Service Limit State for Bridge Foundations

SHRP 2 R19B - Specification Revisions - Issues

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Key Issues

- Load factor calibration issues
- Issues regarding changes to calculation of differential settlement and its effect on structure
- Changes in how load factor is applied
- Any other wording issues
- What are the key sticking points?

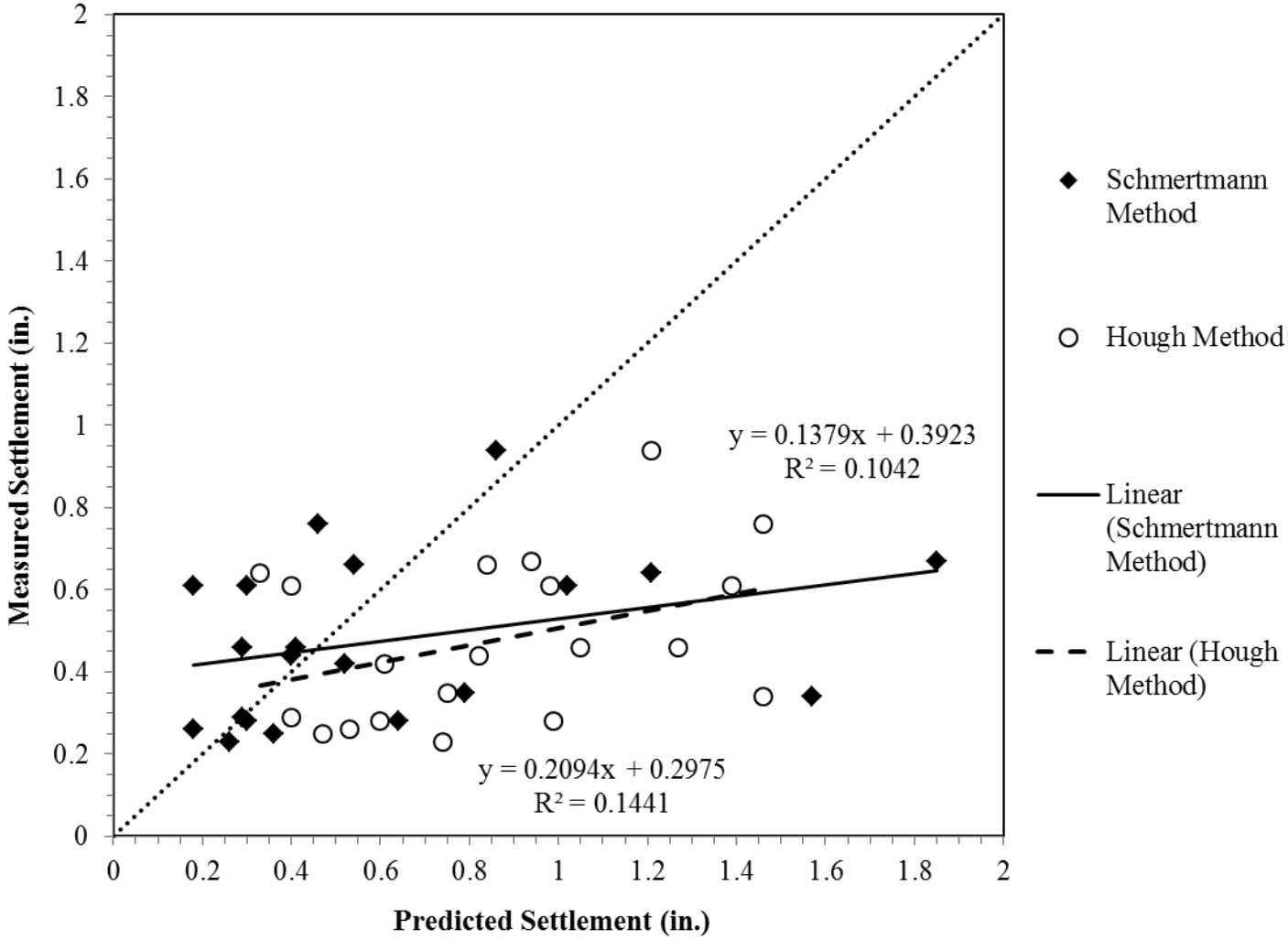
Load Factor Calibration Issues

- Reliability of settlement database
- Target beta values used for different scenarios

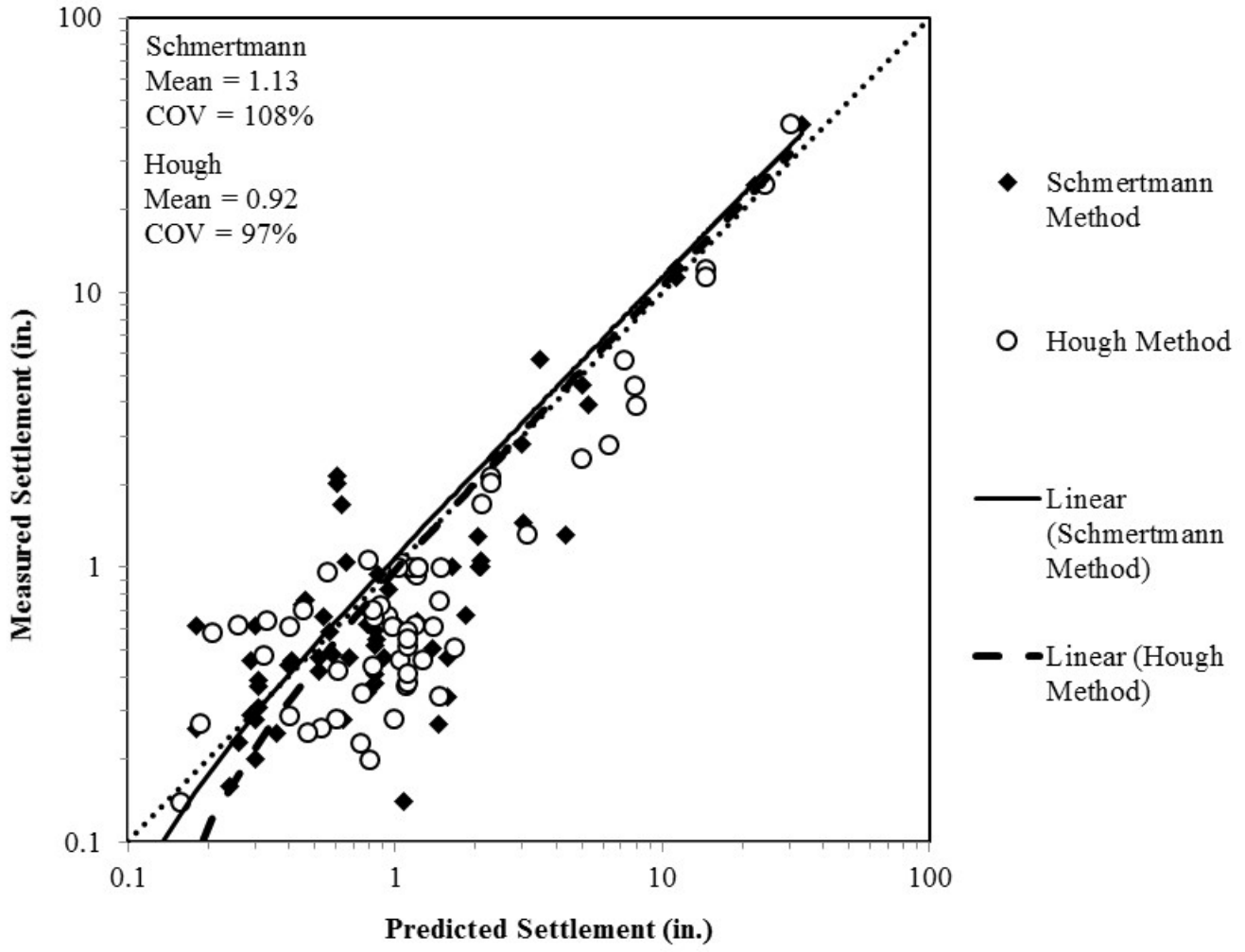
Reliability of Settlement Database

- For original R19B report, only very limited settlement data were available
- Additional settlement data has been gathered and analyzed since the original report was published

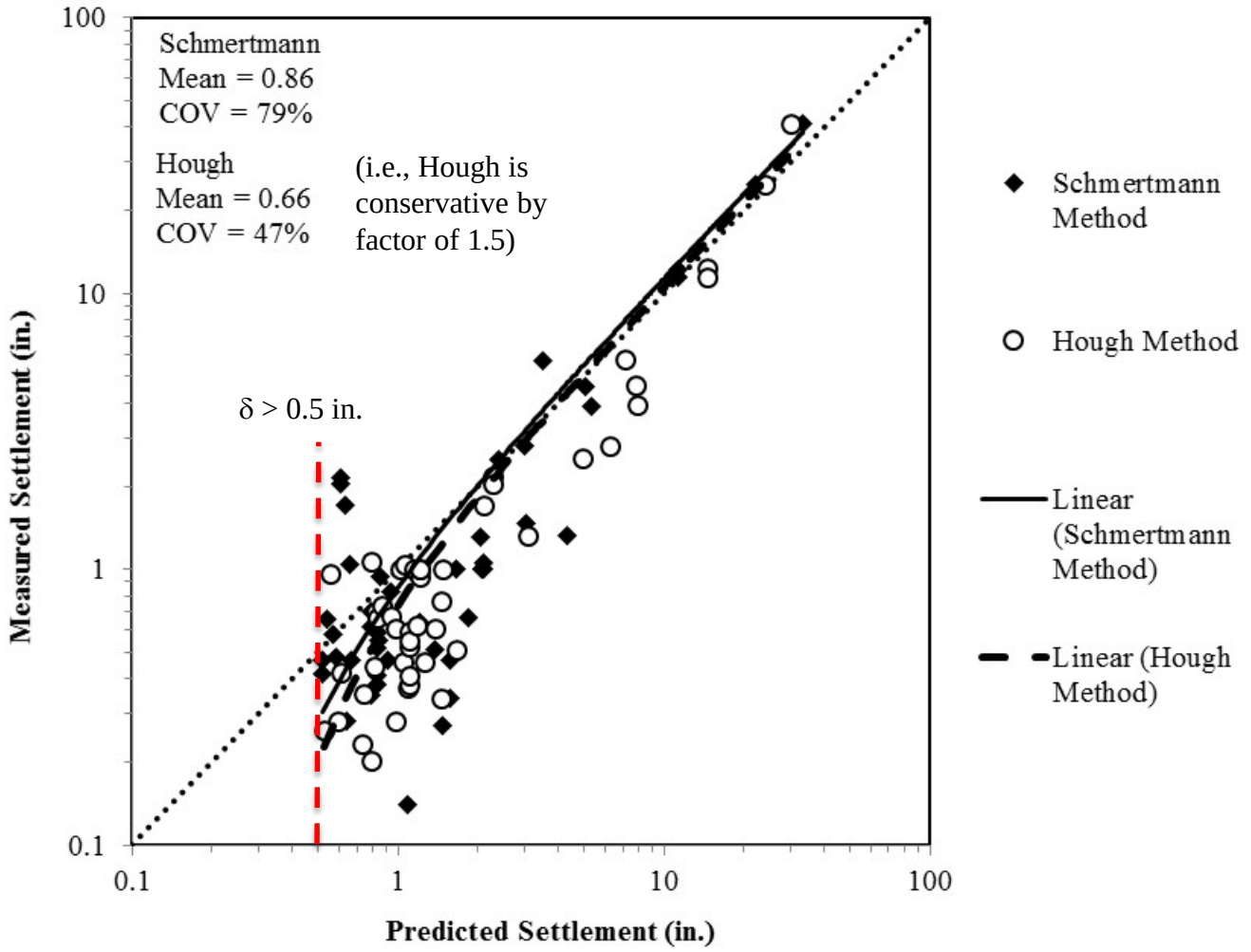
The Original Database Used to Calibrate the SLS for Foundations



Old Database Combined with WSDOT and Other Data



Old Database Combined with WSDOT and Other Data: δ > 0.5 in.



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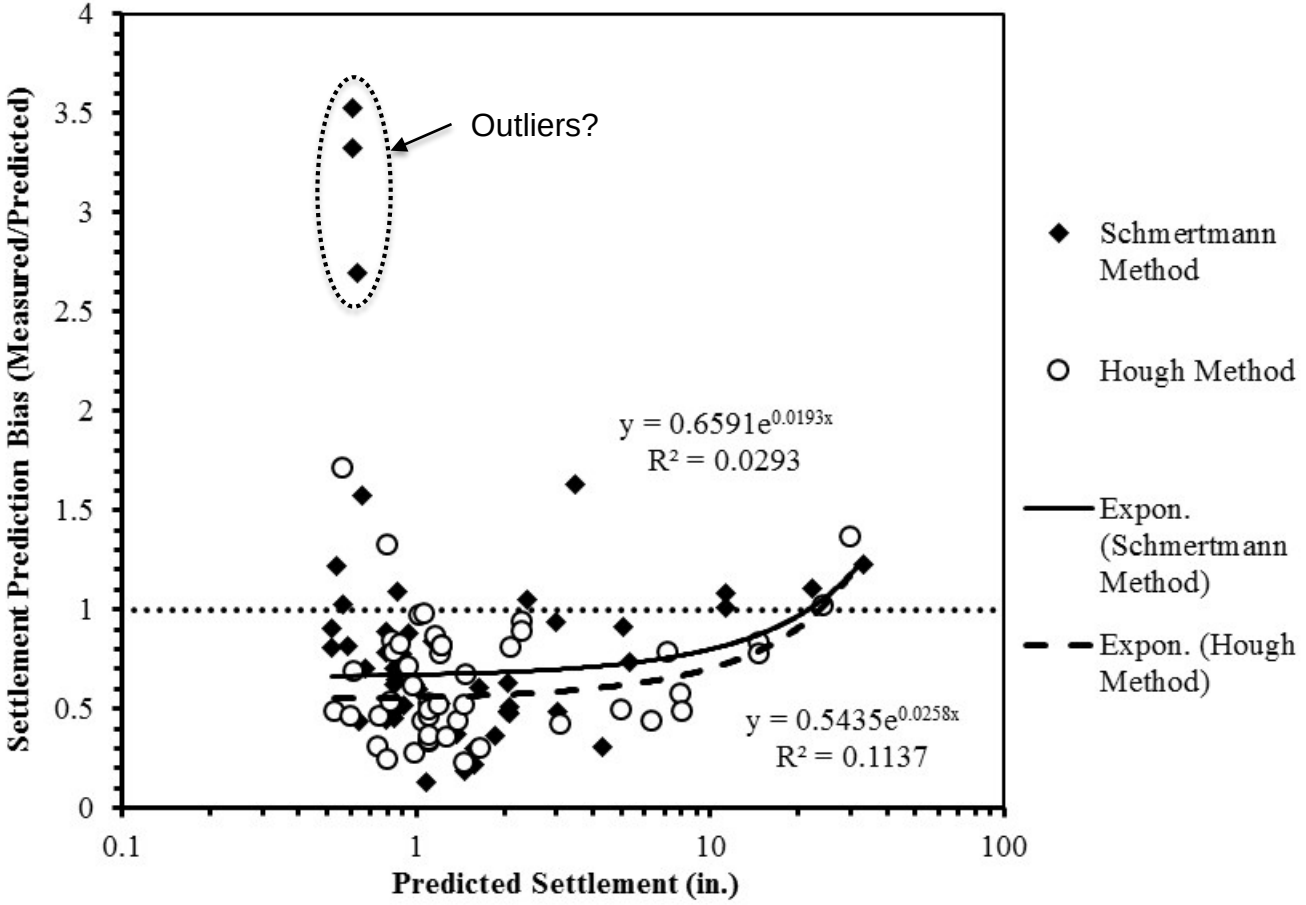
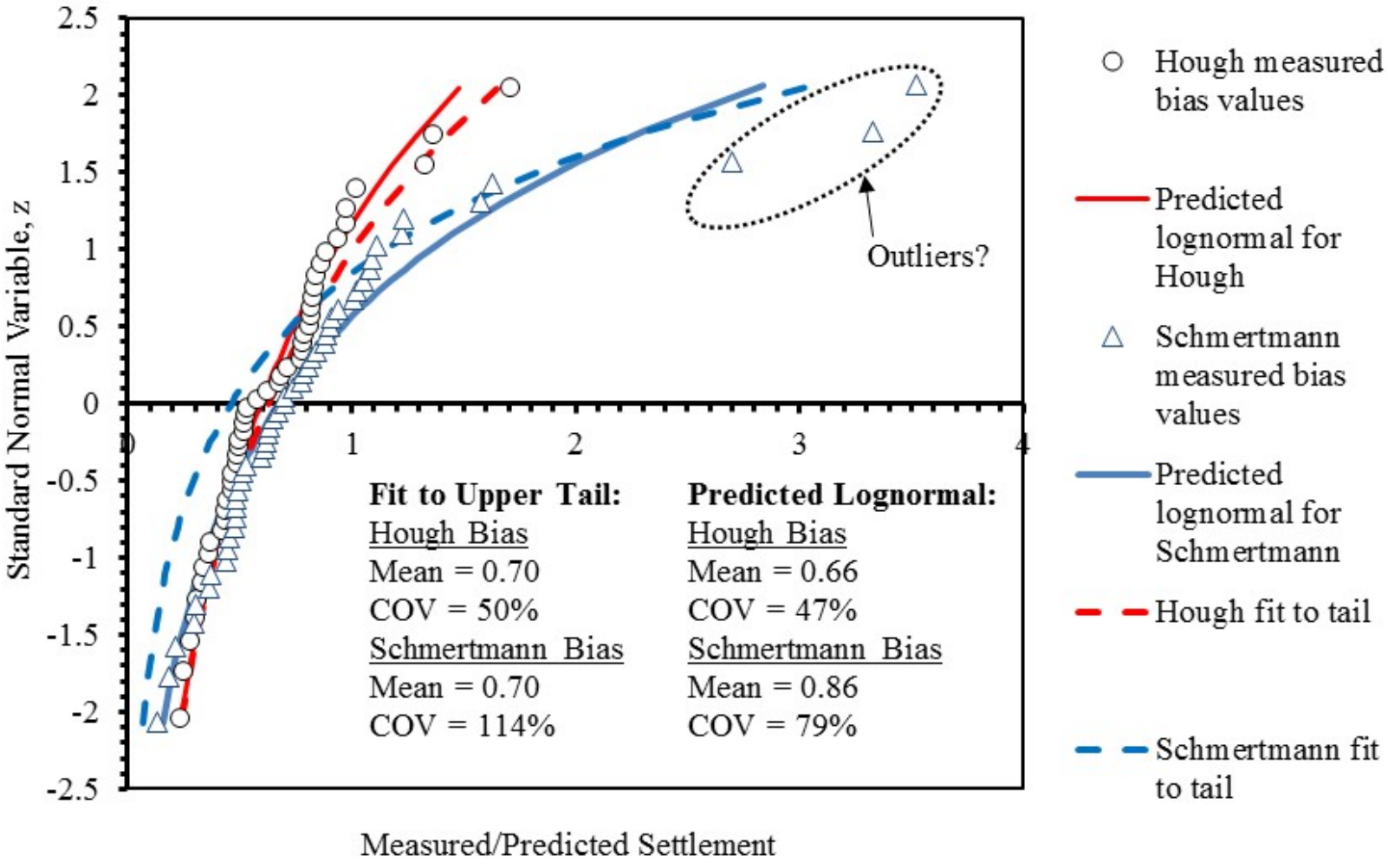


Old Database Combined with WSDOT and Other Data: $\delta > 0.5$ in.



Target Beta Values Used for SLS Settlement Calibration

Table 3.4.1-5 – Load Factors for Permanent Loads Due to Foundation Deformations, γ_{SE}

Foundation Deformation and Deformation Estimation Method	SE
Immediate Settlement (effect of foundation deformations on the bridge superstructure will be reversed by intervention, e.g., shimming, jacking, etc.)	
• Hough method	1.00
• Schmertmann method	1.25
• Local method	*
Immediate Settlement (effect of foundation deformations on the bridge superstructure may not be reversed by intervention, e.g., shimming, jacking, etc.)	
• Hough method	1.35
• Schmertmann method	1.75
• Local method	*
Consolidation settlement	1.00
Lateral Deformation	
• Soil-structure interaction method (P-y or Strain Wedge)	1.00
• Local method	*
*To be determined by the owner based on local geologic conditions.	

$\beta_T = 0.5$ ($P_f = 30\%$; Assumes deformation is reversible)

$\beta_T = 1.0$ ($P_f = 15\%$; Assumes deformation is permanent)

These values have not been calibrated)

Calibration may be revised as a result of new calibration work, but changes will be small.

T15 Decisions Regarding SLS Load Factor Calibration and Design Application

- Proposed load factor values – OK?
  - If plan to make deformations reversible, probably no change
  - If decide to not make deformations reversible, probably more conservative than past practice (i.e., γ_{SE} will be significantly greater than 1.0)
- Target reliability for reversible and irreversible deformation design (i.e., 0.5 and 1.0, respectively) – OK?
- White paper with revised calibrations needs to be completed so it can be cited by AASHTO Specifications (magnitude of load factors needed not expected to change much, if at all) – funding now available to complete the revised calibrations

Design Procedure Changes in Proposed Revisions

- Construction-Point approach
- S_f-0 approach
- How load factor is applied in the service limit design
- Addition of Schmertmann Method for settlement
- Addition of “local method”
- Are the proposed revisions clear, concise, and complete?

Construction-Point Approach

- See new Article 10.5.2.2.2 and new Appendix C10
- As written, it appears that the construction-point approach is mandatory – should it be optional, even though choosing not to do it will be conservative?
- Is the methodology clear, or are revisions in the proposed language required?

S_f–0 Approach

- See new Article 10.5.2.2.2 and new Appendix C10
- As written, it appears that the S_f-0 approach is mandatory – should it be optional?
- The S_f-0 approach could make designs more conservative
  - Past practice has been to estimate settlement at each pier to get differential settlement
  - If load factor accounts for settlement uncertainty, why deterministically assume worst possible case (i.e., 0 settlement)?
  - Note, partial explanation is that the uncertainty in the differential settlement is greater than the uncertainty in the single pier settlement; however, this is not quantified in calibration
- The “legacy” approach is allowed, but only under a very restricted set of conditions
- Is the methodology clear, or are revisions in the proposed language required?

How Load Factor is Applied

- Current proposal is to apply the load factor to the deformation

  "The recommended procedure is to factor the deformations and evaluate the effect on the structure using the factored deformations. If a structural analysis of factored deformations is performed, the resulting force effects are already factored, and these results are used directly in the appropriate load combinations in Table 3.4.1-1. An additional application of γ_{SE} in Table 3.4.1-1 is not required since the force effects are already factored . It is also possible to apply γ_{SE} directly to the force effect resulting from differential settlement."

- Alternate proposal is to calculate the differential settlement applied to a structural member, calculate the induced load in the member, and factor that load with γ_{SE}

Summary of Previous Design Examples to demonstrate Impact of Changes

- Change in procedures and design complexity
- Change in structure member sizes, etc.

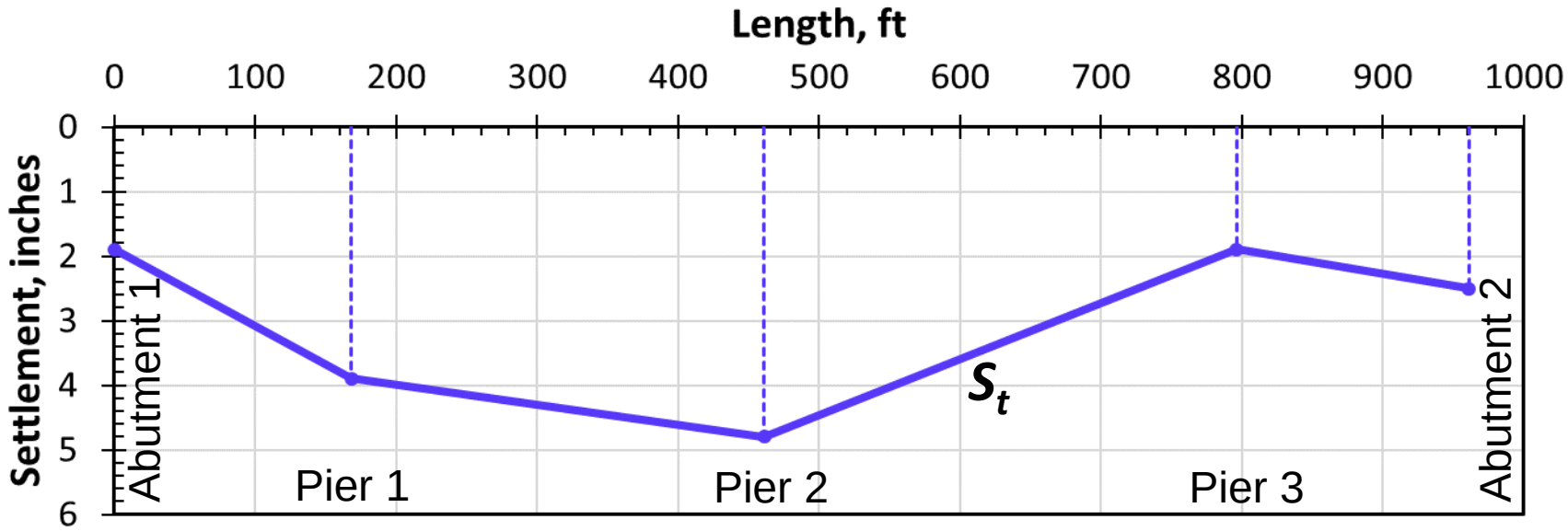
Impact on Bridge Design

- Recall three examples in White Paper (by Naresh Samtani)
  - With input and assistance from Dr. Wagdy Wassef (AECOM)
- Example 1
  - Two span bridge, 100 ft long
  - Span lengths: 50 ft, 50 ft
- Example 2
  - Four span bridge, 961 ft long
  - Span lengths: 168 ft, 293 ft, 335 ft, 165 ft
- Example 3
  - Five span bridge, 660 ft long
  - Span lengths: 120 ft, 140 ft, 140 ft, 140 ft, 120 ft

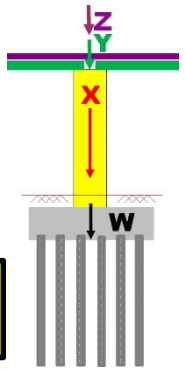
Predicted Unfactored Total Settlements, S_t

S_t based on Service I load combination (TOTAL)

Predicted Unfactored Total Settlements, S_t (in.)				
Abutment 1	Pier 1	Pier 2	Pier 3	Abutment 2
1.90	3.90	4.80	1.90	2.50

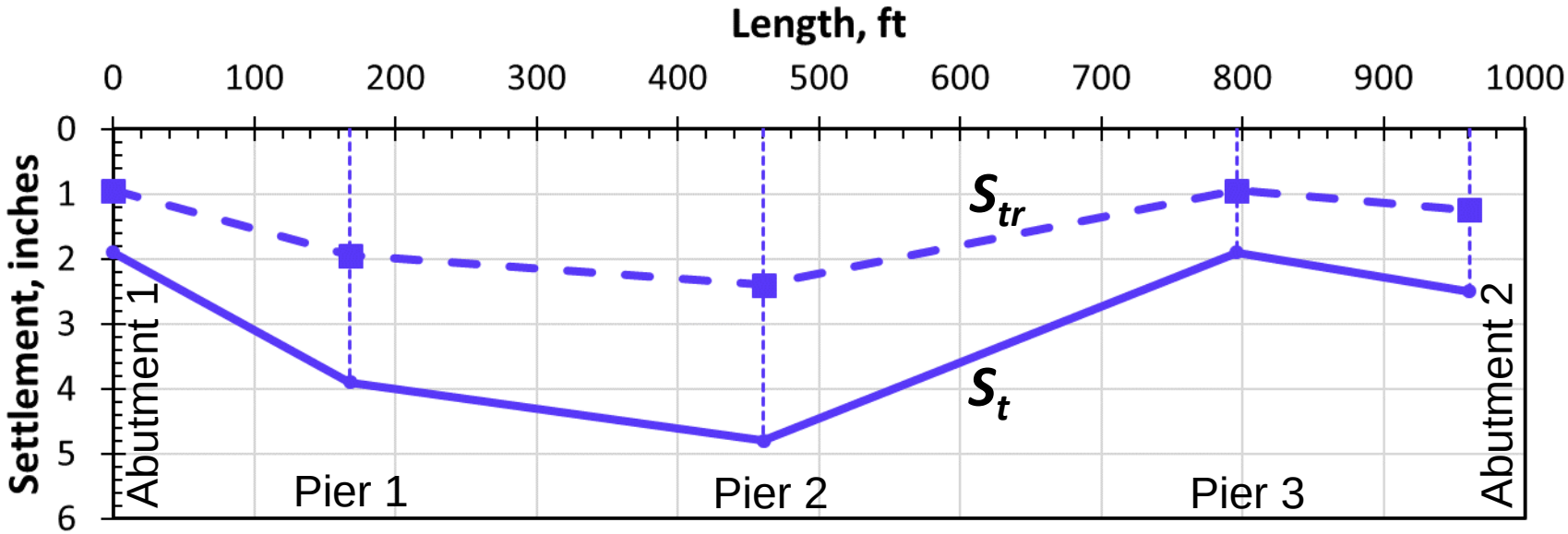


Estimated Unfactored Relevant Settlements, S_{tr}



S_{tr} based on construction point concept

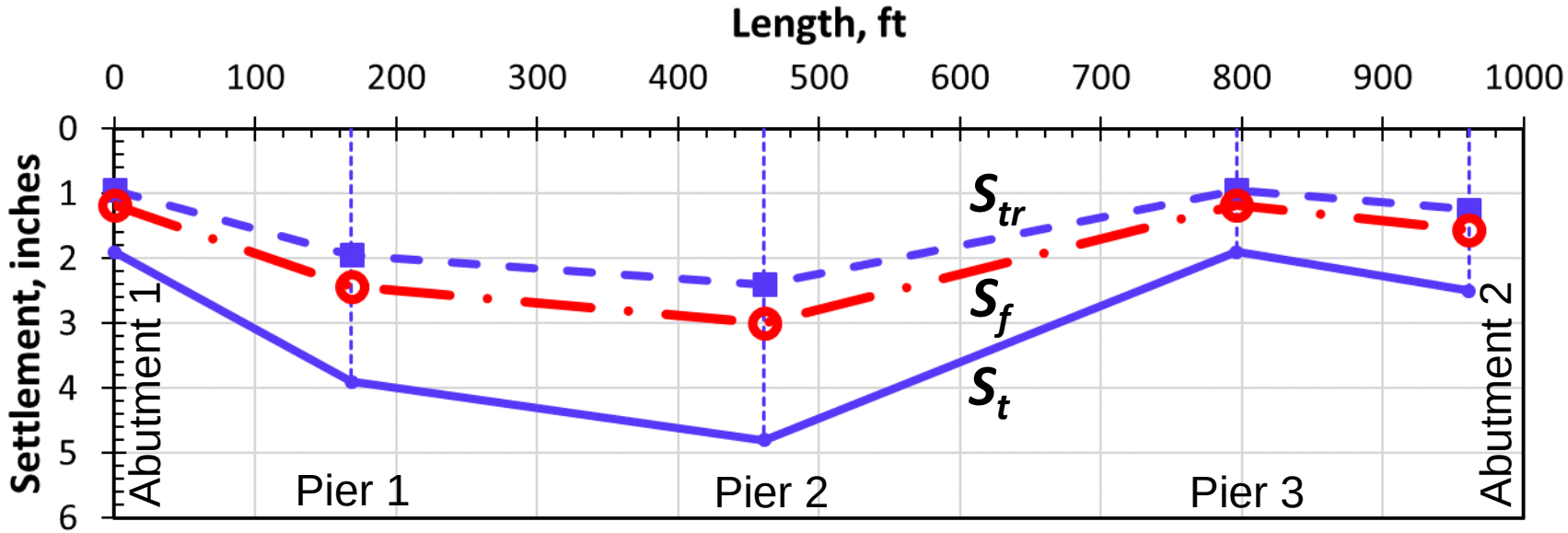
Estimated Unfactored Relevant Settlements, S_{tr} (in.)				
Abutment 1	Pier 1	Pier 2	Pier 3	Abutment 2
0.95	1.95	2.40	0.95	1.25



Factored Relevant Settlements, S_f

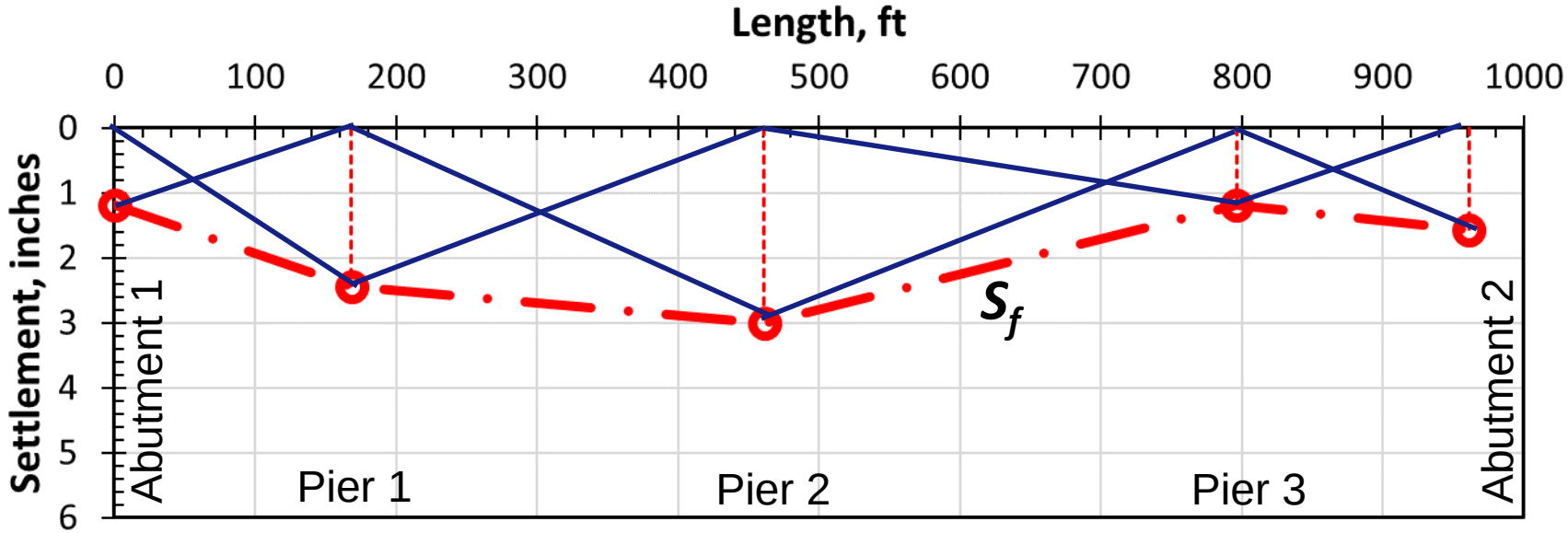
$$S_f = \gamma_{SE} (S_{tr})$$

Factored Relevant Settlements, S_f (in.) using γ_{SE} = 1.25				
Abutment 1	Pier 1	Pier 2	Pier 3	Abutment 2
1.19	2.44	3.00	1.19	1.56



Evaluate Factored Angular Distortions, A_{df}

Factored Angular Distortion, A_{df} (rad.)			
Mode 1: S_f at the left end of the span divided by the span length			
Span 1	**Span 2**	**Span 3**	**Span 4**
0.0006	0.0007	0.0007	0.0006
Mode 2: S_f at the right end of the span divided by the span length			
Span 1	**Span 2**	**Span 3**	**Span 4**
0.0012	0.0009	0.0003	0.0008



Service I Comparison

Case 1: Not consider settlement
Case 2: Consider full settlement with γ_{SE} = 1.0 (current AASHTO)
Case 3: Consider uncertainty in settlement and construction-point concept

		Moment (kip-ft)						
Service I Comparison		Span 1 - 0.4L	Pier 1	Span 2 - 0.5L	Pier 2	Span 3 - 0.5L	Pier 3	Span 4 - 0.8L
Case 1: 1.0 DL + 1.0 LL without SE	Max	10285	-12754	16640	-32725	23254	-23162	6030
	Min	713	-26170	4827	-47099	11256	-40406	-619
Case 2: 1.0 DL + 1.0 LL + γ_{SE} SE (use γ_{SE} = 1.00 and S_t)	Max	13388	-5059	19568	-25693	25675	-18440	6979
	Min	-2368	-33887	3019	-51859	9161	-46752	-1883
Case 3: 1.0 DL + 1.0 LL + γ_{SE} SE (use γ_{SE} = 1.25 and S_{tr})	Max	12224	-7944	18470	-28330	24767	-20211	6623
	Min	-1213	-30993	3697	-50074	9946	-44372	-1409
Ratio of Case 3 to Case 1	Max	**1.189**	0.623	**1.110**	0.866	**1.065**	0.873	**1.098**
	Min	-1.701	**1.184**	0.766	**1.063**	0.884	**1.098**	2.276
Ratio of Case 3 to Case 2	Max	***0.913***	*1.570*	***0.944***	*1.103*	***0.965***	*1.096*	***0.949***
	Min	*0.512*	***0.915***	*1.225*	***0.966***	*1.086*	***0.949***	*0.748*

Some Observations

- The value of γ_{SE} must not be taken literally
  - γ_{SE} = 1.25 does not mean that the total force effects will increase by 25%.
  - γ_{SE} is only one component in a load combination.
- Use of construction point concept in conjunction with γ_{SE} incorporates force effects related to expected sequence of construction
- Examples assumed that:
  - construction-point concept is used
  - Settlement effect is reversible (γ_{SE} = 1.25)
  - S_f-0 approach is used to establish maximum moments
- Result is that new approach is slightly less conservative than current approach, but that depends on using the construction point concept and assuming settlement is reversible
- See White Paper for more detailed information

T15 Decisions Needed Regarding SLS Design for Foundations

- How should load factor should be applied (i.e., to deformations, or to resulting force effect?)
- Should Construction Point method be mandatory?
- Should S_f-0 approach be mandatory?
- Are the restrictions on when the “legacy” approach can be used too restrictive, and if so, what should we do?
- Experiences in trying this out? Can we move forward?

T15 Next Steps

- Make revisions based on the current input
- Try an example design using this proposal to assist in understanding state specific impacts
- Develop final draft specifications by July 2017 to be sent to T5 and T15 members for final review and comment
- Discuss and finalize draft at T15 mid-year meeting (October?)
- Submit as Subcommittee agenda item for Subcommittee consideration in 2018

Comments and Questions