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

Robert F. Pierry, Jr., P.E.[1]; Philip G. King, P.E., BC.GE, F.ASCE[2]; Kenneth M. Struzyk, P.E.[3]; Brian C. Eubanks, P.E.[4]; Dean R. Read, P.E.[5]; Ottis C. Foster, P.E.[6]; and Michael Skoller, P.E.[7]

[1]Pierry Consulting, Inc., Lantana, TX. Email: bob@pierryconsulting.com
[2]SynchroPile, Inc., San Antonio, TX. Email: phil.king@synchropile.com
[3]Accutech Consultants, LLC, San Antonio, TX. Email: kstruzyk@accutechusa.net
[4]Paragon Structural Engineering, Ltd., Plano, TX. Email: brian@pseglobal.com
[5]MLAW Forensics, Inc., Austin, TX. Email: drread@mlawforensics.com
[6]Structural Health Data Systems, Waco, TX. Email: ofosterpe@gmail.com
[7]National Structural Engineering, Inc., Houston, TX. Email: michael@structural.nu

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BACKGROUND

The discussers, the ASCE Texas Section Residential Foundations Task Committee (RFC), disagree with the information presented in the original paper. The discussers believe there are errors in fact and errors in application of the ASCE Texas Section document titled *Guidelines for the Evaluation and Repair of Residential Foundations* (the Guidelines).

The Guidelines were created in response to concerns expressed by the Texas Board of Professional Engineers (TBPE, now named the Texas Board of Professional Engineers and Land Surveyors, TBPELS) in the late 1990s. Two documents were created (the one at issue referenced above), and the most recent versions can be downloaded at the following link:

https://www.texasce.org/resources/publications/residential-foundations/

In creating the Guidelines, the ASCE Texas Section invited licensed engineer members from across the state to participate, and several Texas licensed engineers answered the call for volunteers and donated significant time and effort to create the Guidelines. First adopted in 1990 by the Texas Section, the documents include a request to readers and users to submit proposed changes for future updates. Instructions for submitting proposed changes are provided in the Guidelines. Anyone interested in contributing to bettering the practice of residential foundation engineering in Texas is encouraged to submit proposed changes in accordance with Section 1.5 of the Guidelines. As was done to update Versions 1 and 2, the Committee will meet to consider substantive proposed changes, with the goal of issuing a document that meets generally accepted engineering principles and practice.

The concerns of the discussers include those presented in the following sections.

Localized Deflection

The abstract of the original paper states that the Guidelines "overlook localized deflection." The body of the paper states that the Guidelines "acknowledge and address localized deflection of slab foundation systems, but also does not provide a methodology." Section 5.6 of Version 2 of the Guidelines (2009) is entitled "Localized Deflection" and states, in part, that "The engineer should evaluate the significance of localized deflections and their consequences as in Section 5.5." Section 5.5 of Version 2 is entitled "Overall Deflection." The treatment of deflection, including localized deflection, was broadened in Version 3 by combining previous Sections 5.5 and 5.6 into a single "Section 5.5. Deflection" and adding Figures 1 and 2 to depict various methods of calculating deflection ratio. Figure 2 is entitled "Localized Deflection Ratio."

The original paper focuses on the analysis of localized deflection, which the authors equate with curvature, and particularly localized edge lift/edge drop. The paper claims these mechanical states are "analogous to deflection in a cantilevered beam subject to uniform loading." The paper then refers to a 1999 paper by Marsh and Thoeny regarding angular distortion. The Guidelines consider a three-point analysis necessary for deflection ratio or angular distortion, while angular distortion described by Marsh and Thoeny (1999) requires only two points. Since a two-point analysis measures slope, or average slope, between two points, not deflection, the discussers disagree with the authors' approach to calculating deflection. The authors then go back to deflection analysis in their case study. It is not clear to the discussers whether the paper uses the correct three-point analysis to analyze deflection, or the two-point analysis that the discussers believe to be incorrect.

The original paper does not discuss or account for original construction tolerances. The Guidelines account for this in several ways, including the following excerpts from Sections 5.4 and 5.5 of Version 3:

> "Foundations are generally constructed with surface elevation differences, but caution should be exercised when applying an assumed construction tolerance" (5.4).
>
> "A floor elevation survey can provide valuable information but should not be the only basis for evaluating foundation deflection and tilt. The engineer may use other indications of movement, such as those listed in Section 5.3, to estimate built-in floor unevenness when evaluating performance" (5.4).
>
> "The engineer evaluating deflection must consider the floor level survey (Levels of Investigation B or C), and other indications of movement, such as:
> 1. Brick coursing not level.
> 2. Poor door alignment.
> 3. Levelness of built in horizontal surfaces, such as cabinets, countertops, sills and trim.
> 4. Cracking of exterior and interior wall finishes may indicate deflection, as do most items listed in 5.3 above.
>
> The engineer should use other indications of movement to estimate built-in floor unevenness when evaluating deflection" (5.5).

"The engineer should evaluate the significance of localized deflections and their consequences, but caution is advised when evaluating floor deviations over a distance less than approximately 20 feet because built-in unevenness can dominate" (5.5).

Actual deflection or curvature caused by foundation movement may not be the same as measured deflection or curvature due to built-in elevation differences. It is actual deflection or curvature that causes distress in the finishes, including the 12-item list in Section 5.3, and such distress should be considered when evaluating deflection. While the original paper refers to distress in the case study, it doesn't correlate the distress shown in Figures 4 and 5 with localized/cantilever deflection calculations. Figures 4 and 5 depict exterior brick veneer cracking which is not along the paper's analysis line A-A.

The authors of the original paper are calculating deflection using two points recorded on the foundation and a third point that is assumed, based on the original paper's assumption in the cantilever analysis that the foundation was level or flat beyond the inflection point. As previously noted and discussed further later, this may not be the case due to built-in tolerances or distress indicating foundation movement in the area assumed to be level or flat. To perform a cantilever analysis, there must be evidence of a back-span or a point of fixity. Additionally, to establish a cantilever back-span, there should be evidence of little to no foundation movement as well as little to no foundation movement related distress in the back-span or point of fixity. The original paper does not discuss the presence of a back-span or point of fixity.

Cantilever Deflection Calculation

In the original paper's discussion of cantilever analysis, Figure 2 illustrates that the deflection ratio, which shows as curvature, is equal to $1/(L_c\Delta_c)$, which equates to $\Delta_c L_c$. Figure 2 of Version 3 of the Guidelines shows the deflection ratio for an edge lift or edge drop cantilever is $\Delta/2L$. Both note (i.) to Table 1604.3 in the 2021 International Building Code (IBC), which applies to more than two-family residential structures, and note (b.) to Table R30 l.7 of the 2021 International Residential Code (IRC), which applies to one and two-family residential structures state that: "For cantilever members, L shall be taken as twice the length of the cantilever." The argument could be made that the deflection limits in the IBC and IRC are for serviceability and not performance, or that they are for suspended structural members and not ground-supported foundations. However, Section C1.3.2 of ASCE 7 Standard (ASCE 7) states: "In addition to strength limit states, buildings and other structures must also satisfy serviceability limit states that define function performance and behavior under load and include such items as deflection and vibration." Additionally, Section CC.1. 1 of ASCE 7 states: "Deflections of about 1/300 of the span (for cantilevers, 1/150 of the length) are visible and may lead to general architectural damage and cladding leakage." It is clear that serviceability and deflection are synonymous, and that sufficient deflection, or curvature, results in distress, whether the member is structurally suspended or ground supported. Additionally, if L is used to calculate the allowable deflection of a cantilever, the allowable curvature will be half of the allowable curvature for a simply supported beam using the same L. Curvature (and associated deflection) should not be limited to half of what would actually cause distress. It is clear that engineering principles, model codes, and ASCE 7 all specify the use of 2L for the length of cantilever members when calculating deflections and as such, the discussers believe that Figure 2 in the paper is incorrect.

The paper also incorrectly analyzes “localized curvature deflection” in the case study. Since we do not know the original profile of the foundation and not correlating distress in the finishes in the analysis, the discussers believe that it is inappropriate to consider the section A-A as a cantilever since this section spans approximately two-thirds of the slab length. The authors calculate deflection ratio utilizing only two points, which is a measure of slope. The Guidelines define deflection ratio, as follows:

> “Deflection is characterized by the deflection ratio, which is defined as the maximum deviation of a third point from a straight line between two points divided by the distance (L) between the two points” (5.4).

ENGINEERING JUDGMENT

Engineering judgment and ethics carry considerable weight in forensic analysis. Using the original paper’s example that claims one chosen cross-section is right and the other wrong bypasses the role of engineering judgment and the role of litigation in deciding whether a problem has been appropriately addressed. One must assume an engineer evaluates several sections along with numerous other considerations (several of which are enumerated in the ASCE Texas Guidelines) to reach supportable conclusions about performance. Ethically, an engineer must evaluate the evidence based on the technical merits, without intentional efforts to achieve a desired conclusion. The ASCE Texas Guidelines emphasize the role of engineering judgment and provide basic analytical tools of evaluation that the discussers believe should be used in reaching a conclusion.

CONCLUSION

The discussers believe the Guidelines provide an appropriate way for Texas engineers to evaluate residential foundation performance issues.