10. FOUNDATIONS

Different types of foundations are used throughout the state due to the variety of soil and rock conditions present. This section provides guidance on the design and detailing practices for spread footings, driven piles, and drilled shaft foundations.

10.1 Determination of Foundation Type and Capacity

During preliminary design a number of activities take place to determine the types of foundations to be used and the permitted capacities for foundation components.

Prior to beginning final design on trunk highway projects, designers should review the Foundation Engineer's Memo and the Bridge Construction Unit's Foundation Recommendations.

For bridges on the local road system, the local agency or their consultant will retain a private geotechnical engineering firm to prepare a foundation recommendations report. The report will summarize the geotechnical conditions, the proposed bridge structure, and recommend a foundation type.

10.1.1 Foundation Engineer's Memo

After conducting an exploration program, Mn/DOT's Foundation Engineer summarizes the geotechnical conditions at the site in a memo. The Regional Bridge Construction Engineer reviews the Foundation Engineer's Memo and the Preliminary Plans for the project and prepares the final recommendations concerning the foundations for the project. A sample Bridge Construction Unit Foundation Recommendation is provided in Appendix 10-A.

10.1.2 Foundation Recommendations

Type and Size

Based on geotechnical information and the anticipated type of structure, a foundation type will be recommended. In most cases pile supported footings will be recommended. The piling may be timber, cast-in-place concrete, H-pile, or pipe pile. Where scour is not a concern and soil or rock with adequate bearing capacity is found near the surface, spread footings may be recommended. Occasionally, a footing supported on drilled shafts will be recommended.

Load Capacity

The factored bearing resistance ($\phi_b q_n$) for the material below spread footings and/or the factored bearing resistance (ϕR_n) for piles or shafts will be provided in the Foundation Recommendations.

Settlement/Downdrag

The Foundation Recommendations often specify that an embankment be placed to allow settlement to occur before starting construction of a substructure. A waiting period of 72 hours to several months is then required depending on the types of underlying soils. In some cases, a surcharge embankment (additional height of fill above the profile grade) may also be recommended as a means of accelerating the rate of consolidation.

Depending on the soil profile and length of the settlement waiting period, long term settlement of the soil may introduce downdrag in the piling or shafts. Downdrag is the downward load induced in the pile by the settling soil as it grips the pile due to negative side friction. An estimate of the downdrag load will be given in the Foundation Engineer's Memo.

For piles driven to rock or a dense layer (where pile capacity is controlled by end bearing), the nominal pile resistance should be based on the structural capacity of the pile. For piles controlled by side friction, downdrag will apply a load to the pile that may cause pile settlement. The settlement may result in a reduction of the downdrag load. Due to the uncertainty of the amount of pile settlement, downdrag on friction piles will be considered on a case by case basis.

The amount of downdrag load to consider for design will be specified in the Foundation Recommendations. Note that Mn/DOT has not seen any bridge strength or serviceability problems that have been attributed to downdrag.

[3.11.8]

Transient loads have the effect of reducing downdrag. Therefore, when determining load combinations, do not combine live load (or other transient loads) with downdrag. Consider a load combination that includes dead load plus live load and also a load combination that includes dead load plus downdrag, but do not consider live load and downdrag within the same load combination.

Before using battered piles where downdrag loads exist, discuss with Bridge Design Engineer and Regional Bridge Construction Engineer.

Method of Construction Control

To ensure that foundations will have the capacities anticipated during design, testing or observations are made during construction. These construction controls consist of compaction testing for spread footings, the Mn/DOT Nominal Resistance Pile Driving Formula, Pile Driving Analyzer (PDA) testing, or physical load tests for piling and Cross-hole

Sonic Logging (CSL) for drilled shafts. The Foundation Recommendations will identify the construction controls to be used for the project.

Estimated Pile Length

The soil exploration program will not completely describe the geotechnical conditions at the site. To account for this variability, estimated pile lengths are used in computing bid quantities. Test pile lengths longer than anticipated production pile lengths (typically 10 feet longer) are specified in the Foundation Recommendations. If during construction, the test piles indicate that a longer or shorter length is justified, the production piling quantities and payments are adjusted accordingly.

Estimated Bottom of Footing Elevation

To minimize the potential for scour, settlement, or frost heave problems a recommended bottom of footing elevation will be presented for each substructure location in the Foundation Recommendations.

Other General Information Needed for Plan Preparation

Check pile layouts for interference with in-place utilities (including overhead power lines), drains and existing piles/foundations.

Unique projects may have limits placed on the amount of noise and vibration that can be generated during construction.

10.2 Piles

Several types of piling are available (treated or untreated timber, steel H and thick wall pipe piles, and cast-in-place concrete piles). The Regional Bridge Construction Engineer may recommend that more than one type or size be used for a project.

Steel H-piles are steel H-shaped sections that are usually fitted with manufactured points and driven to a required nominal bearing resistance. H-piles are generally specified for soil conditions where very hard driving is anticipated, including driving to bedrock. In some cases, high strength, small diameter, thick-walled pipe are permitted as a substitute for H-piles. If permitted, this will be indicated in the Foundation Recommendations.

Cast-in-place (CIP) piles are steel pipe piles with a plate welded to the bottom that are driven to a required nominal bearing resistance or to an estimated tip elevation. After driving, the inside of the shell is filled with concrete. Reinforcement may be needed if the pile is subjected to tension or flexure. CIP piles are generally considered to be displacement piles, and are generally used when it is anticipated that the pile tip will not encounter bedrock or very hard driving.

The pay item "Pile Tip Protection" refers to manufactured points for H-piling. The pay item "Pile Points" refers to manufactured points that are used to protect the shells of cast-in-place piles during driving operations. The Regional Bridge Engineer's recommendations will identify whether or not tips or points should be used.

Quantities to be included in a final plan set for structures supported on piling are: 1) length of piling delivered, 2) length of piling driven, 3) number and length of test piles, and 4) pile tip protection or pile points.

Standard Details B201 and B202 contain the standard splices for cast-in-place pile shells and H-piling.

Pile and drilled shaft foundation plans should be dimensioned from working points.

Lateral Load Resistance

A parametric study was conducted for CIP and H-piles modeled in a single layer of sand to determine simplified lateral load capacities to use for design. A pile lateral load computer program and the axial load/moment interaction equation in LRFD Article 6.9.2 (see below) were used for the study.

$$\frac{P_u}{\phi P_n} + \frac{8}{9}\left(\frac{M_u}{\phi M_n}\right) \le 1.0$$

P_u = factored axial load, determined by considering the driveability of each pile and choosing the maximum load that each pile can be driven to without damage based on past experience. For values greater than those shown in Table 10.2.1 below, a separate analysis is required.

ΦP_n = factored axial resistance, calculated per LRFD Articles 6.9.4 and 6.9.5

ΦM_n = factored bending resistance, calculated per LRFD Articles 6.12.2.2 and 6.12.2.3

M_u = maximum factored moment

Values for P_u, ΦP_n, and ΦM_n were determined and the interaction equation was solved for the maximum factored moment M_u. The maximum factored lateral load resistance ϕR_{nh} was determined by applying an incrementally increasing lateral load to the computerized pile and soil model under the axial load P_u until the resulting moment was equal to M_u.

Table 10.2.1 shows the factored lateral load resistance ϕR_{nh} for different piles from the parametric study. The resistance values are based on soil properties for loose sand with an internal friction angle of 30° to 32°. The computer program built-in P-y curves using the "Reese sand" properties and relevant soil modulus, k, were also used. Soils with properties weaker than that of loose sand require a separate analysis. For the CIP piles, the 3 ksi concrete in the piles was included in the total EI for deflection determination, and also for calculation of the axial strength ΦP_n in the piles. The pile cap was assumed fixed in rotation and free in translation.

Table 10.2.1: Lateral Load Resistance of Piles

Pile Type	F_y (ksi)	Wall t (in.)	P_u (tons)	ΦR_{nh} (kips)
12" CIP	45	1/4	100	24
12" CIP	45	5/16	125	24
12" CIP	45	3/8	150	24
12" CIP	45	1/2	200	24
16" CIP	45	1/4	135	28
16" CIP	45	5/16	170	40
16" CIP	45	3/8	205	40
16" CIP	45	1/2	270	40
HP 10x42	50	NA	110	24
HP 12x53	47.8 *	NA	140	32
HP 14x73	43.9 *	NA	190	40

* Actual F_y = 50 ksi. HP section does not meet b/t ratio for compactness. A reduced F_y was used in the analysis to meet requirements per LRFD Article 6.9.4.2.

Pile Load Table Include in the Bridge Plan

Standard practice for construction of pile foundations is to drive piling to refusal or to drive piling to the required nominal pile bearing resistance indicated in the plan. The nominal pile bearing resistance is monitored in the field using the Mn/DOT Nominal Resistance Pile Driving Formula or by using Pile Driving Analyzer (PDA) testing. Two tables are required in the plan when pile foundations are used. (See Appendix 2-H, Section F.) The first table is used to report the factored loads calculated during design of the pile layout. The second table is used to show the nominal resistance that the pile must be driven to in the field, depending on the field control method used.

Use the following values for ϕ_{dyn} based on the field control method used:

- $\phi_{dyn} = 0.40$ for Mn/DOT Nominal Resistance Pile Driving Formula
- $\phi_{dyn} = 0.65$ for Pile Driving Analyzer

Test Piles

Each bridge substructure utilizing a pile-type foundation will typically require one or two test piles. Separate the test piles (use a maximum spacing of about 40 feet) within a foundation unit to facilitate a more accurate assessment by the Field Engineer of the in-situ soil characteristics. The Foundation Recommendation prepared by the Regional Bridge Construction Engineer will specify the number of test piles for each substructure unit. For abutments with all battered piles, place a test pile in the front and in the back row. For pier footings, place test piles near the center of the pile group. If possible, use vertical (plumb) test piles. Number and locate test piles on the Bridge Survey Plan and Profile sheets.

Test piles are used to establish the length for the pier and abutment foundation piles. Based on the pile penetration (number of blows per foot at the end of driving), the size of the pile driving equipment, and the length of the pile being driven, the pile's nominal resistance can be estimated. The procedure used to determine the pile's nominal resistance is described in Bridge Special Provision SB2005-2452.2.

On some projects when specified, foundation test piles are evaluated with electronic equipment attached to the pile during the driving process. This equipment, called a Pile Driving Analyzer or PDA, provides more specific information concerning the nominal resistance of the pile. A pay item for pile analysis must be included in the plan when the PDA is performed by the contractor.

Pile Redriving

Pile redriving is specified in the Foundation Recommendation when the soils are of a type that additional bearing capacity can be gained after the pile has set for 24 hours or more. For this situation, include an item for pile redriving to compensate the contractor for redriving the pile(s) after the required setup time.

[10.7.1.5] **Clear Spacing and Minimum Concrete Cover**

The minimum concrete cover for piles is 9 inches. To facilitate pile driving operations, the minimum center-to-center pile spacing is 2'-6" with 3'-0" minimum preferred.

It may be necessary to increase the plan dimensions of a footing or pile cap when using battered piles to provide the minimum concrete cover of 9 inches.

The standard embedment into a pier or high parapet abutment footing for a driven pile is one foot and should be dimensioned in the plans. Assume the piles are pinned supports.

The standard pile embedment for a low parapet abutment footing is 2'-4".

Battered Piles

The standard pile batter for pier footings is 6 vertical on 1 horizontal. For abutments, the standard batter is 4 vertical on 1 horizontal. Use of a nonstandard batter requires approval from the Regional Bridge Construction Engineer.

Pile layouts for foundations that include battered piles should be dimensioned at the bottom of the footing.

Before using battered piles where downdrag loads exist, discuss with Bridge Design Engineer and Regional Bridge Construction Engineer.

10.3 Drilled Shafts

Drilled shafts are large-diameter reinforced concrete piles constructed by boring a hole into earth and/or rock, inserting a reinforcing cage and filling the cavity with concrete. Drilled shafts may also be called caissons or drilled piers. Because of the high cost of construction, drilled shafts are normally used only when the foundation characteristics of the site, such as bedrock, may cause driven piling to attain bearing capacity at ten feet or less below the footing, when piling cannot be embedded below the computed scour elevation of a streambed, and for other reasons applicable to a particular project. Drilled shafts may also be used to enhance the stability of piers adjacent to a navigation channel.

Information used for the design of drilled shafts is determined by the Mn/DOT Foundations Unit. This information includes depth (length) of the earth and rock portions of the shaft, and maximum load capacity for a given diameter. Load capacity of drilled shafts is provided by end bearing on rock (minimum embedment five feet), or by sidewall friction in soil or rock.

Drilled shafts are designed as columns subjected to axial and lateral loads. Lateral loads may or may not be resisted by passive soil pressure, i.e., scour depth below the streambed (flowline) should not be considered as providing lateral support. If shafts are placed in a group, the minimum center-to-center spacing is three times the diameter (D) of the shaft and appropriate group reduction factors must be applied. When the spacing is greater than 8D the shafts can be designed as individual units. Shaft diameter is determined by the required loading, standard industry drilling equipment, casing size, and other factors unique to the project. Normally, shaft diameters are in the range of 3 to 5 feet. Smaller shafts may be used to replace driven piles in a group, such as that of a pier footing. Larger shafts may be appropriate when a single shaft is used to support a single pier column, or to minimize the number of shafts in a group when deep shafts are required. For a combined earth and rock shaft, the earth portion should be of a diameter that is 6 inches larger than the rock shaft in order to allow passage of special rock drilling tools. If a shaft terminates in rock, the design diameter for the full depth of the shaft should be the same diameter as that of the rock portion.

Detailing of drilled shafts in the plans should consider location, construction methods, foundation conditions, contract administration by district construction personnel, structural integrity of finished shafts, etc. Many details are job specific; therefore, much of this information should be compiled before detailing is started.

Because most of the depth of a shaft is formed by the excavated borehole, it will be necessary to determine if casings, either permanent or temporary, will be used. Permanent casings must be specified whenever shafts are constructed in water, even if the work is contained within a cofferdam and the final cut off elevation is below the streambed because dewatering cannot take place before the shafts are constructed. Some contractors prefer that permanent casings be used through all soil to the top of bedrock in case any of the soil is capable of caving. Permanent casings should not be used in the sidewall friction area of soil or rock. Temporary casings are provided by the contractor for the convenience of construction operations and are removed at the completion of the work. Most casings are provided in diameters of 6 inch increments and should be specified as such. For metric plans, the diameter must be soft-converted to metric units and not rounded off. Otherwise, the contractor may provide custom-made casings at a higher price.

Drilled shafts are reinforced in the same manner as round columns. Cover on the bars should be 3 inches on the sides and 6 inches from the bottom of the shaft. If the shaft design requires a reinforced connection between the top of the shaft and the structure above and hooked bars are intended, the hooks projecting beyond the side of the shaft may prevent subsequent removal of temporary casings. Hooks may be turned inward to avoid this interference; however, possible interference with placement of footing reinforcement should then be checked.

Uncoated reinforcement bars should be used unless the top portion of a shaft will be permanently exposed, or if the bars will be extended into an exposed portion of the structure. In this case, use coated bars only at the top of the shaft unless it is more practical to use coated bars throughout.

When specifying concrete for the shafts, the mix normally used is 1X46 ($f'_c = 5.0$ ksi) if the concrete will be placed in a wet (water-filled) hole, and 1Y46 ($f'_c = 4.0$ ksi) if the concrete will be placed in a dry hole. The first digit should be "3" for air-entrained concrete if the top portion of the shaft will be exposed in the final construction. Aggregate should be no larger than $^3/_4$" to provide for a positive flow around the reinforcement since vibration of the concrete in the greater part of the shaft is not practical.

Payment for the drilled shafts should always include separate items for earth and rock shafts due to the large disparity in the cost of drilling. If it appears to be unlikely that the shaft depth will change during construction, payment for concrete, reinforcement, and permanent casings (if used) can be included in the pay item for the shafts. However, foundation conditions are rarely known with a high degree of accuracy and changes in the shaft quantities may occur. For such situations, separate items for the materials are recommended. In either case, the plans and special provisions must clearly state how payment will be made.

When boulders can be anticipated during drilling, include a pay item for obstruction removal.

Because it is not possible to visually inspect the unexposed portion of a finished shaft, other means of inspection and structural integrity testing have been devised. One such test is Cross-hole Sonic Logging (CSL). This test and other tests should be used only if recommended by the Regional Bridge Construction Engineer since these tests and the preparation of the shafts for the tests can be very costly.

Report maximum factored design load and factored bearing resistance in the plans using one of the Standard Plan Note tables shown in Appendix 2-H, Section F.

10.4 Footings

10.4.1 General

Any footings or foundations with a thickness of 5 feet or greater should be treated as mass concrete. This may require the contractor to modify the concrete mix and/or to instrument the concrete member and take action to ensure that the temperature differential between the inside and outside of the member is small enough to minimize the potential for cracking.

Minimum Soil Cover

The minimum cover (soil, earth, or slope paving) on top of a footing is 12 inches. For a pier footing which extends under a roadway, the minimum cover is 2 feet.

Bottom of Footing

To minimize the potential for frost movements impacting the structure, place the bottom of footings a minimum of 4'-6" below grade. Note that this requirement does not apply to the bottom of integral abutment pile caps.

When feasible, the bottom of footings (or seals if they are used) should be placed below the estimated scour elevation. In many cases this is not economically practical and the bottom of footing elevation should be evaluated using Section 10.6 as a minimum criteria.

Scour

The scour depth to be used for the strength and service limit states is the lesser of the overtopping or 100-year flood.

The scour depth to be used for the extreme event limit state is the lesser of the overtopping or 500-year flood.

For bridges over a river or stream, spread footings are not allowed due to the potential for scour unless they are anchored into rock.

When designing footings in areas of potential scour assume no beneficial ground support for the piling or drilled shafts from the flowline to the predicted total scour elevation during the extreme event load case.

Footing Plan Dimensions/Formwork

Footing plan dimensions should be laid out in a manner that will allow support of the formwork used to construct the substructure elements above it. This is accomplished by extending the footing at least 6 inches beyond the vertical face of the wall or stem.

Footing Thickness/Shear

The footing thickness should be sized such that shear reinforcement is not required. Use the simplified shear method of LRFD 5.8.3.4.1 when the requirement for zero shear within $3d_v$ from column/wall face is met. Otherwise, use the general procedure given in LRFD 5.8.3.4.2.

Footing Flexure Steel and "d" dimensions

For footings with a pile embedment of one foot or less, place flexural reinforcement on top of the cut off piles. For pile footings with an embedment greater than one foot, place reinforcement between the piles.

Dowel Detailing

Dowels connecting the footing to the substructure unit shall be detailed and dimensioned from working points. This reduces the chance of construction tolerances for pile driving and concrete placement impacting the final location of substructure components.

10.4.2 Footings Supported on Piling or Drilled Shafts

Dimension length of pile embedment into the footing in the plans. Identify battered piles with a symbol that differs from vertically driven piles.

Seal Design

A conventional cast-in-place seal is a mass of unreinforced concrete poured under water inside the sheet piling of a cofferdam. Refer to Figure 10.4.2.1. It is designed to withstand the hydrostatic pressure produced at the bottom of the seal when the water above is removed. Dewatering the cofferdam allows cutting of piles, placement of reinforcing steel, and pouring of the footing in a dry environment.

Design of the seal consists of determining a concrete thickness that will counterbalance the hydrostatic pressure with an adequate factor of safety. Design is done under the service limit state.

Lateral forces from stream flow pressure are resisted by penetration of the sheet piling below the streambed elevation and by the bracing inside the cofferdam. The cofferdam design is the responsibility of the contractor.

Use the following procedure for seal design.

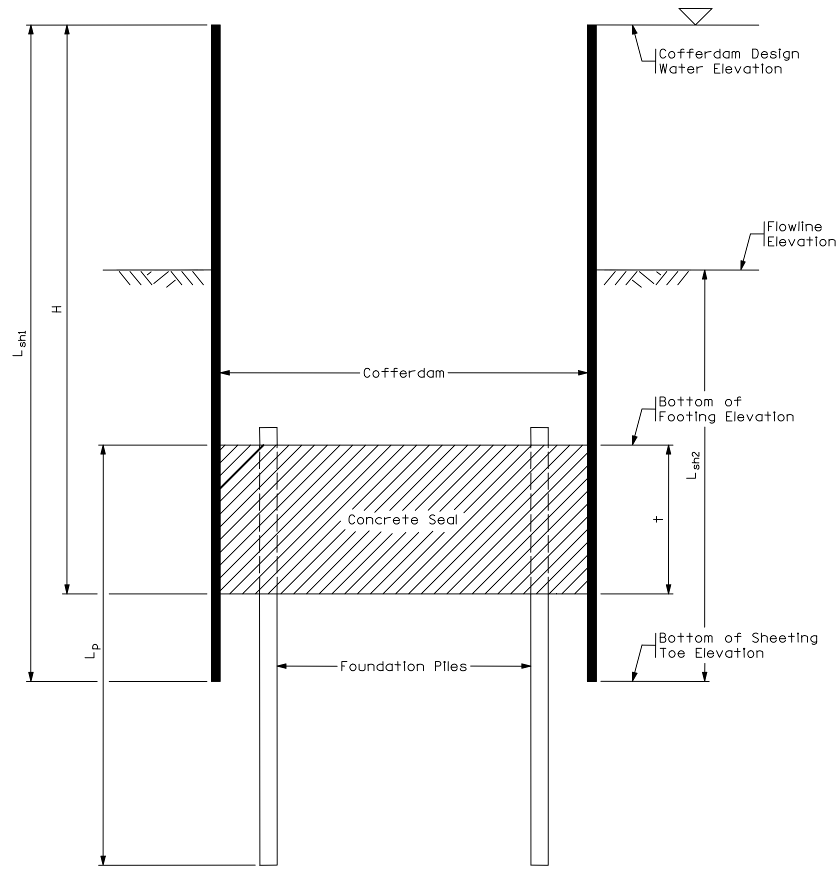

Figure 10.4.2.1

1) Determine preliminary dimensions:
   A rule of thumb for preliminary seal thickness is 0.25H for pile footings. The minimum allowed seal thickness is 3 feet. In plan, the minimum length and width of the seal is 1.5 feet larger than the footing on all sides, but it must also be large enough to avoid interference between sheet piling and battered piles.

2) Determine hydrostatic buoyancy force, P_b, due to hydrostatic pressure developed at the bottom of the seal:

$$P_b = H \cdot A \cdot \gamma_w$$

where $H =$ hydrostatic head, ft

$A =$ plan area of cofferdam minus area of piles, ft^2

$\gamma_w =$ unit weight of water, 0.0624 kips/ft^3

3) Determine resistance due to seal weight, R_{sc}:

$$R_{sc} = A \cdot t \cdot \gamma_c$$

where $t =$ thickness of seal, ft

$\gamma_c =$ unit weight of concrete, 0.150 kips/ft^3

4) Determine sheet pile resistance R_{sh}. This will be the smaller of:

sheet pile weight P_{sh} + soil friction on sheet pile P_{shsoil}

or

bond between sheet piling and seal P_{shseal}

$$P_{sh} = L_{sh1} \cdot p_{cof} \cdot \omega_{sh}$$

where $L_{sh1} =$ length of sheet piling in feet, normally based on sheet piling embedment of approximately H / 3

$p_{cof} =$ nominal perimeter of cofferdam, ft

$\omega_{sh} =$ weight per square foot of sheet piling, normally assume 0.022 kips/ft^2

$$P_{shsoil} = L_{sh2} \cdot p_{cof} \cdot f_{shsoil}$$

where $L_{sh2} =$ length of sheet piling below flowline in feet, normally based on sheet piling embedment of approximately H / 3 (choose conservative value for flowline elevation to account for scour or reduce by 5 ft)

$f_{shsoil} =$ friction of sheet piling with soil, normally assume 0.150 kips/ft^2

$$P_{shseal} = (t - 2) \cdot p_{cof} \cdot f_{shseal}$$

where $f_{shseal} =$ bond of sheet piling to soil, normally assume 1.0 kips/ft^2

5) Determine foundation piling resistance R_{pile}. This will be the smaller of:

foundation pile weight P_p + piling pullout resistance P_{ppull}

or

the bond between foundation piling and seal $P_{pileseal}$

The piling pullout resistance P_{ppull} is the smaller of:

soil friction on all individual piles $P_{pilesoil}$

or

soil friction on pile group P_{grp} + weight of soil in pile group P_{soil}

$$P_p = N \cdot \left[\omega_p \cdot L_p - \left(H + L_p - t\right) \cdot \gamma_w \cdot A_p\right]$$

where $N =$ number of piles

$\omega_p =$ non-buoyant weight per foot of an unfilled pile, kips/ft

$L_p =$ estimated pile length

$A_p =$ end bearing area of pile, sq ft

$$P_{pilesoil} = N \cdot A_{psurf} \cdot f_{pilesoil} \cdot \left(L_p - t\right)$$

where $A_{psurf} =$ surface area of pile per unit length, ft^2
(for H-piles, take $A_{psurf} = 2 \cdot$ (depth + width))

$f_{pilesoil} =$ friction between piles and soil, normally assume 0.150 kips/ft

$$P_{grp} = \left(L_p - t\right) \cdot f_{pilesoil} \cdot p_{grp}$$

where p_{grp} = perimeter of pile group, ft

$$P_{soil} = \left(L_p - t\right) \cdot A_s \cdot \gamma_{sb}$$

where $A_s =$ area of soil engaged by pile group, which is the group perimeter area defined by the outside piles minus the area of the piles, ft^2 (use perimeter at top of pile group)

$\gamma_{sb} =$ buoyant unit weight of soil, $0.040\ kips/ft^3$

$$P_{pileseal} = t \cdot N \cdot A_{psurf} \cdot f_{pileseal}$$

where A_{psurf} = surface area of pile per unit length, ft^2
(for H-piles, take $A_{psurf} = 2 \cdot$ depth·width)

$f_{pileseal}$ = friction between piles and seal, normally assume 1.0 $kips/ft^2$

6) Determine factor of safety, FS, and revise design as needed. The minimum required factor of safety is 1.2:

$$FS = (R_{sc} + R_{sh} + R_{pile}) / P_b$$

10.4.3 Spread Footings

Abutment spread footings supported on rock shall be keyed into rock a minimum of 6 inches. Shear keys should be added to spread footings when needed. Typical shear keys are 12" x 12" or 18" x 18".

To ensure proper bearing capacity below spread footings founded on rock with variable elevation, a 1C63 concrete fill may be placed on the rock to provide a level foundation. Refer to the Foundation Recommendations.

To ensure proper bearing capacity below spread footings not founded on rock, a layer of aggregate with 100% compaction may be specified under spread footings. Refer to the Foundation Recommendations.

Report maximum factored design load and factored bearing resistance in the plans using one of the Standard Plan Note tables shown in Appendix 2-H, Section F.

10.5 Pile Bent Piers and Integral Abutments

For pile bent piers, the pile tips should be driven a minimum of 10 feet below the scour elevation. The resistance of the piling needs to be checked for the condition where the predicted scour event has occurred. When debris loading can be excessive, encasing the piles with a concrete wall will be specified.

For integral abutments, orient H-piles for weak axis bending in the direction of movement and inform the Road Design group of the appropriate approach panel detail to include in the roadway plans.

For pile bent piers, provide 2'-0" of embedment into the cap. A larger pile embedment equal to 2'-6" is used for integral abutments.

10.6 Evaluation of Existing Pile Foundations when Exposed by Scour

The following guidelines may be used with discretion by registered engineers for determination of the stability of existing bridge substructure units supported by pile foundations (see Figure 10.6.1) if estimated scour depths are sufficient to expose piling. Estimated scour depths to be used are those furnished by the Hydraulics Engineer for the lesser of overtopping or a 500-year flood event.

1) For pile bent piers or abutments and for piers or abutments on footings supported by friction piling, the substructure unit is classified as stable with respect to scour if scour depth will not expose more than 50% of the embedded piling, and the unsupported pile length is not more than 24 times the diameter of cast-in-place pile, 24 times the nominal section depth of an H-pile, or 16 times the average diameter of a timber pile.
2) For pile bent piers or abutments or for piers or abutments on footings supported by end bearing piling, the substructure unit is classified as stable with respect to scour if at least 5 feet of the pile will remain embedded in dense material and the unsupported pile length meets the criteria in 1) above.

The substructure unit shall be considered stable if the foundation satisfies one of the above criteria. These guidelines are based on the concept that countermeasures will be taken where inspection reveals scour holes in the vicinity of pile bents or below the bottom of concrete footings. Pile exposures without lateral support will therefore be of relatively short duration.

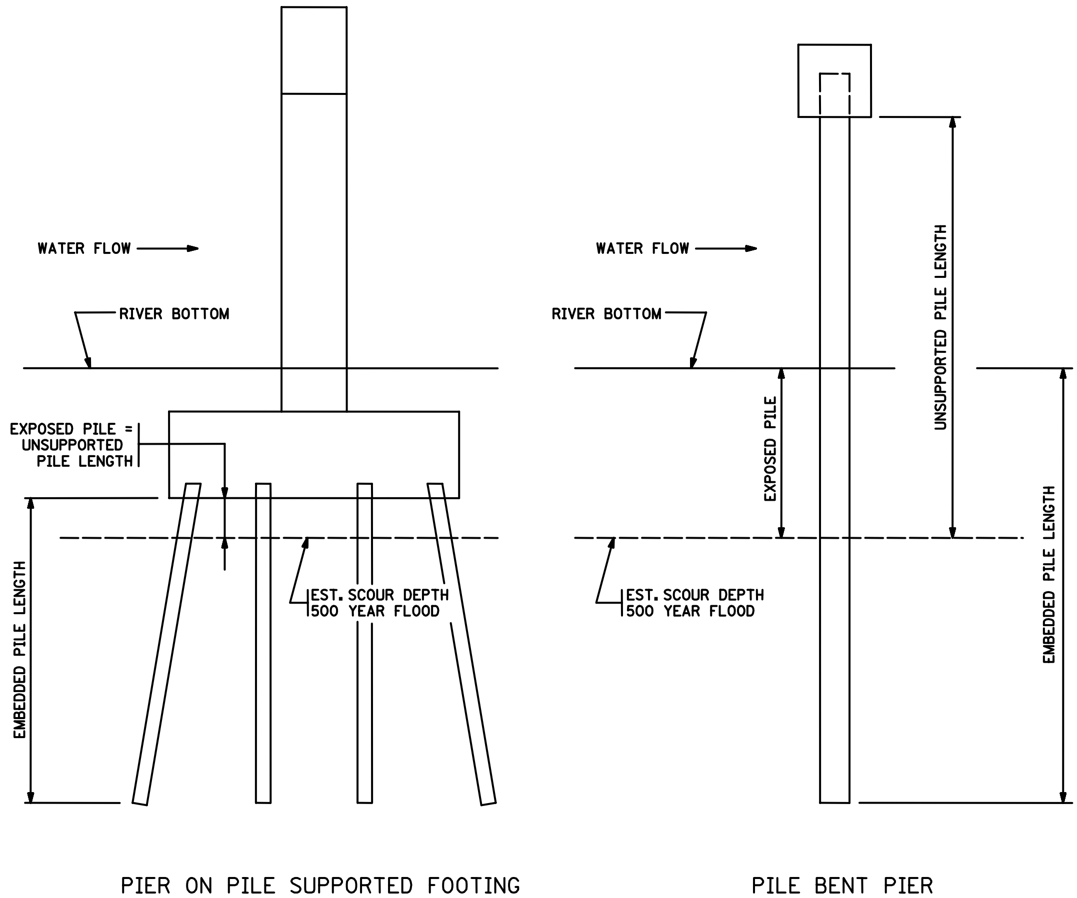

Figure 10.6.1

10.7 Structure Excavation and Backfill

For state aid projects, bridge designers must coordinate their excavation and fill quantities with roadway designers. This is particularly true for projects where grading is let as part of a separate contract. Designers should note the limits of excavation and fill noted in the standard bridge approach treatments (Mn/DOT Standard Plans 5-297.233 and 5-297.234).

The cost associated with excavating material, in and around foundations, depends on several items. These items include: access to the site, the amount of material that needs to be removed, the type of material to be removed (sand, silt, clay, rock, etc.), and the location of the water table. Mn/DOT's Spec. 2451 identifies and describes the standard classes (U, E, R, WE, WR) of excavation by the cubic yard.

Where no rock is present, use a lump sum pay item for structure excavation. The special provisions detail the percentage of excavation paid for at each substructure unit. Where rock is likely to be encountered, pay for the rock excavation as Class R (or WR for rock below water) by the cubic yard. Excavation above the rock is to be paid for as a lump sum. Refer to the Foundation Recommendations.

When aggregate backfill is used under spread footings, the additional excavation below the bottom of footing elevation is considered incidental to placing the backfill material.

Class R excavation may be used by itself, in which case it would cover all conditions of rock removal. When used in conjunction with WR, the lower limits of the Class R should be noted in the Plans as being the same as the upper limits of the WR (the lower water elevation shown in the Plans). Because rock excavation is expensive, adequate boring or sounding information is essential to determine the elevation of the rock surface. If the information furnished is insufficient to determine the elevation of rock, additional data shall be requested from the District.

Appendix 10-A

Sample Bridge Construction Unit Foundation Recommendations

FOUNDATION AND OTHER RECOMMENDATIONS
Bridge Construction Unit

Report No. 1630 Bridge No. 14816

Location 34th St over I-94 (Moorhead)

Substructure Unit	Approx. Station Along NB 34th St	Estimated Bottom Elevation of Footing or Bent Cap	*Factored Spread Footing Bearing Resistance Φq_n (tsf)	Factored Pile Bearing Resistance, ΦR_n (tons)	Pile Type and Size: Other	Pile Type and Size: Steel H	Pile Type and Size: C.I.P. Concrete	Estimated Pile Lengths: Test Piles No.	Estimated Pile Lengths: Test Piles Length	Estimated Pile Lengths: Foundation Pile Length
So. Abut.	125+67	906.0	–	100*-12" / 135*-16"			12"/16"	2	120'	110'
Pier 1	127+03	891.0	–	" "			" "	2	110'	95'
Pier 2	128+30	901.0	–	" "			" "	2	120'	105'
No. Abut.	129+25	907.0	–	" "			" "	2	120'	110'

*Based on Foundation Engineer's Recommendations dated ______ Scour Recommendations N. A.

- ☐ Use special pay items for piling
- ☐ Use thick wall pipe pile option
- ☐ Use the following pile tip protection
  - ☐ Pile points ______
  - ☐ Pile tip protection ______
- ☒ Use lump sum excavation item (except where rock excavation indicated)
- ☐ Excavation to be incidental (to 1A43 Concrete or other)
- ☐ Concrete seal required
- ☐ *Time delay recommended for approach embankment settlement:
  - ☐ ______ months
  - ☐ 72 Hrs.
  - ☐ None

Other Recommendations:

- ☒ Use special concrete placement procedures on deck pours (for skewed bridges, etc.)
- ☐ Paint color of exposed pile shells ______

☒ Remarks (Basis for above determinations):

The designer may use either 12"Ø, 0.25" wall thickness at ØRn = 100 tons, or 16"Ø 0.25" wall thickness at ØRn = 135 tons.
When considering downdrag loads, the designer may use the full structural capacity of the pile (204 tons for 12" CIP, or 310 tons for 16" CIP for ØRn).
The designer shall try to minimize the pile batter.
See the Foundations Engineers Memo regarding settlements – as much as 30" long term.
Include special provision language to require the use of the PDA to determine field pile resistance for all test piles.

Date preliminary received by reviewer 12/6/06 Reviewed by [signature] Concurred by BAI Date 12-13-06

cc: Foundations Engineer, Preliminary Plans Engineer (3 copies), & Program Clerk

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