Guidelines for the Use of Steel Piling for Bridge Foundations

TxDOT Steel Piling Task Force:

Michael Hyzak, P.E.
Marcus Galvan, P.E.
Marie Fisk, P.E.
Amy Smith, P.E.
Dennis Johnson, P.E. (HOU)
Denzel Caldwell, E.I.T.
Johnnie Miller, P.E. (CST)
TxDOT Bridge Division

Published October 24, 2014. © 2014 Texas Department of Transportation.

Introduction

TxDOT bridge substructures are supported by a variety of methods. The most common are:

- drilled shafts
- prestressed concrete square piling
- steel H-piling

Less common are:

- steel round piling
- steel pipe piling
- sheet piling abutments
- prestressed concrete cylinder piling
- reinforced concrete spread footings

Among the advantages of steel H-piling are: easier driving when overburden is very stiff or contains cobbly features; high point bearing resistance; easier shipping and handling; and easier build-up or cut-off in the field. Generally displacement piles (such as prestressed concrete piles and closed ended steel pipe piles) are better at obtaining the required driving resistance than non-displacement piles (such as steel H-piles and some open-ended pipe piles). In stiff soils, displacement piles often require pilot holes and/or jetting to facilitate installation and avoid the increased risk of damage. In such cases, non-displacement piles are often a better choice, since they advance more easily and may avoid damage. Steel piling can be designed to avoid damage in riskier profiles if pile tip reinforcement (shown on the FD standard) is specified and proper installation practice is followed. Steel piling does require additional measures such as coatings and sacrificial thickness to overcome the long-term tendency of steel to corrode in certain environments.

The purpose of this document is to provide guidance on the use of steel piling for bridge foundations. Additional background information on current design and specification practices for piling usage can be found in the Background section of this document.

Pile Material Guidance

Common pile types that can be used effectively for Texas bridges include steel H-piling and square prestressed concrete piling.

Considerations for Steel and Concrete Piling

When piling is in contact with soil or water known to be corrosive, both prestressed concrete and steel piling require corrosion mitigation measures. Prestressed concrete requires High Performance Concrete (HPC) when used in potentially corrosive environments. The precompression built into prestressed concrete piling to resist tensile stresses during installation, does have the secondary benefit of having a generally crack free element in service. Steel piling requires coatings and sacrificial thickness in potentially corrosive environments. AASHTO R 27-01 "Standard Practice for Assessment of Corrosion of Steel Piling for Non-Marine Applications" provides guidance on assessing the corrosion risk of a project location. AASHTO LRFD 10.7.5 provides additional guidance, as well.

Being a displacement element, prestressed concrete piling is generally better suited than steel H-piling for use in loose to medium density sands and weak clays. This is due to the potential difficulty in obtaining driving resistance, and the possible long lengths requiring very long stiff sections. Steel H-piles are suitable when driving through stiff clays or gravels to get to a harder bearing strata and when difficult or erratic driving is anticipated in the upper materials, which must be penetrated for stability. Steel H-piles are also well-suited for designs relying on point bearing, though measurable skin friction can be mobilized as well. For perimeter and area calculations—i.e., skin friction and point bearing, respectively—assume the H-pile acts as an equivalent square. Research has shown that H-piling act as an equivalent square when load tested. Chapter 5 of the Geotechnical Manual provides guidance and considerations for determining foundation lengths. Please contact the Geotechnical Branch of the Bridge Division for additional guidance.

Steel H-piles lend themselves to ease of buildup and cut-off, which is desirable in profiles where there are significant uncertainties of the final length versus the specified length. Contact the Bridge Geotechnical Section if assistance is needed to determine whether a given soil profile might pose such an uncertainty and warrant steel piling.

Protective measures, i.e. protective coatings and sacrificial steel thickness must be used if steel piling are used in areas that are known to have high salt, chlorides, or sulphate levels in the soils. TxDOT's current specifications require an inorganic zinc primer currently as a minimum level of protection.

Pile Use Recommendations by Bridge Site:

Grade Separations

Trestle bents are not recommended for grade separation bridges, since they are seen as vulnerable to vehicular impact. Both steel and concrete piling can be used for pile-supported footings and abutments in grade separation bridges. If recent historical cost data doesn't clearly point to one pile material having an advantage over the other, provide alternate designs with both steel and concrete to ensure low construction cost.

Stream Crossings

Foundation elements for stream crossings are subject to scour, drift impact, and corrosion. Both steel and concrete piling can be used for stream crossings, with some restrictions. For instance, trestle bents should not be used in streams if the scour analysis predicts excessive exposed pile length during the expected structure life, where there is evidence or history of drift load; or, in the case of steel pile trestle bents, in certain environments without considering corrosion and need for coatings and sacrificial thickness. Likewise, pile-supported footings should not be used for stream crossings if the scour analysis indicates the piling would be exposed excessively during the expected structure life.

When using steel piling for stream crossings, it is recommended to require, by plan note, that the piling be coated to a minimum depth of 15' below the maximum predicted scour elevation (for trestle bents), and for 15' below the bottom of footings (for pile supported footings). The specified coating can be found in Item 407 “Steel Piling.” Both steel and prestressed concrete piling can be used for stub-type abutments in stream crossings.

If used on bridges with high salt, chloride, or sulphate levels in the soil, steel piling must use sacrificial thickness in addition to coatings. Sacrificial thickness and coatings guidance is shown in Table 1.

Table 1. Steel Piling Corrosion Protection for TxDOT Bridges

Steel Component	Location and Embedment	Corrosion Protection	Sacrificial Thickness required (in.)		
			Nonaggressive	Moderately Aggressive	Extremely Aggressive
H-piles and Pipe piles	On land or under water, completely buried in ground	None (See Note)	0.0	0.15	0.225
	On land, partially buried in ground	Per Item 407	0.0	0.18	0.27
	In water, partially buried in ground	Per Item 407	0.09	0.18	Not allowed

Values in table are for a design life of 75 years.
Moderately aggressive – swamp; bayou waters; sulfate or chloride soils
Extremely aggressive – industrially polluted soils

Note 1: Corrosion Protection per Item 407 is recommended for multi-pile footings in stream environments.

Note 2: If sacrificial thickness is required, a pile section other than that shown on the standards must be used. As an example, the BTIG-24 standard which covers Trestle Bents for Tx28 through Tx54 girders on a 24' roadway indicates that bents up to 20 ft tall require either 18" Prestressed Concrete Piling or HP 14 x 117 Steel Piling. Looking up pile dimensions in an AISC Steel Manual or vendor catalog, the flanges and webs of an HP 14 x 117 are 0.805 in. In a swamp or bayou with trestle bents in the water, the table would direct the user to an In Water, Partially Buried in Ground Condition in a Moderately Aggressive environment. This requires 0.18" of additional thickness as well as corrosion protection using inorganic zinc primer as noted in Item 407. An H-pile with a flange and web thickness of 0.985" minimum is required. Since HP 14 x 117 is the largest size of the HP14 class, an HP 16 x 162 which has 1.000" thick flanges and webs is required.

Bay Crossings

Prestressed concrete piling fabricated with HPC is recommended for all bridges in salt water, with the exception that steel piling may be considered if the final installation condition keeps the piling out of the oxygenated zone. Steel sheet piling using marine coatings described in the draft Item 407 “Steel Piling” specification for the *2014 TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges* is sufficient for salt-water application. Typical applications for sheet piling in this environment are bulkhead and dolphin structures and generally have a shorter design life than bridge structures. The marine coating is not recommended to be used on H-pile supported bridges in a saltwater environment at this time, until further evidence of long term reliability is available. An exception to this recommendation is the use of steel piling (typically round instead of H-piling) in dense coastal sands where driveability of concrete piling is a concern, provided that the piling final installation condition keeps the piling out of the oxygenated zone. For example, the main piers of the Galveston Bay Causeway and Quintana segmental bridges over saltwater bays were founded on 24" diameter steel pipe piles below a footing at the waterline.

Structural Design of Steel Piling

Designers shall use provisions of AASHTO LRFD 6.15 for the structural design of steel piling for in-service conditions. Higher stresses during driving are permitted by the provisions of AASHTO LRFD 10.7.8. Sacrificial thickness as outlined in Table 1, Steel Piling Protection for Waterway, only needs to be considered for the long term in-service condition and not for the temporal condition during driving. Refer to Chapter 5 of the TxDOT Geotechnical Manual for guidance on determining piling length based on skin friction and point bearing, which is a departure from methods in AASHTO LRFD.

Piling Alternates in PS&E

To ensure the most economical pile type is used for TxDOT projects, designers should evaluate steel piling alternates to prestressed concrete piling. This requirement will be limited to certain conditions for projects letting in September 2015 or later. The Bridge Division will work collaboratively with Districts to identify pilot projects for earlier lettings. These conditions include:

- All single-span bridges regardless of type
- All grade-separation structures
- Select multi-span stream crossings (as collaboratively determined by the Bridge Division and District) that follow the pile recommendations with regard to durability provisions

Case-by-case exceptions to this requirement will be allowed if written justification is submitted to the Bridge Project Development Section during 30% Preliminary Layout Review. Exceptions might be pursued due to not having an alternate design in the scope for consultant designs already underway, or due to a clear technical or cost consideration that makes steel piling impractical. Bid codes and tracking methods are being developed under the new 2014 Specifications Book to capture the relative bids of piling when bid as alternates against one another, as well as to capture the cost of corrosion mitigation measures.

Choosing Between Drilled Shafts and Piling

Soil conditions in large parts of Texas are more conducive to drilled shafts as an appropriate foundation choice. However, drilled shafts can be problematic in high-risk soil profiles such as water-bearing sands and hard strata overlaid with loose overburden. During 30% Preliminary Layout Review, the Bridge Geotechnical Section actively evaluates such higher risk installations where drilled shafts are specified. This review will either recommend a change in foundation type (prestressed concrete and steel H-piling) or provide a piling alternate to the drilled shafts. Steel piling may be included as one of the alternates. The drilled shaft primary bid will include enhanced notes notifying the contractor of specific conditions of concern in the borings and enhanced construction requirements for the drilled shafts. Bid codes and tracking methods are being developed under the new 2014 Specifications Book to capture the relative bids of drilled shafts versus piling when bid as alternates against one another.

Background

Current TxDOT Practices

TxDOT practices are described in the manuals and web-based documents listed below.

1. Title: *Geotechnical Manual*
   URL: http://onlinemanuals.txdot.gov/txdotmanuals/geo/geo.pdf

   Chapter 3 of this manual covers the Texas Cone Penetrometer (TCP) test, among other soil investigation features. Chapter 5 of this manual covers Foundation Design, including Section 1 on Foundation Type Selection, Section 2 on Interpretation of Soil Data, and Section 4 on Piling. Section 1 states: "The use of steel piling in corrosive environments is not recommended … if steel piling must be used, an appropriate protective coating must be selected, additional steel section provided or a combination of these methods utilized to ensure proper performance of the foundation elements." Section 4 discusses the method for setting foundation lengths for piling. Section 4 includes a discussion of Steel Piling Special Considerations which include:

   - The use of steel trestle piles for grade separations is discouraged due to potential vehicle impact.
   - Trestle steel piles for stream crossings may be considered when scour analysis indicates load carrying capacity is not compromised, where there is no history of drift, or where no highly corrosive soil/water exists.
   - Piling in stream crossings must be coated a minimum of 15' below the maximum predicted scour elevation for trestle bents and 15' below footing for pile supported footings.
   - No restrictions are placed on the use of piling at abutments or under pile supported footings regardless of type of crossing, except steel pile supported footings in stream crossings must be set below the maximum predicted scour depth.

2. Title: *Pile Type Selection - Geotech*
   URL: http://ftp.dot.state.tx.us/pub/txdot-info/brg/pile_type.pdf

   This content is proposed to be replaced by the Pile Material Guidance indicated previously.

3. Title: *Construction Bulletin C-8: Pile Driving Manual* (1979, Under revision 2014)
   URL: http://crossroads/org/brg/TS/Papers/Pile%20Driving%20Manual.pdf
   Request a copy from the Bridge Division Geotechnical Section if not a member of TxDOT staff.

The May 1979 TxDOT Pile Driving Manual still resides on the TxDOT Bridge Division's Intranet site and does give some more detailed information with regard to pile selection. It does indicate that steel H-piling is generally used where it is necessary to penetrate through or into strata of high-bearing resistance such as gravel, sand, shale, etc., but it is versatile enough to be used in other conditions.

4. Title: *Bridge Standards* (see sections on Trestle Bents and FD)
   URL: http://www.txdot.gov/insdtdot/orgchart/cmd/cserve/standard/bridge-e.htm

   TxDOT maintains a series of bridge standards, including those for substructure elements. For nearly the entire range of superstructure types with standards for given widths, the substructure standards have both drilled shaft/column and trestle pile bent options using both prestressed concrete piling and steel piling. The predominant sizes of steel trestle piling in these standards include HP 14 x 73, 14 x 117, and 18 x 135 depending on the application. These sizes do not include provision for sacrificial thickness at this time. The Common Foundation Details (FD) standard includes standard drilled shaft details, piling batter, orientation and embedment, steel H pile tip reinforcement and field splicing, and multi-pile footing details.

5. Titles: TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges (2004)

   Special Provision 407---001 “Steel Piling”

   400 Items: Structures (Draft TxDOT Standard Specifications 2014)

   URL: http://ftp.dot.state.tx.us/pub/txdot-info/des/specs/specbook.pdf

   URL: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/specs/2004/prov/sp407001.pdf

   URL: http://ftp.dot.state.tx.us/pub/txdot-info/des/specs/400-item-series.pdf

   The TxDOT Specification Book (2004) has a standard specification and pay item for steel H-piling and steel sheet piling under Item 407. Item 407 includes specifications for material type/grade, construction/fabrication practice, and painting. The 2004 Specification Book is currently in force until the 2014 version being developed is released.

   For H-piles, the 2004 Specification Book calls for ASTM A572 Grade 50 or ASTM A588 materials and allows for shop welding of up to three sections of minimum length 5 ft. The specification calls for shop-painting piling with 3 mils minimum dry film thickness of inorganic zinc primer in accordance with the TxDOT System III or IV paint system specification in Item 446 "Cleaning and Painting Steel." No other intermediate or appearance coatings are required unless indicated otherwise in the plans. The specification indicates to paint the portion of the pile to be above ground, in water, and a minimum distance of 10 ft below ground based on the ground line shown in the plans. It should be noted that the 10 ft minimum distance is not consistent with the 15 ft requirement of the current TxDOT steel piling guideline, nor makes mention of considering the maximum scour depth.

For H-piles, the draft steel piling specification for the 2014 Specification Book calls for ASTM A690 or ASTM A572 Grade 50 materials. Do not use unpainted ASTM A588 weathering material for piling (was formerly in 2004 Specification Book). Weathering steel does not perform well in pile foundation applications. As previously stated, the specification calls for shop-painting piling with 3 mils minimum dry film thickness of inorganic zinc primer in accordance with the TxDOT System III or IV paint system specification in Item 407 "Steel Piling" and Item 441 "Steel Structures." No other intermediate or appearance coatings are required unless indicated otherwise in the plans. The specification indicates to paint the portion of the pile to be above ground or dredge line, in water, and a minimum distance of 15 ft below finished grade or dredge line ground based on the ground line shown in the plans. For marine environments, the specification requires a marine-grade immersion coating system meeting the requirements of NORSOK Standard M-501 Coating System No. 7. The NORSOK standards were developed by the Norwegian petroleum industry for the selection of coating materials, surface preparation, application procedures and inspection for protective coatings to be applied during the construction and installation of offshore installations and associated facilities. As noted earlier, trestle H-pile supported bridges in marine environments with these enhanced coatings are not recommended until TxDOT determines sufficient performance data is available.

Historic TxDOT Usage of Steel Piling and Performance

<u>Usage of Piles on TxDOT Bridges</u>

As indicated in Figure 1, TxDOT has 25 Districts geographically distributed across the state. The Bridge Division used National Bridge Inventory data to look at both on-system and off-system bridge populations to look at geographic usage trends with regard to the piling used. The collected data was also sorted into the type of piling substructure, including:

- Trestle pile bents with concrete piles
- Trestle pile bents with steel piles
- Footings with concrete piles
- Footings with steel piles

Among the key numbers indicated, pile-supported bridges represent 17.8% and 16.8% of our total bridge inventory in the on-system and off-system populations, respectively. The remaining 82%+ are supported on drilled shafts or non-pile footings. For the cases of the pile-supported bridge population, 60% of these bridges are supported by concrete piles in a trestle pile bent configuration. Steel trestle pile bents are used more significantly in the off-system environment with 37% of all pile-supported bridges, compared to only 13% in the on-system environment. For bridges with footings that are supported by piles, concrete was used 3.3 times more often than steel in the on-system environment. Not surprisingly, the off-system environment has virtually no pile-supported footings since these are typically stream bridges with short heights, a logical trestle pile situation. Tables 1 through 4 give detailed information of this analysis.

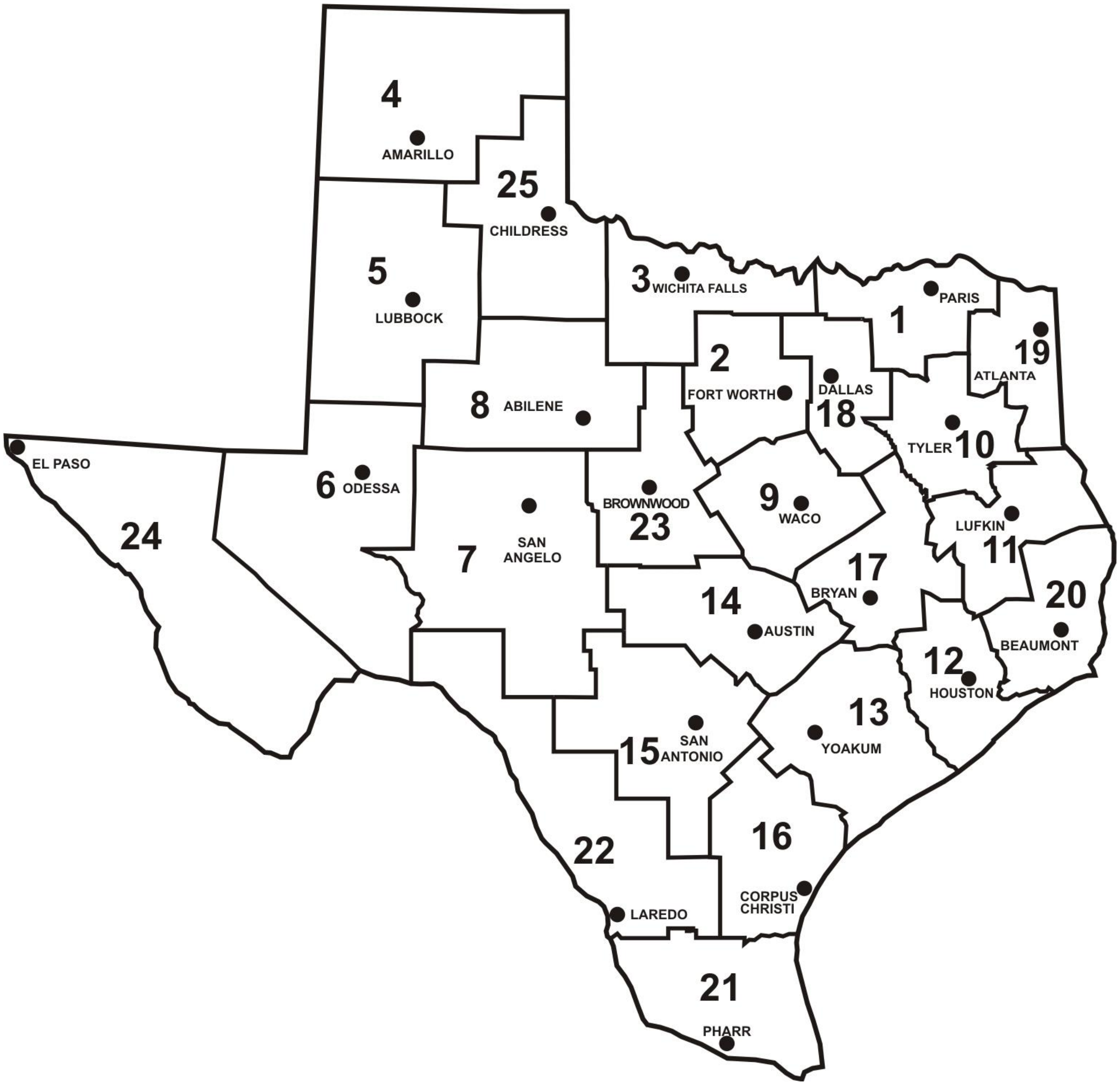

Figure 1. TxDOT Districts

Table 2. TxDOT On-System Bridge Usage of Piling (NBI Data) Showing Number of Bridges Using Piles and Geographic Percentages

District	Concrete Trestle	Steel Trestle	Conc under Ftg	Steel under Ftg	Total	Share of Statewide Pile Usage
Abilene	29	21	3	12	65	1.1%
Amarillo	52	74	2	11	139	2.3%
Atlanta	223	12	38	9	282	4.6%
Austin	67	38	11	13	129	2.1%
Beaumont	382	20	156	24	582	9.6%
Brownwood	25	27	2	2	56	0.9%
Bryan	297	69	21	24	411	6.8%
Childress	33	78	5	16	132	2.2%
Corpus Christi	235	41	138	4	418	6.9%
Dallas	88	78	4	33	203	3.3%
El Paso	104	20	48	14	186	3.1%
Fort Worth	30	19	3	0	52	0.9%
Houston	626	7	472	13	1118	18.4%
Laredo	54	1	1	4	60	1.0%
Lubbock	6	0	0	0	6	0.1%
Lufkin	233	45	12	7	297	4.9%
Odessa	16	4	8	0	28	0.5%
Paris	165	74	0	0	239	3.9%
Pharr	152	0	125	0	277	4.6%
San Angelo	8	3	0	0	11	0.2%
San Antonio	92	16	13	41	162	2.7%
Tyler	342	22	5	44	413	6.8%
Waco	72	63	0	1	136	2.2%
Wichita Falls	31	19	4	5	59	1.0%
Yoakum	397	36	110	80	623	10.2%
Total	**3759**	**787**	**1181**	**357**	**6084**	
Pct Usage by Type Statewide	**61.8%**	**12.9%**	**19.4%**	**5.9%**		

Table 3. TxDOT On-System Bridge Usage of Steel Piling (NBI Data)

District	% Steel in Trestles	% Steel under Ftg
Abilene	42.0%	80.0%
Amarillo	58.7%	84.6%
Atlanta	5.1%	19.1%
Austin	36.2%	54.2%
Beaumont	5.0%	13.3%
Brownwood	51.9%	50.0%
Bryan	18.9%	53.3%
Childress	70.3%	76.2%
Corpus Christi	14.9%	2.8%
Dallas	47.0%	89.2%
El Paso	16.1%	22.6%
Fort Worth	38.8%	0.0%
Houston	1.1%	2.7%
Laredo	1.8%	80.0%
Lubbock	0.0%	----
Lufkin	16.2%	36.8%
Odessa	20.0%	0.0%
Paris	31.0%	----
Pharr	0.0%	0.0%
San Angelo	27.3%	----
San Antonio	14.8%	75.9%
Tyler	6.0%	89.8%
Waco	46.7%	100.0%
Wichita Falls	38.0%	55.6%
Yoakum	8.3%	42.1%

Table 4. TxDOT Off-System Bridge Usage of Piling (NBI Data) Showing Number of Bridges Using Piles and Geographic Percentages

District	Concrete Trestle	Steel Trestle	Conc under Ftg	Steel under Ftg	Total	Share of Statewide Pile Usage
Abilene	3	30	0	0	33	1.1%
Amarillo	2	23	1	0	26	0.9%
Atlanta	26	5	1	0	32	1.1%
Austin	9	27	1	2	39	1.3%
Beaumont	147	24	2	1	174	5.8%
Brownwood	1	38	0	1	40	1.3%
Bryan	33	97	0	0	130	4.3%
Childress	2	17	0	0	19	0.6%
Corpus Christi	48	5	3	0	56	1.9%
Dallas	20	123	1	4	148	4.9%
El Paso	5	0	3	0	8	0.3%
Fort Worth	28	124	0	7	159	5.3%
Houston	1091	17	33	12	1153	38.1%
Laredo	1	3	1	0	5	0.2%
Lubbock	0	1	0	0	1	0.0%
Lufkin	23	133	0	0	156	5.2%
Odessa	0	0	0	0	0	0.0%
Paris	11	135	0	0	146	4.8%
Pharr	185	0	1	0	186	6.1%
San Angelo	4	3	0	0	7	0.2%
San Antonio	9	12	0	2	23	0.8%
Tyler	51	89	0	0	140	4.6%
Waco	2	100	0	0	102	3.4%
Wichita Falls	2	50	0	0	52	1.7%
Yoakum	115	69	6	1	191	6.3%
Total	**1818**	**1125**	**53**	**30**	**3026**	
Pilings Used	**60.1%**	**37.2%**	**1.8%**	**1.0%**		

Table 5. TxDOT Off-System Bridge Usage of Steel Piling (NBI Data)

District	% Steel in Trestles	% Steel under Ftg
Abilene	90.9%	----
Amarillo	92.0%	0.0%
Atlanta	16.1%	0.0%
Austin	75.0%	66.7%
Beaumont	14.0%	33.3%
Brownwood	97.4%	100.0%
Bryan	74.6%	----
Childress	89.5%	----
Corpus Christi	9.4%	0.0%
Dallas	86.0%	80.0%
El Paso	0.0%	0.0%
Fort Worth	81.6%	100.0%
Houston	1.5%	26.7%
Laredo	75.0%	0.0%
Lubbock	100.0%	----
Lufkin	85.3%	----
Odessa	----	----
Paris	92.5%	----
Pharr	0.0%	0.0%
San Angelo	42.9%	----
San Antonio	57.1%	100.0%
Tyler	63.6%	----
Waco	98.0%	----
Wichita Falls	96.2%	----
Yoakum	37.5%	14.3%

Recent Usage of Piles and Drilled Shafts on TxDOT Bridges

Historical bid data was examined over the last 10 years via TxDOT bid tabulation results. Costs and quantity of steel H-piling, square prestressed concrete piling, and steel and prestressed concrete sheet piling were examined. The data shows that prestressed piling was somewhat more economical in a number of districts when compared with steel piling. Exceptions include the Amarillo District, which has soil conditions, remoteness from precast plants, and local preferences that have made steel the preferred piling type. Both piling types were somewhat less economical compared to drilled shafts. However, cost should not be the primary consideration in choosing a foundation type. Appropriateness for the subsurface conditions should be the primary basis. Table 6 compares the two general piling material types to gauge current usage practice for new designs. The data provided previously based on NBI data was for the entire in-service bridge population, but not necessarily representative of current practice.

Table 6. Piling Usage by General Type over the Last 10 Years
(Percentages in Bold are Districts with Heavy Piling Usage)

District	Total Steel H-Piling (LF)	Total Conc Sq Piling (LF)	Total Piling (LF)	Steel Percentage	Concrete Percentage
Abilene	-	-	-	NA	NA
Amarillo	11,768	7,974	19,742	**60%**	**40%**
Atlanta	3,452	40,955	44,407	**8%**	**92%**
Austin	1,414	-	1,414	100%	0%
Beaumont	420	291,922	292,342	**0%**	**100%**
Brownwood	-	2,957	2,957	**0%**	**100%**
Bryan	86	10,977	11,063	**1%**	**99%**
Childress	-	3,244	3,244	**0%**	**100%**
Corpus Christi	-	134,741	134,741	**0%**	**100%**
Dallas	-	-	-	NA	NA
El Paso	-	1,857	1,857	0%	100%
Fort Worth	878	-	878	100%	0%
Houston	11,420	402,540	413,960	**3%**	**97%**
Laredo	-	-	-	NA	NA
Lubbock	-	-	-	NA	NA
Lufkin	-	6,125	6,125	**0%**	**100%**
Odessa	-	-	-	NA	NA
Paris	-	-	-	NA	NA
Pharr	-	147,611	147,611	**0%**	**100%**
San Angelo	-	-	-	NA	NA
San Antonio	26,266	8,200	34,466	**76%**	**24%**
Tyler	-	-	-	NA	NA
Waco	-	-	-	NA	NA
Wichita Falls	-	770	770	0%	100%
Yoakum	-	87,067	87,067	**0%**	**100%**

Performance of Piles on TxDOT Bridges

To date, the performance of steel piling at interior bents of stream crossings has been less than desirable and has required significant maintenance and, in some cases, complete bridge replacement. Retrofit of corrosion-damaged piling to restore load-carrying capacity is a common bridge rehabilitation using either concrete jacketing or steel plate splicing. TxDOT currently is sponsoring research project 6731, “Repair Systems for Deteriorated Bridge Piles,” being performed by a team from the University of Houston and Texas Tech University. This research will identify cost-effective, durable, and rapidly deployable alternatives for the repair and rehabilitation of steel piles. In a national survey of DOT’s around the country (23 responded), the researchers indicated that 78% use steel piling in new construction, but 26% had cited corrosion of steel piles as a frequent problem and another 48% as an occasional problem. A few states (Michigan, New Mexico, Montana) use steel piling in new construction and don’t report problems with performance. Their practices may provide some good guidance on prevention of corrosion-related deterioration.

The performance offset between steel and concrete piles can be seen in the substructure rating NBI data as shown in Figures 3 and 4. For the off-system case, trestle pile bents exhibit nearly a point lower rating than their concrete pile counterparts. The difference is not significant for piles under footings since typically there is no exposure to moisture in the oxygenated zone, but also because they are hidden from view because they are buried. TxDOT has successfully reused existing steel piles under footings on some bridge replacements in the Amarillo District after having exposed them and determining that little or no section loss had occurred. Trestle pile bents in waterways with steel piling are the most problematic case, as shown in Figure 5. However, even steel piles under footings can be problematic if scour exposes the piles, as exhibited in Figure 6.

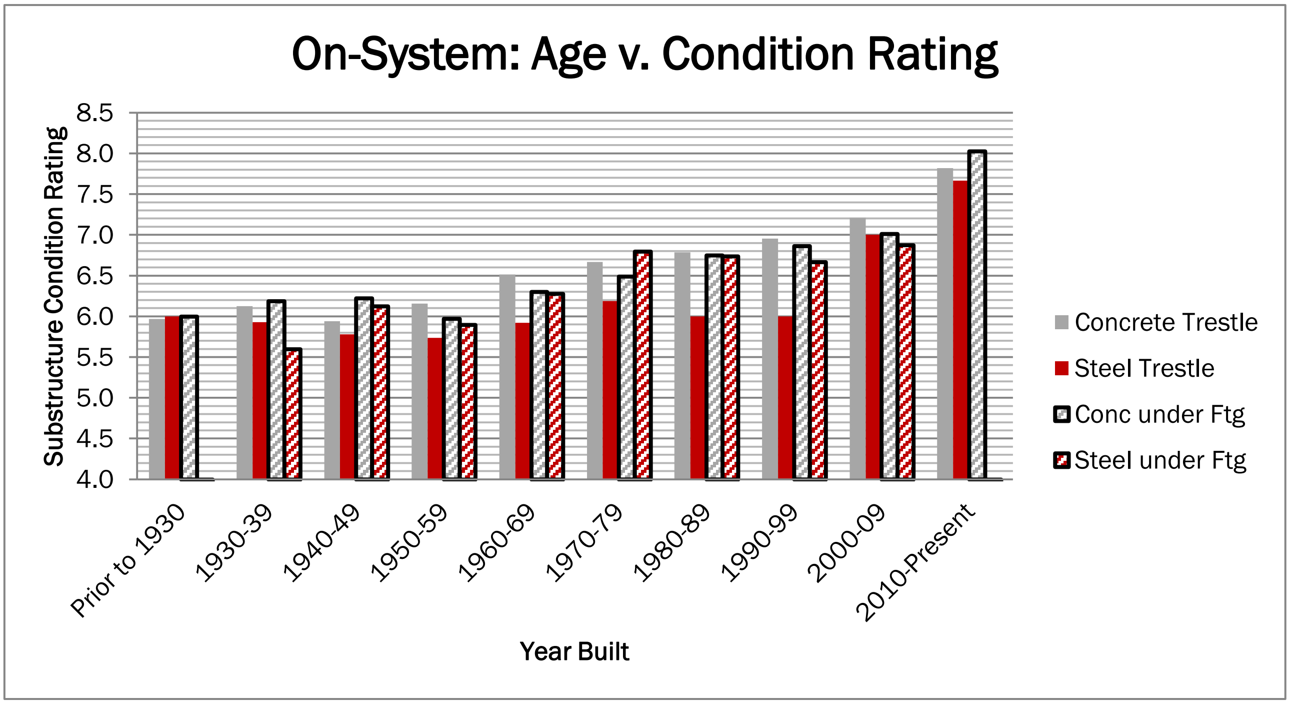

Figure 3. NBI Substructure Condition Rating Versus Age – On System

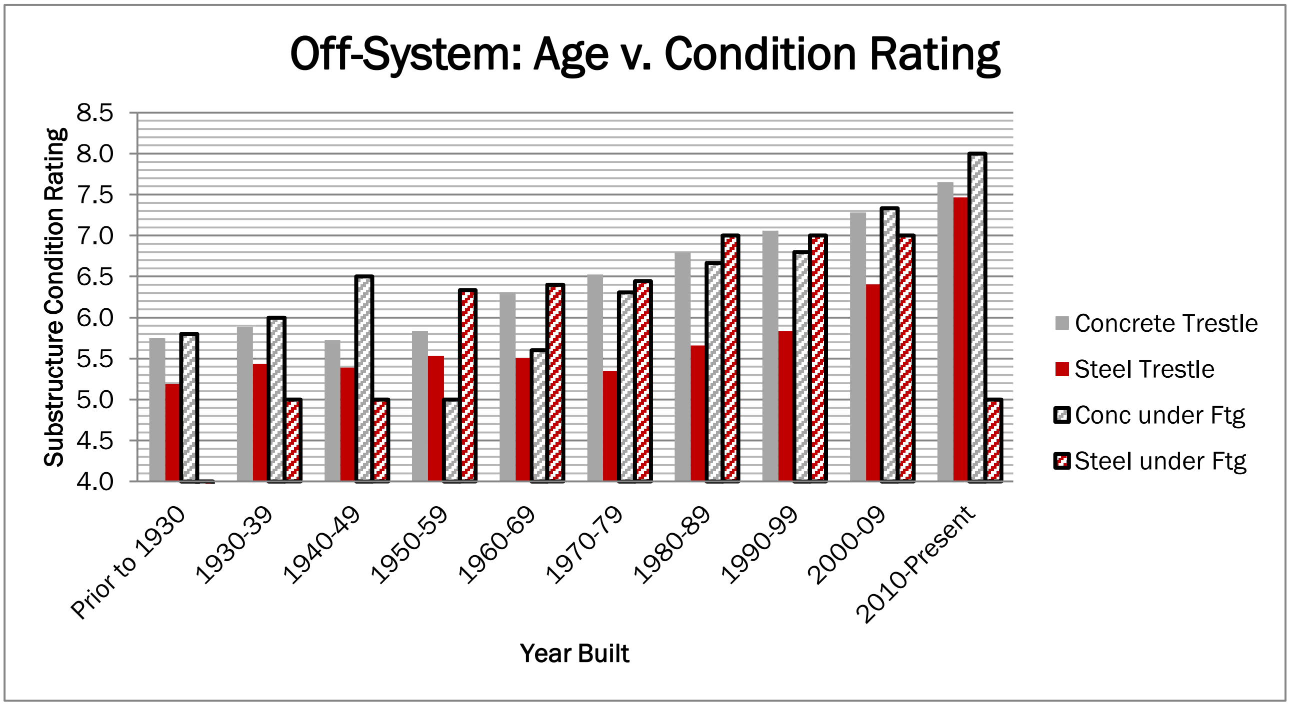

Figure 4. NBI Substructure Condition Rating Versus Age – Off System

Figure 5. Pile Section Loss on a Texas Bridge with Steel Trestle Piles

Figure 6. Pile Section Loss on a Texas Bridge with Steel Piles Under a Footing

Corrosion Mitigation Methods Investigated

Other than restrictions in steel piling use, methods were investigated to mitigate corrosion, particularly sacrificial thickness and coatings. The state DOTs of Florida, California, and Illinois have best documented mitigation methods for piling applications.

The sacrificial thickness guidance presented earlier is essentially the same as the Florida DOT criteria.

Coatings typically are inorganic zinc primers alone or in combination with an acrylic latex or urethane appearance coat--perhaps with an epoxy intermediate coat, inorganic zinc primers with a coat or coats of coal tar epoxy, or dense high-end epoxies with a corresponding primer. Metalizing with zinc or aluminium has also been done, but is not considered the best system because it is sacrificial over time. Based on current recommendations of the TxDOT Construction Division, piling coatings in normal benign environments will consist of inorganic zinc primer because of its good performance. If additional corrosion protection or a desire for a specific color is warranted, an epoxy intermediate coat and urethane coat may be specified. Alternately, a higher-end coating can be pursued using the “marine grade” NORSOK M-501 Table 7 coating that will be in the 2014 TxDOT Specifications. The Construction Division is developing a Department Material Specification (DMS) and MPL (Material Producer List) to provide contractors with better access to information regarding NORSOK M-501 Table 7 compliant coatings. The cost of this type of coating is preliminarily expected to be an additional 2 to 4 times cost premium over normal inorganic zinc. According to the TxDOT Construction Division, coal tar epoxies are becoming less desirable due to worker hazards, environmental issues, and installation sensitivity. There are several states that still use coal tar epoxies in conjunction with zinc primers, and their performance history is longer than the proposed marine grade specification. This is an aspect that warrants further investigation.

For repair and maintenance of in-service piling, the Construction Division recommends organic zinc epoxy.