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# Traffic Signal Support, Indication and Signing

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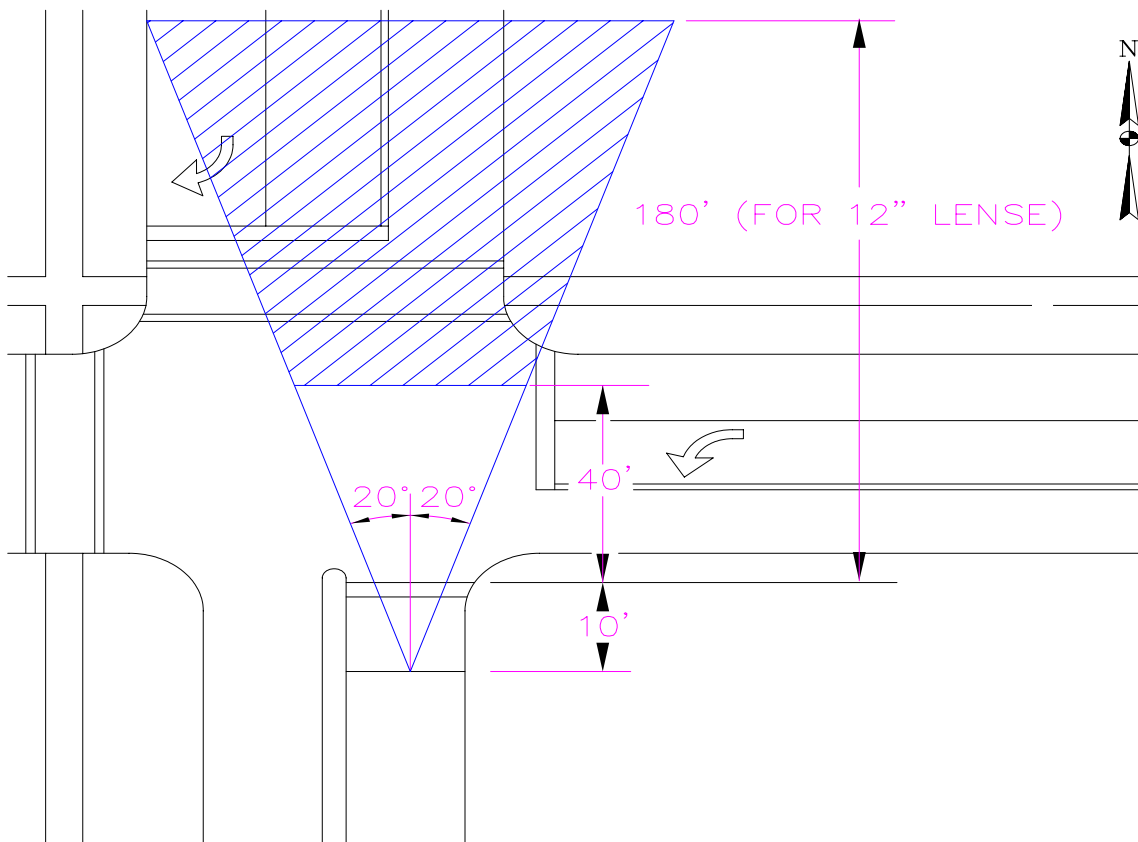
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## TRAFFIC SIGNAL SUPPORTS, INDICATIONS AND SIGNING

This Traffic Signal Design course provides a description of the meaning and use of vehicular and pedestrian signal indications as well as a discussion of basic signal operations. Also included in this course is a discussion of lane use control signals and signs commonly associated with traffic signal installations.

The Manual on Uniform Traffic Control Devices (MUTCD) requires that two "primary signal faces" control the main movement of an approach (usually the thru movement). The MUTCD also requires that there be at least 40 feet of distance from the stop line to one of the primary signal faces and that one of these primary signal faces must be located no further than 180 feet from the stop line.



The MUTCD also recommends that the primary signal faces be located within a 20-degree "cone of vision" as measured from a point 10 feet behind the stop line and in the center of the approach. The purpose of these signal face placement requirements is to ensure good signal visibility.

Supplemental near side signal heads can be added if the primary signal heads are located further than 180 feet from the stop line, or if the primary signal heads cannot be clearly seen when approaching the intersection.

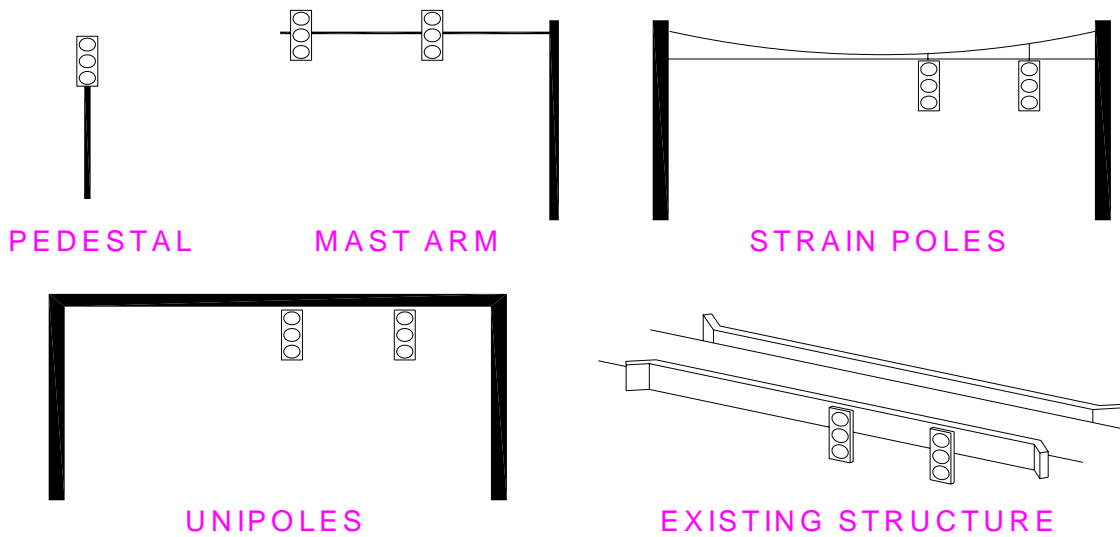


The same location requirements are also beneficial for non-primary signal faces, which typically are those controlling turn lanes.

The MUTCD requires that a minimum vertical clearance of 15 feet be provided between the road surface and the bottom of the lowest signal head. 15 feet provides enough clearance for all vehicles of legal height to pass under the signal head. However, many states have higher vertical clearance requirements to accommodate unusually tall vehicles. For example, the State of Florida has a minimum vertical clearance requirement of 17.5 feet. The MUTCD also requires that the distance between the roadway and the top of the highest signal head be no greater than 25.6 feet. This prevents the signal heads from being mounted too high, making them less likely to be seen by the motorist.

There are five basic types of traffic signal supports:

1. Pedestals
2. Mast Arms
3. Poles
4. Unipoles
5. Existing Structures

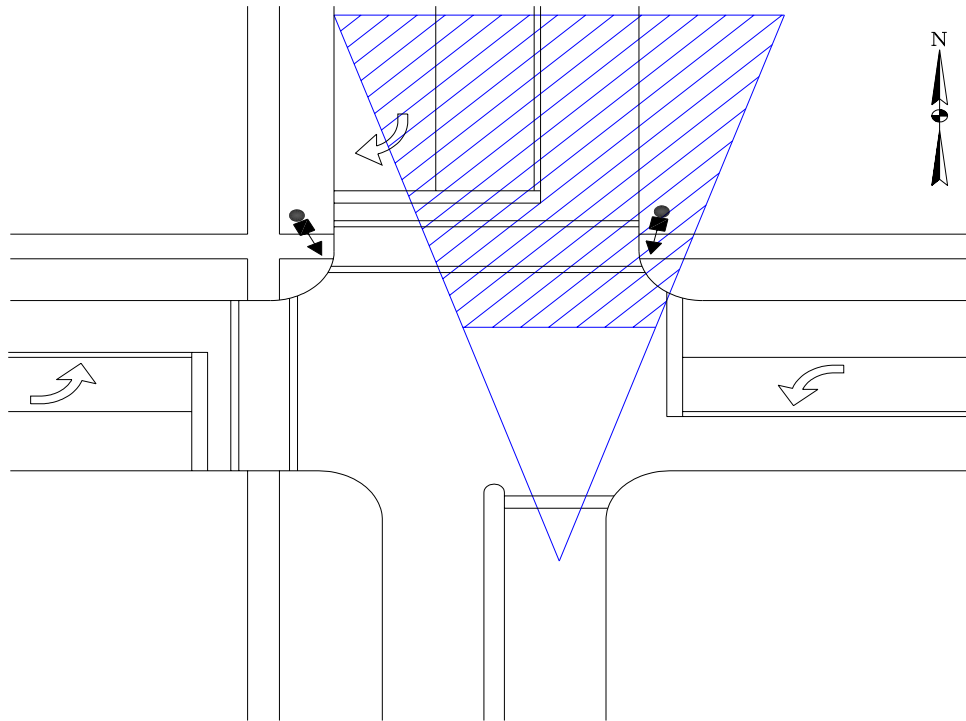


## PEDESTALS

Pedestal supports, which are most commonly found in the downtown areas of older cities, are the simplest and least expensive traffic signal support.



In order to provide the dual indication of thru movements required by the MUTCD, a pedestal is typically provided on each side of a signalized intersection or, if a median exists, one pedestal is located on the right side of the intersection and the other is located in the median.



In downtown areas where room is tight, the pedestal often ends up being located within the sidewalk. Signal pedestals are typically constructed of either steel or aluminum although other materials, such as concrete, can be used. In most instances, the pedestals are bolted to an underground concrete foundation, which gives the pedestal structural stability. The pedestal is typically hollow and the cable from the signal head passes through the inside of the pole to conduit located in the foundation of the pole, and then through this conduit to external conduit that takes the signal cable back to the traffic signal controller.

Signal pedestals are usually around 8 to 10 feet in length. Since the signal head is almost always attached to the top of the pedestal, the 8 to 10 foot of pedestal length is sufficient to provide adequate vertical clearance for any pedestrians or cyclists that might pass under it.

With signal pedestals the traffic signal heads are located to the side of the road whereas, with the other types of traffic signal supports, the signal heads are usually mounted over the road. Mounting the heads over the road requires taller poles since there must be enough vertical clearance for vehicles to pass underneath.

## MAST ARMS

In a mast arm assembly, the signal heads are mounted on a rigid arm that extends over the roadway.



The mast arm assembly consists of two major components: 1. the mast arm pole, which is the vertical component that provides structural strength, and 2. the mast arm itself, which is the horizontal component on which the signal heads are mounted. The mast arm is bolted to the mast arm pole. This attachment usually occurs in the field, which makes it easier to transport the assembly to the site.

The signal heads can be either rigidly attached to the mast arm or can be suspended from the mast arm. A number of manufacturers make special brackets to accommodate rigid mounting. These brackets allow the signal head to be turned to virtually any viewing angle and also allow the head to be vertically positioned as desired. Both horizontal and vertical signal head mounting can be achieved with these brackets. Rigid mounting can also be obtained by fabricating nipples into the mast arm itself; however, this method of attachment greatly reduces the amount of signal head adjustment that can take place.

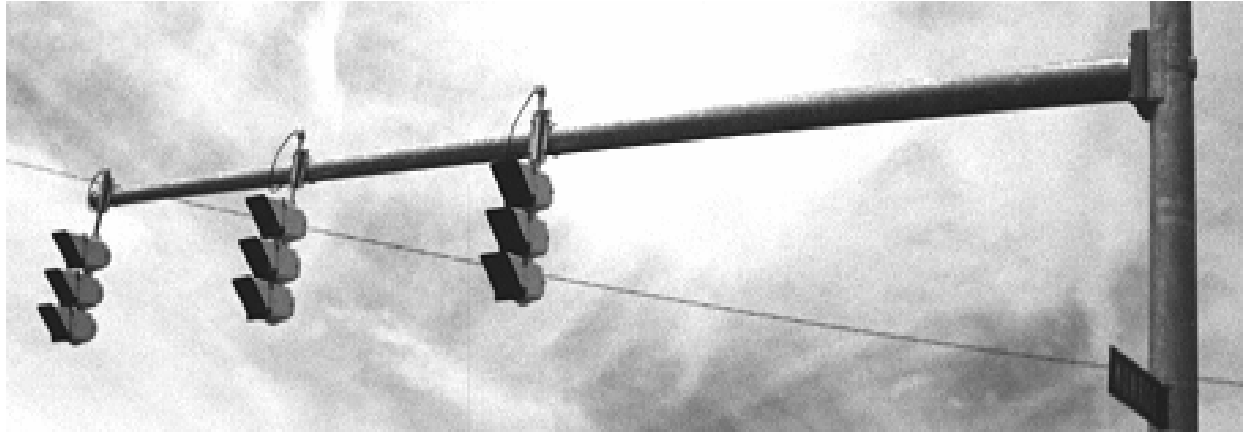
Suspended signals "give" with the wind, resulting in less of a wind load on the mast arm assembly.



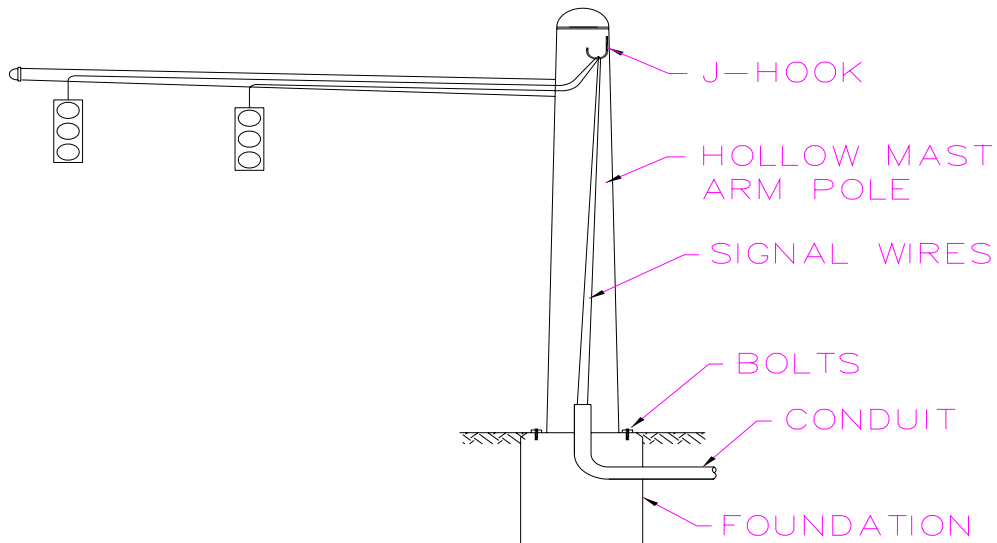
However, many agencies prefer rigidly mounted signal heads since the absence of signal head movement reduces the chance for chaffing of the signal head wires and eliminates the visual flicker caused by signal heads moving in the wind. Another advantage of rigidly mounted signal heads is that a shorter mast arm pole is required because the heads are not suspended beneath the mast arm. Improved aesthetics is also given as a reason for the use of rigidly-mounted signal heads.



Optically programmed signal heads are designed to present a narrow field of view to the motorist so that no ambiguity occurs as to which movement the head controls. For these heads to remain properly "aimed" they must be securely mounted, which ensures that they will not turn in the wind. For this reason, mast arm attachments are preferred over span wire attachments for mounting these heads.



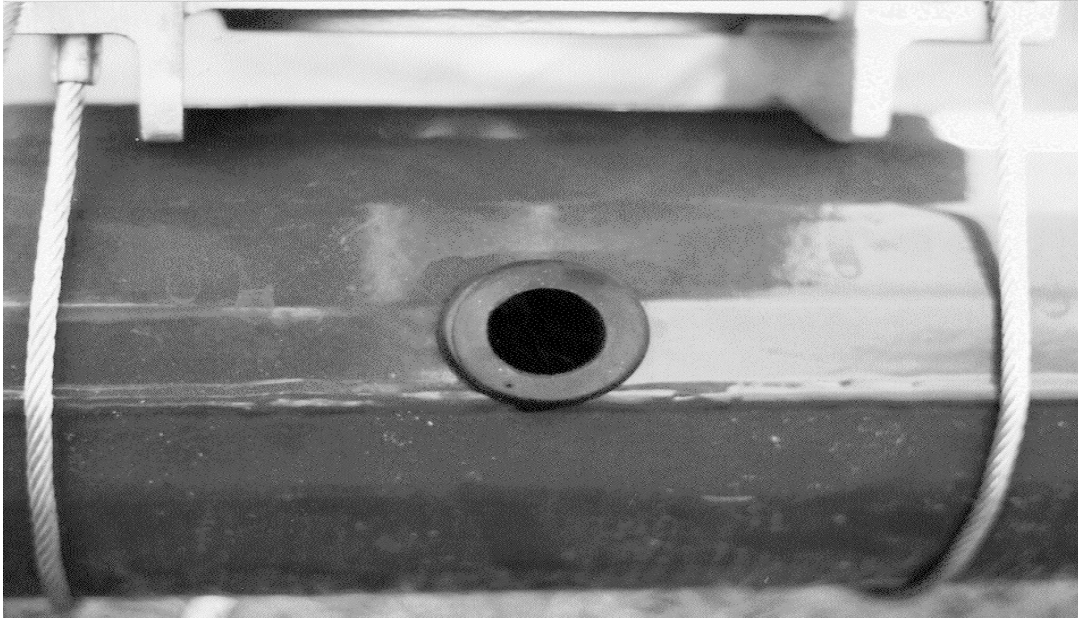
Mast Arm assemblies are typically constructed of either steel or aluminum. The assembly is bolted to a reinforced concrete foundation which gives the assembly additional structural stability. The mast arm and mast arm poles are hollow and the cable from the signal heads passes through the inside of the mast arm and mast arm pole to conduit located in the concrete foundation, and then through this conduit to external conduit that takes the signal cable back to the traffic signal controller.



Holes are provided in the mast arms through which the signal cable will pass to reach the signal heads. Although these holes are sometimes drilled at the factory, in most cases they are field-drilled



to ensure that the holes are properly located at the intended signal head location. Rubber grommets are typically inserted into the holes to prevent the signal cable from chaffing against the jagged edge of the hole.



A J-hook is typically installed on the top inside of the mast arm pole. The purpose of this hook is to physically support the vertical run of signal cable inside the mast arm pole. This hook, which carries the weight of the cable, keeps the cable from pulling on the signal head connections.



Various means are used at the base of the mast arm pole to accommodate the signal cable. Some agencies install a terminal block at the base of the pole and, using this terminal block, make electrical connections between the cable in the mast arm assembly and the underground cable going to the controller. Other agencies merely splice the two cables together at the base of the pole. Still other agencies neither splice nor use a terminal block at the base of the pole (high-water problems are one reason that is often sighted). These agencies use a single signal cable all the way from the signal heads to the controller.

Handholes are openings in a signal support pole that provide access to the inside of the pole. They are typically used during signal cable installation to allow the cable to be pulled inside the pole.



Some agencies prefer to have a large base, referred to as a "transformer base", at the foot of the mast arm pole. A transformer base provides plenty of working room for pulling cables and can also house a terminal block.



Steel mast arm assemblies are typically galvanized to prohibit rusting. Rust is not only unsightly but it can dangerously weaken structural members. Some agencies prefer to have their mast arm assemblies painted (black, brown, green, etc.) since they believe this looks better than the dull silver color of galvanized steel.

Mast arms must be properly handled during installation to ensure that members are not inadvertently bent and to ensure that portions of the galvanized or painted surface are not accidentally scraped off. However, even with careful handling, a certain amount of field galvanizing or paint touch-up is usually required.

The length of the mast arm depends on the location of the mast arm pole with respect to the edge of roadway and the desired location of the signal heads with respect to the travel lanes. Typically mast arm lengths are on the order of 30 to 70 feet. However, as the length of the mast arm grows, the size of the mast arm pole and foundation required to support the arm increases, as does the price of the mast arm assembly.

Mast arm assemblies are sometimes constructed to allow the mast arm to be moved out of the roadway, permitting very tall vehicles to pass. This is typically used along routes where house-moving is expected. Depending on the type of construction used, either the entire mast arm assembly will rotate or just the arm will rotate. Because of the substantial weight and size of the mast arm assembly, special tools and equipment (such as a crane) are needed to rotate it.

The amount of sag of the mast arm depends on the stiffness of the mast arm, with stiffer mast arms having less sag. Sag that is 2% of the mast arm length is a typical value used in design. Consequently, a 50-foot mast arm will usually have about 1 foot of sag.

A mast arm pole is typically between 20 and 25 feet in length, about twice as long as a signal pedestal. The actual length depends on many items, including: the relative elevation of the mast arm foundation with respect to the road, the type of signal head mounting that is used (rigid versus suspended and horizontal vs. vertical), the amount of mast arm sag, and the desired vertical clearance. A mast arm pole may be substantially longer than 25 feet if it is designed to also accommodate a luminaire for roadway lighting.

It is sometimes advantageous to attach two mast arms to one mast arm pole. The mast arm pole and foundation must be designed to support the additional load associated with two mast arms.

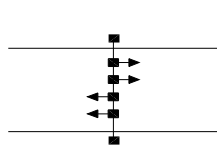


Mast arm installations are typically configured in a box arrangement with one mast arm on each corner. If it is not possible to locate a mast arm pole on each corner then twin mast arms might be used or a diagonal arrangement might be installed.

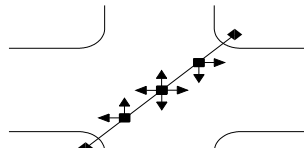
## POLES

Poles are the most common type of traffic signal support. In a pole installation, the signal heads are suspended from a span wire that is connected between the poles. The poles themselves are typically located on the corners of the signalized intersection. Pole installations can be configured in a wide variety of ways:

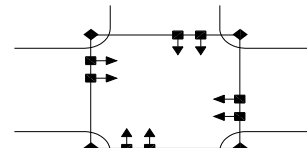
1. Perpendicular Spans
2. Diagonal Spans
3. Box Spans
4. Special Configurations (X-Spans, Z-Spans, V-spans, etc.)



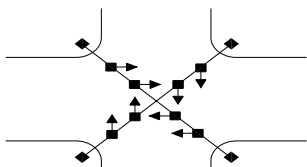
PERPENDICULAR  
(PED. CROSSING)



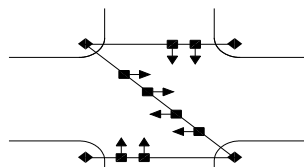
DIAGONAL SPAN



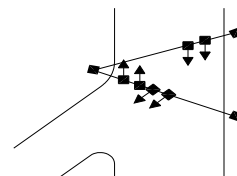
BOX SPAN



X-SPAN



Z-SPAN



V-SPAN

The key issue in selecting a particular configuration for use is the location of the signal heads with respect to the travel lanes. In general, the "best" span is the one that maximizes the visibility of the signal heads by placing them in a good location with respect to the travel lanes they control.

The most common use for perpendicular spans is at mid-block pedestrian signals. Two poles are used and a single span is run perpendicular to the roadway.



Diagonal spans are the simplest, and probably the most common, type of span used for intersection control. Two poles are located catty-corner from each other at the intersection and a single span is run diagonally between the two poles. Since only two poles are required, they are typically the least expensive spans to construct for intersection control.



Box spans use four strain poles, one located on each corner of the intersection, with a span wire run between each of the poles in a box configuration. Although they are more expensive to construct, at most intersections box spans result in superior head placement in comparison to diagonal spans.

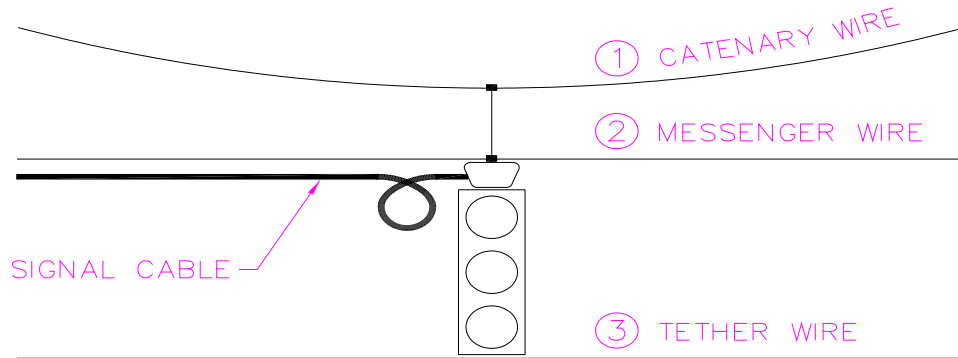


A variety of special span configurations can be used to accommodate unusual intersections. For example, X-spans, Z-spans, or suspended box spans often prove useful at very wide intersections and partial box spans are frequently used at tee intersections.

The 2009 MUTCD provides the following guidance with respect to span design and signal head locations:

*“Locating primary signal faces overhead on the far side of the intersection has been shown to provide safer operation by reducing intersection entries late in the yellow interval and by reducing red signal violations, as compared to post-mounting signal faces at the roadside or locating signal faces overhead within the intersection on a diagonally-oriented mast arm or span wire. On approaches with two or more lanes for the through movement, one signal face per through lane, centered over each through lane, has also been shown to provide safer operation.”*

One, two, or even three support wires can be used in span wire installations. When a single support wire is used, the wire both supports the signal heads and carries the signal cable that is lashed to it. When two wires are used, the top wire (called the catenary wire) provides the structural support while the bottom wire (called the messenger wire) carries the signal cable that is lashed to it. A three-wire system is identical to a two-wire system except that a third wire (called the tether wire) is run below the signal heads to provide additional head stability.



The required diameter of the signal support wires depends on the loads to be carried, with larger diameter wire being used for heavier loads. Care must be taken to ensure that the wire size called for in the plans and specifications is used.

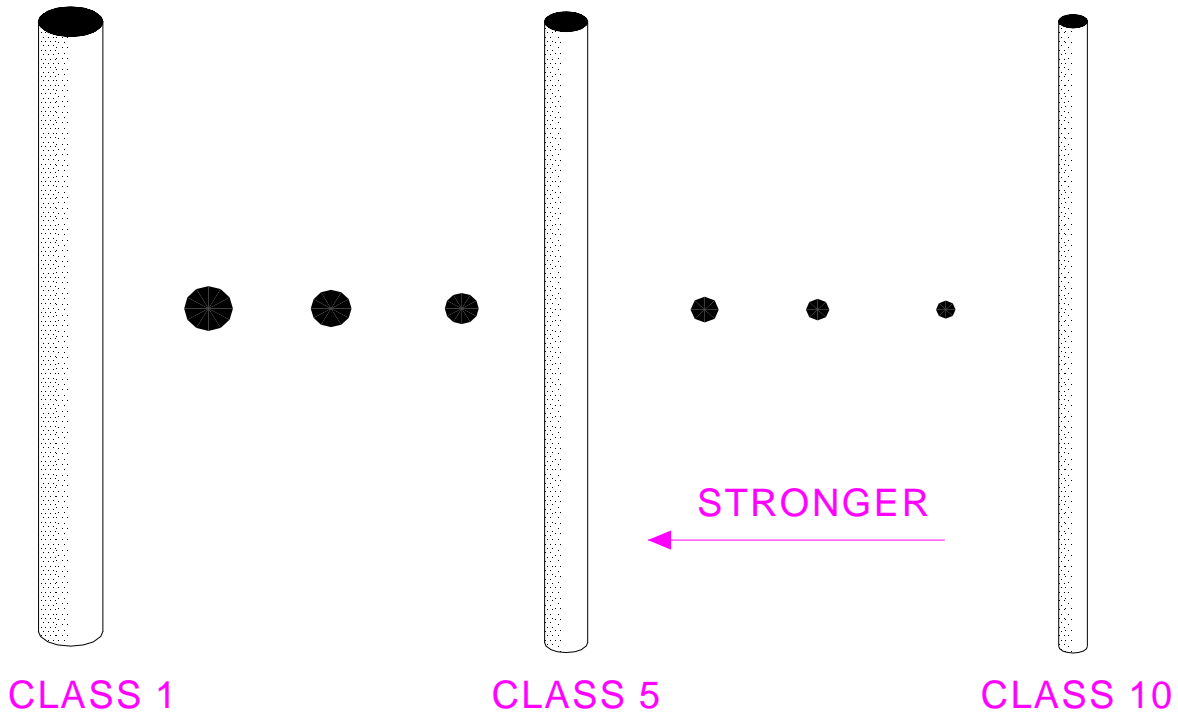


There are four common types of traffic signal support poles:

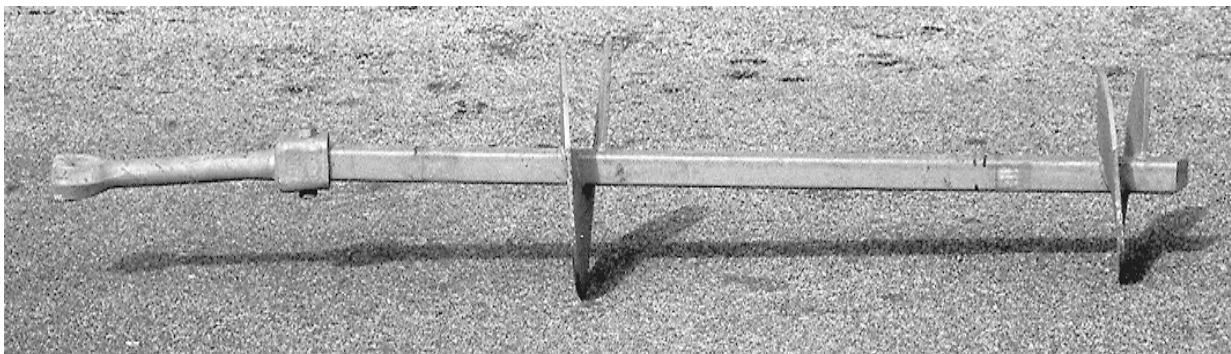
1. Wooden Poles
2. Concrete Poles
3. Steel Poles
4. Aluminum Poles

Wooden poles are typically made out of treated lumber and are essentially the same type of pole used by many utility companies to support overhead wires.

## WOOD POLE CLASSES



The wooden pole is buried in the ground and conduit attached to the outside of the pole is used to run signal cable from the span wires to underground conduit. A rule of thumb for burial depth is that the pole should extend 1 foot underground for each 5 foot of the pole that is above ground. Wooden poles are often guyed opposite the load on the pole to provide additional structural support. Special expandable or screw-type anchors are used to secure the guy wire into the ground:

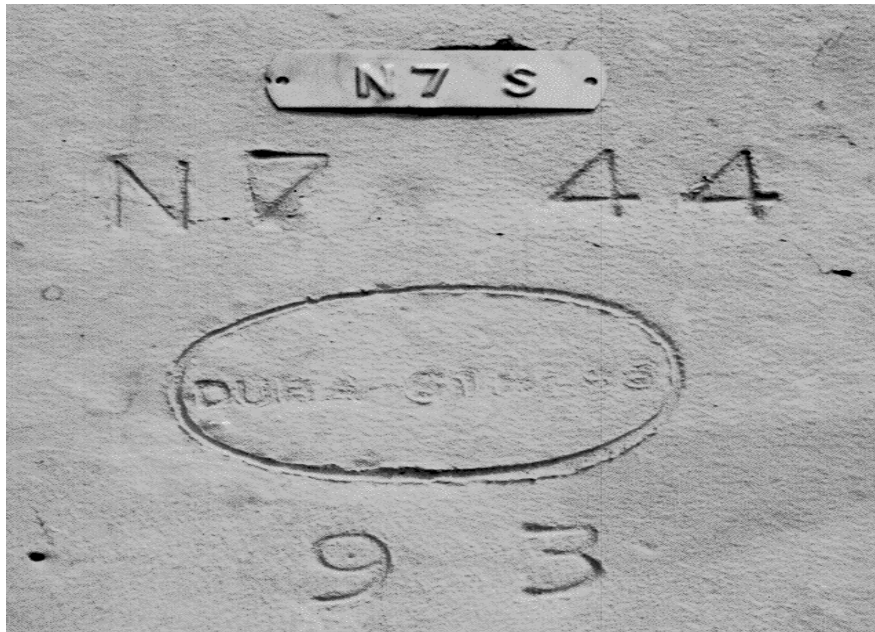




Concrete strain poles are made from prestressed reinforced concrete:



Prestressing allows concrete strain poles to withstand substantial horizontal loads without guying. However, not all concrete poles are prestressed. For example, many concrete light poles and concrete utility poles are not prestressed. Only concrete poles that are prestressed can be considered concrete "strain" poles and only these poles can be used for signal installation without guying. Information describing the pole is usually inscribed into the load face of a concrete strain pole:



This information includes such items as the length of the pole (44 feet), the structural class of the pole (Type N7), the pole manufacturer (Dura-Stress), and the year that the pole was fabricated (1993).

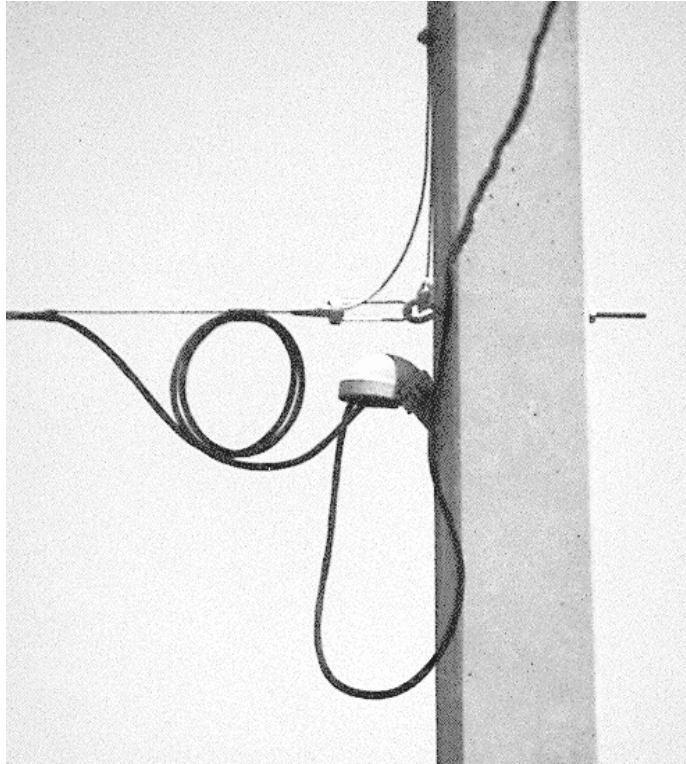
Steel poles are typically bolted to an underground concrete foundation which gives the pole additional structural stability. However, as is done with concrete strain poles, steel poles can be imbedded directly into the ground. The steel pole is hollow and the cable from the signal head passes through the inside of the pole to conduit located in the foundation of the pole, and then through this conduit to external conduit that takes the signal cable back to the traffic signal controller. Aluminum poles are similar in construction to steel poles. Their primary advantage is that they are less corrosive than steel, which can be important in areas exposed to sea air. However, aluminum poles are more expensive than steel poles.

The entry nipple of a strain pole is situated in the upper portion of the pole and is the location where the overhead signal cable enters the hollow strain pole. The picture below shows an entry nipple before the weatherhead has been placed on it.



The diameter of this hole should be large enough to accommodate all of the cables that will need to enter it. Typical diameters for this nipple are between 2 and 3 inches.

The signal cable weatherhead is a special fixture which attaches to the end of the entry nipple of a strain pole. The signal cable enters the hollow strain pole thru the weatherhead. The primary purpose of this weatherhead (which is also referred to as a "gooseneck" because of its shape) is to keep rain water from running along the signal cable, through the conduit, and into the pole. The signal cable weatherhead must be sized to fit the diameter of the entry nipple.

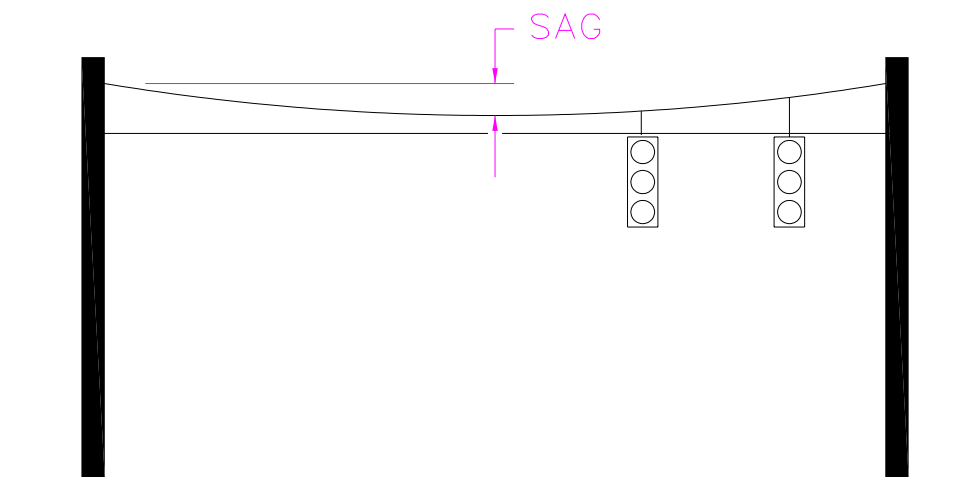


Drip loops are either loops or "dips" that are intentionally placed in the overhead signal cable run to provide locations where rain water will accumulate and drip off the cable. These loops are placed immediately adjacent to each signal head to keep the rain water from running down the signal cable and into the electrical connections contained inside the signal head disconnect. They are also used to help keep rain water from entering the signal pole through the weatherhead. The extra signal cable contained in these loops serves an additional purpose in that it allows the signal heads to be easily moved along the span wire for lateral adjustment purposes or for use in replacing damaged cable. In addition, the slack created by these drip loops helps prevent chaffing of the cable.

Utility poles that are also used to support signal heads are referred to as "joint-use poles". Joint-use poles may be wooden, steel, aluminum or concrete, depending on the preference of the local utility. Having joint-use poles reduces the number of poles at an intersection and, in some cases, can eliminate potential utility conflicts. Concrete joint-use poles differ from regular concrete strain poles in that the reinforcing inside the pole is arranged in a symmetrical pattern, allowing loads to be resisted in all directions rather than in just one direction.

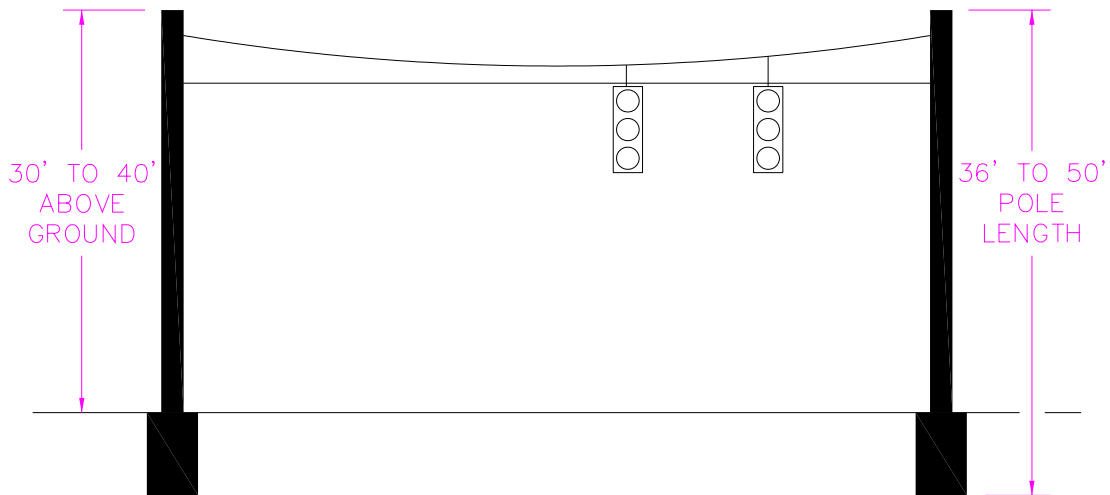


The vertical distance from the point on the strain pole where the catenary wire is attached to the lowest point of the catenary span is called the "sag". Sag of between 5% and 6% of the span length is typically used.



Since there is usually sizeable span sag associated with strain pole installations (a 160 foot span would have vertical sag of about 8 feet), strain poles must be substantially taller than mast arm poles to provide adequate vertical clearance for the signal heads attached to it. A height above ground of

between 30 and 40 feet is common for strain poles; which is about 50% greater than the height of mast arm poles.



The term "unipole" (or "monotube") is often used to refer to signal installations that are made-up of a single overhead structure which extends across the entire intersection. These structures may be comprised of a single pole that looks similar to a mast arm or may use a more elaborate truss-like structure.



The size and appearance of the structure will depend on the distance to be spanned and the number of signal heads and overhead signs that need to be attached to it.

A variety of decorative signal supports have been developed in an attempt to make traffic signals blend-in with their surroundings. These supports are typically used in downtown or historic areas of a city.

Pedestals tend to be the least expensive signal supports while unipole and mast arm installations are usually the most expensive. Strain poles are priced somewhere in between.

Because of the location of the intersection, it is sometimes necessary to mount signal heads directly to existing structures - such as the underside of bridges or viaducts:



When this is done, the cables from the signal head are usually run along the structure in metallic conduit.

It is sometimes desired to mount a luminaire on the top of a traffic signal pole to reduce the number of poles at an intersection. This can be done by adding a luminaire arm and the appropriate wiring.



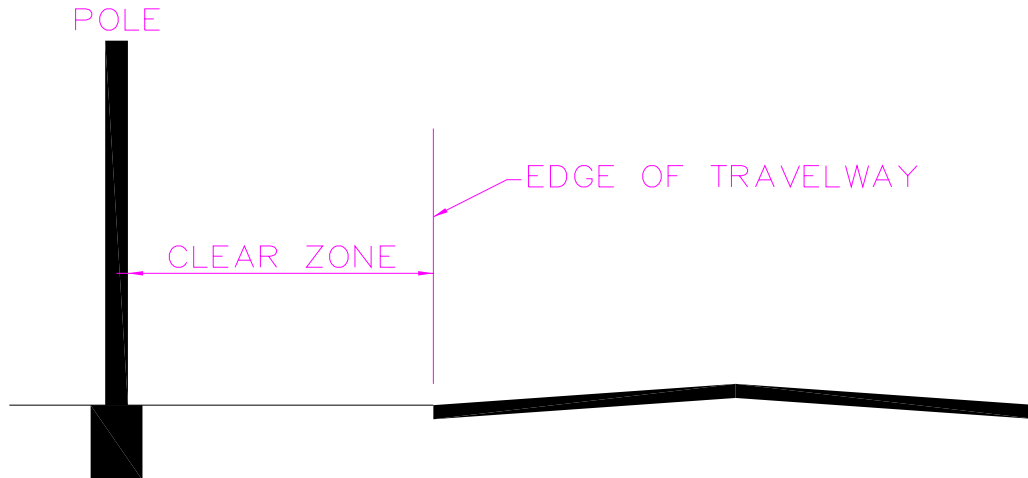
In choosing or evaluating a signal support system, the following issues need to be considered:

- Signal Head Placement (Lateral, Longitudinal and Vertical)
- Cost
- Location Relative to the Clear Zone
- Conflicts with Overhead Utilities
- Conflicts with Underground Utilities
- Vertical Clearance
- Aesthetics
- Susceptibility to Strong Winds

Overhead-mounted signal heads, such as those found in mast arm and strain pole installations, are more conspicuous than side-mounted signals. The conspicuity problem of pedestal-mounted signal heads is most pronounced at wide intersections where the heads may fall outside of the 20-degree cone of vision. Signal heads that control turn lanes can also be a problem when mounted on pedestals since these heads cannot be centered over the lane that they control.

## CLEAR ZONE

The clear recovery zone (or simply "clear zone") is an area outside the edge of the road that must be kept free of obstructions. Most signal supports are non-yielding objects that pose a hazard to motorists who might accidentally leave the road and enter this clear recovery zone. Consequently, these supports must be located outside the clear zone.



The clear zone is narrower for curbed roads than for non-curbed roads, with 4 feet from the face of curb being a typical clear zone distance. For non-curbed roads the width of the clear zone varies by the type of road (arterial, collector, etc.), the type of lane (thru lane versus exclusive turn lane), and the prevailing speed. Non-curbed clear zones typically range from about 8 feet to 24 feet for collector and arterial roads.

Although the clear zone concept applies to poles located in the median as well as poles located on the side of the road, some agencies do not permit signal poles to be located in the median even if they are outside the clear zone. These agencies feel that the median should be completely clear of obstructions since it is susceptible to encroachment by vehicles heading in both directions. An exception to this rule might be pedestal-mounted signal poles that are located on a break-away base.

On curbed roadways with narrow clear zones, all types of signal supports are relatively easy to accommodate. However, the larger required set-back distances for roads without curbs makes strain poles more attractive than either mast arms or pedestal mounted signals on these roads. In order for pedestal mounted signals to be placed outside of the clear zone on uncurbed roads the pedestals must be located a substantial distance from the edge of road, which almost always places the signal heads outside the 20-degree cone of vision. For mast arm assemblies on uncurbed roads, the mast arm has to be very long in order to span the required clear zone and position the heads over the travel lanes.

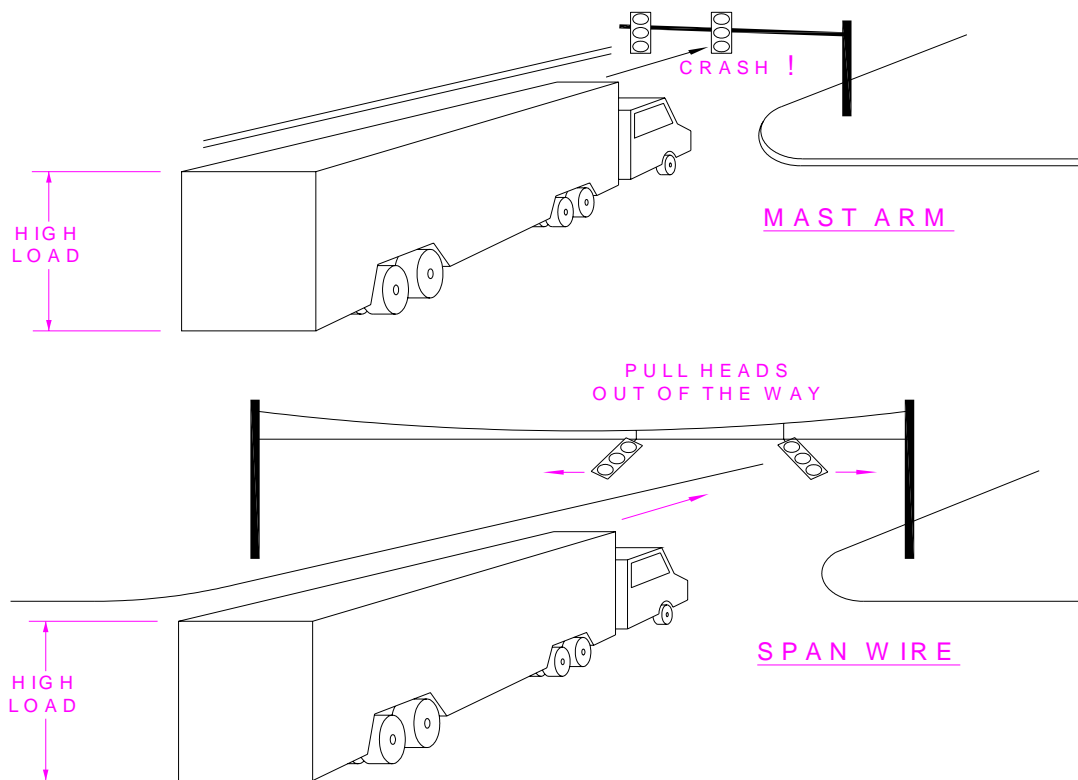


## UTILITY CONFLICTS

The considerable height of strain poles coupled with the fact that span wires "dance around" when strong winds blow make conflicts with overhead utility lines, especially overhead electric lines, an important area of concern for strain pole installations. Mast arms have less of a problem with overhead utility lines because of their shorter stature (they are usually under the electrical lines) and their fixed position. Pedestal-mounted signals have virtually no conflict with overhead utility lines.

Signal supports that have a poured foundation typically experience less conflict with underground utility lines than those that require a pole to be inserted into the ground. Poured foundations can be configured to avoid underground utility lines or, if necessary, the line can be encased in the foundation. This is not as easy to do with wood or concrete strain poles which have little flexibility with regard to the type of foundation used.

Vertical clearance restrictions with respect to over-height vehicles can be a significant issue along certain routes or in certain areas. Pedestal-mounted signals produce no vertical clearance restriction whereas non-rotatable mast arms produce the most serious vertical clearance restriction. Strain poles are somewhere in the middle since signal heads attached to a strain pole can be momentarily "pulled" out of the way to let over-height vehicles pass.



The low mounting height of pedestal-mounted signals is an important benefit if the signal is located near the flight path of an airport. Given strict FAA restrictions on structure height under a flight path, pedestal mounted signals are often the only feasible means of signalization in this situation. A low mounting height is also advantageous for signals near an underpass since the bridge structure can block the view of signals that are mounted overhead.

The low mounting height of pedestal-mounted signals makes them less visually obtrusive than other signal supports, which can be important in historic districts or other areas where visual aesthetics are of primary importance. Strain poles, with their tall supports and associated network of overhead wires, are usually considered the least attractive signal installation. Mast arms are somewhere in between, with painted mast arms usually being preferred over galvanized steel mast arms in areas that are aesthetically sensitive.

Rigidly-mounted signal installations, such as pedestals and mast arms, tend to be less affected by strong winds than strain pole installations. Span wires will snap, signal heads will rotate, and cable lashing will break on a strain pole installation long before mast arms or pedestals will fail. Other than during natural disasters, the failure of signal supports is a fairly rare phenomenon. However, one activity that can cause supports to either lean or totally fail is digging too close to an existing pole foundation. Care must be taken not to excavate near existing poles, especially on the load side of the pole.

## SIGNAL INDICATIONS

The illumination of any signal lens, or combination of signal lenses, constitutes a signal indication. Part 4 of the Manual on Uniform Traffic Control Devices (MUTCD) discusses signal indications in considerable detail. As with other sections of the manual, the emphasis is on uniformity with consistency of color, arrangement, position, and usage emphasized.

In a vertical signal the red indication is always on top and with a horizontal signal the red indication is always to the left. The following are allowable indications on a vehicular signal face:

- Circular red or red arrow
- Circular green or green arrow
- Circular yellow or yellow arrow
- Circular red and a green arrow
- Circular red and a yellow arrow

- Circular green and a green arrow
- Circular green and a yellow arrow
- Circular yellow and a yellow arrow

The circular red indication prohibits the driver from entering the intersection, requiring the driver to stop behind the stop line. If there is no stop line then the driver is required to stop behind the marked crosswalk. If there is no marked stop line or crosswalk then the driver is required to stop before entering the intersection. After coming to a complete stop, the driver is permitted to turn right on a circular red indication if there is no conflicting vehicular or pedestrian traffic. (Left on red is also permitted at the intersection of 2 one-way streets.) It should be recognized that conflicting vehicular traffic includes motorists making U-turns.

The red arrow indication is similar to the circular red indication except that A.) it only prohibits the driver from making the movement indicated by the arrow and B.) turns on red are not permitted unless a RIGHT (or LEFT) ON RED ARROW AFTER STOP sign is installed.

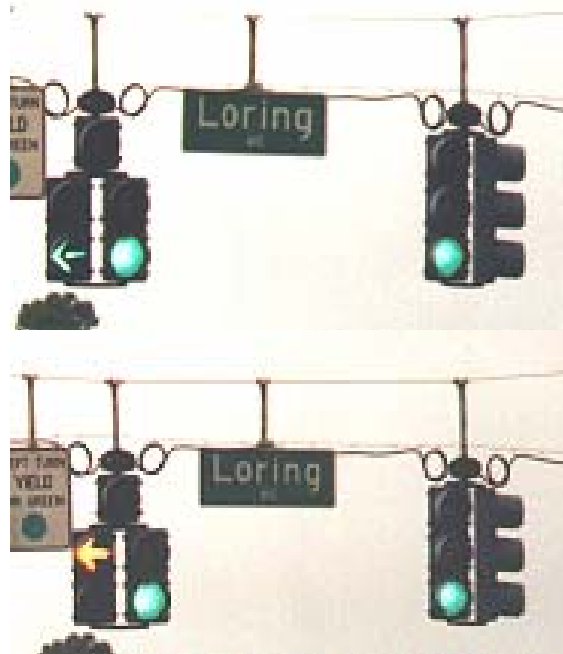
The circular green indication permits the driver to enter the intersection and, unless restricted by signs or other signals, to go straight, turn left, or turn right. When turning left on the circular green a driver must yield to oncoming traffic, and when turning either left or right the driver must yield to pedestrians.

The green arrow indication permits the driver to enter the intersection, but only to make the movement indicated by the arrow. A left turn green arrow also provides the right-of-way to U-turns unless a U-TURN YIELD TO RIGHT TURN sign is posted (in which case the conflicting right turns have the right-of-way) or unless U-turns are completely prohibited by a posted NO U-TURN sign. Green arrows pointing vertically upward (not downward) can be used for straight thru-only movements. These arrows should slope upward in the proper direction when used to indicate angled thru-only movements. However, vertically upward red or yellow arrows are prohibited from use.

The circular yellow or yellow arrow indication informs approaching drivers that the green indication is being terminated and the red indication will soon be displayed. In most states, traffic may legally enter the intersection any time during the yellow interval but may not legally enter the intersection once the red indication is displayed. Most state laws also designate that a vehicle which has legally entered the intersection on a yellow indication has the right to clear the intersection, even if the green indication has been transferred to a conflicting movement. In other words, just because a driver has a green indication does not mean that the driver has the right-of-way.

In a vertical signal the circular yellow lens must be located immediately below the circular red lens while, in a horizontal signal, the yellow circular lens be located immediately to the right of the red circular lens. In a vertical signal the yellow arrow must be located immediately above the green arrow while, in a horizontal signal, the yellow arrow must be immediately to the left of the green arrow.

The MUTCD states that a circular yellow indication must always follow a circular green indication and that a yellow arrow indication must always follow a green arrow indication.



All green arrows, even when they are displayed with a circular green indication, must be terminated with a yellow arrow. A green arrow cannot simply vanish when the protected portion of the interval ends. Such "blind" change intervals are not permitted. The MUTCD requires that each signal lens be independently illuminated. The MUTCD does not permit letters or numbers to be displayed as part of a vehicular signal indication.

The MUTCD permits only one arrow direction per lens. The use of compound arrows (such as a thru-left arrow) is not permitted. This restriction does not preclude the use of two arrows pointing in the same direction, such as a green and yellow left turn arrow in the same lens, if they are illuminated independently. Per the MUTCD, all arrow lenses must be 12-inches in diameter.

A flashing red indication has the same meaning as a STOP sign, requiring a motorist which encounters it to come to a complete stop before entering the intersection. When a flashing red

indication is displayed to all approaches of an intersection, the intersection functions as a multi-way stop.

The flashing yellow indication is a warning to drivers that they should pass through the intersection with caution. When one intersecting street has the flashing yellow indication while the other street has the flashing red indication, the intersection functions as a 2-way stop - with vehicles facing the flashing yellow indication having the right-of-way. Flashing red and yellow arrow indications have the same meaning as their circular counterparts, except that the meaning only applies to the movement indicated by the arrow. For example, a flashing red left arrow means that, if there is no oncoming traffic, one may turn left after coming to a complete stop. The flashing rate for a traffic signal installation should be between 50 and 60 flashes per minute, which is about one flash per second.

The new 2009 edition of the MUTCD allows a flashing yellow arrow indication to be used in a left turn signal head so that permissive left turns (turns through gaps in opposing traffic) can be made during the flashing yellow arrow. Through proper programming of the controller, a given left turn phase can now operate protected-only (left turn on green arrow only) during certain portions of the day and either permissive, or protected/permissive during other portions of the day. This allows maximum flexibility in left turn phasing that was not previously available. In a typical city there are many locations where, for safety reasons, protected-only operation is needed during the weekday rush hours while less restrictive protected/permissive or permissive operation is suitable for the remainder of the day. The flashing arrow permissive left turn indication allows this change in operation to occur in a safe and efficient manner.

Some cities use transit priority signals to control light rail transit vehicles at signalized intersections. The transit priority signal typically consists of white rectangular bar on a black background.

The decision on whether to mount signal heads vertically or horizontally is mostly one of local preference. Horizontal heads have certain advantages:

- They have less wind resistance when mounted on mast arms,
- They have higher vertical clearance, and
- They provide better visibility for signals located near overpasses.

However, horizontal signals are not well suited to pedestal mounting and some would argue that the meaning of 5-section horizontal signal heads is less clear to motorists than 5-section vertical heads.

## SIGNAL RELATED SIGNS

There are three general categories of signs that supplement traffic signal operations:

- Regulatory Signs
- Warning Signs
- Street Name Signs

A variety of regulatory signs are commonly used in conjunction with traffic signal installations. Yield signs are typically used in non-signal-controlled right turn slip lanes at signalized intersections.

"STOP HERE ON RED" signs tell the motorist where to stop his or her vehicle during the red indication. These signs should only be used when confusion exists as to exactly where the vehicle should be stopped. "DO NOT BLOCK Intersection" signs are used to instruct the motorist not to stop in the middle of the intersection. During periods of traffic congestion, queues from one signal may back through an adjacent signal. If this happens and motorists do not keep the intersection area clear, the capability of the traffic signal to move traffic could be severely reduced. "Left Turn YIELD on Green Ball" signs reinforce the requirement that motorists turning left without a green arrow must yield to oncoming traffic. "LEFT TURN SIGNAL" (or "RIGHT TURN SIGNAL") signs are used to clarify the movement controlled by a particular signal face. These signs should be located adjacent to the signal face to which they apply.

When used, the MUTCD requires lane-use control signs to be mounted overhead, and aligned with, the lanes to which they apply. The purpose of these signs is to indicate the movement or movements that can legally be made from a particular lane.



The MUTCD allows "NO TURN ON RED" signs to be installed on a given approach to a signalized intersection when an engineering study determines that one or more of the following conditions exist:

- The sight distance for seeing approaching vehicles is inadequate,
- The characteristics of the intersection could lead to unexpected conflicts,
- There is an exclusive pedestrian phase,
- Significant conflicts with pedestrians occur due to right-turn-on-red maneuvers,
- More than 3 right-turn-on-red accidents per year have occurred on a particular approach,
- There is significant crossing activity by children, the elderly or handicapped individuals.

The MUTCD does not permit stop signs to be used with traffic signals unless: 1. the signal indications for the approach or approaches with the stop sign flashes red at all times, or 2. the purpose of the stop sign is to control a minor street or driveway located within the signalized intersection but which does not require signal control since there exists an extremely low potential for conflict.

Warning signs that are commonly used in conjunction with traffic signal installations include:

- signal ahead sign
- pedestrian crossing sign, and
- school crossing sign

When used in conjunction with a signalized intersection, street name signs are either mounted overhead at the intersection or are mounted in advance of the intersection (or both). Advance placement of street name signs gives the driver more time to make decisions regarding lane changing or turning. Some agencies use internally illuminated or edge lit LED street name signs to increase the readability of the sign at night.



## HAZARD IDENTIFICATION BEACONS

Hazard identification beacons are flashing circular yellow indications used to supplement a regulatory or warning sign or to mark locations requiring special caution. Signs which sometimes make use of hazard identification beacons include:

- School speed zone signs,
- SIGNAL AHEAD signs,
- DO NOT STOP ON TRACKS signs, and
- Curve signs



Locations requiring special caution which might make use of a hazard identification beacon include:

- Dangerous intersections,
- Mid-block crosswalks,
- Obstruction in or near the roadway, and
- Tunnels or viaducts with low vertical clearance

Hazard identification beacons should be operated only during those times when the hazard or regulation exists.

## STOP SIGN BEACONS

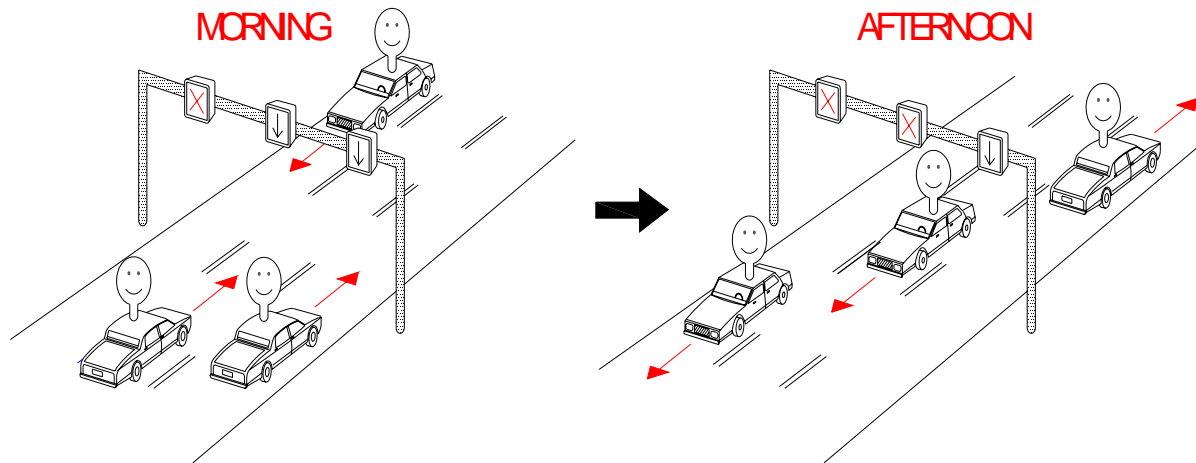
Stop sign beacons are flashing circular red indications used to supplement a STOP sign. Although only one lens is required, if two lenses are used then

- the signals shall be flashed simultaneously if aligned horizontally or
- the signals shall be flashed alternately if aligned vertically.

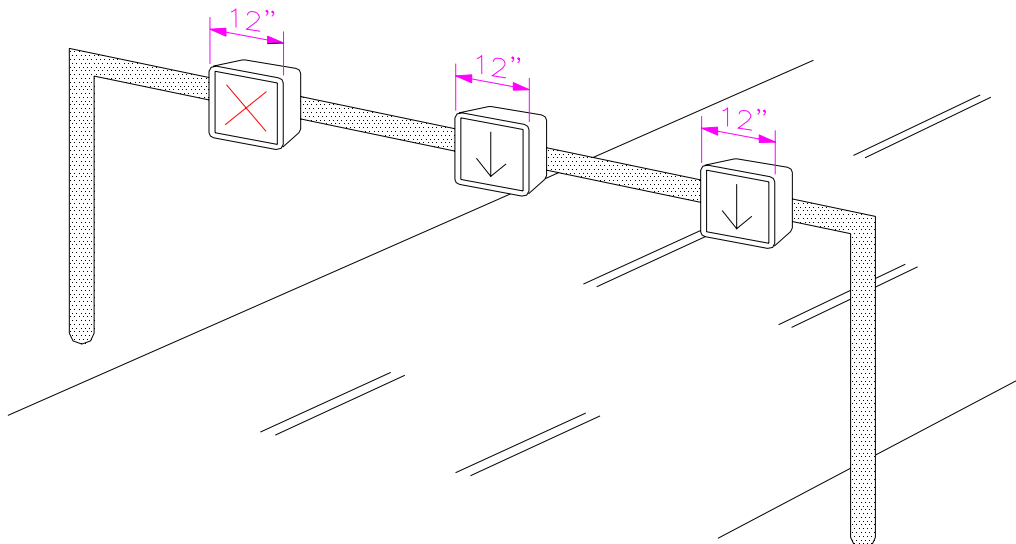


## LANE-USE CONTROL SIGNALS

Lane-use control signals are special overhead signals having indications which permit or prohibit the use of specific lanes on a road. Lane-use control signals are most commonly used for reversible-lane control. Having the ability to "reverse" lanes so that there are more lanes in one direction during certain periods and more lanes in the opposite direction during other periods can be very valuable. For example, to better handle rush hour traffic, we may want to maximize the number of inbound lanes heading towards downtown in the morning and outbound lanes heading away from downtown in the afternoon.



Lane-use control signals have a rectangular face with a nominal width of 12 inches. A separate signal head is mounted over each lane of the road being controlled.



The MUTCD requires that lane-use control signals be placed at frequent enough intervals along the roadway so that a motorist will be able to see at least one indication, and preferably two indications,

at all times. On roadways having signalized intersections the lane-use control signals must be placed far enough away from traffic signals so that motorists do not misconstrue them as traffic signals. There are three indications used by lane-use control signals:

1. Downward Green Arrow
2. Red "X"
3. Yellow "X" (Steady and Flashing)



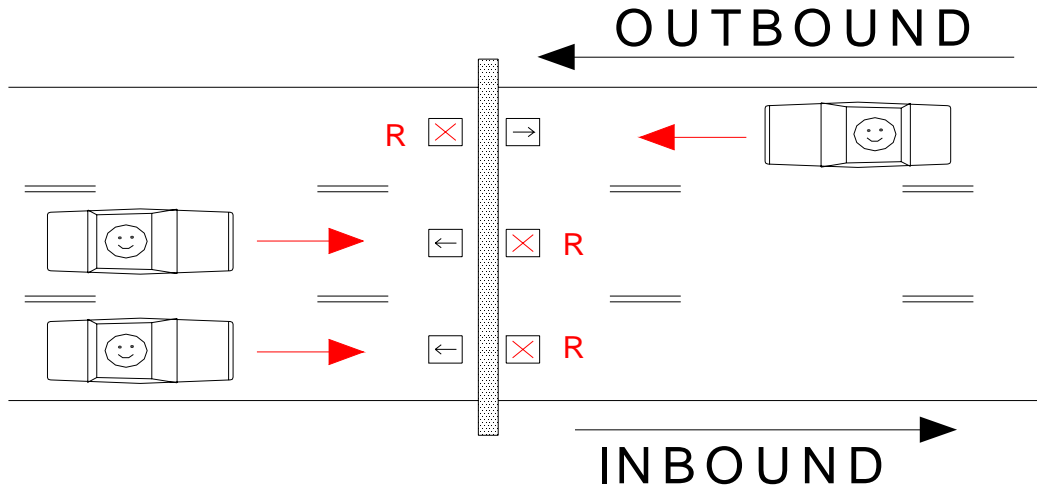
A downward green arrow means that a motorist is permitted to drive in the lane over which the green arrow is located. A red "X" means that a motorist shall not drive in the lane over which the red "X" is located. A steady yellow "X" means that a motorist should prepare to vacate the lane over which the yellow "X" is located since a red "X" will soon be displayed.

A flashing yellow "X" means that a motorist is permitted to use the lane over which the flashing yellow "X" is located to make left turns, but the motorist is cautioned that opposing vehicles may also be using this lane to make left turns. In other words, a flashing yellow "X" designates a two-way-left-turn (TWLT) lane.

In the following example, the lane use of a 3-lane road is changed from "2 lanes inbound and 1 lane outbound" to "1 lane inbound and 2 lanes outbound":

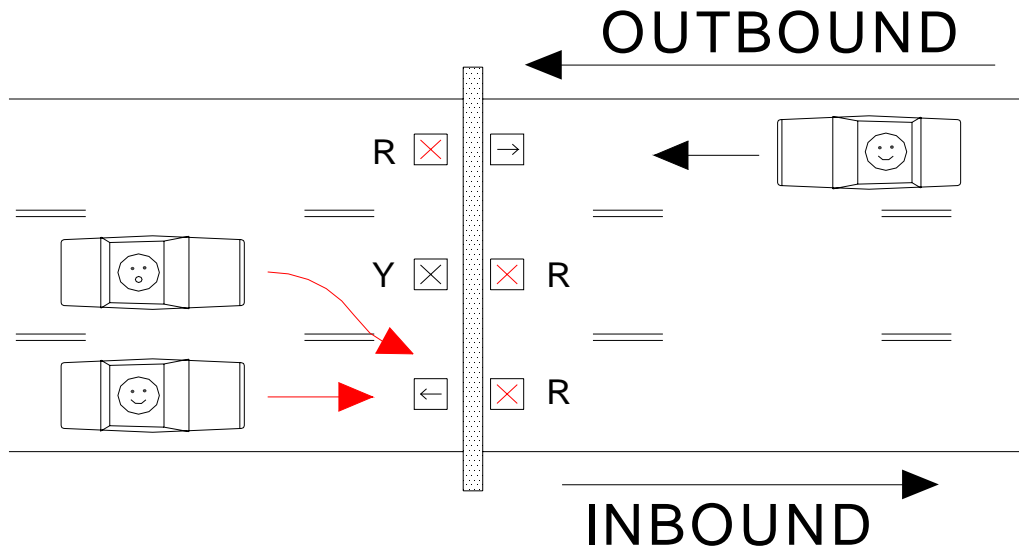
- A. In the initial condition, inbound traffic sees a green arrow in both the right and center lanes and a red "X" in the left lane while outbound traffic sees a green arrow in the right lane and a red "X" in the left and center lanes.

**INITIAL CONDITION**



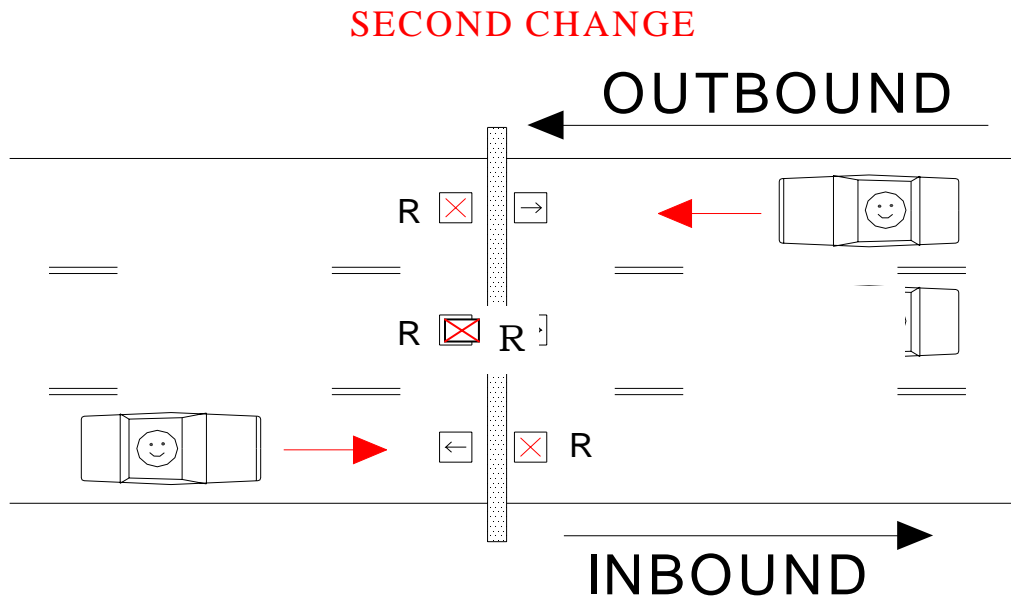
- B. The first change occurs as a steady yellow "X" is displayed to inbound traffic, informing inbound motorists that they should vacate the center lane.

**FIRST CHANGE**



- C. The second change occurs when a steady red "X" is displayed in the center lane to inbound traffic while maintaining the steady red "X" in the outbound center lane, thus informing

motorists in both directions that they cannot use the center lane. This safety interval reduces the potential for head-on collisions.



D. The third and final change occurs when a green arrow is displayed over the center lane for outbound traffic, providing a second lane for outbound motorists.

