

North Texas BPI



July 11-14, 2022

Protection of Plumbing from Expansive Soils Under Foundations

Protection of Plumbing from Expansive Soils under Foundations

North Texas Building Professional Institute

July 13, 2022

Irving, Texas



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INTRODUCTION

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INTENDED AUDIENCE

Design Professionals

MEP Engineers

Structural Engineers

Geotechnical Engineers

Architects

Building Officials, Plan Reviewers & Plumbing Inspectors

Contractors

Plumbing Contractors

Concrete Contractor

General Contractors

Owners

OVERVIEW

Expansive Soil

Construction Approaches

Litigation History

Standard of Care

Current Codes

Code History

Upcoming 2024 IPC

Focus: Non-Isolated Plumbing Under Isolated Slabs

INTELLECTUAL PROPERTY NOTICE

Some of the methods and devices which are discussed in this presentation are inventions by various parties and have been **PATENTED** or are **PATENT-PENDING**. These methods and devices are referenced in this presentation without naming the manufacturers. A primary purpose of referencing these methods and devices is to discuss the relative technical advantages and disadvantages of various approaches used in the industry today. This presentation is not an inducement to patent infringement. Therefore, this slide is hereby providing **NOTICE** to all attendees that attendees should assume all methods and devices discussed in this presentation are **PATENTED** or are **PATENT-PENDING** unless they verify otherwise. Attendees are welcome to contact the Presenters and request more information related to intellectual property for any specific methods and devices referenced, if desired.

EXPANSIVE SOIL

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EXPANSIVE SOIL

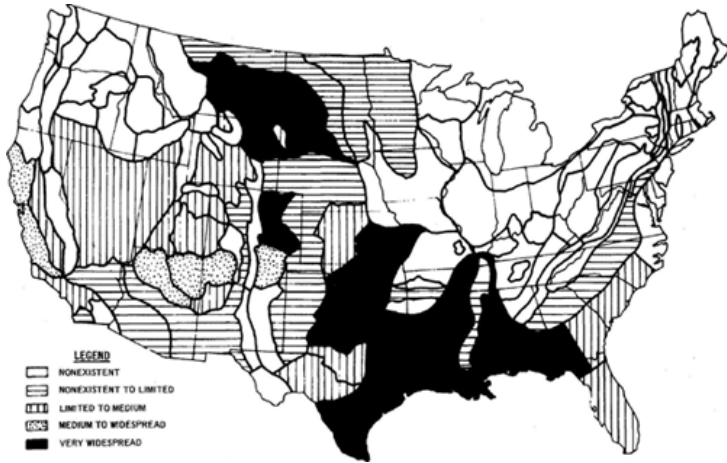


Image from the US Department of Transportation
Federal Highway Administration

Publication No. FHWA NHI-05-037 Chapter 7

May 2006

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Introduction to Expansive Soil

- Geology Matters!
- Site History Matters!
- Weather Conditions Matter!
- Groundwater Matters!
- Soils Are Anything But Uniform – “Soils were made by God, not by Man.”
- Estimating Soil Movement To The Nearest One Inch Is, At Best, Challenging (And Estimates To The Nearest Quarter Inch May Be A Fool’s Errand.)
- Soil Swell Pressures Are Measured In Tons Per Square Foot.

Expansive soils are the most costly natural hazard in the United States, causing more damage than all other natural hazards combined, including earthquakes, floods, tornadoes and hurricanes

FEMA 1982 Special Statistical Survey:
Data, Injuries and Property Loss by Type of Disaster 1970-1980. Washington D.C.

EXPANSIVE SOIL



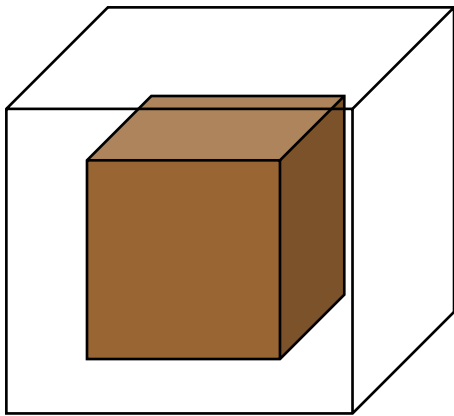
Introduction to Expansive Soil

Soil heave can be measured in ***feet***

Swell pressures can exceed ***five tons per square foot***

Soil behavior is almost always variable in both space and time!

EXPANSIVE SOIL



Introduction to Expansive Soil

Increase in moisture content ➡ Increase in volume (Swelling)
Decrease in moisture content ➡ Decrease in volume (Shrinking)

Geotechnical Engineers estimate heave using various methods

- Potential Vertical Rise (TxDOT method from the 1950s)
- Vijayvergiya & Ghazzaly (1973)
- several others

Soil shrink-swell is a four-dimensional phenomenon ($L^3 \times T$)

Depth of the “Active Zone” varies from site to site (e.g. 3 ft to 30+ ft)

“Expansive Soil” is defined by the IBC (2021 IBC Section 1803.5.3)

EXPANSIVE SOIL

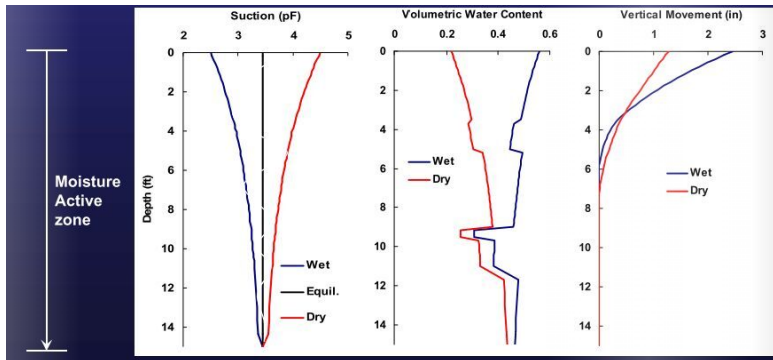


Image from a Slide by Lytton, Bryant and Read in a December 10, 2008 Presentation to the Houston Foundation Performance Association

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Introduction to Expansive Soil

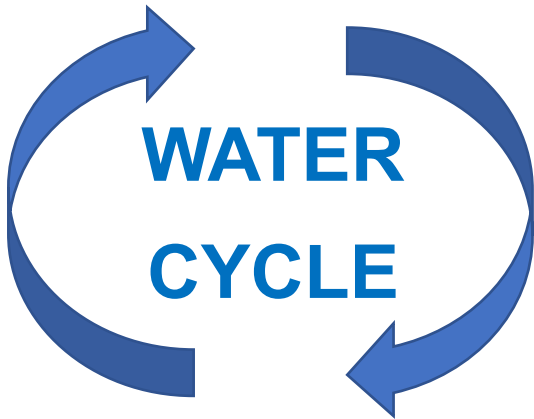
The “Potential Vertical Movement” or “PVM” method.

This is a “term of art” chosen By Dallas N. Little, P.E. and Robert L. Lytton, P.E. to describe another method to predict soil movement in expansive soils. This method has a number of very serious limitations, including the assumption that soil moves in a linear fashion (i.e. no hysteresis.) The most common version of the PVM method relies on soil suction – itself a rather tenuous soil property.

Most (90%+) structural damage is due to soil heave, not soil shrinkage. The use of “PVM” can mislead all parties to misunderstand the risks to properties from expansive soil behavior.

It is truly unfortunate that “Potential Vertical Movement” was chosen.

EXPANSIVE SOIL



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Example Causes of Moisture Change

Seasonal variations in rainfall/drought

Irrigation Systems

Adding New Trees/Bushes

Removing Existing Trees/Bushes

Ponding Rainwater

Exterior Plumbing Leaks

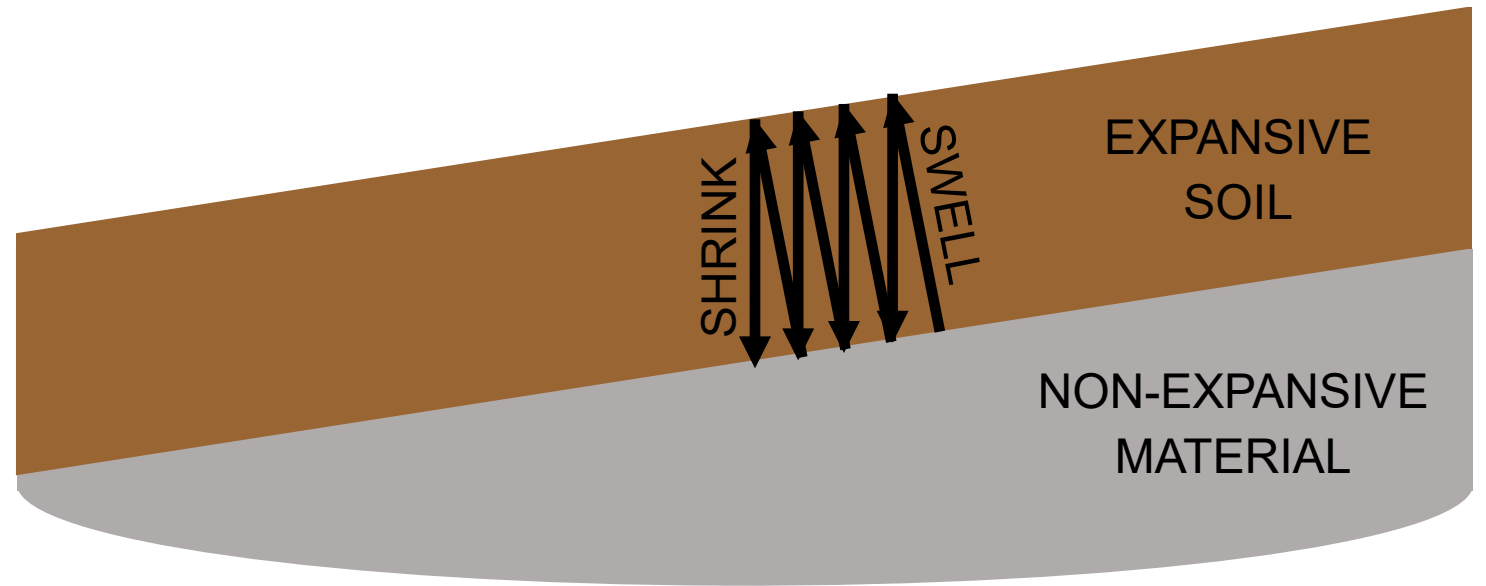
Under-Slab Plumbing Leaks

Adding Impervious Flatwork

Removing Impervious Flatwork

EXPANSIVE SOIL

Example of Cyclical Effects:
“Downhill Creep” can also cause lateral movement of the soil where a layer of expansive soil is on a relatively steep slope



This phenomenon is not as common as some engineers think. The effects of water-filled shrinkage cracks on slope stability are often mistaken for downhill creep.

EXPANSIVE SOIL

Beyond Expansive Soil

Examples of other types of volumetric soil changes:

- Settlement
- Frost Heave
- Collapsible Soils

Strategies that work for expansive soils often work for other geotechnical problems as well.

EXPANSIVE SOIL

Hire A Qualified Geotechnical Engineer!

A qualified and experienced geotechnical engineer can significantly reduce your risk of unsatisfactory architectural, structural and mechanical systems performance. Education, training, and experience really do matter.

A recent quote from Mark Gravely (Texas plaintiffs' attorney):

"I sue a lot of architects, mechanical engineers, and structural engineers. I sue geotechnical engineers the least of any design professionals." (Personal communication June, 2022.)

CONSTRUCTION APPROACHES

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FOUNDATION TYPES

Non-Isolated Slabs versus Isolated Slabs

Non-Isolated Slabs (where the slab is supported by soil under the slab)

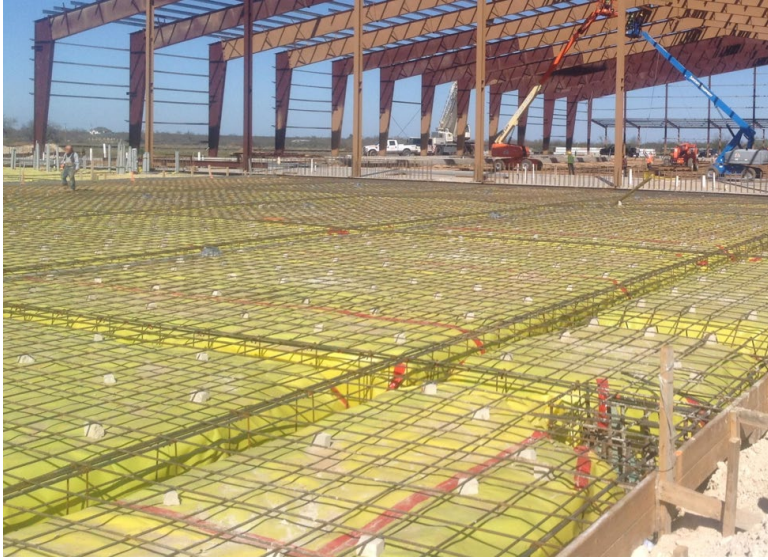
- Stiffened Slab-on-Ground
- Uniform Thickness Slab-on-Ground with Footings or Non-Isolated Grade Beams
- Uniform Thickness Slab-on-Ground with Isolated Grade Beams (bearing on piers/piles)

Isolated Slabs (where the slab is not supported by soil under the slab) can be subdivided into:

- Slab-on-Crawlspace
- Slab-on-Voidwork, where the void is created by special forms

FOUNDATION TYPES

Sketches of Non-Isolated Slabs



FOUNDATION TYPES



Non-Isolated Slabs:
Stiffened Slab-on-Ground



FOUNDATION TYPES

Non-Isolated Slabs:
Uniform Thickness Slab-on-Ground
With Footings or Non-Isolated Grade Beams



FOUNDATION TYPES

Non-Isolated Slabs: Uniform Thickness Slab-on-Ground With Isolated Grade Beams



The bottom and sides of grade beams are often formed. Grade beams typically bear on deep foundations (i.e., piers). “Soil Retainers” are retaining walls that prevent soil from entering the voidspace under the grade beams.

FOUNDATION TYPES

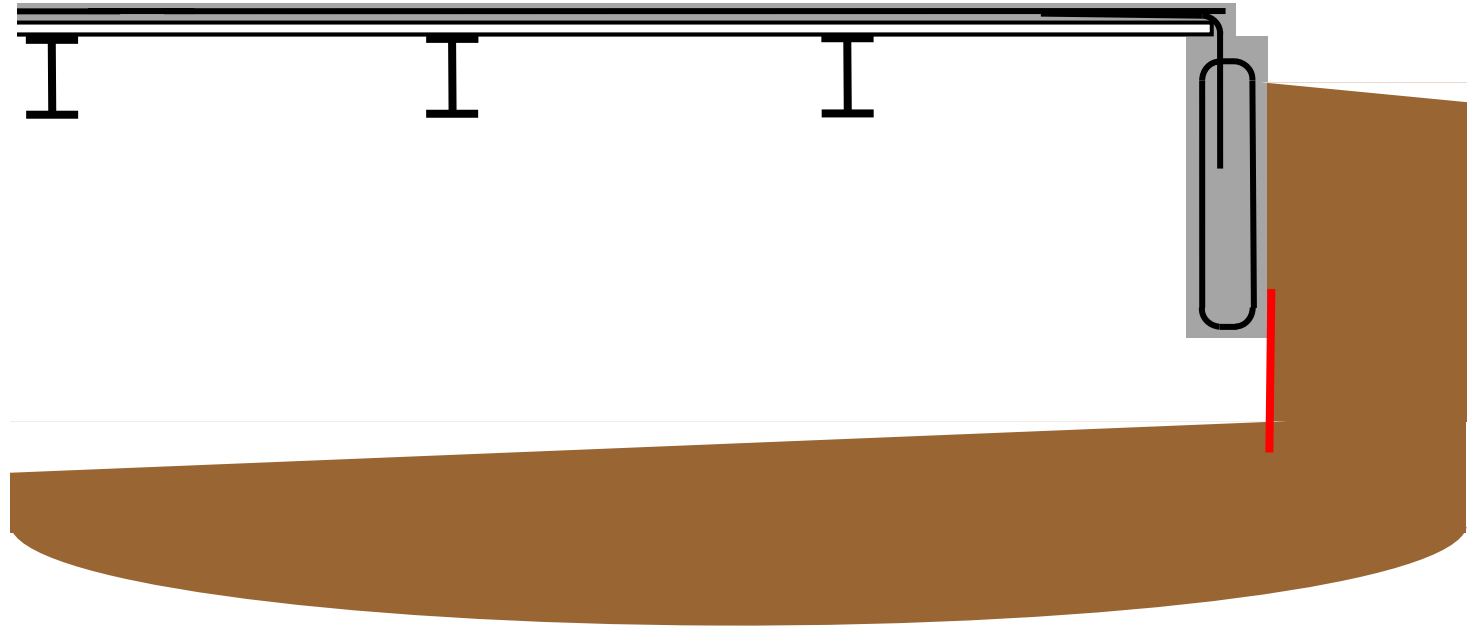
Sketches of Isolated Slabs



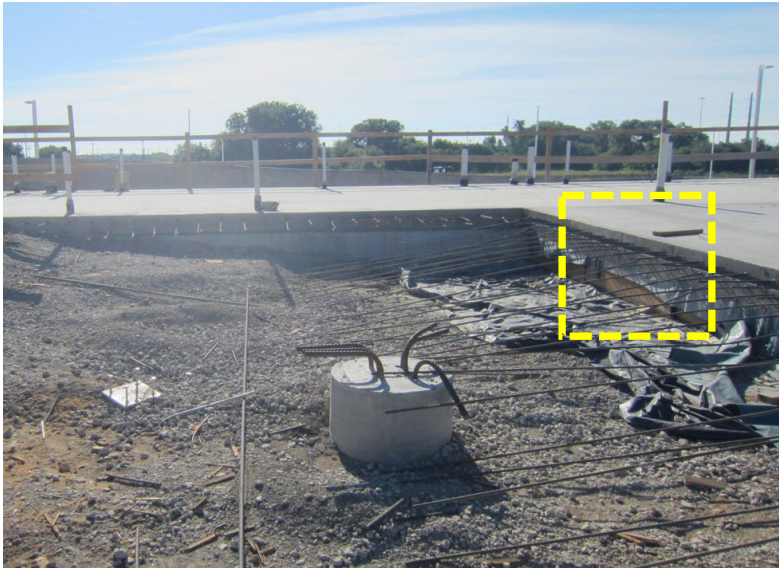
FOUNDATION TYPES



Isolated Slabs: Slab-on-Crawlspace



Slabs often consist of a composite system of steel beams with slab poured on metal deck, precast concrete (double tees or hollow core planks). Grade beams and girder beams typically bear on deep foundations. “Soil Retainers” are retaining panels or walls that protect the voidspace under the perimeter grade beams.



FOUNDATION TYPES



Isolated Slabs: Slab-on-Voidwork



When the slab is poured, the slab reinforcement and concrete are supported by a layer of “voidwork”. However, the voidwork is designed to degrade, collapse or otherwise create a space under the slab. Deep foundations support the slab permanently, on a grid about 20 ft each way.

FOUNDATION TYPES

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Isolated Slabs: Slab-on-Crawlspace vs. Slab-on-Voidwork

The terms “under-floor space” and “crawl space” are used in the IBC but not defined. A crawl space is a type of under-floor space where a person can crawl. The space under a Slab-on-Voidwork is an under-floor space but not a crawl space.

2021 IBC 1202.4 Under-floor ventilation: Requires ventilation requires natural or mechanical ventilation of “crawl spaces”. However, the IBC does not require all under-floor spaces be ventilated.

2021 IBC 1209.1 Crawl spaces: Requires that “crawl spaces” be provided with a minimum 18”x24” access opening. However, this does not require all under-floor spaces have an access opening.

Crawl spaces also typically have a minimum dimension of 18” clear under all slab framing, typically slope to drains, and often have lighting.

Under-floor spaces under Slabs-on-Voidwork rarely have access, ventilation, 18” minimum clear height, drainage or lighting.

EXPANSIVE SOIL ILLUSTRATION

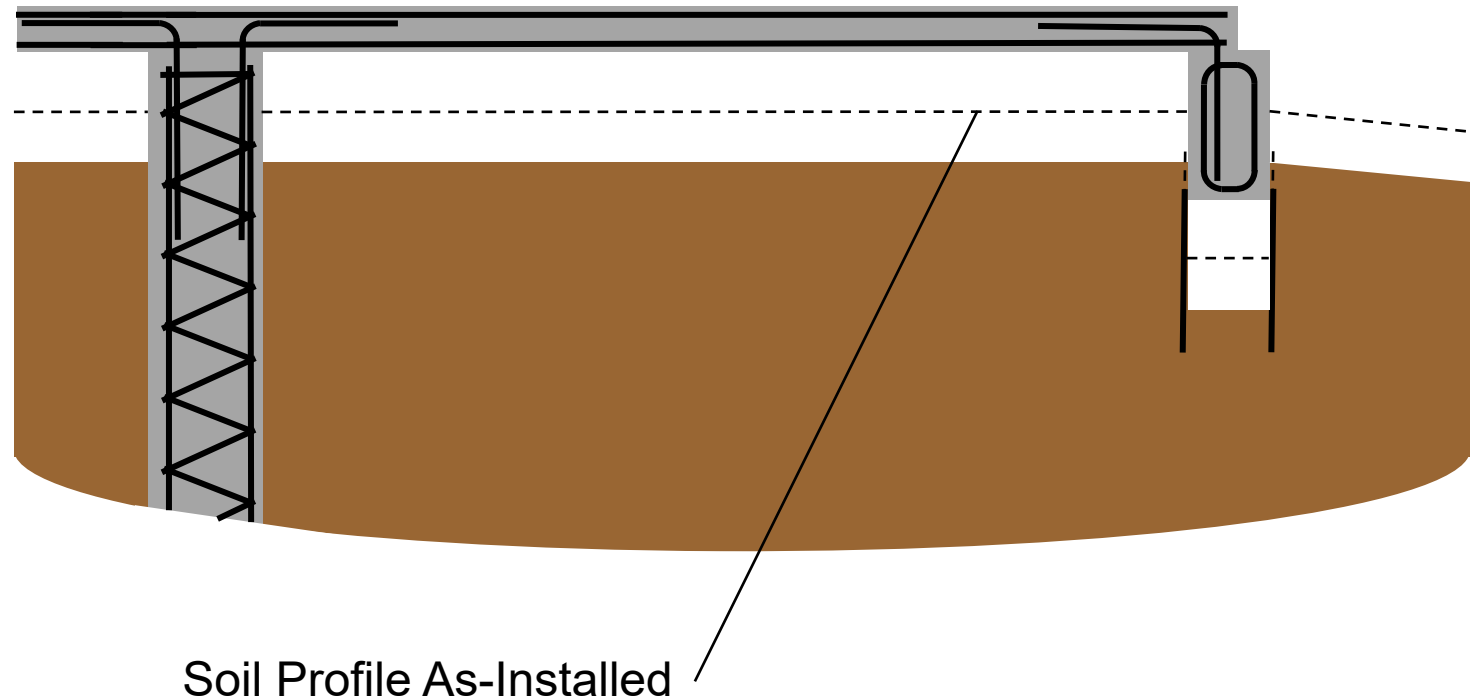
The following slides illustrate examples of Expansive Soil Behavior under **Isolated Slabs**

Please note that similar types of movement can occur under all foundation types. For non-isolated slabs, the movement will occur to the extent that the slab stiffness (and any resisting elements such as deep foundations) allows the soil movement to occur. Remember: soil swell pressures can be quite large – measured in tons per square foot – while most shallow foundation systems exert less than 400 psf on the ground.

“It’s not so much what the foundation does to the ground as it is what the ground does to the foundation.” (Garland L. Burch, P.E. around 1992)

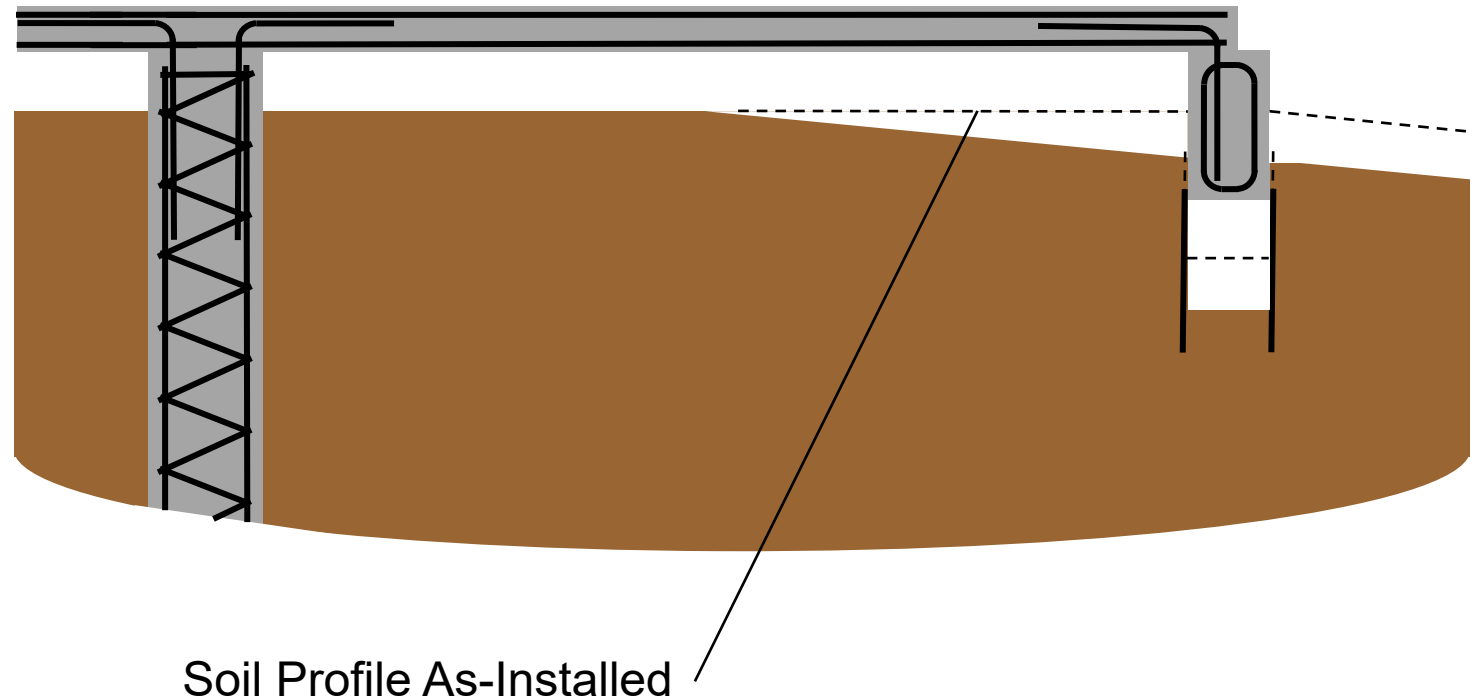
EXPANSIVE SOIL ILLUSTRATION

General Under-Slab Settlement (Examples: Uncompacted Fill Settlement, Overburden Increase Settlement)



EXPANSIVE SOIL ILLUSTRATION

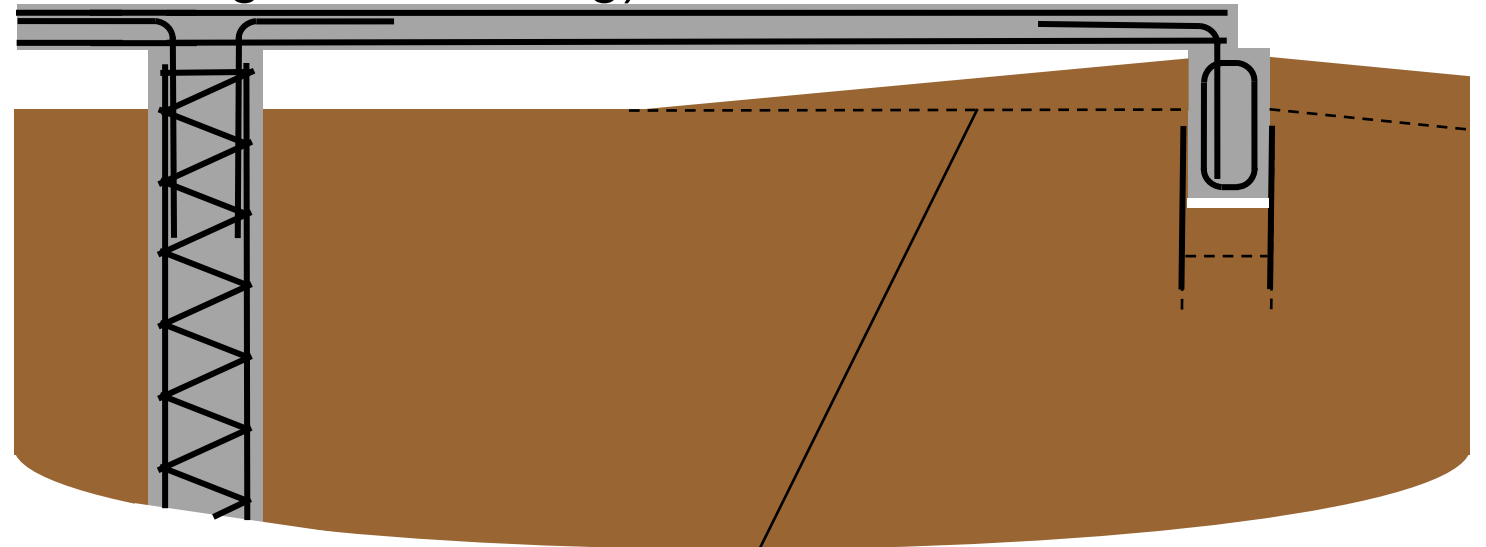
Perimeter Under-Slab Shrinkage (Examples: Seasonal Drying Shrinkage, Root-Induced Shrinkage)



EXPANSIVE SOIL ILLUSTRATION

Perimeter Under-Slab Swelling

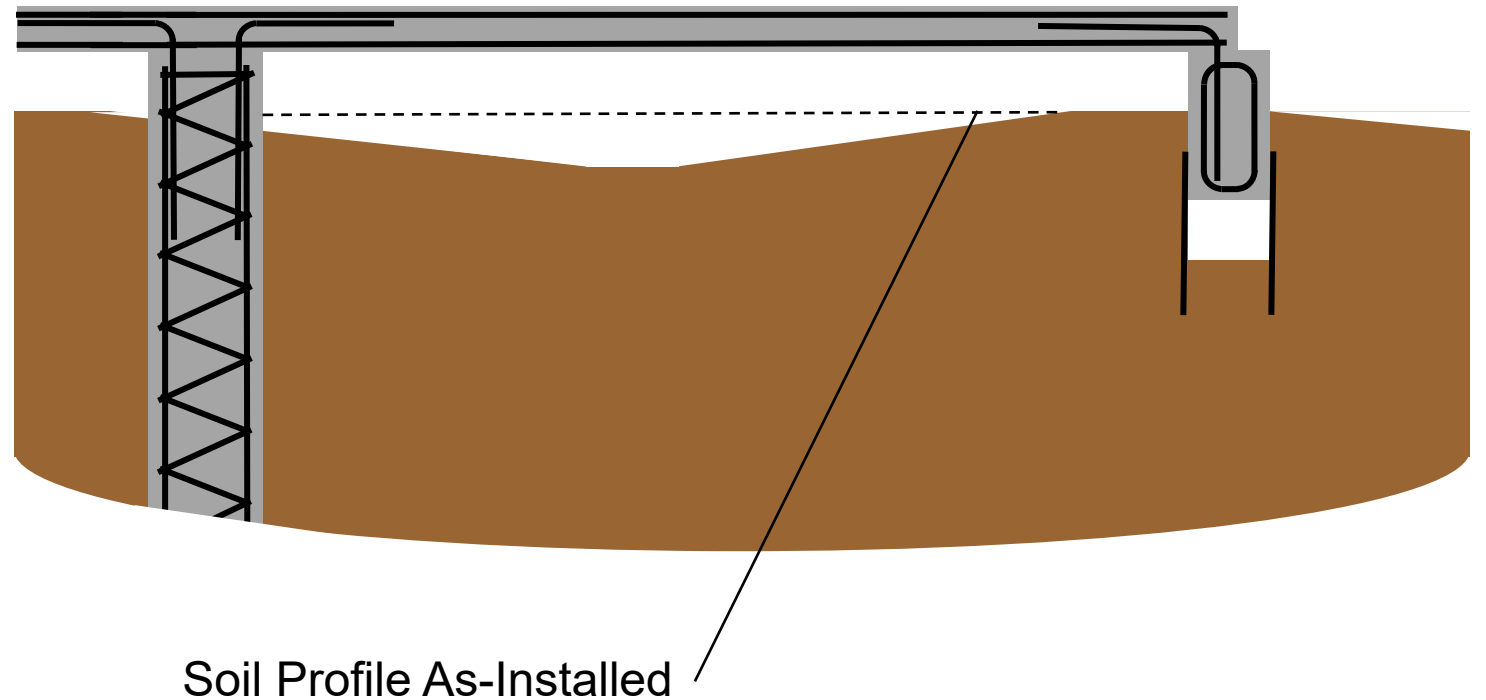
(Examples: Seasonal Wetting Swelling, Over-Irrigation Swelling, Scouring Rainfall Collection Swelling, Post-Construction Tree Removal Swelling, Perimeter Plumbing Leak Swelling)



Soil Profile As-Installed

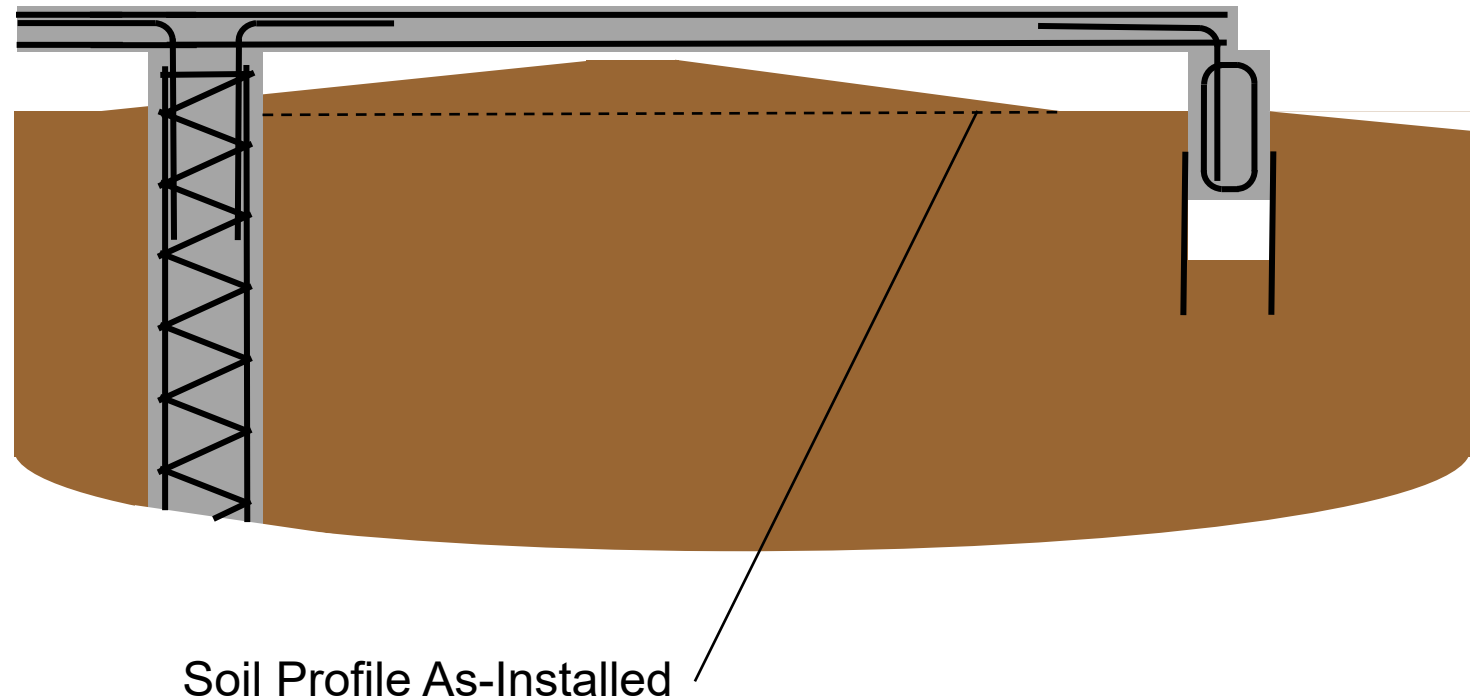
EXPANSIVE SOIL ILLUSTRATION

Localized Under-Slab Settlement
(Example: Irregular Bedrock Elevations, Poor Fill
Compaction, etc.)



EXPANSIVE SOIL ILLUSTRATION

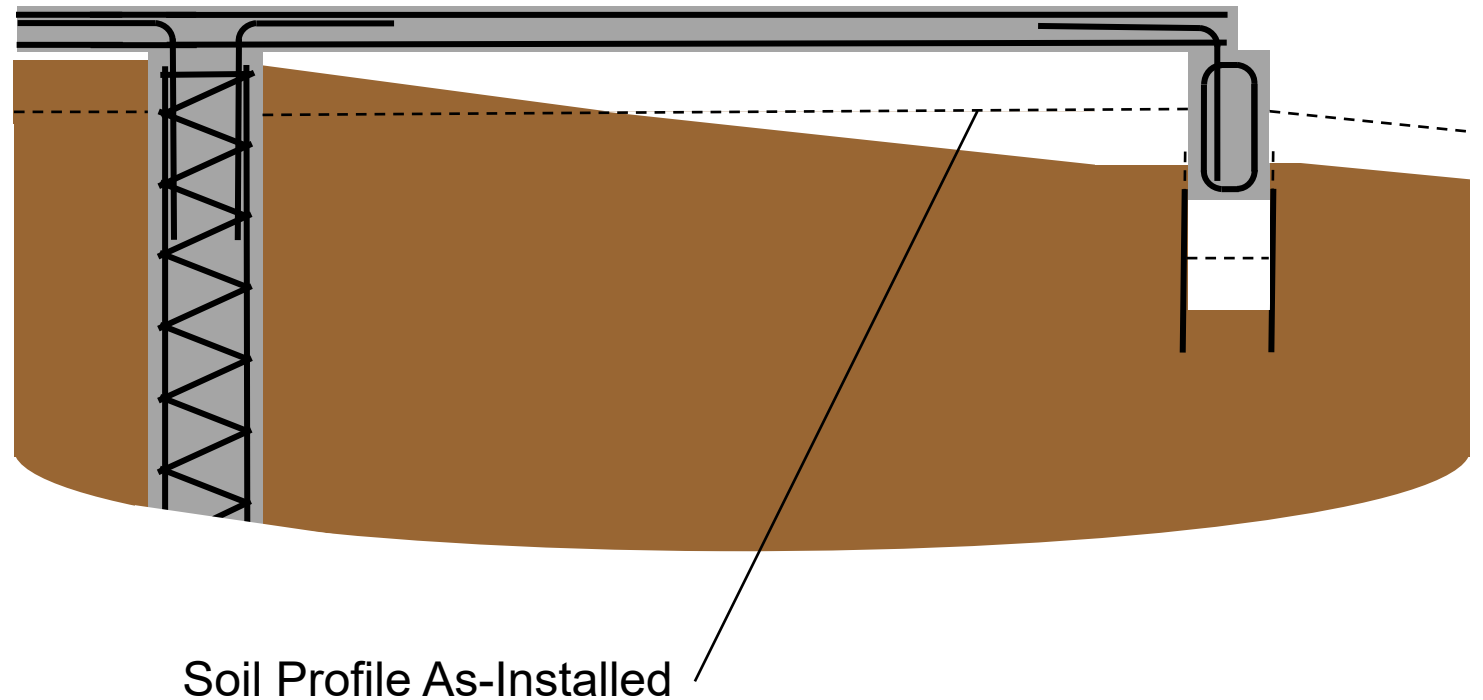
Localized Under-Slab Swelling
(Example: Under-Slab Plumbing Leaks, Isolated Pre-Construction Tree Removal without Proper Grubbing)



EXPANSIVE SOIL ILLUSTRATION

Complex Under-Slab Swelling & Shrinking

(Example: Moisture Migration in Partially Saturated
Heterogenous Soil Conditions)



PLUMBING APPROACHES

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Plumbing Approaches in Industry Today

Non-Isolated Slabs

Non-Isolated Plumbing

Isolated Slabs

Slab-on-Crawlspace

Non-Isolated Plumbing

Isolated Plumbing

Slab-on-Voidwork

Non-Isolated Plumbing

Isolated Plumbing

← **1ST INVENTED IN 2020**

PLUMBING APPROACHES

Non-Isolated Slabs (Slab-on-Ground) With Non-Isolated Plumbing

1. Expansive soil is typically removed or modified to reduce the Potential Vertical Movement (PVM) to 1" or less.
2. Because the plumbing is conventionally buried, the slab and plumbing underneath typically both move together as the soil swells/shrinks.
3. If plumbing becomes damaged by expansive soil movement, the slab can typically be sawcut above the damage and the plumbing can be repaired as feasible maintenance. A Structural Engineer may be involved if it is a post-tensioned slab, to address the cutting of post-tensioning strands and re-tensioning them, but the approach is generally the same.

PLUMBING APPROACHES

Slab-on-Crawlspace (Isolated Slab) With Non-Isolated Plumbing

1. The crawlspace provides an accessible under-floor space that isolates most of the plumbing from expansive soil damage.
2. However, often at the perimeter, where the plumbing transitions to being buried outside of the building, the plumbing becomes non-isolated and damage can occur, but the crawlspace access makes repairs feasible.

PLUMBING APPROACHES

Slab-on-Crawlspace (Isolated Slab) With Non-Isolated Plumbing



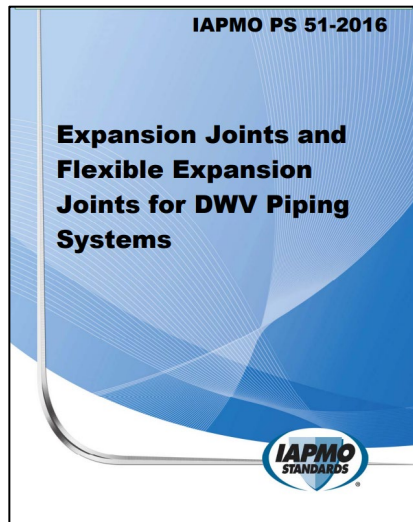
PLUMBING APPROACHES

Slab-on-Crawlspace (Isolated Slab) With Isolated Plumbing

1. The crawlspace provides an accessible under-floor space that isolates all of the plumbing from expansive soil damage.
2. Where the plumbing transitions to being buried outside of the building, a flexible expansion joint is provided with an initial vertical offset that is sufficient to allow the upward potential vertical movement estimated by the geotechnical engineer. And, the Plumbing Designer selects the flexible expansion joint unit so that it can also allow the downward potential vertical movement estimated by the geotechnical engineer without breaking the plumbing.

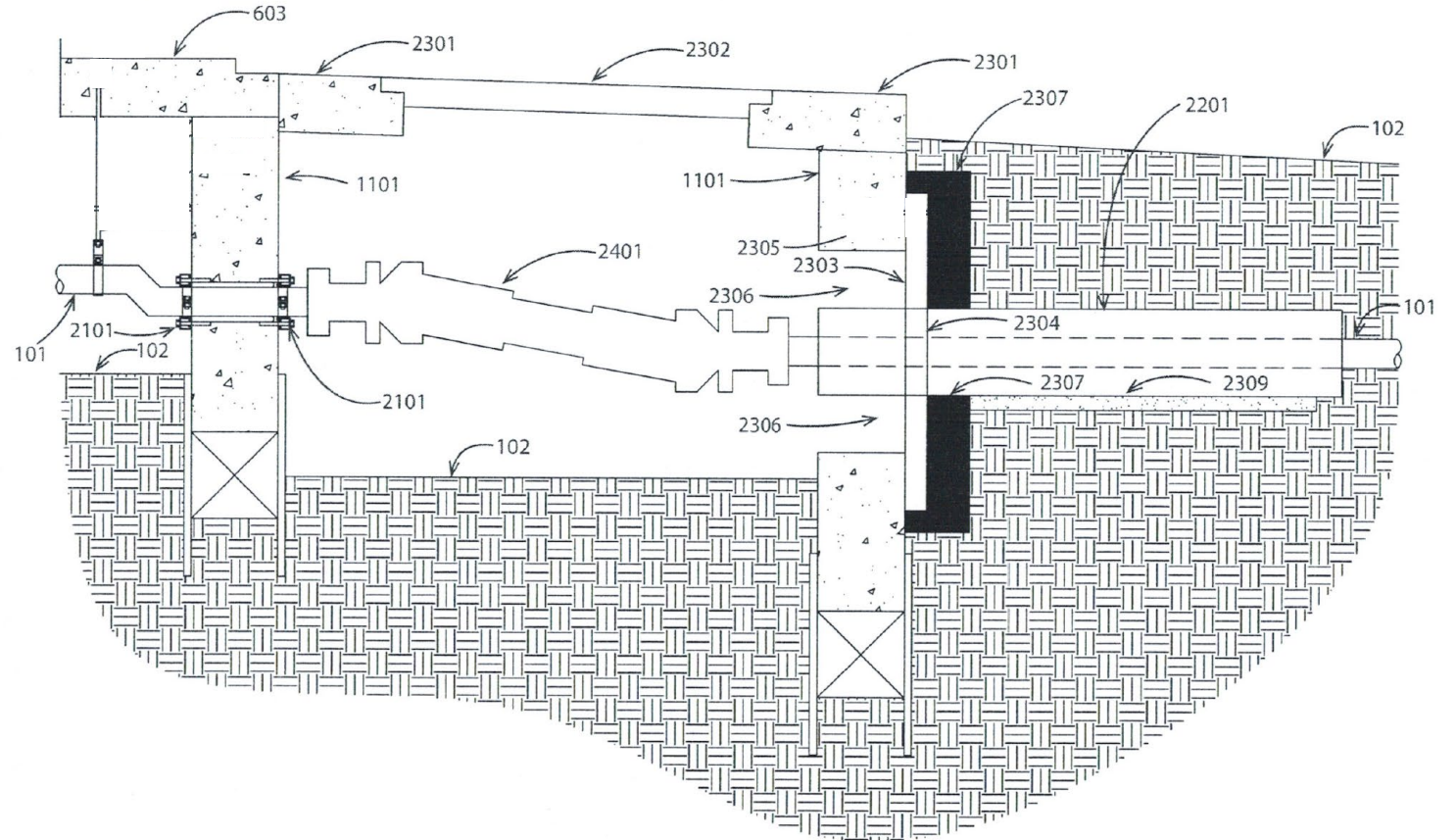


PLUMBING APPROACHES



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Slab-on-Crawlspace (Isolated Slab) With Isolated Plumbing



Note: This is an example of a PATENT-PENDING method.

PLUMBING APPROACHES

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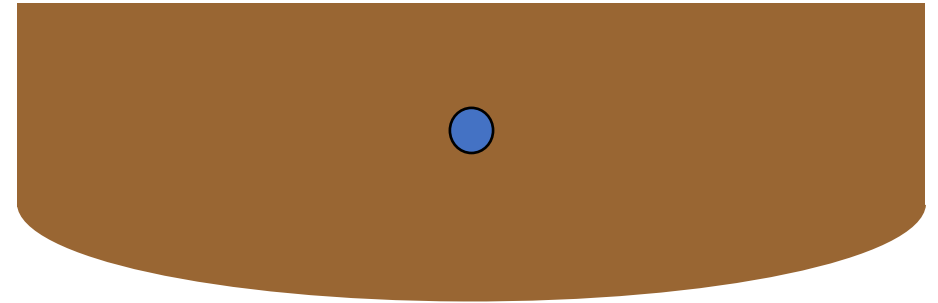
Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

1. Plumbing has to bridge between a moving system (the soil) and a non-moving system (the slab), so re-occurring damage is common.
2. Any damage to the plumbing under the slab becomes extremely expensive to repair because there is no access and the slabs typically CANNOT be sawcut immediately over the damaged plumbing because it will structurally weaken the slab, which can and has caused areas of the slab to fall.
3. Small, temporary access openings are typically sawcut in the slab, in between pier lines in both plan directions, and soil is hand excavated (shovel by shovel) and wheelbarrowed out of the building to reach the damaged plumbing. After all this effort, the repairs typically do not isolate the plumbing. Because they do NOT solve the under-lying reason that damage occurred, plumbing damage can reoccur.

PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



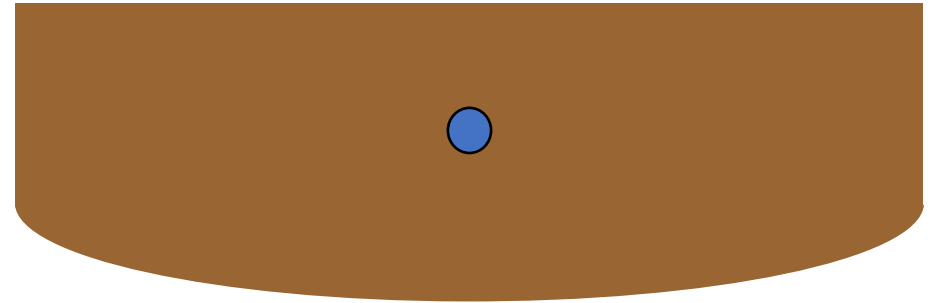
Non-Isolated
Void Systems



PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



Non-Isolated
Void Systems

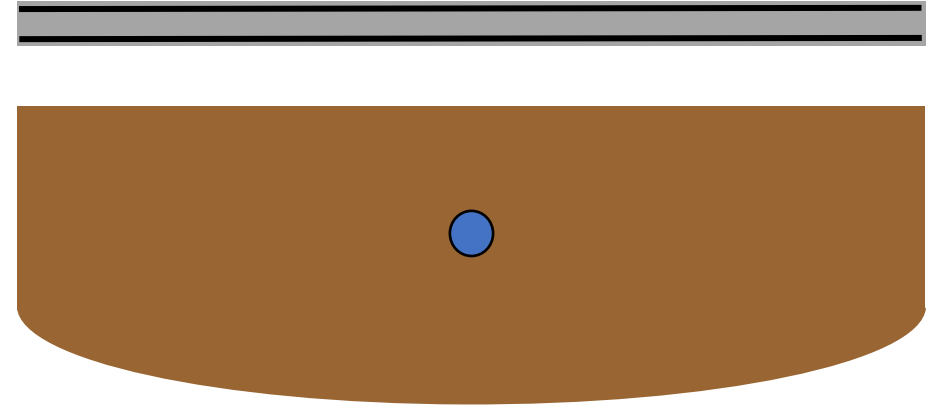


PLUMBING APPROACHES

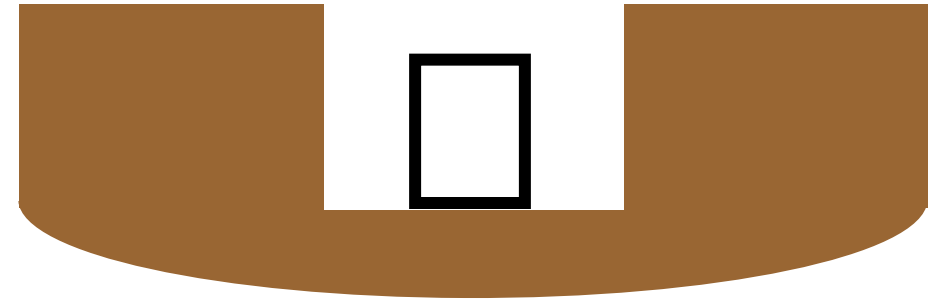
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Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



Non-Isolated
Void Systems

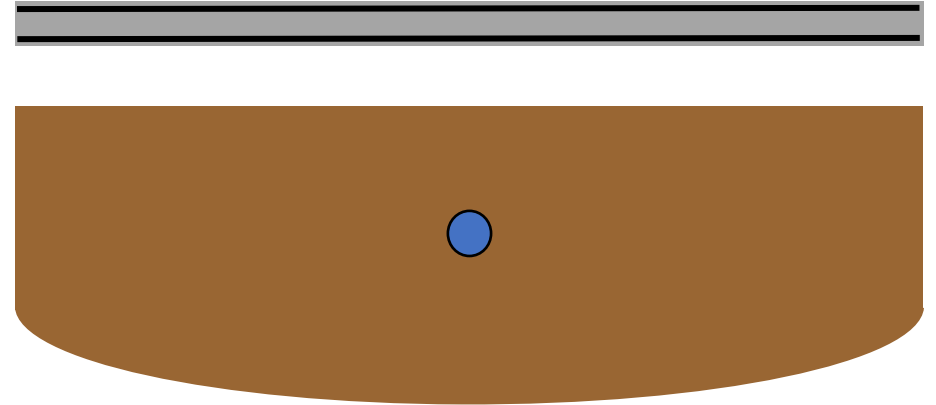


This is a conceptual example.
Product details vary.

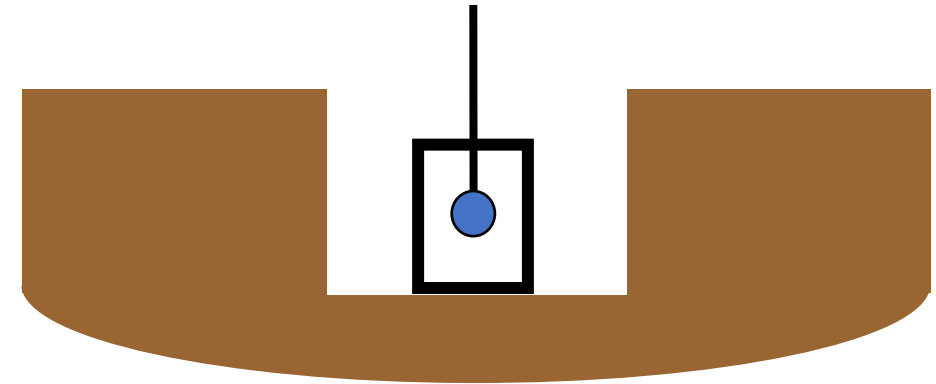
PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



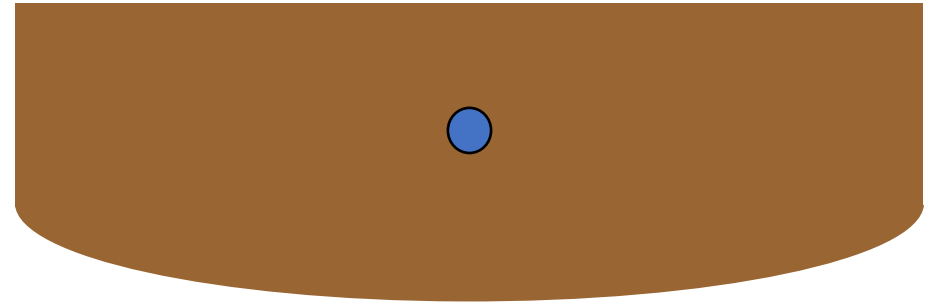
Non-Isolated
Void Systems



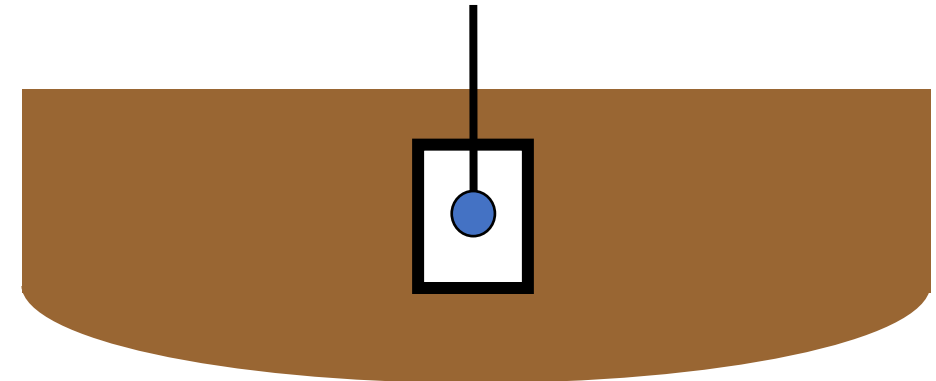
PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



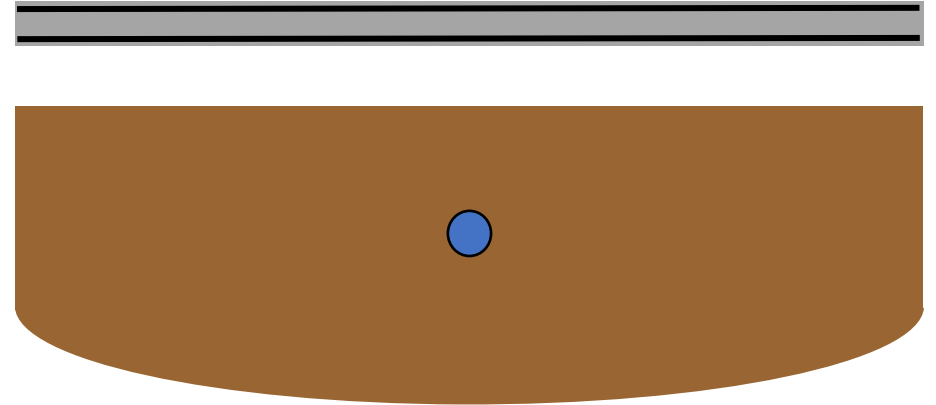
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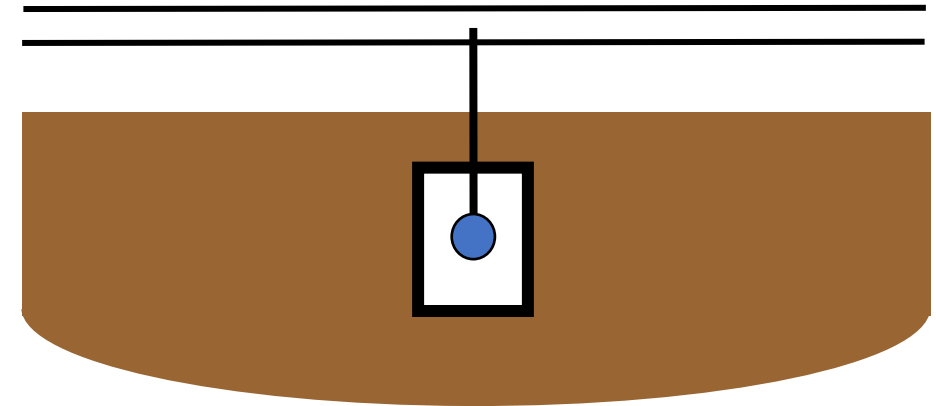
PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



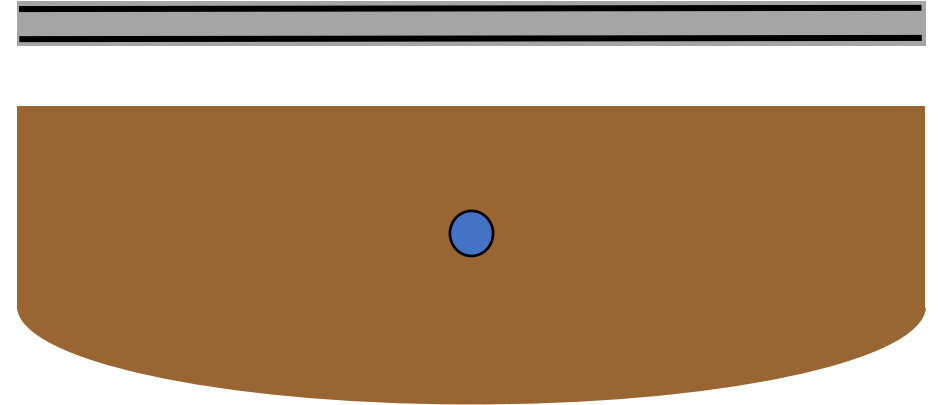
Non-Isolated
Void Systems



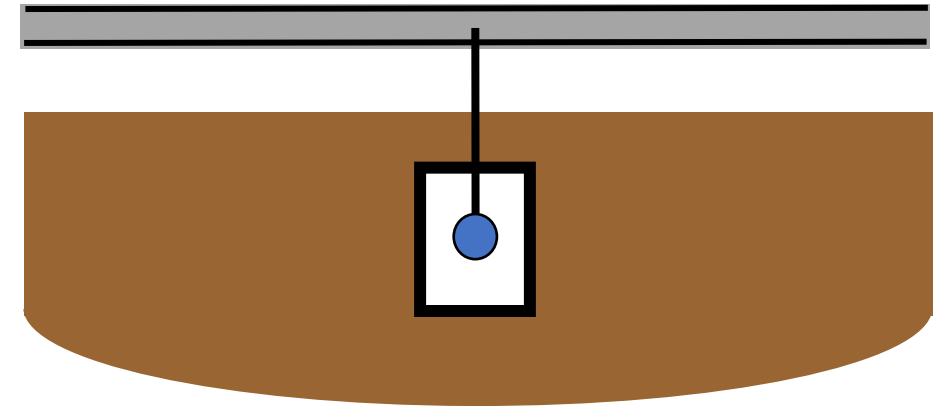
PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



Non-Isolated
Void Systems



Regardless of how the manufacturers may claim that their connection will flex or slip if soil movement occurs, these systems do not isolate the plumbing, hangers and supports below the slab from all soil-induced loads.

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PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Non-Isolated Plumbing

Buried Pipe



Examples of
Non-Isolated
Void Systems



PLUMBING APPROACHES

Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

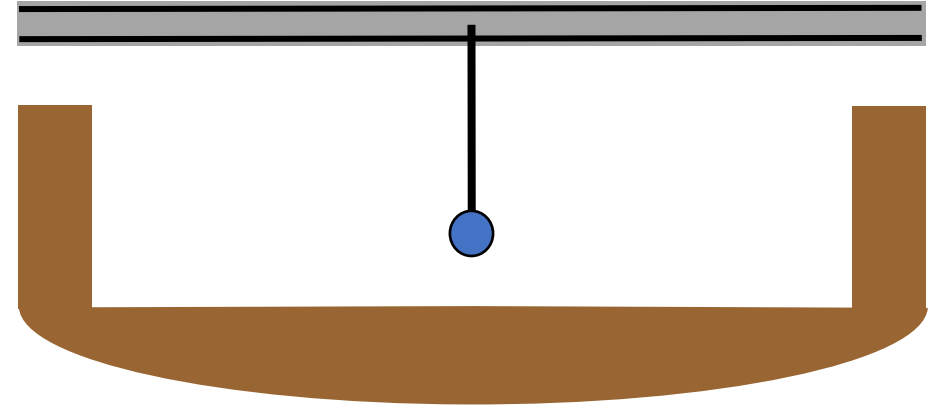
1. Plumbing, hangers and supports below the slab are not in contact with the subgrade and no assemblage of materials is in contact with both the subgrade and any plumbing, hangers or supports below the slab. This allows the estimated potential vertical movement and the potential horizontal movement to occur without damaging the plumbing.
2. Flexible expansion joints are installed in concrete vaults at the building perimeter to allow access for routine inspection, maintenance and replacement of flexible expansion joints. (Similar to that shown for flexible expansion joints for Slab-on-Crawlspace with isolated plumbing,

PLUMBING APPROACHES

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Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

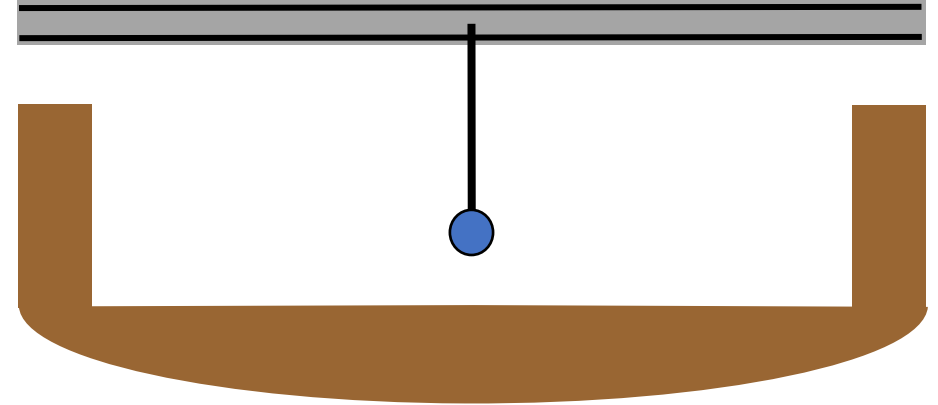


PLUMBING APPROACHES

DP

Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

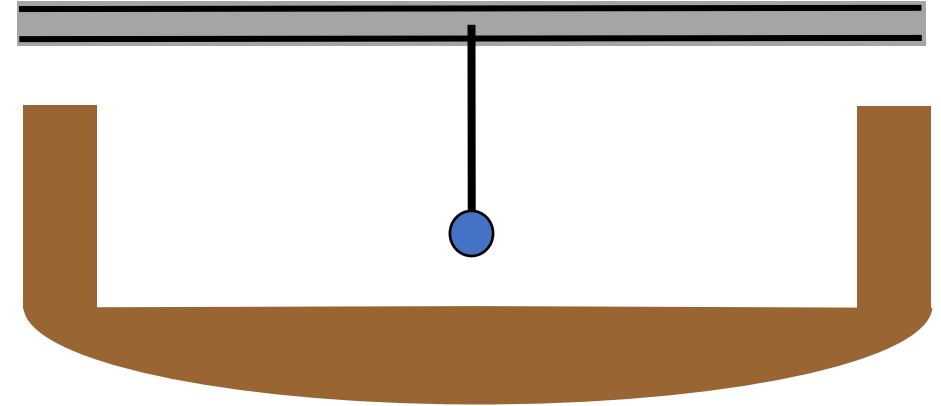


PLUMBING APPROACHES

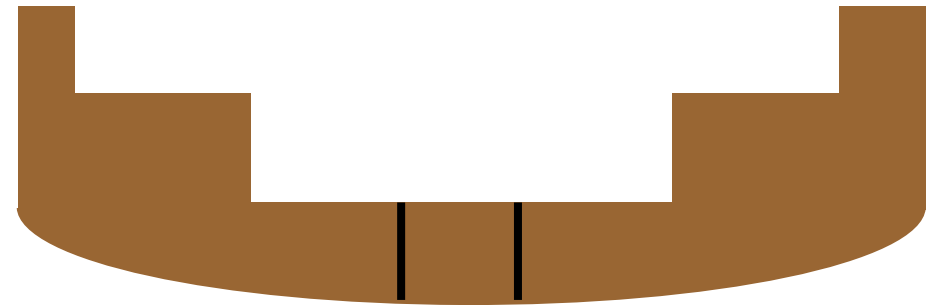
DP

Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

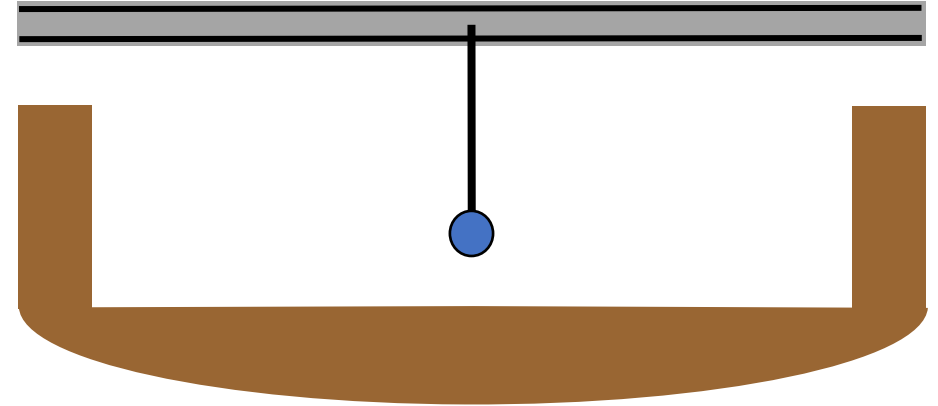


PLUMBING APPROACHES

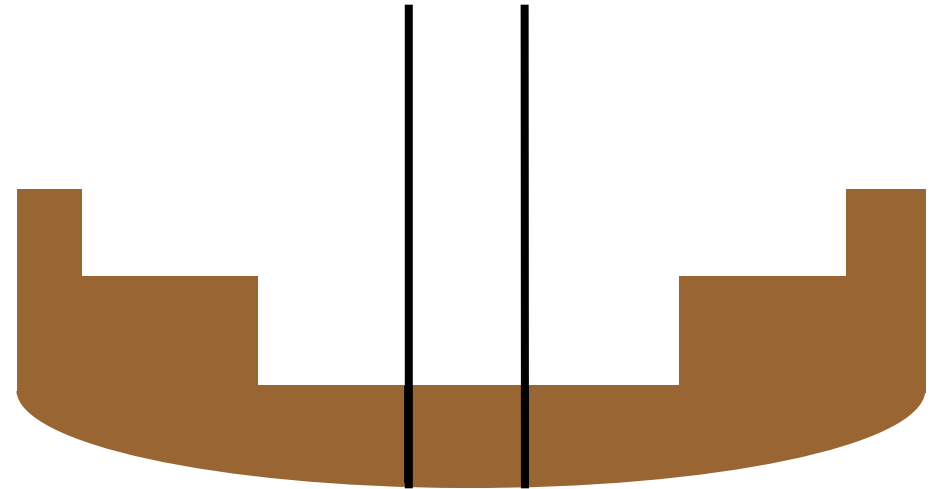
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Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

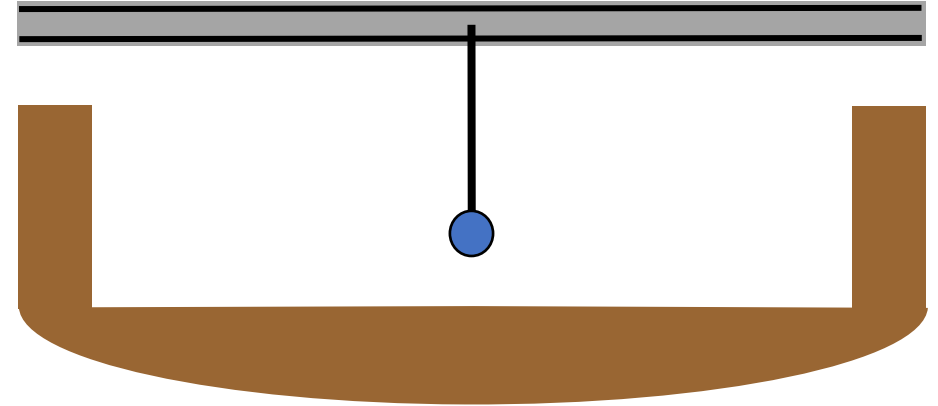


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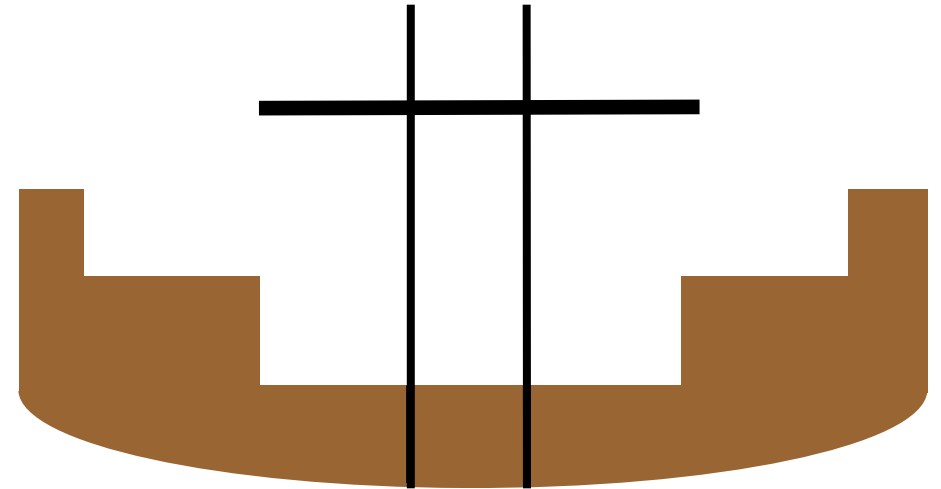
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Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

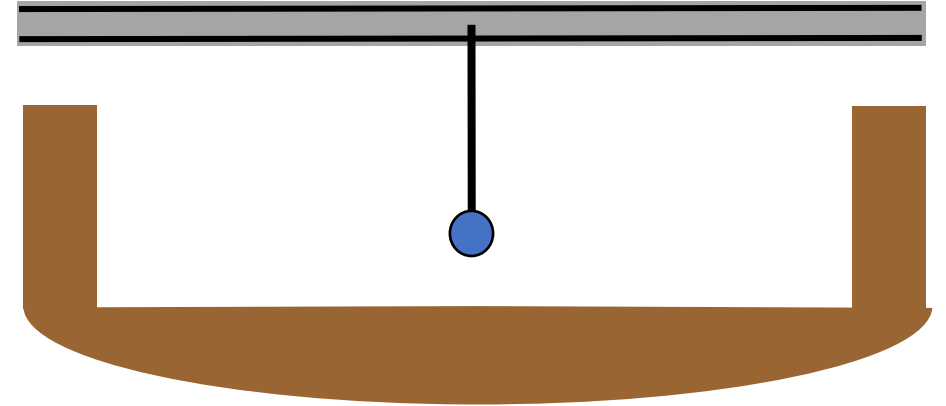


PLUMBING APPROACHES

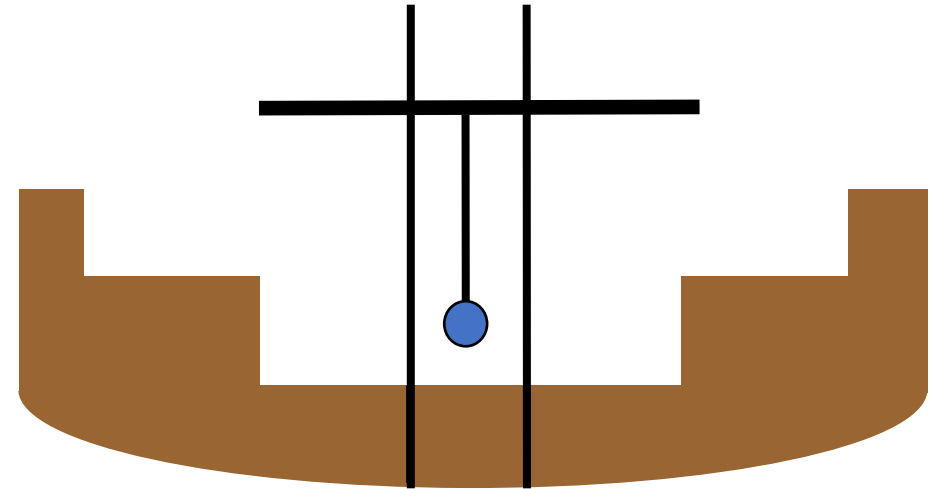
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Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



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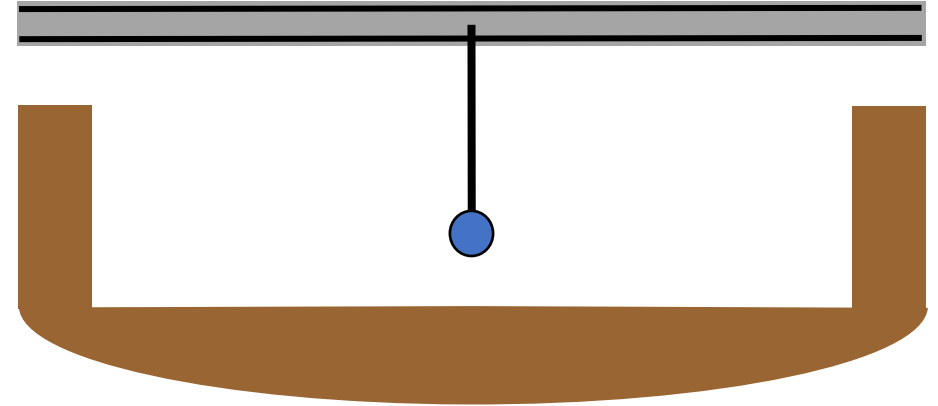


PLUMBING APPROACHES

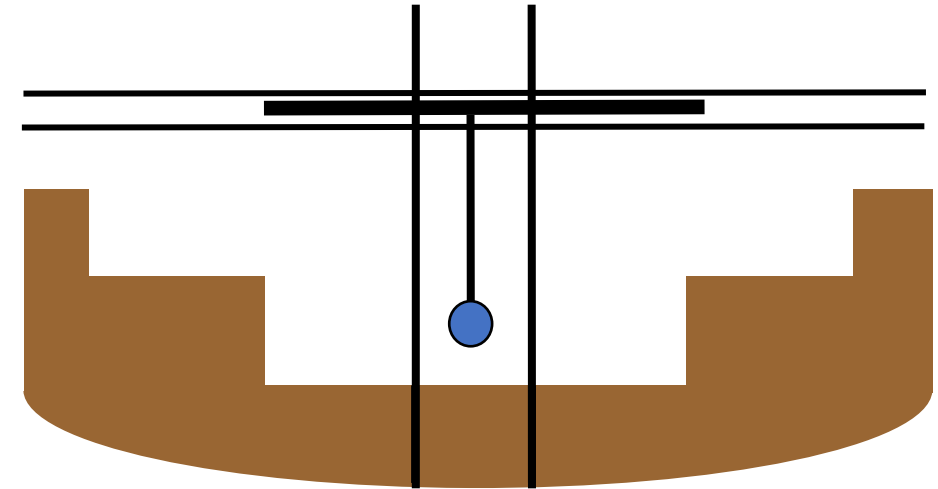
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Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

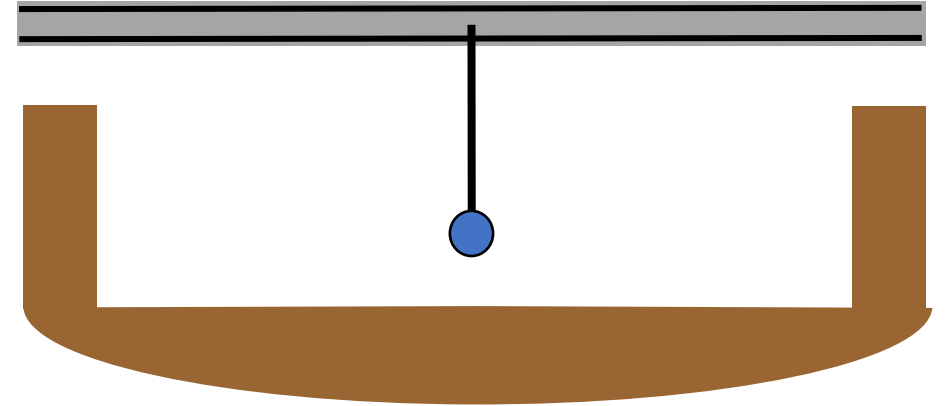


PLUMBING APPROACHES

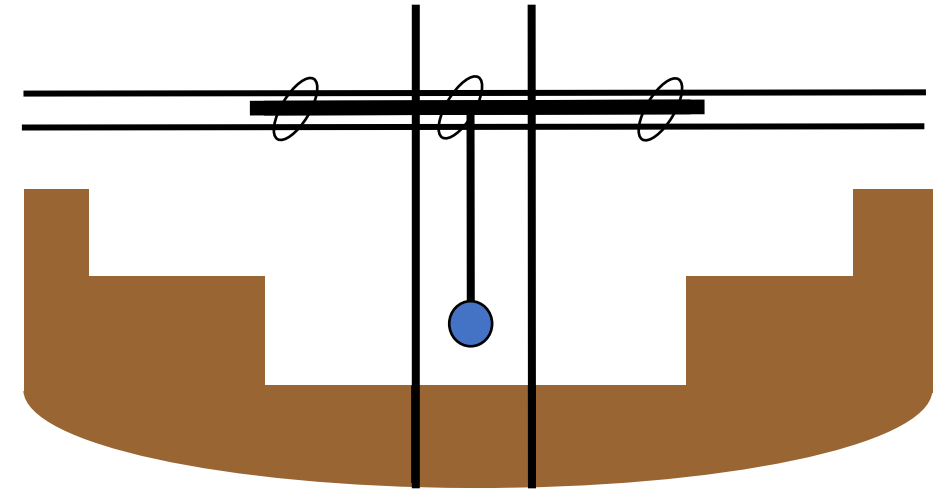
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Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

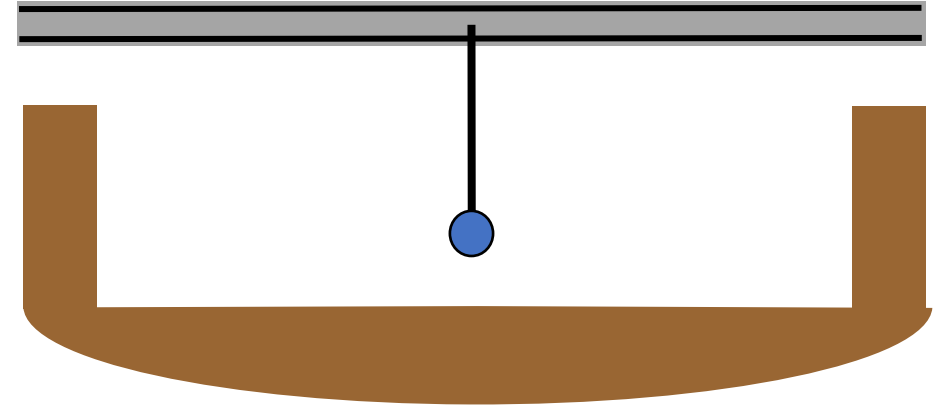


PLUMBING APPROACHES

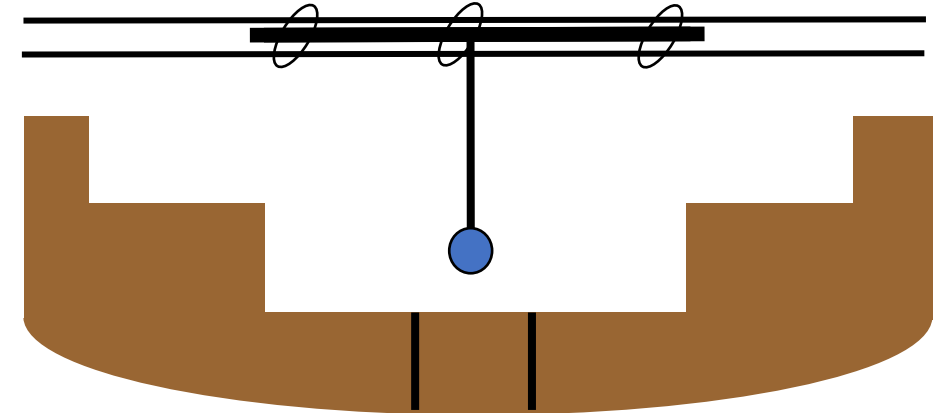
DP

Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed

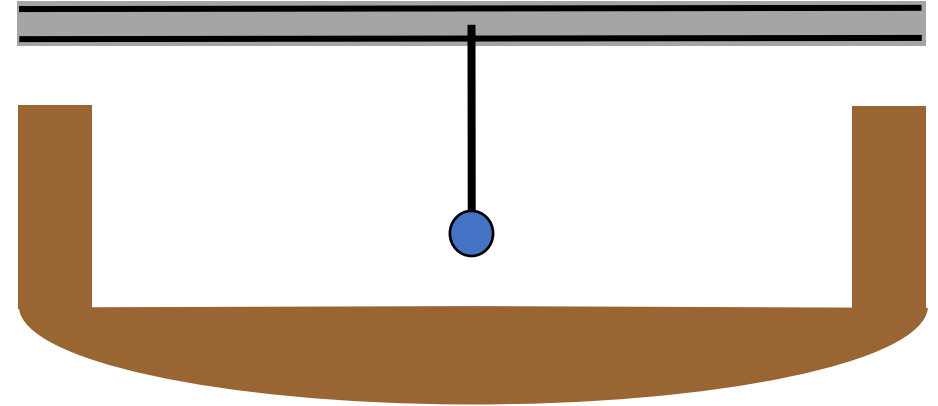


PLUMBING APPROACHES

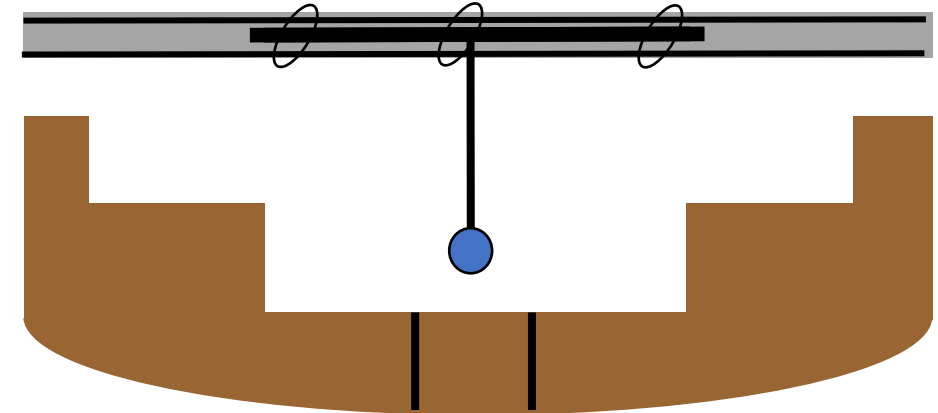
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Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed



Pre-Installed



PLUMBING APPROACHES

DP

Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing

Post-Installed

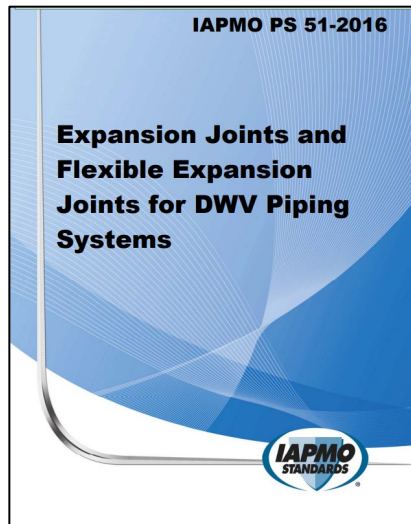


Pre-Installed

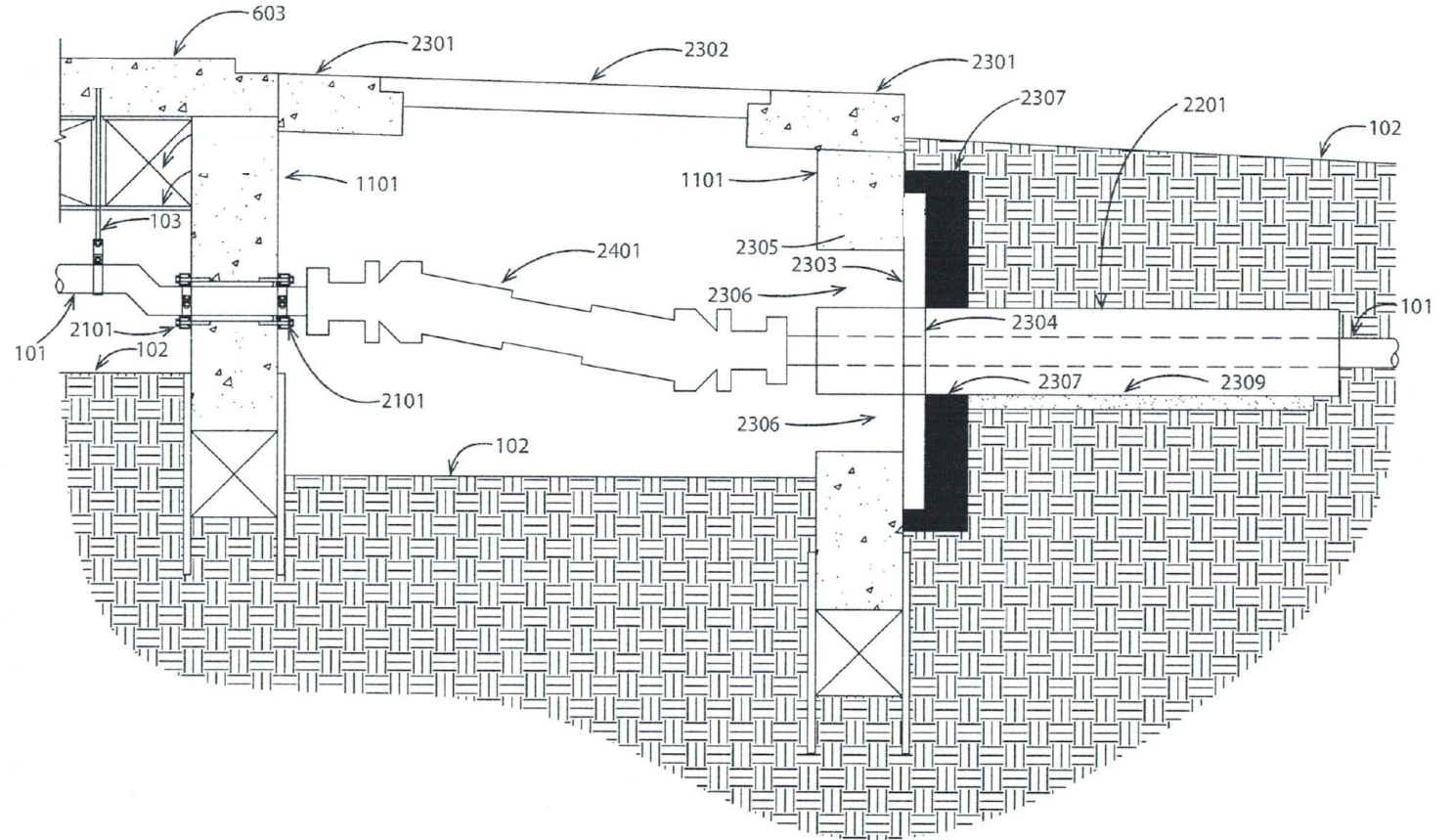




PLUMBING APPROACHES



Slab-on-Voidwork (Isolated Slab) With Isolated Plumbing



LITIGATION HISTORY

JF

LITIGATION HISTORY

Non-Isolated Slabs

Non-Isolated Plumbing

Isolated Slabs

Slab-on-Crawlspace

Non-Isolated Plumbing ← MAJOR LITIGATION

Isolated Plumbing

Slab-on-Voidwork

Non-Isolated Plumbing ← MAJOR LITIGATION

Isolated Plumbing

LITIGATION HISTORY

In the United States Court of Federal Claims

No. 09-672C

(Filed: September 7, 2012)

BPLW ARCHITECTS & ENGINEERS, INC.,
Plaintiff,
v.
THE UNITED STATES,
Defendant.

Gregory N. Ziegler, with whom was Alexander G. Blue, Macdonald Devin, P.C., Dallas, Texas, for Plaintiff.

P. David Oliver, with whom were Stuart Delery, Acting Assistant Attorney General, Joanne E. Davidson, Director, Franklin E. White, Jr., Assistant Director, Shelley D. Weger, and Kenneth D. Woodrow, Trial Attorneys, Commercial Litigation Branch, Civil Division, U.S. Department of Justice, Washington, DC, for Defendant.

OPINION AND ORDER

WHEELER, Judge.

The Government contracted with BPLW Architects & Engineers, Inc. to provide architectural and engineering services for the construction of two student dormitory buildings at Lackland Air Force Base in San Antonio, Texas. Shortly after the general contractor, CF Jordan, finished construction of the dorms, below grade piping problems occurred, resulting in the flooding of several dorm units. The Government contracted with CF Jordan to repair some of the broken pipes and with another contractor, Tepa EC, LLC to replace the entire subsurface piping system and to remedy the inadequate grading around the dorms.

Federal Court Ruling re Isolated Slabs and Non-Isolated Plumbing

“The Government claims that BPLW provided a negligent underfloor piping design, as the design failed to accommodate the “highly expansive” soils in the San Antonio area. In addition, the Government claims that BPLW provided a negligent civil site grading design, as it did not provide for the requisite five percent slope away from the dorms. The Government contends that these negligent designs caused the piping problems at the dorms and led it to incur substantial expense to repair broken pipes, replace the underfloor piping system, and remedy the site grading.”

“As set forth below, the Court finds that BPLW did indeed provide negligent underfloor piping and civil site grading designs, as both failed to comply with the contract requirements and the applicable standard of care.”

BPLW ARCHITECTS & ENGINEERS, INC. V. THE UNITED STATES
IN THE UNITED STATES COURT OF FEDERAL CLAIMS
NO. 09-672C (FILED: SEPTEMBER 7, 2012)

The remediation was post-Installed JF
isolated plumbing under slab-on-voidwork

“On the advice of the forensic consultant, the client chose to excavate a deep crawl space under the building floor – essentially a basement – so workers could access the sewer lines and repair them. This labor-intensive effort cost about \$8.3 million*. Not surprisingly, the client filed construction-defect claims against all the design firms involved, the constructor-in-charge, and the mechanical constructor. **The client was seeking \$25 million to pay for sewer-line repairs, floor-slab repairs, interior repairs, lost revenue from residents, resident-relocation costs, attorney’s and expert’s fees, and court Costs.**” **All financial factors are reported in 2020 dollars. Foundation approx.*

“The Member Firm agreed to a settlement two weeks before the trial; seven years after the client initiated the claim; and eleven years after the Member Firm initiated the project.”

LITIGATION HISTORY

JF

Examples of Litigation reported in the News re Isolated Slabs and Non-Isolated Plumbing

ISD Petitions to Further Investigate Architects, Inc

By Christine Lee • Published June 25, 2014 • Updated on June 26, 2014 at 1:10 pm



Trending Stories

- COLLEYVILLE
Rabbi Grateful To
After Synagogue
Center Fire

The Independent School District wants to know if Architects, Inc., who designed the now closed football stadium, is also responsible for causing millions of dollars in damages at its properties.

A North Texas school district wants to know if the same company that designed the now closed football stadium is behind problems with their buildings.

The nearly \$60 million football stadium closed two years after opening. Engineering experts said the stadium's cracks were caused by problems in the structural design.

- \$60M High School Stadium Closed by Cracks

That structural design was made by Architects, Inc., the same company that designed two of Independent School District's campuses — Elementary School and Middle School.

Both schools sit on top of a type of soil that could be difficult to build on. In documents filed for a deposition, the ISD stated they shared that information with Architects. In the filing, the school district also stated that shifting soil caused foundation problems to leading leaks in both schools, costing the district about \$4 million to fix.

- ISD Reveals Information From Stadium Engineering Study

ISD issued a statement saying that the two problems were detected and resolved back in 2009 and 2012. They said the petition comes after a lengthy review in an effort to hold the responsible contractors accountable.



(Texas) district sues architect and builder over facility conditions at intermediate school

Oct. 3, 2017

The district contends that a faulty foundation at Intermediate School has led to structural defects.

Mike Kennedy

The (Texas) district has sued the firms that designed and built one of its intermediate schools 11 years ago over what it contends is a faulty foundation that has resulted in structural defects.

The reports that Intermediate School in which opened in 2006, is beset by deteriorating conditions such as cracks in walls and concrete, and

LITIGATION HISTORY

ML

Examples of Damage with Slab-on-Voidwork and Non-Isolated Plumbing With only 1/2" Vertical Movement

>\$1M Damage
at a High School

1/2" movement like this can
occur in Buried Plumbing or
Non-Isolated Void Systems



Damage under Slab-on-Voidwork
to Non-Isolated Plumbing is likely
much more common than realized.

LITIGATION HISTORY

Examples of Repairing Non-Isolated Plumbing under an Slab-on-Voidwork after only 1/2" Vertical Movement (>\$1M)



ML

This repair simply replaced cracked plumbing in a non-isolated condition, so damage is expected to re-occur again.

LITIGATION HISTORY

Examples of Plumbing Damage under Slab-on-Crawlspace where Plumbing Transitions to Non-Isolated Plumbing



Cracked Plumbing



Backdraining Plumbing

STANDARD OF CARE

DP

STANDARD OF CARE

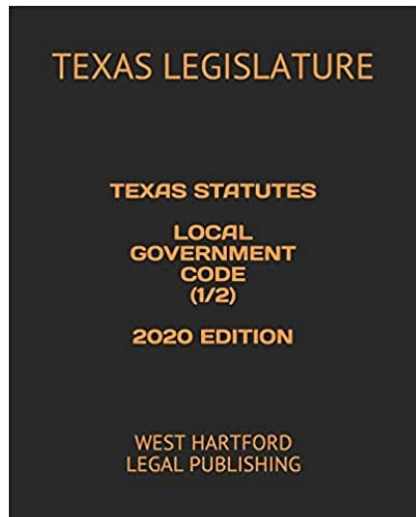
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No Limitation of Liability on Public Work

If a design firm has \$2M in errors and omissions insurance and has to pay \$25M in litigation for negligence, which was the amount of the claim in GBA Case Study 108, on a public work project where there is no limitation of liability, the insurance carrier would have to pay \$2M and **the design firm would have to pay \$23M.**

The typical defense for a specifying engineer is to show that they complied with applicable construction codes and practiced within the “standard of care”, as both are typically required in agreements defining an engineer’s scope.

STANDARD OF CARE



DP

Texas Local Government Code

Section 271.904

- (d) A contract for engineering or architectural services to which a governmental agency is a party must require a licensed engineer or registered architect to perform services:
- (1) with the professional skill and care ordinarily provided by competent engineers or architects practicing under the same or similar circumstances and professional license; and
 - (2) as expeditiously as is prudent considering the ordinary professional skill and care of a competent engineer or architect.

SUBJECTIVE

WILL A JUDGE OR JURY FIND A PLUMBING ENGINEER WHO SPECIFIED NON-ISOLATED PLUMBING UNDER A SLAB-ON-VOIDWORK TO BE "COMPETENT"?

STANDARD OF CARE

DP

Concerns for Design Professionals when the Standard of Care Changes

If a lawsuit occurs years after plans are signed and sealed by an Engineer, it is difficult for a Judge or Jury to disregard changes that happened after the plans were signed and sealed. If engineers stop specifying non-isolated plumbing in the future, expert witnesses will testify that their opinion is non-isolated plumbing is not within the standard of care during the trial. Judges and Juries should not consider this testimony to be relevant, but it is hard for non-technical people to understand the distinction, especially as there is plenty of evidence today that non-isolated plumbing should not be specified under slab-on-voidwork foundations.

It's hard to defend "saving" a Client \$1/sf on construction costs when evidence like this emerges in the industry that the Client may have to spend \$10/sf every few years in plumbing repairs (not including the costs of interrupting building function) over and over again. It just looks like engineering negligence to a Client after the damage occurs.

STANDARD OF CARE

FPA-SC-11.1 Specification and Application of Void Spaces Below Concrete Foundations Foundation Performance Association - Structural Committee				
18 Jul 14 Page 1 of 11				
SPECIFICATION AND APPLICATION OF VOID SPACES BELOW CONCRETE FOUNDATIONS				
by The Structural Committee of The Foundation Performance Association Houston, Texas www.foundationperformance.org				
Document # FPA-SC-11-1				
Rev. # 1 ISSUE HISTORY (Some internal committee issues omitted)				
Rev #	Date	Description	Subcommittee Chair(s)	Subcommittee Members
0A	03 Jan 13	Issued for Committee Review		
0B	29 Jan 14	Issued for FPA Peer Review 1		Ron Kelm Larry Lanz
0C	09 Apr 14	Issued for Committee Review	Michael Skoller	Rob Riedel Mike Turner
0D	10 Apr 14	Issued for FPA Peer Review	Greg Carr	Nicole Wylie
0E	11 Jun 14	Issued for Committee Review		
1	18 Jul 14	Issued for Website Publication		

DP

15 Year-Old Guidance from the Foundation Performance Association

“Specification and Application of Void Spaces Below Concrete Foundations” by a Committee of the Foundation Performance Association in 2014 (with similar language in 2007)

3.7 CONSIDERATIONS FOR UNDER-SLAB UTILITIES

“Under-slab utilities should be carefully designed when Void Space is provided between the Slab Area and Grade Beams and the soil. Expansive Soil should not support under-slab utilities below an Isolated Slab on an Isolated Foundation. Under-slab piping must remain stationary with respect to the Slab Area.”

IF ANY UPWARD SOIL MOVEMENT OCCURS UNDER A NON-ISOLATED VOID SYSTEM UNDER A SLAB-ON-VOIDWORK, THE PLUMBING WILL NOT REMAIN STATIONARY WITH RESPECT TO THE SLAB AREA.

STANDARD OF CARE

[illegible]

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Recent events that have begun to further change plumbing design practices under Isolated Slab Foundations

The Structural Engineers Association of Texas (SEAoT) proposed new provisions for the 2024 IPC (International Plumbing Code) and submitted a 14-page Rationale Statement. This statement was based on a review by a collaboration of structural, mechanical and geotechnical engineers of the state of the practice, recent litigation, a publication from the Foundation Performance Association, and various products on the market. The code change proposal was supported by the American Institute of Architects, the Geoprofessional Business Association, the American Council of Engineering Companies – Texas, and various mechanical, geotechnical and structural engineers (many having been sued).

The new provisions were approved (with some floor modifications clarifying what SEAoT proposed) by government voting across the country and **the change will be in the 2024 IPC, requiring isolation of plumbing, prohibiting buried pipes, and prohibiting non-isolated void systems under slab-on-voidwork foundations where expansive soil is present.**

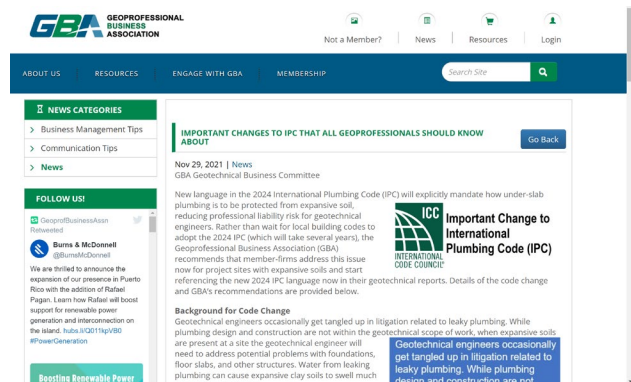
In November 2021, GBA issued a recommendation to its thousands of Geotechnical Engineers across the country that Geotechnical Engineers explicitly recommend isolation of plumbing under Slab-on-Voidwork in their soil reports.

STANDARD OF CARE

GBA Recommends Isolation of Plumbing under Isolated Slabs

“For geotechnical reports on projects with expansive soils where the floor slab will be above a crawlspace or void forms, GBA recommends that the reports include recommendations that are consistent with this new section of the 2024 IPC, regardless of whether the IPC or the UPC is locally adopted.”

<https://www.geoprofessional.org/news/important-changes-to-ipc-that-all-geoprosessionals-should-know-about/>



CURRENT CODES

DP



CURRENT CODES



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International Plumbing Code All Editions from 2000 to 2021

SECTION 305 PROTECTION OF PIPES AND PLUMBING SYSTEM COMPONENTS

Stress and strain. Piping in a plumbing system shall be installed so as to prevent strains and stresses that exceed the structural strength of the pipe. Where necessary, provisions shall be made to protect piping from damage resulting from expansion, contraction and structural settlement.

CURRENT CODES

DP

Discussion on Code Interpretation

2021 International Building Code Example:

From Section 104.1: “The building official shall have the authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions.”

From Section 105.4: “The issuance or granting of a permit shall not be construed to be a permit for, or an approval of, any violation of any of the provisions of this code or any other ordinance of the jurisdiction. Permits presuming to give authority to violate or cancel the provisions of this code or other ordinances of the jurisdiction shall not be valid. The issuance of a permit based on construction documents and other data shall not prevent the building official from requiring the correction of errors in the construction documents and other data. The building official is authorized to prevent occupancy or use of a structure where in violation of this code or any other ordinances of this jurisdiction.”

International Property Maintenance Code (All Editions)

“Plumbing fixtures shall be properly installed and maintained in working order, and shall be kept free from obstructions, leaks and defects and be capable of performing the function for which such plumbing fixtures are designed. Plumbing fixtures shall be maintained in a safe, sanitary and functional condition.”

CURRENT CODES



DP



IAPMO Uniform Plumbing Code All Editions from <2000 to 2024

“Piping in connection with a plumbing system shall be so installed that piping or connections will not be subject to undue strains or stresses, and provisions shall be made for expansion, contraction, and structural settlement.”

CURRENT CODES



DP

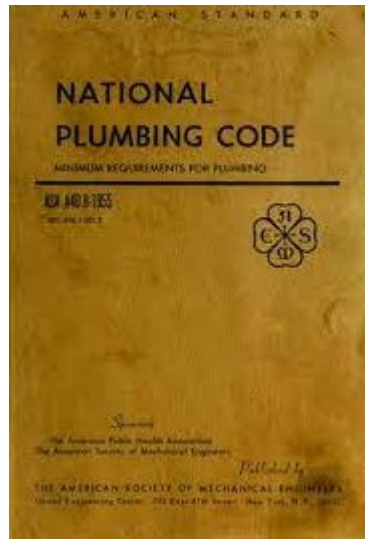
CODE HISTORY

DP

ASA A40.8 National Plumbing Code 1955 Edition

Some of the relevant “Basic Principles” in this document indicate that protection of plumbing from expansive soil is a health, safety and welfare issue.

CODE HISTORY

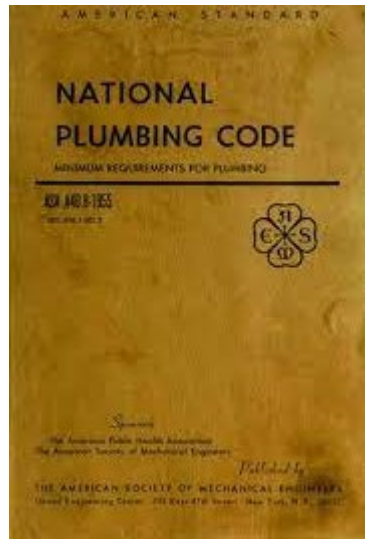


DP

ASA A40.8 National Plumbing Code 1955 Edition

Principle No. 9: The piping of the plumbing system shall be of durable material, free from defective workmanship, and so designed and constructed as to give satisfactory service for its reasonable expected life.

CODE HISTORY

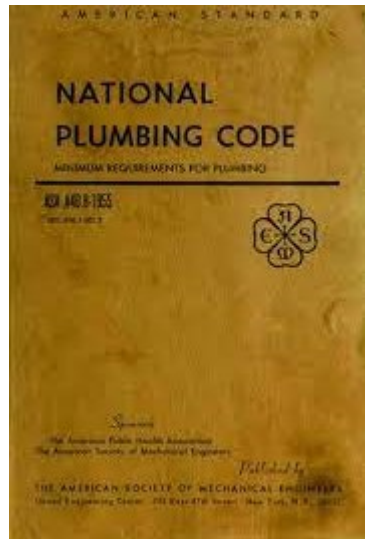


DP

ASA A40.8 National Plumbing Code 1955 Edition

Principle No. 18: Where a plumbing drainage system may be subjected to backflow of sewage, suitable provision shall be made to prevent its overflow in the building.

CODE HISTORY

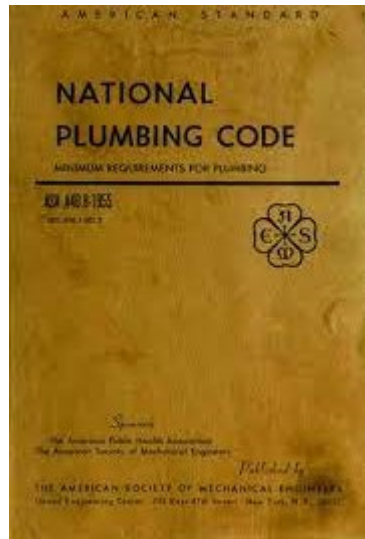


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ASA A40.8 National Plumbing Code 1955 Edition

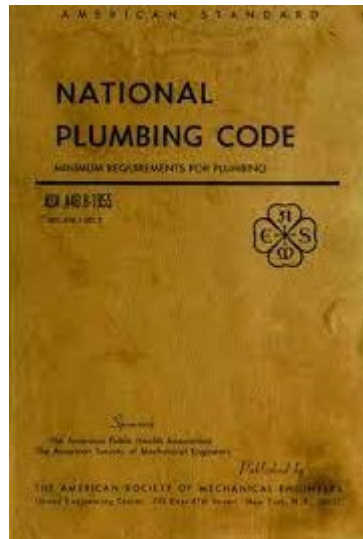
Principle No. 19: Plumbing systems shall be maintained in a sanitary and serviceable condition.

CODE HISTORY



DP

CODE HISTORY



DP

ASA A40.8 National Plumbing Code 1955 Edition

Principle No. 22: Sewage or other waste from a plumbing system which may be deleterious to surface or subsurface waters shall not be discharged into the ground or into any waterway unless it has first been rendered innocuous through subjection to some acceptable form of treatment.

UPCOMING 2024 IPC

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UPCOMING 2024 IPC



INTERNATIONAL
CODE
COUNCIL®

DP

International Plumbing Code New Language in the 2024 Edition

Explicitly requires protection of plumbing from expansive soil and defines when expansive soil is present.

Allows buried plumbing under Slabs-on-Ground.

Requires complete isolation of plumbing under Slab-on-Crawlspace and Slab-on-Voidwork: ***“It shall not be permitted for the plumbing, hangers and supports below the slab or below the framing to be in contact with soil or any assemblage of materials that is in contact with soil within the active zone.”***

Exception 1 allows buried pipe for drainage of crawl spaces

Exception 2 allows attachment to piers if the plumbing, hangers and supports are otherwise isolated.

305.8 Expansive Soil. Where expansive soil is identified under buildings in accordance with Section 1803.5.3 of the International Building Code, but not removed in accordance with Section 1808.6.3 of the International Building Code, plumbing shall be protected in accordance with Section 305.8.1 or 305.8.2.

305.8.1 Non-Isolated Foundations. Under foundations with slabs that are structurally supported by a subgrade, it shall be permitted for plumbing to be buried.

305.8.2 Isolated Foundations. Under foundations with a slab or framing that structurally spans over an under-floor space which isolates the slab or framing from the effects of expansive soil swelling and shrinking in accordance with Section 1808.6.1 of the International Building Code, the plumbing shall be suspended so that plumbing, hangers and supports are isolated, by a voidspace, from the effects of expansive soil swelling and shrinking.

Exception: It shall be permitted for plumbing to be buried if the plumbing provides drainage of an under-floor space.

To protect the voidspace, soil shall be sloped, benched or retained in accordance with an approved design methodology.

It shall not be permitted for the plumbing, hangers and supports below the slab or below the framing to be in contact with soil or any assemblage of materials that is in contact with soil within the active zone. It shall not be permitted for a slab and plumbing to be lifted as an assembly to create the voidspace unless the under-floor space is a crawlspace with access to allow inspection of plumbing after lifting.

Exception: It shall be permitted for the piping, fittings, hangers, and supports below the slab or below the framing to be in contact with structural elements of the foundation that are designed to resist the effects of expansive soil swelling and shrinking in accordance with Section 1808.6.1 of the International Building Code.

Organic materials subject to decay shall not be used for hangers, supports and soil retention systems. Materials subject to corrosion shall not be used for hangers, supports and soil retention systems unless protected in an approved manner.

Where plumbing transitions to a buried condition beyond the perimeter of the foundation, an adequately flexible expansion joint shall be provided in the plumbing system to accommodate the effects of expansive soil swelling and shrinking.

IAPMO rejected the proposed change because they **believe it is clear that UPC already requires that** plumbing engineers design/specify plumbing so as to protect plumbing from expansive soil, and those engineers would be at fault even if someone were to argue that the code is not sufficiently clear.

IAPMO REJECTION



DP

Rejection of SEAoT's Proposal by 2024 IAPMO UPC Committee

“I’m going to reject this proposal on a few reasons. Number one, I think the code is already pretty clear in requirements to support and protect piping. And, if the soil is no good to support the piping, they have to provide alternative methods of supporting the piping, not just the soil. I’ve personally installed many piping systems underground that are hanging from the slab on grade because of conditions similar to this. Secondly, the engineering of a system, the design of a system, is based in part on the plumbing code, not in whole on the plumbing code.”

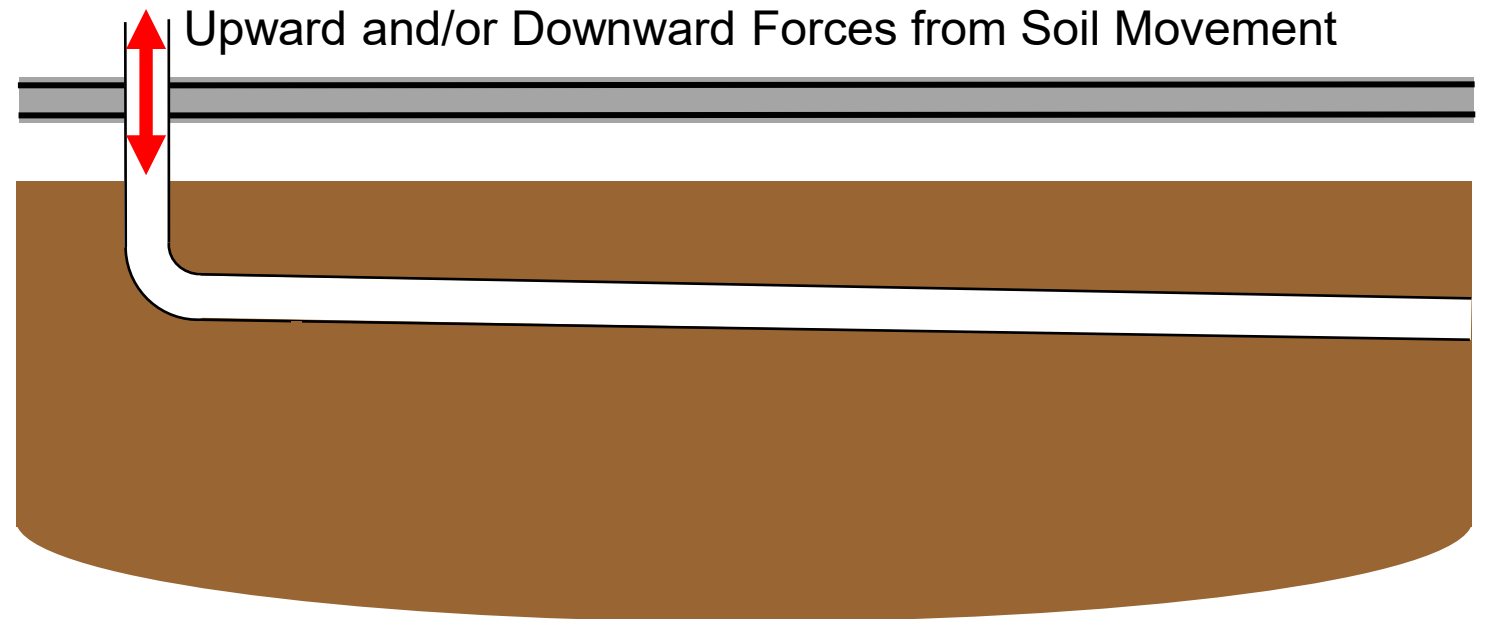
“I’m really aware of this problem. I have first-hand knowledge of it in areas up in the Mission District of San Francisco. They have these issues. It is expensive to repair. But, here’s what my problem is. As a plumber, I rely on the soils engineers or I rely on the mechanical plumbing engineers to design these systems and it kind of bothers me when it’s said, “Well, the owner doesn’t want to do it because it’s too expensive so we’ll throw it on the plumber.” When I make a recommendation in plumbing that an owner do something and I think there’s a significant liability risk and they turn me down, I walk away from the project.”

FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

Where pipes can be sleeved, the following damage can occur:

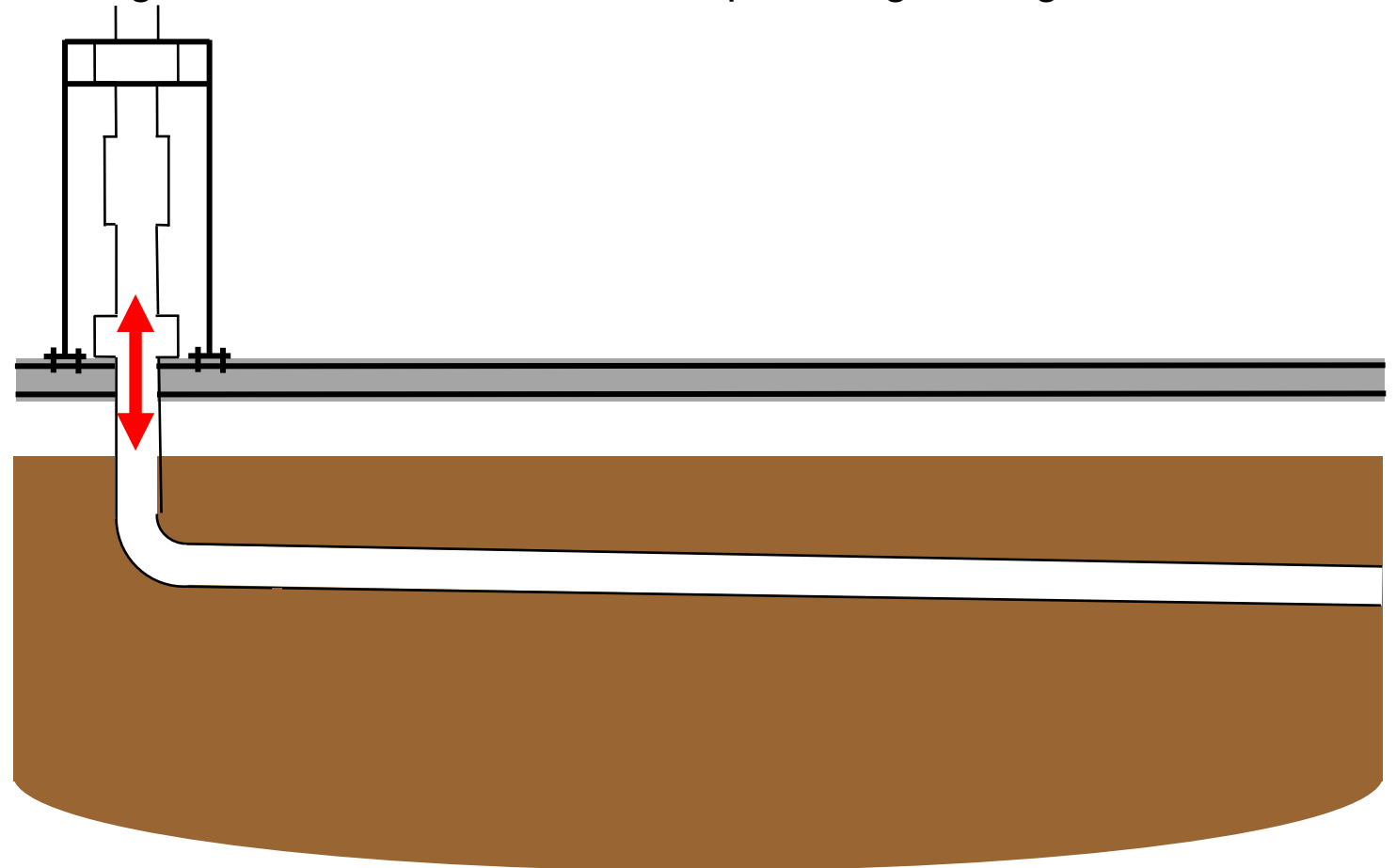
- Cracking pipes in walls at wall penetrations (e.g. wall cleanouts).
- Cracking walls at wall penetrations.
- Lifting walls and ceilings up at wall penetrations.
- Reversing slope in lateral ss pipes, in walls and/or above ceilings.
- Lifting toilets.
- Cracking pipes below slab if the sleeve does not allow enough slip.



FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

Plumbing Expansion Joints

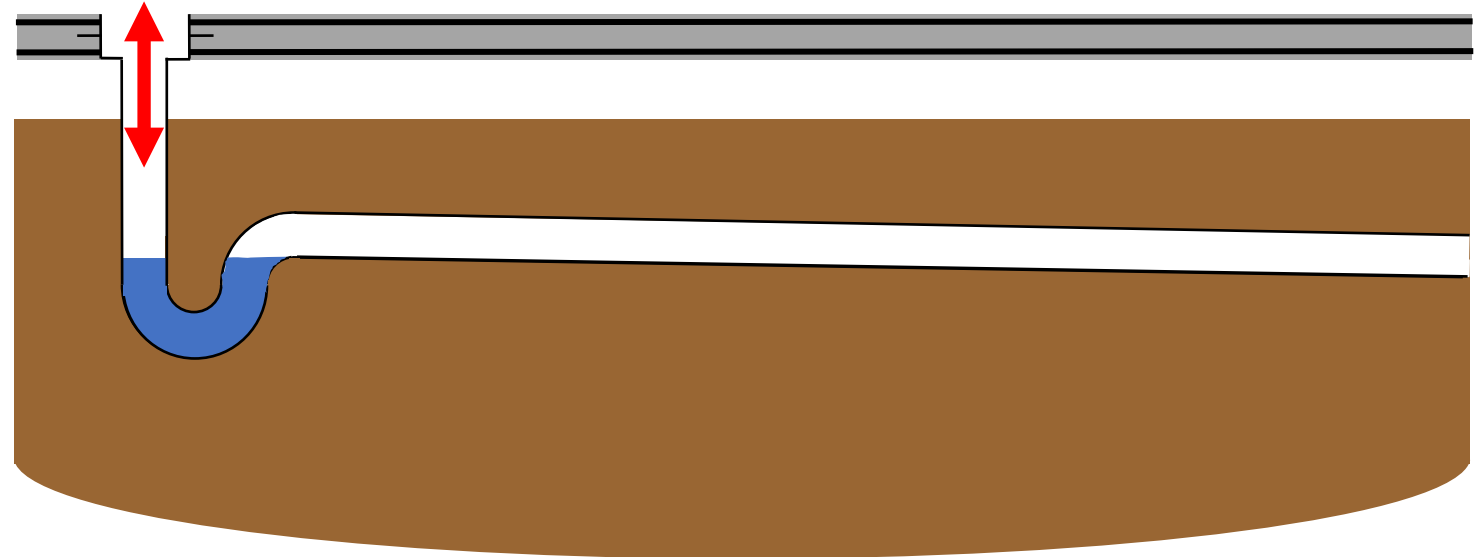
Vertical Expansion Joints in the Plumbing, if anchored at the TOP of the vertical expansion joint to a frame which is mounted onto the slab and designed to resist the upward and downward forces can avoid damage above-slab but under-slab plumbing damage can occur.



FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

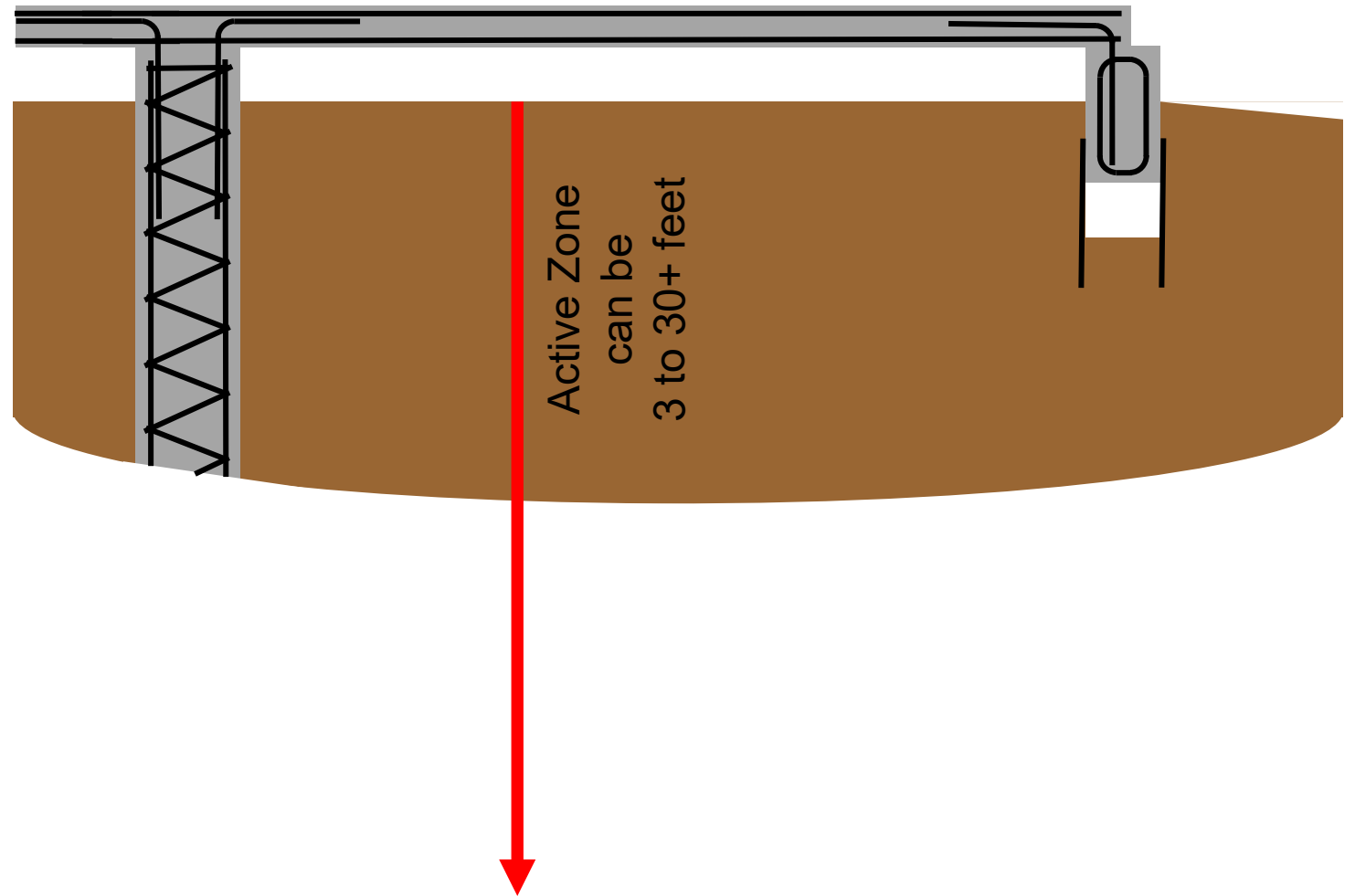
In some cases it is necessary to attach plumbing to the slab without a sleeve
(Example: Floor Drain)

At floor drains, upward movement can lift floor drains up above the floor so they no longer are able to drain the floor, this upward movement can cause damage to flooring and, if a P-Trap cracks due to the stresses, the P-Trap can drain out and allow noxious odors to enter the occupied space, while the plumbing crack allows untreated sewage to enter the subgrade which can also cause additional heave that can progressively worsen problems.



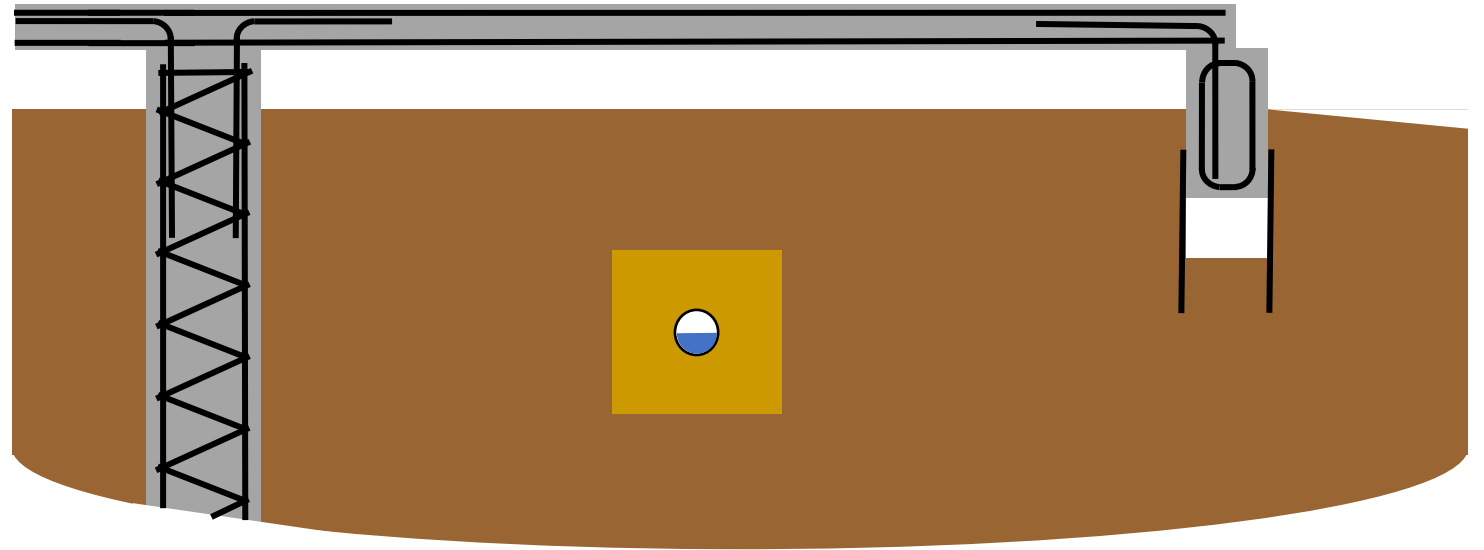
FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

“Active Zone”: The Zone In Which Soil Volume Changes Can Occur



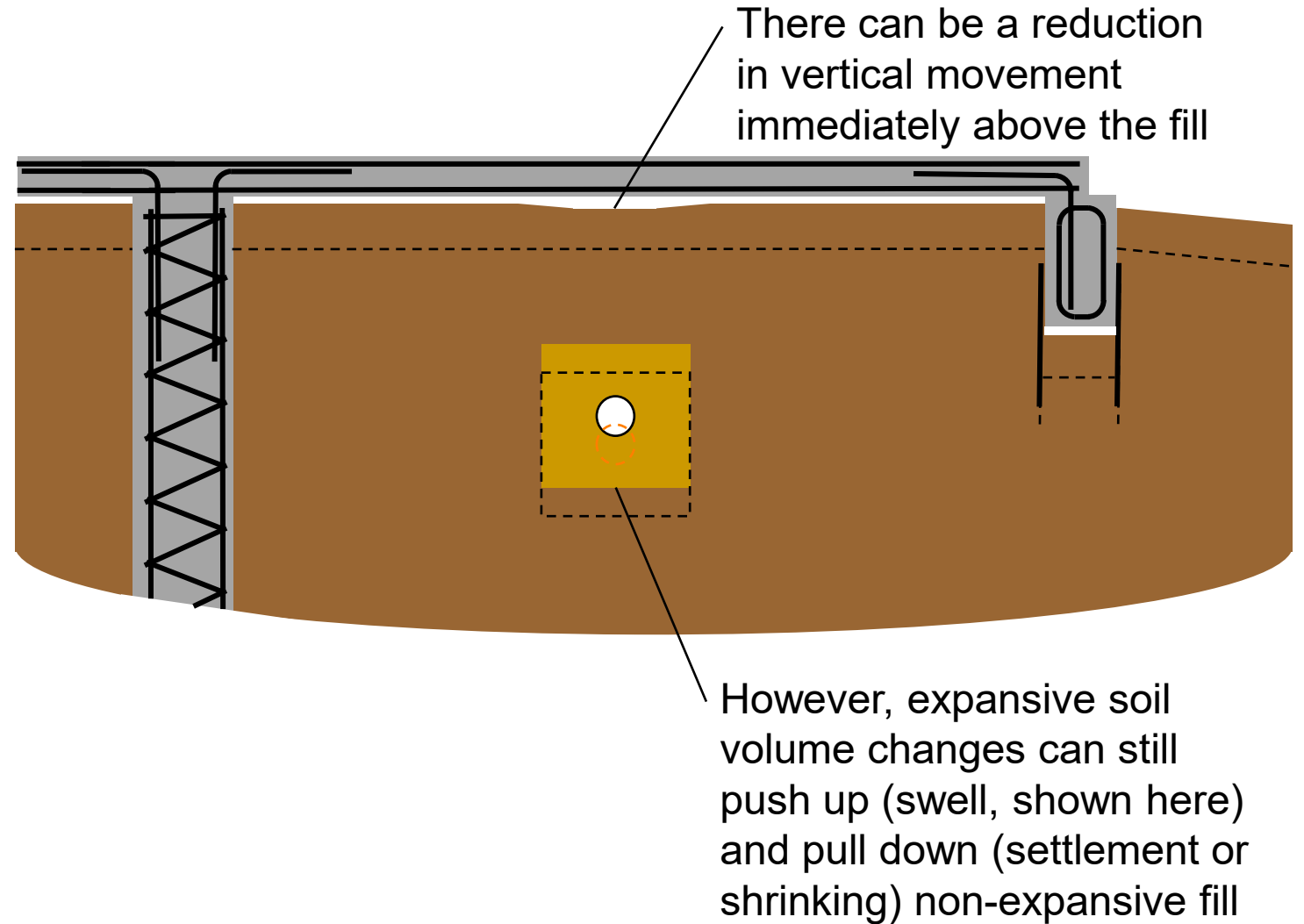
FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

Non-Expansive Fill in the Active Zone



FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

Non-Expansive Fill in the Active Zone



FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

JF

DISCUSSION ON EXAMPLES SHOWING FAILURE MODES

In this presentation, illustrations will show examples of some potential failure modes. To protect plumbing under slab-on-voidwork foundations (where creating access after occupancy is expensive), design professionals should design and/or specify work so as to avoid these and other predictable failure modes where expansive soil could cause damage to the plumbing and other systems in the building such as the foundation, flooring, walls and ceilings. Similar concerns exist for slab-on-crawlspace foundations because access is typically limited.

As an example of how to avoid this damage, where the following illustrations show a pipe cracking due to bending overstress, a plumbing designer could specify a thicker pipe that is strong enough to withstand the predicted bending stresses. Where plumbing lines are expected to have negative slope, a Plumbing Designer could specify a sewage grinder pump. Where soil retaining components and bracing for soil retaining components are expected to retain soil, the specifying professional should verify that all components have sufficient strength and stiffness when subjected to the effects of expansive soil.

FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

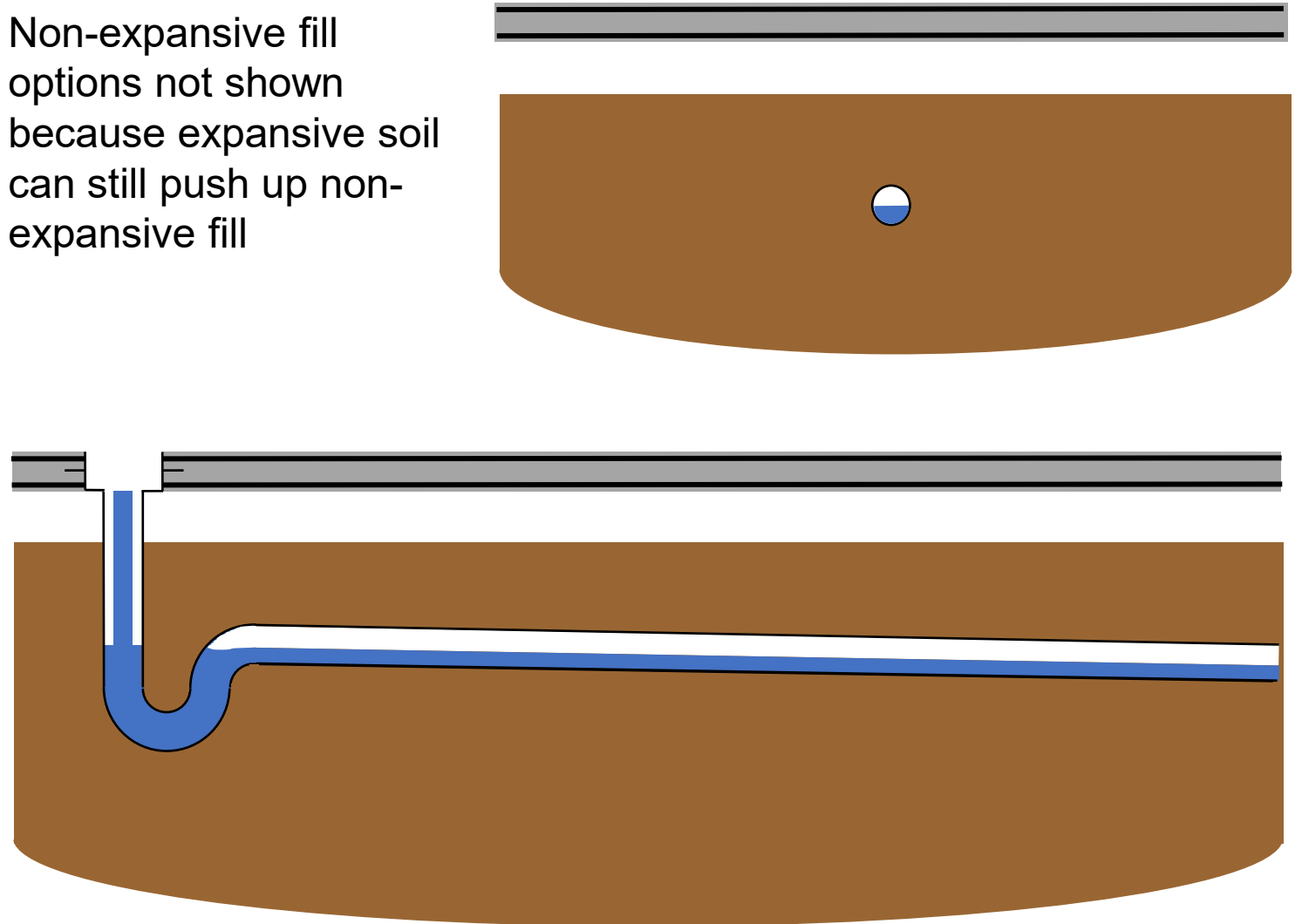
BURIED PLUMBING
LOAD CASE EXAMPLES

**FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS**

**BURIED PLUMBING
LOAD CASE EXAMPLES**

Installed Conditions

Non-expansive fill
options not shown
because expansive soil
can still push up non-
expansive fill



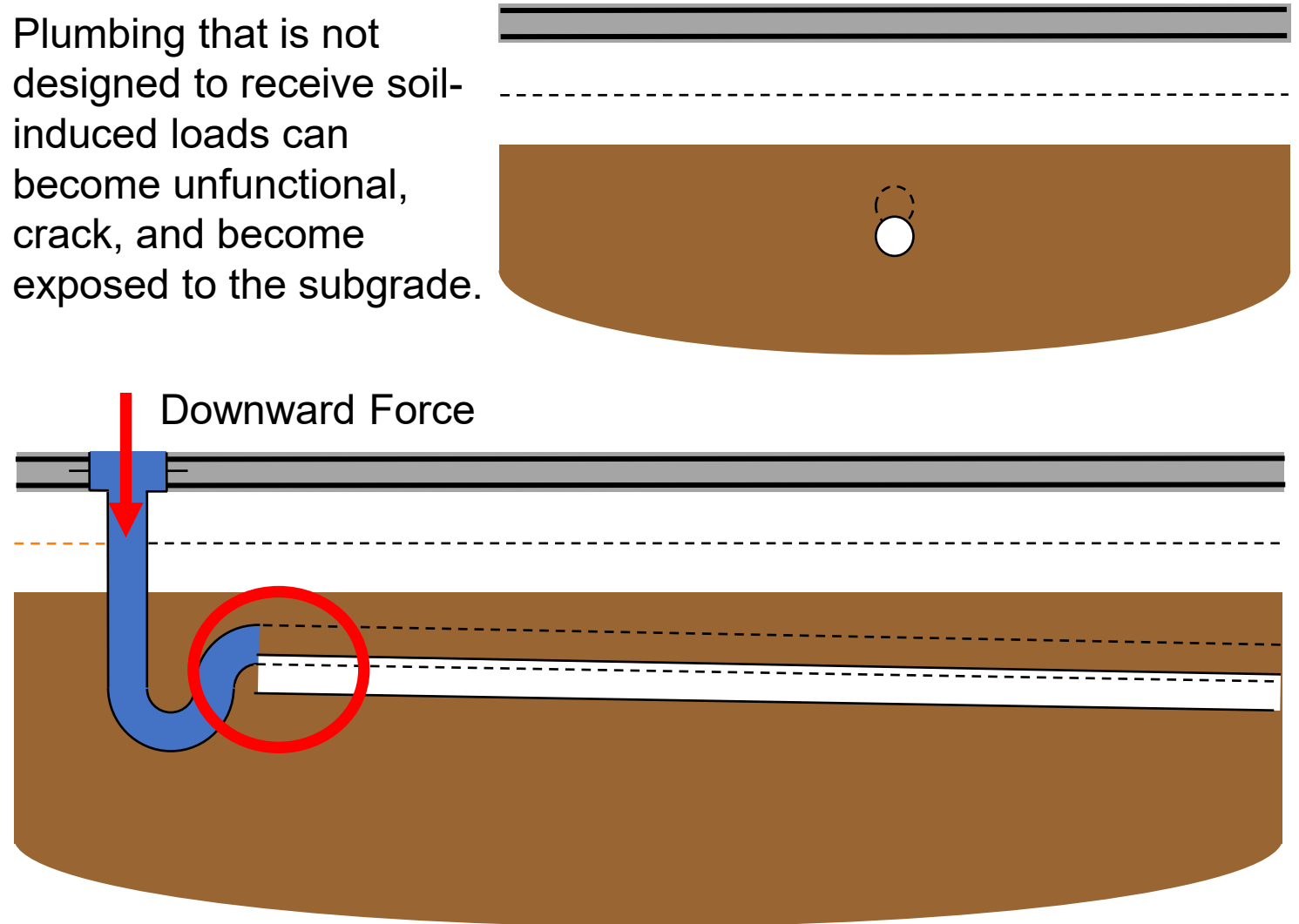
FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

BURIED PLUMBING
LOAD CASE EXAMPLES

JF

General Under-Slab Settlement

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.

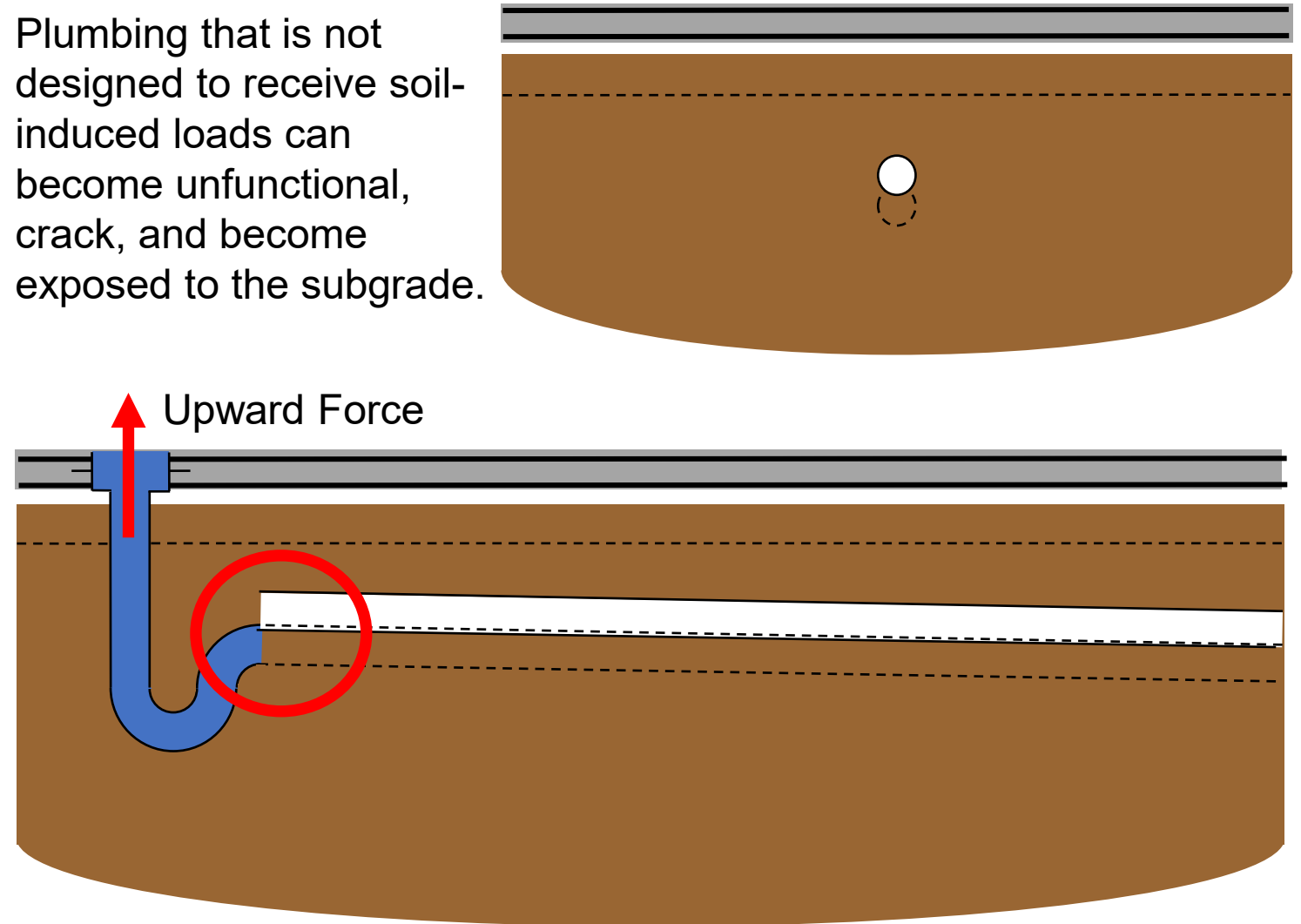


FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

BURIED PLUMBING
LOAD CASE EXAMPLES

General Under-Slab Swelling

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



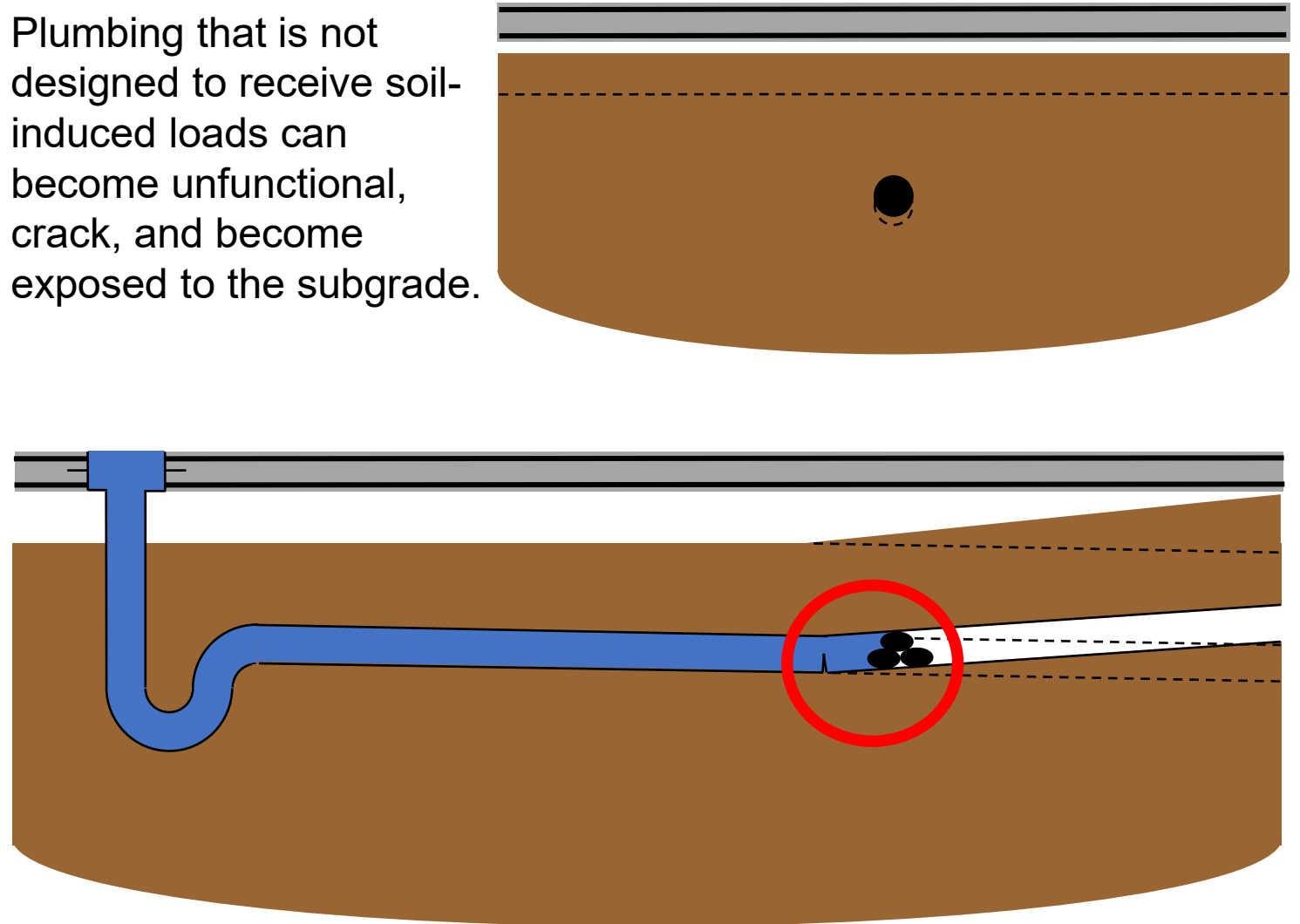
FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

BURIED PLUMBING
LOAD CASE EXAMPLES

JF

Perimeter Under-Slab Swelling

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.

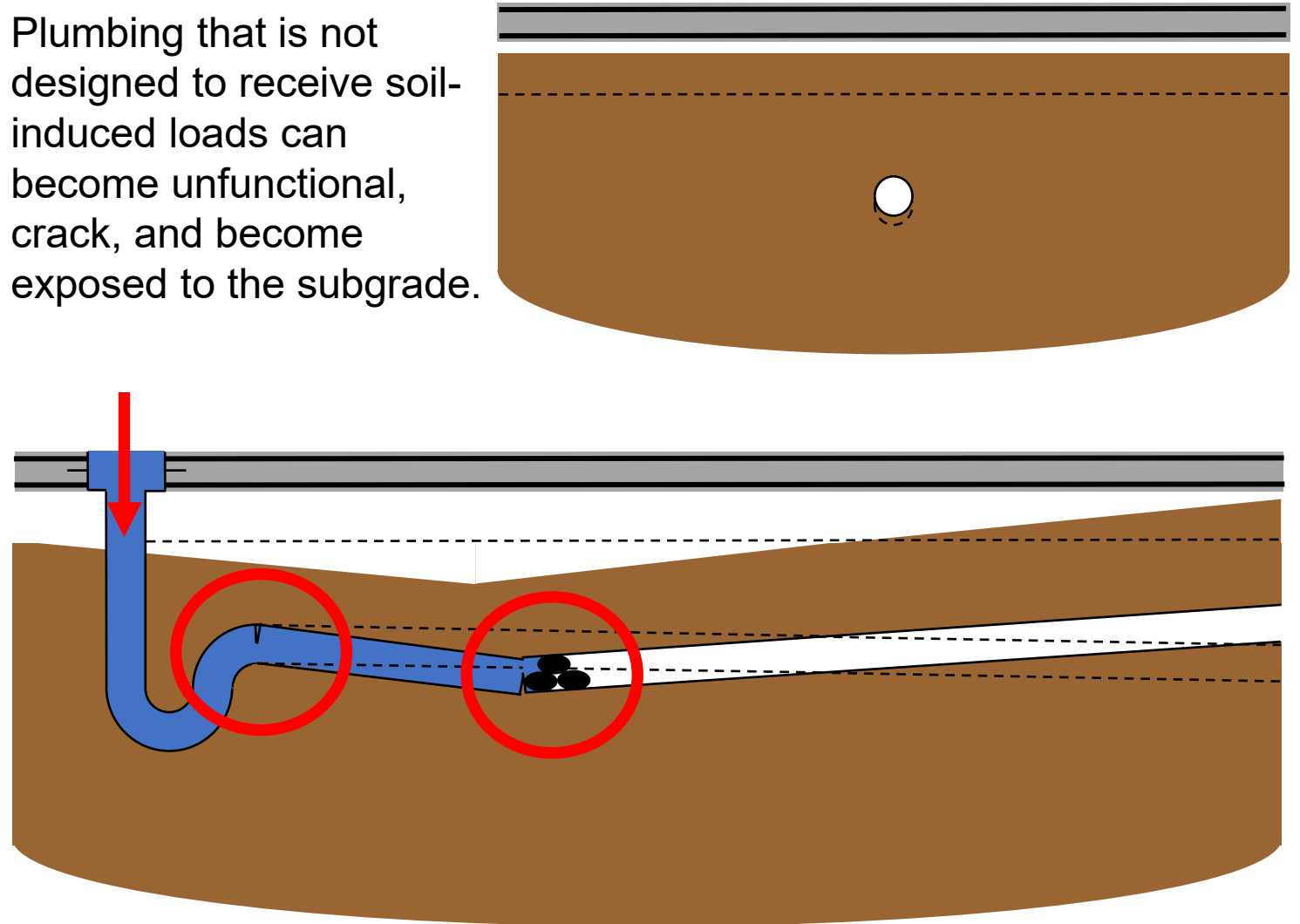


FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

BURIED PLUMBING
LOAD CASE EXAMPLES

Complex Under-Slab Swelling & Shrinkage

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



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ISOLATED SLABS

NON-ISOLATED
VOID SYSTEMS

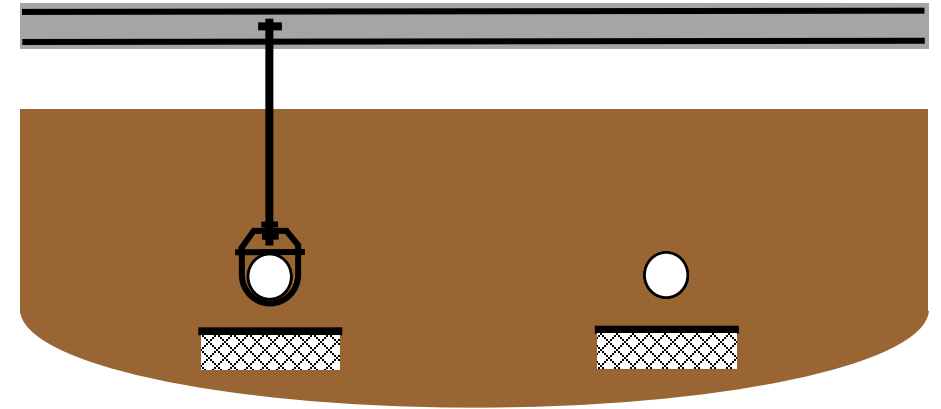
FOCUS:
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PLUMBING UNDER
ISOLATED SLABS

NON-ISOLATED
VOID SYSTEMS

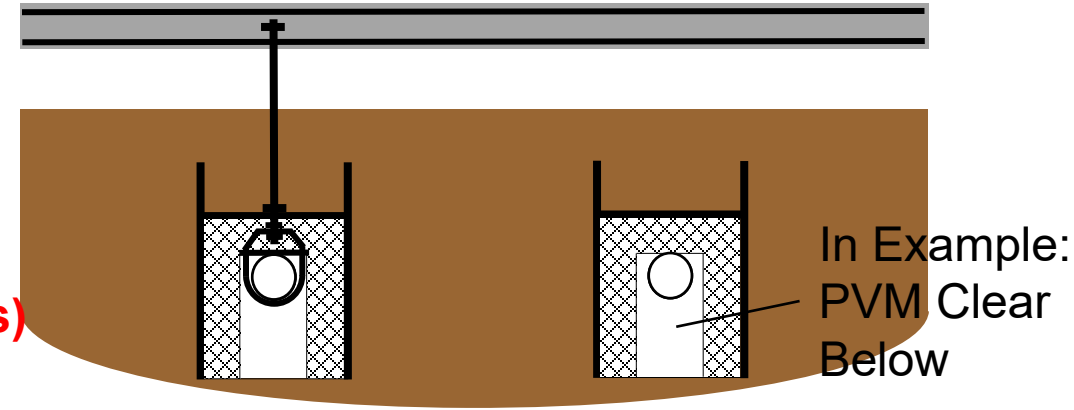
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Examples

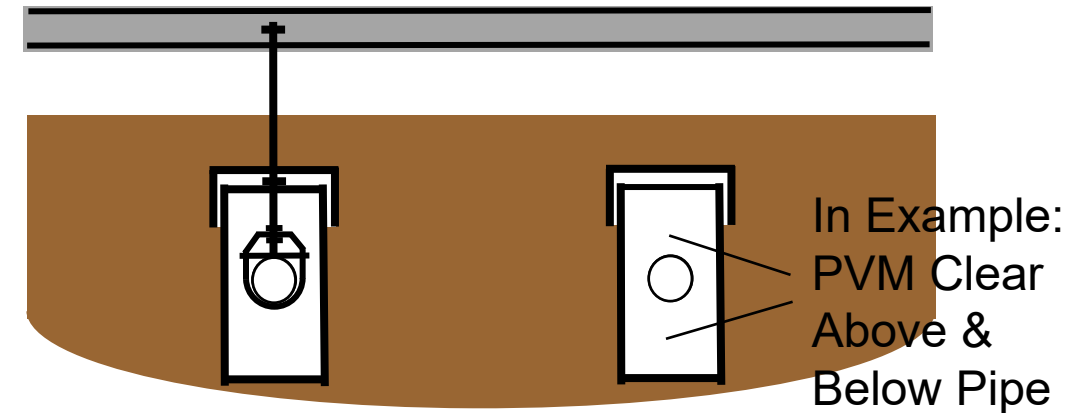
Mesh & Plywood
Under Plumbing



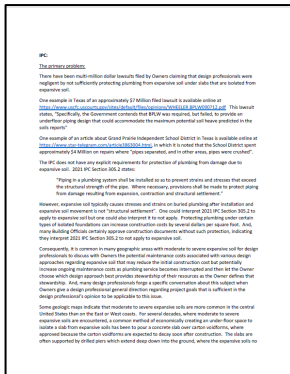
Mesh & Plywood
Above Plumbing
**(Similar to above
and below examples)**



Plastic Side Panels
& Crossbars



FOCUS: NON-ISOLATED PLUMBING UNDER ISOLATED SLABS NON-ISOLATED VOID SYSTEMS



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Structural Engineers Association of Texas (SEAoT) 14 Page Statement

“In these instances [*referring to Non-Isolated Void Systems*], the Mechanical Engineers are relying on the Manufacturer’s claims as a proprietary product and not designing a system that includes these products. However, **these products retain soil as they move in response to swelling and shrinking and they impart loads onto the structure and hangers that must be accounted for.**”

Many design approaches which use these products in an attempt to partially isolate plumbing may actually make matters worse than if the plumbing was simply buried, even though the manufacturers claim that the product will provide a void and some Owners spend money on these products with an expectation that these products will provide a complete void.”

Numerous failure modes are described in the statement for various proprietary non-isolated void systems on the market.

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MULTI-DISCIPLINARY COORDINATION

Design of non-isolated void systems to protect plumbing often requires a specialized understanding of geotechnical, structural and mechanical engineering and their interactions. **The specifying professional (typically the Mechanical Engineer of Record) should ensure that they have necessary education and experience or that they hire those that do to assist in the design.**

Furthermore, the following illustrations show how many Non-Isolated Void Systems can impart loads onto non-plumbing systems, such as foundations, flooring, walls, ceilings, etc... When these systems are specified, regardless of whether or not the intent is to actually protect the plumbing or not, the Specifying Professional (typically the Mechanical EOR) should provide the locations and magnitudes of any such loads to other relevant design professionals (Structural EOR, Architect of Record, Civil EOR, etc...) so that they can design for said loads.

MULTI-DISCIPLINARY COORDINATION

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SPECIFICATION OF A PRODUCT VERSUS DESIGN OF A SYSTEM

If a design professional specifies a product that can be used to protect plumbing but does not specify what is necessary for the product to protect the plumbing, the design professional should not expect that the product will protect the plumbing. There are design professionals who specify products like this simply because their understanding is that an Owner believes a product may perform better than other approaches, without any expectation that the system will protect the plumbing.

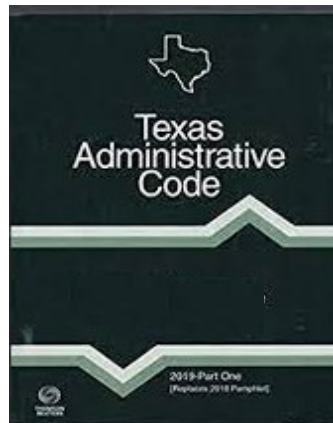
If, instead, a design professional actually intends to protect plumbing from expansive soil by using a non-isolated void system, there are often many features that must be specified. This can be a performance specification (e.g. design for 20,000 psf swell pressure, 9" design vertical movement up and down, etc...) and/or hard specification (e.g. three layers of 3/4" thick plastic side boards, 1/4" thick washer, 9" clearance, etc...)

Some product manufacturers do not engineer their products for each project. And, product engineers often limit their responsibility.

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Texas Board of Professional Engineers and Land Surveyors

22 Texas Administrative Code § 137.59(a): “Engineers shall practice only in their areas of competence.”

22 Texas Administrative Code § 137.63(b)(6) prohibits engineers relying on information from other parties in a manner that is not careful and diligent: “The engineer must practice engineering in a careful and diligent manner.”

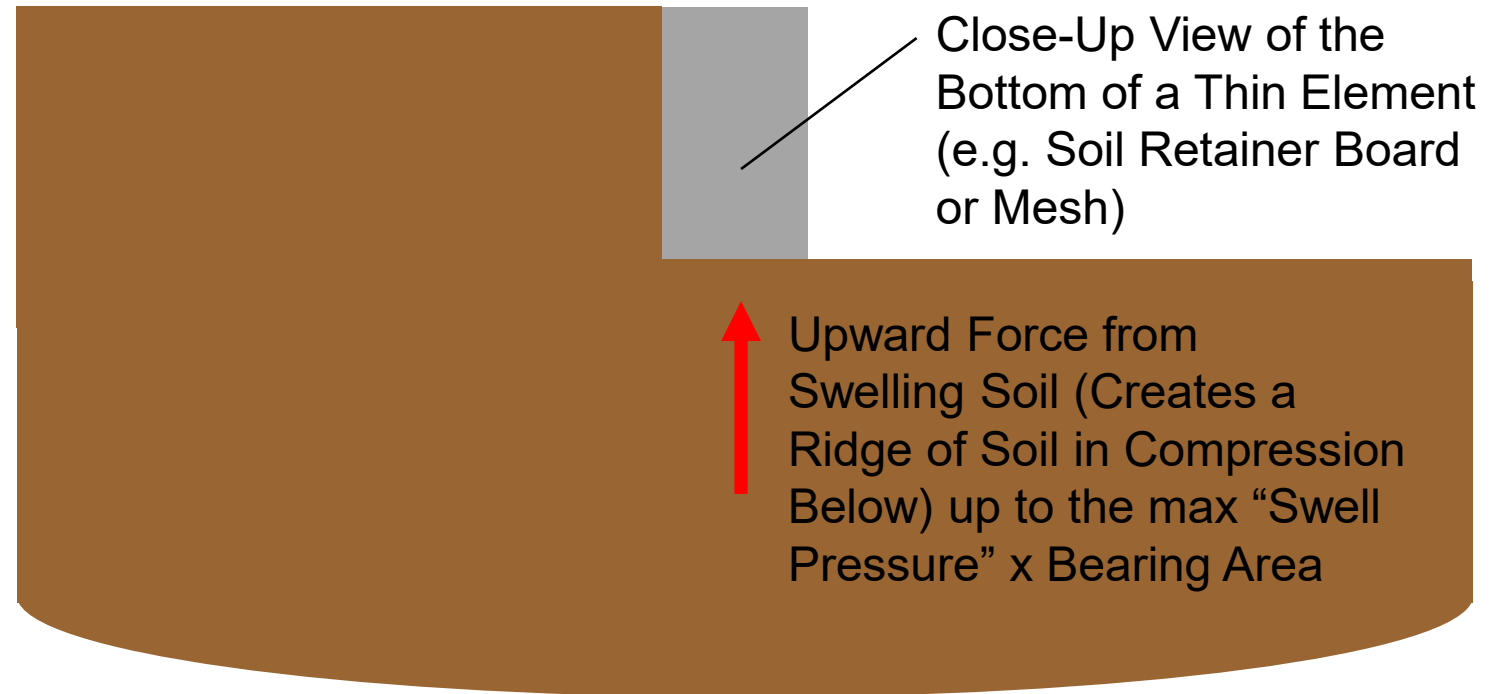
Numerous disciplinary actions related to these sections of the Texas Administrative Code by the Board over the years. In one recent example: “**Mr. _____ failed to practice engineering in a careful and diligent manner by relying on information from a contractor**” with a “Three Year Probated Suspension contingent upon remittance of an Administrative Penalty of \$4,000.00 and successful completion of Texas Tech University Engineering Ethics Basic Course.”

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“Knife Edge” Theory Debunked: The Bottom of a Thin Element

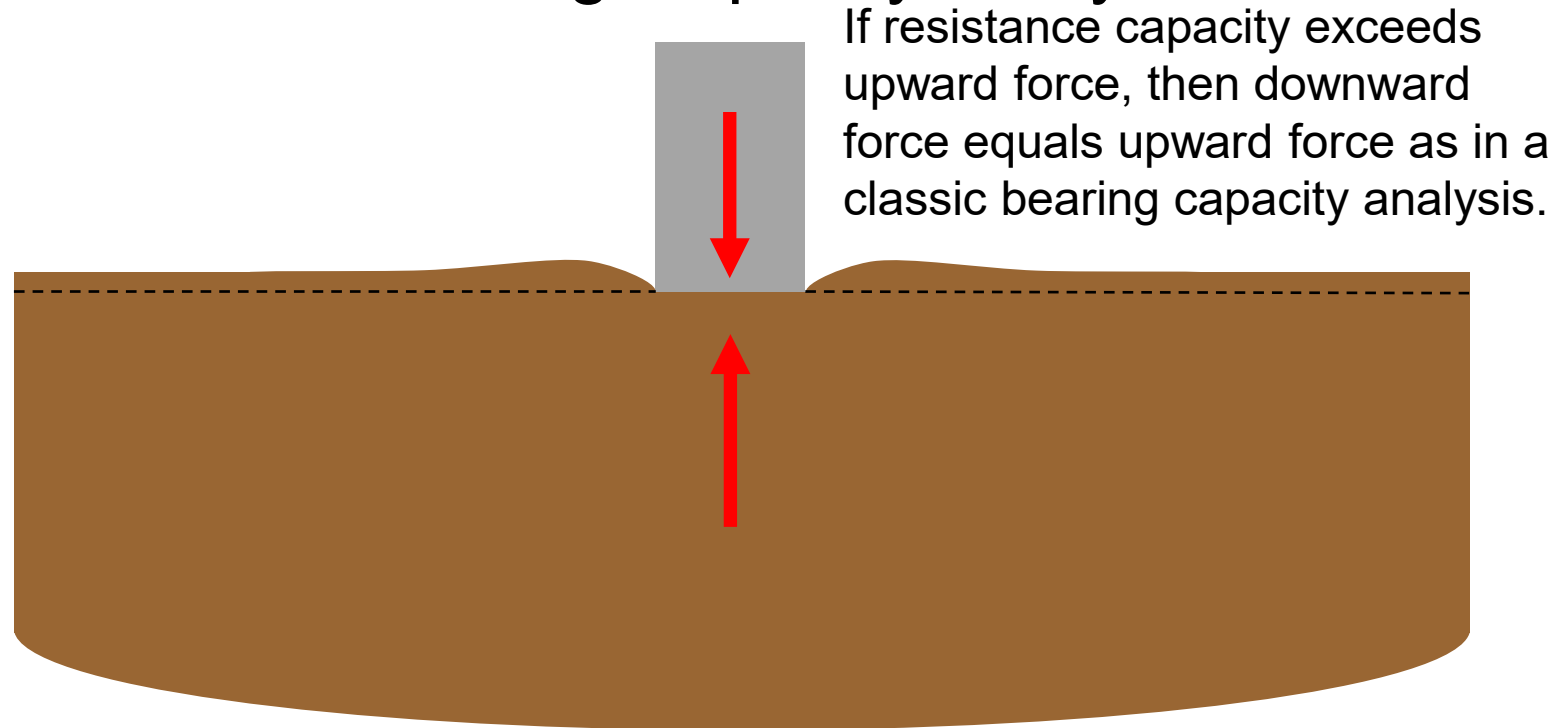


The knife edge theory claims that thin enough elements will cut through soil without any upward force from swelling soil. The maximum “Swell Pressure”, which can develop if soil is not allowed to expand, can exceed 20,000 psf (Chen, 1988). At 20,000 psf, the upward force on four layers, each a 1/4” thick, would be 1,666 plf.

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“Knife Edge” Theory Debunked: Classical Bearing Capacity Analysis

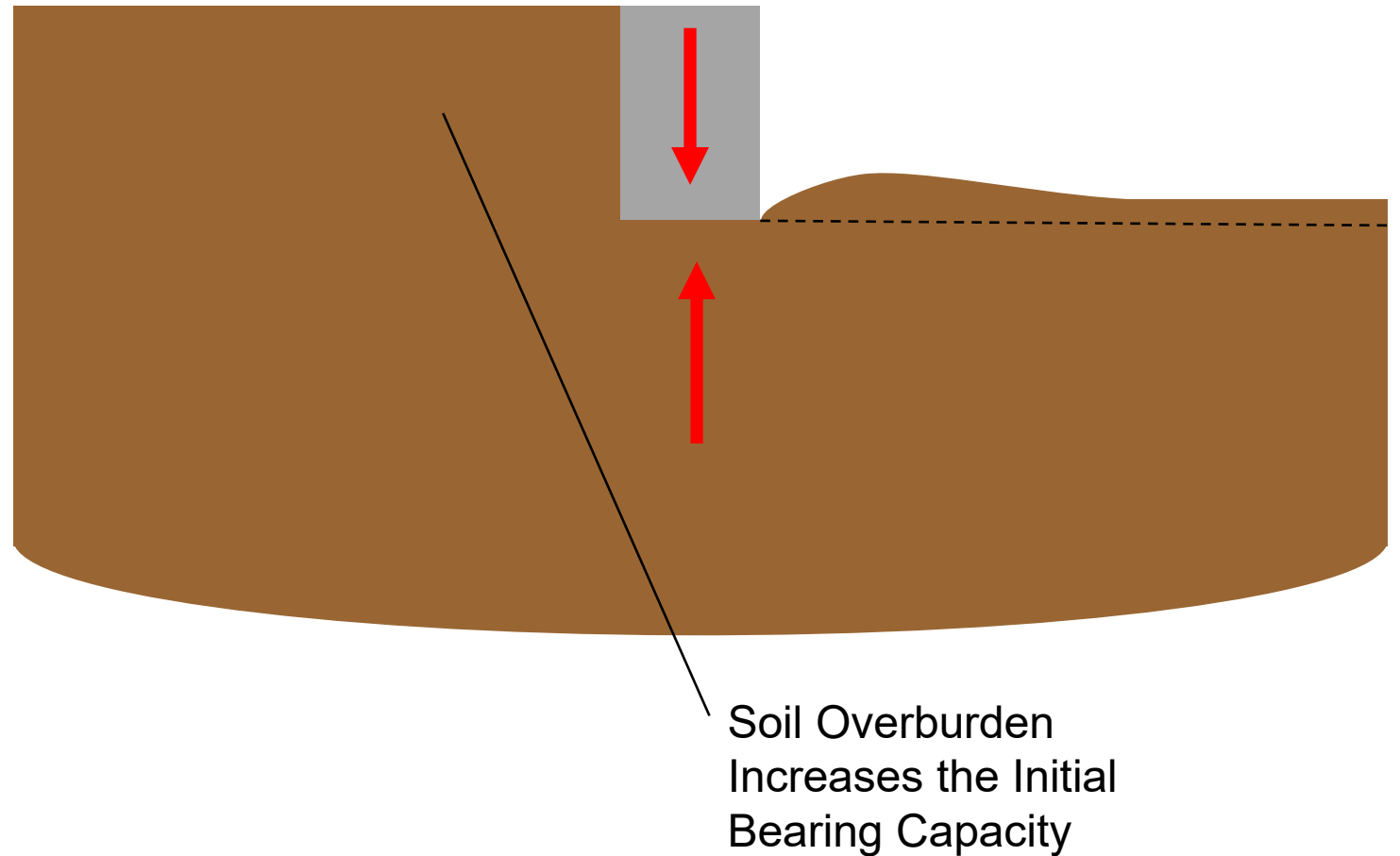


For a thin element to cut into the soil as soil swells, no matter how thin the element is, the soil is displaced by shear failure planes in the soil. If there is no overburden soil on either side, this is similar to a classic geotechnical shallow bearing capacity analysis.

“Knife Edge” Theory Debunked: Increased Initial Bearing Capacity

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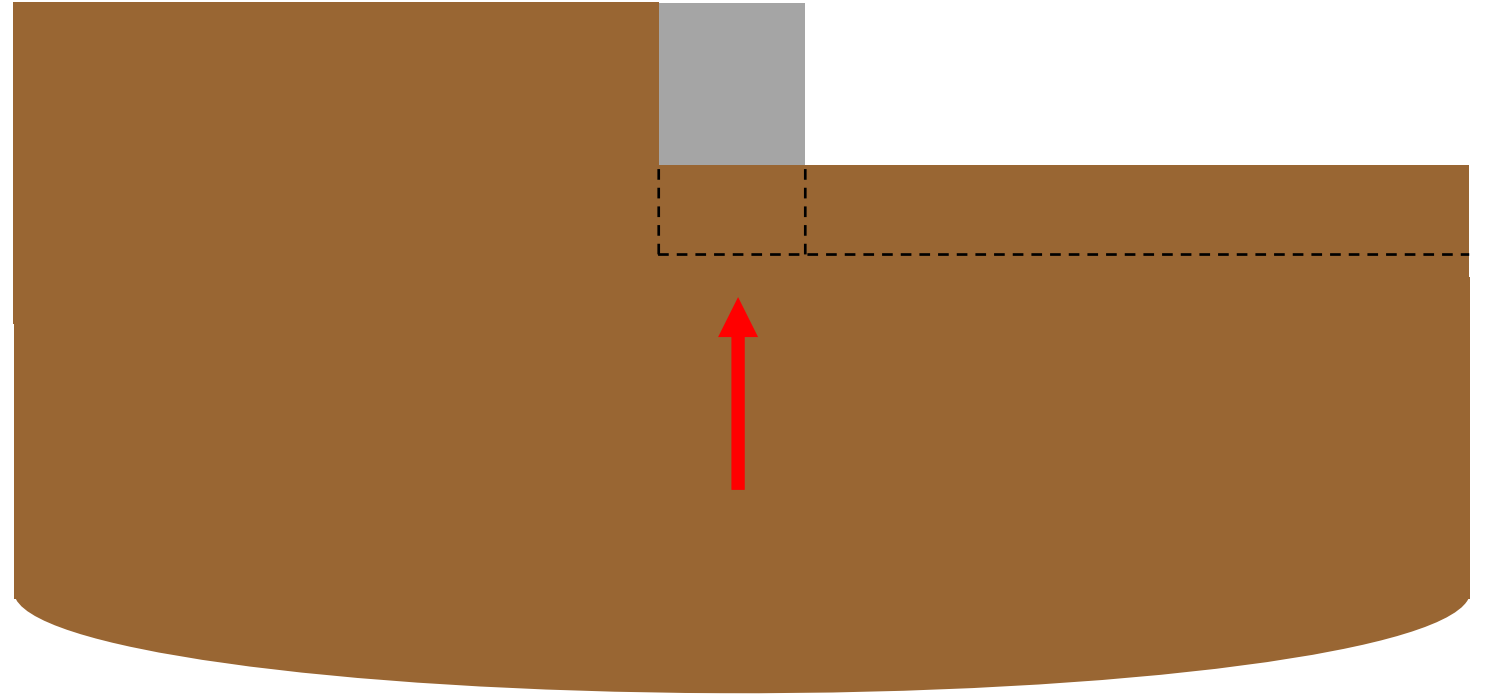
**NON-ISOLATED
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“Knife Edge” Theory Debunked:
Resistance Capacity < Bearing Capacity



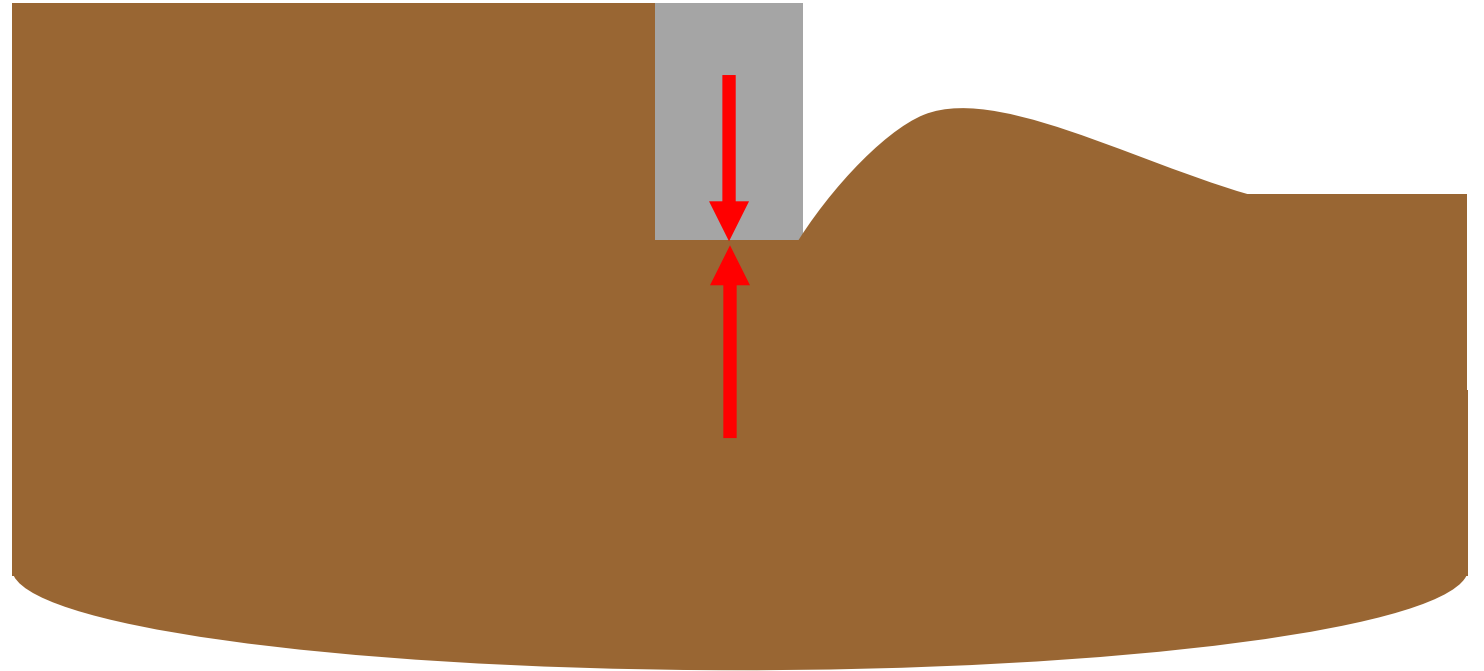
If the resistance capacity of the thin element is less than the initial bearing capacity, the thin element will rise.

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“Knife Edge” Theory Debunked:
Progressive Bearing Capacity Increase

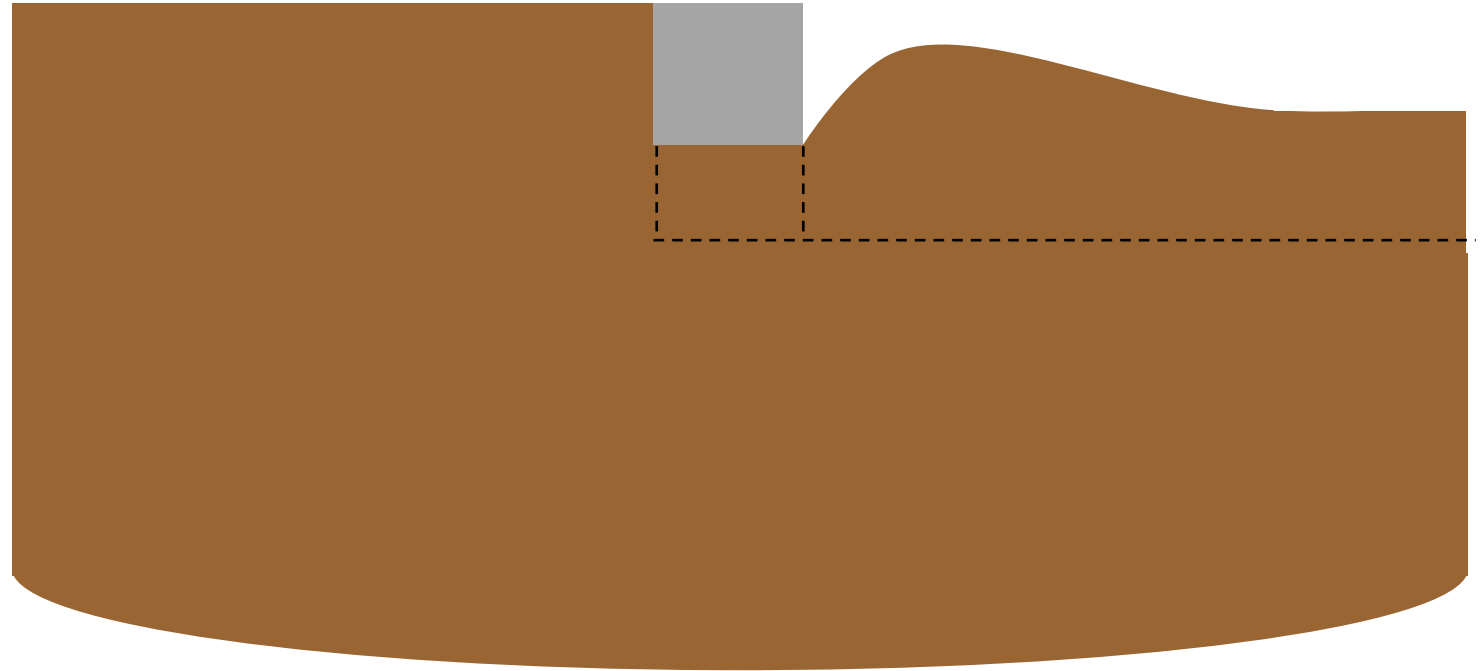


If resistance capacity is greater than initial bearing capacity: After initial bearing capacity failure, there is a progressive increase in further Bearing Capacity failure until either the maximum vertical movement of the expansive soil occurs, the swell pressure is reached or the upward force exceeds the resistance capacity.

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“Knife Edge” Theory Debunked: Post-Bearing-Capacity-Failure Lift



As the bearing capacity progressively increases with initial heave, if the upward force exceeds the resistance capacity, the thin element will lift up. Keep in mind the soil resistance will not be uniform – so deformation of the thin element is quite likely.

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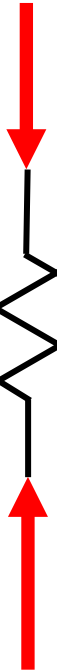
**NON-ISOLATED
VOID SYSTEMS**

Mesh/Soil Vertical Interaction

Vertical sheets of expanded metal lath mesh in compression act similar to a classic spring when in compression. As in physics, $F = kx$. The compressive force equals the spring coefficient times the distance compressed. This does not change what was discussed in debunking the knife edge theory. It simply means that the resistance capacity of a mesh system is going to be a function of the distance compressed.

The bearing area of vertical sheets of expanded metal lath can increase as the mesh is compressed.

The bearing area of vertical sheets of expanded metal lath can also increase as soil swells in between mesh elements.



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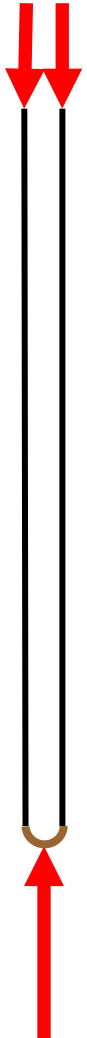
**NON-ISOLATED
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Fluted-Plastic/Soil Vertical Interaction

The effective bearing area of vertical fluted plastic retainer boards, with plastic webs that connect two planes of plastic sheets, can be as large as a solid sheet with a thickness equal to the gap between the two planes if soil bridges across the planes by “arching action”, where an upside-down compression arch forms in the soil.

A similar phenomenon is seen in much larger foundations: open-end driven piles. In some cases a soil “plug” forms in the bottom of the pile, significantly increasing resistance to pile driving.



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NON-ISOLATED VOID SYSTEMS

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Lateral Pressures

In classic geotechnical engineering, three specific types of lateral soil pressures are often addressed:

Active (sliding at a downward angle into a cantilevered retaining wall)

At-Rest (sliding at a downward angle into a “basement” wall)

Passive (soil resisting the sliding of a retaining wall)

In addition, **hydrostatic pore water pressures** can occur where the soil is not drained (e.g. weep holes in a retaining wall).

Vertical **surcharge loading** nearby such as compaction equipment loads can create horizontal pressures too.

With expansive soil, there is an additional type of lateral pressure caused by **soil swelling**, which is a three-dimensional phenomenon. It is often difficult for geotechnical engineers to be able to estimate these pressures. The potential horizontal expansive soil swelling movement can be greater than the potential vertical movement and the horizontal expansive soil swelling swell pressure can be greater than the vertical swell pressure.

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Lateral Pressures

2021 IBC Section 1610.1 excerpt (Previous editions similar):

“Foundation walls and retaining walls shall be designed to resist lateral soil loads from adjacent soil. Soil loads specified in Table 1610.1 shall be used as the minimum design lateral soil loads unless determined otherwise by a geotechnical investigation in accordance with Section 1803. Foundation walls and other walls in which horizontal movement is restricted at the top shall be designed for at-rest pressure. Retaining walls free to move and rotate at the top shall be permitted to be designed for active pressure.

Lateral pressure from surcharge loads shall be added to the lateral soil load. Lateral pressure shall be increased if expansive soils are present at the site. Foundation walls shall be designed to support the weight of the full hydrostatic pressure of undrained backfill unless a drainage system is installed in accordance with Sections 1805.4.2 and 1805.4.3.”

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Lateral Pressures

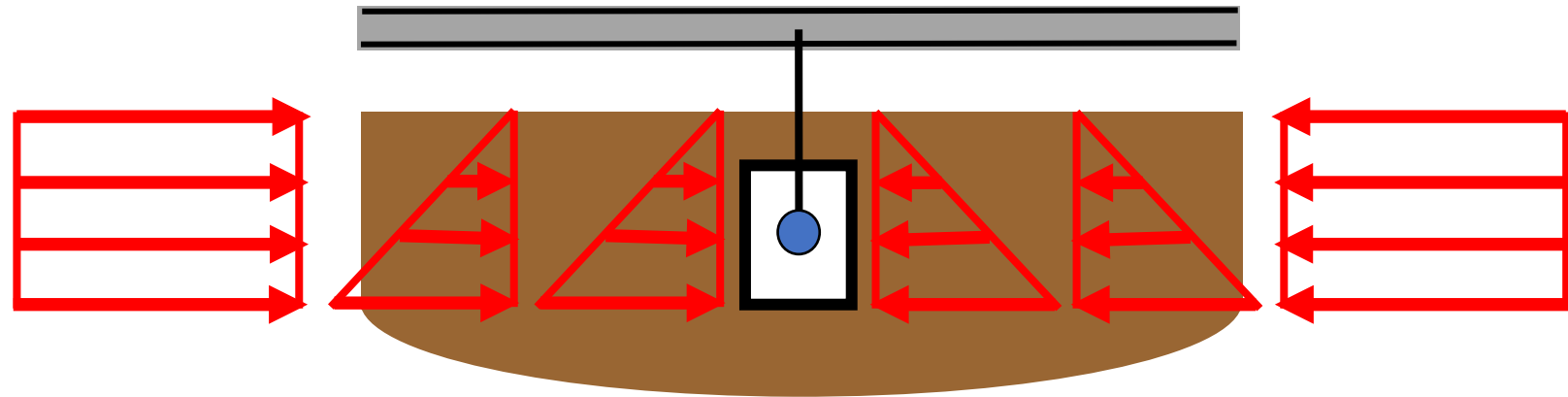
2021 IBC Section 1610.1 excerpt (previous editions similar):

It is important to note that **Table 1610.1 Lateral Soil Load** indicates that **inorganic clays of high plasticity are “unsuitable as backfill material”**. These types of soils and other soil types also “unsuitable as backfill” are common in many areas where slab-on-voidwork foundations are used.

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Lateral Pressures
An Example with Expansive Soil



Swelling Pressure	Water Pressure	Equiv. Fluid Pressure*	Equiv. Fluid Pressure*	Water Pressure	Swelling Pressure
20,000 psf	62.4 pcf	60 pcf	60 pcf	62.4 pcf	20,000 psf

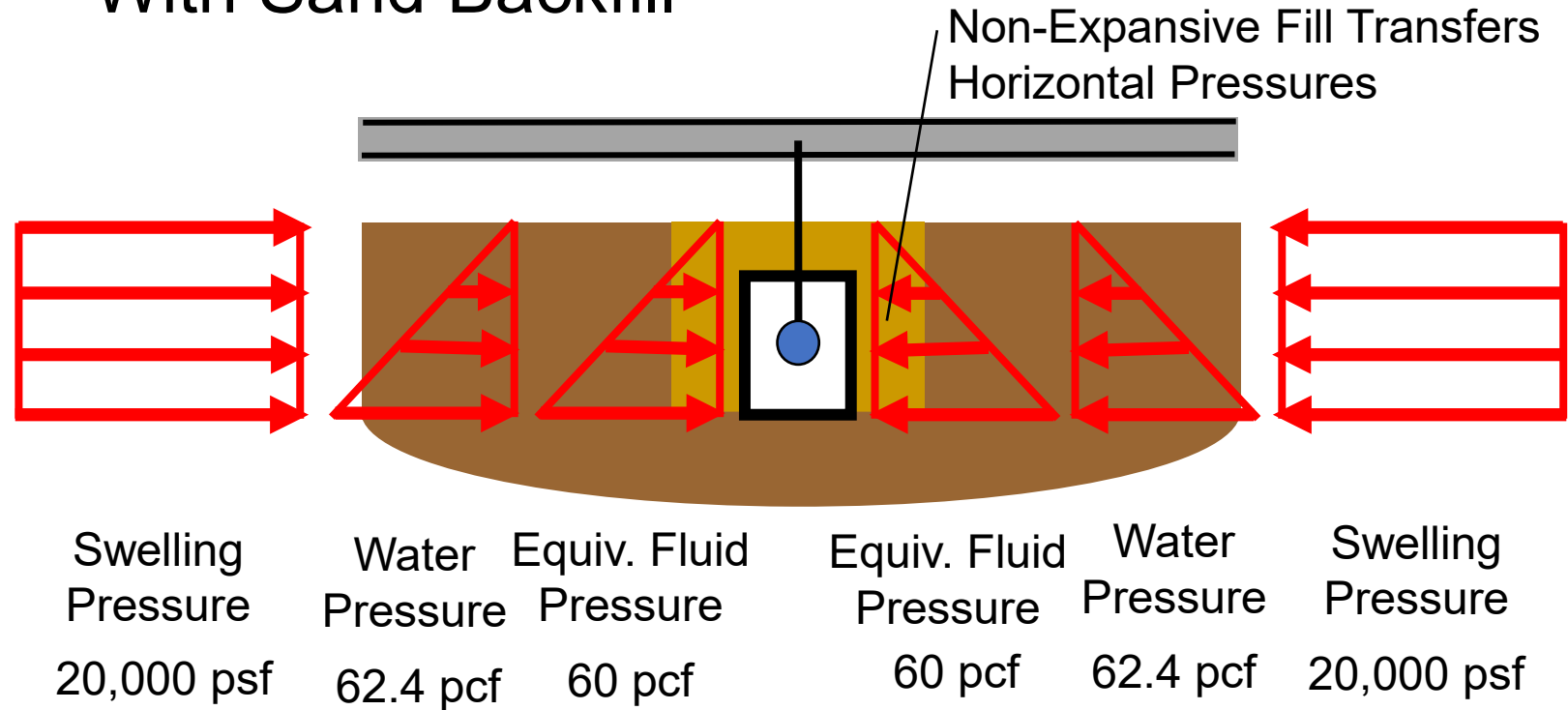
Notes:

- 1) Example does not show lateral pressure from compaction equipment
- 2) * represents at-rest condition

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Lateral Pressures
An Example with Expansive Soil
With Sand Backfill



See previous slide for notes

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Lateral Pressures

2021 IBC Chapter 16 STRUCTURAL DESIGN (Previous editions are similar):

H = “Load due to lateral earth pressures, ground water pressure or pressure of bulk materials.”

Load Resistance Factor Design (LRFD) Load Combinations:

Load Factor of **1.6** for lateral earth pressure

Allowable Stress Design (ASD) Load Combinations:

Load Factor of **1.0** for lateral earth pressure

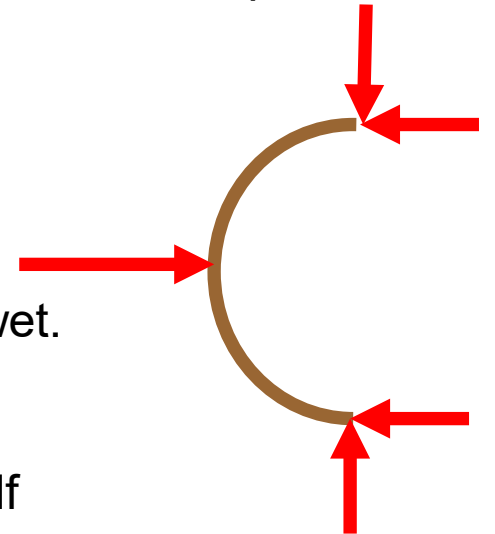
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Lateral Soil-Arch Design

If an engineer were to assume a soil arch forms and reduces the lateral pressure on a soil-retainer that prevents soil from damaging plumbing, it would be important for the engineer to verify that the arch will function under gravity. If the arched shape is compromised, the lateral arch can fail and cause all lateral loads to push on the soil retaining system. There needs to be sufficient vertical resistance at the top and bottom of the lateral arch to prevent the lateral arch from spreading open; where soil retainers are near the subgrade, this may be problematic. There needs to be sufficient horizontal resistance; therefore, horizontal components that keep soil retainers apart must be able to act as horizontal columns resisting this load without buckling. As the arch itself consists of soil and lateral swelling pressures can be significant, the modulus of elasticity of the soil (where it compresses under load) may not be sufficient to maintain the arch shape if wet. And, as the arch itself consists of material that is expanding as the lateral swelling occurs, the very expansion of the arch itself may push itself inward, causing the arch shape to collapse.



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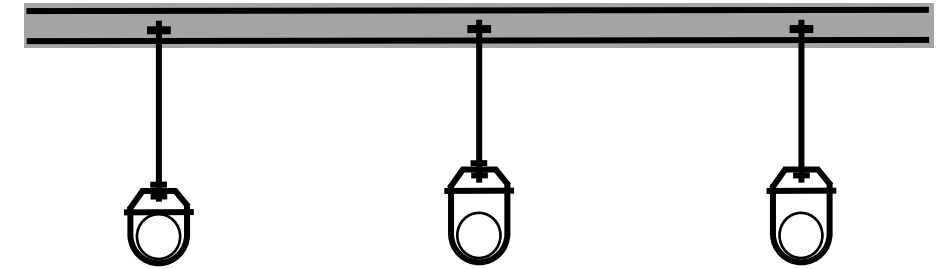
**NON-ISOLATED
VOID SYSTEMS**

DP

UPLIFTED PIPE IN A CLEVIS HANGER

Examples of Various
Installed Conditions

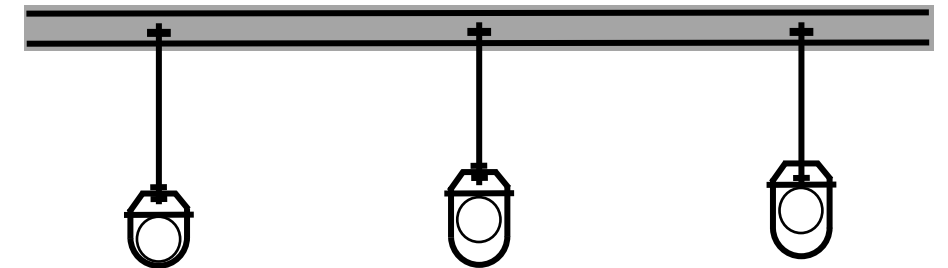
If soil-induced loads lift a pipe, movement is **restrained** with either no movement at all or some movement distance. If the vertical movement caused by soil is less than this distance, the pipe is **unrestrained** at the clevis.



Top nut, with
a bolt at top
of pipe

Top nut,
with a bolt
above pipe

A bolt above
pipe, but no
top nut



No vertical
movement if
rod does not
buckle

Some vertical
movement

Some vertical
movement

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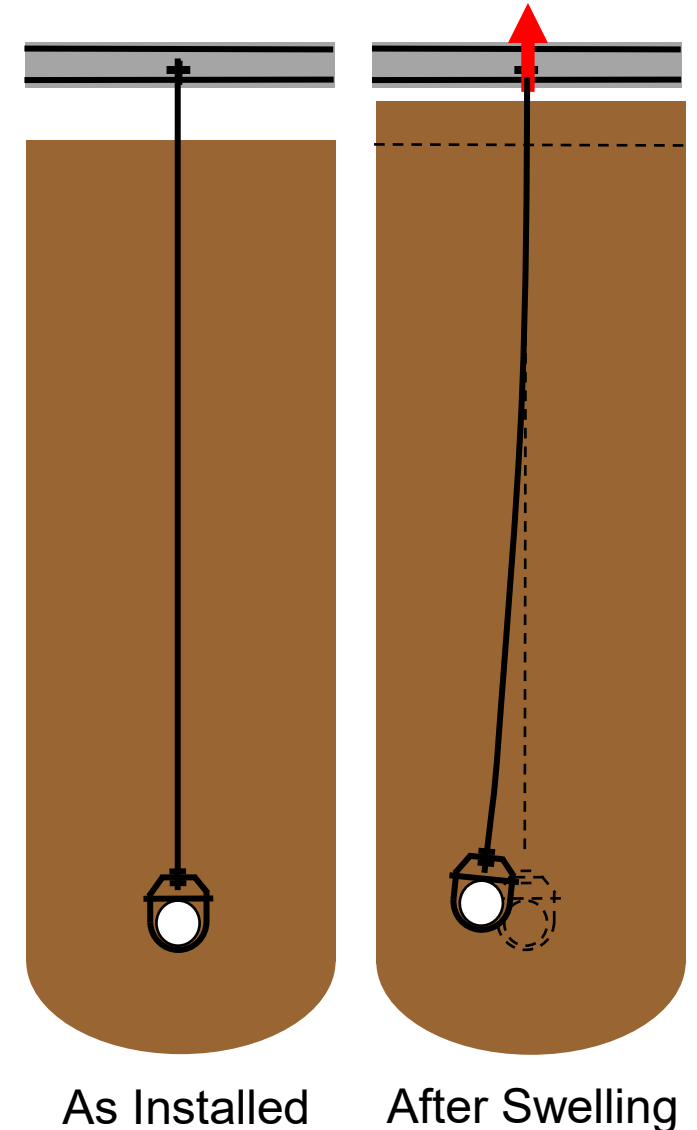
**NON-ISOLATED
VOID SYSTEMS**

ML

UPLIFTED PIPE IN A CLEVIS HANGER

If soil-induced loads lift a pipe that is restrained by a clevis but the rod begins to buckle (Examples: larger swell forces and/or longer rods, especially rods with tall voidspaces and/or rods in intentionally uncompacted loose fill which may not sufficiently brace the rod from buckling, or soil after shrinking):

Movement can be **partially unrestrained**, in that the pipe is allowed to move up, and **partially restrained**, in that the rod still transfers some load into the slab as the rod is not allowed to buckle completely due to the soil medium in which it is buckling.



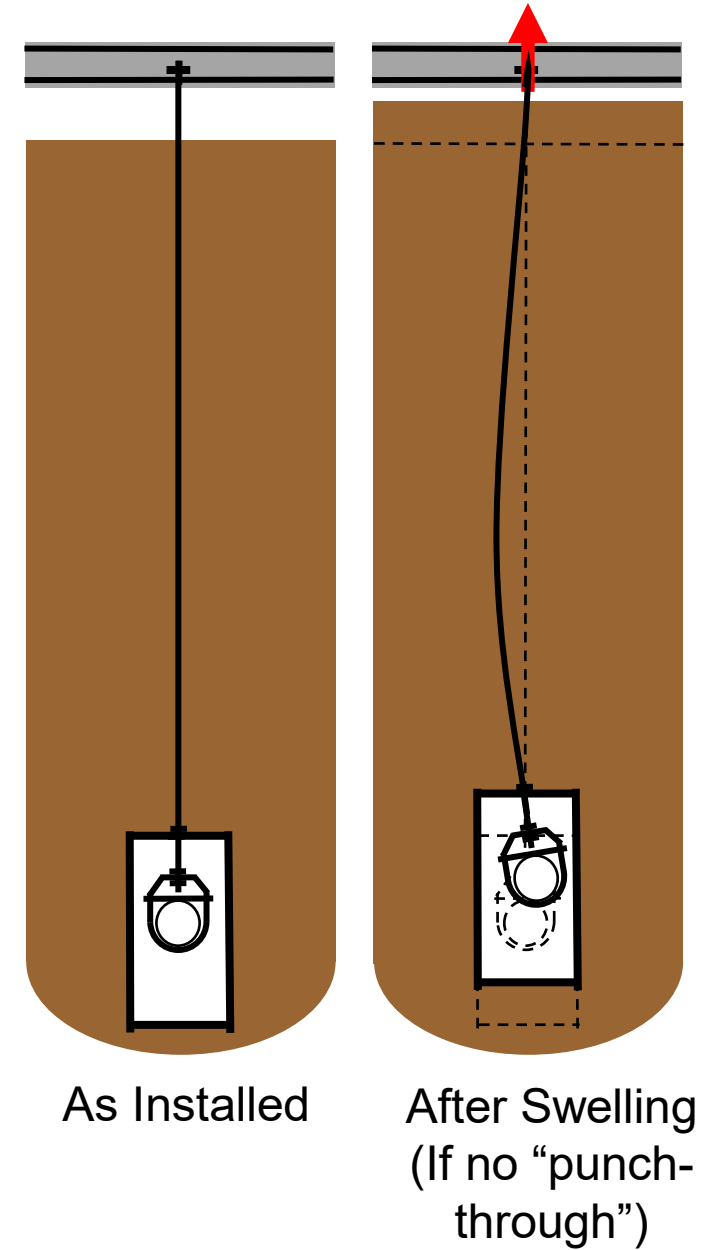
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NON-ISOLATED VOID SYSTEMS

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PIPE LIFT BY SOIL RETENTION SYSTEMS

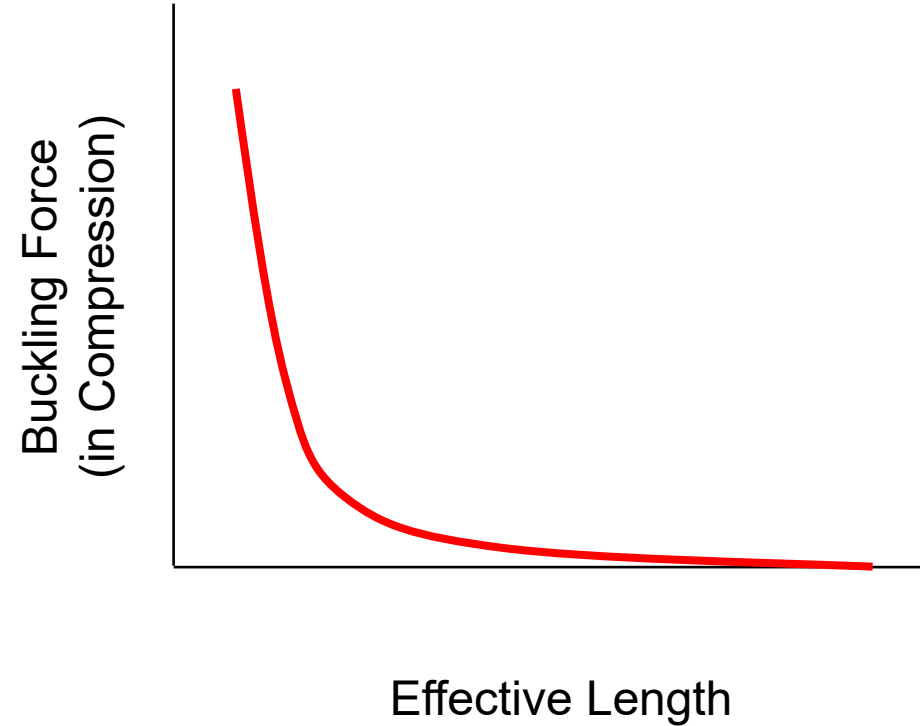
If soil loads lift a soil retention system that is restrained by a nut on top of the system which transfers load to a threaded rod, there will be an initial force pushing up on the slab. The rod can begin to buckle (Examples: larger swell forces and/or longer rods, especially rods with tall voidspaces and/or rods in intentionally uncompacted loose fill which may not sufficiently brace the rod from buckling), which would cause the pipe to lift. If the nut punches through the pipe hanger support element(s) of a soil retention system and punches through any soil friction on the threaded rod before buckling, the system might rise without lifting the pipe further.



DESIGNING THREADED HANGER RODS

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ISOLATED SLABS**

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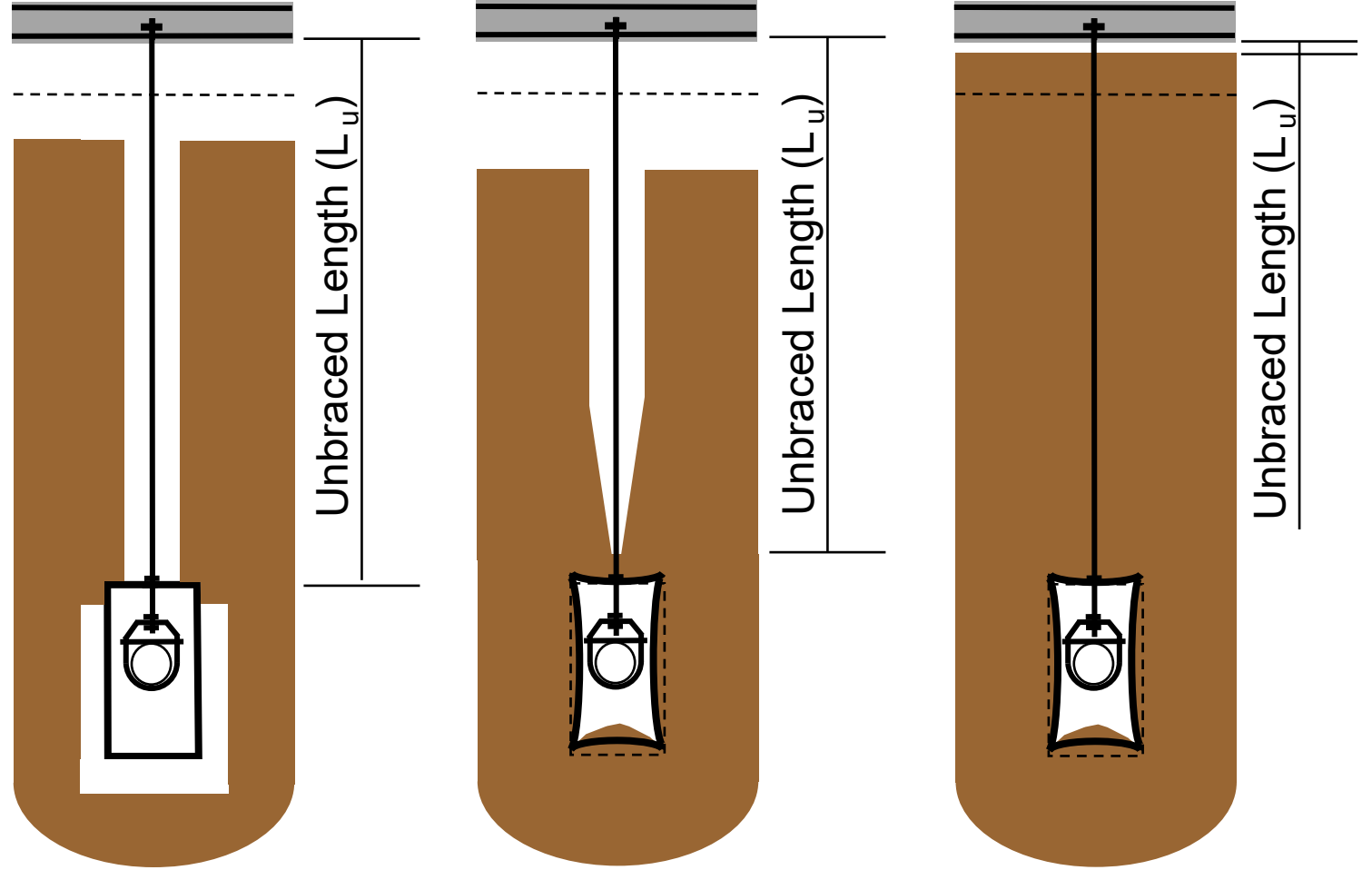
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DESIGNING THREADED HANGER RODS

(Unconservatively assuming soil acts as a rigid brace)



Least Uplift
(Actually Tension)
Greatest L_u

Intermediate Uplift
Intermediate L_u

Greatest Uplift
Least L_u

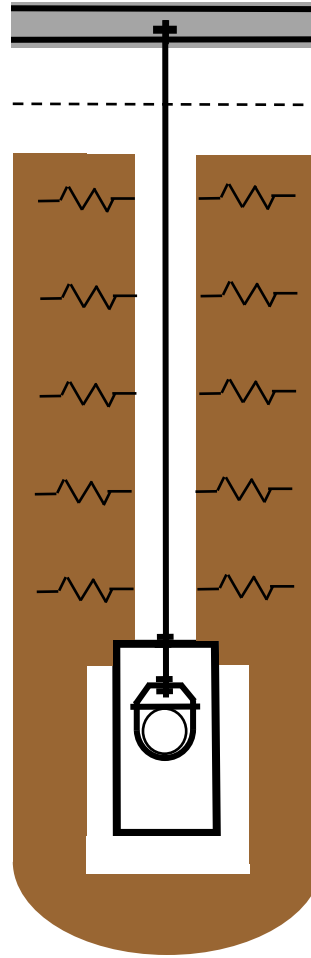
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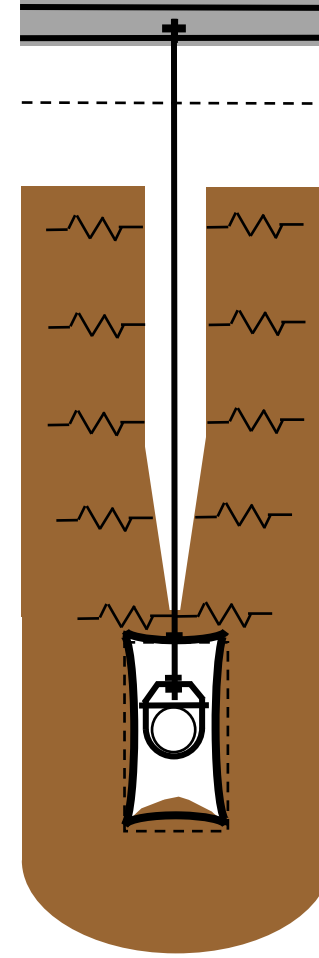
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DESIGNING THREADED HANGER RODS

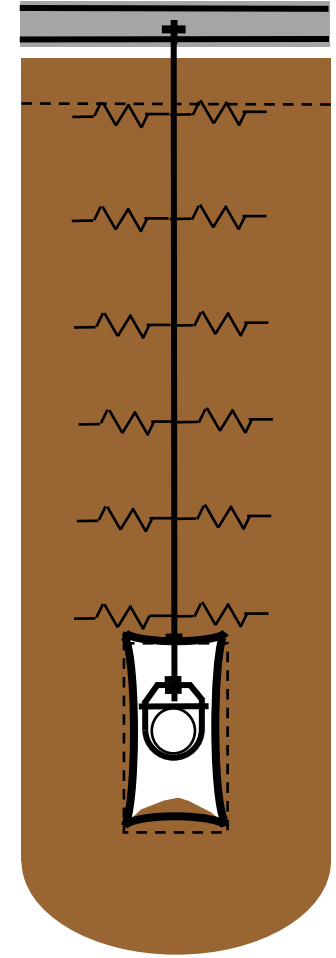
(Modeling Soil acts as a series of Offset Soil Springs)



Least Uplift
(Actually Tension)



Intermediate Uplift



Greatest Uplift

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DESIGNING THREADED HANGER RODS PUNCHING THROUGH WASHERS

In addition to overcoming the skin-friction resistance of any soil in contact with the threaded rod, for a threaded support rod to not buckle and allow a soil-retention system (that also functions as the support system for the nut during installation to support the plumbing before the slab is poured) to slide upward during soil swelling, the nut on top of the support system will need to either push through the support system in a punching-shear failure or need to deform the support system so that the nut can pass through the support system.

As an example, the IBC requires that sheet metal washers comply with AISI S100 “North American Specification for the Design of Cold-formed Steel Structural Members”. AISI S100 has provisions that provide the DESIGN strength permitted; however, the applicable value for the design of a threaded rod would be the ULTIMATE capacity, multiplying the design strength by an appropriate increase factor to account for the coefficient of variation in the statistical data used in determining the ultimate capacity.

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DESIGNING THREADED HANGER RODS PUNCHING THROUGH WASHERS

Clamping forces (e.g. on top of a washer) can significantly increase the ultimate deformed-failure resistance capacity of a washer. Designers should exercise caution when relying on test data indicating that a support system will deform before reaching the punching-shear capacity if the testing program does not accurately replicate clamping forces which should be expected to occur. Clamping forces greater than those at installation can develop after installation as components of non-isolated void systems above a support nut can often deform under loading from backfill and any construction equipment over the system during installation.

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DESIGNING THREADED HANGER RODS ACCELERATED CORROSION DUE TO SOIL CONTACT

Clay soil can have a higher corrosion rate than sandy soils. And, soil contact can accelerate corrosion of metals where soil moisture is present. The relative acidity of the soil moisture is an important factor in the corrosion rate. For example with galvanized steel, in relatively lower pH soil the evolution of hydrogen can eliminate the possibility of protective film formation.

Generally, building codes (including plumbing codes) require that corrosive metals be protected in a manner approved by the building official. Protection that may be acceptable in an environment where the metals are not in contact with soil may not be acceptable if they are in contact with soil.

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LOAD CASE EXAMPLES

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MESH & PLYWOOD UNDER PLUMBING

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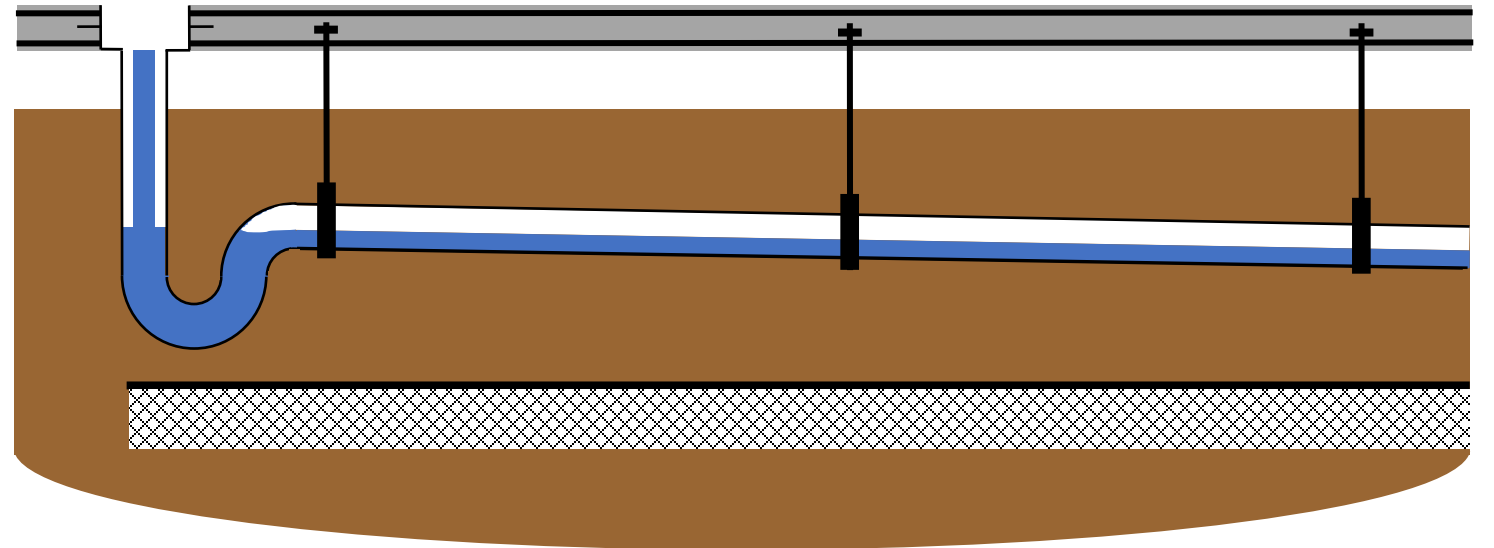
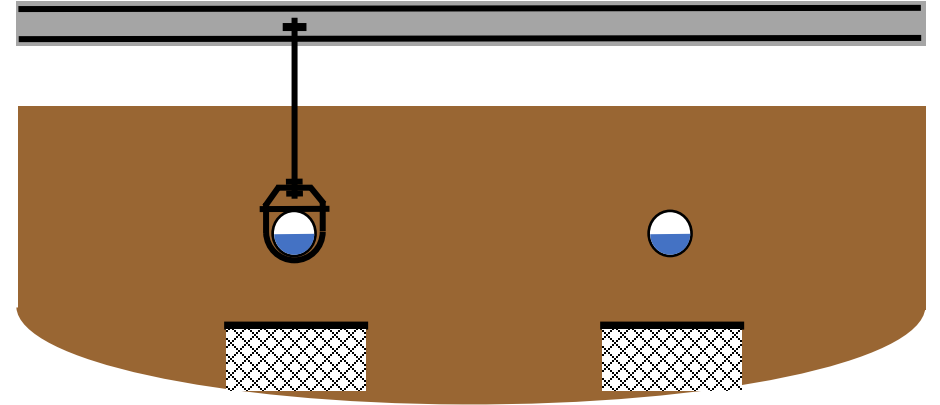
NON-ISOLATED
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LOAD CASE EXAMPLES

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MESH & PLYWOOD UNDER PLUMBING

Installed Conditions

Non-expansive fill
options not shown
because expansive soil
can still push up and pull
down non-expansive fill.



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ISOLATED SLABS

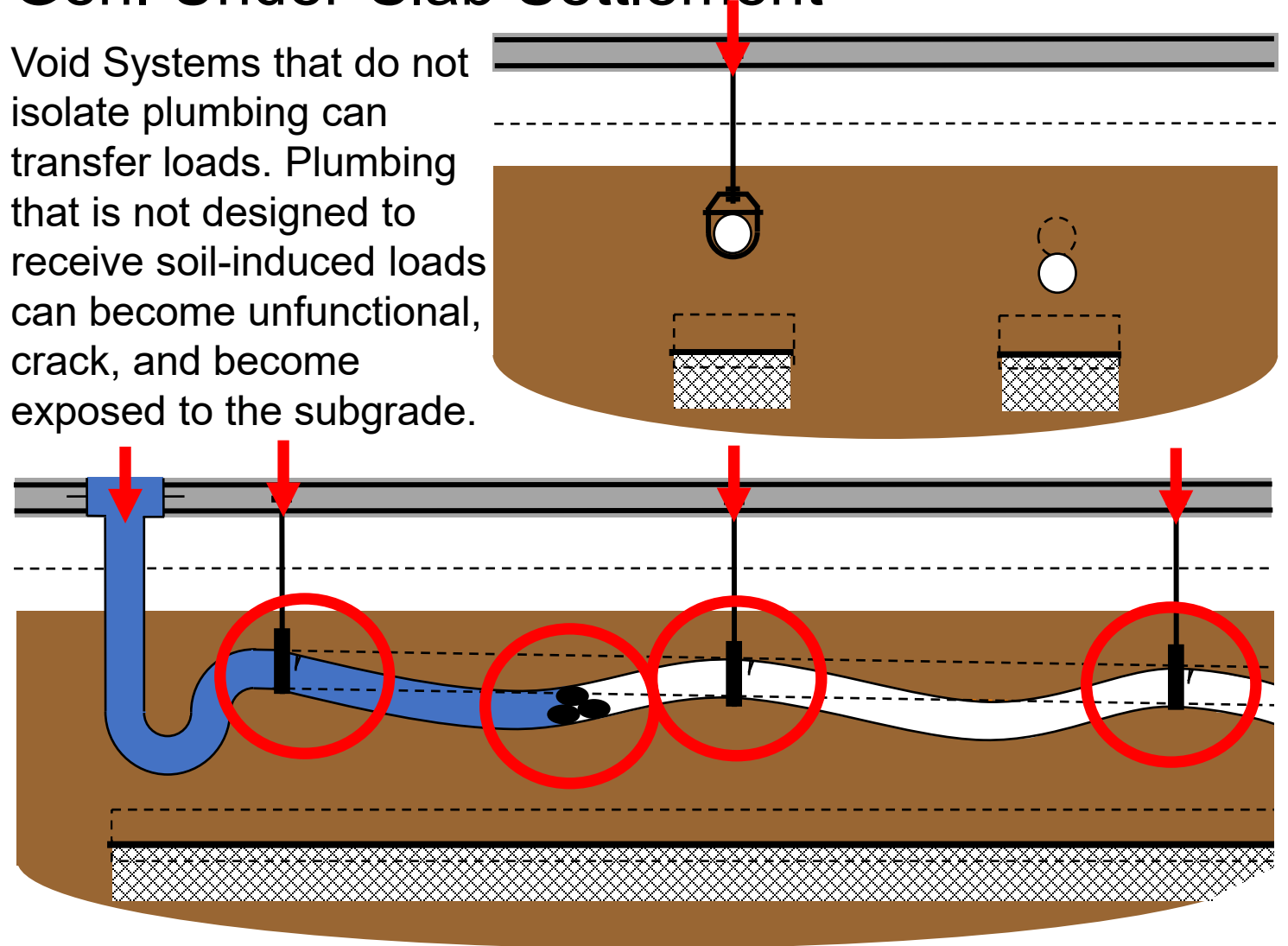
NON-ISOLATED
VOID SYSTEMS
LOAD CASE EXAMPLES

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MESH & PLYWOOD UNDER PLUMBING

Gen. Under-Slab Settlement

Void Systems that do not isolate plumbing can transfer loads. Plumbing that is not designed to receive soil-induced loads can become unfunctonal, crack, and become exposed to the subgrade.



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PLUMBING UNDER
ISOLATED SLABS

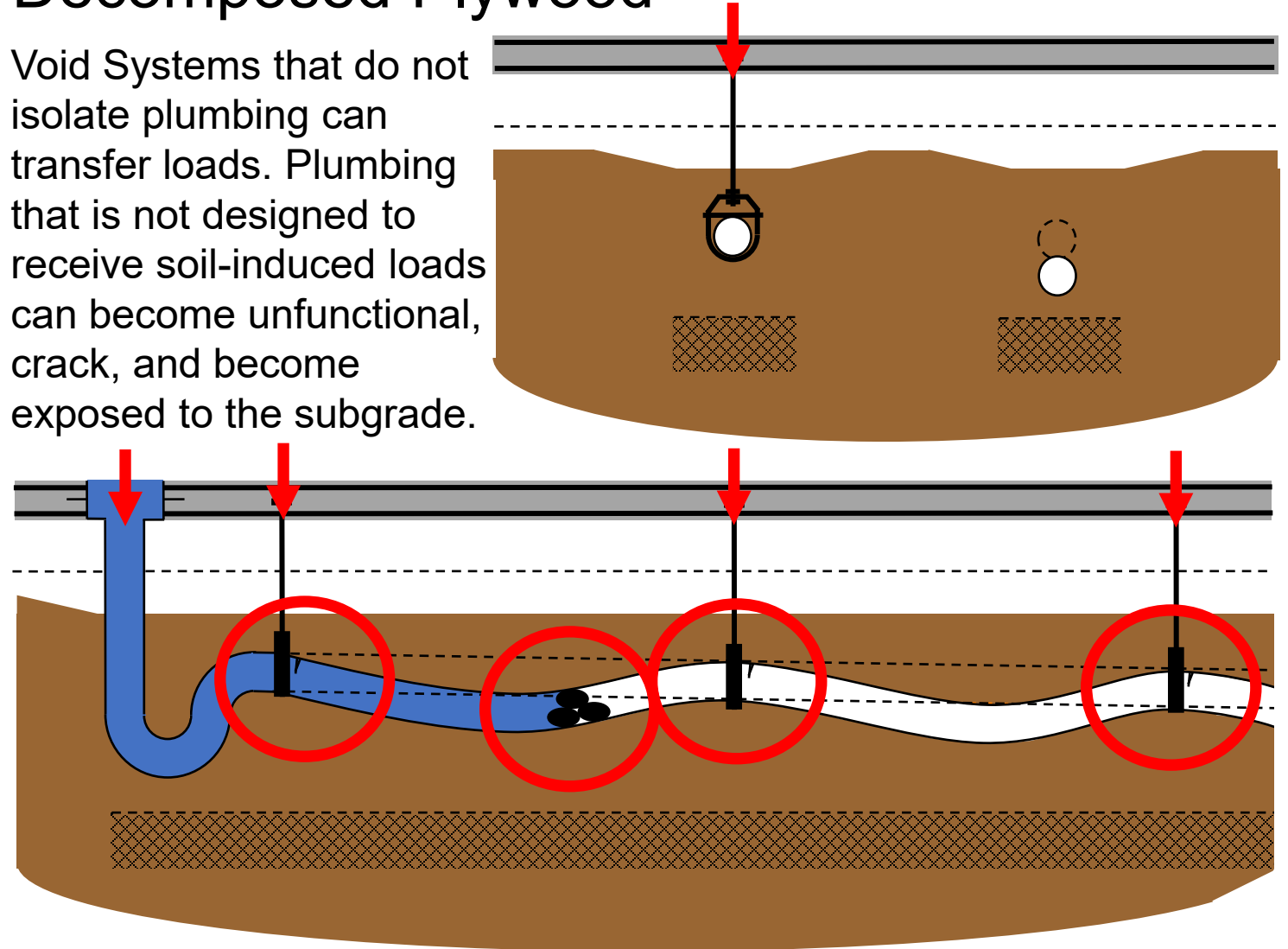
NON-ISOLATED
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LOAD CASE EXAMPLES

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MESH & PLYWOOD UNDER PLUMBING

Decomposed Plywood

Void Systems that do not isolate plumbing can transfer loads. Plumbing that is not designed to receive soil-induced loads can become unfunctonal, crack, and become exposed to the subgrade.



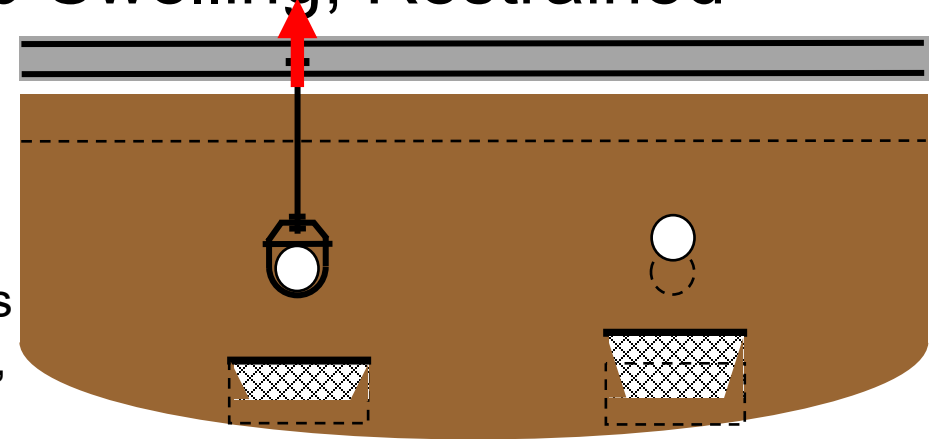
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NON-ISOLATED
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LOAD CASE EXAMPLES

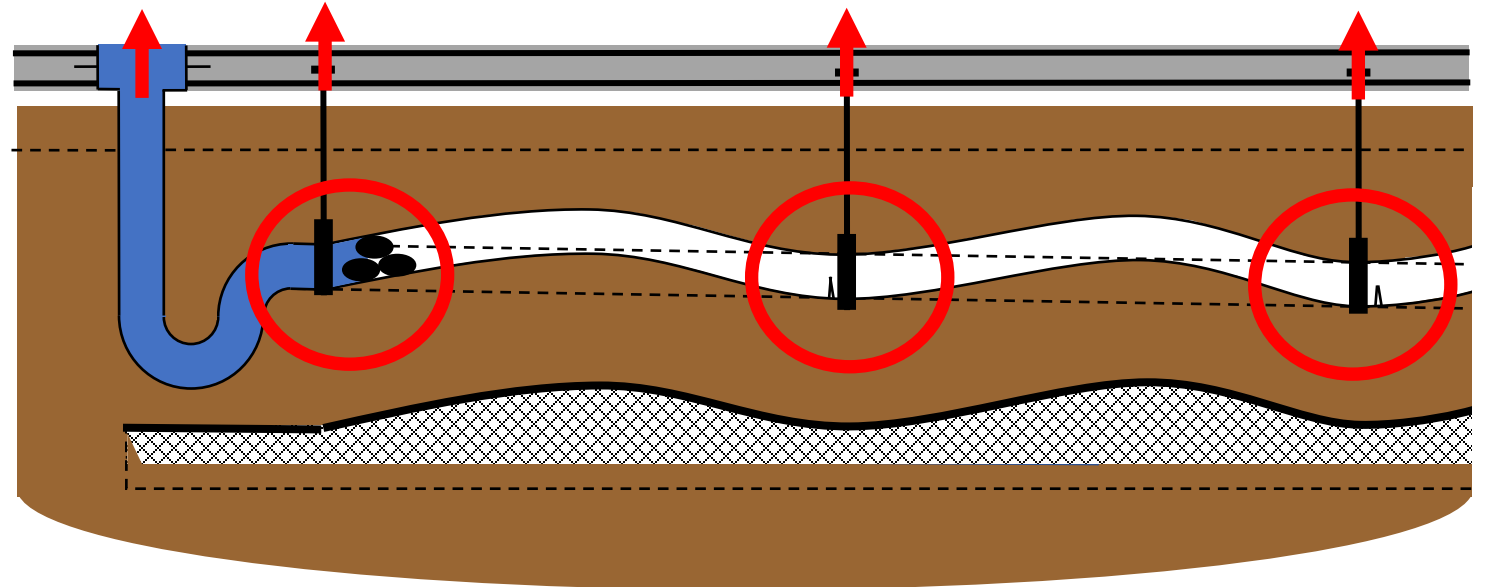
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MESH & PLYWOOD UNDER PLUMBING
Gen. Under-Slab Swelling, Restrained

Void Systems that do not isolate plumbing can transfer loads. Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



Forces on slabs can cause damage too.



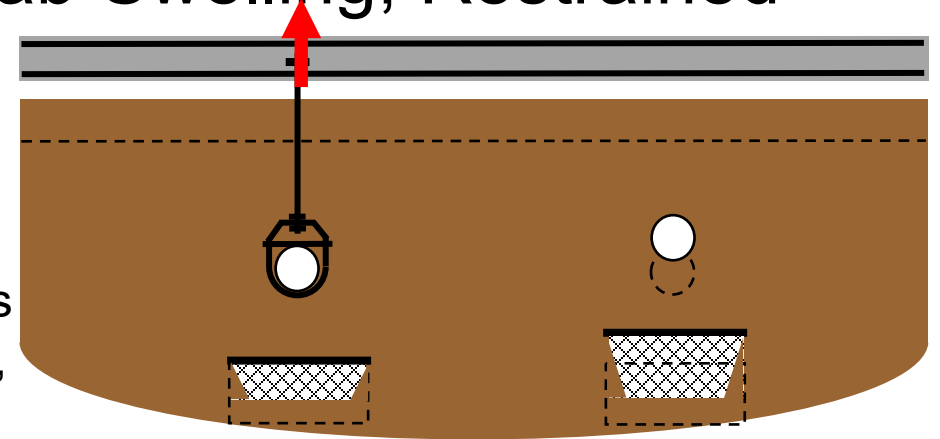
FOCUS:
NON-ISOLATED
PLUMBING UNDER
ISOLATED SLABS

NON-ISOLATED
VOID SYSTEMS
LOAD CASE EXAMPLES

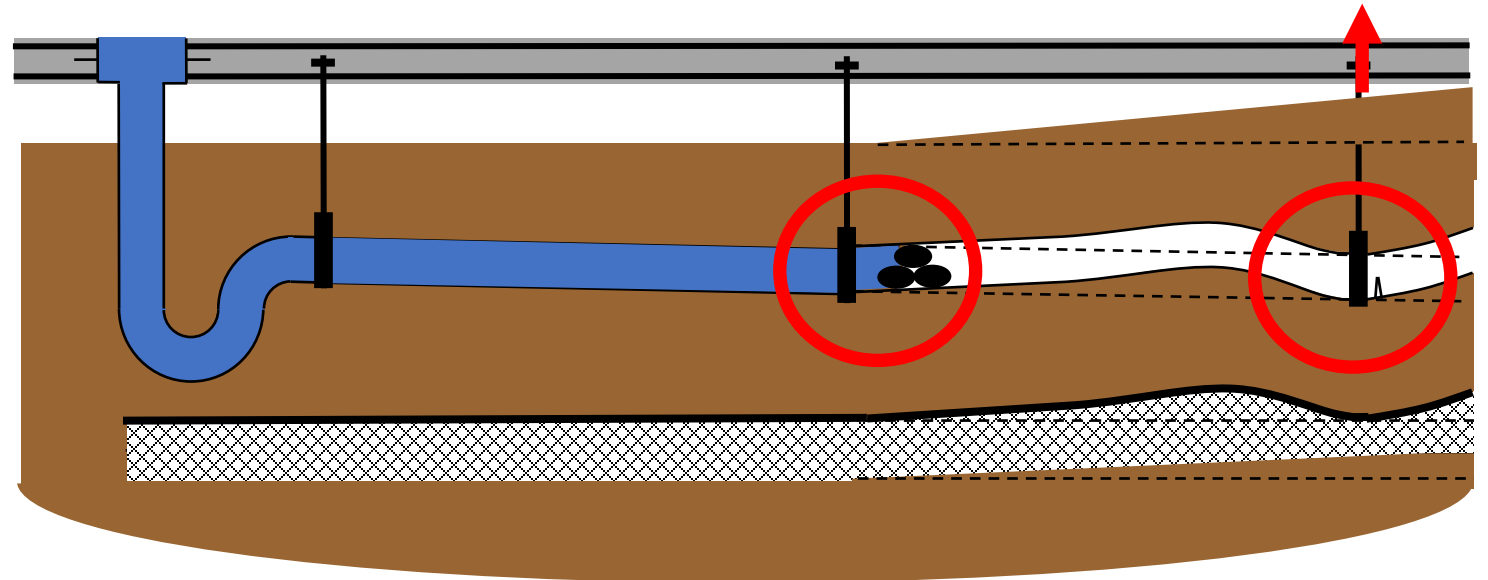
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MESH & PLYWOOD UNDER PLUMBING
Perim. Under-Slab Swelling, Restrained

Void Systems that do not isolate plumbing can transfer loads. Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



Forces on slabs can cause damage too.



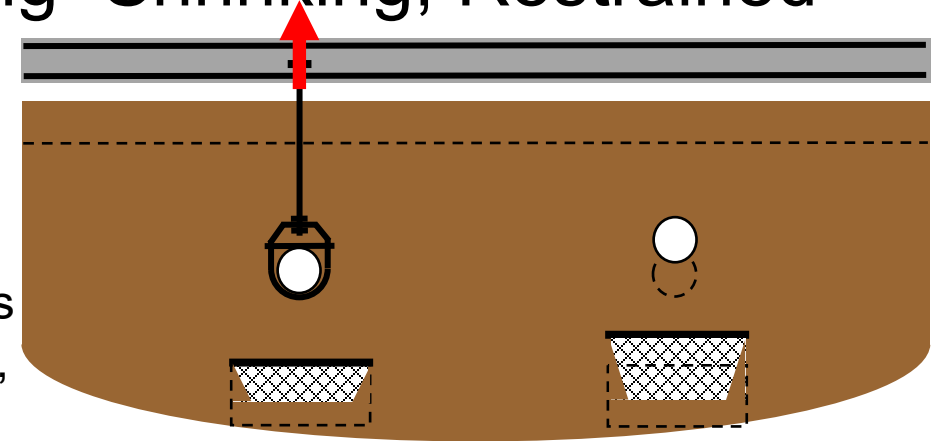
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LOAD CASE EXAMPLES

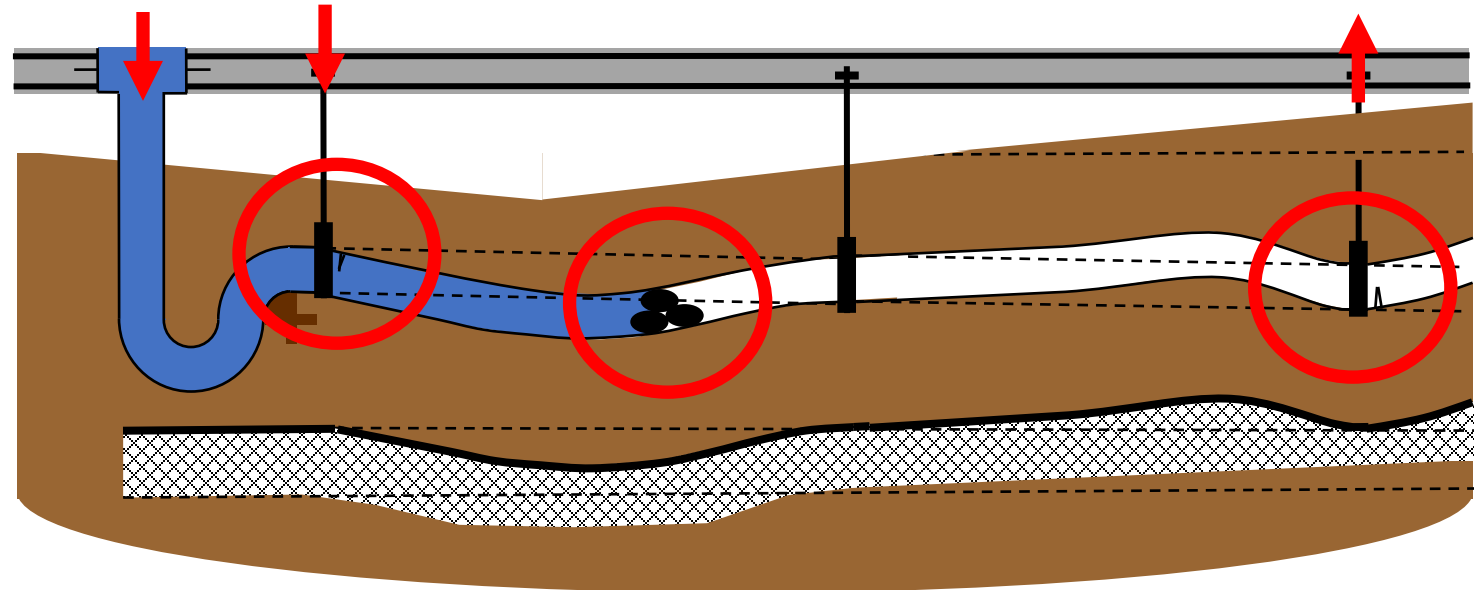
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MESH & PLYWOOD UNDER PLUMBING
Complex Swelling+Shrinking, Restrained

Void Systems that do not isolate plumbing can transfer loads. Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



Forces on slabs can cause damage too.



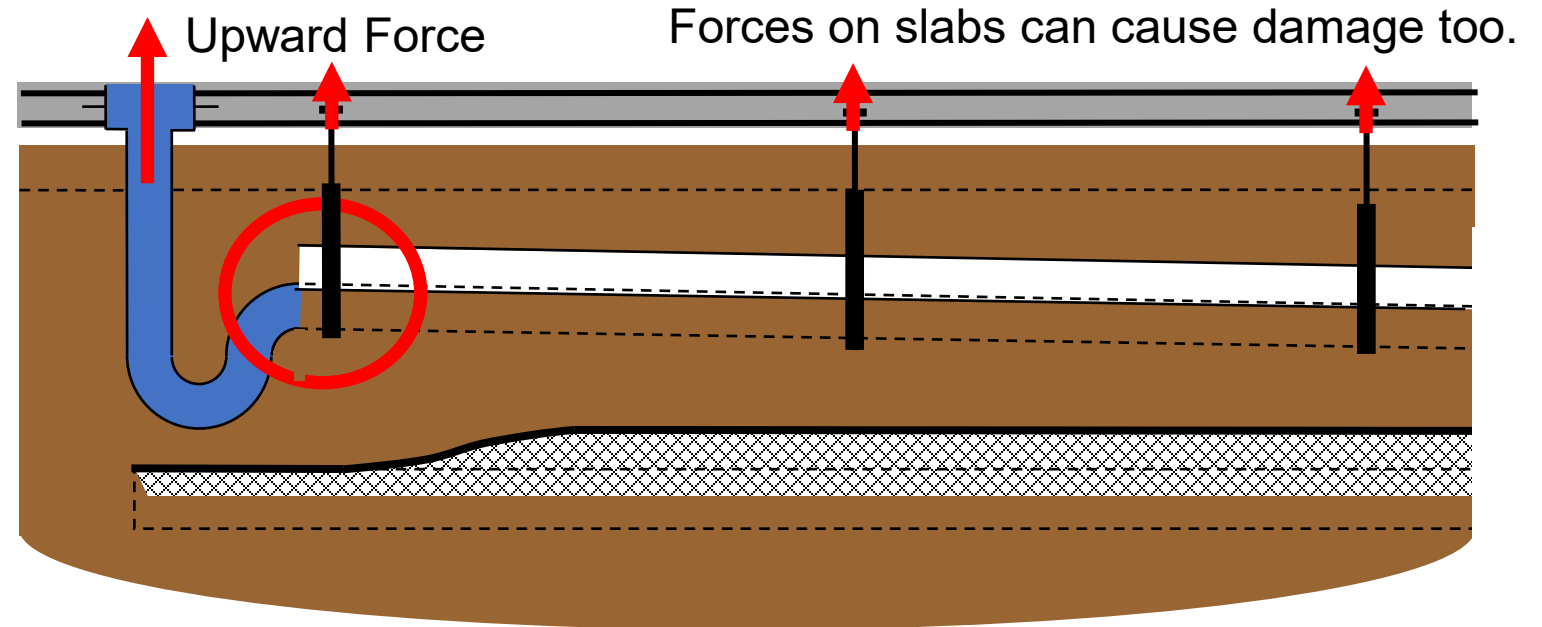
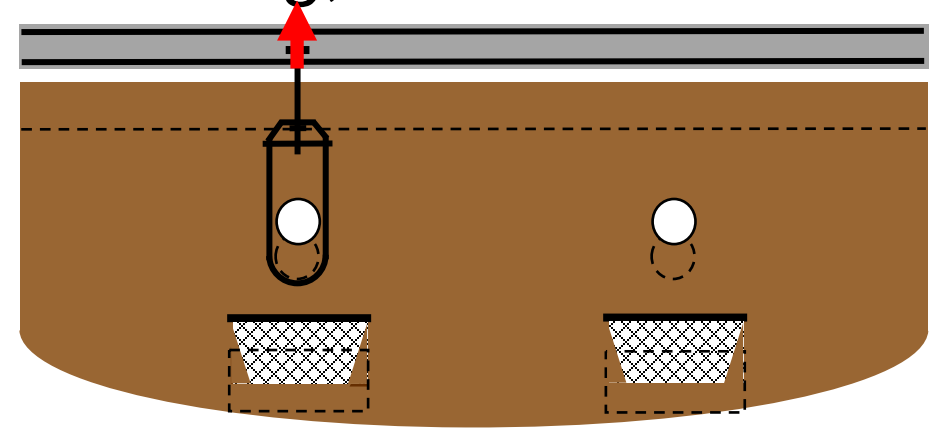
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NON-ISOLATED
VOID SYSTEMS
LOAD CASE EXAMPLES

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MESH & PLYWOOD UNDER PLUMBING
Gen. Under-Slab Swelling, Unrestrained

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



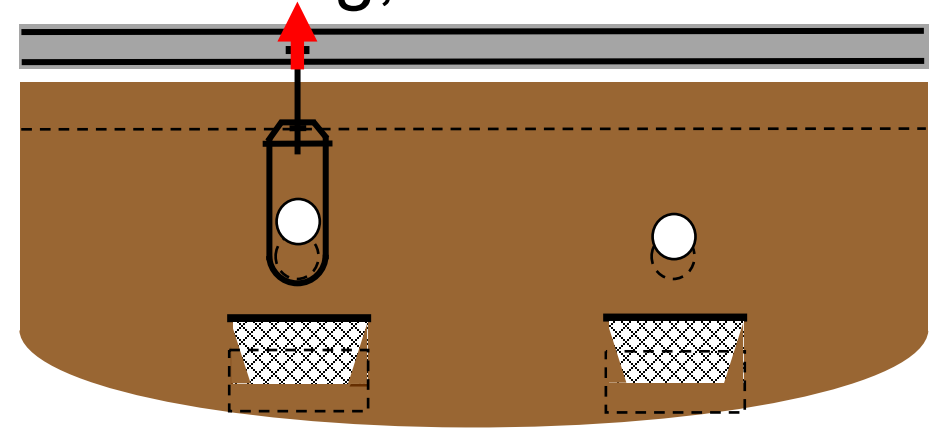
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LOAD CASE EXAMPLES

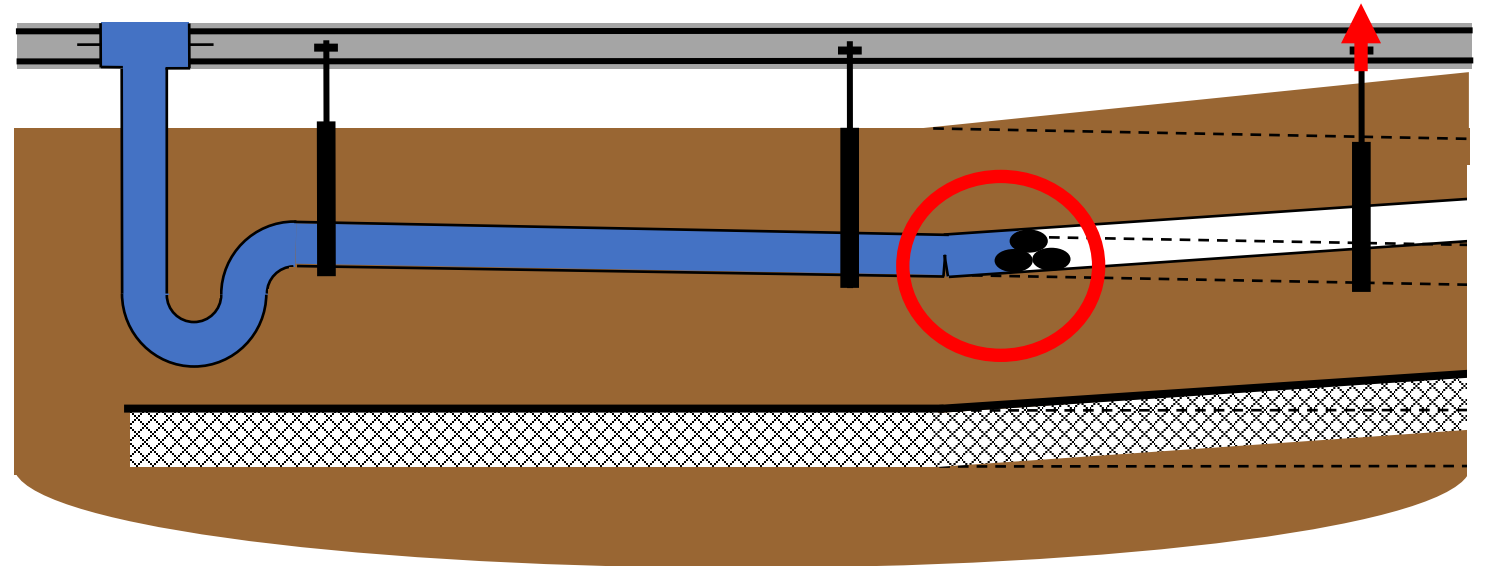
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MESH & PLYWOOD UNDER PLUMBING
Perim. Under-Slab Swelling, Unrestrained

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



Forces on slabs can cause damage too.



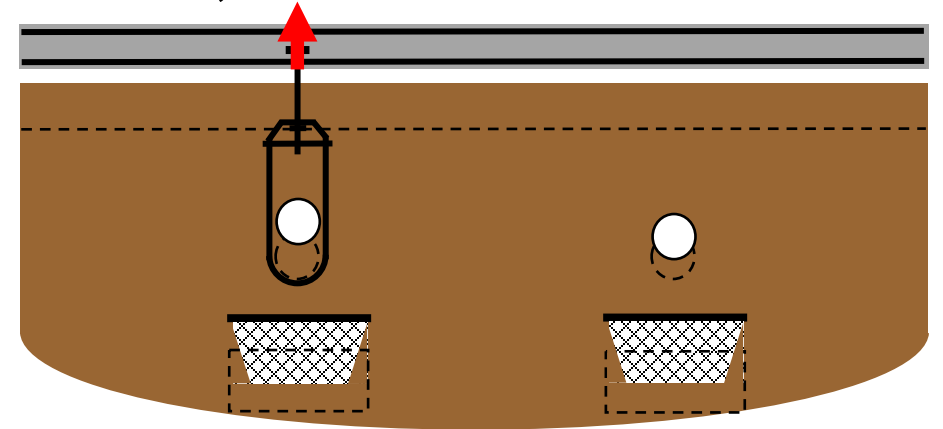
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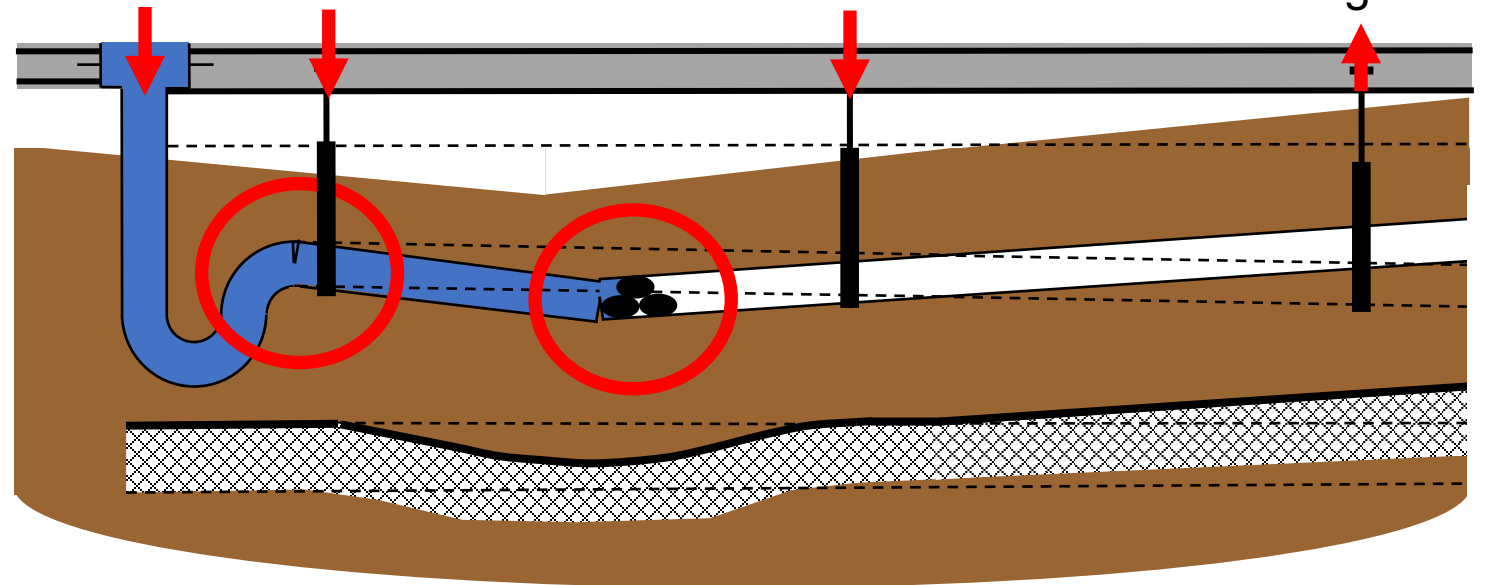
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MESH & PLYWOOD UNDER PLUMBING
Complex Swell+Shrink, Unrestrained

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



Forces on slabs can cause damage too.



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PLASTIC SIDE PANELS AND CROSSBARS

FOCUS:
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**NON-ISOLATED
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PLASTIC SIDE PANELS AND CROSSBARS ALTERNATIVE METHODS & MATERIALS

2021 IBC Section 1604.1 (Previous editions are similar):

“Building, structures and parts thereof shall be designed and construction in accordance with strength design, load and resistance factor design, allowable stress design, empirical design or conventional construction methods, as permitted by the applicable material chapters and referenced standards.”

2021 IBC Chapter 26 PLASTIC (Previous editions are similar) has no provisions permitting plastic to be used as a structural material.

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PLASTIC SIDE PANELS AND CROSSBARS ALTERNATIVE METHODS & MATERIALS

2021 IBC Section 104 (previous versions of IBC are similar)

“An alternative material, design or method of construction shall be approved where the building official finds that the proposed alternative meets all of the following:

1. The alternative material, design or method of construction is satisfactory and complies with the intent of the provisions of this code,
2. The material, method or work offered is, for the purpose intended, not less than the equivalent of that prescribed in this code as it pertains to the following:
 - 2.1 Quality.
 - 2.2 Strength.
 - 2.3 Effectiveness.
 - 2.4 Fire resistance.
 - 2.5 Durability.
 - 2.6 Safety.”

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PLASTIC SIDE PANELS AND CROSSBARS ALTERNATIVE METHODS & MATERIALS

Historical Example: Soil retainers adjacent to a void under a gradebeam, specified by the Structural Engineer of Record

As these soil retainers are in a simply supported condition, they are statically determinate, which allows significantly less testing. Material properties back-calculated from one test can be applied to non-tested conditions. (The example of a non-isolated void system with plastic side panels and crossbars, on the other hand, is statically indeterminate if tested as a three-dimensional assemblage with partial fixity at connections, requiring significantly more testing of load cases.)

If these soil retainers were to fail, the soil uplift would be resisted by a reinforced concrete gradebeam that has a significant amount of strength and stiffness, as well as typically the dead load of a suspended slab and the dead load of an exterior wall, which is a significant amount of resistance. (If a non-isolated void system with plastic side panels and crossbars fails, on the other hand, the impacted plumbing system often has little relative strength or stiffness.)

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PLASTIC SIDE PANELS AND CROSSBARS ALTERNATIVE METHODS & MATERIALS

Some examples of alternative design considerations for plastic:

What design method is used to determine the appropriate Φ resistance factor for LRFD or allowable stress for ASD for plastic?

How will these values account for effects of temperature on plastic?

How will these values account for effects of ultra-violet light exposure before installation?

How will these values account for effects of cyclical loading fatigue?

How will these values account for variation of material properties?

What are the specified construction tolerances and how will these values account for specified construction tolerances?

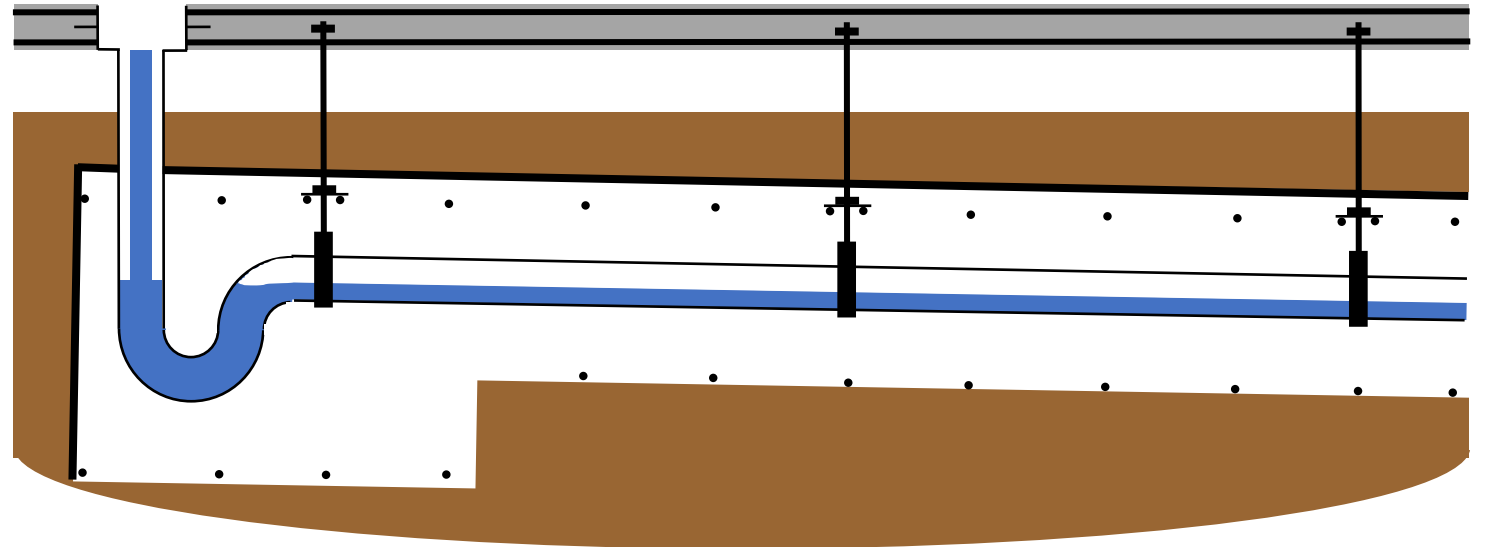
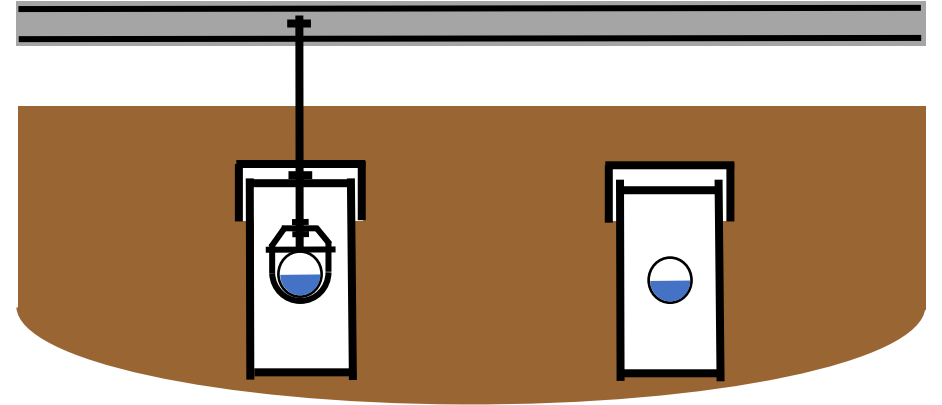
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PLASTIC SIDE PANELS AND CROSSBARS Installed Conditions

Non-expansive fill
options not shown
because expansive soil
can still push up and pull
down non-expansive fill.



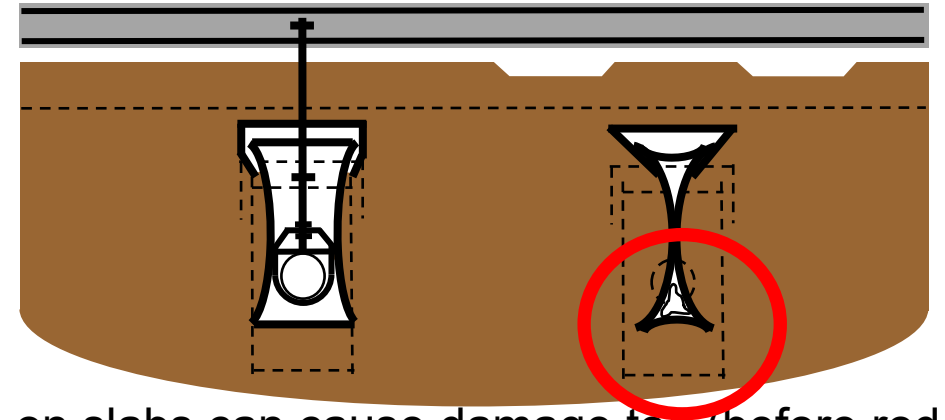
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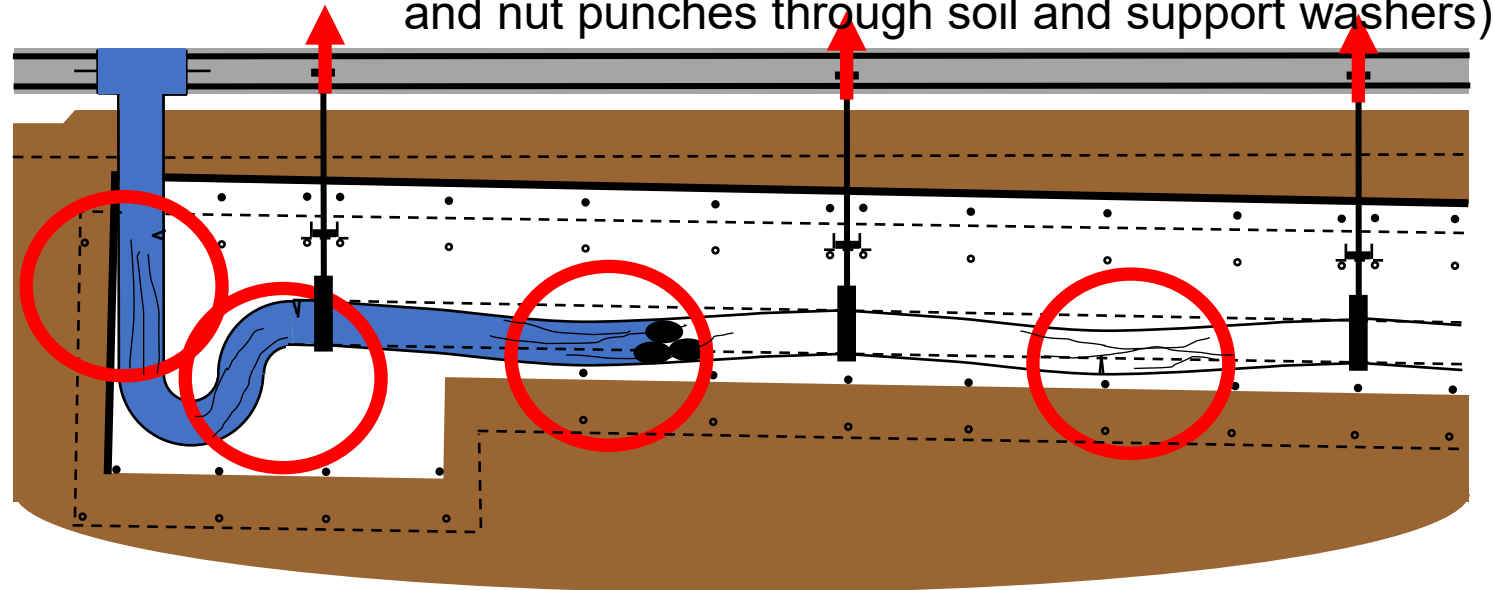
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PLASTIC SIDE PANELS AND CROSSBARS Gen. Swelling, No Rod Buckling

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



Forces on slabs can cause damage too (before rod and nut punches through soil and support washers).



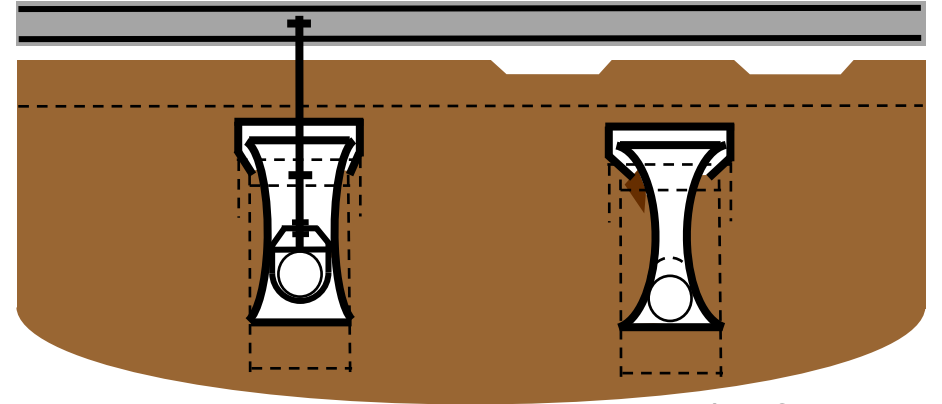
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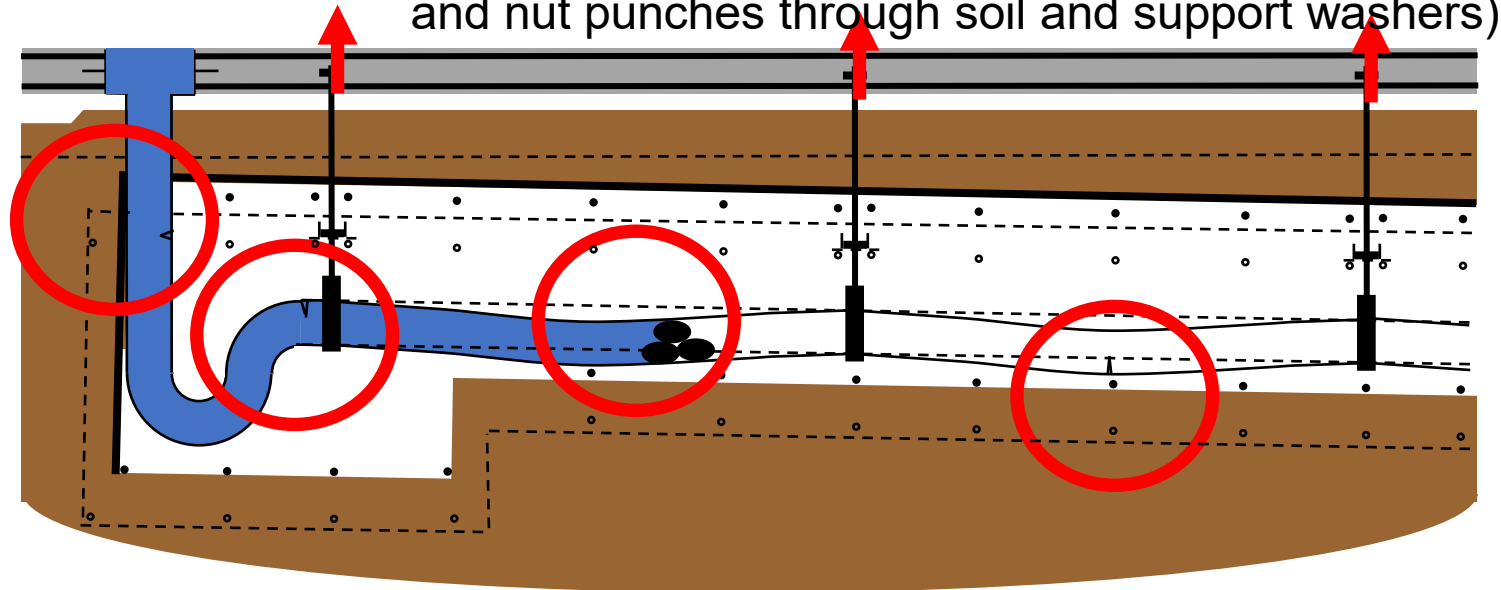
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PLASTIC SIDE PANELS AND CROSSBARS
Gen. Swelling, No Rod/Crossbar Buckling

Plumbing that is not designed to receive soil-induced loads can become unfunctional, crack, and become exposed to the subgrade.



Forces on slabs can cause damage too (before rod and nut punches through soil and support washers).



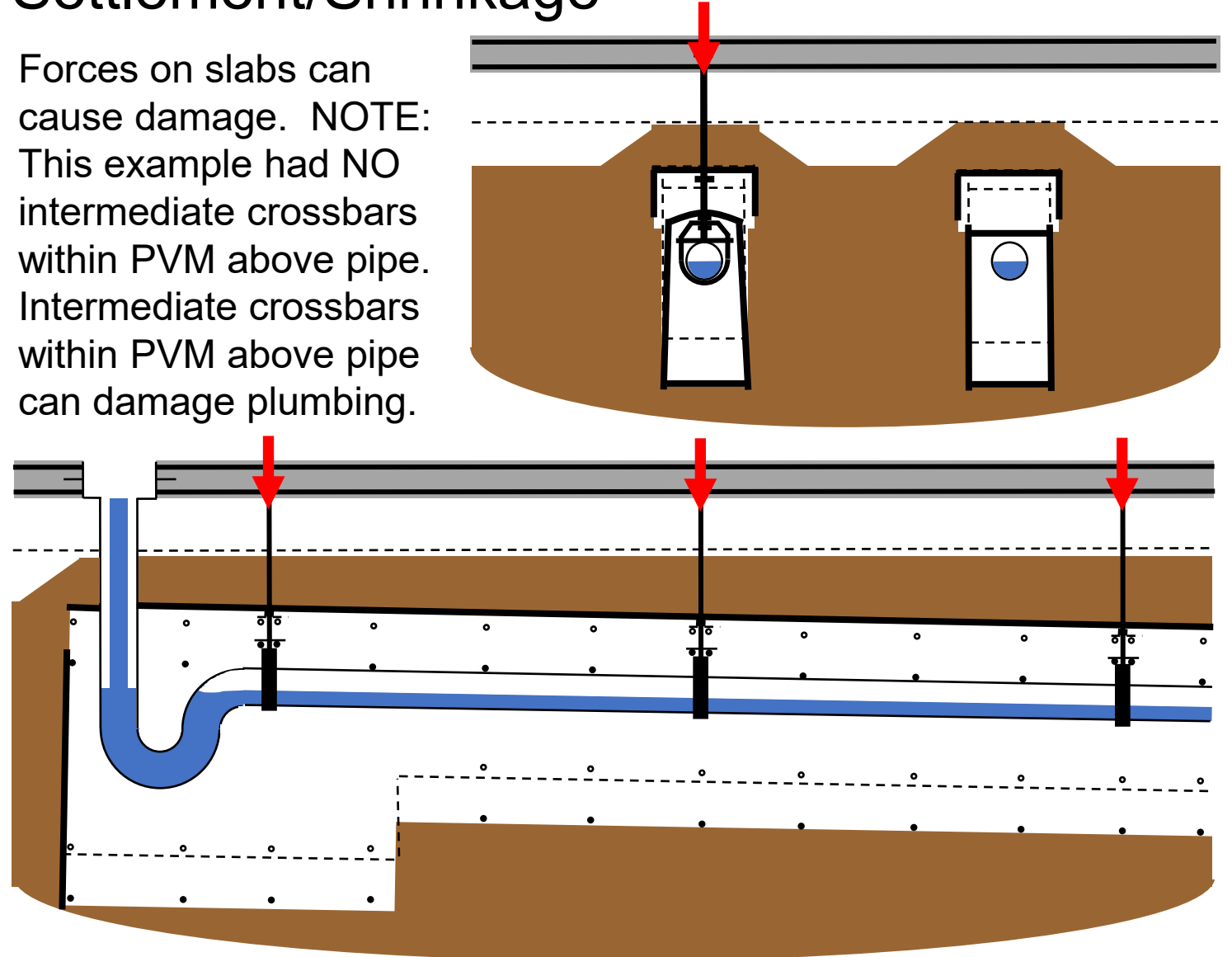
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PLASTIC SIDE PANELS AND CROSSBARS Settlement/Shrinkage

Forces on slabs can cause damage. NOTE: This example had NO intermediate crossbars within PVM above pipe. Intermediate crossbars within PVM above pipe can damage plumbing.



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**NON-ISOLATED
VOID SYSTEMS**

SWELL/SHRINK CYCLE DEFORMATIONS

Designers need to also carefully consider the effects of swell/shrink cycles on the deformed shape of non-isolated void systems.

As an example for plastic side panels and crossbars, in a shrinkage condition, any crossbars that bend upon contact with clevises or pipes (causing crossbar deflection) will have an initial mid-span deflection that can significantly reduce the axial buckling capacity of the crossbar in a swell condition, especially if there is “plastic” deformation (in this case referring to “plastic” as the opposite of elastic in material behavior).

Furthermore, cyclical stress reversals typically lead to failures due to material fatigue at significantly lower stresses than at initial conditions.

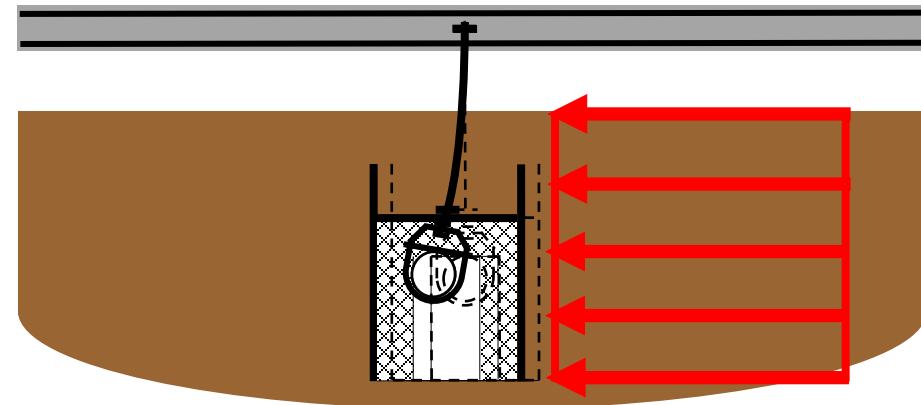
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NET HORIZONTAL FORCES

Non-Isolated Void Systems will shift horizontally under net horizontal forces (where horizontal forces are not balanced by equal horizontal forces on an opposing side of a Non-Isolated Void System). These shifts can damage plumbing (cracks and backdraining) by causing pipes to not only shift horizontally but also swing upward.

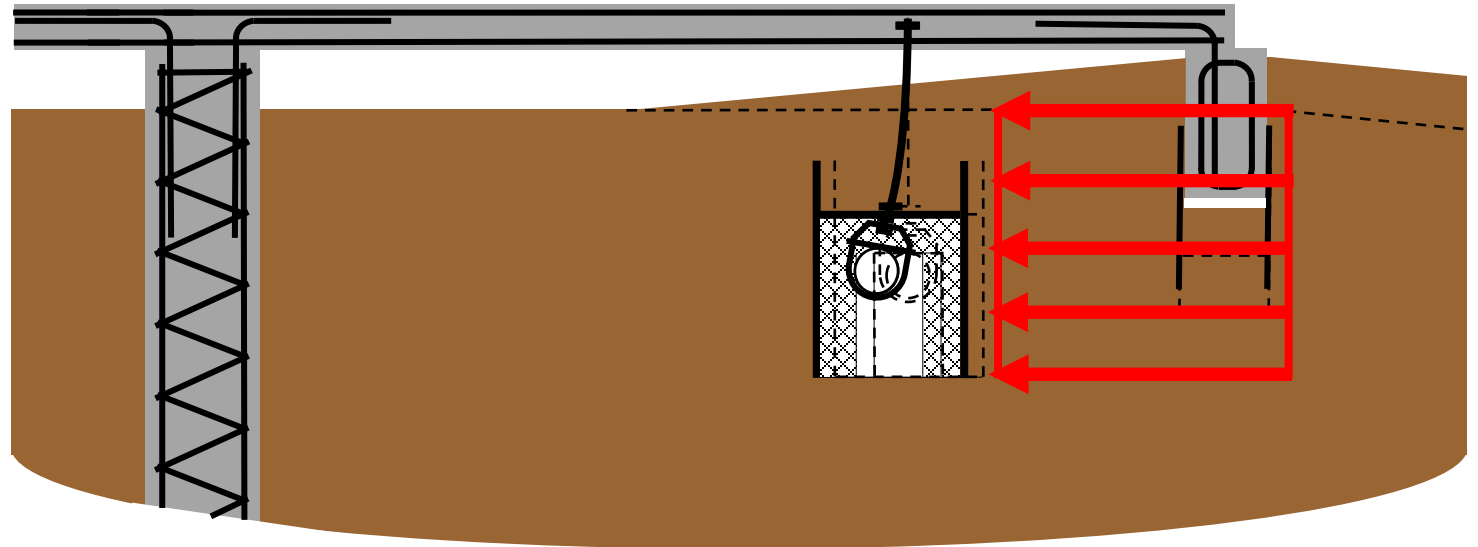


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VOID SYSTEMS

NET HORIZONTAL FORCES

Soil swelling on one side of a Non-Isolated Void System can create net horizontal forces that push Non-Isolated Void Systems and damage plumbing. As an example, this could occur where plumbing runs near and parallel to an exterior grade beam and then exterior soil swells after being exposed to moisture.



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STRUCTURAL ENGINEERING OF NON-ISOLATED VOID SYSTEMS

Non-Isolated Void Systems are typically not labelled and listed products that have been deemed to comply with construction codes by a certification body for the purposes of protecting plumbing in expansive soil. If they were, conditions of the listing would define limitations.

Where soil retaining components and bracing for soil retaining components are expected to retain soil, the specifying professional needs to verify that they will be sufficient to resist axial compression buckling, out-of-plane flexural plastic hinge failure, failure due to combined compression and flexure, account for P-delta effects of bracing under beam column axial displacement of braces, and more.

It is uncommon for Mechanical Engineers to have the education and experience necessary to perform or review the structural engineering tasks necessary to design a non-isolated void system so that it complies with all applicable construction codes. If a Mechanical Engineer specifies a non-isolated void system, they are not allowed to rely on a manufacturer's claims unless the manufacturer provides an engineered design with the seal of an engineer that is accepting this responsibility.

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DELEGATED DESIGN OF NON-ISOLATED VOID SYSTEMS

A design professional specifying a non-isolated void system should not attempt to specify that the design of the system be delegated during construction (e.g. with shop drawings bearing the seal of a Professional Engineer). It is the responsibility of the specifying professional to sufficiently define the scope of the Delegated Design Engineer. Simply specifying that the shop drawings be sealed does not define any responsibility for the Delegated Design Engineer. Furthermore, it is not appropriate for design professionals to try to divest their responsibility with vaguely defined and broad specification language for this complex multi-disciplinary issue where data in the industry is sorely lacking and other design professionals on a project need to coordinate scopes with this task. Therefore, for all of the reasons stated in this presentation and more, it is not feasible for a Mechanical Engineer to properly specify all of the multi-disciplinary criteria and collaboration required for any specific non-isolated void system.

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Scenarios for a Mechanical Engineer to consider if they do NOT require isolation of plumbing under Slab-on-Voidwork:

If isolation of plumbing is recommended by the Geotechnical Engineer...

If the Building Official interprets the plumbing code to require protection of plumbing from expansive soil, or if a Judge/Jury in a future lawsuit may not consider the code requirements for protection of plumbing to even be subject to interpretation...

If the Contract Scope requires compliance with a changing standard of care that cannot be defined without a Judge/Jury in a future lawsuit...

If the Contract Scope does not include, as a basic service, the specialty geotechnical, mechanical and structural engineering design of non-isolated void systems to protect plumbing from expansive soil....

If the Plumber might issue an RFI during construction requesting verification that the plumbing will be protected from expansive soil...

If there is no Limitation of Liability...

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RECOMMENDATION

We recommend Mechanical Engineers **immediately cease and desist the practice of permitting Non-Isolated Plumbing (Buried Plumbing or Non-Isolated Void Systems) under Slab-on-Voidwork** foundations, regardless of whether the IPC or UPC applies or whatever edition applies, whatever the geotechnical engineer estimates to be the probability of movement occurring, whatever the building official will allow, and however hard the owner demands to reduce the initial cost of construction and claims they will accept the risks of damage that would requiring extensive and repeated maintenance.

We recommend Mechanical Engineers **immediately begin complying with the provisions already approved by ICC for the 2024 IPC** (provided in this presentation) for protection of plumbing from expansive soil, which is also recommended by the Geoprofessional Business Association:

Non-Isolated Plumbing is allowed under Non-Isolated Slabs

Isolated Plumbing is required under Isolated Slabs

THANK YOU