m have been calculated by the method specified in Appendix A.3 of “*Design and Construction of Post-Tensioned Slabs-on-Ground*”, 2nd Edition¹⁴ in accordance with 5.3 of the “*Standard Requirements for Analysis of Shallow Concrete Foundations on Expansive Soils*”, design shall be based upon controlling moments (M_L and M_S), shears (V_S and V_L), and differential deflections (Δ_o) for edge lift and center lift swell modes as determined by the procedure set forth in the “*Design and Construction of Post-Tensioned Slabs-on-Ground*”, 2nd Edition.¹⁴

R1.0 – SCOPE

Post-tensioned residential concrete foundations designed by this standard generally conform to the requirements for plain concrete specified in Chapter 22 of ACI 318-02². These foundations will typically contain less reinforcement, prestressed and non-prestressed, than the ACI 318-02 requirements for reinforced concrete. This standard is intended to be a stand-alone document, uniquely developed for the design of post-tensioned concrete foundations on expansive soils and is supported by the performance of many thousands of existing conformant foundations. As such, it is intended that this standard be independent of ACI 318-02 and the conflicting parts of the general building code into which this standard is incorporated.

Shallow post-tensioned concrete foundations are commonly used in residential construction, usually up to three stories in height, and in light commercial construction. The limit of applicability of these provisions is established by limits on the perimeter load P (see **4.3.5**).

This standard is based upon “*Design of Post-Tensioned Slabs-on-Ground*”, 3rd Edition, Post-Tensioning Institute, Phoenix, Arizona, 2004¹ and the user is referred to that document and the commentary to this standard for background and interpretational information which clarify its application.

R1.1 – All requirements contained in the referenced standard document are applicable to all shallow concrete foundations built on expansive soils, regardless of type of reinforcement, including the soil model, minimum requirements for geometry, procedure for determining internal forces and deflections, and additional notation, definitions, and commentary.

In Section 5.3 of the Standard Requirements for Analysis of Shallow Concrete Foundations on Expansive Soils, the designer is permitted to use the 2nd Edition method to determine the soil parameters, e_m and γ_m . This option has been provided to finalize the transition period from the old 2nd Edition method to the 3rd Edition method, and to allow for the completion of existing projects issued under the 2nd Edition. However, while the 2nd Edition design procedure used in its entirety will give appropriate results, soil parameters calculated by the 2nd Edition method must not be used with the 3rd Edition structural design procedure as set forth in this Standard.

2.0 – NOTATION

- A = Area of gross concrete cross-section in direction being considered, in²
- A'_b = Maximum area of the portion of the bearing surface that is geometrically similar to and concentric with the tendon anchorage, in²
- A_b = Bearing area beneath a tendon anchorage, in²
- A_{bm} = Total area of rib concrete = $n b h$, in²
- A_{ps} = Total cross-sectional area of prestressed reinforcement, in²
- A_s = Total cross-sectional area of non-prestressed reinforcement, in²
- b = Width of individual rib, in.
- C_{Δ} = Coefficient used to establish minimum foundation stiffness (see **Table 2**)
- CR = Prestress loss due to creep of concrete, kips
- E_c = Modulus of elasticity of concrete = $33w^{1.5}\sqrt{f'_c}$ psi
- E_{cr} = Long-term or creep modulus of elasticity of concrete, psi. Unless more refined calculations are used, may be taken as one-half E_c
- ES = Prestress loss due to elastic shortening of concrete, kips
- e_p = Eccentricity of post-tensioning force (distance between the CGS and the CGC, positive when CGS is above CGC, negative when CGS is below CGC), in.
- e = Base of natural (Naperian) logarithms
- f = Applied flexural concrete stress (tension negative, compression positive), psi
- f'_c = Specified compressive strength of concrete, psi
- f'_{ci} = Concrete compressive strength at time of stressing tendons, psi

R2.0 – NOTATION

Equations in this standard are unit-specific, i.e., variables must be entered with units specified in this section.

Unless specifically stated otherwise, all foundation parameters (geometry, internal forces, prestress force, reinforcement, etc.) are based upon the entire cross-section or full width of the section being designed.

- f_{bp} = Allowable bearing stress under tendon anchorages, psi
- f_c = Allowable compressive flexural stress in concrete, psi
- f_{pc} = minimum average effective compressive stress due to prestress = $\frac{1,000P_r}{A}$, psi
- f_{pu} = Specified tensile strength of prestressing steel, psi
- f_{py} = Specified yield strength of prestressing steel, psi
- f_t = Allowable flexural tension stress in concrete, psi
- f_y = Specified yield strength of non-prestressed reinforcement, psi
- h = Total depth of rib, measured from top surface of slab to bottom of rib, in.
- H = Total depth of a uniform thickness foundation, in
- I = Gross moment of inertia of cross-section, in⁴
- L = Total foundation length (or total length of design rectangle) in direction being considered (short or long), perpendicular to W , ft
- L_L = Long length of design rectangle, ft
- L_S = Short length of design rectangle, ft
- M_L = Maximum applied service load moment in long direction from either center lift or edge lift swelling condition, positive if producing tension at bottom of foundation (edge lift), negative if producing tension at top of foundation (center lift), ft-kips/ft
- M_S = Maximum applied service load moment in short direction from either center lift or edge lift swelling condition, positive if producing tension at bottom of foundation (edge lift), negative if producing tension at top of foundation (center lift), ft-kips/ft
- n = Number of ribs in a cross-section of width W

n_T = Total number of tendons in short or long direction

P = A uniform unfactored line load acting along entire length of perimeter ribs which includes the weight of the exterior wall and that portion of superstructure dead and live loads which frame into exterior wall, excluding any portion of foundation concrete weight (see **4.3.5**), lb/ft

P_e = Effective prestress force after losses due to elastic shortening, creep and shrinkage of concrete, and steel relaxation, kips

P_r = Effective prestress force after losses due to tendon friction, elastic shortening, creep and shrinkage of concrete, steel relaxation, and subgrade friction (see **4.0**), kips

P_i = Prestress force in tendon immediately after stressing and anchoring tendons, considering effects of tendon friction (see **4.0**), kips

P_s = Prestress force at jacking end immediately before anchoring tendons, (see **4.0**), kips

q_{allow} = Allowable soil bearing pressure, psf

RE = Prestress loss due to steel relaxation, kips

S = Interior stiffening rib spacing used for moment and shear equations, ft. (see **4.3.2.2**)

SF = Shape Factor = $\frac{(\text{Foundation Perimeter})^2}{(\text{Foundation Area})}$

where foundation perimeter is in ft and foundation area is in ft²

SG = Reduction in compressive force on concrete cross-section caused by subgrade friction, kips

SH = Prestress loss due to concrete shrinkage, kips

S_B = Section modulus with respect to bottom fiber, in³

S_T = Section modulus with respect to top fiber, in³

t = Slab thickness in a ribbed foundation, in.

V = Controlling shear force under service load, larger of V_S or V_L , kips/ft

Subgrade friction (SG) does not directly affect the force in the prestressing steel, but it does affect the axial force acting on the concrete cross-section and, for convenience, can be grouped with the other losses in prestress force.

Typically $P_s = 0.8 A_{ps} f_{pu}$

- V_L = Maximum shear force in long direction under service load from either center lift or edge lift swelling condition, kips/ft
- V_S = Maximum shear force in short direction under service load from either center lift or edge lift swelling condition, kips/ft
- v = Applied shear stress under service load, psi
- v_c = Allowable shear stress in concrete, psi
- W = Foundation width (or width of design rectangle) in direction being considered (short or long), perpendicular to L , ft
- W_{slab} = Foundation weight, lb
- w = unit weight of concrete, lb/ft³
- z = smaller of L or 6β in direction considered, ft
- β = Approximate distance from edge of foundation to point of maximum moment and/or shear, based on relative stiffness of soil and foundation = $\frac{1}{12} \sqrt[4]{\frac{E_c I}{1,000}}$, ft
- μ = Coefficient of friction between foundation and subgrade (see 4.1)

2.1 ABBREVIATIONS

- CGC = Geometric centroid of gross concrete section
- CGS = Center of gravity of prestressing force

3.0 – DEFINITIONS

Center Lift: A soil swell mode wherein soil moisture content at perimeter of foundation is less (drier) than soil moisture content at the center of the foundation.

Edge Lift: A soil swell mode wherein soil moisture content at perimeter of foundation is more (wetter) than soil moisture content at the center of the foundation.

Geotechnical Engineer: Design professional preparing the soil report and foundation recommendations.

Ribbed Foundation: A foundation system consisting of a uniform thickness slab with stiffening ribs satisfying the requirements of **4.3.2** projecting from bottom of slab in both directions. Slab and ribs are considered to act monolithically.

Stiffness: For purposes of this standard, product of E_{cr} and I .

Uniform Thickness Foundation: A foundation system consisting of a solid slab of uniform thickness throughout, with no required ribs.

4.0 – GENERAL

4.1 – Loss of Prestress – Effective prestress force after all losses shall be:

$$P_r = P_i - ES - CR - SH - RE - SG$$

where, in lieu of a more detailed analysis:

$$P_i = \frac{P_s}{1 + 0.002L}$$

$$SG = \frac{W_{slab}}{2000} \mu$$

R4.1 - Loss of Prestress – ES , CR , SH , and RE can be calculated with generally accepted methods for estimating losses in prestressed concrete, as described in Reference 4. Total prestress loss (after effects of tendon friction) is the sum of ES , CR , SH , and RE .

The expression for P_i assumes a high-side friction “wobble” coefficient of 0.002 (see ACI 318-02 Table R18.6.2), and one-end tendon stressing (i.e., P_i is assumed to act at the far end of the tendon).

Subgrade friction SG does not directly affect the tendon force; however it has the same effect as reducing the prestress force acting on the concrete cross-section and therefore, for simplicity, can be conveniently and mathematically grouped with the other factors that do actually affect the force in the tendon. The expression for SG represents the maximum effect of subgrade friction, which occurs at the center of the foundation, where the frictional force resisting movement is based upon the weight of half of the slab, i.e. $W_{slab}/2$.

Both of these values are conservative since the location of maximum moment is one β -length inward from the edge of the foundation. A more detailed analysis of tendon friction and subgrade friction, reflecting the tendon force at the actual location of maximum moment, is permitted.

For normal construction practices, μ should be taken as 0.75 for slabs on polyethylene and 1.0 for slabs cast directly on a sand base.

4.2 – Overlapping Rectangles – Design criteria specified in this standard are based upon a rectangular ribbed foundation. Foundation shapes that do not consist of a single rectangle shall be modeled with overlapping design rectangles that are as large as possible, within the actual foundation footprint, with each design rectangle analyzed separately. Each design rectangle shall have slab and rib geometry consistent with that of the actual foundation within the area of the design rectangle. The properties of the controlling design rectangle (concrete geometry and prestress force) shall be applied to the entire foundation plan.

4.3 – Ribbed Foundations – Calculations for ribbed foundations shall be based upon criteria specified in **4.3.1** through **4.3.5**. Geometry resulting in larger gross section properties may be used for actual construction.

4.3.1 – Minimum Slab Thickness – Minimum slab thickness t shall be 4 in.

4.3.2 – Ribs

4.3.2.1 – Minimum Size

(a) **Depth** – Minimum rib depth h shall be the larger of $(t + 7)$ in. or 11 in. When more than one rib depth is used in actual construction, ratio between the deepest and the shallowest rib depths shall not exceed 1.2.

(b) **Width** – Rib width b used in section property calculations shall be the actual rib width, subject to a minimum of 6 in. and a maximum of 14 in. Rib widths may vary within the specified ranges.

4.3.2.2 – Spacing - S used in moment and shear equations shall be the average rib spacing if the ratio between the largest and the smallest spacing does not exceed 1.5. If the ratio between the largest and the smallest spacing exceeds 1.5, S used in moment and shear equations shall be 0.85 times the largest spacing. S

R4.2 – Overlapping Rectangles – Primary attention should be given to rectangles that most reasonably represent the main portion of the foundation. Long narrow rectangles may not represent the overall foundation and in most cases should not govern the design. For examples illustrating the use of the overlapping rectangle procedure, see Reference 1.

If SF exceeds 24, the designer should consider modifications to foundation foot print, strengthened foundation systems, soil treatment to reduce swell or the use of additional non-prestressed reinforcement and/or additional ribs in areas of high torsional stresses. Analysis by finite element procedures may also be used in the case of SF>24.

R4.3 – Ribbed Foundations – Frost depth often requires the use of perimeter ribs that are substantially deeper than required in the design for expansive soil movement. Designers should consider the use of additional reinforcement in these deeper rib sections.

R4.3.2.1(a) – Minimum Size - The equations for internal forces and deflections in this standard were derived assuming a uniform moment of inertia across the full width of the foundation, implying that all ribs are the same depth⁵. Successful experience exists, however, supporting the use of different rib depths in design (such as a deeper edge rib), provided that the depths do not vary by more than 20%.

used in the moment and shear equations shall not be less than 6 ft or greater than 15 ft. The rib spacing used in the section properties shall be the actual rib spacing but not greater than 15 ft.

4.3.2.3 – Continuity – Ribs shall be continuous between the edges of the foundation in both directions.

4.3.3 – Minimum Prestress Force - The effective prestress force P_e shall not be less than $0.05A$ (kips).

4.3.4 – Soil Bearing Pressure - Applied soil bearing pressure shall be the entire dead and live load from the superstructure and the foundation divided by the bearing area of ribs plus a portion of the slab equal to 16 times the slab thickness for interior ribs and 6 times the slab thickness for edge ribs. The applied soil bearing pressure shall not exceed q_{allow} as specified by the geotechnical engineer.

4.3.5 – Perimeter Load –When P varies, and the ratio between largest and smallest exceeds 1.25, use largest value for center lift design and smallest value for edge lift design.

R4.3.2.3 – Continuity – To be considered as a continuous rib in the design rectangle the rib should (a) be continuous, or (b) overlap a parallel rib with adequate length and proximity so as to be effectively continuous, or (c) be connected to a parallel rib by a perpendicular rib which transfers by torsion the bending moment in the rib.

R4.3.3 – Minimum Prestress Force - If excessive shrinkage cracking is anticipated the designer should consider increasing the minimum force to $0.1A$ (kips) and details to minimize restraint to shortening.

R4.3.4 - Soil Bearing Pressure - See Reference 1 for examples of the calculation of bearing area in accordance with this section.

R4.3.5 – The mathematical analysis forming the basis for the equations for internal forces and deflections in this standard⁵ considered perimeter loads between 600 and 1,500 lb/ft. Based upon successful experience with foundations built with perimeter loads up to and exceeding 2,500 lb/ft and designed using these equations, the PTI Slab-on-Ground Committee is confident that the equations will yield reasonable results for perimeter loads in excess of those used in the research. It should be noted that the definition of P includes dead **and** live load in both swell modes. Removing live load in the edge lift swell mode may result in unnecessarily conservative edge lift moments, since the equations in this standard were derived from foundation deformation computations that considered the foundation loaded with both dead and live load. In the edge lift swell mode designers may use dead load and sustained live load, or dead load only, if either is judged to be appropriate.

4.4 – Uniform Thickness Foundations – Any ribbed foundation conforming to all requirements of this standard (except **4.3.4** and **7.2**) may be converted to an equivalent uniform thickness foundation. Converted uniform thickness foundations shall satisfy all requirements of **7.0**, **8.0**, and **9.0**.

R4.4 – Uniform Thickness Foundations – When converting a ribbed foundation to a uniform thickness foundation, the ribbed foundation must satisfy all requirements applicable to ribbed foundations, with the exception of soil bearing (see **4.3.4**) and cracked section provisions (see **7.2**). The converted uniform thickness foundation must conform to the flexural stress criteria in Section **7.0** (including the cracked section requirements in **7.2**), shear criteria in Section **8.0**, and minimum stiffness requirements in Section **9.0** (note that β distances can be different in the conformant ribbed foundation and the converted uniform thickness foundation).

4.4.1 – Uniform Thickness Foundation Conversion Minimum thickness shall be:

R4.4.1 – Uniform Thickness Foundation Conversion -The conversion from ribbed to uniform thickness foundation is based upon equal moments of inertia. Units of the uniform thickness conversion equation are not immediately obvious. The equation is derived as follows: The gross moment of inertia (in units of in⁴) for a rectangular uniform thickness foundation is $\frac{(12W)H^3}{12}$

$$H = \sqrt[3]{\frac{I}{W}}$$

H shall not be less than 7-1/2 in. unless a continuous rib, conforming to **4.3.2.1**, is provided along the entire perimeter.

where W is in feet and H is in inches. Equating this to the moment of inertia of the ribbed foundation I (also in units of in⁴), and eliminating the constants 12 in both numerator and denominator, yields: $I = WH^3$

Solving for H :
$$H = \sqrt[3]{\frac{I}{W}}$$

where H is in in., I is in in⁴, and W is in ft

4.4.2 – Minimum Prestress Force – The effective prestress force P_e shall not be less than $0.6HW$.

R4.4.2 – Minimum Prestress Force - The required minimum force per unit of cross-sectional area in the uniform thickness foundation is the same as for the ribbed foundation (**4.3.3**). This results in substantially larger total prestress force in the uniform thickness foundation than in the equivalent ribbed foundation, since the cross-sectional area of the uniform thickness foundation is always larger than that of the ribbed foundation.

4.4.3 – Soil Bearing Pressure - Applied soil bearing pressure shall be the entire dead and live load from the superstructure and foundation divided by the entire plan area of foundation. The applied soil bearing pressure shall not exceed q_{allow} as specified by the geotechnical engineer.

4.5 - Cover to Reinforcement - Minimum concrete cover to tendons and non-prestressed reinforcement shall be:

4.5.1 In foundations cast on soil or sand, 1 in. from bottom, top, or edges of slabs or ribs.

4.5.2 In foundations cast on a vapor retarder, 3/4 in. from bottoms or edges of slabs or ribs, and 1 in. from top of slabs or ribs.

5.0 – MATERIALS

5.1 – Concrete

5.1.1 – Concrete shall have a minimum specified compressive strength of 2,500 psi at 28 days. Exposure conditions may require higher strength (see **6.0**).

5.1.2 – Admixtures containing calcium chloride shall not be used.

5.2 – Reinforcement

5.2.1 – Prestressed Reinforcement

5.2.1.1 – Prestressing steel shall conform to ASTM A 416⁶.

5.2.1.2 – Allowable Stresses

(a) At Jacking Force – Tensile stress shall not exceed $0.94f_{py}$ or $0.80f_{pu}$.

(b) Immediately After Prestress Transfer – Tensile stress at anchorage devices shall not exceed $0.70f_{pu}$.

5.2.2 - Non-Prestressed Reinforcement

5.2.2.1 – Deformed reinforcement shall conform to ASTM A 615⁷, Grade 40 or 60 or ASTM A 706⁸.

5.2.2.2 – Welded wire reinforcement shall conform to ASTM A 185⁹.

5.3 – Anchorages and Couplers

5.3.1 – Anchorages and couplers shall conform to "Specifications for Single-Strand Unbonded Tendons," Post-Tensioning Institute, May, 2003¹⁰, Section 2.2. See **6.2** for additional requirements in aggressive environments.

5.3.2 – Bearing stress under anchorages shall not exceed:

At transfer of prestress force:

$$f_{bp} = 0.8f'_{ci} \sqrt{\frac{A'_b}{A_b}} - 0.2 \leq 1.25f'_{ci}$$

Where: Actual Bearing Stress = $\frac{P_i}{n_T A_b}$

After all prestress losses:

$$f_{bp} = 0.6f'_c \sqrt{\frac{A'_b}{A_b}} \leq f'_c$$

Where: Actual Bearing Stress = $\frac{P_e}{n_T A_b}$

6.0 – DURABILITY

6.1 – Foundation concrete exposed to freezing and thawing or to deicing chemicals shall have a minimum specified compressive strength of 3,000 psi at 28 days.

6.2 – Concrete in direct contact with soil containing water-soluble sulfates or chlorides shall conform to the following:

6.2.1 -- Soil Sulfates

6.2.1.1 – For soil sulfate concentrations greater than or equal to 0.1% but less than 0.2% by weight, concrete shall be made with Type II or V cement.

6.2.1.2 – For soil sulfate concentrations equal to or greater than 0.2% by weight, concrete shall be made with Type V cement (or approved equivalent) and shall have a minimum compressive strength of 3,000 psi at 28 days.

6.2.1.3 – Concentrations of water-soluble soil sulfates shall be determined by California DOT Test 417¹¹, or other current test method recognized in the governing building code or commonly used in the geographic area of the project.

R6.2 – When a moisture control barrier such as a polyethylene vapor retarder is placed between the concrete and the soil, the concrete is not considered to be in direct contact with soil within the context of Section **6.2**.

6.2.2 -- Soil Chlorides

When concrete is in direct contact with soil containing concentrations of chloride ions in excess of 500 ppm, as determined by California DOT Test 422¹² or other current test method recognized in the governing building code or commonly used in the geographic area of the project, the tendons and reinforcing steel shall be protected from corrosion by either **6.2.2.1**, **6.2.2.2**, or **6.2.2.3**.

6.2.2.1 – Use of minimum concrete cover in accordance with **Table 1**.

R6.2.2 – the California Department of Transportation (CALTRANS) in its “*Corrosion Guidelines*”¹⁵ defines a site as corrosive if chloride concentration in the soil is greater than or equal to 500 ppm.

R6.2.2.1 – **Table 1** is derived from Table 8.22.1 of the California Department of Transportation’s Bridge Design Specifications¹⁶

Table 1 - Recommended Minimum Concrete Cover for Corrosive Soil

	Chloride Concentration (ppm)		
	500 - 5,000	5,001 - 10,000	>10,000
Minimum Concrete Cover	3 in.	4 in.	5 in.

The above minimums are not required if encapsulated tendons are used per 6.2.2.2 and/or other means of mitigating corrosion are used per 6.2.2.3, unless otherwise specified.

6.2.2.2 - Use of encapsulated tendons in conformance with “*Specifications for Single-Strand Unbonded Tendons*”, Post-Tensioning Institute, May 2003,¹⁰ Section 2.2.6.

6.2.2.3 – Other means of mitigating corrosion as approved by the Engineer.

R6.2.2.3 –ACI Report 222.3R-03 “*Design and Construction Practices to Mitigate Corrosion of Reinforcement in Concrete Structures*”¹⁷ describes a variety of techniques that may be used to protect steel embedded in concrete against corrosion.

7.0 – FLEXURE

Concrete flexural stresses shall be calculated as follows:

$$f = \frac{1,000P_r}{A} \pm \frac{12,000M_{L,S}}{S_{T,B}} \pm \frac{1,000P_r e_p}{S_{T,B}}$$

7.1 – Concrete flexural stress calculated in accordance with 7.0 shall not exceed the following:

Tension: $f_t = 6 \sqrt{f'_c}$

Compression: $f_c = 0.45 f'_c$

R7.0 – FLEXURE

Sign convention used in this standard considers concrete tension stresses as negative, compression stresses positive.

7.2 – Cracked Sections – Sufficient reinforcement, prestressed or non-prestressed and in any combination, shall be provided to develop $0.5M_L$ and $0.5M_S$ for both swell modes, using conventional cracked section flexural strength methods, with a ϕ factor of 1.0.

R7.2 – Cracked Sections – This requirement ensures that uncracked and cracked section capacities are equivalent. Because of the post-cracking increase in soil support adjacent to the crack, equivalency does not require reinforcing for the full values of M_L and M_S . After considerable study, the Committee felt that reasonable equivalency is provided throughout a wide range of soil and foundation parameters by providing reinforcing for $0.5M_L$ and $0.5M_S$. Reference 13 addresses types of cracking and their ramifications in post-tensioned residential foundations.

7.2.1 - Tensile force in prestressed reinforcement shall be taken as P_e and tensile force in non-prestressed reinforcement shall be taken as $A_s f_y$.

7.2.2 – Non-prestressed reinforcement, if required, shall be placed perpendicular to the perimeter of the foundation, starting with minimum concrete cover from foundation edge, and extending inward with a minimum length of 2β .

8.0 – SHEAR

Applied concrete shear stress v produced by V_L or V_S shall be calculated as follows:

R8.0 – SHEAR

Area resisting applied shear is based upon the web area of the ribs alone, consistent with generally accepted structural engineering practice.

8.0.1 – Ribbed Foundations

$$v = \frac{1000(V_L \text{ or } V_S)}{nbh}$$

8.0.2 – Uniform Thickness Foundations

$$v = \frac{1000(V_L \text{ or } V_S)}{A}$$

8.1 – Applied shear stress v calculated in accordance with **8.0** shall not exceed the following:

$$v_c = 2.4\sqrt{f'_c} + 0.2f_p$$

9.0 – STIFFNESS

Foundation stiffness $E_{cr}I$ in both short and long directions and for both soil swelling modes, shall conform to the following:

R9.0 – STIFFNESS

Differential foundation deflection is controlled by providing minimum foundation stiffness in accordance with the equation presented, which is applicable to both edge lift and center lift swell modes.

$$E_{cr} I_{L \text{ or } S} \geq 12,000 M_{L \text{ or } S} L_{S \text{ or } L} C_{\Delta} z_{L \text{ or } S}$$

9.1 - C_{Δ} values specified in **Table 2** for prefabricated roof trusses may be waived, and smaller values based upon the appropriate superstructure material may be used, if joinery details are specified that permit relative vertical movement between prefabricated roof trusses and intersecting non-bearing partition walls while providing required lateral bracing.

This equation was derived by relating permissible deflection and the slab length over which it occurs (from previous editions of PTI's "Design and Construction of Post-Tensioned Slabs-on-Ground") to an assumed parabolic shape. The committee feels this method for controlling differential deflections, which directly relates foundation stiffness to permissible curvatures and deflections, is simpler and reasonably equivalent to differential deflection criteria presented in previous editions. The minimum stiffness $E_c I$ required should be determined for each direction considering both swell modes.

Reference 18 discusses the relationship between construction effects and actual deflections in greater detail.

R9.1 - The PTI Slab-on-Ground Committee is aware of significant problems (severe drywall cracking, large wall/ceiling separations) in residential wood-framed structures with prefabricated long-span roof trusses when the trusses are rigidly attached to non-bearing partition walls between the truss supports. In that case, even a small relative vertical movement between the two ends of the extremely rigid trusses can cause distress. To mitigate this condition, **Table 2** requires very high C_{Δ} values (resulting in very large required stiffnesses) when prefabricated roof trusses are used, regardless of the superstructure material. As a preferable alternative to these restrictive C_{Δ} values in **Table 2**, joinery details can be provided between the trusses and the intersecting non-bearing partitions which permit relative vertical movement without inducing stress into the partitions.

Smaller values of C_{Δ} may be used for other superstructure materials listed in **Table 2** if effective jointing details are used to minimize cracking, such as closely spaced control joints in brick or stucco walls.

Table 2 – Stiffness Coefficient C_{Δ}

Superstructure Material	Center Lift	Edge Lift
Wood Frame Without Plaster	240	480
Stucco or Plaster	360	720
Brick Veneer	480	960
Concrete Masonry Units	960	1,920
Prefabricated Roof Trusses ¹	1,000	2,000

¹ *Trusses which span across the full length or width of the foundation from edge to edge.*

REFERENCES

- 1) "*Design of Post-Tensioned Slabs-on-Ground*", 3rd Edition, Post-Tensioning Institute, Phoenix, AZ, 2004
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