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Increase Use of Spread Footings on Soils to Support Highway Bridges

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Federal Highway Administration

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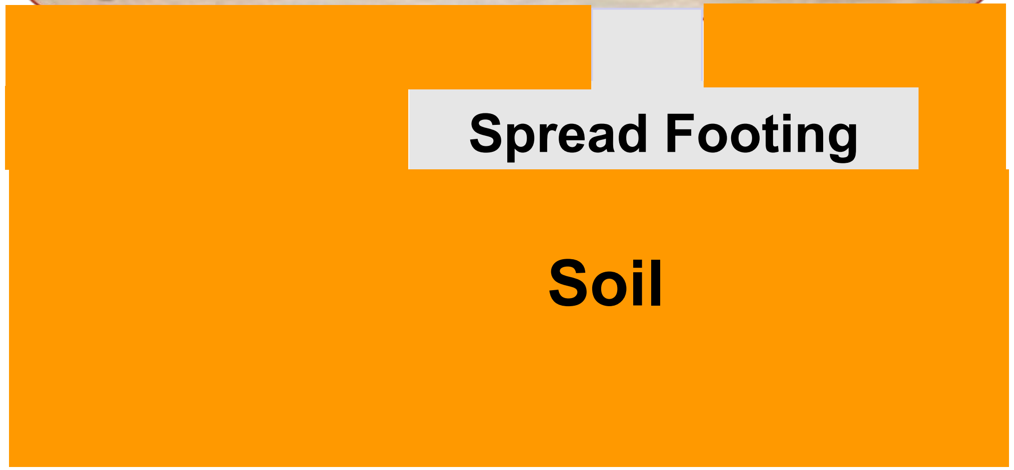
Spread Footings on Soils to Support Bridges



Advantages of Spread Footings

Cost/time savings in foundation design, construction and maintenance:

- Simpler and more flexible design and construction
- Use common materials, equipment, and labour
- Construction: safer and fewer problems/claims
- Maintenance: safer and less disruption to traffic
- Address issues with using deep foundations

2007-2010 FHWA Surveys of State DOTs Distribution Use of Bridge Foundations

Spread Footings on Soils	Spread Footings on Rock	Driven Piles	Drilled Shafts
11.5 %	12.5 %	56.5 %	19.5 %

- States with extensive use
- States with no or limited use

States with Extensive Use of Spread Footings

States	Spread Footings (%)		Deep Foundations (%)	
	Soil	Rock	Driven Piles	Drilled Shafts
Northeast States				
Connecticut	50	25	20	5
Vermont	40	10	45	5
Massachusetts	35	15	20	27
New Hampshire	30	30	30	10
New York	30	15	47	3
New Jersey	30	20	40	5
Southwest States				
New Mexico	30	10	30	30
Nevada	25	3	18	54
Arizona	20	5		
Northwest States				
Idaho	20	10	60	10
Oregon	20	10	60	10

States with No or Limited Use of Spread Footings

	No Use	Limited Use (<10%)
Midwest	Iowa, Missouri	Illinois, Indiana, Wisconsin, Minnesota, Ohio
Northeast	West Virginia	Maine, Virginia, Maryland
Southeast	All States	
Southwest	Texas, Arkansas	Colorado, Utah
Northwest	South Dakota, North Dakota	Wyoming, Hawaii

FHWA Conclusion: Use of spread footings when appropriate is not considered by many State DOTs

States with No or Limited Use of Spread Footings. **Why?**

- **Due to “perceived obstacles.”**
- **Not due to valid obstacles (i.e., scour)**

These states are missing an opportunity to save time and money by not considering spread footings

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FHWA Goals

Promote the use of spread footings on soils to support highway bridges when appropriate.

Per AASHTO/FHWA consider spread footings bearing on:

- Competent natural soils
- Improved natural soils
- Engineered granular fills (embankment)
- Engineered MSE fills (walls, embankments)

FHWA Reference

https://www.fhwa.dot.gov/resourcecenter/teams/geohydraulics/spreadfootings.pdf

U.S.Department of Transportation
Federal Highway Administration

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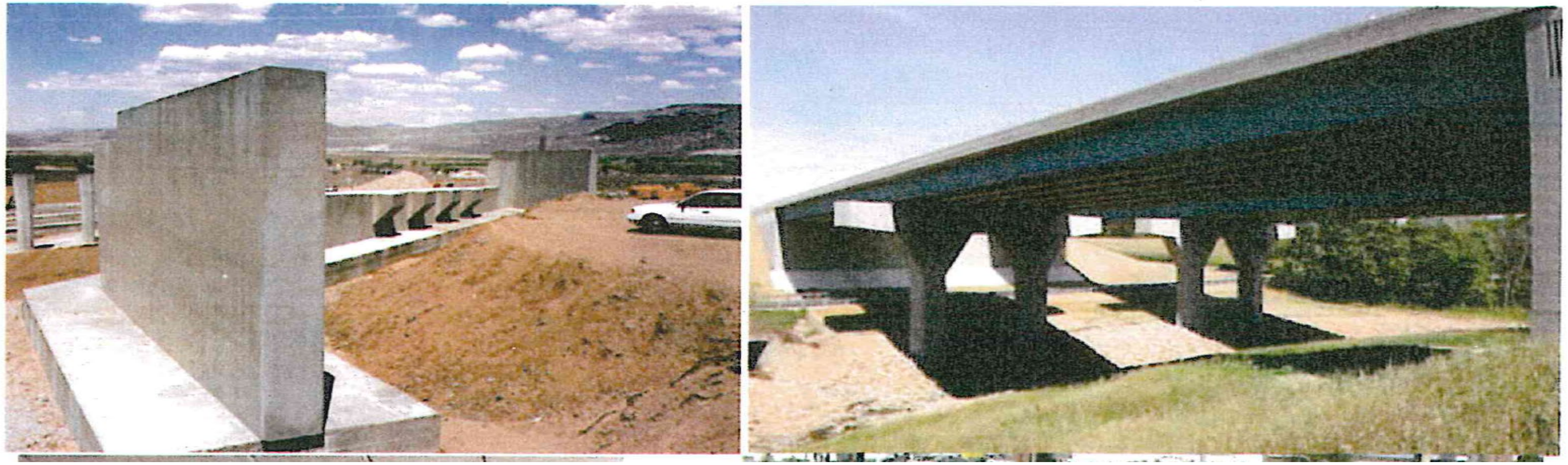
Implementation Guidance for Using Spread Footings on Soils to Support Highway Bridges



Approach Used in the FHWA Reference

- Identified perceived obstacles in using spread footings
- Developed:
  - Recommendations to address perceived obstacles
  - Guidance to implement the recommendations

8 Recommendations to address Perceived Obstacles

1. Deploy AASHTO/FHWA technical resources
2. **Review FHWA surveys of State DOTs for use, performance, and selection of spread footing**
3. Consider spread footing on granular/MSE fills and with semi-integral and integral abutments.
4. Consider load tests and instrumentation programs
5. Deploy adequate subsurface investigation, construction, and quality control procedures.

8 Recommendations to address Perceived Obstacles

6. **Deploy a rational procedure for settlement analysis of bridges supported on spread footings bearing on soils**
7. Develop a rational procedure to determine the LRFD design bearing resistances for spread footings
8. Based on previous recommendations, develop LRFD Guidance for:
   - Selection of spread footings, and
   - Design of spread footings

1. Use and Performance of Spread Footings to Support Bridges: Northeast States

State	Soils (%)	Rocks (%)	Performance
Connecticut	50	25	Good performance
Vermont	40	10	Good performance
Massachusetts	35	15	Good performance
New Hampshire	30	20	Good performance
New York	30	15	Good performance
New Jersey	30	20	Good performance
Delaware	13	4	Good performance
Pennsylvania	10-20	45-55	Good performance
Rhodes Island	10		Good performance
Maine	5	31	Good performance
Virginia	5	30	Good performance
Maryland	2-4		Good performance
West Virginia	0	20	No use

Use and Performance of Spread Footings to Support Bridges: Southeast States

State	Soils (%)	Rocks (%)	Performance
Tennessee	1	40	Use of spread footings is minimal in these states. No performance information is reported from these states.
Florida	1	-	
Arkansas	1	22	
Alabama	5	10	
North Carolina	0	10	
Mississippi	5	0	
South Carolina	Rarely used		
Louisiana	0		
Georgia and Kentucky	Not reported, use is expected to be minimal		

Summary: Use and Performance of Spread Footings to Support Bridges

- Use of spread footings varies significantly (0 to 50%)
  - Across different regions in the USA
  - Among states in the same region

- **All State DOTs that used spread footings reported:**
  - **Good performance and economical use of all their bridges supported by spread footings bearing on soils**

Conclusion: many states are missing an opportunity to save time and money by not considering spread footings when appropriate

Summary: Selection of Spread Footings on Soils to Support Bridges

- **Bridges supported on spread footings bearing on all recommended soil types <u>have been safely and economically constructed by State DOTs</u>**

- **State DOTs considered <u>favorable and unfavorable</u> conditions for selection of spread footing**

II. Rational Settlement Analysis of Bridges Supported on Spread Footings Bearing on Soils

1. Service Limit State for Settlement

2. Bridge Tolerable Settlement

3. Foundation and Bridge Settlements

4. Summary and Recommendations

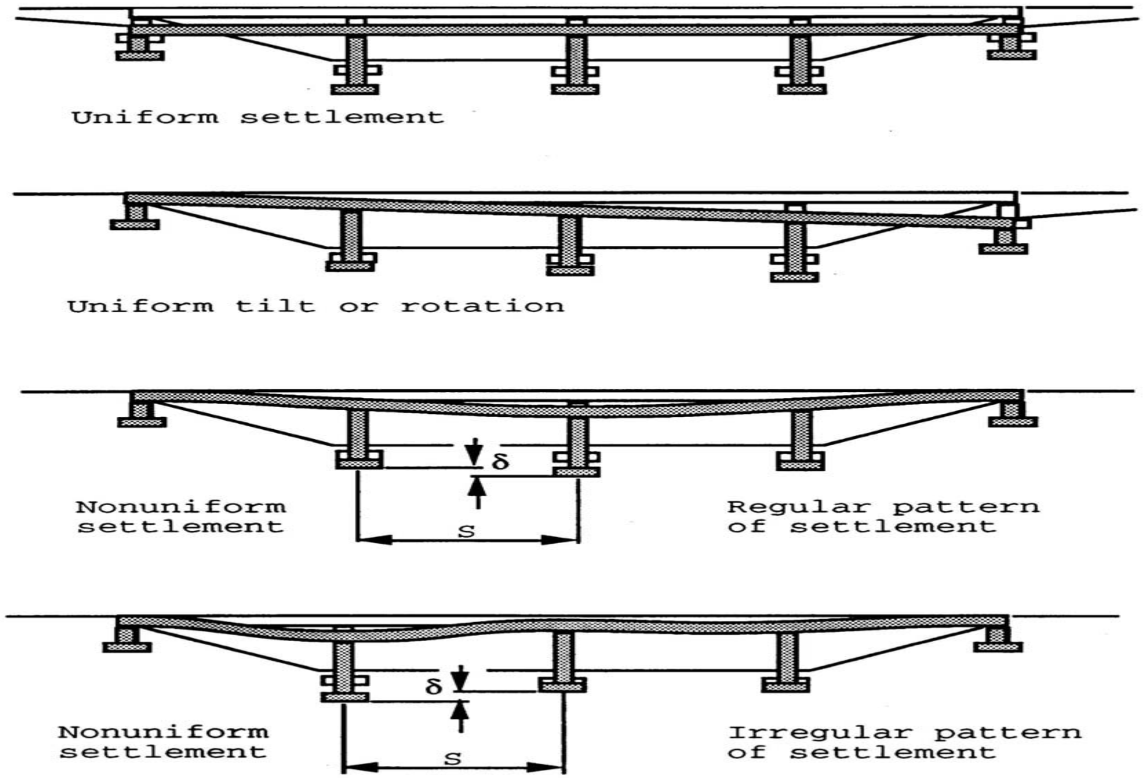
1. Service Limit State for Settlement
Three Types of Settlements

- **Bridge foundation settlement (S_F).** Due to loads transferred to the foundation during
  a. Placement of bridge substructure (i.e., piers)
  b. Placement of bridge superstructure (i.e. deck, girders)
  c. After construction due to traffic loads

- **Bridge settlement at foundation locations, $S_B \leq S_F$**
  - Foundation settlements during stages b and c

- **Bridge settlement at foundation locations that impacts bridge performance, $S_{BP} \leq S_B$**

Bridge Settlements: Uniform, Differential, Angular Distortion



A = Angular Distortion

$$A = \frac{\text{Difference in Settlement Between Foundations}}{\text{Distance Between Foundations}} = \frac{\delta}{S}$$

Bridge Performance Problems due to Excessive Bridge Settlement

- Structural distress/cracking of bridge superstructure
  - Due to excessive angular distortion
- Other bridge problems: clearance, rideability, safety, drainage, and aesthetic
- Damage to structures associated with the bridge (i.e., wing walls, utilities, bridge approach roadway).

Service Limit State for Settlement of Bridge (not Foundation)

$$S_{BP} \leq S_{BT}$$

- S_{BP}: Bridge settlement that impacts bridge performance
- S_{BT}: Bridge Tolerable settlement

Note: Spread footing performance is ensured with just the strength limit state

2. Bridge Tolerable Settlements (S_{BT})

- **Goal:** prevent bridge performance problems
- **Preliminary Design.** Develop acceptable range of tolerable settlements based on:
  - Settlement measurements of bridges performed well during their design lives
  - Practices of State DOTs that successfully constructed bridges supported by spread footing
- **Final Design:** Develop bridge specific tolerable settlement

3. Foundation Settlement (S_F)

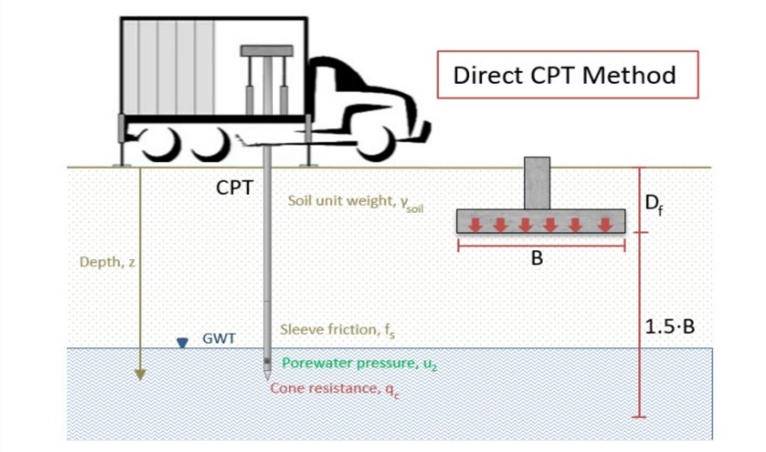
- Foundation settlement is the summation of
  - Elastic or immediate settlement
  - Consolidation time-dependent settlement

- AASHTO: live loads may be omitted from consolidation settlement of clays

- FHWA (2006a): settlement of cohesive soils and structural fill

2018 Accurate CPT-Based Settlement Analysis Method for Spread Footing

- New MnDOT CPT Design Guide. Free, online
  - **Chapter 3: Direct CPT Method for Shallow Foundations**
    - Based on 130 Footings on sands
    - Step by step instructions; worked examples



$$q_{max} = h_s \cdot q_{tnet} \cdot \left(\frac{s}{B}\right)_{max}^{0.5} \cdot \left(\frac{L}{B}\right)^{-0.345}$$

$$s = B \cdot \left[\frac{1}{h_s} \cdot \frac{q_{max}/_{FS}}{q_{tnet}} \cdot \left(\frac{L}{B}\right)^{0.345}\right]^2$$

Where:

h_s = the foundation soil formation parameter

q_{tnet} = the net corrected cone tip resistance

Bridge Settlement that Impacts Bridge Performance (S_{BP})

- Don' t consider foundation settlement that occurs:
  - Before placement of bridge superstructure.
  - **During placement of bridge superstructure but can be accommodated or corrected with no impact on bridge performance.**

Bridge Settlement that Impacts Bridge Performance (S_{BP})

- FHWA (987, 2010):
  - Foundation settlement occurs prior to bridge deck may not impact bridge performance. For example,
    - Settlement due placement of girders.
  - 60% to 75% of S_F occurs before placement of bridge superstructure
  - S_{BP} is 25% to 50% of S_F

- **Geotechnical Engineer:** compute S_F at various stages
- **Structural Engineer:** finalize S_{BP} as less than S_F

Settlement Analysis by both Project Geotechnical and Structural Engineers

Stage	Foundation Compression Load by Structural Engineer	Foundation Settlement (S_F) by Geotechnical Engineer	Bridge Settlement that Impact Bridge Performance (S_{BP}) by Structual Enginneer
1	Q_1	S_{F1}	0
2	Q_2	S_{F2}	0
3	Q_3	S_{F3}	S_{F3} - S_{F2}
4	Q_{se}	S_{Fse}	S_{Fe} - S_{F2}

4. Summary and Recommendations

- **Presented more accurate/economical settlement analysis than commonly considered in practice**
  - Much smaller computed settlements
  - Larger tolerable settlement

- **Service limit state for settlement is for bridges not for footings.**
  - Consider bridge settlement that impact bridge performance not footing settlement

4. Summary and Recommendations

- Bridges with spread footings on soils can perform well with respect to settlement.

- Concerns of bridge settlement should not limit State DOTs from considering spread footings on soils to support highway bridges

III. Implementation

Benefits: Cost/time saving in highway construction projects

- **State DOTs should implement the recommendations and guidance described in this presentation. Why?**
  - Address their concerns with using spread footings on soils to support highway bridges
  - **Help them develop more accurate and economical LRFD design guidance for selection and design of spread footings.**

Needed mostly by State DOTs with limited or no use of spread footings bearing on soils to support bridges

Questions/Comments
Thank Your

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