# Frequently Asked Questions

## Design of Uniform Thickness Foundations

*Answer from the PTI DC-10 Slab-on-Ground Committee* April 2010 • Issue No. 12

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**Q** What is the history of the PTI design procedure for a Uniform Thickness Foundation (UTF)?

**A** The UTF was first introduced in the PTI second edition[1] in 1996. In the PTI second edition,[1] the minimum UTF thickness was solely determined using a conversion equation based on the moment of inertia of a "*conformant ribbed foundation*" (refer to the PTI second edition,[1] Section 6.12).

The UTF procedure prescribed in the PTI third edition[2] and the Design Standard[3] was expanded to ensure that the UTF could resist the applied moments and shears of the conformant ribbed foundation and in addition the cracked section and soil-bearing criteria for the UTF were added.

**Q** What is a "*conformant ribbed foundation*"?

**A** A conformant-ribbed foundation is a "*buildable*" ribbed foundation design that complies with all of the following design requirements:

- Flexure
- Shear
- Stiffness
- Ribs and tendons must be "*buildable*" (for example, no fractions for number of ribs and tendons)
- Rib limitations
  - Rib spacing (≥6 and ≤15 ft [≥1.8 and ≤4.6 m]) (Note: if the rib spacing is less than 6 ft (1.8 m), the actual rib spacing may be used in the section property calculations but the rib spacing shall not be less than 6 ft (1.8 m) in the parametric equations for moment and shear.
  - Rib depth (≥11 in. [≥280 mm]) and rib depth variation limited to 20% within a direction, not between short and long directions.
  - Rib width (≥6 [≥150 mm] and ≤14 in. [≤350 mm])
  - Rib continuity
- Minimum prestress force of 0.05*A*
- Cracked section
- Soil bearing

EXCEPTION: The following design requirements <u>DO NOT</u> need to be satisfied when the "*conformant ribbed foundation*" is to be transformed to a UTF design:

- Cracked section of the ribbed foundation
- Soil bearing of the ribbed foundation

**Q** How is a UTF designed using the PTI third edition[2] procedure?

**A** Once a conformant ribbed foundation has been designed, it may be converted to a UTF. The minimum thickness ($H$) is computed based on an equivalent moment of inertia of a conformant ribbed foundation. For the short and long direction of the design rectangle, the minimum thickness of the UTF is determined from the moment of inertia of the "*conformant ribbed foundation*" in the direction of consideration using the perpendicular length or width,* designated as $W$, as seen in the following equation†

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

where $H$ is the UTF minimum thickness (in. [mm]), $I$ is the moment of inertia of the conformant ribbed foundation (in.$^4$ [mm$^4$]), and $W$ is the corresponding length or width of the design rectangle (ft [m]) perpendicular to the direction that $H$ is being computed.

Note: Considering the short and long directions of the design rectangle, the equation above becomes

$$H_{short} = \sqrt[3]{\frac{I_{short}}{Length}} \qquad H_{long} = \sqrt[3]{\frac{I_{long}}{Width}}$$

The minimum required thickness of the UTF shall be the larger of $H_{short}$ or $H_{long}$.

Section 4.4.1 of the Design Standard[3] requires a perimeter rib if the UTF thickness is less than 7.5 in. (190 mm). If perimeter ribs are required to comply with this provision, all perimeter ribs shall conform to the following criteria:

*The term length corresponds to the longest dimension and width to the shortest dimension of the design rectangle, expressed in ft.

†The derivation of this equation is found in Section R4.4.1 of the Design Standard.[3]

- •A minimum depth of 11 in. (280 mm) or $H + 7$ in. (175 mm), whichever is greater; and
- •A minimum width of 6 in. (150 mm). Because the maximum rib width only applies to the section properties calculations of the "*conformant ribbed foundation*", any rib width 6 in. (150 mm) or wider is in compliance with the requirements of Section 4.4.1.

When permiter ribs are provided by not required by Section 4.4.1 of the Design Standard,[3] the perimeter ribs need not comply with the aforementioned geometry requirements.

In any case, perimeter ribs cannot be used in the design equations to add strength or stiffness to the UTF due to the large spacing between the perimeter ribs, which would invalidate the assumption of uniform section properties across the full width of the foundation. See last question below.

The deep perimeter ribs or edge beam, however, have been effectively used to impact the lateral moisture transfer at the perimeter of a building, thus reducing the soil design parameters. These potential benefits should be evaluated by a qualified geotechnical engineer.

The UTF should have the same or greater cross-sectional precompression provided by post-tensioning tendons as the conformant ribbed foundation. Because the UTF cross-sectional area will invariably be greater than the area of the conformant ribbed foundation, additional tendons will be required in the UTF to achieve the same or greater compressive stress. While the tendons in a UTF are commonly located at the centroid of the UTF cross section, there is no requirement that they be located there.

The PTI third edition[2] requires the UTF to be checked for the following:

- •Flexure;
- •Shear;
- •Stiffness;
- •Cracked section;
- •Soil bearing.

The flexural and shear stress, stiffness, and cracked section provisions are checked by calculating the stresses in the UTF, resulting from the applied service moments and shears of the conformant ribbed foundation with the section properties of the UTF. The applied service moments and shears are not recalculated using the UTF geometry. In fact, this cannot be done because the parametric equations for the applied service moments and shears use the rib depth and spacing and a UTF does not have ribs. Because the UTF will invariably have a greater cross-sectional area and the same or greater compressive stress, shear does not control the UTF design.

The UTF thickness is based on the moment of inertia of the conformant ribbed foundation; however, the UTF should still be checked for compliance with the required minimum stiffness because rounding off can lead to noncompliance.

If the UTF is found to not be in compliance with the flexural strength and serviceability requirements of the PTI third edition,[2] the UTF can be brought into compliance by several methods, including increasing the thickness, increasing the compressive force (adding tendons), or utilizing an eccentricity of the compressive force provided by the tendons. If the UTF is found to not be in compliance with the minimum stiffness requirement, the UTF can be brought into compliance by increasing the UTF thickness and/or by increasing the concrete compressive strength.

**Q** How is a UTF design optimized?

**A** The "*conformant ribbed foundation*" with the smallest possible moment of inertia results in the thinnest possible UTF; however, the conformant ribbed foundation with the smallest possible moment of inertia may not be the most economical ribbed foundation. Because the UTF thickness is a function of the corresponding "*conformant ribbed foundation's*" moment of inertia, one method of optimizing the UTF is to reduce the conformant ribbed foundation's moment of inertia to the extent possible while remaining conformant. In general, closely spaced wide and shallow ribs in the "*conformant ribbed foundation*" will result in the most efficient UTF because the parametric equations for the applied service moments are influenced mostly by rib depth.

Additional UTF efficiency may be obtained by positioning the post-tensioning tendons in the ribbed foundation so that the eccentricity of the resultant compressive force counteracts the controlling mode of soil movement (edge lift or center lift). For example, if the controlling mode of soil movement is edge lift, then the engineer may be able to reduce the ribbed foundation's moment of inertia (thereby reducing the required UTF thickness) by locating the post-tensioning tendons so that the resultant force is located below the centroid of the ribbed foundation cross section. This will result in an eccentric force that counteracts the edge lift soil movement. There is no limit on the eccentricity of the compressive force from the post-tensioning tendons of the "*conformant ribbed foundation*."

NOTE: As a part of being conformant, the conformant ribbed foundation's parameters should be "*buildable*". Fractional beams or tendons or tendons located outside of the concrete section cannot be used to optimize the UTF. The depth and width of the ribs in the short direction, however, can be different than the depth and width of the ribs in the long direction.

**Q** Can the perimeter ribs of a UTF be considered in the strength and stiffness?

**A** No. Perimeter ribs CANNOT be considered as adding to the strength and stiffness of the UTF. The section properties of the UTF shall be calculated using the uniform thickness part of the foundation, excluding any perimeter ribs (refer to Design Standard[3] Sections 4.4.1 and R4.4.1). Because the PTI design procedure assumes uniform section properties across the foundation, the inclusion of the perimeter rib in the UTF section properties would invalidate this assumption due to the large spacing between perimeter ribs.

Perimeter ribs may add strength and stiffness at the slab's edge in the direction of the rib, but they have little or no impact in the direction perpendicular to the slab edge or in the slab's interior where the applied service moments from soil movements are the largest. Because the maximum moments occur perpendicular to the slab edge at distance β, perimeter ribs alone are ineffective in adding strength or stiffness at the point of maximum bending.

## REFERENCES


1. PTI Committee DC-10, "Design and Construction of Post-Tensioned Slabs-on-Ground," second edition, Post-Tensioning Institute, Farmington Hills, MI, 1996, 101 pp.

2. PTI Committee DC-10, "Design and Construction of Post-Tensioned Slabs-on-Ground, third edition with 2008 supplement," Post-Tensioning Institute, Farmington Hills, MI, 2008, 156 pp.

3. PTI Committee DC-10, "Design and Construction of Post-Tensioned Slabs-on-Ground, third edition with 2008 supplement, Standard Requirements for Design of Shallow Post-Tensioned Concrete Foundations on Expansive Soils," Post-Tensioning Institute, Farmington Hills, MI, 2008, pp. 137-156.



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Frequently Asked Questions, Mar. 2010



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