FLORIDA DEPARTMENT OF TRANSPORTATION

FDOT MODIFICATIONS TO STANDARD SPECIFICATIONS FOR STRUCTURAL SUPPORTS FOR HIGHWAY SIGNS, LUMINAIRES AND TRAFFIC SIGNALS (LTS-5)

FDOT STRUCTURES MANUAL
VOLUME 9
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Structures Design
Florida's Transportation Engineers

Table of Contents

1 INTRODUCTION

1.1 Scope

Add the following:

Conform to the date specific AASHTO Publications listed in ***Structures Manual Introduction*** I.6 References.

C 1.1

Add the following:
Structures Manual Introduction I.6 is updated annually to reflect the specific specifications editions and interims adopted by the FDOT.

2 GENERAL FEATURES OF DESIGN

2.1 Scope

Add the following:

See Chapter 7 and 29 of the FDOT ***Plans Preparation Manual*** regarding the use of FDOT Design Standards and other plans preparation requirements.

C 2.1

Add the following:
The FDOT ***Plans Preparation Manual*** contains additional FDOT requirements.

2.5 Functional Requirements

2.5.2 Structural Supports for Signs and Traffic Signals

2.5.2.2 Size, Height and Location of Signs

Add the following:

Span type overhead sign structures in urban locations shall be designed either for the actual signs shown on the signing plans or for a minimum sign area of 120 sq. ft. (12 ft. W x 10 ft. H) per lane, whichever is the greater. If the signing plans require signs for only one traffic direction, the minimum sign area per lane requirement applies to the traffic lanes in this direction only.

Cantilever type overhead sign structures in urban locations shall be designed either for the actual signs shown on the signing plans or for a minimum sign area of 80 sq. ft. (8 ft. W x 10 ft. H) located at the end of the cantilever, whichever provides the more stringent load or stress at the location under consideration.

C 2.5.2.2

Add the following:
Minimum sign areas provide a reasonable allowance for future sign panel installations without the need for a new support structure.

Minimum sign areas for overhead variable message sign supports are normally not required.

See the FDOT ***Plans Preparation Manual***, Volume 1, Introduction for a link to the Urban Area Boundary Maps

Figures 1 and 2 show how to apply the above minimum sign areas for span type overhead sign structures in urban locations.

Overhead signs in rural locations should be designed for the actual sign shown on the signing plans.

Figure 1 Example: actual signs

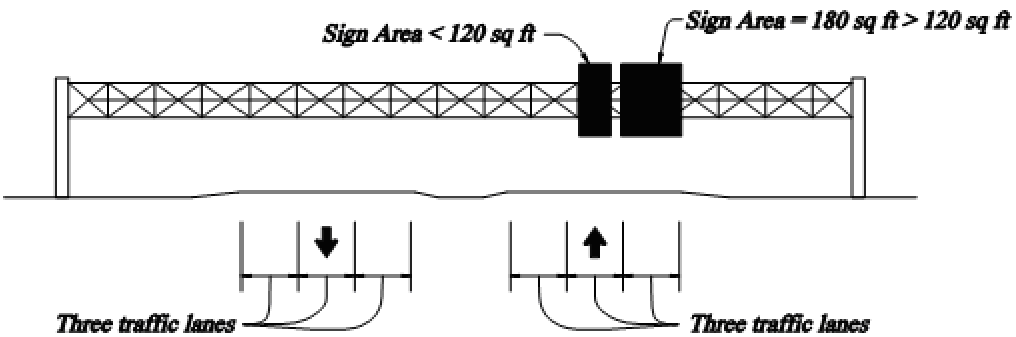
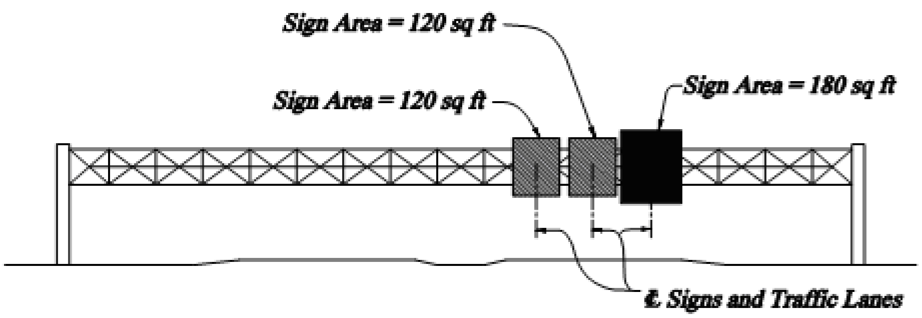


Figure 2 Example: signs used in design



2.5.2.4 Variable Message Signs

Add the following:

For all overhead Variable Message Sign (VMS) structures, the horizontal member shall consist of a truss with a minimum of two chords with a minimum center-to-center distance between the chords of 3'-0". See FDOT section 11.8 for VMS maximum span-to-depth ratios.

C 2.5.2.4

Add the following:

The minimum requirements given provide additional measures to limit the possibility of galloping.

Since cantilever overhead Variable Message Sign (VMS) structures are more susceptible to fatigue than span overhead VMS structures, span structures should be used whenever possible.

In Florida, overhead VMS structures are typically referred to as Dynamic Message Sign (DMS) structures.

2.5.2.5 Horizontal Span and Cantilever Limits

New Section, add the following:

Sign and signal structures shall be limited to the following maximum horizontal lengths:

Structure Type	Max Length
Span Overhead Sign	250 feet
Cantilever Overhead Sign	50 feet
Mast Arm	78 feet
Span Wire Assembly	250 feet

C 2.5.2.5

Add the following:

These limits were chosen based on past practice and practical experience.

A FDOT Design Variation is required when sign or signal structure limits are exceeded. The design variation documentation shall include the type of structure, height, length, discussion of alternatives, and costs.

3 LOADS

3.8 Wind Load

Delete the last paragraph and add the following:

The use of Appendix C is only permitted for the evaluation of existing structures.

C 3.8

FDOT ***Plans Preparation Manual***, Volume 1, Section 25.4.27 defines the structures where evaluation is necessary.

3.8.2 Basic Wind Speed

Delete the entire paragraph including Figure 3-2, and add the following:

The wind loads shall be based on the wind speeds (mph) shown in FDOT SDG Table 2.4.1-2

C 3.8.2

Add the following:

FDOT SDG Table 2.4.1-2 was derived from the ASCE 7-05 wind speed map.

To simplify the design process, FDOT has designated one wind speed per county.

3.8.3 Wind Importance Factor I_r

Add the following Wind Importance Factor to Table 3-2:

Recurrence Interval Years	V = 85-100 mph	V > 100 mph	Alaska
1.5	0.45	0.2	---

Delete Table 3-3 and add the following FDOT Table 3-3:

FDOT Table 3-3 Minimum Design Life

Design Life	Structure Type
50-year	Overhead sign structures
	Luminaire support structures >50' in height.
	Mast Arms
	Monotubes
	Steel Strain Poles
	ITS Camera Poles
25-year	Luminaire support structures ≤ 50' in height.
	Concrete Strain Poles
10-year	Roadside sign structures
1.5-year	Temporary construction signs

A 1.5-year design life (I_r = 0.2) for temporary construction signs shall only be used with a 150 mph design wind speed.

C 3.8.3

Add the following:

A 1.5-year design life has been added for temporary construction signs. The importance factor is calculated based on "Wind Speed for Design of Temporary Structures" by D.W. Boggs and J.A. Peterka, Structures Congress, 1992, Compact Papers, ASCE, 1992.

Florida has traditionally designed Luminaire support structures, 50 feet in height and less, and strain poles for a 25 year design life.

Concrete strain poles are designed for zero tension stress, therefore a twenty-five year design life is appropriate.

3.8.6 Drag Coefficients C_d

Replace the coefficient of drag for Traffic Signals in Table 3-6 with the following:

Traffic Signals - no ability to swing - 1.2

Traffic Signals - installed with the ability to swing on span wire systems under full wind load - 0.7

C 3.8.6

Add the following to note 2 at the bottom of Table 3-6:

A drag coefficient for traffic signal installed with the ability to swing has been established through research (Cook 2007). On span wire systems where signal and signs are allowed to swing, varying C_d as a function of swing angle is allowed (Hoit and Cook 1997).

3.8.7 Lift Coefficient for Traffic Signals C_l

New Section, add the following:

For traffic signals installed with the ability to swing on span wire systems under full design wind speed (Group II loading), use a coefficient of lift C_l equal to 0.4. To compute the lift pressure, use Eq. 3-1 substituting C_l for C_d. Using a reduced signal area based on the swing angle, compute the lift force and apply in a vertical direction opposite dead load.

C 3.8.7

Add the following:

A lift coefficient of 0.4 on traffic signals installed on span wire systems has been established through research (Cook 2007). On span wire systems where signal and signs are allowed to swing, varying C_l as a function of swing angle is allowed (Hoit and Cook 1997).

3.9 Design Wind Loads On Structures

3.9.1 Load Application

Add the following:

Use the following areas for traffic signals:

Item	Projected Area
12" Signal	1.36 sf
8" Signal	0.70 sf
3 Section Backplate	5.67 sf
4 Section Backplate	6.83 sf
5 Section Backplate	8.00 sf

When the full design wind speed is used for Group II loading on span wire systems, use a reduced signal and sign area based on the following swing angles:

Wind Speed	Swing Angle
110 mph	45 degrees
130 mph	55 degrees
150 mph	60 degrees

C 3.9.1

Add the following:

Swing angles for traffic signals and signs installed on span wire systems have been established through research (Cook 2007).

Areas given are for standard signals in Florida.

3.9.3 Design Loads for Vertical Supports

Add the following:

When 3 or 4 span wire pole structures are connected, analyze the system with wind directions of 0, 45, and 90 degrees. If other angles are used, document the angles in the analysis report.

C 3.9.3

Add the following:

More refined analysis is typically not required due to the number of approximate assumptions made in the analysis. Other angles may be analyzed and substituted if program results are not consistent at the specified angles.

3.10 References

Add the following:

Cook, R.A. (2007). ***Development of Hurricane Resistant Cable Supported Traffic Signals*** (FDOT Report# BD545 RPWO #57). Gainesville, Florida: University of Florida.

Hoit, M.I., Cook, R.A. (1997). ***Computer Aided Design Program for Signal Pole and Span Wire Assemblies With Two Point Connection System*** (FDOT Report# 0510653). Gainesville, Florida: University of Florida.

5 STEEL DESIGN

5.5 Material - Structural Steel

Add the following:

Do not specify ASTM A588 (rustic, Corten, “self-oxidizing", or "self-weathering") steel in sign, signal, or lighting structures.

C 5.4

Add the following:

In some environmental conditions in Florida, A588 steel has deteriorated significantly faster than expected.

5.13 Cables And Connections

Add the following:

Use the cable breaking strength values specified in FDOT Specification 634.

C 5.13

Add the following

Cables used in the construction of span-wire pole structures are listed in FDOT Specification 634.

5.14 Details of Design (Rev. 01/12)

5.14.2 Base Plate Thickness

Add the following:

For base plate connections without stiffeners on 50 year recurrence interval structures, the minimum base plate thickness shall be 2½ inches.

C 5.14.2

Add the following:

Research has proven full-penetration groove welds combined with thicker base plates increases the pole-to-base-plate connection fatigue strength.

5.15 Welded Connections

5.15.1 Circumferential Welded Splices (Rev. 01/12)

Add the following:

On steel sign and signal structures, no circumferential welds are permitted on the uprights, arms or chords with the exceptions of the base plate weld, the flange plate connections on tubular truss members, and the mitered arm-to-upright angle weld on monotubes.

C 5.15.1

Add the following:

The Department's intent is to avoid any unnecessary welds on sign, signal or lighting structures.

5.15.3 Base Connection Welds (Rev. 01/12)

Add the following:

For base plate connections without stiffeners on 50 year recurrence interval structures, only use full-penetration groove welds.

C 5.15.3

Add the following:

Research has proven full-penetration groove welds combined with thicker base plates increases the pole-to-base-plate connection fatigue strength.

5.16 Bolted Connections

Add the following:

Design all pole to arm connections on Mast Arm structures as "through bolted". Tapped connections are not permitted.

C 5.16

Add the following:

Through bolted connections provide fully tensioned A325 bolts.

5.17 Anchor Bolt Connections

Add the following:

All sign, signal, and lighting structures designed for a minimum service life of 50 years (wind speed based on a 50-year mean recurrence interval) shall use a minimum of six, Grade 55, ASTM F1554 anchor bolts at the pole to foundation connection.

C 5.17

Add the following:

A minimum of six anchor bolts provides redundancy and better distribution of forces through the base plate.

5.17.1 Anchor Bolt Types

Delete anchor bolts types listed in the second and third bullet and add the following:

Both Adhesive anchors and threaded post-tensioning bars are not permitted.

C 5.17.1

Add the following:

FDOT only allows straight headed anchor bolts.

Adhesive anchor and threaded post-tensioning bars have undesirable creep and ductility behavior respectively.

5.17.2 Anchor Bolt Materials

Add the following:

Only use ASTM F 1554 anchor bolts with 55 ksi yield strength.

C 5.17.2

Add the following:

ASTM F 1554 Grade 55 anchor bolts provide sufficient ductility after yield to engage all the anchor bolts on the tension side of the base plate.

5.17.3 Design Basis

5.17.3.3 Use of Grout

Add the following:

Grout pads underneath the baseplates in double-nut moment joints of miscellaneous highway structures (i.e. mast arms, overhead sign structures, high mast lights, steel strain poles and monotube structures) are not required.

C 5.17.3.3

Add the following:

Inspections have shown that a poorly functioning grout pad is worse than no grout pad at all. For poles without a grout pad beneath the base plate, the double-nut moment joint requires adequate tensioning of the anchor bolts. It is critical that the nuts beneath the base plate, typically referred to as leveling nuts, are firmly tightened and locked to prevent loosening. This locking mechanism is accomplished through the turn of the nut method specified in FDOT Specification 649 or a properly place grout pad.

5.17.4 Anchor Bolt Design

5.17.4.3 Bending Stress in Anchor Bolts

Change "should" to "shall" in the first sentence.

C 5.17.4.3

Add the following:

Testing has shown significant reduction in anchor bolt capacity when the standoff distance is greater than one bolt diameter.

6 ALUMINUM DESIGN

6.1 Scope

Add the following:

Do not specify aluminum overhead sign structure supports with the exception of the vertical sign panel hangers, which may be aluminum or steel.

C 6.1

Add the following:

Aluminum overhead sign structures have been prone to unacceptable levels of vibration and fatigue cracking.

7 PRESTRESSED CONCRETE DESIGN

7.5 Design

7.5.1 Method of Design (Rev. 01/12)

Add the following:

For Standard Prestressed Concrete Pole Design, see Instructions for Design Standard Index 17725, for the Service Moment Capacity and Ultimate Moment Capacity. An increased percentage of Allowable Stress for Group II loading (LTS Table 3-1) is not applicable for Prestressed Concrete Poles, since Group II loading is an ultimate moment capacity calculation.

C 7.5.1

Add the following:

FDOT uses Standard Prestressed Concrete Poles in accordance with Index 17725 and Specification 641. After analysis of the proposed span-wire pole structure, the Designer selects the appropriate pole using the design moment values given in the Instructions for Design Standards for Index 17725.

7.5.2 Concrete Strength

Replace this section with the following:

The minimum compressive concrete strength shall be 6 ksi.

C 7.5.2

Add the following:

FDOT uses Class V Special, 6 ksi or Class VI 8.5 ksi concrete in accordance with Specification 346.

7.10 Durability

7.10.2 Concrete Cover

Replace this section with the following:

The minimum clear concrete cover for all prestressed and non-prestressed poles is 1 inch.

C 7.10.2

Add the following:

FDOT requires a minimum 1 inch cover on all concrete poles in all environments.

10 SERVICEABILITY REQUIREMENTS

10.5 Camber

Replace this section with the following:

Provide permanent camber equal to 1.5 times the dead load deflection for overhead sign structures. For span overhead sign structures, arch the horizontal member upwards and for cantilever overhead sign structures rake the vertical support backwards. For mast arm signal structures, provide a two degree upward angle at the arm/upright connection.

C 10.5

Add the following:

Permanent camber equal to 1.5 times the dead load deflection provides for a better appearance than the relatively small L/1000 given in AASHTO. For mast arms, a two degree upward angle at the arm/upright connection is standard industry practice.

11 FATIGUE DESIGN

11.5 Design Criteria (Rev. 01/12)

Add the following:

The provisions found in Chapter 4 of NCHRP W176, "Cost-Effective Connection Details for Highway Sign, Luminaire, and Traffic Signal Structures", may be used as an alternate to Article 11.5.

C 11.5

Add the following:

NCHRP W176 contains the latest information on fatigue design and will likely be adopted by AASHTO. By adopting the provisions early, fatigue design requirements will be more accurate and in some cases, less costly.

11.6 Fatigue Importance Factors (Rev. 01/12)

Add the following:

Use Fatigue Category II for all sign, traffic signal, and lighting support structures meeting the limits in 2.4.2.5 and designed using FDOT Design Standards and Programs or designed in accordance with Chapter 4 of NCHRP W176, "Cost-Effective Connection Details for Highway Sign, Luminaire, and Traffic Signal Structures". Use Fatigue Category I for all other sign, traffic signal, and lighting support structure designs including all VMS support structures.

C 11.6

Add the following:

Research performed at the University of Texas (Report 0-4178) concluded increasing "the end plate thickness for a 10-inch mast arm from 1.5 inches to 2 inches increased the fatigue life from category E' to category D."

Since FDOT Design Standards and programs for Mast Arm signal structures, overhead tri-chord sign trusses, and High-mast light poles use relatively thick base plates, Fatigue Category II is appropriate. In addition, there have been no reports of fatigue damage to sign, signal and lighting structure designed using FDOT programs and built using FDOT Design Standards.

11.7 Fatigue Design Loads

11.7.1 Galloping (Rev. 01/12)

Replace the 2nd, 3rd and 4th paragraphs with the following:

Vibration Mitigation devices are not allowed in lieu of designing for galloping.

Exclude galloping loads for the fatigue design of overhead cantilevered sign and VMS support structures with three or four chord horizontal trusses with bolted web to chord connections.

C 11.7.1

Add the following:

Vibration mitigation devices are seldom necessary and installed only after excessive vibration has been observed and the device is approved by the Department.

Cantilevered sign support structures with horizontal three or four chord trusses have never been reported to vibrate from vortex shedding or galloping. (ref. FHWA Guidelines for the Installation, Inspection, Maintenance and Repair of Structural Supports for Highway Signs, Luminaries, and Traffic Signals)

11.8 Deflection

Add the following:

In addition, VMS structures shall also meet the following maximum span-to-depth ratios:

VMS Structure Type	Max. Span-to-Depth Ratio
Overhead Span Structure	25
Overhead Cantilever Structure	9

C 11.8

Add the following:

The minimum requirements given provide additional measures to limit the possibility of galloping

11.9 Fatigue Resistance (Rev. 01/12)

Add the following:

The provisions found in Chapter 4 of NCHRP W176, "Cost-Effective Connection Details for Highway Sign, Luminaire, and Traffic Signal Structures", may be used as an alternate to Article 11.9.

C 11.9

Add the following:

See C11.5

13 FOUNDATION DESIGN

13.6 Drilled Shafts

Add the following:

Drilled shafts are the standard foundation type on high mast light poles, span overhead signs, mast arms, monotubes, and steel strain poles.

C 13.6

Add the following:
For standard drilled shaft details, see Design Standard Indexes 11320, 17502, 17723 and 17745 for span overhead sign structures, high mast light poles, steel strain poles, and mast arms respectively.

13.6.1 Geotechnical Design

13.6.1.1 Embedment

Add the following:

Use a safety factor against overturning of 2 when using the Broms method.

For torsion resistance in drilled shafts supporting Mast Arm signal and cantilever overhead sign structures, use the following equations:

$$T_u \le \frac{T_n}{SF_{tor}}$$

Where

$$T_n = \pi D L F_s\left(\frac{D}{2}\right) + \pi\left(\frac{D}{2}\right)^2 L\gamma_{conc}\left(\frac{D}{3}\right)\mu$$

$$F_s = \sigma_v \omega_{fdot}$$

$$\sigma_v = \gamma_{soil}\left(\frac{L}{2}\right)$$

$$\mu = \tan(\phi_{soil})$$

T_u = Torsion force on the drilled shaft

T_n = Nominal torsion resistance of the drilled shaft

SF_{tor} = Safety Factor against torsion
= 1.0 for Mast Arm signal structures
= 1.3 for overhead cantilever sign structures

D = diameter of the drilled shaft

L = length of the drilled shaft

F_s = unit skin friction

σ_v = effective vertical stress at mid-layer

C 13.6.1.1

Add the following:
FDOT experience has established a safety factor of 2 produces conservative designs.

The torsion resistance equation is based on the theory for the Beta Method (O'Neill and Reese, 1999). A single ω_{fdot} factor of 1.5 is used to adjust for the concurrent overturning and torsional forces and to compare with past FDOT practice. Since the consequence of a torsion soil-structure failure is usually small, some rotation is typically allowable from the design wind.

Since cantilever overhead sign structures can have significantly more torsion than a Mast Arm, a higher safety factor of 1.3 is appropriate.

ω_{fdot} = load transfer ratio

= 1.5 for granular soils where the allowable shaft rotation may exceed 10 degrees

γ_{conc} = unit weight of concrete

γ_{soil} = unit weight of soil

μ = Coefficient of friction between the shaft and soil

ϕ_{soil} =soil friction angle

13.6.2 Structural Design

Add the following:

Longitudinally reinforce drilled shaft foundations with a minimum of 1% steel. At a minimum, place #5 stirrups at 4 inch spacing in the top two feet of shaft. In cantilever structures, design for shear resulting from the torsion loading on the anchor bolt group.

C 13.6.2

Add the following:

Using 1% steel is conservative for flexural design in most cases. Additional stirrups in the top of the shaft provides resistance against shear failure in the top of the shaft. Due to torsion, additional stirrups may be required in cantilever structures.

13.6.2.1 Details (Rev. 01/12)

Replace the second sentence with the following:

A minimum concrete cover of six inches over steel reinforcement is required.

Add the following:

The minimum diameter for drilled shafts is 36 inches. A minimum main reinforcement clear spacing of six inches is required for proper concrete consolidation. Stirrups in drilled shafts for sign, signal and lighting structures are exempt from this requirement.

C 13.6.2.1

Add the following:

FDOT requires six inches of cover to ensure durability in drilled shafts.

Concrete consolidation below the anchor bolts becomes more difficult with reinforcement clear spacing less than six inches.

13.10 Embedment of Lightly Loaded Small Poles and Posts

Add the following:

When using the Broms method for ground sign foundation design, use a safety factor against overturning of 1.3. When using the Broms method for direct burial concrete pole foundation design, use a safety factor against overturning of 1.5.

13.11 References

Add the following:

Cook, R.A. (2007). ***Anchor Embedment Requirements for Signal/Sign Structures*** (FDOT Report# BD545 RPWO #54). Gainesville, Florida: University of Florida.

APPENDIX C

C.1 Alternate Method

Add the following:

When evaluating existing structures in accordance with ***PPM*** 25.4.27, the following design assumptions are permitted:

- an allowable overstress of 1.4 is allowed for Group II loading.
- allowances for future loads is not required
- evaluation using Section 11, Fatigue Design, is not required.
- evaluation of the foundation capacity is not required.

C C.1

Add the following:

By allowing an overstress factor of 1.4, consistent with previous editions of LTS, properly designed existing structures will be allowed to remain in place in accordance with the ***PPM***.

C.2 Wind Load

Delete the 2nd and 3rd sentence and add the following:

The design wind pressures shall be computed using the wind pressure formula, Eq. C-1, with the appropriate wind speed shown in FDOT Table C.2-1, Wind Speed by County.

C C.2

Add the following:

To simplify the design process, FDOT has designated one wind speed per county.

FDOT Table C.2-1 Wind Speed by County

County (Dist)	10 year	25 year	50 year	County (Dist)	10 year	25 year	50 year
Alachua (2)	60	80	90	Lee (1)	80	90	100
Baker (2)	60	80	90	Leon (3)	60	70	80
Bay (3)	70	80	90	Levy (2)	70	80	90
Bradford (2)	60	80	90	Liberty (3)	60	80	90
Brevard (5)	80	90	100	Madison (2)	60	70	80
Broward (4)	90	100	110	Manatee (1)	80	90	100
Calhoun (3)	60	80	90	Marion (5)	60	80	90
Charlotte (1)	80	90	100	Martin (4)	80	90	100
Citrus (7)	70	80	90	Miami-Dade (6)	90	100	110
Clay (2)	60	80	90	Monroe (6)	90	100	110
Collier (1)	80	90	100	Nassau (2)	70	80	90
Columbia (2)	60	70	80	Okaloosa (3)	70	90	100
DeSoto (1)	70	80	90	Okeechobee (1)	70	80	90
Dixie (2)	70	80	90	Orange (5)	70	80	90
Duval (2)	70	80	90	Osceola (5)	70	80	90
Escambia (3)	70	90	100	Palm Beach (4)	80	100	110
Flagler (5)	70	80	90	Pasco (7)	70	90	100
Franklin (3)	70	90	100	Pinellas (7)	70	90	100
Gadsden (3)	60	70	80	Polk (1)	70	80	90
Gilchrist (2)	60	80	90	Putnam (2)	60	80	90
Glades (1)	70	80	90	St. Johns (2)	70	80	90
Gulf (3)	70	90	100	St. Lucie (4)	80	90	100
Hamilton (2)	60	70	80	Santa Rosa (3)	70	90	100
Hardee (1)	70	80	90	Sarasota (1)	80	90	100
Hendry (1)	70	80	90	Seminole (5)	70	80	90
Hernando (7)	70	90	100	Sumter (5)	60	80	90
Highlands (1)	70	80	90	Suwannee (2)	60	70	80
Hillsborough (7)	70	80	90	Taylor (2)	70	80	90
Holmes (3)	60	70	80	Union (2)	60	80	90
Indian River (4)	80	90	100	Volusia (5)	80	90	100
Jackson (3)	60	70	80	Wakulla (3)	70	80	90
Jefferson (3)	60	70	80	Walton (3)	70	80	90
Lafayette (2)	60	80	90	Washington (3)	60	80	90
Lake (5)	60	80	90				

VOLUME 9 - REVISION HISTORY

5.14..............Added new section and commentary.

5.15.1...........Revised wording for base plate weld type.

5.15.3...........Added new section and commentary.

7.5.1.............Changed cross reference to IDS and deleted reference to QPL.

11.5..............Added new section and commentary.

11.6..............Added cross reference to NCHRP report.

11.7.1...........Added requirement for evaluating overhead cantilevered structures.

11.9..............Added new section and commentary.

13.6.2.1........Added minimum drilled shaft size. Revised commentary.