45th Annual Midwest Geotechnical Conference

RISK MANAGEMENT AND REHABILITATION of EXISTING STRUCTURAL FOUNDATIONS for NEW INFRASTRUCTURE FACILITIES

Jerry A. DiMaggio
jdimaggio@ara.com

ASCE | KNOWLEDGE & LEARNING

SINCE THE 1800's THE NAME and FAMILY DIMAGGIO HAS REPRESENTED THE VERY BEST IN COFFEE, BASEBALL AND CIVIL ENGINEERING/ INFRASTRUCTURE CONSTRUCTION EXCELLENCE!

Topics Discussed

- Concept and rationale of structural foundation reuse
- Advantages and limitations of structural foundation reuse
- Programmatic and process challenges of foundation reuse for owners, designers and contractors
- Risk based considerations and mitigation strategies based structural and geotechnical failure modes
- Assessment and evaluation approach at a program and project level
- Design and construction changes between the time of original design and construction to the time for reuse
- Technical challenges and knowledge gaps in the current state of the practice and art
- Potential solutions to rehabilitate and enhance structural foundations

Topic Background

- This webinar addresses the program, process and project issues associated with the **risk management and rehabilitation (reuse and enhancement) of existing structural foundations (both shallow and deep).**
- Reuse of existing structural foundations is an emerging technical subject which provides **significant opportunities (benefits of cost and schedule) as well as risks (compatibility, long term reliability and costs)** for the infrastructure owners, designers and the heavy construction community.
- Until recently, this topic has not been studied in-depth and a suite of programmatic, process and technical challenges must be addressed **to minimize costs, risks and liability for owners, designers and constructors.**

* This webinar is significantly based on U.S. public surface transportation experience and practice for bridges and structures but the technical concepts and programmatic issues are applicable to all civil engineering facilities.

Topic Background (continued)

- Existing foundations may **require rehabilitation and enhancements to meet the performance requirements and loading demands of the new structure.**

- Materials and techniques which can and have been applied to enhance the structural and geotechnical resistances of an existing foundation include **micropiles, augercast piles, driven piles, drilled shafts and several ground improvement methods including grouting, and controlled modulus columns.**

- **Reuse of existing foundations (with or without enhancements) is not applicable for all projects** because of geometric constraints, environmental restrictions or current design and performance requirements for the new facility. **However, when applicable the time and cost benefits may be significant and can be accomplished with confidence.**

Bridge Piers on shallow and deep foundations

FREEWAY 2100 W
ONE WAY
FREEWAY
ONLY
ONLY

Major Multi-span Bridge over Water

Four Foundation Options

Build a new foundation adjacent to an existing one: This option is the simplest from an engineering perspective. It can be costly and may have an impact from environmental and permitting perspectives. If new alignment is required, it may entail property and ROW acquisition and utility scope. In water crossings, additional scour analysis is required. If existing foundations need to be removed, additional time on-site is required.

Build a new in-place foundation: The existing foundation is demolished and replaced with a new one. When the new structure must be in the same location removal and replacement could be costly.

Reuse the existing foundation: This option requires no new foundation/substructure repair or rehabilitation work. The existing foundation is reused "as is" **after an assessment and analysis of the existing foundation's load-carrying resistance and condition to meet the new service life requirements.**

Reuse the existing foundation and enhance the resistance: Enhancement examples include adding piles or shafts; soil improvement measures such as grouting; and underpinning using micropiles.

FHWA's Foundation Characterization Program

- The objective of FHWA's Foundation Characterization Research Program is to develop and evaluate methodologies for characterizing structural foundations to determine unknown geometry, material properties, integrity, and load-carrying capacity.
- The program supports needs in three areas: geotechnical and hydraulic hazards, changes in current loads, and foundation condition assessments.
- In the area of hazards, a foundation's vulnerability to scour and seismic events are of particular concern in addition to the post-event assessments (after flooding, hurricane, seismic, or impact forces).
- The program examines the impacts that current loadings have on foundations over time. Changes in design codes and functional needs can result in increased loading conditions that are different from the original design intent.
- The third area of study addresses concerns related to degradation, decay, and long-term or in-service performance of substructure materials.

The Indiana Department of Transportation and the Kentucky Transportation Cabinet used accelerated bridge construction and a prefabricated bridge system (a lateral slide) to rehabilitate the Milton-Madison Bridge between Milton, KY, and Madison, IN. Crews reused and strengthened the existing foundation, and then replaced the superstructure with a preassembled steel truss.

Foundation Reuse Management Program

- Adopt a risk based "Asset Management Approach" (develop policies, technical and business procedures and budgets
- Define responsibilities and roles (owner, designers and constructors)
- Define the criticality and *"design life"* of *"new"* structure
- Conduct an office and field study (our current knowledge base and capabilities are somewhat limited). These studies require resources.
- Consider schedule, costs and qualitatively/ quantitatively assess risks

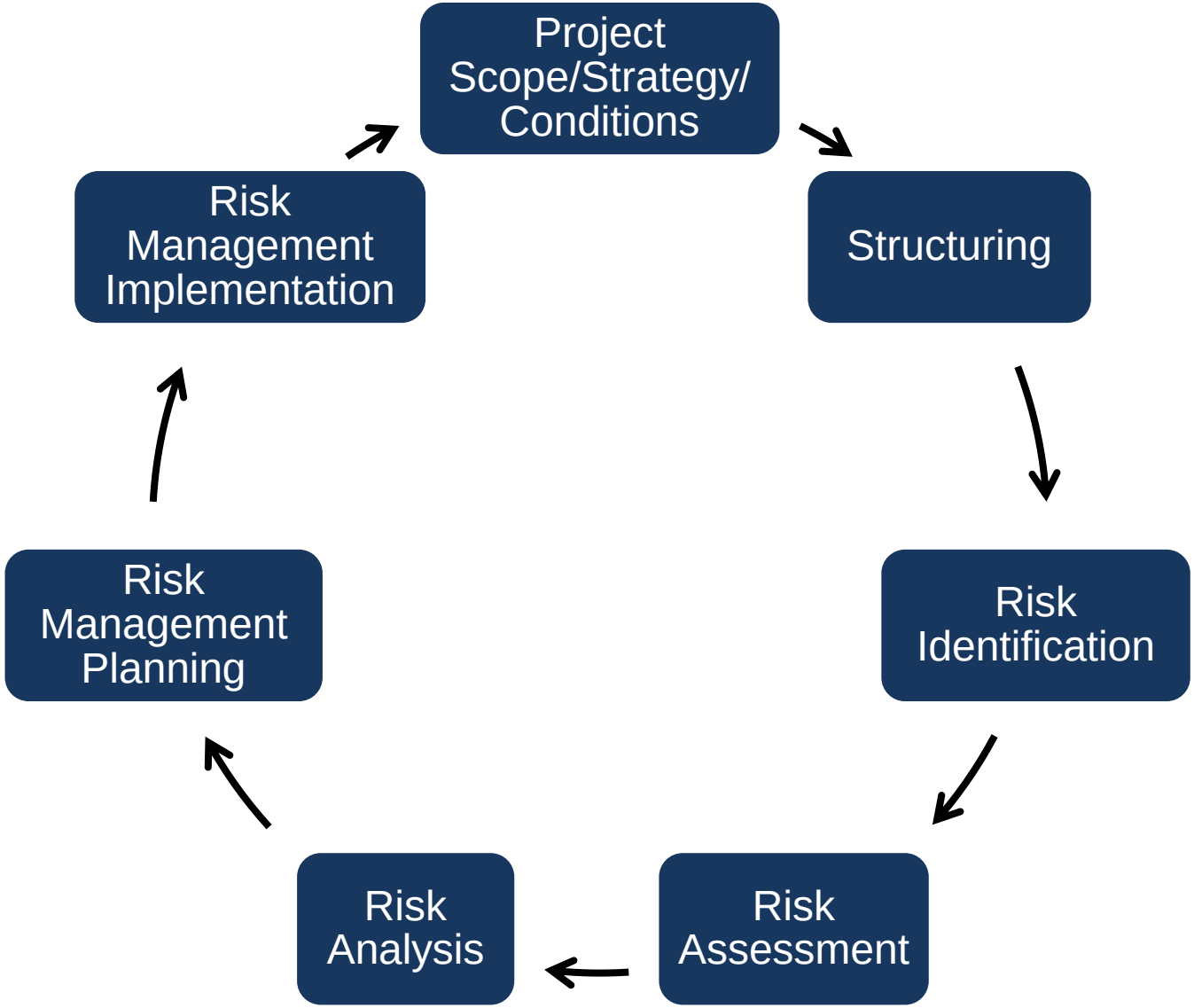
Risk Management Process

- Formal, flexible and efficient process to
  - Identify, assess, analyze, monitor and manage project and program risks and opportunities
  - Anticipate and plan for potential issues and opportunities
- Better understanding and control of project and program outcomes

Risk/Opportunity Definition

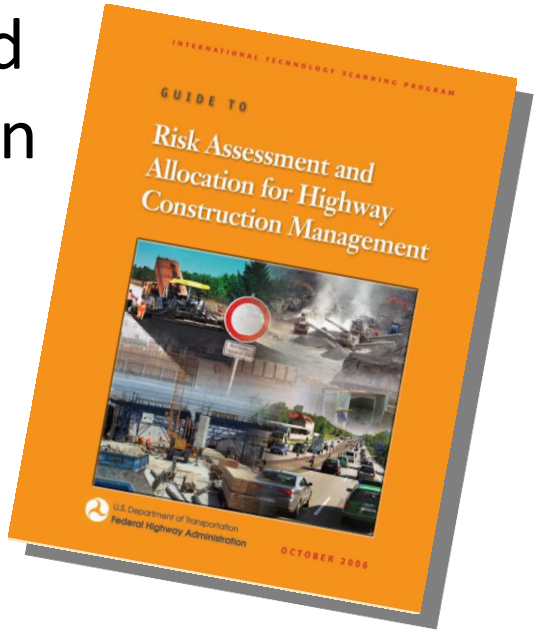
- Events that *might* occur, which are outside of base assumptions and could change “base” project and program performance
- Risk has a negative impact (problem)
- Opportunity has a positive impact (improvement)

Risk Management Process



Background of Risk Management Process

- Best practice since the 1970s
- Widely used by private companies and some public agencies (e.g. USCOE, FTA, FRA, WSDOT, MTA)
- FHWA (2006) "Risk Assessment and Allocation for Highway Construction Management" (*Risk Guidelines*), with training/ implementation materials
- FHWA Risk Management Tools



Risk Management Benefits

- Is very proactive
- Has been shown to:
  - Decrease majority of project/program issues
  - Recognize substantial project/program cost savings
- Is “best practice”
- Is applicable to all projects and phases
- Assists project team and management to better understand challenges/issues

Risk Management Limitations

What are some of the RM limitations?

- Could be perceived as a time-consuming process
- Requires resources and commitment at multiple levels
- Benefits may not be immediately obvious

Foundation Reuse Management Program

- ***Adopt a risk based "Asset Management Approach" (develop policies, technical and business procedures and budgets)***

- ***Define responsibilities and roles (owner, designers and constructors)***

- Define the criticality and *"design life"* of *"new"* structure

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- Consider schedule, costs and qualitatively/quantitatively assess risks

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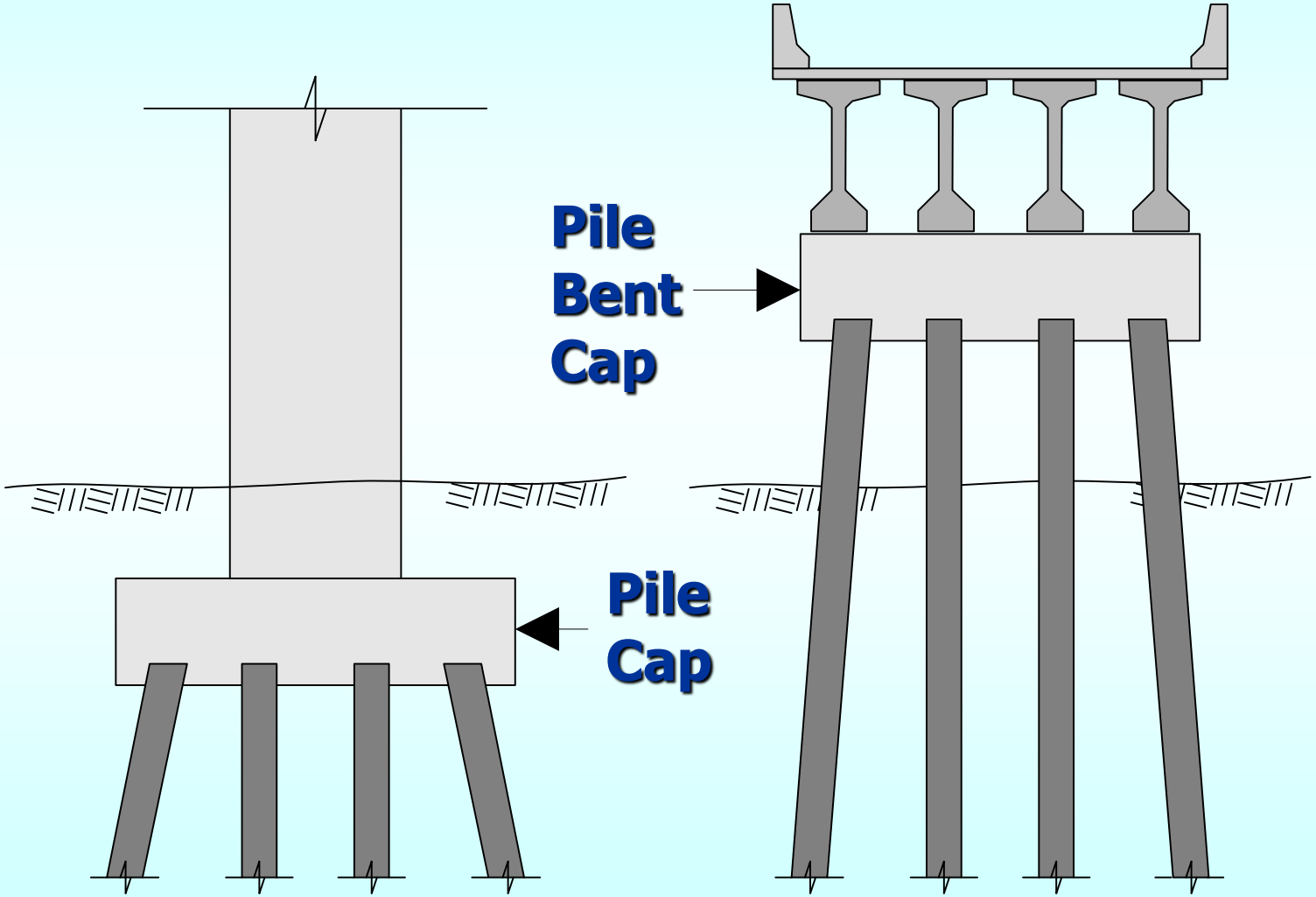
Reuse of Structural Foundations

* ***Type and age and condition of existing structure***
* ***Type and extent of rework***
* **Changes in load magnitude and load combinations**
* **Changes in extreme event and performance criteria**
* **Changes to project delivery and finance methods (ABC, D-B, PPP)**
* **Changes to structural design and construction practices**
* **Changes to geotechnical design and construction practice**
* **Potential for substructure and foundation material deterioration**
* **Advancements to load tests and NDE tests and evaluation**
* **Advancements to geotechnical equipment and materials**

Existing Pile Cap, Pile Bent Cap



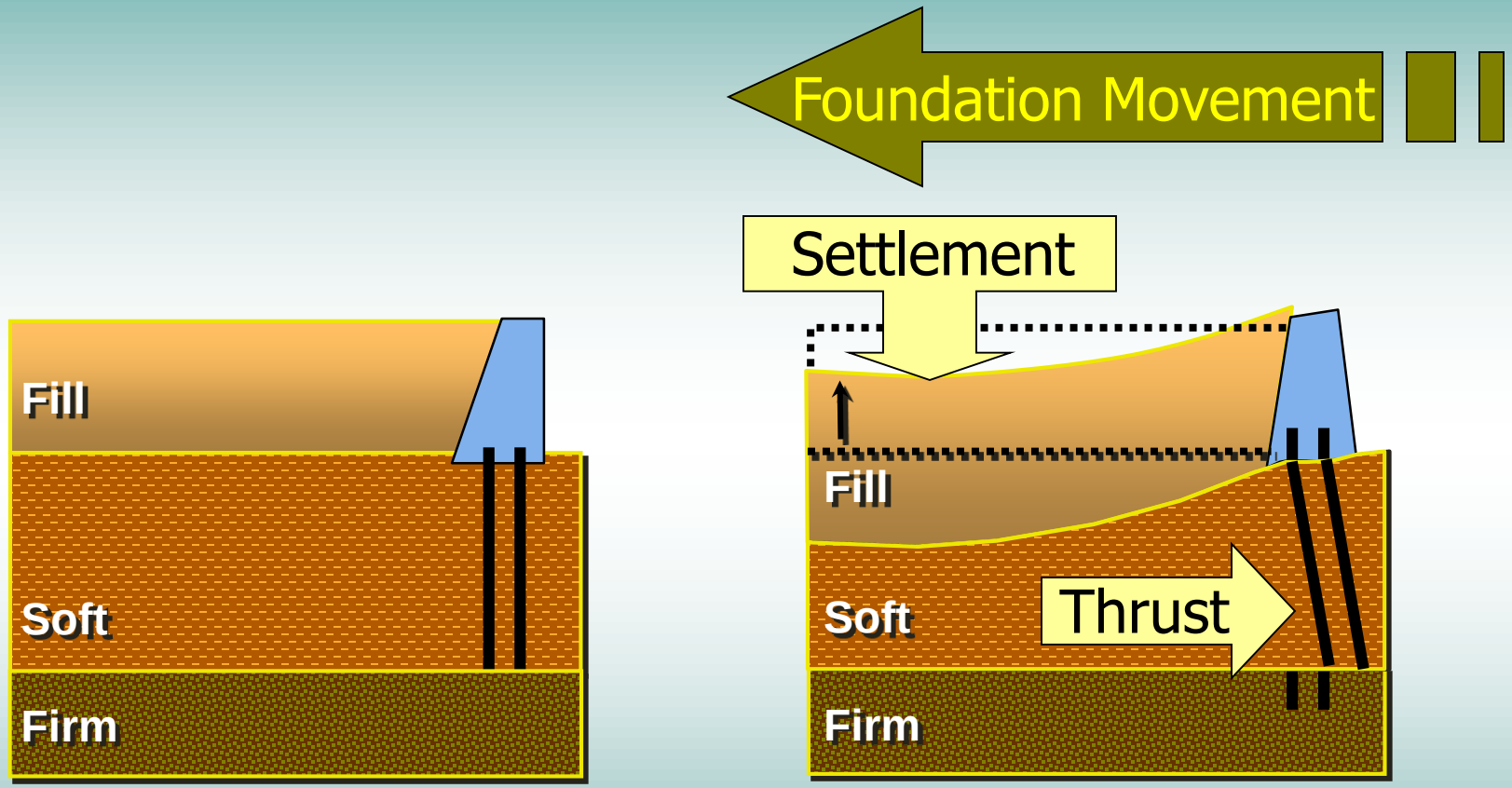
NEW FACILITY UNDER CONSTRUCTION

Bearing Resistance Failure

Deformatiuon Impact on Structures

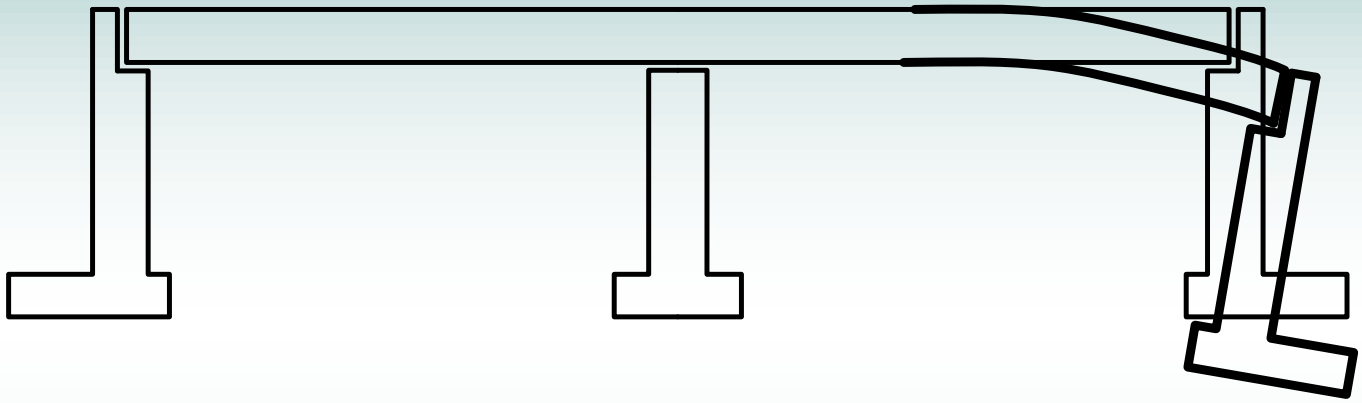
- Predicted additional 1 ft. of settlement **over next 10 years**

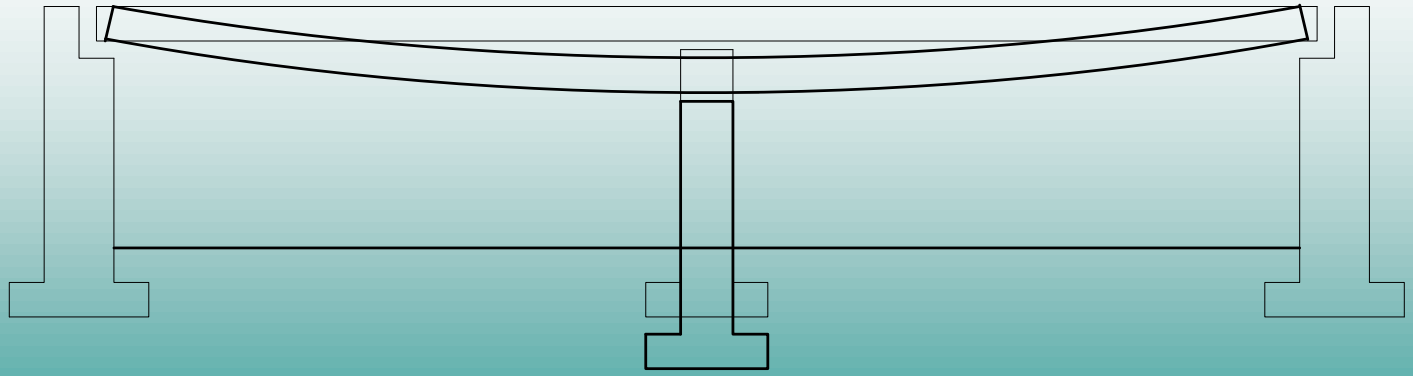
Lateral "Squeeze" of Soft Subsoil



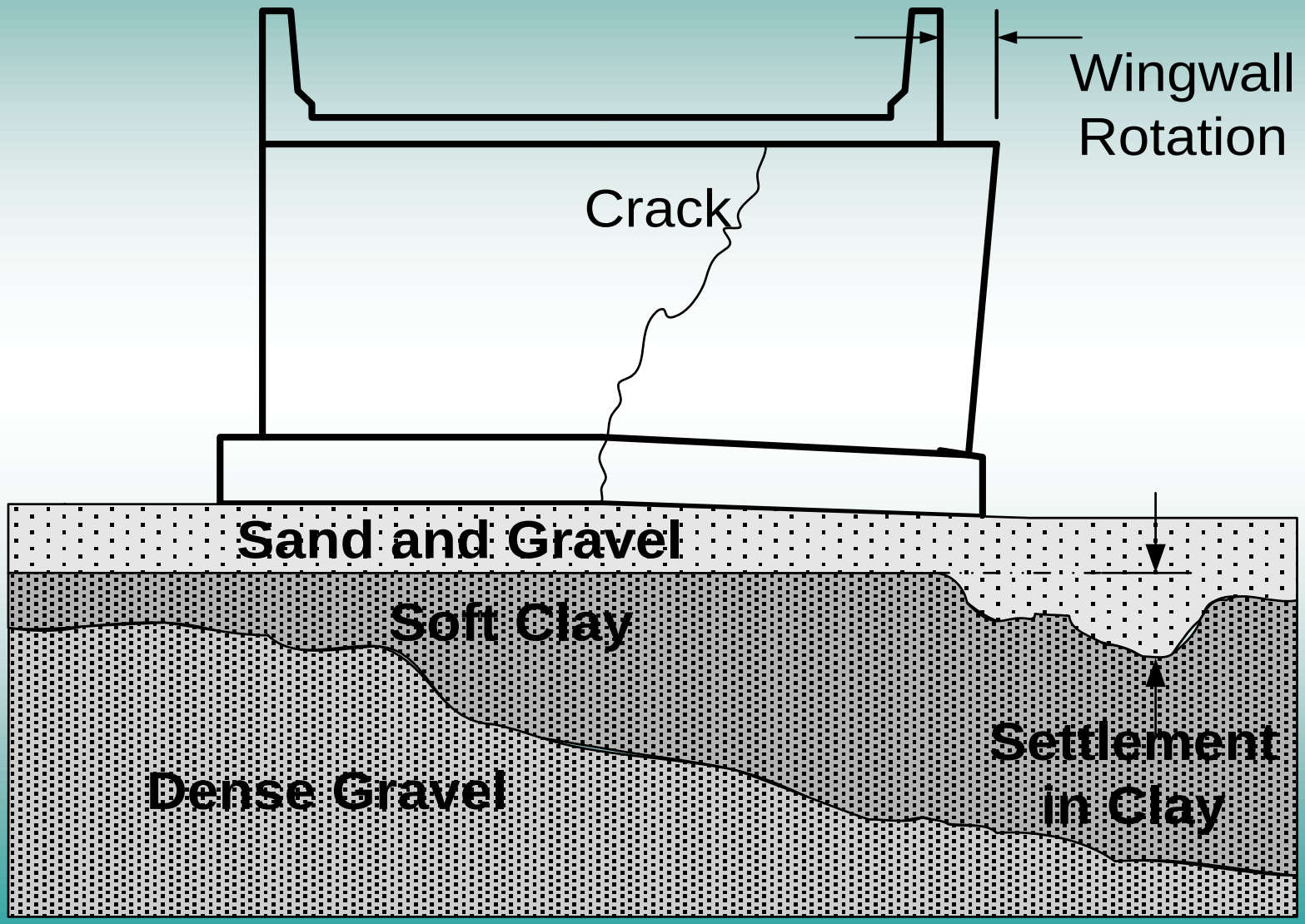
Foundation Rotates Toward Fill

Differential Settlement





Transverse Differential Settlement



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LRFD (or LSD or RBD)

Load Modifier (η_i)

Load Effect (Q_i)

Nominal Resistance (R_n)

$$\Sigma \eta_i \gamma_i Q_i \leq \phi R_n$$

Load Factor (γ_i)

Resistance Factor (ϕ)

Factored Load Effect ≤ Factored Resistance

EXTREME EVENT LOADING:
Seismic, Ice, Vehicle, Vessel, Scour

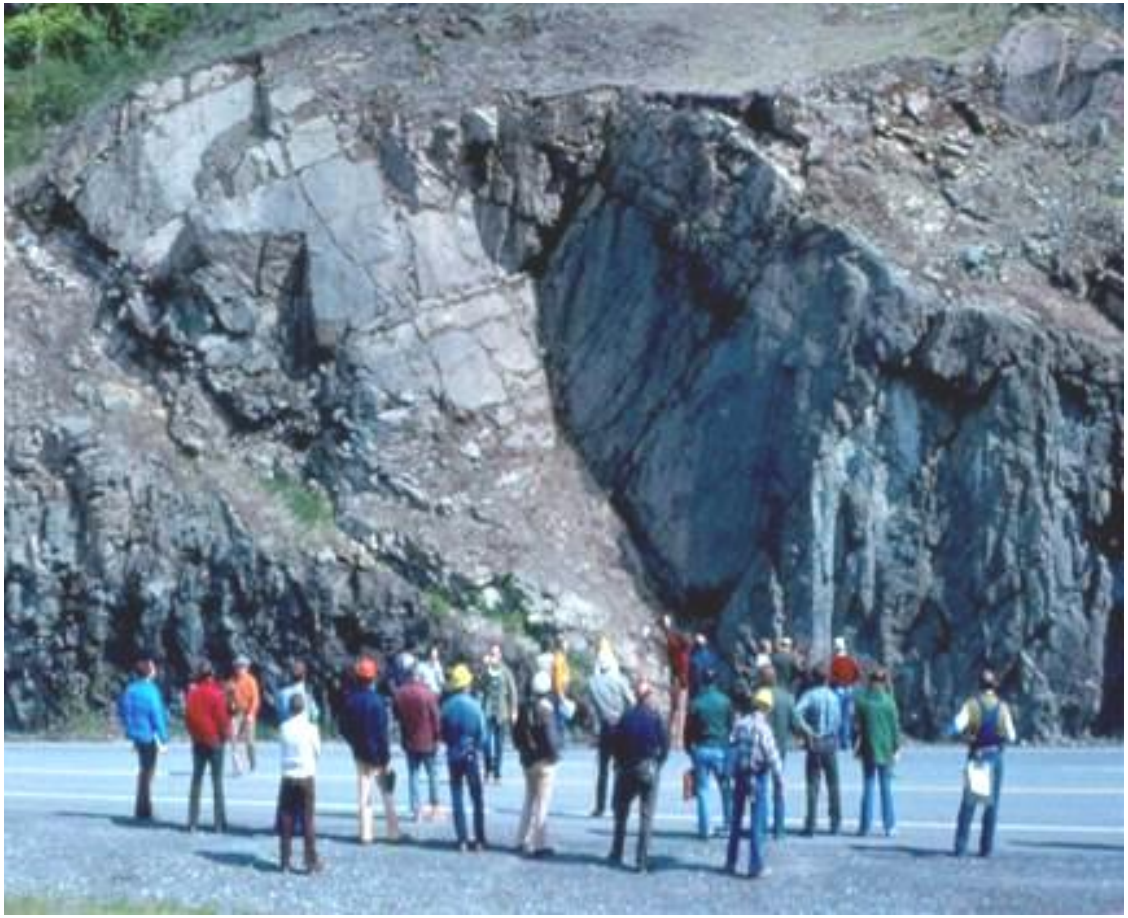
Seismic Extreme Event Limit State

Area effects versus local effects

We have the learned the meaning of the word "drivability"

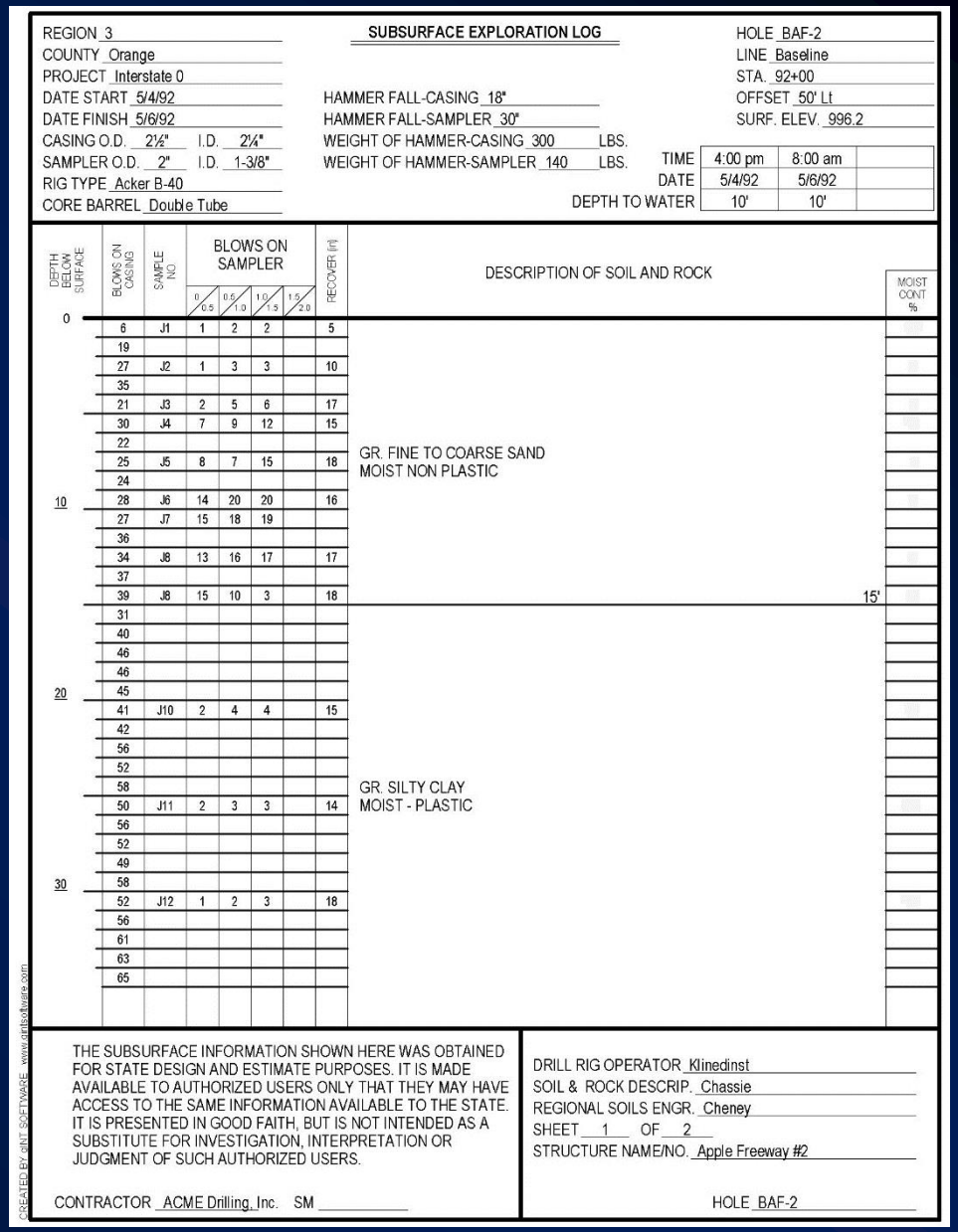
Rock Characteristics

- **Strength**
  - Intermediate geomaterials, q_u = 50-1500 psi
    $N1_{60}$ (or N_{60})> 50
  - Hard rock, q_u > 1500 psi
- **Rock mass properties**



Old Subsurface Info

- Review information accurately
- Reevaluate data
- Perform a new engineering analysis



SUBSURFACE EXPLORATION LOG

REGION 3
COUNTY Orange
PROJECT Interstate 0
DATE START 5/4/92
DATE FINISH 5/6/92
CASING O.D. 2½" I.D. 2¼"
SAMPLER O.D. 2" I.D. 1-3/8"
RIG TYPE Acker B-40
CORE BARREL Double Tube

HAMMER FALL-CASING 18"
HAMMER FALL-SAMPLER 30"
WEIGHT OF HAMMER-CASING 300 LBS.
WEIGHT OF HAMMER-SAMPLER 140 LBS.

HOLE BAF-2
LINE Baseline
STA. 92+00
OFFSET 50' Lt
SURF. ELEV. 996.2

TIME	4:00 pm	8:00 am	
DATE	5/4/92	5/6/92	
DEPTH TO WATER	10'	10'	

DEPTH BELOW SURFACE	BLOWS ON CASING	SAMPLE NO.	BLOWS ON SAMPLER 0/0.5	0.5/1.0	1.0/1.5	1.5/2.0	RECOVER (in)	DESCRIPTION OF SOIL AND ROCK	MOIST CONT %
0	6	J1	1	2	2		5		
	19								
	27	J2	1	3	3		10		
	35								
	21	J3	2	5	6		17		
	30	J4	7	9	12		15		
	22								
	25	J5	8	7	15		18	GR. FINE TO COARSE SAND MOIST NON PLASTIC	
	24								
10	28	J6	14	20	20		16		
	27	J7	15	18	19				
	36								
	34	J8	13	16	17		17		
	37								
	39	J8	15	10	3		18	15'	
	31								
	40								
	46								
	46								
20	45								
	41	J10	2	4	4		15		
	42								
	56								
	52								
	58							GR. SILTY CLAY MOIST - PLASTIC	
	50	J11	2	3	3		14		
	56								
	52								
	49								
30	58								
	52	J12	1	2	3		18		
	56								
	61								
	63								
	65								

THE SUBSURFACE INFORMATION SHOWN HERE WAS OBTAINED FOR STATE DESIGN AND ESTIMATE PURPOSES. IT IS MADE AVAILABLE TO AUTHORIZED USERS ONLY THAT THEY MAY HAVE ACCESS TO THE SAME INFORMATION AVAILABLE TO THE STATE. IT IS PRESENTED IN GOOD FAITH, BUT IS NOT INTENDED AS A SUBSTITUTE FOR INVESTIGATION, INTERPRETATION OR JUDGMENT OF SUCH AUTHORIZED USERS.

CONTRACTOR ACME Drilling, Inc. SM

DRILL RIG OPERATOR Klinedinst
SOIL & ROCK DESCRIP. Chassie
REGIONAL SOILS ENGR. Cheney
SHEET 1 OF 2
STRUCTURE NAME/NO. Apple Freeway #2

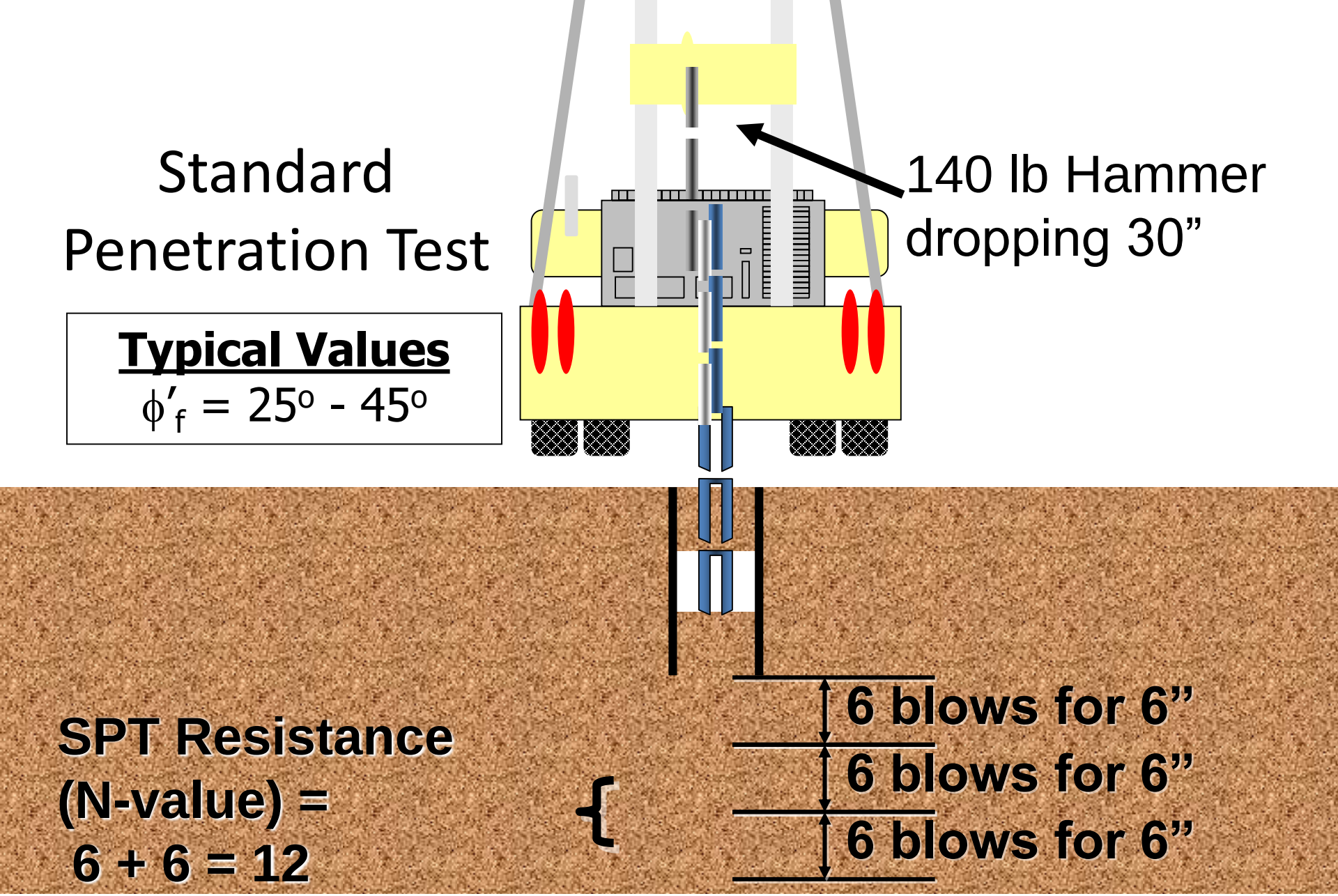
HOLE BAF-2

CREATED BY gINT SOFTWARE www.gintsoftware.com

Standard Penetration Test

Typical Values

$\phi'_f = 25^o - 45^o$



AASHTO Soil and Rock Design Property Selection

- In-situ and Geophysical Tests
- Laboratory Tests
- Back Analysis based on Site Performance
  - Assess **Variability** of subsurface materials and test methods
  - **Sensitivity analysis**: mean and mean minus 1 sigma
  - Service Limit: **Evaluate upper and lower bound**
  - Strength Limit: **Average property values** were used for calibration (not minimums)

Selection of Soil and Rock Strength

- **Rate of construction loading** to soil conductivity
- Effect of Applied **Load Direction** on measured shear strength
- Effects of expected **levels of deformation** on structure
- Influence of Construction Sequence

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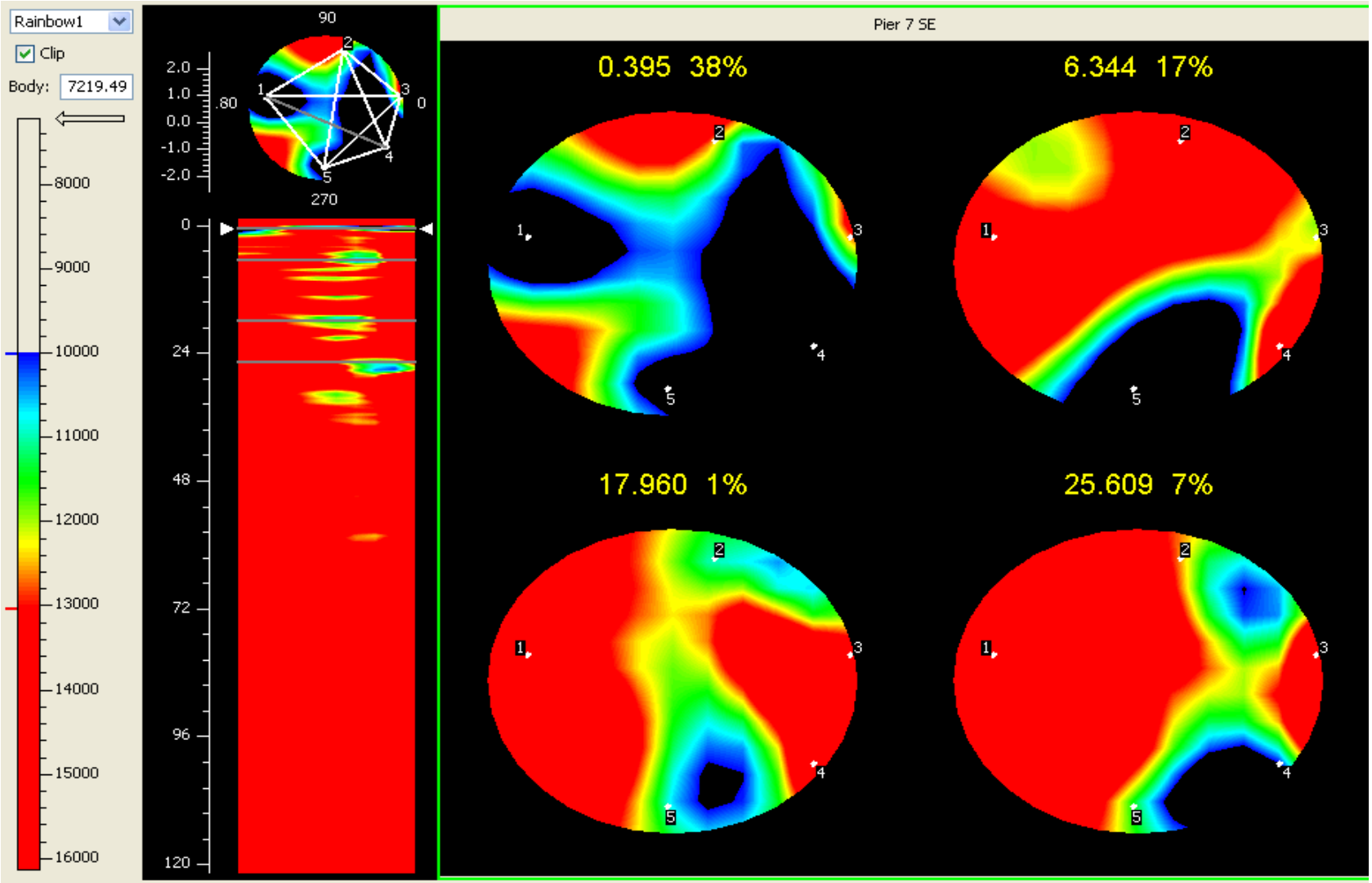
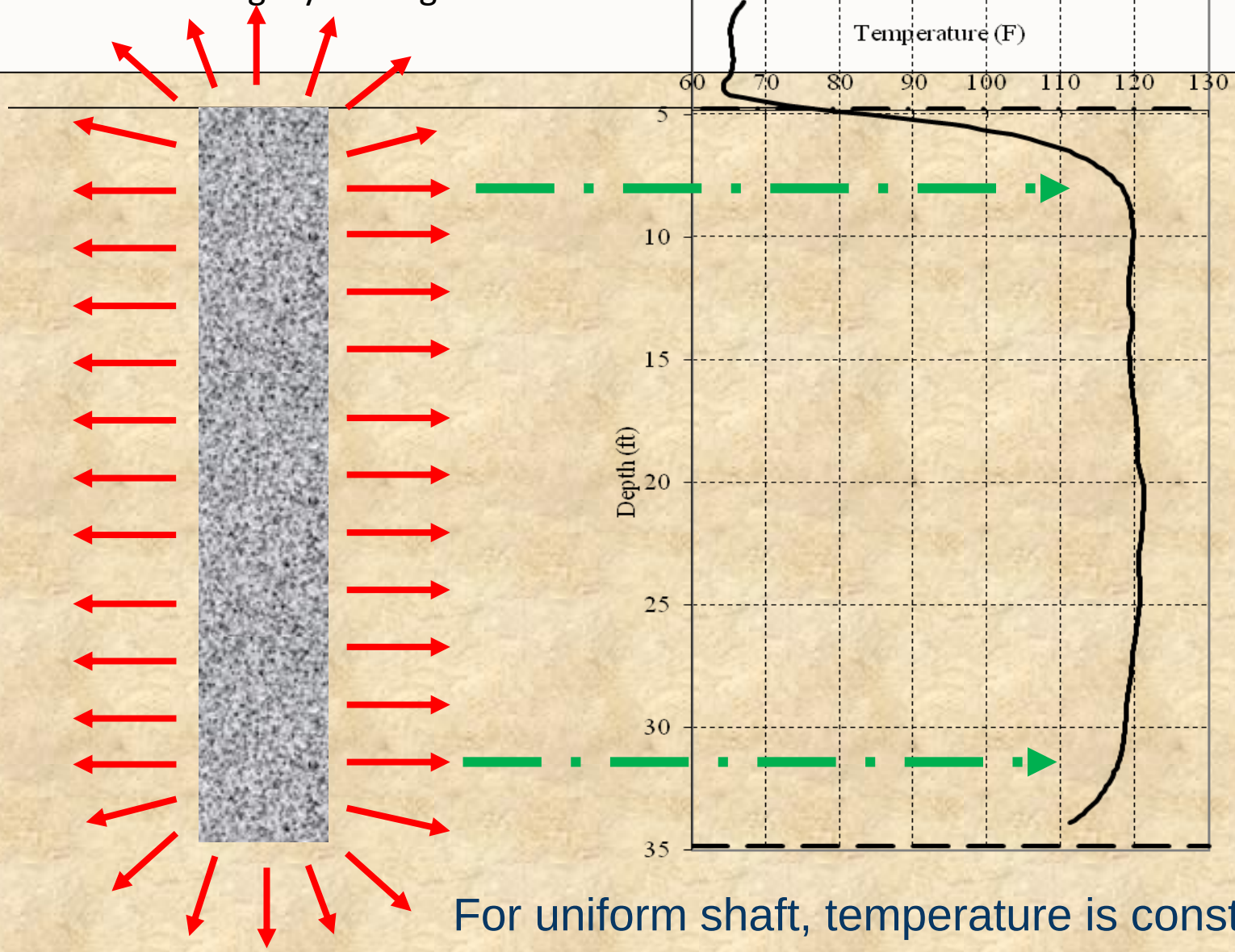
Non-destructive Evaluation Tests

- *Sonic Echo / Impulse-response*
- *Coring*
- *Bending Wave*
- *Ultrasonic surface spatial waves*
- *Parallel Seismic*
- *Cross-hole Acoustic ("CSL")*
- *Gamma-Gamma (Backscatter g)*
- *Concreteoscope (endoscope)*
- *Thermal Integrity Profiling*
- *High-Strain Impact*
- *Static / Statnamic Load Test*
- *Visual Observation*
- *Others*

Tomography Analysis



Thermal Integrity Testing



For uniform shaft, temperature is constant, except 1 diameter at top and bottom roll-off

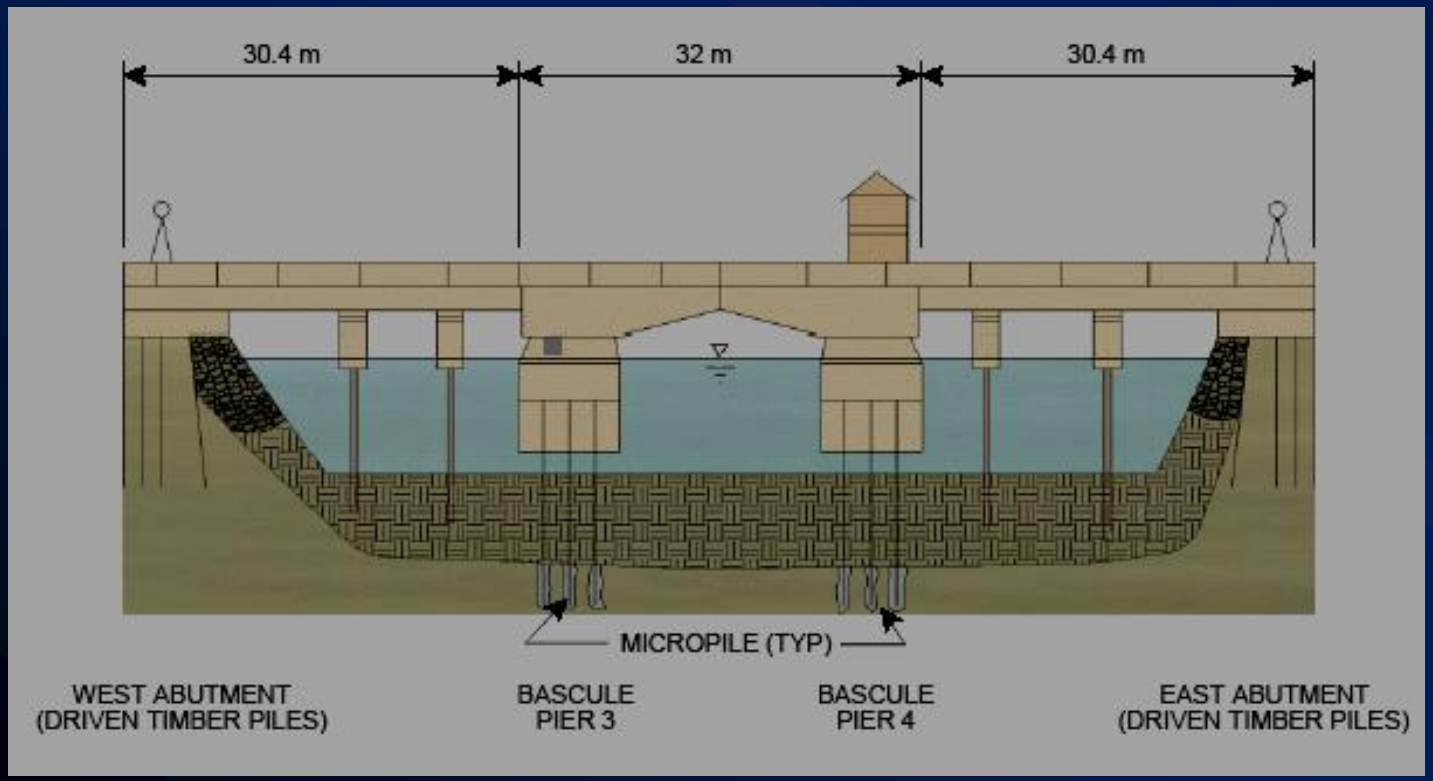
P&H

Enhancing (rehabilitating) Existing Structural Foundations

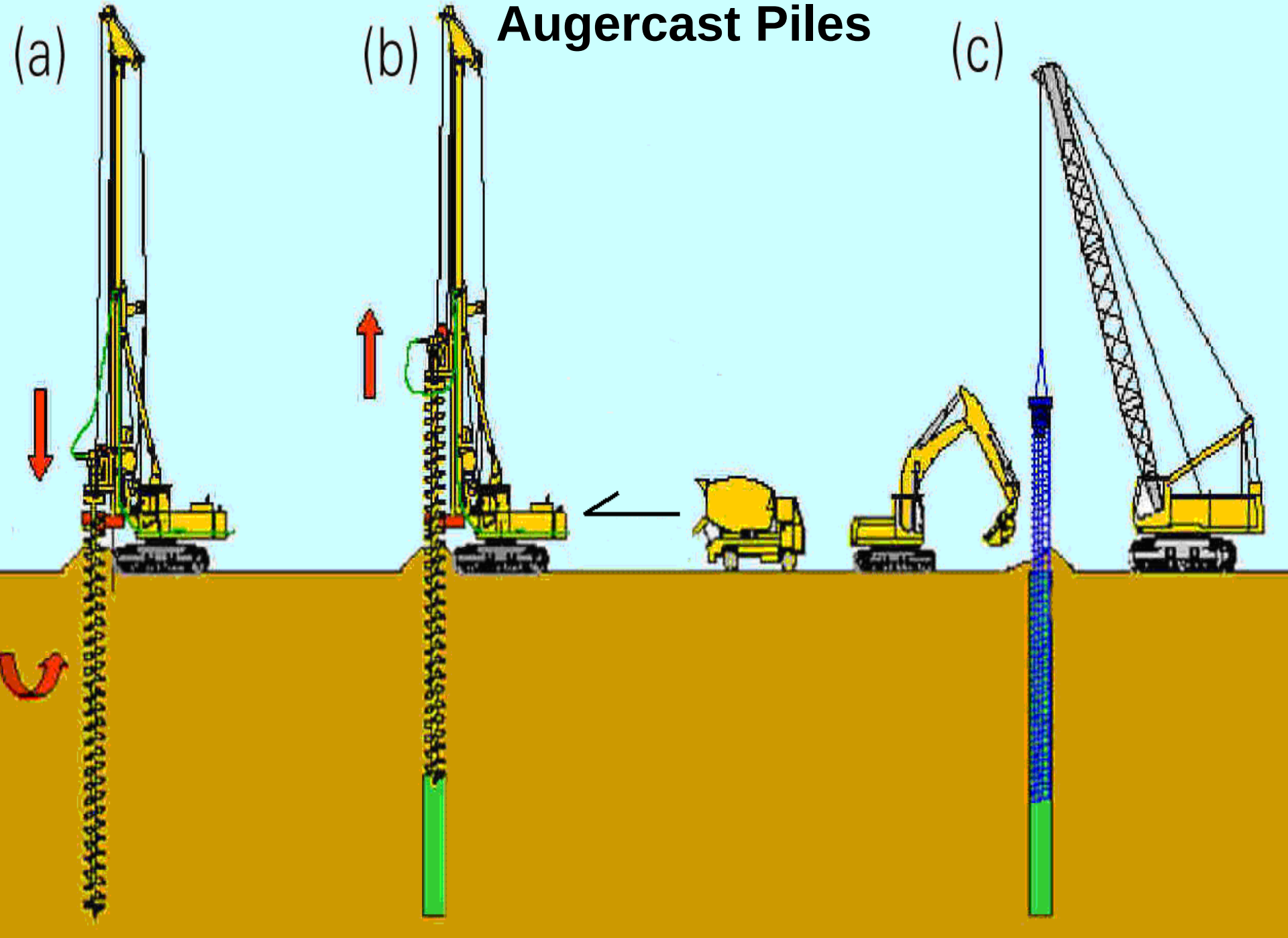
- Office study of loads, resistances and performance criteria
- Design checks for all Structural and Geotechnical limit states (strength, service and extreme event)

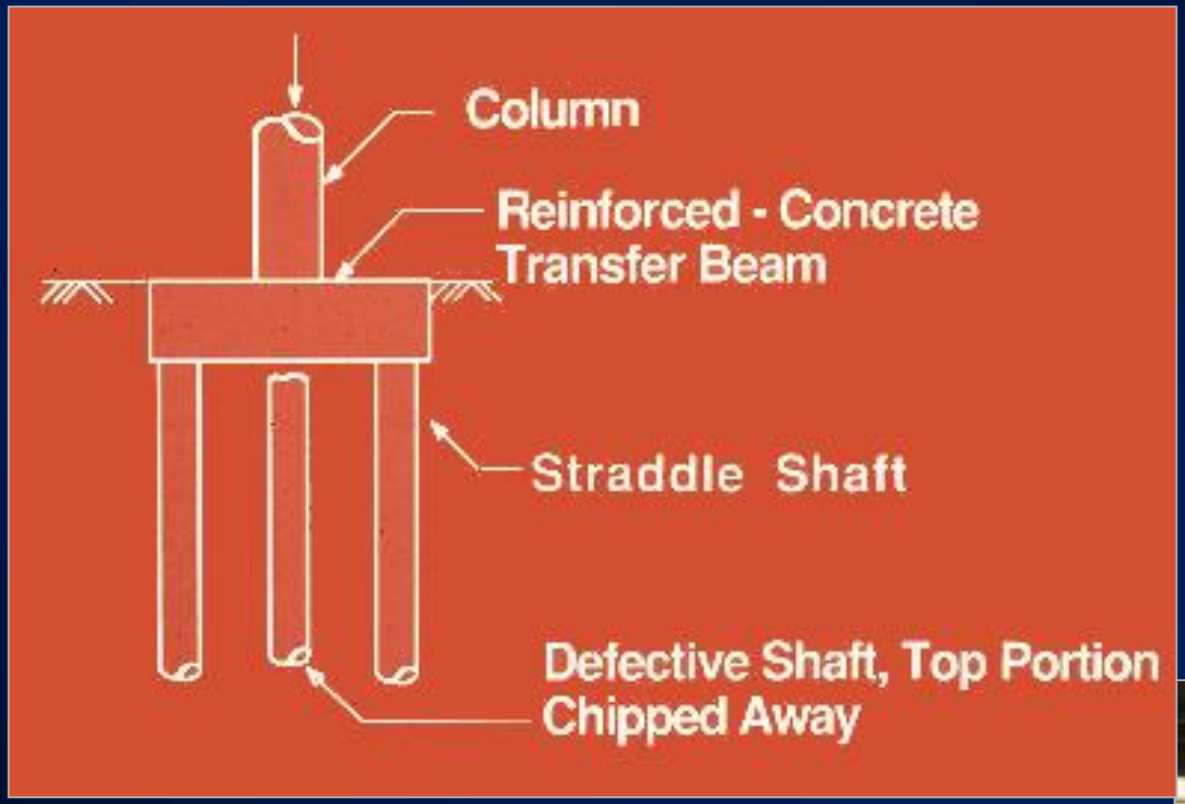
- Micropiles
- Augercast piles
- Drilled shafts
- Driven piles
- Grouting and other ground improvement methods

Preloaded Micropiles for Pocomoke River Bridge, Maryland



Augercast Piles





Install Straddle Shafts

Drilled Shaft for Bridge

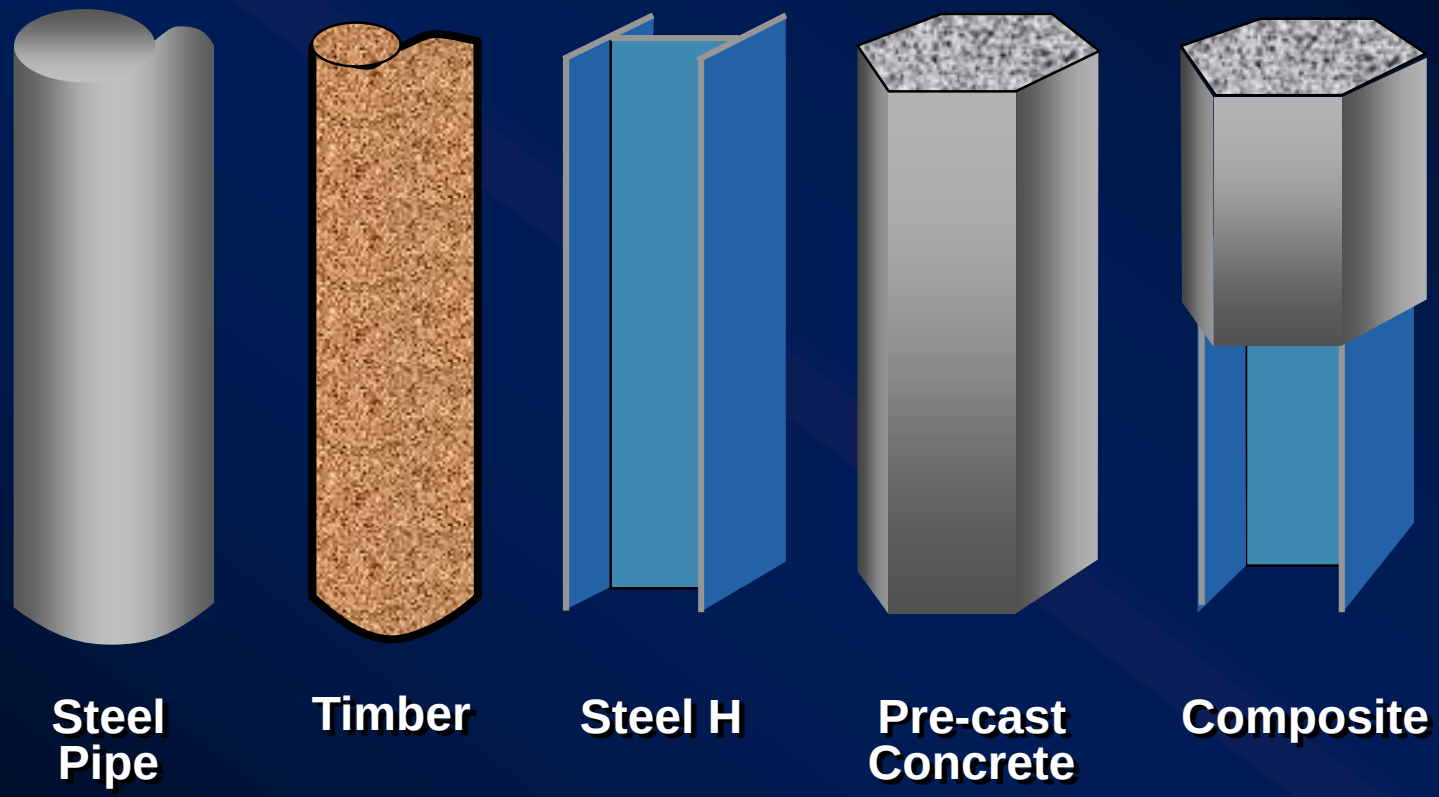
Widening

Seismic Retrofit of Richmond /San Rafael Bridge, CA

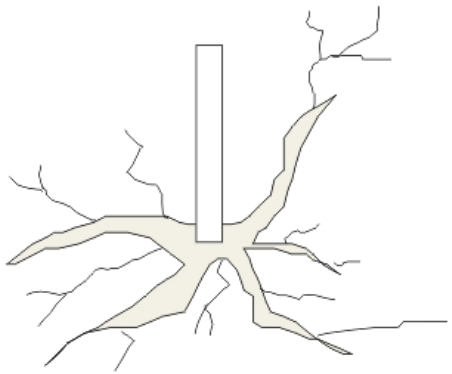
Courtesy: Agra Foundations

Types of Driven Piling

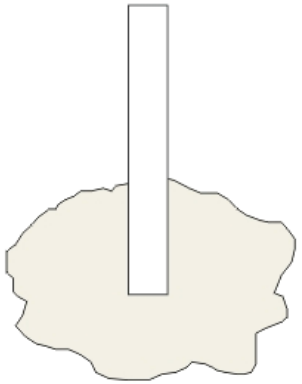
Higher Strength
Improved Design
Better Construction Control



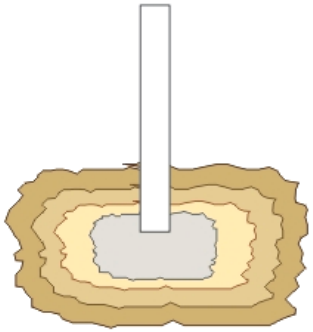
Cleveland Innerbelt - Ohio
HP 18x204 Driven Piles to Bedrock
Nominal Bearing Resistance -2150K
Length to 180’
09/17/2014



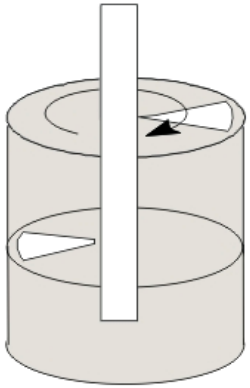
Slurry Grout
(Intrusion)



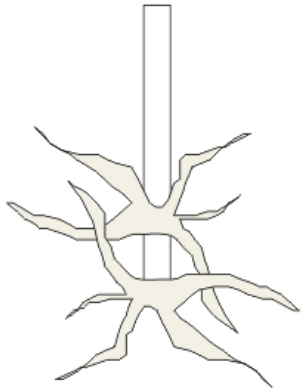
Chemical Grout
(Permeation)



Compaction Grout
(Displacement)



Jet Grout
(Erosion)



Fracture Grout
(Fracture)

Thank You. Questions?

Jerry DiMaggio, PE, D.GE
Principal Civil Engineer
Applied Research Associates. Inc
phone: (443) 852-4829
email: jdimaggio@ara.com