Discussion of "Evaluation of Methods for Localized Differential Foundation Movement in Post-Tensioned Concrete Foundations"

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INTRODUCTION

The discussers believe that the original paper "Evaluation Methods for Localized Foundation Movement in Post-Tensioned Concrete Foundations" has multiple inaccuracies, deviates from fundamental mathematical and engineering principles, and violates model building codes. This discussion was prepared by a task group (TG) of the Post-Tensioning Institute (PTI) DC-10 Slab-on-Ground Committee. The purpose of this response is to outline inaccuracies in the original paper which can be misleading to the public and result in false analysis of concrete slab-on-grade (SOG) foundation performance. In the opinion of the TG, false results can lead to improper or unnecessary repairs to properly functioning SOG foundations. More importantly, this response addresses the proper methodology for localized foundation movement to assist professionals in the evaluation of SOG foundations.

IBC Provisions for Post-Tensioned Slab-on-Ground Foundations

A major topic of the original paper deals with deflection, distortion, and curvature with respect to evaluation of SOG foundations for global and localized conditions and how that affects the structure. The authors state that the International Building Code (IBC) "…is the governing body for the design of slab-on-grade foundations…", and then they quote Section 1808.6.1, which does not apply to post-tensioned slabs-on- ground. Section 1808.6 of the 2018 IBC states that "Foundations for buildings and structures founded on expansive soils shall be designed in accordance with Section 1808.6.1 **or** 1808.6.2." In fact, Section 1808.6.2 deals directly with slab-on-grade foundations and contains reference to the Post-Tensioning Institute standard, PTI DC10.5. The discussers believe the authors have neglected the flow of the building code to include the statement they quote from Section 1808.6.1 regarding foundations placed on or within the active zone of expansive soils. Adherence to the flow and scope of the building code means that from the root section dealing with expansive soils (Section 1808.6), a designer would proceed to Section 1808.6.2 and then on to the PTI DC10.5 standard or another approved method. Simply stated, the IBC does not "mandate" the portion of Section 1808.6.1 quoted in the original paper in relation to post-tensioned slabs-on-grade. Therefore, the discussers believe that this statement by the authors is misleading and does not apply the IBC provisions to foundations on expansive soils in the manner stated.

PTI Design Procedure

The discussers believe that the authors' statement that the PTI design procedure for slabs-on-ground is based on elastic (non-cracked) analysis is incorrect. As they stated in the original paper, "The intent of the PTI design standards is to provide a foundation system that behaves elastically (i.e., remains uncracked) for the maximum soil movement anticipated at a given site." The PTI design procedure does, in fact, account for cracked sections in its design methodology (refer to PTI 10.5). Therefore, the discussers believe that this statement appears misleading and does not apply to foundations designed per the PTI design procedure in the manner stated.

Distress Analysis and Correlation

The discussers agree that visual distress correlated with a properly recorded floor elevation survey and foundation profile corresponding to the visual distress are required tools in the evaluation of post-tensioned slabs-on-grade. The original paper focuses on an isolated foundation profile section and does not clearly correlate distress with the chosen foundation profile section. As such, the foundation analysis is partial and incomplete and should not be used to evaluate the performance of the foundation.

Definitions

A couple of well recognized definitions for deflection and deflection/curvature are: ***Deflection*** *is the perpendicular distance moved by a point from the neutral reference during the bending of the member (ASCE)* and
Deflection/Curvature *is the vertical distance between point 2 and the straight line drawn between points I and 3. Point 2 is the point along the foundation section profile the greatest distance from the straight line drawn between points 1 and 3.*
It is important to note that to have deflection, there must be bending <u>and</u> curvature.

The authors state that "curvature is also known as deflection or bending."
Curvature is not necessarily a deflection as deflection requires movement. A curvature can be present as a result of original built-in construction that needs to be considered in the performance analysis. Also, deflection cannot happen without curvature.
Further, based on fundamental mathematical and engineering principles, deflection/curvature must be measured based on three points. Two points will only measure the slope or average slope between two points which may be the result of original construction, deflection/curvature, or both.

Localized Deflection/Curvature

The authors state that PTI DC10.8-18 Guide for Performance Evaluation of SOG Foundations does not include an example or procedure to address localized deflection/curvature, but Section

6.3.2 of this document shows how to calculate localized deflection/curvature. Local deflection/curvature must consider original construction tolerances, which the authors may not have considered and did not reference in their paper. The shorter the local distortion/curvature consideration, the greater the impact original construction tolerances may have on the analysis. The Specification for Tolerances for Concrete Construction and Materials published by the American Concrete Institute (ACI 117-10) specifies an elevation tolerance of ±0.75 inches, which correlates to 1.5 inches of allowable built-in diselevation across a slab foundation. Measuring short sections of a foundation can result in false failures solely from original construction that falls within ACI 117 allowances. To avoid this problem, it is necessary to have a minimum distance such as the 25 feet noted in the PTI DC10.8-18 procedure.

Cantilever Analysis

The authors describe the cross section in the original paper as a cantilever deflection. The discussers believe this is an inaccurate assumption for multiple reasons. One, there is no deflection/curvature or bending consistent with a cantilever within the authors' section. Two, the authors only use two points to calculate assumed deflection. By using only two points, the authors define global or planar (rigid body) tilt or an average slope, which is not deflection/curvature. The discussers believe that the use of the two points of measurement for a cantilever ignores fundamental engineering principles. To have a cantilever member, there must be fixity or a back-span or point of reference also known as a neutral reference or original shape. This would include knowing the rotation in degrees at the point of inflection (this point defines the point of fixity of the cantilever). To establish the cantilever back-span, one must demonstrate little or no foundation movement in that area via a distress inventory and analysis. Otherwise, if distress is present in the assumed back span, it indicates a cantilever condition does not exist, as there is not demonstrated fixity.

The authors' two-point deflection measurement is really three-point deflection measurement with a presumed third point based on an assumed original relatively level condition.
There is no basis provided in the original paper to establish the presence of the back-span. As previously discussed, the assumed level condition is not reasonable.
Fig. 1 contains examples of the proper method of evaluating a cantilever deflection. L as the length for the evaluation of the assumed cantilever section is used in the original paper. To properly evaluate a cantilever deflection, 2L should be used for the length.

Proper mathematical and engineering principles as well as the building code dictate the use of 2L for the length of a cantilever when calculating deflection for a cantilever. The IBC, International Residential Code (IRC), ASCE 7, and the ASCE Texas Section (Guidelines for the Evaluation of Repair of Residential Foundations Ver. 3) all clearly state 2L is to be used in the evaluation of cantilever deflections. It is also noteworthy that the PTI DC10.8-18 Guide for Performance Evaluation of SOG Foundations does not prohibit cantilever analysis, but rather illustrates an example of incorrect cantilever analysis when there is no evidence of a back-span (Fig. 2). Therefore, the analysis method deviates from model building codes as well as basic mechanics in their method of evaluating an assumed cantilever deflection.

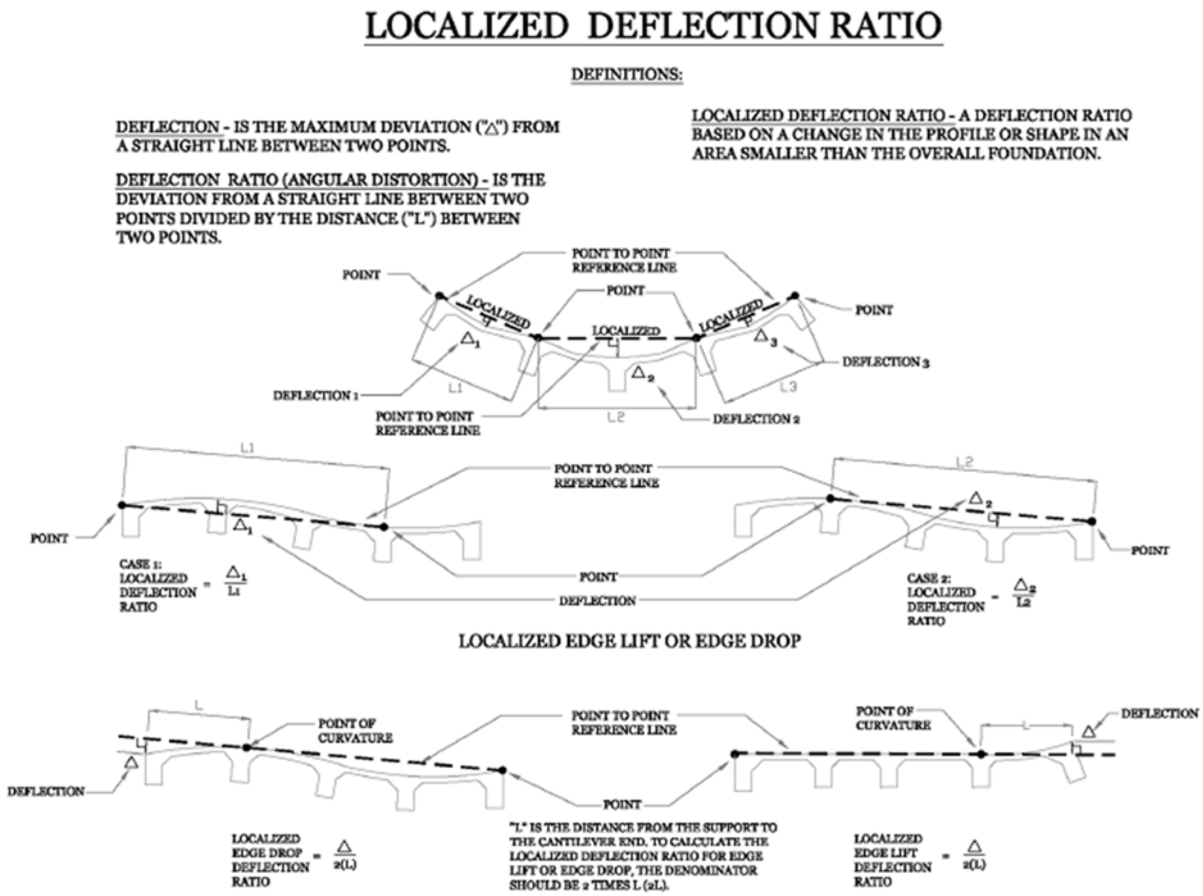

Figure 1. Localized Deflection Ratio from Guidelines for the Evaluation and Repair of Residential Foundations Ver. 3 (Source: TX ASCE).

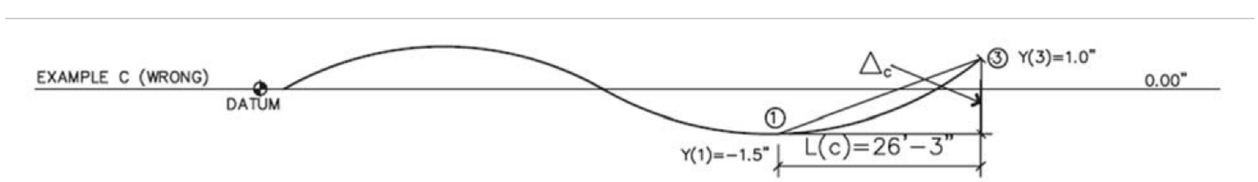

Figure 2. Example of Incorrect Cantilever Analysis (No Evidence of Back Span) (Source: PTIDC10.8-18 Guide for Performance Evaluation of SOG Foundations).

Appendages

The original paper includes discussion of appendages not being properly designed or analyzed. The case study in the original paper does not include an appendage and therefore does not reinforce information about foundation appendage performance.

This response has been prepared by PTIDC-10 Slab-on Ground Committee.