

6.2 Piles

6.2.1 General

Piles directly support bridge substructure components. In addition to the information in this series of articles the designer should review the information for specific substructure components: abutments [BDM 6.5] and piers [BDM 6.6].

6.2.1.1 Policy overview

The office designs piles by the allowable stress design method with foundation information provided by the Soils Design Section.

Of the available pile types, the office most often specifies steel H-piles because of capacities and lengths required for support of substructure components. When using steel H-piles for integral abutments for pretensioned prestressed concrete beam (PPCB) and continuous welded plate girder (CWPG) bridges the office requires the HP 10x57 (HP 250x85) shape [BDM 6.5.1.1.1]. When using steel H-piles for integral abutments for continuous concrete slab (CCS) [and rolled steel beam \(RSB\)](#) bridges and for support of other substructure components the office prefers the HP 10x42 (HP 250x62) shape. To avoid construction errors the office prefers that only one of the two HP-10 (HP-250) shapes be used on a project [OBS MM No. 79].

For relatively short bridges where site conditions permit, the designer is encouraged to consider timber piles. For site conditions that favor displacement piles the designer is encouraged to consider prestressed concrete piles. Pile choices for typical substructure components are summarized in Table 6.2.1.1.

Table 6.2.1.1. Pile choices for support of substructure components

Substructure Component	Pile Choices ⁽¹⁾
Integral abutment	Steel HP 10x57 (HP 250x85) for PPCB and CWPG bridges, HP 10x42 (HP 250x62) for CCS and RSB bridges; timber for bridge lengths to 200 feet (61.000 m)
Stub abutment	Steel HP; timber; 12 inch (310 mm) prestressed concrete
Pier	Steel HP; timber; 12 inch (310 mm) prestressed concrete, steel pipe
Pile bent [OBS SS P10A]	Steel HP; 14 or 16 inch (356 or 406 mm) prestressed concrete, 14 or 16 inch (356 or 406 mm) steel pipe

Table note:

- (1) Although the choices generally are listed in order of preference the designer is encouraged to consider timber and prestressed concrete piles where appropriate.

On most Iowa bridge sites, piles derive their bearing capacity from friction and end bearing. In cases where piles bear on rock they shall be driven to seat into the rock a distance recommended by the Soils Design Section.

6.2.1.2 Design information

The soils design package provided for each bridge site by the Soils Design Section contains the soil logs needed for pile design [BDM 6.1.2], and the preliminary situation plan locates the borings. Design of piles shall be in accordance with the soils information chart prepared by the Soils Design Section [BDM 6.2.1.5] except as modified in this series of articles.

For specification, material, or construction information beyond the information in this manual and the soils information chart, the designer should consult the following sources. The publications are available from the offices listed and also are available on the Iowa Department of Transportation web site (<http://www.dot.state.ia.us>).

- Office of Specifications, *Standard Specifications for Highway and Bridge Construction, Series 2001*, Articles 2501, 4165, 4166, and 4167.
- Office of Materials, Instructional Memoranda, 467 and 467.02
- Office of Construction, Construction Manual and New Bridge Construction Handbook

6.2.1.3 Definitions

Natural ground elevation is the average natural ground elevation along the longitudinal centerline of the foundation.

6.2.1.4 Abbreviations and notation

CCS, continuous concrete slab

CMP, corrugated metal pipe

CWPG, continuous welded plate girder

MSE, mechanically stabilized earth

N or N-value, standard penetration test number of blows per foot (300 mm). N also may be given as **SPT NO**, the Standard Penetration Test Number, in the soils information chart reference.

PPCB, pretensioned prestressed concrete beam

RSB, [rolled steel beam](#)

6.2.1.5 References

Dirks, Kermit and Patrick Kam. *Foundation Soils Information Chart, Pile Foundation*. Ames: Iowa Department of Transportation, Office of Road Design, January 1989/September 1994. (Contact the Soils Design Section of the Office of Design for a copy of the publication.)

Office of Construction. *Construction Manual*. Ames: Office of Construction, Iowa Department of Transportation, 2001. (Available on the Internet at: <http://www.dot.state.ia.us/construction/index.htm>)

Office of Materials. *Inspection and Acceptance Pile Points for Steel H-Piles, Instructional Memorandum 467.02*. Ames: Office of Materials, Iowa Department of Transportation, 2002. (Available on the Internet at: <http://www.erl.dot.state.ia.us/>)

Office of Materials. *Inspection and Acceptance of Steel Piles, Instructional Memorandum 467*. Ames: Office of Materials, Iowa Department of Transportation, 2002. (Available on the Internet at: <http://www.erl.dot.state.ia.us/>)

Sunday, Wayne and Kyle Frame. *New Bridge Construction Handbook*. Ames: Office of Construction, Iowa Department of Transportation, 2000. (Available on the Internet at: <http://www.dot.state.ia.us/construction/structures.htm>)

6.2.2 Load application

Load application to piles must be considered with respect to the substructure component supported by the piles. Abutment and pier articles [BDM 6.5 and 6.6] cover additional load topics, and the designer should review those articles in addition to the articles below.

6.2.2.1 General

Most pile loads are transmitted directly from substructure components such as abutments, pier footings, and pile bent caps. For fully embedded piles, impact should be deducted from the vertical loads. If piles penetrate compressible soils and delays for consolidation are not permissible under the proposed construction schedule, downdrag forces shall be added to the vertical loads. If there is an anticipated horizontal movement in the soil surrounding a pile group, the designer shall consider lateral deflection and any associated lateral forces.

For standard abutment, footing, and pile cap details the office assumes axial vertical loads transmitted to piles. If nonstandard pile head details cause significant eccentricity, the designer shall consider the eccentric load in design.

6.2.2.2 Impact [AASHTO-I 3.8.1]

The AASHTO specifications [AASHTO-I 3.8.1] make the general distinction that impact shall be applied to the portions of piles that extend above ground but not to the portions of piles below ground. As a conservative design simplification, the office requires the designer to include impact for the entire length of a pile that has a portion unsupported by soil, such as a pile in a pile bent or an integral abutment pile in a prebored hole filled with bentonite slurry. However, the designer shall not include impact on a stub abutment pile in a prebored hole.

6.2.2.3 Downdrag

For soils that are labeled compressible in the soils package for the bridge project, the designer shall consider downdrag forces caused by negative skin friction. Downdrag forces add to the pile loads through negative skin friction if time is not allowed for the consolidation delay sometimes required for abutment berms [OBS MM No. 140].

When downdrag is to be considered the designer shall determine the following:

- Design load;
- Downdrag force from the soils chart without an additional safety factor;
- Pile length for design load plus downdrag force, embedment, and cutoff; and
- Total driving resistance [OBS MM Nos. 87 and 20].

See the revised memo [OBS MM No. 87] for an example of downdrag computations.

For steel H-piles the total driving resistance shall not exceed the force that would cause a stress of 12 ksi (83 MPa). If the driving resistance exceeds the force that would cause 9 ksi (62 MPa) the designer shall request a wave equation analysis for the piles from the Office of Construction.

The plans shall note the values for the following:

- Theoretical driving resistance,
- Resistance in and above compressible layers,
- Resistance for downdrag forces, and
- Resistance for the design load [OBS MM Nos. 87 and 20].

6.2.3 Service load groups and application to piles [AASHTO-I Table 3.22.1A]

In general, pile load groups and allowable stress increases are given in the AASHTO specifications [AASHTO-I Table 3.22.1A], but the designer shall consider the needed adjustments for impact and downdrag.

Piles supporting stub abutments shall be designed considering earth pressure and Load Groups I and IV as interpreted in this manual [BDM 6.5.2.4 and 6.5.3.1.1].

6.2.4 Analysis and design [AASHTO-I 4.5.1.3, 4.5.1.7]

Piles shall be designed by the allowable stress design method.

In general the design penetration for any pile should be a minimum of 10 feet (3.050 m) in hard cohesive or dense granular soil and a minimum of 20 feet (6.100 m) in soft cohesive or loose granular soil [AASHTO-I 4.5.1.3]. Piles driven through embankments should penetrate 10 feet (3.050 m) into original ground [AASHTO-I 4.5.1.7].

Piles shall be designed using the soils information chart prepared by the Soils Design Section [BDM 6.2.1.5]. The chart contains recommendations for pile design as well as an example pile length

determination in Appendix D. Depending on subsurface conditions, the pile capacity may be the accumulated skin friction capacity through several soil layers, the end bearing capacity at rock, the accumulated skin friction capacity plus end bearing capacity at rock [OBS MM No. 55], or the accumulated skin friction capacity plus end bearing capacity in soil.

Pile length shall be determined so that the design bearing value due to friction, end bearing, or a combination of friction and end bearing will be achieved below the lowest of the following elevations:

- Bottom of predrilled hole,
- Bottom of pile encasement,
- Bottom of compressible fill when berm consolidation delays are not permissible, or
- Probable scour elevation (piers).

Additional considerations for determining the pile length are the following.

- The heads of steel and timber piles shall be trimmed one foot (305 mm) to account for driving damage.
- Heads of piles shall be embedded in abutments, footings, bent caps, and pier caps the length given in the pile detailing article [BDM 6.2.5].
- Natural ground elevation is the average natural ground elevation along the longitudinal centerline of the foundation.
- Compressible soil layers can be expected to cause downdrag forces.
- The bentonite slurry [IDOT SS 2501.19] required for filling of a prebored hole for a pile shall be assumed to provide no vertical or lateral support to the pile. The slurry also shall be assumed to cause no downdrag forces.
- A pile battered no more than 1 horizontal to 4 vertical may be assumed to carry the same vertical load as a pile driven vertically; there need be no reduction for angle of the pile [OBS MM No. 9].
- If several pile types or sizes are feasible, the designer should determine the most economical alternative.

For steel H and timber piles, length shall be specified to the nearest 5-foot (1.500-m) increment. For prestressed concrete piles, length shall be specified to the nearest 1-foot (305 mm) increment, except that pile extensions shall be specified to the nearest 5-foot (1.500 m) increment.

Maximum centerline pile spacing shall be 8 feet (2.440 m), and minimum centerline pile spacing shall be 2.5 feet (760 mm). Based on soil conditions and additional rules below, piles shall be spaced at a centerline distance that does not exceed the maximum or minimum limits. The minimum centerline distance to a footing edge shall be 1.5 feet (460 mm).

When a mechanically stabilized earth (MSE) retaining wall is placed in front of integral abutment piles, the piles typically are sleeved with corrugated metal pipe (CMP). For compaction of the fill between the sleeves and placement of the metal strip reinforcing, a minimum clear distance of 24 inches (600 mm) is preferred. With the typical 24-inch (600-mm) diameter CMP and a 24-inch clear distance, the centerline pile spacing will be 4 feet (1.220 m). Therefore, the designer needs to consider the minimum pile spacing carefully for integral abutments behind MSE walls.

The office also requires 36 inches (900 mm) clear between the MSE wall and the CMP sleeves. The extra clearance is intended to permit compaction of the backfill and prevent the bentonite in the CMP sleeves from freezing.

The minimum number of piles for an integral abutment shall be based on one pile per beam.

For bridges longer than 130 feet (39.600 m) prebored holes are required for integral abutment piles. The standard depth of 10 feet (3.050 m) [MM No. 23] for a prebored hole may be increased to reduce or eliminate downdrag forces [OBS MM No. 14]. If a prebored hole has a depth greater than the 15 feet (4.570 m) permitted in the methods memo the designer shall check the pile as an unbraced column.

For integral abutments the office requires that all piles be driven vertically, but for all other substructure elements the designer should batter some of the piles as indicated on standard sheets. Typically the front row and wing wall piles for stub abutments, the perimeter piles for pier footings, and the end piles for pile bents should be battered. The preferred batter is 1 horizontal to 4 vertical, with 1 to 6 as an acceptable alternative for stub abutments and piers, and the preferred batter for pile bents is 1 horizontal to 12 vertical. The designer shall check battered piles for interference with existing and new foundations.

For T-pier foundations subject to scour, the designer shall check unsupported length and size of pile according to pier footing guidelines [BDM 6.6.4.1.3.1].

For each foundation the designer should attempt to use the minimum number of piles required for structural support. Individual pile layouts for each foundation are preferred, and the designer should not add extra piles to replicate foundations.

6.2.5 Detailing

Piles shall be embedded in substructure elements and shall have the head reinforcing listed in Table 6.2.5.

Table 6.2.5. Minimum pile embedment and pile head reinforcing

Substructure element	Minimum embedment	Pile head reinforcing
Integral abutment for A or B pretensioned prestressed concrete beams	2 feet (600 mm)	Spiral ⁽¹⁾
Integral abutment for C or D pretensioned prestressed concrete beams	2 feet (600 mm)	Spiral ⁽¹⁾ and bent p bars ⁽²⁾
Integral abutment for steel plate girders	2 feet (600 mm)	Spiral ⁽¹⁾ and bent p bars ⁽²⁾
Stub abutment on timber piles	2 feet (600 mm)	Spiral ⁽¹⁾
Stub abutment on steel piles	2 feet (600 mm)	None
Pier footing	1 foot (300 mm)	None
Continuous concrete slab pile bent cap (not monolithic with slab)	1.5 feet (460 mm)	None
Continuous concrete slab pile bent cap (monolithic with slab)	1 foot (300 mm)	Cap steel (bent dowels) ⁽³⁾

Table notes:

- (1) Spiral is placed around each pile head as detailed on standard sheets [OBS SS 2078-2098, 4426, (M2078-M2098, M4426)]. [Spiral should not be epoxy coated.](#)
- (2) For the bent p bars see the Abutment Pile Plan on standard sheets [OBS SS 2085-2091, (M2085-M2091)].
- (3) Cap steel (bent dowels) is detailed on standard sheets [OBS SS P10A, 4421-4425, (MP10A, M4421-M4425)]

For pier footings with reinforcing placed directly above H-pile, pipe pile, or timber pile heads, plans shall include a note requiring that all battered piles be trimmed to a horizontal line to aid in placement of reinforcement [OBS MM No. 117]. Prestressed concrete piles should not be trimmed.

Plans shall state the design bearing for piles in tons (kN). See standard notes [BDM 11.7.2 E720 (M720), E820 (M820)]. In many cases the design bearing will be less than the maximum allowable bearing value.

For projects for which downdrag forces are included in the pile design, the E833 (M833) note shall be included on the plans.

For projects involving the Excavate and Dewater bid item the E832 (M832) note shall be included on the plans.

6.2.6 Guidelines by pile type

For guidelines in selecting pile type for integral abutments see the guidelines in the integral abutment article [BDM 6.5.4.1.1].

6.2.6.1 Steel H

Steel H-piles shall be of material meeting ASTM A 572/A 572M Grade 50 (345) [IDOT SS 4167.01], unless an exception is approved by the supervising Section Leader.

Steel H-piles are feasible in most Iowa soils and may be designed for end bearing, friction bearing, or a combination of end and friction bearing. Allowable vertical loads for steel H-piles laterally supported by soil shall be determined using the end bearing and friction charts in the soils information chart [BDM 6.2.1.5]. Piles that tip out in soil ~~generally should~~ shall have a maximum allowable stress of 6000 psi (41 MPa), which is a rule intended to limit settlement. The Soils Design Section may recommend a higher allowable stress for H-piles in granular materials with N-values above 100, unless special approval for a higher allowable stress is given by the Soils Design Section.

In general steel H-piles driven for bearing in bedrock shall be designed for end bearing only. However, for H-piles designed to be seated in bedrock with N-values of 100 ~~or more to 200~~, the pile friction capacity may be included if soil layers have suitable capacity [OBS MM No. 55], and the use of combined friction and end bearing capacity is approved by the Soils Design Section.

Steel H-piles Piles driven to rock shall have the following a maximum allowable axial stress.

- ~~of 6000 psi (41 MPa) for end bearing on rock with N-values of 100 to 200.~~ Piles shall have a maximum allowable stress of
- 9000 psi (62 MPa) for end bearing on rock with N-values greater than 200,
- 9000 psi (62 MPa) for friction plus end bearing on rock with N-values of 100 to 200, with approval of the Soils Design Section,
- 12,000 psi (83 MPa) and for pier piles with friction plus end bearing on rock with N-values greater than 200, with drivability analysis during design and approval of the Soils Design Section and Assistant Bridge Engineer, and-
- 12,000 psi (83 MPa) for pier piles with end bearing on rock with N-values greater than 200, with drivability analysis during design and approval of the Soils Design Section and Assistant Bridge Engineer.

The 12,000 psi (83 MPa) allowable stress is a special case not included in the soils information chart and is to be used only in cases identified by the Soils Design Section or a geotechnical consultant. Before using the 12,000 psi (83 MPa) stress an Office of Bridges and Structures designer or consultant designer shall contact the Office of Construction for the wave equation drivability analysis.

-Table 6.2.6.1 gives the maximum allowable loads for typical pile shapes at ~~several~~ the maximum allowable stresses. Higher loads may be permissible if bearing is verified by a pile load test. The plans for a specific bridge shall note the actual required bearing capacity.

Table 6.2.6.1. Maximum allowable vertical loads for typical H-piles

Pile Size	Maximum Allowable Load		
	At 6000 psi (41 MPa)	At 9000 psi (62 MPa)	At 12,000 psi (83 MPa)⁽²⁾
HP 10x42 (HP 250x62)	37 tons (328 kN)	55 tons (496 kN)	74 tons (656 kN)
HP 10x57 (HP 250x85)	50 tons (443 kN)	75 tons (670 kN)	100 tons (886 kN)
HP 12x53 (HP 310x79) ⁽¹⁾	46 tons (410 kN)	70 tons (620 kN)	92 tons (820 kN)
HP 14x73 (HP 360x108) ⁽¹⁾	64 tons (566 kN)	96 tons (856 kN)	128 tons (1132 kN)
HP 14x89 (HP 360x132)	78 tons (693 kN)	117 tons (1048 kN)	156 tons (1386 kN)

Table notes:

- (1) The HP 12x53 (HP 310x79) and HP 14x73 (HP 360x132) shapes are noncompact at a yield stress of 50 ksi (345 MPa) and shall not be used in integral abutments [OBS MM No. 79].
- (2) [An allowable stress above 9000 psi \(62 MPa\) is permissible only for pier foundations and requires a drivability analysis during design, as well as approval of the Soils Design Section and Assistant Bridge Engineer.](#)

For steel H-piles in P10A (MP10A) pile bents, standard sheets [OBS SS P10A (MP10A)] give the maximum allowable loads.

Steel H-piles driven to bedrock should penetrate the surface of the rock to depths [recommended by the Soils Design Section](#) in the soils information chart [BDM 6.2.1.5], [unless the Soils Design Section recommends otherwise](#).

For sites where adequate bearing can be achieved above bedrock, steel H-piles shall be designed using the friction and end bearing recommendations in the soils information chart [BDM 6.2.1.5]. If piles tip out in granular material with N-values less than 25, end bearing capacity shall be neglected. In cases where piles are projected to achieve bearing within 5 feet (1.524 m) of bedrock the designer should consider driving the piles to rock.

The designer should consider using approved driving points [OM IM No. 467.02] if H-piles must be driven through soil layers containing boulders or if piles must be driven into sloping rock surfaces. Verify the need for driving points with the Soils Design Section. If points are needed, note the requirement on the plans [BDM 11.7.2 E722, E821].

In the absence of special analysis, the maximum allowable shear load at the head of a steel H-pile shall be 6 kips (27 kN). The allowable horizontal component of a battered pile may be added to the allowable shear load.

6.2.6.2 Concrete-filled steel pipe

In general, concrete-filled steel pipe piles are not economical for typical Iowa bridges and have been used recently only at contractor request as a substitution for steel H-piles.

If the designer selects concrete-filled steel pipe piles for P10A (MP10A) pile bents, materials, details, and maximum allowable loads shall be as specified on standard sheets [OBS SS P10A (MP10A)]. Construction shall be conducted in accordance with the standard specifications [IDOT SS 2501.04].

Driving points may be needed for pipe piles in some soil conditions. The designer shall verify the need for driving points with the Soils Design Section.

6.2.6.3 Timber

Timber piles for permanent foundations shall be treated and shall meet the requirements in the standard specifications [IDOT SS 4165].

Although the soils information chart indicates otherwise, timber piles now are considered feasible only in soils with N-values of 25 or less. Timber piles shall not be used in soils that contain boulders, and timber piles for support of bridge substructure components shall not be used for bearing on rock.

The maximum timber pile length shall be 55 feet (16.760 m), and the minimum pile length shall be 20 feet (6.100 m), with intermediate lengths in 5-foot (1.500-m) increments.

Because allowable bearing values for timber piles are dependent on pile length, it may be necessary to determine pile length prior to designing an abutment or pier. Because of indeterminate bending stresses, for integral abutments the maximum bearing value for a timber pile shall be 20 tons (178 kN). For stub abutments and piers the maximum bearing value shall be 20 tons (178 kN) for piles 20 to 30 feet (6.100 to 9.150 m) long and 25 tons (222 kN) for piles 35 to 55 feet (10.670 to 16.760 m) long. The bearing values for a specific bridge project shall be verified with the friction and end bearing charts in the soils information chart [BDM 6.2.1.5]. The plans shall note the actual required bearing capacity.

For bridges with integral abutments and lengths of 150-200 feet (45.700-61.000 m) the heads of timber piles shall be wrapped with padding as detailed on standard sheets [OBS SS 2078-2084 (M2078-M2084)]. No padding is required if the bridge length is less than 150 feet (45.700 m).

In the absence of special analysis, the maximum allowable shear load at the head of a timber pile shall be 4 kips (18 kN). The allowable horizontal component of a battered pile may be added to the allowable shear load.

For large projects with 1500 feet (457.200 m) or more of timber piles and especially when piles tip into soft material with N-values of 10 or less, the designer should consider requiring a test pile or a pile load test. A test pile or a pile load test should be located in a relatively dry abutment or pier footing but not in a prebored hole or in a cofferdam.

Timber piles should be fitted with metal driving shoes only when recommended by the Soils Design Section. Figure 6.2.6.3-1 gives the driving shoe detail for timber piles less than 40 feet (12.190 m) in length, and Figure 6.2.6.3-2 gives the detail for piles 40 to 55 feet (12.190 to 16.760 m) in length.

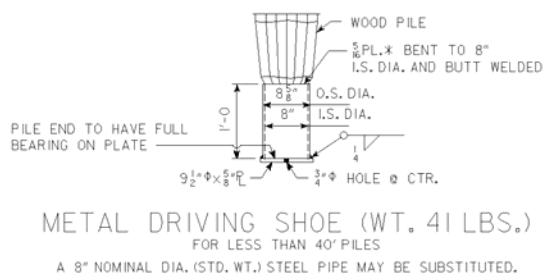


Figure 6.2.6.3-1. Metal driving shoe for timber piles less than 40 feet (12.190 m) in length

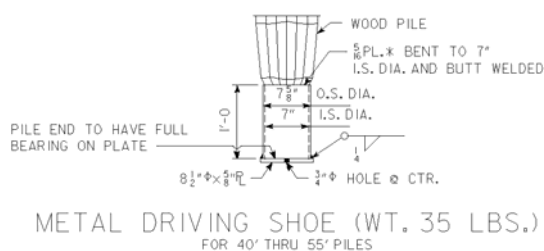


Figure 6.2.6.3-2. Metal driving shoe for timber piles 40 to 55 feet (12.190 to 16.760 m) in length

6.2.6.4 Prestressed concrete

Prestressed concrete bearing piles shall meet the material, strength, and other requirements of the standard specifications [IDOT SS 2407].

The designer may consider 12-inch (310-mm) square prestressed concrete piles for support of piers and stub abutments but not for integral abutments [OBS SS 1046 (M1046)]. Prestressed concrete piles 14 or 16 inches (360 or 410 mm) square are an option for pile bents as detailed and noted on standard sheets [OBS SS P10A (MP10A)].

Prestressed piles are feasible only in soils that permit displacement piles and soils that provide adequate bearing through friction or a combination of friction and end bearing. General guidelines are to avoid using prestressed concrete piles in very firm glacial clay with standard penetration test blow counts above 20 and to avoid using prestressed concrete piles in any soil with blow counts above 30. Prestressed piles shall not be used in soil with an N-value greater than 40. The soil layer at the tip of the pile shall have an N-value in the 25 to 40 range, with no boulders.

The designer shall consult with the Soils Design Section regarding the need for steel driving points.

Allowable vertical loads for prestressed concrete piles laterally supported by soil shall be determined using the end bearing and friction charts in the soils information chart [BDM 6.2.1.5]. Regardless of capacity determined from the soils information chart, the maximum capacity for 12-inch (310-mm) square piles detailed on standard sheets [OBS SS 1046 (M1046)] shall be limited to 50 tons (450 kN). Maximum capacities for 14-inch (360-mm) and 16-inch (410-mm) square piles are given on standard sheets [OBS SS P10A (MP10A)]. The plans for a specific bridge shall note the actual required pile bearing capacity.

The maximum length of an individual 12-inch (310 mm) foundation pile section shall be 55 feet (16.760 m). When piles longer than 55 feet (16.760 m) are required, pile splices shall be used to fasten pile sections together. Only one splice will be allowed for overall pile lengths in the 56 to 110-foot (17.070 to 33.500 m) range. Pile sections shall be welded together at the splice after the first section is driven.

Standard sheets [OBS SS 1046 (M1046)] require a steel splice plate on the driving end of the pile. Pile suppliers can be expected to provide 5-foot (1.525-m) and 10-foot (3.050-m) extensions for splicing a pile that does not achieve required bearing at the expected depth.

Top portions of 12 inch (310 mm) prestressed concrete piles to be embedded in stub abutment or pier footing concrete shall be roughened, after driving, by sandblasting or other approved methods to improve bond between piles and footing [OBS SS 1046 (M1046) and IDOT SS 2403.14].