

R. Michael Gray, P.E.

Registered Professional Structural Engineer (72949)

TBPE Certificate of Registration Number F-2171

SBCCI Registered One and Two Family Dwelling Inspector (4700)

Webmaster for www.HoustonSlabFoundations.com

Telephone: 281-358-1121: grayspe@Gmail.com

Structural Engineering Foundation Performance Evaluation For
Client: William Adams
property located at
2103 Seven Maples Drive
Kingwood, Texas

R. Michael Gray



consulting only

Date: Tuesday, June 16, 2020

R. Michael Gray, P.E.

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PROJECT DESCRIPTION

Building Type: detached single family home	Approximate Year House Built: 1987
Number of Stories: 2	Was Client Present?: yes
Was Building Occupied?: yes	Was the Owner Present? yes, the owner was the client

PURPOSE AND SCOPE OF THE REPORT

This purpose of this report is to render independent, unbiased, subjective opinions regarding the structural performance of the subject foundation. My intent is to provide you information that will allow you to better understand the performance of the foundation addressed in the report.

Definition Of Performance

From the *Standards of Practice* for licensed real estate inspectors published by the Texas Real Estate Commission:

Achievement of an operation, function or configuration relative to accepted industry standard practices with consideration of age and normal wear and tear from ordinary use.

Some commentary from a standard engineering text¹:

A common misconception, even among some engineers, is that foundations are either perfectly rigid and unyielding, or they are completely incapable of supporting the necessary loads and fail catastrophically. This "its either black or white" perspective is easy to comprehend, but it is not correct. All engineering products, including foundations, have varying degrees of performance that we might think of as various shades of gray.

Disclaimers

In the conduct of my work, I do not perform any action that, in my, judgment, could damage the property or endanger the safety of any person.

Although care is taken in preparing this report, no representations are made regarding any latent, concealed or obstructed defects that may exist. This report is not fully exhaustive; not every possible defect was discovered and reported. The content of the report should be considered as an independent first impression opinion of how well or poorly the foundation is performing.

¹ *Foundation Design – Principles and Practices* by Donald P. Coduto, Prentice Hall, 1994

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My opinions are based on perceived conditions as compared to my training, knowledge and experience. The opinions in this report are, therefore, subjective. They are not based upon any code requirements, performance standards and/or compliance with any Federal, State or local codes, lender requirements and/or other legal requirements unless otherwise stated in the report.

Every statement in this report is an opinion. A different engineer may have different opinions regarding the performance of the foundation.

This engineering investigation is not exhaustive: the investigation will not reveal all deficiencies.

Property conditions change with time and use. For example, foundations tilt and bend as changes in the moisture content of the soil causes the soil to shrink and swell. Most foundation distortion in Southeast Texas is a consequence of changes in the moisture content of the supporting soil. Soil moisture changes are mainly driven by changes in the weather, watering practices, drainage, and vegetation.

Foundation bending will stress wall coverings such as drywall and brick veneer and floor coverings such as tile. In some cases the stress may not be enough to fracture the drywall or brick veneer, but these materials may crack with only a small degree of additional movement.

I prepared this report for the specific benefit of the client named on page one. It is based on my observations at the time of the investigation. Any reader of this report other than the client, should understand that relying on this report may provide incomplete or outdated information and may not meet your specific needs.

Repairs, professional opinions, and additional reports may affect the meaning of the information in this report.

A BRIEF EXPLANATION OF HOW I EVALUATE THE STRUCTURAL PERFORMANCE OF A SLAB FOUNDATION

This report is a Level B evaluation as defined in the Texas Section of the American Society of Civil Engineers publication *Guidelines for the Evaluation and Repair of Residential Foundations, version 2*. (Here after referred to as: TxASCE Guidelines.) My engineering performance evaluation is mostly visual with some elevation measurements.

Finish Floor Elevation Measurements: I make elevation measurements on the finish floor using a digitized, electronic manometer, specifically a Technidea ZipLevel Pro-2000. I use the elevation measurements for the following:

- **Determine The Dominant Expansive Soil Movement Distortion Mode:** Slab-on-ground foundations on expansive soils exhibit a long-run and a short-run distortion mode. Most older slab foundations in the Greater Houston Area will exhibit a surface shape of an upside down bowl as shown below. This shape (see figure #1) is known as a center-lift or long-run distortion mode. When the weather is exceptionally wet, the

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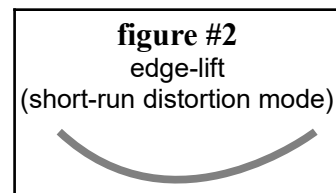
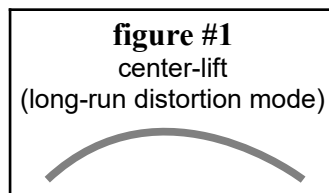
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surface shape may invert to that of a right-side up bowl. (see figure #2.) This shape is known as an edge lift or short-term distortion mode. I use the elevation measurements to determine the dominant distortion mode in the two principle directions: front to back and side to side.



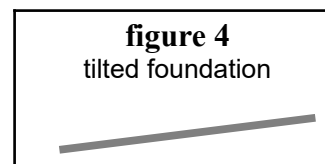
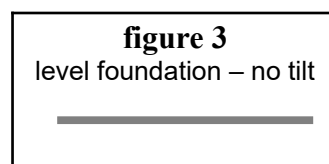
- **Evaluate Overall Foundation Levelness:** When a slab-on-ground foundation reacts to expansive soil movement, the foundation surface and the finish floor may become less level. I use the measurements to assess the overall levelness of the foundation as compared to my experience with other foundations of a similar age, construction and location.

Note: Overall levelness refers to the maximum difference between any two points. There are no code requirements or any other engineering standard that requires an existing slab-on-ground foundation to meet a specific overall levelness standard.

It is important to understand that a slab-on-ground foundation can perform very well even if it is severely out of level. In my opinion, stability is much more important than overall levelness.

The best way for a buyer to assess the levelness of a slab-on-ground foundation is to walk it to decide if the levelness of the foundation is acceptable to him or her.

- **Estimate Foundation Tilt Due To Expansive Soil Movement:** All slab-on-ground foundations tilt when they react to expansive soil shrinking and swelling. Tilt is rarely a significant structural issue, but I use the elevation measurements to estimate how much the foundation has tilted in the two principle directions: front-to-rear and side-to-side.



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- **Estimate Foundation Bending (Deflection) Due To Expansive Soil Movement:** This is the most difficult aspect of foundation performance evaluation since there is normally no as-built elevation measurements.

Slab foundation bending racks the walls on the ground floor causing distress and (potentially) damage to the foundation and house structure. I use the elevation measurements to estimate how much bending the foundation exhibits in two principle directions.

Distress / Damage Evaluation:

I make judgments about the performance of a foundation based on visible distress and damage to the supported structure consistent with the apparent foundation distortion mode. (Distress and damage are apparent irregularities in the finished structure. Distress refers to irregularities that are minor and have no clear cause. Damage is more severe and usually has an identifiable cause. (These definitions are from *Diagnosing and Repairing House Structure Problems*, Edgar O. Seaquist, 1980 McGraw-Hill, Inc.)

The distress / damage I normally find most reliable includes the following:

1. Maximum and cumulative crack widths in the brick veneer, stone veneer and/or stucco exterior walls. Where appropriate, I use cumulative crack widths to make an estimate of how much bending the foundation exhibits.
2. Distress judged likely due to foundation distortion.
3. Door frame distortion likely due to foundation distortion.
4. The degree of rotation of the fireplace chimney away from the house structure.
5. Significant structural damage, usually accompanied by severe distress in the drywall, brittle floor coverings, brick veneer & stucco.
6. Levelness of normally level surfaces, specifically sills and countertops.

The data from items 1 and 4 are used primarily to make estimates of how much bending the foundation exhibits. The data from items 2, 3, 5 and 6 are used primarily to judge the reliability of the various estimates of foundation tilt and bending are.

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WHAT I DO NOT DO IN MY ENGINEERING FOUNDATION PERFORMANCE EVALUATION

- **No Engineered Repair Plan:** While I normally provide a general description of needed repairs, the report is not intended to be used as an engineering design document for the repair of the foundation.
- **Foundation Distortion Due To Expansive Soil Movement Only:** My foundation performance evaluation is directed to performance issues due to foundation distortion caused by expansive soil movement. Expansive soil movement is the cause of virtually all significant foundation performance issues in the Greater Houston Area.
- **Calculations:** All calculations are estimates only and are made to make engineering judgments. They are not precise.

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FOUNDATION PERFORMANCE EVALUATION EXECUTIVE SUMMARY

This section is an executive summary of the report. The executive summary includes a summary of my opinions regarding the performance of the foundation.

Issues	summary comments
1. What type of foundation is this?	This is a slab-on-ground foundation. Slab-on-ground foundations are the most common house foundation in the Greater Houston Area. Slab-on-ground foundations typically bend and tilt so that during the life of the house there will be door frame distortion, drywall cracks and brick veneer cracks.
2. How does the foundation performance compare to other homes in this area?	Better than average considering age, repair history and location. It is important to understand that from a structural perspective, the deflection curves indicate that the foundation performance is better than it was in 2017.
3. Does the house show distress that is probably due to foundation distortion?	Based on my observations of the house, it is my engineering judgment that the house does exhibit (very minor) visible distress due to foundation distortion.
4. Does the house show distress that is not likely to be due to foundation distortion	Yes, nothing beyond normal wear and tear. For a list of examples of distress often misidentified as being due to foundation distortion can be found here .
5. Does the house show damage or structural integrity issues that are probably due to foundation distortion?	Based on my observations of the house, it is my engineering judgment that the house does not exhibit visible damage or structural integrity issues due to foundation distortion.
6. Engineer’s opinion of the visually apparent foundation performance.	In the judgment of this engineer, the foundation is performing in a serviceability sense within what I consider to be an acceptable range of structural performance given the apparent age, construction, repair history, and location of the house.

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Issues	summary comments
7. Is the foundation performance adequate in terms of usability and serviceability of the house?	It is my judgment that the foundation is performing in a way that does not materially impair the usability and serviceability of the house.
8. Is the foundation performance adequate in terms of structural damage to the house?	It is my judgment that the foundation is performing in a way that is not significantly impairing the ability of the structural frame of the house structure to carry normal imposed loads in a safe manner.
9. Is the apparent geometry of the foundation surface as indicated by Finish Floor Elevation Profiles consistent with normal foundation performance?	The Finish Floor Elevation Profiles, in this engineer's opinion, are consistent with normal foundation surface geometry taking into consideration published ACI construction tolerances and expected foundation surface distortion for foundations in this area and age.
10. Is foundation underpinning structurally necessary?	It is my judgment that foundation underpinning is not structurally necessary for this house. It is my judgment that this question should be answered in the affirmative only if foundation distortion is clearly causing significant structural integrity issues that cannot be addressed without underpinning the foundation.
11. Is foundation underpinning recommended?	I do not recommend additional underpinning the foundation for this house. It is my judgment that any improvement in the future performance of the foundation is outweighed by the risk of damage to both the house and the foundation that could result as an unintended consequence of the foundation underpinning process.

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Issues	summary comments
12. Is there any distress or damage caused by foundation distortion that cannot be repaired without underpinning the foundation?	There is no distress or damage that might be caused by foundation distortion that cannot be repaired without underpinning the foundation. When no structural or integrity safety issues are involved, it is acceptable to make minor repairs to a house including repairs to drywall, brick veneer and door issues. ²
13. Are any concrete repairs recommended?	no
14. Comments concerning previous engineering reports.	There were no previous engineering reports other than a report this engineer made in 2017. The normal indicators of foundation distortion indicate less deflection (bending) today than what I saw in 2017.

² [Texas Section ASCE Guidelines for the Evaluation and Repair of Residential Foundations, version 2.](#)

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Options For Improving Slab Foundation Performance

When it is desired to improve foundation performance, the following are options for you to consider with my comments.

Make no repairs	<p>The guidelines published by the Texas Section of the American Society of Civil Engineers state: so long as there are no structural integrity issues, foundation repair is optional.³</p> <p>There is nothing wrong with living with the house as it is. In my opinion, this is the most popular response to distress caused by expansive soil movement.</p>
Make cosmetic repairs only	<p>So long as there are no structural integrity issues, making only cosmetic repairs is acceptable according to the Texas Section ASCE <i>Guidelines for the Evaluation and Repair of Residential Foundations, version 2.</i></p>
Drainage improvements	<p>Over the long run, poor drainage may prevent your slab-on-ground foundation from performing as well as it otherwise could. Click here for a video explaining how to maintain proper drainage around a slab foundation.</p>
Tree / vegetation issues	<p>I saw no evidence that the trees and other vegetation are having a significant adverse effect on the foundation performance. The normal recommendation is to leave any trees alone that do not appear to be causing a significant structural problem.</p>
Ground cover issues	<p>I saw no ground cover issues.</p>
Automatic watering system	<p>Using an automatic foundation watering system during dry periods is always prudent. I saw no automatic watering system at this house. A lawn sprinkler system is not a foundation watering system.</p>

³ [Texas Section ASCE Guidelines for the Evaluation and Repair of Residential Foundations, version 2.](#)

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Building modifications	<p>All roof eaves should be guttered and water from the gutter system should be discharged onto well sloped ground 5-feet from the foundation or discharged into an underground drainage system.</p> <p>To reduce brick veneer cracking due to foundation distortion you should consider adding movement joints in to the brick veneer. Every PE has his or her ideas about the best way to do this. I recommend that a movement joint be installed around 8 or 9 feet from the end of each brick veneer wall. Other joints can be installed near window and door openings. It is preferable that movement joints be spaced so there is no more than 10-feet between joints. The reader might find this article and this similar article of interest</p>
Underpinning	<p>Underpinning is what most people call foundation repair. In my opinion, additional underpinning is not a good option for this foundation. The distress due to foundation distortion is minimal and underpinning this foundation is not cost-effective. It would probably be a waste of money.</p>

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FOUNDATION PERFORMANCE EVALUATION

SIGNIFICANT OBSERVATIONS

My Understanding of The Structural History of the House	
1. Past underpinning of the foundation? Yes. It is not clear to me why this foundation was underpinned.	5. Past masonry fireplace chimney rotation: None
2. Past brick veneer / stucco separations: Yes, cosmetic only.	6. Were site-specific soil reports available? No
3. Past drywall cracking or other drywall irregularities: Nothing consistent with excessive foundation distortion.	7. Were previous engineering reports or foundation drawings available?: Yes, a report made by this engineer in 2017.
4. Past door sticking, door binding, door latching or door frame distortion: Only very minor sticking and easily repaired without underpinning the foundation.	8. Has owner received a foundation repair proposal? No.

1. Foundation cracking and levelness due to foundation distortion	
structural foundation cracking	There was some cracking in the exposed garage concrete but it was, in my opinion, normal shrinkage cracking; No structurally significant cracks were observed; as is normally the case, most of the foundation surface was concealed from view; see the comments below concerning cracks in concrete
width of largest structural crack	not applicable
levelness	Based on walking the floor, although there is some sloping in the floor, the slab surface appeared to not have been severely distorted by foundation distortion.
<p>Comment: Wedge cracks and hairline or very tight cracks are not structurally significant to the performance of the foundation and are not reported. Cracks covered by floor coverings are not visible and are not reported; should floor coverings be removed and it is desired for this engineer to evaluate these cracks, this can be done for an additional fee.</p> <p>Comment: Brittle floor tiles will crack even with very minor foundation distortion; to a significant extent floor tile cracking can be avoided by using an uncoupling membrane, a flexible thinset (often referred to as a latex or polymer modified thinset) and soft joints (also called movement or expansion joints) in the tile every 10 feet or as specified by the tile manufacturer.</p> <p>Comment: You may find this (somewhat technical) article on cracks in slab foundations of interest.</p> <p>Comment: This video shows how to repair concrete cracks such as the one in your garage.</p>	

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2. Drywall cracks and cabinet/wall separation due to foundation distortion

There was no cracking or other irregularities consistent with foundation distortion.

Comment: Whether cracks of this nature are related to foundation distortion is largely a matter of judgment; I do not report cracks that, in my judgment, are clearly not related to foundation distortion.

Comment: Vertical and horizontal drywall cracks, in my experience, are usually caused by something other than expansive soil foundation distortion; more likely causes include poor drywall fastening, poor drywall finishing, concentrated load paths in the framing, normal shrinkage of wood framing and normal construction errors in the framing

Comment: Drywall cracks in ceilings, in my engineering judgment, are frequently not related to expansive soil foundation distortion; they are usually related to framing details and drywall application

Comment: Stress marks in drywall are irregularities in the drywall that are not cracks, and are usually vertical or horizontal. They are normally caused by age and poor workmanship.

3. Door issues due to foundation distortion

There was no door frame distortion due to foundation distortion. All doors were functional.

Comment: Door distress that is not related to foundation distortion such as hardware defects or moisture problems is not reported.

Comment: Door frame distortion can indicate foundation distortion but may not be indicative of excessive foundation distortion.

Comment: In my engineering judgment, door frame distortion upstairs in a multistory house is usually not related to expansive soil foundation distortion.

4. Floor issues due to foundation distortion

There were no distress consistent with foundation distortion in the finish flooring.

Comment: Floor distress usually shows in floor tile as cracks and separations. In wood finish flooring, there will be separations between the individual in the wood finish flooring. Some floor issues are caused by moisture issues and are not reported. Floor issues are usually cosmetic.

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5. Cracks and separations in exterior walls due to foundation distortion.
There were no cracks or separations in the exterior brick veneer.

5. Cracks and separations in exterior walls					
wall	number of cracks and separations	largest crack or separation (inches)	cumulative crack/separation width (inches)	estimated deflection ratio	repaired cracks/separations
front	1	3/16	3/16	.19/360	yes
right	0	0	0	0/360	none
left	1	3/16	3/16	.19/360	yes
rear	not applicable - siding				
<p>Comment: It would be prudent to add vertical movement joints in the brick veneer in each wall. I recommend a movement joint in each brick veneer wall around 5 feet from each end and every 10 feet. Any mason or handyman can do this work. Movement joints allow the brick veneer to accommodate to foundation distortion will less brick veneer cracking that would otherwise occur.</p> <p>Comment: Cracks and other openings that appear to be caused by thermal stresses or other non-foundation related causes are not reported; cracks that appear to be due to rusting lintels are not reported.</p> <p>Comment: I would not normally consider foundation underpinning as a viable option unless one or more of the estimated deflection ratios exceeded 1/360.</p> <p>Comment: The estimated deflection ratios are based on brick veneer cracks/separations that are visible. It does not take into account repaired brick veneer cracks/separations.</p>					

6. Masonry fireplace chimney rotation

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gap between house and fireplace chimney	none
height above foundation at which gap was measured	not applicable

7. Visible evidence structural damage to the structural frame
There was no visible evidence of structural damage to the frame structure.

8. Visible evidence suggesting structural integrity issues
There was no visible evidence suggestive of structural integrity issues.

It should be noted that the distress and damage reported in this section is not intended to be a complete list of all the foundation distortion related distress and damage in the house.

It should also be understood that it is not unusual for a homeowner to make repairs to the house including repairs to damage that is caused by foundation distortion. There is nothing wrong with a homeowner making repairs to the house, but I make no claim that I can detect such repairs. In addition, the owner's disclosure statement does not require the owner to disclose such repairs.

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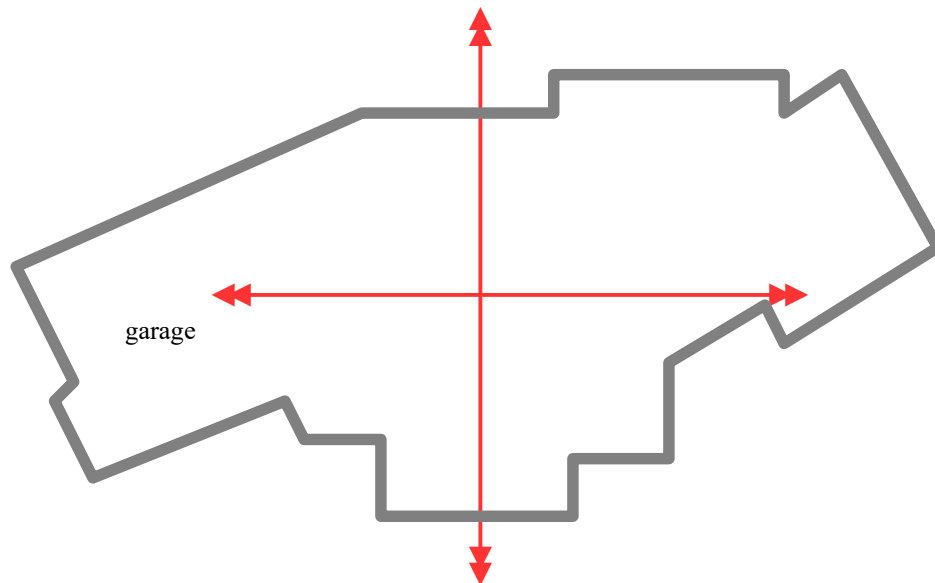
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Sketch Showing Approximate Locations of the Profiles



street

roughly proportional but not to
scale

FOUNDATION TILT/ESTIMATED DEFLECTION ANALYSIS USING FINISH FLOOR ELEVATION PROFILES

I made some finish floor elevation measurements and used these to create side to side and front to rear Finish Floor Elevation Profiles as shown below. I analyze profiles to make engineering estimates of the apparent deflection and the tilt of the foundation across specific profiles of interest.

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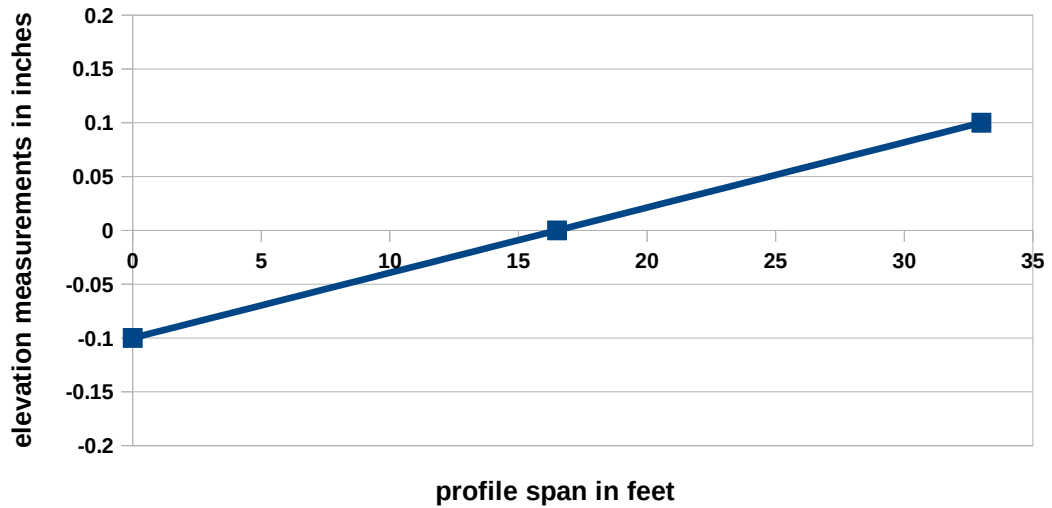
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Front (door) To Rear Estimated Deflection/Tilt Profile



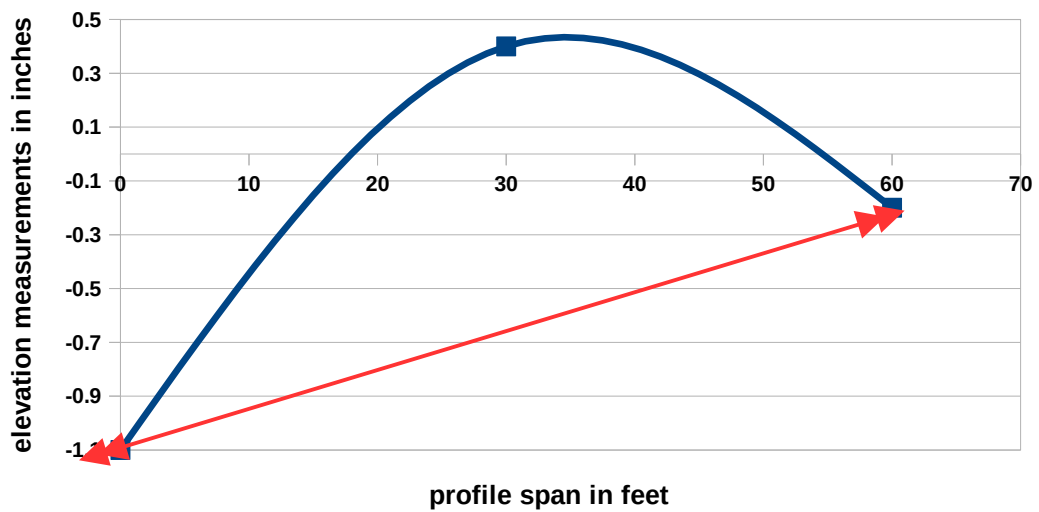
profile span (feet)	deflection (inches)	deflection ratio (over 360)	tilt (%)
33	0	0.00	<1%

**dominant distortion mode:
no deflection – normal tilt only**

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Left Side To Right Side Estimated Deflection/Tilt Profile



profile span (feet)	deflection (inches)	deflection ratio (over 360)	tilt (%)
60	0.9	0.45	<1%

**dominant distortion mode:
moderate normal center-lift with
normal tilt**

R. Michael Gray, P.E.

Registered Professional Structural Engineer (72949)
TBPE Certificate of Registration Number F-2171
SBCCI Registered One and Two Family Dwelling Inspector (4700)
Webmaster for www.HoustonSlabFoundations.com
Telephone: 281-358-1121: grayspe@Gmail.com

Other Observations

The following observations were noted at the house. Please note that any of these conditions could have an adverse effect on the future performance of the foundation.

- **Area:** This building is located in an area (southeast Texas) which is known to contain active or expansive soils. This means that the building is at a higher risk for foundation induced distress, especially if the foundation is not properly maintained. Please visit [this website](#) for more information about how to properly maintain your foundation.
- **Foundation Maintenance:** The most important things you can do to maintain good foundation performance is to make sure you address the following things: [watering your foundation the right way](#), understanding the [importance of positive foundation drainage](#) and mitigating the effect of trees with [root barriers](#) where appropriate. When you are connected to the Internet, [click here to learn more about watering your foundation](#). Also, click [here](#) for more information about how droughts affect Houston area foundations.
- **Distress Not Related To Foundation Distortion:** Over the life of the house, distress can develop in the finish materials that is not consistent with how a framed structure reacts to slab foundation distortion. More likely causes are age, initial settlement, and poor workmanship. You might find [this article](#) of interest.
- **Drought:** The Greater Houston Area periodically experiences a severe drought. In expansive soil areas, this type of weather can result in soil movement that can cause foundation distortion that is significantly in excess of what foundations are normally expected to experience. In drought situations, foundations are at risk of experiencing rapid and severe movement that, in turn, can result in damage to the house in the forms of cracks in wall covering materials (especially brick veneer, stone veneer, stucco and drywall) and floor tile.
- **An Inside Look At The Foundation Repair Business:** In case you are interested, you might find [this website](#) owned by a retired foundation contractor for 25 years in the Dallas/Fort Worth area.

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2103 Seven Maples Drive
Kingwood, Texas

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Annotated References

[Guidelines for the Evaluation and Repair of Residential Foundations, version 2](#), The TBPE has indicated to Texas Professional Engineers that they may consult this document to determine if an engineer making foundation performance evaluations has done so competently. It is a guideline, not a standard-of-care and I treat it as such.

[Repair of Residential and Light Commercial Foundations](#), Robert Brown PE. One of the very few books written by a Texas Professional Engineer who also ran a foundation repair business.

[Foundations in Expansive Soils, \(especially chapter 9 Remedial Procedures\) US Army Corps of Engineers](#) Anyone considering underpinning their slab foundation should read this first. They make a strong case that most homes that show distress / damage should not be underpinned because the distress / damage is not severe enough to warrant underpinning.

Foundation Design: Principles and Practices 1994 by Donald P. Coduto. This book contains (in Chapter 2) an excellent description of how engineers assess the performance of foundations.

Post-Tensioning Institute (PTI) Design & Construction of Post-Tensioned Slabs-on-Ground. The official design manual for post-tensioned slab-on-ground foundations. For engineers only.

[PTI Performance Evaluation of Slab-on-Ground Foundations](#). Completely debunks the use of a single elevation survey to make definitive statements about foundation distortion. Unfortunately the suggested alternative approach has many of the same problems as the methodology the author criticizes.

[Texas Board of Professional Engineers \(TBPE\) Policy Advisory 09 98A](#). This policy advisory was the first written guidance to Texas Professional Engineers concerning what the TBPE look for in foundation performance evaluations. [It has since been superseded by the Texas Section ASCE document](#), but it still is an interesting window into how the TBPE views foundation performance evaluations.

[So Your House Is Built On Expansive Soils](#), Shallow Foundations Committee of the Geotechnical Engineering Division of the American Society of Civil Engineers. Excellent non-technical material.

[Has Your House Got Cracks?. A Guide To Subsidence and Heave of Buildings on Clay, second edition](#), T J Freeman, R M C Driscoll, and G S Littlejohn. A British publication for homeowners, home inspectors and real estate agents.

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Criteria for Selection and Design of Residential Slabs-on-Ground, report no. 33 to the Federal Housing Administration. The first attempt to develop a rational method to design slab-on-ground foundations on expansive soils. Initially it found very little acceptance among home builders and engineers working for home builders. The engineering community revolted against this report arguing that it was too conservative. Today, some of its recommendations are more widely accepted.

[Expectations of Underpinning, Foundation Repair Association.](#) A fundamentally defective discussion of what you can expect after foundation underpinning. The problem is that they recommend foundation repair first and taking care of drainage issues, lack of watering, and tree issues after the foundation work is done. In my opinion, these things should be taken care of before the foundation is underpinned. In many cases, taking care of these issues would make underpinning unnecessary.

[Diagnosing and Repairing House Structure Problems,](#) Edgar O. Seaquist, 1980 McGraw-Hill, Inc. An excellent book that addresses how to diagnose irregularities, distress, and damage in houses.

Handbook of Construction Tolerances, David Kent Ballast, 1994 McGraw-Hill, Inc. This is the standard handbook for construction tolerances.

Texas A&M Agrilife Extension: [Maintenance of Existing Foundations on Expansive Clay Soils](#)
Very good free document on how to maintain your foundation to get better performance.

The International Masonry Institute: [Masonry Movement Joint Failures.](#) Masonry construction, such as brick veneer, should include movement joints that allow the masonry to move with the foundation without cracking the brick masonry. Unfortunately, the typical Houston house shows little or no understanding of how many joints are needed or where they should be.

You can find an informative inside look at the foundation repair business at [Richard Rash's site.](#) Mr. Rash is a retired foundation repair contractor. In his blog site he explains how the foundation repair business really works.

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