NCHRP 24-31

LRFD DESIGN SPECIFICATIONS FOR SHALLOW FOUNDATIONS

Final Report
September 2009

APPENDIX C
QUESTIONNAIRE SUMMARY

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

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DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Samuel G. Paikowsky, Sc.D.
Professor

June 18, 2007

RE: NCHRP Project 24-31
LRFD Design Specifications for Shallow Foundations

Dear DOT and FHWA Engineer;

The Geotechnical Research Laboratory at the University of Massachusetts Lowell in cooperation with Geosciences Testing & Research, Inc. (GTR) of North Chelmsford, Massachusetts is conducting project 24-31 under the AASHTO-sponsored National Cooperative Highway Research Program (NCHRP). The objective of this project is to develop and calibrate procedures, and write specifications for the design of shallow foundations. The new specifications will be based on analyses of databases containing case histories.

To maximize the effectiveness of the recommendations, the research team would appreciate your help with the following:

1. Complete the attached survey, which is aimed at obtaining information about the practices of shallow foundation design and construction. Note: the questionnaire should be completed by practicing geotechnical engineers. Please forward this correspondence to the correct person or notify us if your DOT is not actively engaged in foundation design or review. This survey can be filled in electronically and emailed back to Mary Canniff at Mary_Canniff@uml.edu. Your response will enable us to better address the needs of the different DOT agencies and when establishing the state of practice, will allow us to address your state's needs.
2. We would very much appreciate your help in obtaining information related to all types of shallow foundations field-testing (prototype or large-scale).

If the information is available in a report we will be glad to make the copies and send you back the originals. Please send the information to the undersigned at:

Samuel G. Paikowsky
Geotechnical Engineering Research Laboratory
University of Massachusetts Lowell
1 University Ave.
Lowell, MA 01854

We realize how busy you are and, therefore, sincerely appreciate your efforts in sharing your personal and departmental experience with others. Your response determines our ability to incorporate your practices in the AASHTO specification and, hence, the quality of our work.

Sincerely yours,

Samuel G. Paikowsky

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NCHRP PROJECT 24-31
LRFD Design Specifications for Shallow Foundations

June 2007

SURVEY ON SHALLOW FOUNDATIONS DESIGN, ANALYSIS AND CONSTRUCTION*

(Geotechnical Engineering)

STATE: 39 States, 1 Canadian Province

ENGINEER/S: 49 Engineers responded______________________

Please mail back to: Dr. Samuel G. Paikowsky
Geotechnical Engineering Research Laboratory
Civil & Environmental Engineering Dept.
University of Massachusetts Lowell
1 University Ave.
Lowell, MA 01854

OR

This questionnaire can be filled out electronically and emailed back.

Please Email back the electronic version to:
Mary_Canniff@uml.edu

*The original form was used as the base for the summary encompassing all the responses.

Shallow Foundations Design, Analysis and Construction

I. Foundation Alternatives

1. Our previous questionnaires conducted in 1999 and 2004 resulted with the following distribution of bridge foundation usage. Please use the lines below to assess your current usage **(over the past 3 years, 2004-2006)** if different:

	shallow foundations		driven piles		drilled foundations*	
1999/2004		14%/17%		75%/62%		11%/21%
current		17 %		59 %		24 %

2. Out of all constructed piers, assess the % of those supported by shallow foundations: 17 %
   Out of the above, assess the % founded on:

   Rock 56.3% IGM 16.3% (cemented soils/ weathered rock) Frictional Soil 23.9% sand/gravel Cohesive Soil 3.4% clay/silt

   Alabama-3, Arizona-10, Georgia-5, Idaho-10, Illinois-2, Indiana-20, Michigan-50, Massachusetts-4, Nevada 5, Washington-10

   If any were built on cohesive soils, what ratio was built **without** ground improvement measures (geosynthetic, wick drains, etc.)? 68%

3. Out of all constructed abutments, assess the % of those supported solely by shallow foundations: 19%
   Out of the above, assess the % founded on:

   Rock 55.3% IGM 17.3% (cemented soils/ weathered rock) Frictional Soil 24.4% sand/gravel Cohesive Soil 3.0% clay/silt

   Arizona-5, Georgia-5, Idaho-10, Illinois-10, Michigan-25, Massachusetts-2, Nevada-10, Oregon-1, Vermont-10, Washington-10, CA (Alberta)-10

   Were any integral bridge abutments supported on shallow foundations? .. No 68% Yes 28%
   If yes, please assess the % of those out of all abutments on shallow foundations 25 %.

   If any abutments were built on cohesive soils, what ratio was built **without** ground improvement measures (geosynthetic, wick drains, etc.)? 50 %

   Georgia-100, Idaho-100, Michigan-100, Massachusetts-80, Nevada-90, Vermont-50, Washington-5, CA (Alberta)-25

* Drilled Foundations including drilled shafts, auger cast piles, micropiles, etc., excluding driven shell cast in place (e.g. monotube).

II. Design Considerations – Foundations on Rock

1. When evaluating rock condition and engineering properties;

do you use rock cores?	No 5%	Yes 90%
do you evaluate RQD?	No 8%	Yes 88%
do you conduct uniaxial (unconfined) compressive strength tests?	No 8%	Yes 88%
do you conduct point load strength index tests?	No 63%	Yes 33%

If you conduct other tests, please specify 15 responses (38%)

Alabama	Determine size and spacing of discontinuities
Georgia	split tensile tests
Illinois	Percent recovery and detailed description, and coring time
Iowa	We do evaluate RQD and conduct uniaxial compressive strength tests for drilled shafts.
Minnesota	Split tensile
Mississippi	Very little, if any, shallow rock in MS. - Section for design on rock will be left blank.
Nevada	X-ray diffraction
Ohio	Pressuremeter
Oklahoma	Texas Cone Penetrometer (TCP)
Oregon	Unit weight
Pennsylvania	Rock cores are always taken, RQD is always evaluated. Compressive strength tests are generally performed. Point loads tests are rarely done.
South Dakota	The type of field investigation and lab testing conducted depends upon the structure
Texas	Texas DOT uses deep foundations exclusively. Texas Cone Penetrometer (TCP) is our primary evaluation tool. Cores, RQD and UU tests may also be utilized.
Wisconsin	Unconfined compression tests are only performed on a limited basis.
CA – Alberta	SASW, geophysical tests

2. When evaluating bearing resistance of rock, which do you use? (can be both)
Only Presumptive values 19.4% Only Engineering Analysis 22.2% Use Both 58.3%

   a. For presumptive values, do you use AASHTO's* Table C10.6.2.6.1-1? No 38% Yes 53%
   If in addition or alternatively you use other presumptive values, please specify 14 responses (35%)

Alabama	ASD methodologies 17th Edition Section 4.4.8.1
Arizona	We currently use AASHTO 2002 17th Edition and have not transioned to AASHTO 2004 3rd Edition, so most of the following questions do not apply.
Arkansas	Based on knowledge of geological conditions in our area we use reduced values in table C10.6.2.6.1-7
Iowa	We use historic Iowa DOT allowable bearing values for rock
Kansas	Utilize experience derived values also
Maine	We also consult Canadian Foundation Engineering Manual, 2006, Section 9.3
New Hampshire	used as a guide
New York	NYC Building Code, Appendix A, Article 26; NAVFAC D.M. - 7.2
Oregon	In combination with engineering judgment
Pennsylvania	Presumptive tables were permitted in the past, bearing resistance is now calculated.
South Dakota	For in-situ rock we have pre-determined values from experience over the years.
Wisconsin	Temper values based on local conditions/experience.
Wyoming	Hough
CA - Alberta	Canadian Foundation Engineering Manual, Ed. 4 and as modified for local experience.

* All references are made to AASHTO LRFD Interim 2006 or 2007 edition

b. For engineering analysis or bearing resistance on rock, the AASHTO specifications (section 10.6.3.2) provide guidelines to use analytical and semi-empirical correlation to Rock Mass Rating (RMR).

Would you like a specific method to be presented? No 18% Yes 70%

If you currently use a semi-empirical design method, do you use Carter and Kulhawy (1988) mentioned in the commentary (C10.6.3.2.2)? No 35% Yes 33%

Please specify if other (including computer programs) 10 responses (25%)

Indiana	We use presumptive values.
Maine	We use Kulhawy and Goodman (1980) International Conf. on Structural Foundations of Rock, May 1980, Pells "Design of Foundations on Discontinuous Rock" and Bowles, 5th Ed, Section 4-16, based on Stagg & Ziekiewicz (1968).
Nevada	We prefer GSI approach over RMR
New Hampshire	We reference Spread Footings for Highway Bridges (FHWA/RD-86/185) which references Kulhawy
Oregon	also use Hoek-Brown methods and engineering judgment
Pennsylvania	Carter and Kulhawy is presented/permitted in the commentary of our Design Manual, Part 4. However, the semi-empirical procedure using the Nms from Hoek is used.
South Dakota	Experiences with in-situ rock from past projects is used to figure bearing.
Texas	TxDOT has a design methodology utilizing the TCP test. A computer program WINCORE, is available to assist with design
Washington	Geomechanic Rock Mass Rating System, RMR, as specified in WSDOT GDM Chapter 5. http://www.wsdot.wa.gov/fasc/EngineeringPublications/Manuals/GDM/GDM.htm
CA - Alberta	Hoek & Marinos (2000) Geological Strength Index (GSI)

If you currently use an analytical design method, do you use Kulhawy and Goodman (1987) 25%, Goodman (1989) 8%, or Sowers (1979) 8% mentioned in the specifications (C10.6.3.2.3).

Please specify if other (including computer programs) 6 responses (15%)

Indiana	we use presumptive values
Nevada	Canadian Geotechnical Society (CGS), Hoek-Brown Strength Criterion correlated to GSI.
New York	In-house rock socket program
Oregon	Hoek-Brown; re FHWA NHI-01-023
Washington	We do this so infrequently, we would likely check all three.
CA – Alberta	Sigma/W

c. Do you evaluate failure by sliding for footings on rock? No 23% Yes 60%

If no, please specify the reason, if yes please specify the method of calculation and factors (F.S. or resistance factor) you are applying 20 responses (50%)

Alabama	Typically key footings into the rock one to two feet.
Arkansas	Footings are typically keyed into rock 1.5ft to 2.0ft
Connecticut	It could be either, depending on the code that is being used AASHTO Standard Spec-ASD, AREMA, or AASHTO-LRFD
Idaho	Use resistance factor of about 0.5 (Note that Table 10.5.5.2.2-1 in AASHTO does not have resistance factor for sliding for rock).
Illinois	per AASHTO LRFD
Indiana	We use AASHTO Table 10.4.6.5-2 to get Poisson's ratio. We use a Factor of Safety of 1.5
Iowa	The Bridge Design Manual requires that spread footings be notched into rock. For typical bridges the notching provides adequate sliding resistance.

Maine	Sliding calculated for Strength I using min vert load and max horiz loads, and a resistance factor of 0.80 based on reliability theory analysis for footing on sand, but also have used RF of 0.90 which translates to a FS of 1.5
Maryland	We will seat footing into rock
Minnesota	Footings are typically dowelled to rock with enough dowels to resist the lateral force.
Nevada	We use limit equilibrium method as discussed in FHWA Module 5 "Rock Slopes" with a superimposed foundation loading. Factor of Safety against sliding failure should be at least 1.5 for static condition and 1.1 for seismic condition.
New Hampshire	SF = 1.5 per Working Stress, Resistance factor = 0.8 per LRFD
North Carolina	Note: This is done by our Structure Design Unit. We determine bearing capacity and settlement. Most of our footings are keyed or carried into rock, therefore, sliding is a major concern.
Ohio	FS 1.5
Oregon	as described in FHWA NHI-01-023
Pennsylvania	Currently the designer has the option to evaluate sliding for footings on rock. Historically, sliding is not checked if the footing is embedded below the top of rock one foot.
South Dakota	Footings are usually doweled and/or neatlined into the rock
Utah	We haven't yet had a need to do a sliding evaluation with the LRFD code, but if we did, we'd have to determine a design method and a resistance factor for rock (not provided in code).
Washington	1.5 or 0.67
CA – Alberta	Using LRFD if the sliding is based on friction use resistance factor of 0.8, if the sliding is based on cohesion use resistance factor of 0.6

Do you limit the eccentricity of footings on rock? No 10% Yes 75%

If yes, please specify criteria (i.e. e/B ≤ ⅜, section 10.6.3.3 or others) 29 responses (73%)

Arizona	AASHTO 2002
Arkansas	section 10.6.3.3
Connecticut	AASHTO
Hawaii	Per AASHTO LRFD Bridge Design Specifications
Idaho	section 10.6.3.3
Illinois	per AASHTO LRFD
Indiana	We use e/B ≤ 1/4 from section 8.4.3.1 of FHWA NHI 06-089 "Soils and Foundation Manual"
Iowa	Less than or equal to 1/4 footing dimension in any direction (AASHTO Std. 4.4.8). We plan to use the 3/8 limit under LRFD.
Kansas	e/B < 3/8
Massachusetts	middle half
Michigan	Resultant must be in center ¼ of footing
Minnesota	As per LRFD 10.6.3.3
Nevada	Same criteria as addressed in Section 10.6.3.3. For static loading, the location of the bearing pressure resultant on the footings should be within 3B/8 of the center of the footings on rock. For seismic loading, the location of the resultant force should be within B/3 of the center of the footings.
New Hampshire	10.6.3.3
New York	10.6.3.3
North Carolina	e/B < ¼ Note: This is done by our Structure Design Unit. We determine bearing capacity and settlement. Most of our footings are keyed or carried into rock, therefore, sliding is a major concern
Ohio	e/B ≤ ¼
Oklahoma	section 10.6.3.3
Oregon	e/B < 3/8

Pennsylvania	Resultant force must fall in the middle ¾ of the footing for rock; middle ½ for soil
South Dakota	Bridge keeps the resultant in the middle 1/3 of the footing.
Tennessee	1/3 to 3/8
Utah	We use section 10.6.3.3
Vermont	10.6.3.3
Washington	AASHTO 3/8ths
Wisconsin	e/B < 1/4
Wyoming	B/6
CA – Alberta	Reduce length and width of footing by 2x eccentricities in length or width directions respectively, resultant force must be through middle third of foundation (e < B/6)

3. For settlement evaluation of footings on rock or IGM:

   a. We do **<u>not</u>** analyze settlement in such cases as the specifications assume settlement less than 0.5 inches for fair to very good rock 70%
   If you do not calculate settlement for another reason, please include a short explanation: 2 responses (5%)

   Iowa – Historically the Iowa DOT has experienced no problems with settlement of spread footings on rock.

   Nebraska – no settlement issue on rock.

   b. We use the AASHTO procedures for broken/jointed rock outlined in section 10.6.2.4.4 .... No 25% Yes 28%

   c. We use other procedures or computer programs along 10% or instead of 5% the procedures outlined by AASHTO.
   If other procedures/programs, please specify: 4 responses (10%)

   Michigan – model poor rock as soil

   Nevada – We also use Kulhawy (1987) Simplified Method and Army Corps Engineers-Manual EM 1110-1-2908.

   North Carolina – we do not analyze settlement in rock.

   CA-Alberta – Sigma/W.

   d. We usually limit the settlement to:
   0.5in 33% 1.0in 18% other 6 responses (15%)

Illinois	We have no written limit - 1.0 would be considered excessive in most every case
Michigan	Limit settlement to 1.0in for footings on poor rock.
Oregon	based on structure tolerances
Pennsylvania	Differential settlement (between adjacent substructure units) is also evaluated.
South Dakota	SDDOT assumes 1/4" or less for settlement

   e. Do you analyze lateral displacements of shallow foundations on rock? No 70% Yes 5%

   If no, please explain, if yes please specify the procedures and/or software you are using 16 responses (40%)

Illinois	We have never had a problem due to the lateral displacement of footings
Iowa	By notching footings into rock, we prevent significant lateral displacements. Historically the Iowa DOT has experienced no known problems.

Kansas	Our practice is to totally key our footings into rock eliminating lateral movements
Massachusetts	HEP @ Ko
Minnesota	Footings are dowelled to rock and assumed not to move.
Nevada	Only for deep foundations
New Hampshire	Through limiting the vertical settlement that occurs after placement of the superstructure to < 1-1.5", the horizontal movement is usually within acceptable limits.
New York	We perform geologic inspection during construction to ensure there is not adverse jointing that would cause problems. Keyways, doweling etc. can be ordered in construction if there is concern about sliding or lateral displacement.
North Carolina	Done by structures
Ohio	If sliding FS > 1.5 then the lateral displacements are generally acceptable.
Oklahoma	We only use shallow foundations on very competent rock.
Oregon	usually key footings into solid rock
Tennessee	We presume fixity on rock.
Utah	Shallow foundations have been on single span bridges. Lateral analysis hasn't been required.
South Dakota	The foundation unit is keyed into the rock
Wisconsin	Displacements have not been an issue.

III. Design Considerations – Foundations on Soils

1. Do you follow the AASHTO LRFD Specifications (section 10.6)?.......... No 33% Yes 50%
   If no, please specify what guidelines/code/procedure you follow in the Geotechnical design of shallow foundations 16 responses (40%)

Alabama	Have not converted to LRFD yet, still using 17th Edition Section 4.4
Arizona	We currently use AASHTO 2002 17th Edition and have not transitioned to AASHTO 2004 3rd Edition, so most of the following questions do not apply.
Arkansas	We do not use footings founded in soil.
Connecticut	Generally follow AASHTO guidelines; however as in working stress designs there will always be some exceptions that require you to depart from the code.
Georgia	Empirical values to limit settlement to <0.5"
Indiana	We follow the old AASHTO. We will use LRFD starting in January 2008
Iowa	We do not use spread footings on soil for bridges. Spread footings on soil for other structures such as sign trusses and light towers are designed by the AASHTO standard specifications.
Kansas	We do not use shallow foundations with soil as the foundation medium for bridge footings
Maryland	AASHTO Allowable Stress Design
Mississippi	AASHTO ASD Standard Spec. – Will use LRFD Spec. for future designs.
North Carolina	Not yet, we are in the process of using LRFD
Pennsylvania	AASHTO LRFD as modified by PennDOT's Design Manual Part 4
South Dakota	AASHTO Standard Specification for Highway Bridges
Wisconsin	Still using ASD, but moving to LRFD
Wyoming	AASHTO Working Stress Design used in this timeframe.
CA – Alberta	National Building Code of Canada, National Bridge Code

2. Do you use the LRFD AASHTO specification for bearing pressures at the service limit state (section 10.6.2.6)? .... No 38% Yes 35%

If yes, do you use the presumptive values of Table C10.6.2.6.1-1?........ No 43% Yes 13%

If no, do you calculate the service limit procedures based on limit displacements? .... No 15% Yes 40%

If no, please explain your procedure 4 responses (10%)

Illinois	Use factored resistance and estimate service settlement
Nebraska	ASD
New York	Question is unclear
South Dakota	Experience and unconfined compression strength test results

Do you apply any safety margin (F.S. or R.F.) to a foundation determined on the basis of settlement calculations?.. No 55% Yes 8%

As the specifications do not address this issue, please explain 7 responses (18%)

Connecticut	We are applying the FS or RF; however the value is 1
Illinois	Resistance factor on nominal bearing resistance controlled footing and check settlement not excessive to structural engineer.
Nevada	If the settlement is within structure tolerable limit, we do not apply further F.S. or R.F. to the allowable bearing capacity.
New Hampshire	The settlement calcs are based on service load.
New York	Service limit bearing pressure is applied to soil, settlements calculated. Settlement must be< structure tolerable settlement.
Oregon	Resistance factor is 1.0 at service limit state - settlement determined based on allowable structure settlement criteria
Utah	Specs do address the issue, the RF is 1.0 for service limit sate used in settlement calculations.

3. If instead of 8% or in addition to 18% the above you use other procedures or computer software for the evaluation of bearing capacity of shallow foundations, please specify: 12 responses (30%)

Connecticut	Various published techniques for estimating settlement. No formal practice established.
Georgia	CBEAR
Illinois	We have a spreadsheet to calculate nominal bearing pressure and elastic settlement
Maine	CBEAR
Massachusetts	FHWA and/or Text books
Mississippi	ASD Standard Spec. (FS bearing capacity = 3.0); settlement not a problem on sand/gravel (no shallow foundations on clay) - will use LRFD Specification for future designs. Remaining questions deal mainly with the LRFD Spec. After some experience with this code, MS will gladly update the unanswered sections.
New Hampshire	Use procedures in AASHTO 10.6.3
North Carolina	none
Pennsylvania	PennDOT's Pier and Abutment/Retaining Wall programs calculate the bearing resistance for spread footings on soil. Bearing resistance for rock is determined using a hand calculation and the bearing resistance for rock is a program input.
South Dakota	SDDOT runs unconfined compression strength tests
Wisconsin	Use AASHTO ASD guidelines
CA - Alberta	Sigma/W, in-house spreadsheets

4. Do you use the theoretical general bearing capacity estimation presented in section 10.6.3.1.2?.. No 15% Yes 58%

If no, please elaborate on any bearing capacity factors, shape factors and inclination factors you are using that are different than those specified by AASHTO 4 responses (10%)

Iowa	We do not use the formula and thus have no need for special factors.
Massachusetts	Not all the factors (s, d, and i) are used.
North Carolina	use the usual Meyerhof equations
CA - Alberta	We use the Canadian Foundation Engineering Manual, Which provides a general bearing capacity equation which may be identical to 10.6.3.1.2

Do you find it reasonable to omit the load inclination factors as explained in C10.6.3.1.2a? .... No 13% Yes 53%

Do you limit the eccentricity of the footing? .... No 5% Yes 63%

If yes, please specify criteria (i.e. $e/B \leq 1/4$, section 10.6.3.3 or others) 22 responses (55%)

Alabama	As noted in Section 10.6.3.3
Arizona	AASHTO 2002
Connecticut	AASHTO guidelines
Idaho	section 10.6.3.3
Illinois	10.6.3.3
Indiana	We use $e/B \leq 1/6$ with ASD Method. After January 2008, we will use $e/B \leq 1/4$ with LRFD
Iowa	Less than or equal to 1/6 of the footing dimension (AASHTO std. 4.4.7).
Maine	$e/B < 1/4$
Michigan	Follow criteria of section 10.6.3.3
Minnesota	As per LRFD 10.6.3.3
Nevada	Same criteria as addressed in Section 10.6.3.3. For static loading, the location of the bearing pressure resultant on the footings should be within B/4 of the center of the footings on soils. For seismic loading, the location of the resultant force should be within B/3 of the center of the footings.
New Hampshire	10.6.3.3
New York	$e/B < 1/4$
Ohio	$e/B \leq 1/4$
Oregon	$e/B < 1/4$
Pennsylvania	The resultant must fall in the middle half of the footing.
South Dakota	Keep the resultant in the middle ⅓ of the footing
Utah	Section 10.6.3.3
Vermont	10.6.3.3
Washington	AASHTO ¼th
Wisconsin	$e/b < 1/4$
CA – Alberta	$e/B < 1/6$

Please comment on the above 8 responses (20%)

Iowa	AASHTO Standard Specifications for Structural Support for Highway Signs, Luminaires and Traffic Signals has not yet been converted to LRFD.
Massachusetts	Load inclination factors must be used in the Final Design of footings.
New Hampshire	Use of these limits have produced satisfactory designs for years.
North Carolina	above and below done by structures
Oregon	more reasonable than FOS against overturning approach
Pennsylvania	Intitally, when inclination factors were considered, factored loads were used in their calculation. The factored loads caused an increased footing width; unfactored loads are now used.
Utah	We are not sure if it is reasonable to omit the load inclination factors and have used them in our designs.
CA – Alberta	Eccentricity controlled to place resultant within middle third of the footing.

Do you reduce the soil's strength parameters considering punching shear (section 10.6.3.1.2b) in addition to the natural decrease of the bearing capacity factors with the soil's internal friction angle ϕ?.. No 45% Yes 23%
Please explain 12 responses (30%)

Indiana	We do not build footings on compressible, loose soils. We do not use deep footings or high loads on dense sands.
Iowa	We do not use spread footings on soil for bridges
Massachusetts	Generally, the soils are either compacted, densified, or replaced.
Nevada	We reduce the soil cohesion and friction angle by 1/3 for footings located on loose or soft soils where there is a possibility for local or punching shear.
New Hampshire	Punching shear is rarely applicable to our wide foundations.
New York	We would not consider spread footings on soils where punching shear would control.
North Carolina	Never done this before
Oregon	limiting settlement criteria (service limit) controls over punching shear
South Dakota	LRFD has not been implemented yet in South Dakota
Utah	We haven't considered it to be a critical mode of failure and haven't analyzed it in past.
Vermont	We avoid spread footings in these conditions.
Washington	If punching shear is possible, we would follow AASHTO

Do you use the procedures described in section 10.6.3.1.2c for footings on a slope? .... No 13% Yes 58%
Please specify your opinion, experience and/or other methods you use 15 responses (38%)

Georgia	Provide berm of sufficient length.
Illinois	adequate
Indiana	The AASHTO method is very difficult and cumbersome.
Massachusetts	Graphical solution to area affected (see Bowles text book).
Michigan	More detail should be provided for the figures to determine reduced bearing capacity due to the footing near a slope.
Nevada	Figure 10.6.3.1.2c-1 needs to be improved for easier interpretation.
New Hampshire	Use methods in Foundation Design by Donald Coduto, 1994, p.254 - Shields Method.
North Carolina	We use Bowles book, also we design very few footings on slopes.
Oregon	Ncq and Nyq (Meyerhof) is reasonable approach and gives reasonable (though somewhat conservative) values.
Pennsylvania	Experience has been that the use of the procedure decreases the bearing capacity; sometimes drastically and results in a larger footing.
South Dakota	SDDOT has not changed to LRFD for design yet. We continue to use AASHTO Standard Specifications for Highway Bridges
Utah	Use AASHTO methods in the code.
Washington	We use the Meyerhoff (NAVFAC 7.2) method which has been reproduced in AASHTO. It has worked well for us. No known issues with respect to performance.
Wisconsin	End slopes adjacent to shallow footings are often critical.
CA – Alberta	Same as CFEM

Do you use the procedures described in sections 10.6.3.1.2d,e,f for footings on a layered soil system?.. No 30% Yes 38%
Please specify your opinion, experience and/or other methods you use 18 responses(45%)

Connecticut	Haven't had the situation to justify its use. If we did, we would consider its use.
Illinois	adequate

Indiana	We either design for the more critical soil layer or we design for the stronger layer (on top) while considering a distributed load on a weaker soil layer (below the stronger layer).
Iowa	We do not use spread footings on soil for bridges
Maine	Started doing LRFD geotechnical reports and analyses this year - have not had a situation yet for usage of 10.6.3.1, but intend to follow the Article 10.3.3.1.2.
Massachusetts	Very rarely.
Michigan	Use weaker soil layer for bearing capacity calculation when within Hcrit.
Nevada	Sometimes, we use weighted average of cohesion and friction angle of layered soils in bearing capacity analysis.
New Hampshire	Use methods in Principles of Foundation Engineering by Braja Das, 1984, p. 120.
North Carolina	We use methods from class notes from NCSU
Oregon	not used often - bridge footings usually avoided in these conditions due to settlement of bearing capacity concerns.
Pennsylvania	PennDOT's ABLRFD program uses the referenced section to calculate bearing resistance for up to a two layered soil system.
South Dakota	SDDOT has not changed to LRFD for design yet. We continue to use AASHTO Standard Specifications for Highway Bridges
Utah	We have used this when we have a layered system.
Vermont	We evaluate the bearing capacity of the underlying weak layer using the soil parameters for that layer and a bearing pressure based on a 2 on 1 distribution for the depth in question.
Washington	The method sometimes gives results that are suspect. In that case, engineering judgment has to be applied. This is done by generally being more conservative. If the resulting bearing is too low, we have switched foundation types, performed overexcavation, or ground improvement to provide adequate bearing and tolerable settlements.
Wisconsin	Look at lower layer soils and determine which layer has the lower strength. Analyze this layer.
CA – Alberta	CFEM

Do you use the procedures described in section 10.6.3.1.3 for semi-empirical evaluation of bearing capacity?... No 40% Yes 28%
Please specify your opinion, experience and/or other methods you use 10 responses (25%)

Connecticut	We may use the semi-empirical method in conjunction with other traditional methods.
Massachusetts	Not for final/detailed design.
Nevada	We use SPT to calculate nominal bearing capacity, but only for preliminary analysis and not for final analysis.
New Hampshire	Would be used in comparison with other methods.
North Carolina	We use local experience and results from testing done in the 1970's. Soil density and the traditional bearing capacity factors have been replaced by a factor that varies linearly with blow count/cone resistance I'd prefer to see soil density retained as a variable as it seem to me particularly for foundations at depth density would have an effect. Since backfill is being placed above the footing the density might actually be known.
Oregon	semi-empirical methods are allowed (per AASHTO) - generally the SPT method yields higher capacity and settlement (SLS) controls design.
South Dakota	SDDOT has not changed to LRFD for design yet. We continue to use AASHTO Standard Specifications for Highway Bridges
Utah	Easier to use when lab data is limited, but you have blow counts.
Vermont	N/A
Wisconsin	Check computed bearing with the presumptive bearing capacities presented in Hough.

5. Table 10.5.5.2.2.1 specifies resistance factors for bearing resistance with very little differences between the methods by which the bearing capacity is obtained, the loading applied to the foundation and the subsurface conditions. Can you please comment on the factors and the rational based on your experience? 19 responses (48%)

Alabama	The rational as outlined in the discussion appears logical at this time.
Connecticut	Not enough experience to provide comment
Illinois	The LRFD is very new to most and it is appropriate these resistance factors are all about the same until more field varification and research can be done.
Indiana	We have no experience with LRFD
Iowa	We have not used the factors yet.
Massachusetts	Agree. The resistance factors should have different values for different loading, subsurface properties, and extent of testing.
Nevada	Generally, these factors are in agreement with ASD method (Load Factor/Resistance Factor = Factor of Safety).
New Hampshire	Recommend one resistance factor (e.g. 0.45) for all the methods that is calibrated against the traditional safety factor of 3.0 used for calibrating allowable bearing capacity in WSD. In view of the overall uncertainties in predicting the ultimate bearing capacities.
New York	Most of the designs are controlled by sliding and not bearing capacity.
North Carolina	I don't trust any of the methods enough to actually use high soil strength parameters for foundation design, so it makes sense to me to have the same resistance factors, and use conservative soil parameters.
Oregon	The factors are consistent with ASD (FOS = 2.5 - 3.0) which has been the standard of practice and used successfully for many years. No comment on the rational behind them.
Pennsylvania	PennDOT currently utilizes bearing resistance factors which are based on experience, sample designs performed when AASHTO was initially implemented, and from a calibration with LRD resistance factors.
South Dakota	SDDOT has no experience to date
Tennessee	Different methods should not provide big differences in results. There is some inter-relation between all methods.
Utah	They seem pretty tight, but we don't have enough experience yet to comment.
Vermont	To date, the LRFD code has been providing reasonable designs when compared to historical results using ASD.
Washington	We pretty much follow AASHTO. It is rare that we would be more conservative and even more rare that we would choose more aggressive (higher resistance) values than those specified.
Wisconsin	We do not use this table because still using ASD. Values appear reasonable.
CA – Alberta	Not familiar with this issue.

6. Do you evaluate failure by sliding for footings on soil? .... No 3% Yes 70%
If yes, what area of foundation do you use for the sliding evaluation?
Full area 33% Effective area 30%
If yes, do you use the values recommended in section 10.6.3.3.7?........ No 13% Yes 30%
If no, please specify what interfacial friction values you use 8 responses (20%)

Iowa	We do not use spread footings on soil for bridges
Maine	LRFD Table 3.11.5.3-1
Minnesota	tan delta per LRFD 10.6.3.4
New Hampshire	Table 3.11.5.3-1
Ohio	10.6.3.4??
South Dakota	We use values from local experience

Vermont	What is 10.6.3.3.7?
CA-Alberta	Depends on soil type

Do you consider passive resistance for your lateral resistance?............. No 55% Yes 13%
If yes, do you consider limited value due to limited displacement (e.g. 50% as suggested by section C10.6.3.4)?.. No 8% Yes 13%
Please explain/comment 13 responses (33%)

Alabama	We do not want to count on the passive in case it is later removed.
Illinois	We only use passive pressure when the footing is deep and the soil or rock can be counted upon for the life of the structure.
Iowa	Individual designers may use passive pressure, but sliding generally is not a concern for sign trusses and light towers.
Minnesota	There is no LRFD 10.6.3.3.7. Passive resistance is only considered in front of shear keys when they are needed.
Nevada	We usually ignore the contribution of passive resistance of upper 3 feet of the embedment. Please note that we could not find Section 10.6.3.3.7.
New York	Where is section 10.6.3.3.7?
North Carolina	Done by structures
Oregon	There is no article 10.6.3.3.7. May consider passive resistances in certain conditions where it can be safely assumed for the life of the structure.
Pennsylvania	Passive pressure is not considered for cantilever abutment and retaining wall designs.
South Dakota	To be conservative we assume no passive resistance
Washington	Most foundations are sized for service such that there is more than enough friction on the bottom to handle sliding. In rare cases, we have had had to use passive to meet sliding criteria. When it is needed it generally is for an extreme event case so the 50% displacement limit is not invoked.
Wisconsin	Neglect passive pressure of soil in front of footing.
CA-Alberta	depends on footing level relative to frost penetration, water table and other factors

7. Traditionally, footings design on soils is limited by the settlement of the foundation. No safety factors are provided, however to the estimation of the foundation size based on limiting settlement. Should that issue be of concern?............. No 35% Yes 25%
Please elaborate 18 responses (45%)

Alabama	Only in that the zone of influence may affect surrounding structures, etc.
Connecticut	It is always assumed that engineering judgment is applied in any design and you should always check the reasonableness of the design. It's probably an assumption that should be validated by research.
Hawaii	Allowable bearing capacity, which includes safety factor, is used to estimate footing size.
Illinois	Structural engineers do not want to consider that the spread footing will settle any amount. The service settlement should be checked under the service group but the structural engineers need more help in determining how much settlement can be tolerated. At abutments, footing settlement can eliminate the bump at the end of the bridge if the structural engineer would design the bridge to withstand the deflection but they do not want to do that yet
Iowa	Generally settlement is not a concern for spread footings for sign trusses and light towers.
Maine	We often recommend sizing footing based on service load group and the presumptive bearing capacity values that have a FS already, or by settlement analysis.

Michigan	Our bridges are typically designed to handle 2" of differential settlement. 1" settlement was previously assumed for allowable bearing pressures including a F.S. The new Hough method appears to overpredict settlement by a factor of 2. We anticipate needing to use between 1.5-2.0" settlement to get comparable results to 17th Edition results.
Nevada	We proportion footing dimensions to tolerable settlement limit of 1 inch.
New Hampshire	There is conservatism in the settlement calcs.
New Jersey	The allowable bearing capacity used to size the footing traditionally is based on limited settlement, e.g. 1"
North Carolina	Conservatism is built into settlement calculations. The amount and practical effects of settlement are rough estimates made at the judgment of the Engineer. There is no rational basis for multiplying Engineering judgment by a safety factor. Also this is a service limit so whatever margins for error we want could be applied there.
Oregon	Don't understand the issue here
Pennsylvania	Load factors and resistance factors are used for forces and bearing pressure to provide a "factor of safety". Note that under the LFD design procedure, no safety factors were applied to the amount of settlement.
South Dakota	SDDOT provides foundation improvements on sites with high settlement concerns so it shouldn't be a concern.
Tennessee	Settlement calculations are not always accurate. There should always be a judgment between bearing from settlement and allowable bearing capacity limit.
Utah	Applying an extra factor of safety for this service condition seems punitive if the engineer is confident in his settlement calculations. We feel sufficient conservativism is built into the soil property selection and settlement analysis.
Washington	It is not a concern unless you do not check for bearing. To do one without the other is not good engineering. You must check both to ensure that the service case and the strength case are not too close together.
CA-Alberta	High safety factors, 2 or 3, are often applied to the maximum resistive load in order to limit deformation. This may or may not be conservative in relation to a large footing that spans soil types, or rests partly on a soil and partly on rock. Differential settlement criteria may govern over absolute settlement concerns.

8. Do you conduct prototype (plate) or full-scale load testing on footings? ... No 73% Yes 3%
   If yes, please specify the procedure you use to determine:
   the ultimate bearing capacity and its extrapolation: 2 responses (5%)

   Connecticut – Some limited plate testing has been done; however, it has been 20 years since the last one was performed.

   Massachusetts – 3 tests

   the load at the limit displacement and its extrapolation: 1 response (3%)

   Massachusetts – Terzaghi and Peck (1948, 1967)

The project team would greatly appreciate receiving any available test results (see cover letter).

If there is any additional information you feel was not covered, or would like to elaborate on, please specify below:

13 responses (33%)

Colorado	I have filled out a small portion of the attached questionnaire. Since the Geotechnical Program at CDOT does not normally involve in actual foundation design, I do not have much information to provide. Let me know if you have questions.
Iowa	As mentioned several times in the comments above, Iowa does not use spread footings on soil for support of highway bridges (but does use spread footings on soil for sign trusses, light towers, and other structures). Iowas is just beginning to use LRFD for design of bridge substructures. We usually use pile foundations for support of abutments and piers and we are in the process of converting our pile design procedures to LRFD based on our database of pile load tests. The questionnaire does not fit our practice very well.
Louisiana	We are not able to contribute with this survey because Louisiana does not have rock and the soil conditions are not conductive for the use of shallow foundations
Maine	In March 2004 MaineDOT reported the following foundation type usage for the years 1999-2000 in response to question 1: 36% - shallow foundations; 58% driven piles and 6% IPCDF (Drilled Shafts). I don't know why the historical Maine Data you printed in Question 1 is different. [Laura Krusinski of Maine DOT who made the comment was contacted – our numbers reflect the arithmatic average of all states]
Michigan	I am a bridge designer. I have a comment on the use of effective footing widths for allowable bearing calculations. It is very impractical to have to iterate back and forth with several allowables for each load case for service and strength conditions. Many DOT's have separate responsibilities from the Geotechnical and Structural aspects. The allowable pressures are the responsibility of the Geotechnical Division which is how we all prefer it, but even if we as designers had charts of allowables to input for various effective footing widths there will be more chance for input or programming errors to occur in the transfer or use of the data. One allowable each for Service and Strength conditions based on a gross footing width with the eccentricity limited to B/6 instead of B/4 seems to be an attainable method to me. Whether a re-calibration of resistance factors needs to be done or other ways to give comparable results to the 17th Edition method, it seems like it should be pursued.
Mississippi	Mississippi has no experience with shallow foundation design using LRFD. It will likely be a couple of years before we can provide meaningful input.
New York	Please do not construe any of our responses as an endorsement of the specification. We are simply trying to understand and implement the code the best we can considering there are project schedules that must be maintained. From the geotechnical standpoint we have observed no benefit to the structure design as a result of this implementation.
North Dakota	No real rock to speak of - rest of survey [sections II & III] does not apply.
South Dakota	The state of South Dakota is just beginning to look into LRFD for design purposes. Most of the geotechnical responses were provided using the AASHTO Standard Specifications for Highway Bridges and accumulative experience over the year.
Texas	Texas DOT uses deep foundations exclusively. Since the survey is for shallow foundations, we have left most questions unanswered.
Vermont	Question III.6 references AASHTO 10.6.3.3.7. I was not sure what you meant there as the 2007 code does not have that section so I left it blank. If you would like to discuss, please call me. Thanks, Chris Benda
Wyoming	Questions with respect to the design considerations were not answered, as those structures designed within this time frame were not based on the LRFD design methodology. Working stress design guidelines of the AASHTO bridge design Specifications were used.
CA-Alberta	We typically do not use spread footings for transportation infrastructure due to scour concerns (piers), settlement concerns (abutments) and frost heave issues (piers and abutments). In-stream piers constructed on spread footings are considered a more invasive design, and are generally not favored by environmental and fishery regulatory agencies. The department has a design bulletin that precludes the use of steel plate culverts founded on shallow footings, partly related to failure of some culverts designed in this manner. The department is starting to use integral MSE/abutment designs for rail crossings and overpass designs however the overwhelming preference is to use driven or drilled piles.