

CHAPTER 9

TRAFFIC SIGNAL DESIGN – SUPPORTS AND SIGNAL HEADS

9.1 Traffic Signal Supports

The two basic types of traffic signal supports are strain poles and mast arm poles. Traffic signal supports shall be in accordance with current TDOT standards and specifications and the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*. In addition, traffic signal supports shall be in accordance with the NEC and the NESC. Adjacent utility poles shall not be used for traffic signal supports in new installations, unless physical conditions preclude the installation of separate traffic signal supports. In these cases, it is important to coordinate the traffic signal design and installation with the affected utility company. All traffic signal projects on a state route or that are being designed with TDOT's involvement (i.e. in-house design, consultant design, local programs projects being let by TDOT, etc.), shall be analyzed with TDOT's Intersection Pole Designer Software. This software is free and shall be obtained through the TDOT Traffic Operations Division, Traffic Engineering Office.

9.1.1 Traffic Signal Strain Poles

A traffic signal strain pole is a pole (wood, steel, or concrete) to which span wire is attached for the purpose of supporting the signal wiring and signal faces (See TDOT *Standard Drawings T-SG-1, T-SG-4, and T-SG-8*). Wood poles should only be used for temporary traffic signal installations. Steel or concrete strain poles should be considered when span lengths exceed 90 feet or easements/right-of-way will be required for guy wires. Traffic signal strain poles should also be considered when a box span arrangement is used to provide additional strength.

- **Span Length:** Strain poles should be located so as to limit the distance between the stop line and the signal heads to a maximum of 180 feet. The minimum breaking strength for span wires shall be noted in the plans. Each span wire shall be grounded.
- **Minimum Cable Breaking Strength:** The minimum cable breaking strength may be reduced to 2.25 times the maximum tension force listed on TDOT's Intersection Pole Designer Software output, provided either Group II or Group III load combination governed the span wire design. This change in design philosophy is in conformance with Article C5.13 of the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals*. Currently TDOT's Intersection Pole Designer Software internally uses a minimum safety factor of 3 to calculate the minimum cable breaking strength. Therefore, the designer will have to manually calculate the minimum cable breaking strength until TDOT's Pole Designer Software can be updated. This change will reduce

the diameter and grade of the ASTM A475 span wire required to meet the minimum cable breaking strength.

- **Strain Pole Height Determination:** The height of a strain pole is determined by Equation 9.1. When providing a pole height on signal plans, it is important to specify that the top of the pole foundation should usually be at the same elevation as the roadway crown. In cut areas, fill may be required to prevent the foundation from protruding out of the ground. An exception is on high-fill roadway sections where the pole must be located outside of the fill area. Consideration must be made to ensure an adequate pole length is specified in such a situation.

$$PH = 2 + L_s S + c + H + d$$

Equation 9.1 – Pole Height

Where:

- PH = Pole Height (feet)
- L_s = Maximum Span Length (feet)
- S = Design Sag (usually 5%)
- c = Clearance above Road (17.5 feet typical)
- H = Height of Signal Head with Backplate (usually 4.5 feet)
- d = Side-slope Drop-off (feet from crown of road)

Where two span wires attach to the same strain pole, the pole height will be determined by using the longer of the two span wires. Pole heights shall be rounded up where necessary to be specified in even number feet (i.e. 26, 28, 30, etc.).

- **Strain Pole Location:** Generally, strain poles should be located outside of the clear zone, inside the right-of-way.
 - **Signal Location:** Strain poles should be located so that signal faces hung on their span wire are located between 40 to 180 feet from the approach stop line.
 - **Minimum Horizontal Clearances:** On curbed roadways, poles shall be located no closer than two feet to the front of curb. In all cases, traffic signal poles should be located as far as practical from the edge of the travel lane without adversely affecting signal visibility.
 - **Pedestrian Considerations:** When installing a pedestrian pushbutton, poles should be located adjacent to the sidewalk within reach of pedestrians in accordance with the MUTCD.
- **Luminaires:** Where street lights are installed on traffic signal poles, their design shall be integrated with the pole and they shall be mounted at a minimum height of 30 feet above the roadway. Actual mounting height shall be determined by the luminaire photometrics.

- **Tether Wires:** Tether wires shall be installed on all span wire assemblies to minimize traffic signal face movement due to wind effects. Tether wires must be able to breakaway from poles when hit or snagged.
- **Span Wire Layouts:** Span wire layouts in general allow for further pole placement from the roadway than do mast arm installations. In addition, they eliminate the need for boring under the roadway by allowing signal and detector cables to be run overhead on the signal span wire. If possible, diagonal span wire layouts should always be avoided. Typical strain pole span wire layouts are shown in Figure 9.1. The following are the most common span wire arrangements:

- **Box Span Arrangement:** This signal arrangement is the most common and places strain poles on each of the four corners of the intersection.

Advantages:

- Allows good alignment of signal heads;
- Provides the required minimum 40-foot distance between the signal heads and stop line on all approaches;
- Provides shorter span wire lengths and sag than diagonal spans;
- Provides locations for pedestrian signals.

Disadvantages:

- Requires four poles;
 - Could require supplemental signal faces if the signal faces are more than 180 feet beyond the approach stop line.
- **Suspended Box Arrangement:** This signal arrangement is a box span arrangement, but the box is connected to the poles by diagonal spans. This is typically used at large intersections in order to minimize the distance between signal faces and the stop line. A variation where two corners of the box are connected by diagonal spans and the other two corners are connected directly to the poles is often used for skewed intersections. The suspended box arrangement should be avoided, if possible, due to potential issues maintaining the height of traffic signal faces.

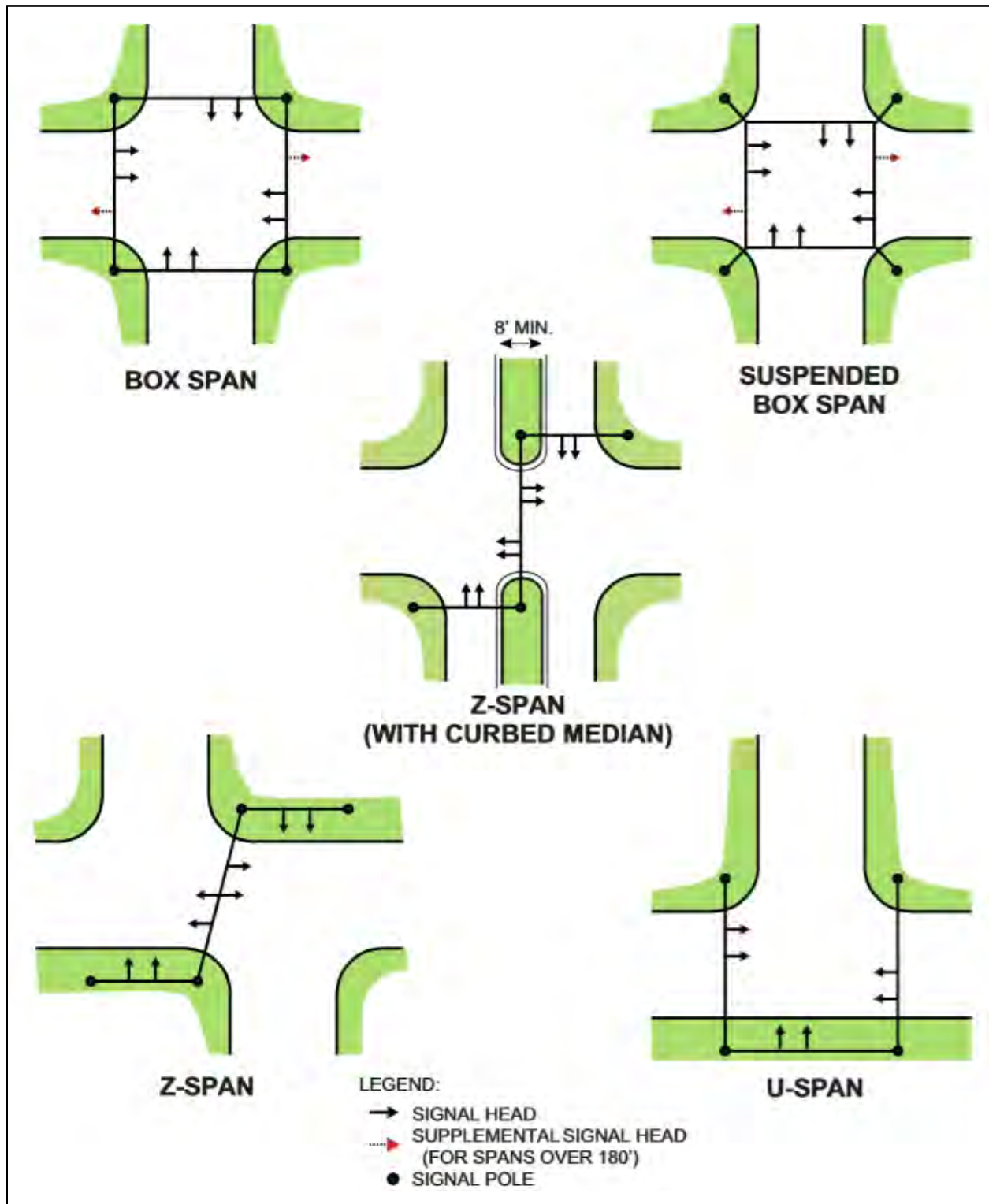
Advantages:

- Same advantages as box arrangements, plus;
- Decreased distance between the signal heads and stop line.

Disadvantages:

- Same as box span arrangement but more difficult to install.

Figure 9.1 – Typical Strain Pole Span Wire Layouts



- **Z-Span Arrangement:** Z-spans are applicable at offset intersections. Z-span installations may be applicable on divided roadways where median clear zone requirements can be met.

Advantages:

- On divided roadways, shorter span wires are required across the street with the median;
- Provides good signal face placement for offset intersections.

Disadvantages:

- On divided roadways, it places traffic signal poles in median areas, where they are more likely to be struck by vehicles. Check clear zone requirements;
- On divided roadways, additional pedestal poles may be needed if pedestrian signals and detectors are required;
- On divided roadways, pedestrians cannot see the parallel signal indications once they get to the median area.

- **U-Span Arrangement:** U-spans are applicable at T-intersections.

Advantages:

- Reduces the span wire length needed.

Disadvantages:

- Adds signal cable length;
- Depending upon the surrounding terrain, guy wires may be needed to support the strain poles.

9.1.2 Traffic Signal Mast Arm Poles

A mast arm pole is a cantilever structure that permits the overhead installation of the signal faces without overhead messenger cables and signal wiring, which is run inside the arm structure (See TDOT Standard Drawing T-SG-9). Mast arm supports provide a more rigid mounting for signal heads and overhead signs than do span wire installations. They also require less maintenance because signal faces and signs are less likely to rotate or turn around in the wind. Mast arm installations are more aesthetically pleasing than span wire installations, since there is no overhead span wire or visible signal wiring. Mast arm supports are considered when they would result in fewer overall poles, when utilities are underground, or when aesthetics are a concern. Generally, mast arm layouts are more expensive than strain pole layouts. However, through the use of dual mast arm poles, mast arm layouts can reduce foundation and mast arm support costs, and they can become cost comparable to strain pole layouts. The installations of traffic signal mast arms are also more expensive than strain poles because they require boring under the roadway to route signal and detector cables to the controller cabinet.

- **Traffic Signal Mast Arm Length:** Mast arm length must be specified on signal plan sheets. The arm length is determined by taking into account signal face placement in relation to the approach travel lanes and the pole distance off the edge of the travel way. Mast arm lengths shall be limited to 90 feet or less. In all cases, the last signal head on a mast arm is located at least seven feet from the end of the mast arm. In addition, mast arms greater than 60 feet shall require a 4-foot diameter width for the foundation. Table 9.1 shows mast arm values that are to be used in TDOT’s Intersection Pole Designer Software instead of the program default values.

Table 9.1 – Typical Values for Mast Arm Length

Mast Arm Length (Feet)	Mast Arm Diameter (Inches)	Mast Arm Weight (Pounds/Foot)
30 or less	8.25	17.90
31 thru 35	8.50	20.25
36 thru 40	9.00	21.80
41 thru 45	9.50	23.00
46 thru 50	10.00	27.50
51 thru 55	10.50	31.50
56 thru 60	11.00	38.10
61 thru 65	11.30	41.00
66 thru 70	11.60	43.95
71 thru 75	12.70	50.85
76 thru 80	13.80	57.75
81 thru 85	14.90	64.65
86 thru 90	16.00	71.55

- **Traffic Signal Mast Arm Height:** Typical mast arm poles have a 22-foot shaft, unless street lighting is integrated with the traffic signal pole.
- **Traffic Signal Mast Arm Pole Location:** The requirements are the same as those listed for the location of strain poles (See Section 9.1.1).
- **Luminaires:** The requirements are the same as those listed for the location of strain poles (See Section 9.1.1).

➤ **Traffic Signal Mast Arm Pole Layouts:** The following describes the two layouts of traffic signal mast arm poles, single and dual, and shown in Figure 9.2.

- **Single Mast Arm Layout:** A typical single mast arm installation can be used at the intersection of two undivided roadways.

Advantages:

- Provides the required minimum 40-foot distance between the signal heads and stop line of all approaches;
- Provides good far-side signal face visibility for pedestrians;
- Provides locations for pedestrian signal indications and pedestrian detectors where needed.

Disadvantages:

- Requires four mast arm poles and foundations for a typical four-leg intersection.

- **Dual Mast Arms Layout:** The dual mast arm arrangement is often applicable at offset intersections and at T-intersections.

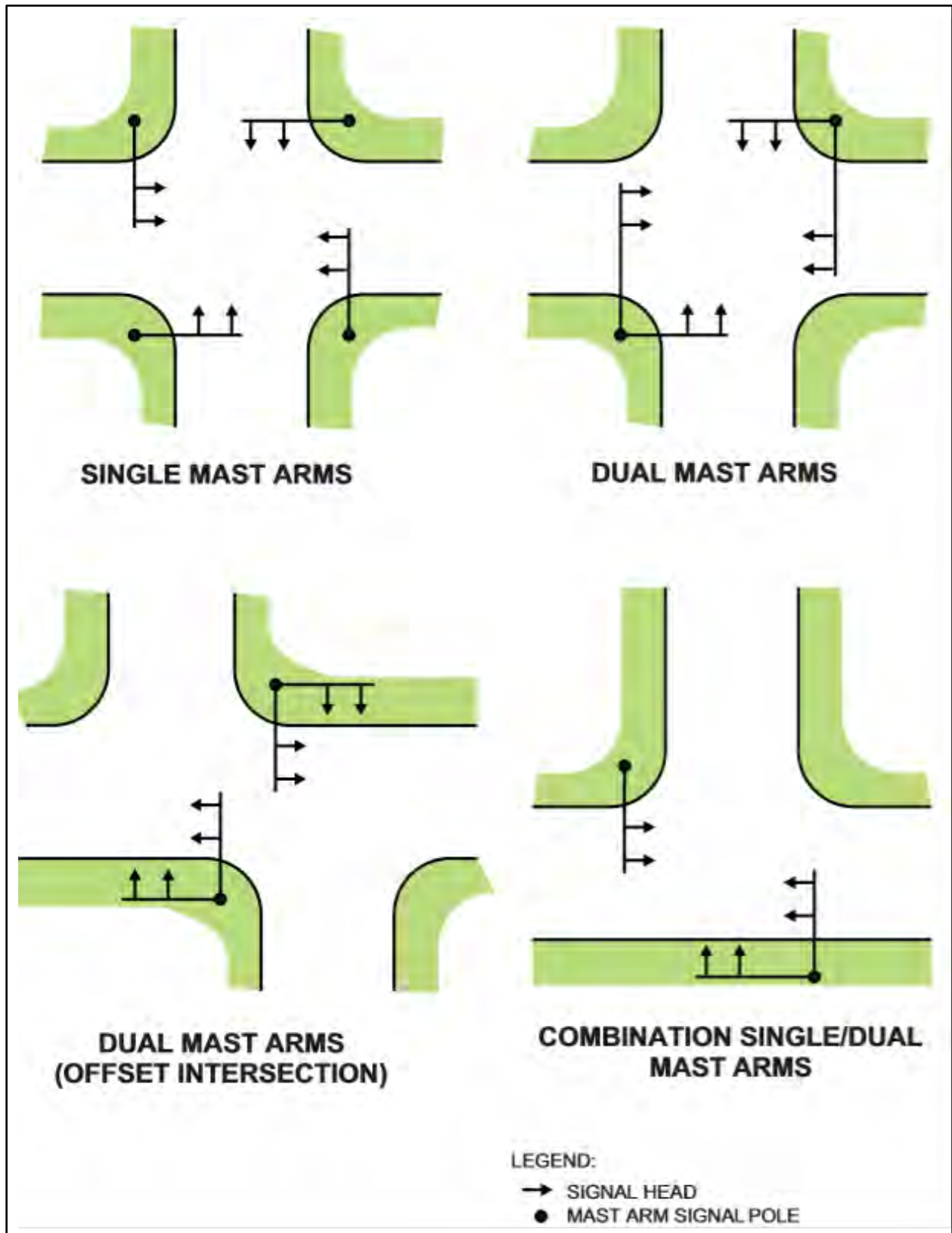
Advantages:

- Uses fewer poles than a strain pole or single mast arm arrangement;
- Provides good signal face placement for offset intersections;
- Good for locations with corners lacking right-of-way for poles.

Disadvantages:

- Additional traffic signal poles may be needed if pedestrian signals and detectors are required;
- Sight lines to the signal faces may be obscured.

Figure 9.2 – Typical Mast Arm Pole Layouts



9.2 Traffic Signal Indications

Traffic signal indication design shall comply with the MUTCD Sections 4D.04 through 4D.25. In addition, the following information should be considered.

9.2.1 Lens Size, Illumination and Shielding

All new traffic signal vehicular indications should be 12-inch diameter LED lenses (See TDOT Standard Drawing T-SG-7). The use of LED lights conserves energy and reduces maintenance requirements. As a minimum, all signal indications shall be equipped with cut away (partial) visors to prevent the sun phantom effect (signal appearing to be on due to the sun reflecting on the signal indication lens). Signal visors exceeding twelve inches in length shall not be used on free-swinging signal faces.

9.2.2 Traffic Signal Housing

Aluminum or polycarbonate traffic signal housings are recommended for traffic signal indications. Due to its light weight, polycarbonate traffic signal housing must either be tethered or rigidly mounted to minimize wind sway. Tethered traffic signal housing must have break-away clamps to allow it to swing free during heavy wind conditions. Aluminum traffic signal housing weigh more, but require less maintenance and is more durable than polycarbonate traffic signal housing. Traffic signal housing should have a black or yellow finish. The inside of signal visors and the entire surface of louvers and fins shall have a dull black finish.

9.2.3 Traffic Signal Backplates

Traffic signal backplates increase the contrast between the signal indications and the signal background. Backplates shall be used at all rural locations, on approaches 45 mph or greater, and at urban locations where glare or other visual distractions are present which include a rising/setting sun or intensive advertising signing along the roadway. Where used, backplates shall have a dull black finish along with a retro-reflective strip around the border of the backplate (See TDOT Standard Drawing T-SG-9A).

9.2.4 Strobe Lights

The use of strobe lights within or adjacent to any traffic signal indication is prohibited.

9.2.5 Countdown Displays

The use of countdown displays as part of a vehicular traffic signal indication is prohibited.

9.2.6 Number of Signal Faces on an Approach

The number of primary signal faces and the need for supplemental signal faces is determined by the following criteria:

- **Primary Signal Faces:** If a signalized through movement exists on an approach, a minimum of two primary signal faces shall be provided for the through movement. If a signalized through movement does not exist on an approach, a minimum of two primary signal faces shall be provided for the signalized turning movement that is considered to be the major movement from the approach. Where two or more left-turn lanes are provided for a separately controlled protected only left-turn movement, a separate primary left-turn face shall be provided for each lane. The same applies for right-turn lanes.
- **Supplemental Signal Faces:** Supplemental signal faces are used to maximize visibility of traffic signal indications, to minimize issues of approaching vehicles traveling behind large vehicles (trucks, buses, etc), or in locations where sun glare is problematic.

A supplemental near-side signal face is required where primary signal faces are located more than 180 feet beyond the stop line. A supplemental near-side signal face may be beneficial where primary signal faces are located between 150 feet and 180 feet from the stop line. A supplemental near-side or far-side signal face may also be beneficial where approaching speeds are 45 mph or greater.

9.2.7 Visibility of Signal Faces on an Approach

The two primary signal faces required as a minimum for each approach should be continuously visible to traffic approaching the traffic control signal, from a point at least the minimum sight distance provided in Table 9.2 in advance of and measured to the stop line. This range of continuous visibility should be provided unless precluded by a physical obstruction or unless another signalized location is within this range. If approaching traffic does not have a continuous view of at least two signal faces for at least the minimum sight distance shown in Table 9.2, a sign (two signs in case of a median) shall be installed to warn approaching traffic of the traffic control signal and a warning beacon may be used.

Table 9.2 – Minimum Sight Distance for Signal Visibility

Approach Speed (mph)	Minimum Sight Distance for Signal Visibility (Feet)
20	175
25	215
30	270
35	325
40	390
45	460
50	540
55	625
60	715

Note: Distances in this table are derived from stopping sight distance plus an assumed queue length for shorter cycle lengths (60 to 75 seconds).

9.2.8 Mounting Height of Signal Faces

Table 9.3 provides the minimum vertical clearance (from the bottom of the signal housing to the roadway, sidewalk, or median) and the maximum mounting height (from the roadway, sidewalk, or median to the top of the signal housing) for vertical and horizontal mounting of traffic signal faces. It is good practice to align red signal indications at the same height. Table 9.4 provides the maximum mounting height to the top of the signal housing for overhead signals located between 40 feet and 53 feet from the stop line (See Figure 9.3). Individual signal sections shall be mounted vertically rather than horizontally, unless sight distance or vertical clearance concerns dictate.

Table 9.3 – Mounting Height of Signal Faces

Mounting	Location	Minimum Height to Bottom (Feet)	Maximum Height to Top (Feet)
Vertical	Roadway	17.5 (Recommended)	25.6
		16.5 (Minimum)	
	Sidewalk	8	19
	Median	4.5	19
Left-Turn	Roadway	17.5 (Recommended)	25.6
		16.5 (Minimum)	
	Sidewalk	8	22
	Median	4.5	22

Table 9.4 – Mounting Height to Top of Signal Housing (40-53 Feet)

Horizontal Distance from Stop Line (Feet)	Height to Top of Signal Housing Above Pavement (Feet)
40	21.0
41	21.3
42	21.7
43	22.1
44	22.4
45	22.7
46	23.2
47	23.5
48	23.8
49	24.2
50	24.5
51	24.9
52	25.3
53	25.6

Note: Distances in this table are derived from stopping sight distance plus an assumed queue length for shorter cycle lengths (60 to 75 seconds).

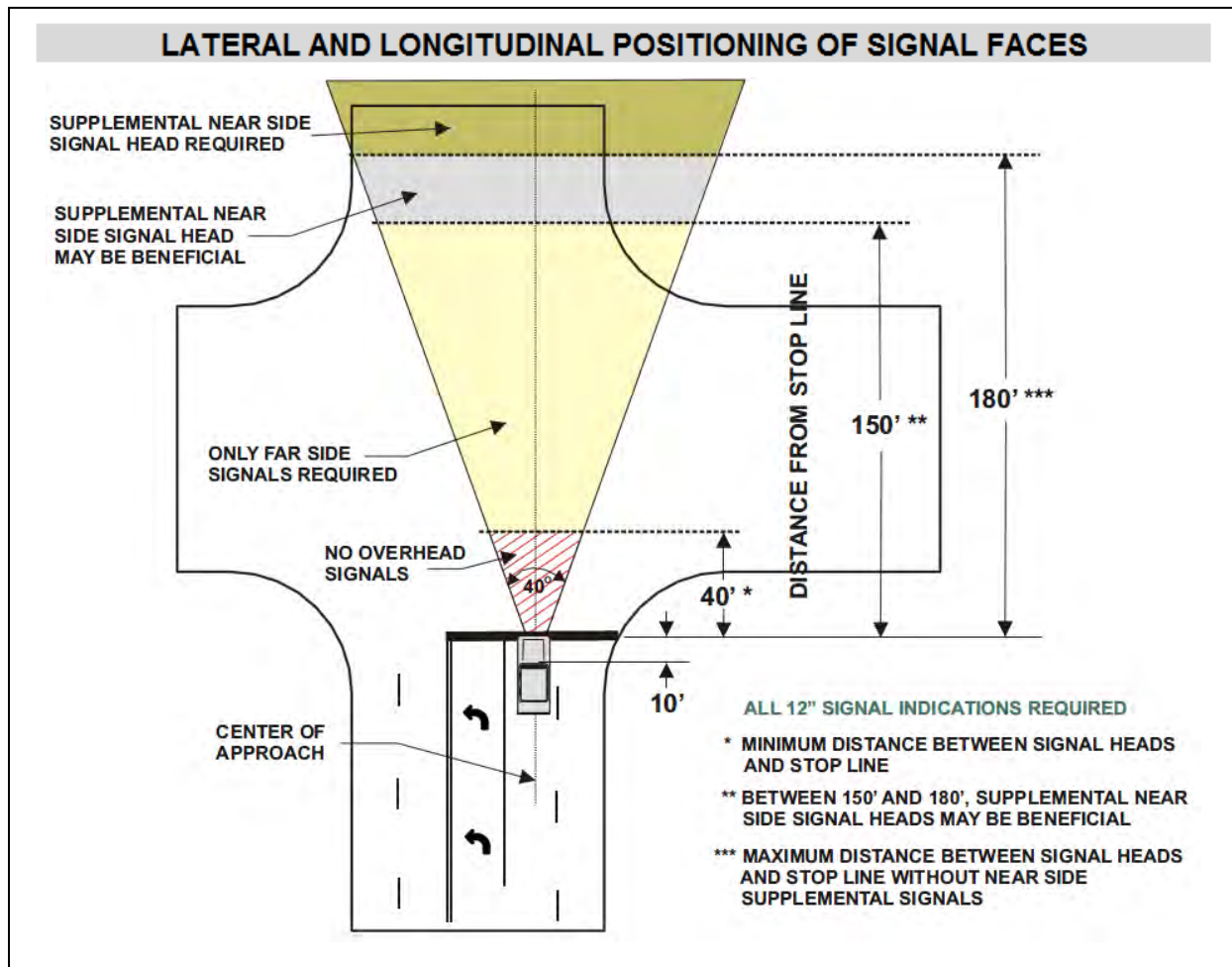
9.2.9 Lateral and Longitudinal Positioning of Signal Faces

At least one and preferably both of the two minimum primary signal faces required in Section 9.2.6 shall be located within the cone of vision illustrated in Figure 9.3. Signal faces on the same span wire or mast arm are typically placed twelve feet apart and shall be placed no closer than eight feet of horizontal separation between faces on the same movement (measured from center to center).

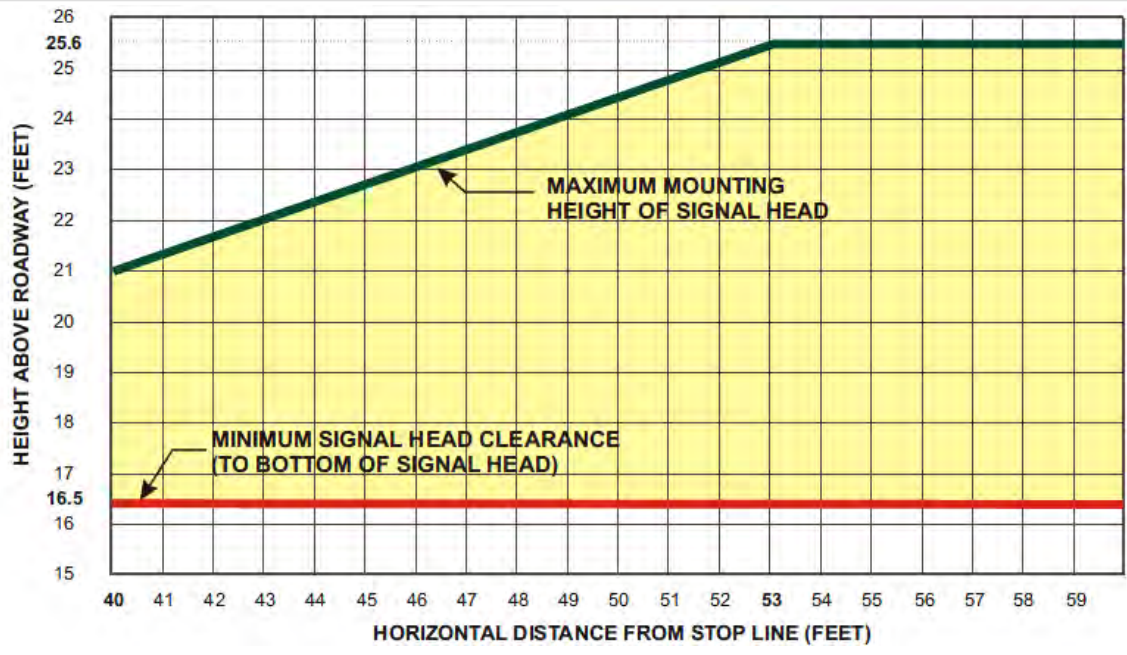
9.2.10 Shared and Separate Signal Faces

A shared signal face controls both a turn movement and the adjacent through movement, always displaying the same color of circular signal indication as the adjacent through signal face. A shared signal face can serve as one of the two required primary signal faces for the through movement (See Section 9.2.6). A separate signal face exclusively controls a turn movement and displays indications that are applicable only to the turn movement. A separate signal face cannot serve as one of the two required primary signal faces for the through movement.

Figure 9.3 – Positioning of Signal Faces



MOUNTING HEIGHT OF SIGNAL FACES



9.2.11 Signal Face Number and Arrangement

Typically, traffic signal faces should be centered over the lanes to which they apply or positioned over lane lines between lanes (shared signal faces). Depending upon the number of approach lanes to the intersection and the traffic signal phasing operation for that approach, the number and type of traffic signal faces will vary. Refer to *TDOT Standard Drawings T-SG-7A through T-SG-7S* for the recommended minimum arrangement of signal faces in Tennessee. For additional information regarding specific lane configurations or for alternative arrangements of signal faces, refer to the *MUTCD*.

9.2.12 Optically Programmed Signal Heads

Optically programmed signal heads may be used when the site physical geometry or operational problems require their use. When considered for a location, the use of optically programmed signal heads should be reviewed by TDOT. One situation to consider restricted visibility is where signal heads are placed very close to one another (e.g. closely spaced or offset intersections). The conflicting indications can be confusing to drivers because motorists could see both green and red indications. This confusion can be reduced through the use of optically programmed heads, which uses special lenses to significantly restrict visibility angles and distances and prevent motorists at one intersection from viewing the signal indications at the other intersection. When using optically programmed heads, the designer must clearly specify them on the plan sheet and clearly delineate their desired view limits. Because optically programmed signal heads have highly restricted viewing angles (far more restricted than standard signal heads), they are very sensitive to movement and must be either rigidly mounted or tethered. Designers must consider that because optically programmed heads can restrict visibility distance they can also severely restrict stopping sight distance. Signal phasing must be chosen carefully so that the designer does not create a situation where motorists have inadequate warning of a red indication.

9.2.13 Louvers

Another means of restricting the viewing angle and viewing distance for signal heads is the use of louvers. Louvers are vertical slats fitted to the tunnel visor designed to restrict lateral (side-to-side) visibility. Whereas optically programmed heads can restrict both longitudinal and lateral visibility, louvers restrict only lateral visibility and thus have limited applications. Louvers are most commonly used at intersections where the roads cross at oblique angles which could allow motorists the ability to view signal indications for two approaches and be confused. In short, louvers restrict visibility, thus eliminating potential confusion. Designers should consider the use of louvers when the angle of intersection between two roadways is 35° or less. Louvers are typically less expensive than optically programmed heads and do not need to be tethered.

9.2.14 Use of Signs at Signalized Intersections

The MUTCD Section 4D.34 and the sections listed below provide standards and guidelines regarding the use of signs at signalized intersections.

- Section 2B.18 – Movement prohibition signs;
- Sections 2B.19 to 2B.22 – Lane control signs;
- Section 2B.51 – Pedestrian crossing signs;
- Section 2B.52 – Pedestrian and bicycle actuation signs;
- Section 2B.53 and 2C.48 – Traffic signal signs;
- Section 2C.36 – Signal ahead warning signs;
- Section 2D.43 – Street name signs;
- Section 2D.44 – Advanced street name signs.

9.2.15 Use of Stop Signs at Signalized Intersections

The MUTCD Section 4D.34 mentions that STOP signs shall not be used in conjunction with any traffic signal operation, except when:

- The signal indication for an approach is a flashing red at all times;
- A minor street or driveway is located within or adjacent to the area controlled by the traffic signal, but does not require separate traffic signal control because an extremely low potential for conflict exists.

9.2.16 Pedestrian Signal Indications

Pedestrian signal indications consist of illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DON'T WALK when steady). When the UPRAISED HAND pedestrian signal indication is flashing it means that a pedestrian shall not start to cross the roadway, but any pedestrian who has already started to cross shall proceed to the other side of the traveled way or to the median. The MUTCD Chapter 4E provides standards and guidelines regarding pedestrian control features. All new pedestrian signal indications shall be displayed within a rectangular background and shall consist of symbolized messages. TDOT requires the use of a one-section integrated pedestrian head on new signal installations with the countdown display. Symbol designs shall follow the Standard Highway Signs and Markings and colors shall be consistent with the Pedestrian Traffic Control Signal Indications. TDOT requires the symbols on the pedestrian signal indication to be a minimum of twelve inches high. A pedestrian change interval countdown display (MUTCD Section 4E.07) shall be used where the calculated pedestrian change interval is more than seven seconds to inform pedestrians of the number of seconds remaining in the pedestrian change interval. The countdown display shall be displayed simultaneously with the flashing UPRAISED HAND signal indication. TDOT requires the numbers (digits) on the countdown display to be a minimum

of nine inches. The bottom of the pedestrian signal housing (including brackets) shall be mounted between eight and ten feet above the sidewalk level. See *TDOT Standard Drawing T-SG-6* for typical pedestrian signal indication design guidelines.