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GUIDELINES ON DESIGN AND INSTALLATION OF ROAD TRAFFIC SIGNALS

THE INDIAN ROADS CONGRESS
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1. GENERAL

The Traffic Engineering Committee constituted a Subcommittee for formulating guidelines on design and installation of road traffic signals. Initial draft on the subject was prepared by Shri S. M. Parulkar. The Subcommittee held several meetings and the final meeting was held at Bombay on the 7th September, 1983 where the draft guidelines were examined critically and finalised jointly by Dr. N. S. Srinivasan and Shri S. M. Parulkar. These guidelines were considered by the Traffic Engineering Committee (personnel given below) in their meeting held at Nagpur on the 10th January, 1984. The Committee authorised Dr. N. S. Srinivasan and Shri S. M. Parulkar to finalise the guidelines on the basis of comments of the members.

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The revised guidelines were considered and approved by the Specifications & Standards Committee in their meeting held at New Delhi on the 22nd August, 1985.

Later on the above mentioned guidelines were considered and approved by the Executive Committee in their meeting held at New Delhi on the 22nd August, 1985 and the Council in their 114th meeting held at Panaji (Goa) on the 6th September, 1985 for being published by the Indian Roads Congress.

1. INTRODUCTION

The purpose of this publication is to give general guidelines for design and installation of road traffic signals for control of traffic.

2. SCOPE

These traffic control devices include traffic control signals, beacons, lane-use control signals and emergency traffic control signals.

3. DEFINITIONS RELATED TO ROAD TRAFFIC SIGNALS

3.1. Road Traffic Signals

Any power operated traffic control device except a sign by which traffic is regulated, warned, or alternatively directed to take some specific action.

3.2. Traffic Control Signal

A type of road traffic signal whether manually, electrically or mechanically operated by which traffic is alternately directed to stop and proceed in a specified direction.

3.3. Pre-timed Signal (Fixed Time)

A type of traffic control signal which directs traffic to stop and permits it to proceed in accordance with predetermined time cycles and intervals.

3.4. Flashing Beacons

A traffic signal head or similar type of device, having a yellow or red lens in each face, which is illuminated by rapid intermittent flashes.

3.5. Flashing Red (Stop Signal)

When the red lens of a signal face is illuminated by rapid intermittent flashes, drivers of vehicles shall stop before entering the nearest cross-walk at an intersection or at a stop line when marked.

3.6. Flashing Yellow (Caution Signal)

A traffic signal indication for which the yellow lens is illuminated with rapid intermittent flashes to signify that drivers of vehicles may proceed through the intersection or pass such signal only with caution.

3.7. Signal Head

An assembly containing one or more signal faces.

3.8. Signal Face

That part of a signal head provided for controlling traffic in a single direction and turning indications may be included in signal face.

3.9. Primary Signal Face

The signal face which is nearest to and facing the incoming traffic.

3.10. Secondary Signal Face

A signal face showing the same indications as on a primary signal face, usually further away from the incoming traffic and on its off-side (Right).

3.11. Signal Indication

The illumination of a traffic signal lens or equivalent device or of a combination of several lenses or equivalent devices at the same time.

3.12. Optical Unit

An assembly of redirecting cover glass or lens reflector, lamp and lamp socket with necessary supporting parts to be used for providing a single signal indication.

3.13. Redirecting Cover Glass or Lens

That part of optical unit which redirects the light coming directly from the lamp and reflector.

3.14. **Signal Support**

The physical means whereby a signal head is supported in a particular location.

3.15. **Signal Installation**

All of the equipment and materials involved in the signal control of traffic at an intersection.

3.16. **Controllers**

A complete electrical mechanism for controlling the operation of a traffic control signal.

3.17. **Manual Controller**

A controller for operating traffic control signals by manual operation.

3.18. **Automatic Controller**

A controller for operating traffic control signals automatically.

3.19. **Auxiliary Manual Controller**

A separate and distinct manual controller attached to an automatic controller by means of which the traffic control signals may be operated manually when the automatic timer is disconnected.

3.20. **Fixed Time Controller**

An automatic controller for supervising the operation of traffic control signals in accordance with a predetermined fixed time cycle and division thereof.

3.21. **Master Controller**

A synchronous motor-driven controller or an induction motor-driven controller provided with a sychronous supervisory mechanism designed to supervise the signal system and the operation of all inter-connected controllers so as to maintain definite time relationship of all such controllers and to operate the remote signal shut down, flashing indication, total time-cycle change, and other features of operation.

3.22. **Timer**

The automatic timing mechanism in a controller including all dials for adjusting or shutting intervals and offsets, switching and flashing mechanism, signal circuit contacts, motors gears and camshaft, and also, in the master controller, the total time-cycle control and re-synchronisation reset mechanism.

3.23. **Time Cycle**

The total time period required for one complete sequence of signal indications.

3.24. **Traffic Phase**

A part of the time cycle allocated to any traffic movement receiving the right-of-way or to any combination of traffic movements receiving the rights-of-way simultaneously during one or more intervals.

3.25. **Vehicular Phase (Vehicular Movements)**

A traffic phase allocated to vehicular traffic.

3.26. **Pedestrian Phase**

Traffic phase allocated exclusively to pedestrian traffic.

3.27. **Interval**

Any one of the several divisions of the time cycle during which, the traffic control signal indication of any particular signal face, does not change.

3.28. **Clearance Interval**

The time of display of the signal indication following right-of-way interval (yellow).

3.29. **All Red Period**

A clearance interval or part thereof during which all the signal faces controlling vehicular traffic at an intersection give red indications.

3.30. **Intergreen Period**

The time from the end of the green period of the phase losing right-of-way to the beginning of the green period of the phase gaining right-of-way.

3.31. **Late Release**

During the same phase, when one particular movement/ movements are allowed to take place a little later than the actual start of the phase.

3.32. **Early Cutoff**

During the same phase when particular movement/movements are terminated before the actual end of the phase.

3.33. **Interval Sequence**

A predetermined consecutive order of appearance of traffic control signal indications during successive intervals within the time cycle.

3.34. **Manual Operation**

The operation of an automatic controller mechanism by means of a hand operated switch.

3.35. **Flashing Features**

A relay or other device installed in a controller which, energized from a remote point or by an automatic time switch, discontinues normal signal operation and causes the flashing of any predetermined combination of signal lights.

3.36. **Emergency Features**

A relay or other device installed in a controller which when energized from a remote point, discontinues the normal signal operation and displays special signal indications for the movement of emergency vehicle, etc.

3.37. **Signal System**

Two or more signal installations operating in co-ordination.

3.38. **Co-ordinated Control System**

The operation of two or more traffic control signal installations with definite inter-relations.

3.39. **Simultaneous System**

A signal system in which all signals always give the same indication (along a given street at the same time).

3.40. **Alternate System**

A signal system in which the alternate signals or groups of signals give opposite indications for a given street at the same time.

3.41. **Simple Progressive System**

A signal system in which the various signal faces controlling a given street give 'GO' indication in accordance with a timing schedule to permit (as early as possible) continuous operation of groups of vehicles along the street at a planned rate of speed which may vary in difierent parts of the system

3.42. **Flexible Progressive System**

A signal system in which the intervals at any signal may be independently adjusted to the traffic requirements at the intersections and in which the 'GO' indications at separate signals may be started independently at the instant that will give the maximum efficiency.

3.43. **Area Traffic Control System**

This involves co-ordination of traffic signals over a complete network of signals covering an area that may be considered homogeneous from the point of view of traffic operation. Such a system has to be computer aided as the problem is extremely complex because of crossing of several routes at common intersections.

II. TECHNICAL ASPECTS OF ROAD TRAFFIC SIGNALS

1. GREEN SIGNAL

All permitted traffic movements, shall be indicated by green arrows. The arrows shall be stencil cut, and pointing in the direction in which traffic movement is permitted. Traffic except pedestrians, facing a GREEN ARROW, may cautiously enter the intersection only to make the movement indicated by such arrow or arrows shown at the same time.

2. STEADY AMBER SIGNAL

Traffic facing a steady circular amber signal indication is thereby warned that a related green movement is being terminated or that a red indication will be immediately exhibited, thereafter the vehicular traffic shall not enter the intersection. The vehicle operator must be in readiness to accept an impending change, in right-of-way assignments. The amber interval is a transition interval between termination of related green movement and exhibition of a red indication or between termination of a red indication and commencement of related green movement. In the first case, it is called 'Clearance Amber' and in the second case, it is called 'Initial Amber'.

A clearance amber shall be provided between the termination of a green arrow indication and the showing of a green indication to any conflicting traffic movement.

3. STEADY RED SIGNAL

Traffic facing a steady circular RED SIGNAL shall stop at a clearly marked stop line, before entering the cross-walk on the near side of the intersection or if none, then before entering the intersection and shall remain standing until an indication to proceed is shown.

4. FLASHING SIGNAL

4.1. Flashing Red (Stop Signal)

When a red lens is illuminated with rapid intermittent flashes, drivers of vehicles shall stop at a clearly marked stop line, but if none, then before the cross-walk on the near side of the inte-

rsecting roadway where the driver has a view of the approaching traffic on the intersecting roadway prior to entering the intersection. The right to proceed shall be subject to availability of safe gap in the cross-traffic stream.

4.2. Flashing Amber (Caution Signal)

When an amber lens is illuminated with rapid intermittent flashes, drivers of vehicles may proceed through the intersection or pass such signal only, with caution.

When an amber arrow is illuminated with rapid intermittent flashes, drivers may proceed in the direction indicated by the arrow, with caution.

5. PEDESTRIAN SIGNAL

5.1. Movements of pedestrians shall be controlled with separate pedestrian signal heads.

5.2. Pedestrians facing a steady green with human figure in readiness to move, may proceed across the roadway within the marked cross-walk adjacent to the pedestrian signal.

5.3. Pedestrians facing a steady red with a standing human figure, shall not enter the roadway.

5.4. When a flashing red with a standing human figure is exhibited, those pedestrians already on the carriageway shall quickly proceed to the nearest refuge island or foot-path and those on the foot-path or refuge island shall not enter the carriageway.

6. SIZE AND DESIGN OF SIGNAL LENSES

6.1. The aspect of all signal lenses shall be circular. There shall be two sizes for lenses such that the net diameter of exposure towards traffic (after taking into account the hoods, etc.) is 200 mm or 300 mm. Normally, 300 mm lenses should be used in the following cases:

(1) For intersections on highways in suburban area with 85th percentile approach speeds exceeding 70 kmph.

(2) For intersections in busy urban area with 85th percentile approach speeds exceeding 50 kmph.

(3) For intersections with wide 3 lane approaches and other problem locations such as those with conflicting or competing background lighting in urban areas.

6.2. Arrows on green or amber lenses shall be pointed vertically upward to indicate a straight through movement and in horizontal direction to indicate a turn approximately at right angle. When the angle of a turn is substantially different from a right angle, the arrows should be positioned on an upward slope at an angle approximately equal to that of the turn.

6.3. Each arrow lens shall show only one arrow direction. The arrow shall be the only illuminated part of the lens visible. In special circumstances, the same lens may show two-arrow directions.

6.4. Except for the requirements of this section all lenses shall conform to the standards of the I.S.I. 7537-1974. ("Indian Standard Specification for Road Traffic Signals").

7. ARRANGEMENT OF LENSES IN SIGNAL FACES

7.1. The lenses in a singal face shall be arranged in a vertical straight line and in a vertical array, lenses of the same colour shall be arranged horizontally adjacent to each other at right angles to the basic straight line arrangement.

7.2. In each signal face, red lens shall be located above all other lenses. A circular amber lens shall be located below the red lens. Green lens with straight arrow shall be placed below the circular amber lens. On either side of this green lens, other green lenses, with directional arrows shall be placed in a horizontal straight line, in logical order of the directional indications. If turns are prohibited at a particular intersection, illuminated signs showing turn prohibitions shall be displayed in that position where the lens with the green arrow would have been placed, if that directional movement were allowed.

8. ILLUMINATION OF LENSES

8.1. Each signal lens shall be illuminated independently. When a signal lens except in a pedestrian signal is illuminated and the view of such an indication is not otherwise physically obstructed, it shall be clearly visible (to drivers it controls) from a distance of at least 400 metre under normal atmospheric conditions.

8.2. The intensity and distribution of light from each illuminated signal lens should conform to the Standard of I.S.I. When the flashes are used, they should not cause excessive glare or distraction.

9. VISIBILITY AND SHIELDING OF SIGNAL FACES

9.1. Each signal face shall be so adjusted that its indications will be of maximum effectiveness to the approaching traffic for which they are intended.

9.2. A visor shall be fitted to each of the optical system and unless otherwise specified shall be as per IS: 7537-1974. The visors should be dipped at an angle of 5 degree $\pm$ 3 degree to the horizontal so as to aid in directing the signal indication, specifically to approaching traffic as well as to reduce "Sun phantoms" resulting from external light entering the lens. The visors for primary signals and secondary signals may be different as shown in, Fig 1.

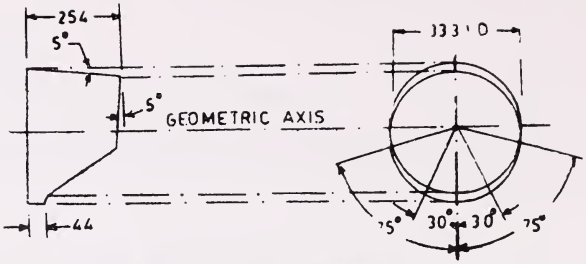
9.3. In general, vehicular signal faces should be aimed to have maximum effectiveness for an approaching driver located at a distance from the stop line equal to the distance traversed while stopping. This distance should include, that covered while bringing the vehicle to a stop from an average approach speed. The influence of curves, grades and obstructions should be considered in directing and locating signals.

9.4. Irregular street design frequently necessitates placing signals for different street approaches, with a comparatively small angle between their indications. In such cases, each signal indication shall to the extent practicable, be shielded or directed by visors, louvers or other means, so that approaching driver can see only the indication controlling his movement. Tunnel visors exceeding 300 mm length shall not be used in signal aspects.

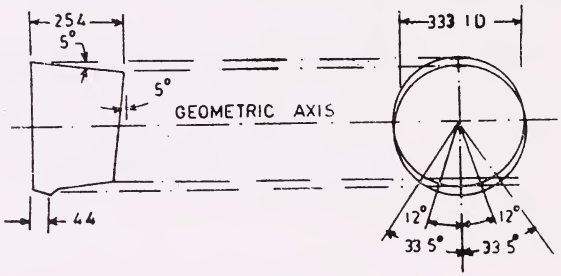
10. NUMBER AND LOCATION OF SIGNAL FACES

10.1. The primary consideration in signal face placement shall be visibility. Drivers approaching at signalised inter-section or other signalised area, such as a mid-block cross-walk, shall be given a clear and unmistakable indication of their right-of-way assignment. Critical elements are lateral and vertical angles of sight, towards a signal face, as determined by typical driver eye position, vehicle design and the vertical longitudinal and lateral position of the signal face. The geometry of each intersection to be signalised, including vertical grades and horizontal curves, should be considered in signal face placement.

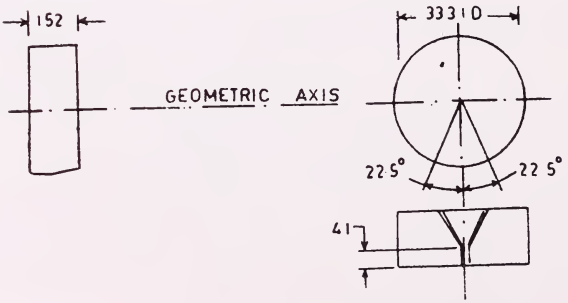
10.2. The visibility, location and number of signal faces for



a) PRIMARY SIGNAL



b) SECONDARY SIGNAL



c) PEDESTRIAN SIGNAL

Note : All dimensions in millimetres

Fig. 1. 300 mm signal visors

each approach to an intersection or a midblock cross walk shall be as follows :

(i) A minimum of two signal faces for through traffic shall be provided and should be continuously visible from a point at least the distances given in Table 1, in advance of and upto the stop line, unless physical obstruction to their visibility exists.

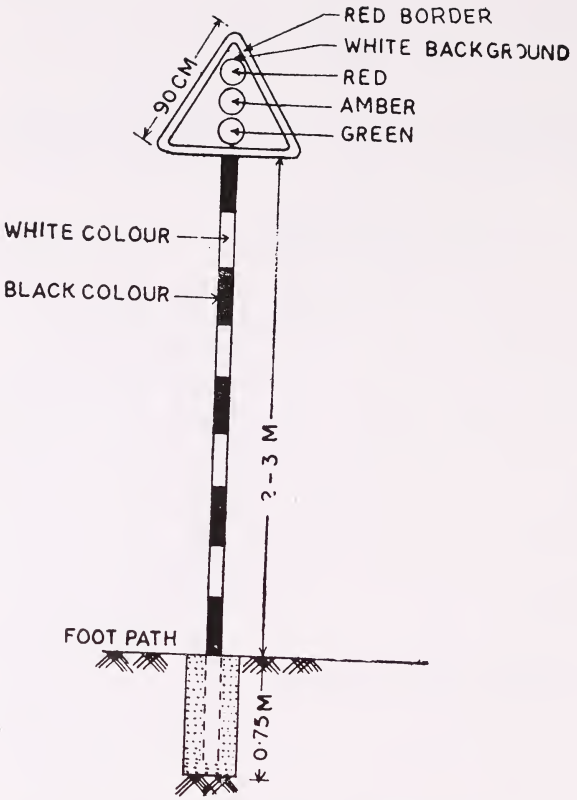
TABLE 1. MINIMUM VISIBILITY DISTANCES FOR DIFFERENT APPROACH SPEEDS

85th percentile speed (kmph) or (average approach speed)	Minimum visibility distance (metres)
35	45
40	50
45	60
50	70
55	80
60	90
65	100
70	110
75	120
80	135
85	145
90	160
95	170
100	185

One of the above mentioned signal faces shall be erected on the near side of the intersection (called the primary) and the other on the far side (called the secondary). The primary shall be on the near side of the intersection at the stop line on the left side of the approaching traffic and the secondary shall be not less than 12 metre nor greater than 36 metre on the far side of the intersection but to the right on the footpath or at the median island, if available.

(ii) Where physical conditions prevent drivers having a continuous view of atleast two signal indications as specified in (i) above a suitable sign shall be erected in advance to warn the approaching traffic. The specifications of the sign is shown in, Fig. 2. This may be supplemented by a hazard identification beacon (Flashing amber).

(iii) Supplementary signal faces should be used, when an engineering study has shown that they are needed to achieve both advance and immediate intersection visibility. When used, they should be located to provide optimum visibility for the movement to be controlled.



The side of the triangle is 90 cm for a standard size and 60 cm for a reduced size of sign.

Fig. 2. Signal ahead sign

The following limitations apply :

(a) Right turn arrows shall not be used in near-left faces.

(b) Left turn arrows shall not be used in far-right faces.

A far side median mount signal shall be considered as a far-right signal for this application.

At signalised mid-block cross-walks, there should be at least one signal face over the travelled road-way for each approach. In other respects a traffic control signal at a mid-block location shall meet the requirements set forth in these standards.

11. HEIGHT OF SIGNAL FACES

11.1. The bottom of the housing of a signal face, not suspended over a roadway, shall be at a height of 2.5 metre above the footpath or if none above the pavement grade at the centre (crown) of the roadway.

11.2. The bottom of the housing of a signal face, suspended over a roadway, shall be at a height of 5.5 metre above the pavement grade at the centre of roadway.

11.3. Optimum visibility and adequate clearance shoul be guiding considerations in deciding signal height. Grades on approaching streets may be important factors, and should be considered in determining the most appropriate height. However, the maximum heights of bottom of housing of post-mounted signal face should not exceed 4.6 metre and while in the case of overhead signal face, the same should not exceed 5.8 metre.

12. TRANSVERSE LOCATION OF TRAFFIC SIGNAL SUPPORTS AND CONTROLLER CABINETS

12.1. In the placement of signal supports, primary consideration shall be given for ensuring the proper visibility of signal faces as described in section II-8 and II-9. However, in the interest of safety, signal supports and controller cabinets should be placed as far as practicable from the edge of the travelled way, without adversely affecting signal visibility.

12.2. Supports for post mounted signal heads at the side of a street with kerbs shall have a horizontal clearance of not less than 60 cm within the limits of normal vertical clearance. A signal support should not obstruct a cross-walk.

12.3. On medians, the above minimum clearances for signal supports should be obtained where practicable. Any support, which cannot be located with the required clearances, should be of breakaway type or should be guarded as far as practicable.

12.4. The transverse location of primary and secondary units of signals on a typical four arm intersection is shown in, Fig. 3. The plan indicates clearly the minimum horizontal distance of the supports from the kerb, their placement with respect to the pedestrian crossings, locations on the central median, etc. The necessary road markings are also indicated thereon.

12.5. The minimum and maximum heights of signal housing from the surface level of carriageway and side walk are indicated in, Fig. 4.

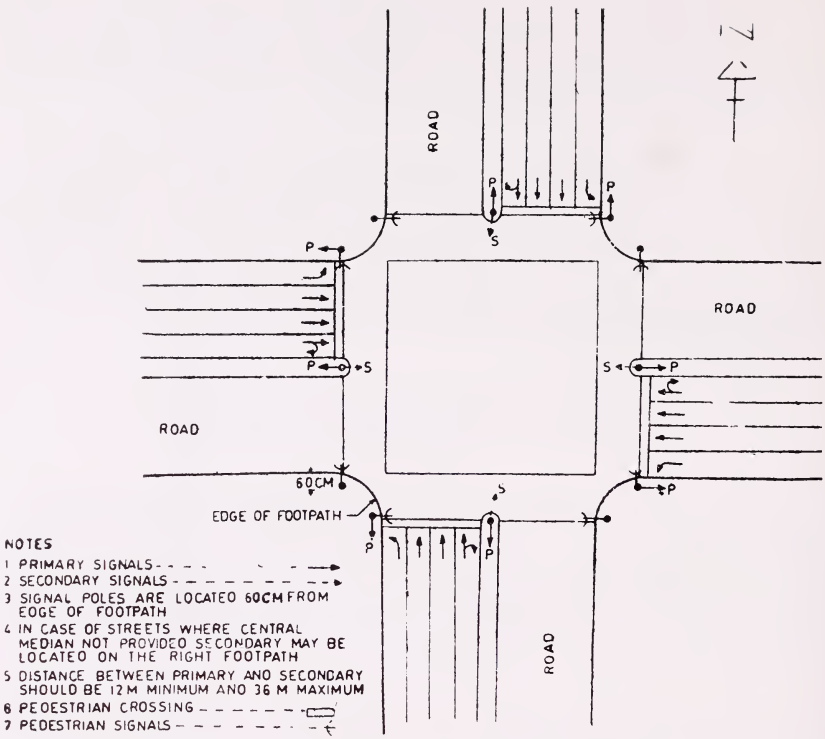


Fig. 3. Transverse location of signal supports

13. SPECIFICATIONS FOR SIGNAL FOUNDATIONS

13.1. The poles shall be first positioned in pits of 900 mm x 900 mm x 1050 mm deep.

13.2. The poles shall then be embedded in M 200 concrete to a minimum of 300 mm below ground level and 300 mm above ground level. The circular area of embedding concrete shall have a minimum diameter of 450 mm.

13.3. All the cables supplying power to the controller and signal heads shall run through R.C.C. ducts when these are required to cross the carriageway.

13.4. The ducts shall be of 150 mm internal diameter and laid at a depth of about 1000 mm from the level of the carriage-

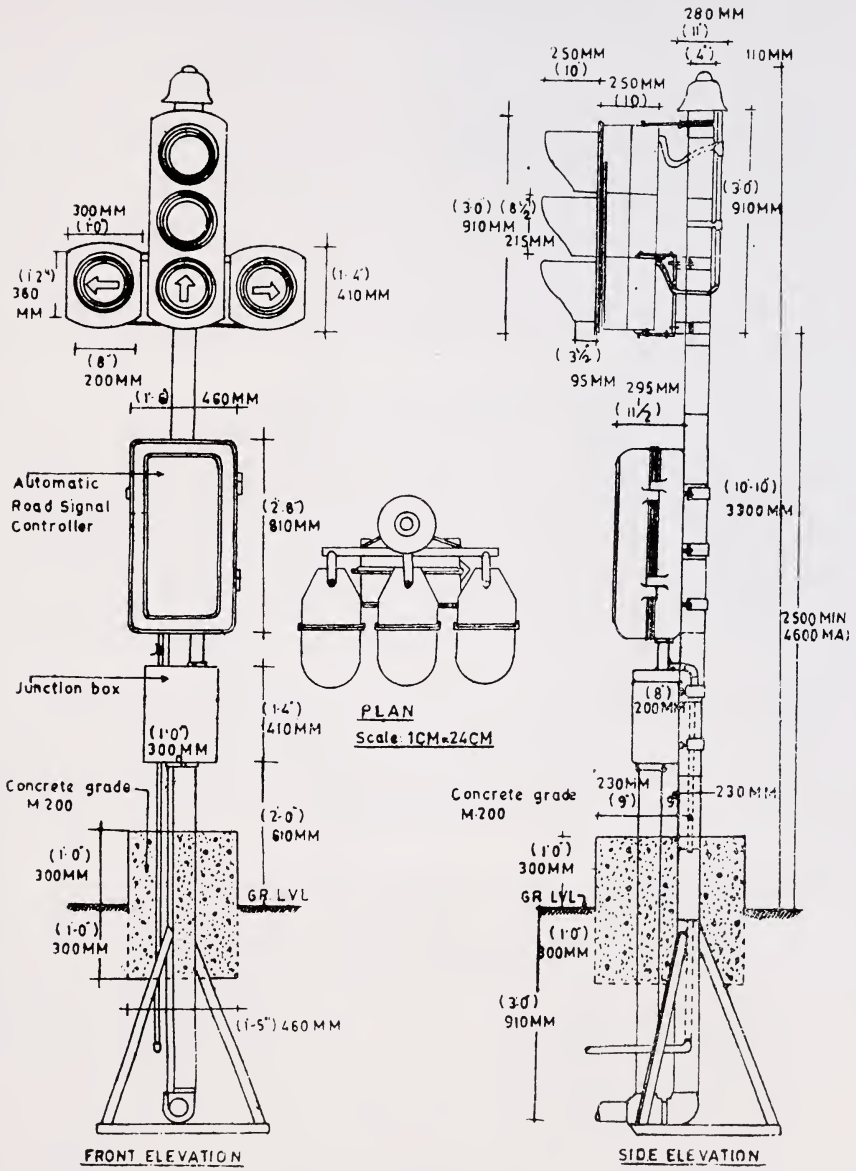


Fig. 4. Typical foundation details of signal pole

way. Typical foundations details and cable layouts are indicated in, Figs. 4 and 5 respectively.

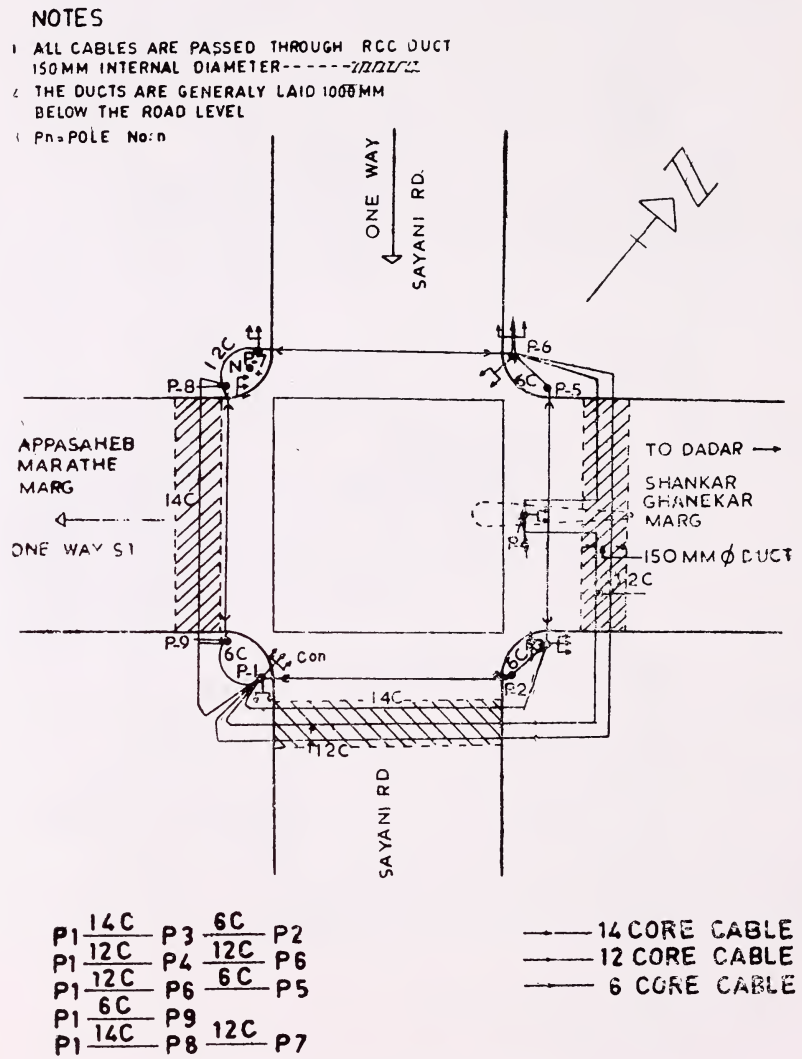


Fig. 5. Typical cable layout diagram

13.5. For overhead type traffic signals, the pit should be 1200 mm × 1200 mm × 1800 mm deep. The poles are to be

embedded in M 200 concrete to a minimum of 500 mm below ground level and 500 mm above ground level. The circular area of embedding concrete shall have a minimum diameter of 500 mm.

14. CO-ORDINATION OF TRAFFIC CONTROL SIGNALS

14.1. Traffic control signals within 1 km of one another along major route or in a net work of intersecting major routes should be operated in co-ordination, preferably with inter-connected controllers. However, co-ordination need not be maintained across boundaries between signal systems which operates on different time cycles.

14.2. *Appendix* 1, indicates methodology for interconnection of adjacent signals along a particular route.

15. FLASHING OPERATION OF TRAFFIC CONTROL SIGNALS

15.1. All traffic signal installations shall be provided with an electrical flashing mechanism supplementary to the signal timer. A manual switch or where appropriate, automatic means, shall be provided to actuate the flashing mechanism. The signal timer shall be removable without affecting flashing operation. The mechanism shall operate in a manner similar to a flashing beacon, to provide intermittent illumination of selected signal lenses.

15.2. The illuminating element in a flashing signal shall be flashed continuously at a rate of 50-60 flashes per minute when the applied voltage varies in the range between 20 per cent and 15 per cent of its nominal value and $\pm$ 4 per cent of its nominal frequency and over a temperature range 0 degree C to 55 degree C as per IS: 7537-1974.

15.3. Automatic changes from flashing to stop and go operation shall be made at the beginning of major street green interval. Automatic changes from stop and go operation to flashing shall be made at the end of major street red interval. For manual switches, the changes may be made at any time.

16. CONTINUITY OF OPERATION

16.1. A traffic signal installation shall be operated as a stop and go device or a flashing device.

16.2. When a signal installation is not in operation, such as prior to placing it in service, during seasonal shut downs, or when it is not desirable to operate the signals, they should be hooded,

turned or taken down to clearly indicate that the signal is not in operation.

16.3. When a traffic signal installation is being operated as a flashing device, the amber indication shall be flashed in at least two required signal faces on each approach on which traffic is not stopped and the red indication shall be flashed in at least two required signal faces on each approach on which traffic is required to stop and proceed.

16.4. When a traffic signal is being operated in the usual stop and go manner, at least one indication in each signal face shall be illuminated.

17. SIGNAL OPERATION RELATING TO TRAFFIC FLOW

17.1. Traffic control signals shall be operated in a manner consistent with traffic requirements. Data from traffic and engineering studies shall be used to determine the proper phasing and timing for a signal.

17.2. Since traffic flows and patterns change, it is necessary that the traffic data be updated and re-evaluated regularly.

17.3. To ensure that the approved operating pattern including timing is displayed to the driver, regular checks including the use of accurate timing devices should be made.

18. MAINTENANCE OF TRAFFIC SIGNALS

18.1. Prior to the installation of any traffic control signal, the responsibility for its maintenance should be clearly established. The responsible agency should provide for the maintenance of the signal and all of its appurtenances in a responsible manner. To this end, the agency should:

(i) Provide for alternate operation of signal during a period of failure either on flash or manually, or by having manual traffic direction by proper authority as may be warranted by traffic volumes or congestion.

(ii) Have properly skilled maintenance staff available without undue delay for all emergency calls, including lamp failures.

(iii) Provide properly skilled maintenance for all components.

(iv) Maintain the appearance of the installation in a manner consistant with the intention of this standard, with particular emphasis on painting and on cleaning of the optical system.

(v) Provide adequate stand-by equipment to minimise interruption of signal operation, due to equipment failure.

(vi) Service equipment and lamps, as frequently as experience proves necessary, to prevent undue failures.

18.2. Every controller should be kept in effective operation in strict accordance with its predetermined timing schedule. In this regard, the manufacturer shall be insisted upon to ensure that the design of any control equipment shall be such that when the right-of-way signal is shown to one phase, it shall not be possible through failure of any operating component of the controller to give a right-of-way signal to a conflicting traffic phase. A device shall be provided in the equipment housing which continuously monitors the controller signal and if the controller fails to cycle for any reason other than power failure, it shall cause automatic change over to flashing of amber light or turn off all signal lights as per IS: 7537-1974.

19. PAINTING

19.1. The insides of visors (hoods) and the entire surface of louvers and fins and the front surface of back plates shall have dull black finish to minimise light reflection to the side of the signals.

19.2. To obtain the best possible contrast with the visual back ground, it is desirable to paint the signal post, and signal housing with traffic yellows.

20. AUXILIARY SIGNS

Auxiliary signs used with traffic signals such as restrictions of turning movements, etc. shall be located adjacent to the signal face to which they apply. When used in conjuction with traffic signals, illuminated signs, shall be designed and mounted in such a manner so as to avoid glare and reflections that seriously detract from the signal indications. The traffic control signal shall be given dominent position and brightness to assure its target priority in the overall display.

21. REMOVAL OF CONFUSING ADVERTISING LIGHTS

There should be legal authority to prohibit the display of any unauthorised sign, advertisement, signal, marking or device which interferes with the effectiveness of any official traffic control device.

22. DETERMINATION OF CYCLE LENGTHS AND GREEN PERIOD IN SIGNAL PHASING

22.1. Pedestrian Green

The width of carriageway to be crossed in metre may be

divided by the assumed walking speed of 1.2 metre per second to determine the green interval required for pedestrian to cross the carriageway. A value of seven seconds must be added to this value being the reaction time of the pedestrian and the total value will then be the green time that should be allotted for the pedestrian phase.

22.2. The optimum cycle length should be designed such that delay at all approaches will be minimised. It should be such that adequate pedestrian clearance time is available for crossing all approaches. Adequate increased timing for commercial as well as turning vehicles should also be provided. The cycle lengths should be multiples of five. If it works out to odd number, it should be rounded off to the immediate higher multiple of five. The maximum cycle length recommended is preferably 120 seconds being the maximum acceptable delay for drivers of vehicles and pedestrians.

22.3. The apportionment of green time for vehicles on an individual approach should be done in proportion to the number of vehicles per lane of that approach. At the intersections, the approach lanes shall be considered to be 2.8 metre in width.

22.4. There shall preferably be not more than a maximum of 4 phases in any given cycle.

22.5. There shall be 3 cycle lengths worked out for a day, namely, for (1) morning peak period, (2) afternon off peak period, (3) evening peak period.

22.6. The following assumptions are made while calculating the green time for vehicles:

(a) The vehicles arriving at an intersection on an approach, distribute themselves equally on the different approach lanes meant for a particular direction.

(b) The number of vehicles arriving on an approach is equal in all-cycles, having identical cycle lengths.

(c) The reaction time to start from stop position for the first vehicle is 6 seconds and subsequent vehicles follow the first vehicle with an uniform headway of 2 seconds. A typical design of signal timing is given in *Appendices 2* & 3.

III. WARRANTS

1. ADVANCE TRAFFIC AND ENGINEERING DATA REQUIRED

1.1. A comprehensive investigation of traffic conditions and physical characteristics of the location is required to determine the necessity for a signal installation and to furnish necessary data for the proper design and operation of a signal that is warranted. Such data desirable should include :

(i) The number of motorised vehicles entering the intersection in each hour from each approach during 10 consecutive hours of a representative day. The 16 hours selected should contain the greatest percentage of 24 hours traffic.

(ii) Vehicular volumes for each traffic movement from each approach for at least 2 hours morning and 2 hours evening peak periods classified by vehicle type (trucks, buses, passenger cars, taxis, jeeps, tempos, motor cycles and scooters). Non-motorised vehicles such as (hand carts, bullock carts, victorias, rickshaws, pedel cycles, etc.). For convenience, the classification may be heavy vehicles, light vehicles, motor cycles and scooters and non-motorised vehicles.

(iii) Pedestrian volume counts on each cross walk during the same periods as vehicular counts in para (ii) above and also during hours of highest pedestrian volumes.

(iv) The 85th percentile speed of all vehicles on the uncontrolled approaches to the location. If not, at least an average speed of approach must be recorded.

(v) A condition diagram showing details of the physical layout including such features as intersectional geometrics, channelisation, grades, sight distance restrictions, bus stops and routings, parking conditions, pavement markings, street lighting, drive ways, location of nearby rail-road crossings distance to nearest signals, utility poles and fixtures, and adjacent land use, etc.

(vi) A collision diagram showing accident experienced by type, location direction of movement, severity, time of day, date and day of week for at least one year.

1.2. The following data are also desirable for a more precise understanding of the operation of the intersection and may be obtained during periods specified in para 1.1. (ii) in this chapter:

(i) Delay in seconds per vehicle determined separately for each approach.

(ii) The 85th percentile speed of vehicles on the controlled approaches at a point near to the intersection but unaffected by the control.

(iii) Pedestrian delay time for at least two 30 minute peak pedestrian delay periods of an average week-day or like periods of a Sunday or Saturday.

1.3. Adequate roadway capacity at a signalised intersection is desirable. Widening of both the main highway and intersecting roadway may be warranted to reduce the delays caused by assignment of right-of-way at intersections controlled by traffic signals. Widening of intersecting roadway is often beneficial to operation on the main highway because it reduces the signal time that must be assigned to side-street traffic. In urban areas, the effect of widening can be achieved by elimination of parking at intersectional approaches. It is always desirable to have at least two lanes for moving traffic on each approach to a signalised intersection. Additional width may be necessary on the leaving side of the intersection as well as on the approach side, in order to clear traffic through the intersection effectively. Before an intersection is widened, the additional green time needed by pedestrians to cross the widened streets should be checked to ensure that it will not exceed the green time saved through improved vehicular flow.

2. WARRANTS FOR TRAFFIC SIGNAL INSTALLATION

2.1. Traffic control signals should not be installed, unless one or more of the signal warrants specified herein are met. Information should be obtained by means of traffic and engineering studies and compared with the requirements set forth in the warrants. If these requirements are not met, a traffic signal should neither be put into operation not continued in operation (if already installed).

2.2. When a traffic control signal is indicated as being warranted, it is presumed that the signal and all related traffic control devices, and markings are installed according to the standards set forth in the previous sections. It is further presumed that signal indications are properly phased, roadways properly designed, and that there is adequate supervision of operation and maintenance of the signal. All of its related device and traffic signal controller shall be selected on the basis of engineering study and judgement. All the mechanical and electrical equipment shall conform to I.S.I. standards.

2.3. An investigation of the need for traffic signal control should include where applicable, at least an analysis of factors contained in the following warrants :

Warrant 1 — Minimum vehicular volume
Warrant 2 — Interruption of continuous traffic
Warrant 3 — Minimum pedestrian volume
Warrant 4 — Accident experience
Warrant 5 — Combination of warrants

3. WARRANT 1 — MINIMUM VEHICULAR VOLUME

3.1. The minimum vehicular volume warrant is intended for application where the volume of intersecting traffic is the principal reason for consideration of signal installation. The warrant is satisfied when for each of any 8 hours of an average day, the traffic volume given in Table 2 exist on major street and on the higher volume, minor street approach to the intersection.

3.2. These major street and minor street volumes are for the same 8 hours. Each traffic lane marked at the intersection, shall be minimum 2.8 metre wide. During the 8 hours mentioned above, the direction of higher volume on the minor street may be on one approach during same hours and the opposite approach during other hours.

3.3. When the 85th percentile speed of major street traffic (or average approach speed) exceeds 50 kmph or when the intersection lies within the built-up area of an isolated community having a population of less than 2.5 lakhs the minimum vehicular warrant is 70 per cent of the requirements above (in recognition of differences in the nature and operational characteristics of traffic in urban and rural environments and small municipalities).

TABLE 2. MINIMUM VEHICULAR VOLUME FOR WARRANT-1

Number of lanes for moving traffic on each approach		Motor vehicles per hour on major street (total both approaches)	Motor vehicles per hour on higher volume minor street approach (one direction only)
Major Street	Minor Street		
1	1	650	200
2 or more	1	800	200
2 or more	2 or more	800	250
1	2 or more	650	250

4. WARRANT 2 — INTERRUPTION OF CONTINUOUS TRAFFIC

4.1. The interruption of continuous traffic warrant applied to operating conditions where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or hazard in entering or crossing the major street. The warrant is satisfied when, for each of any 8 hours of an average day, the traffic volume given in Table 3 exist on the major street and on the higher volume minor street approaching the intersection, and the signal installation will not seriously disrupt progressive traffic flow.

TABLE 3. MINIMUM VEHICULAR VOLUME FOR WARRANT 2

Number of lanes* for moving traffic on each approach		Motor vehicles per hour on major street (total of both approaches)	Motor vehicles per hour on higher volume minor street approach (one direction only)
Major Street	Minor Street		
1	1	1000	100
2 or more	1	1200	100
2 or more	2 or more	1200	150
1	2 or more	1000	150

*These traffic lanes at intersection shall be minimum 2.8 metre wide.

4.2. During the 8 hours, the direction of higher volume on the minor street may be on one approach during some hours and on the opposite approach during other hours. When the 85th percentile speed (or average approach speed) of major street traffic exceeds 60 kmph or when the intersection lies within the built-up area of an isolated community, having a population of less than 2.5 lakhs, the interruption of continuous traffic warrant is 70 per cent of the requirements above (in recognition of difference in the nature and operational characteristics of traffic in urban and rural environments and smaller municipalities).

5. WARRANT 3—MINIMUM PEDESTRAIN VOLUME

5.1. The minimum pedestrain volume warrant is satisfied when for each of any 8 hours of an average day, the following traffic volumes exist :

(i) On the major street, 600 or more vehicles per hour enter the intersection (total of both approaches) or where there is a raised median island 1.5 metre or more in width, 1000 or more vehicles per hour (total of both approaches) enter the intersection on major street, and

(ii) During the same 8 hours as in para (i) above, there are 150 or more pedestrains per hour on the highest volume cross-walk crossing the major street.

5.2. When the 85th percentile speed (or average approach speed) of major traffic exceeds 60 kmph, or when the intersection lies within the built-up area of an isolated community having a population of less than 2.5 lakhs the minimum pedestrian volume warrant is 70 per cent of the requirements above (in recognition of the difference in the nature and operational characteristics of traffic in urban and rural environments and smaller municipalities).

5.3. A signal installed under this warrant at an isolated intersection or mid-block, should be of the traffic actuated type with push buttons for pedestrains crossing the main street. If experience proves that it is being tampered with or misuse anticipated, they can be of the usual fixed time cycle and phases. If such a signal is installed at an intersection, it should be equipped and operated with control devices which provide proper co-ordination with other signals in the system.

5.4. Signal installed according to this warrant shall be equipped with pedestrian indications conforming to requirements set forth in previous sections. Signals may be installed at non-intersection locations (mid-block) provided the requirements of this warrant are met, and provided that the related cross-walk is not closer than 300 metre to another established cross-walk. Kerb side parking should be prohibited for 75 metre before and 75 metre beyond the cross-walk. Phasing, co-ordination and installation must conform to standards. Special attention should be given to the signal head placement and the signs and markings used at non-intersection locations, to be sure that drivers are aware of this special application.

6. WARRANT 4—ACCIDENT EXPERIENCE

The accident experience warrant is satisfied when :

(i) Adequate trial of less restrictive remedies with satisfactory observance and enforcement have failed to reduce the accident frequency, and

(ii) Five or more reported accidents, of types susceptible of correction by traffic signal control have occurred within a period of 12 months, each accident involving personal injury or property damage to an apparent extent of Rs 2000 or more.

(iii) The signal installation will not seriously disrupt traffic flow.

7. WARRANT 5—COMBINATION OF WARRANTS

7.1. In exceptional cases, signals may be justified occasionally where no signal warrant is satisfied but where two or more of warrants 1,2 and 3, are satisfied to the extent of 80 per cent or more of the stated volume.

7.2. Adequate trial or other remedial measure which causes less delay and inconvenience to traffic should precede installation of signals under this warrant.

IV. FUNCTIONAL SPECIFICATIONS FOR INTERSECTION CONTROLLER

1. The standard controller shall provide for six phases with green, amber and red intervals in each phase. In each phase, the green interval shall be adjustable in steps of 2 seconds from 10 seconds to 60 seconds and in case of any failure in sequential operation, the green interval shall never be less than 10 seconds.

2. The amber interval shall be adjustable to either 2,3,4 or 5 seconds and in case of any failure in sequential operation, the amber interval shall never be exhibited less than 2 seconds.

3. Vehicle signal sequence shall be Red-Amber-Green-Amber. However, there shall also be a facility for vehicular signal sequence of Red-Green-Amber, if required as optional. Normally, an Amber indication should appear between green and red as 'Clearance Amber'. The equipment should be capable of skipping the 'Initial Amber', if so desired by the Traffic Engineer.

4. Facilities shall be provided for flickering of left turn arrows, etc.

5. Facilities shall be provided for pedestrian crossing in each case. Provision shall also be available for flashing of the red pedestrian crossing signal for a period of 6 seconds adjustable to 4 seconds and 6 seconds plus 2 seconds steady Red phase during the clearance interval (All Red Phase).

6. The standard controller shall have provision for 3 cycles with different intervals in each cycle pattern to cater to morning, evening and off-peak traffic flow conditions during the day. A circuit shall also be incorporated which enables different phasing sequence in each cycle if so required. In addition, one cycle of amber flashing on main roads and red flashing on minor roads shall also be provided to cater to night traffic conditions. The controller shall be capable of changing over automatically from one pattern to the next one at preset times of the day.

7. There shall be facility for manual control of the signal indication, as optional.

Appendix 1

NEED FOR CO-ORDINATED CONTROL

Need for co-ordinated control of signals arises on a main traffic route when it is desirable to reduce delays and avoid main traffic from having to stop at every junction. When a signal indicates a stop aspect at a junction, a queue of vehicles is formed behind the stop line. When the signal changes to green, the vehicles start moving in a platoon. If this platoon is made to meet a green aspect at the next junction, no delay is caused to the vehicles. This principle of linking adjacent signals so as to secure maximum benefits to the flow of traffic is called co-ordinated control of signals.

The co-ordination of signals is sought for with the following objectives in view :

(i) To pass maximum amount of traffic without enforced halts.

(ii) To have minimum overall delay to traffic streams, both in the main and side roads.

(iii) To prevent the queue of vehicles at one intersection from extending and reaching to the next intersection.

In general, the co-ordination of signals is aimed at giving a progressive movement to traffic in a specified direction at a predetermined speed. In practice, it is usually found that about 60 per cent of the vehicles are able to clear the intersections in the corridor. It is therefore necessary that the signals are not separated by large distances so as to ensure the driver's visibility to maintain a constant rate of motion. Where the visibility is impaired due to large distances, it is advisable to introduce an additional signal so as to enable continuity of perception of green by the driver along the entire route of co-ordination.

OFF-SET

The off-set is defined as the difference between the starts of green time at the successive upstream and downstream signals. This is an important consideration in planning a system of co-ordination. If the start of green at the downstream signal is off-set at a particular value such that the platoon, which starts at the upstream signal upon a green indication there, arrives at the downstream signal just in time for the green signal, the platoon has an unhindered movement, Fig. 6.

TIME AND DISTANCE DIAGRAM

In planning a system of co-ordinated signal control, it is often expedient to indicate the system diagrammatically by what is known as a "time-and-distance" or "time-and-space" diagram. On this diagram, the time and signal settings are indicated along the horizontal axis to a suitable scale, whereas the distance travelled along the major route is plotted vertically to a suitable scale. A typical time and distance diagram for a one-way street is shown in, Fig. 7 and one for a two-way-street is shown in, Fig. 8.

TYPES OF CO-ORDINATED SIGNAL SYSTEMS

The four basic types of co-ordinated signal systems are:

(i) Simultaneous system, also known as synchoronised system

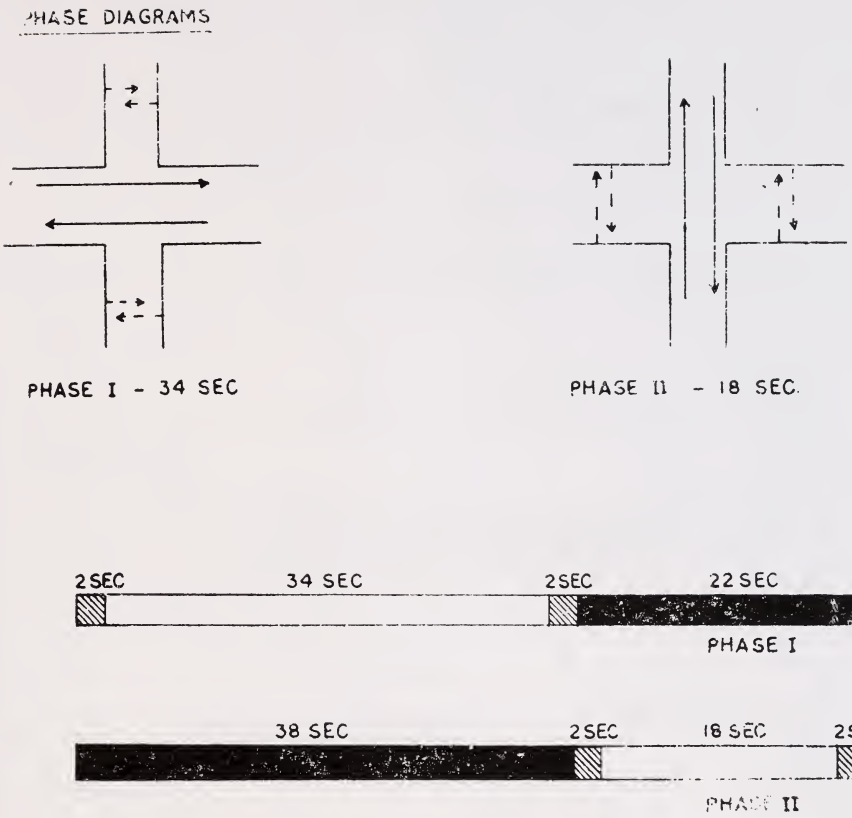


Fig. 6. Signal phasing and band diagrams

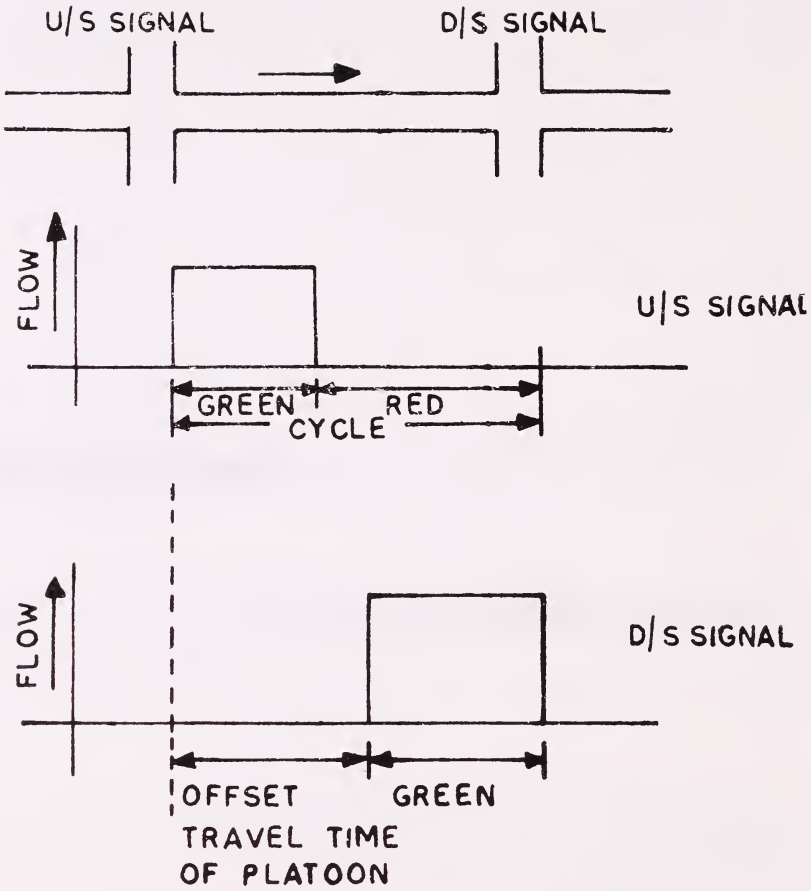

U/S SIGNAL
D/S SIGNAL
FLOW
U/S SIGNAL
GREEN
RED
CYCLE
FLOW
D/S SIGNAL
OFFSET
GREEN
TRAVEL TIME
OF PLATOON

Fig. 7. Offset

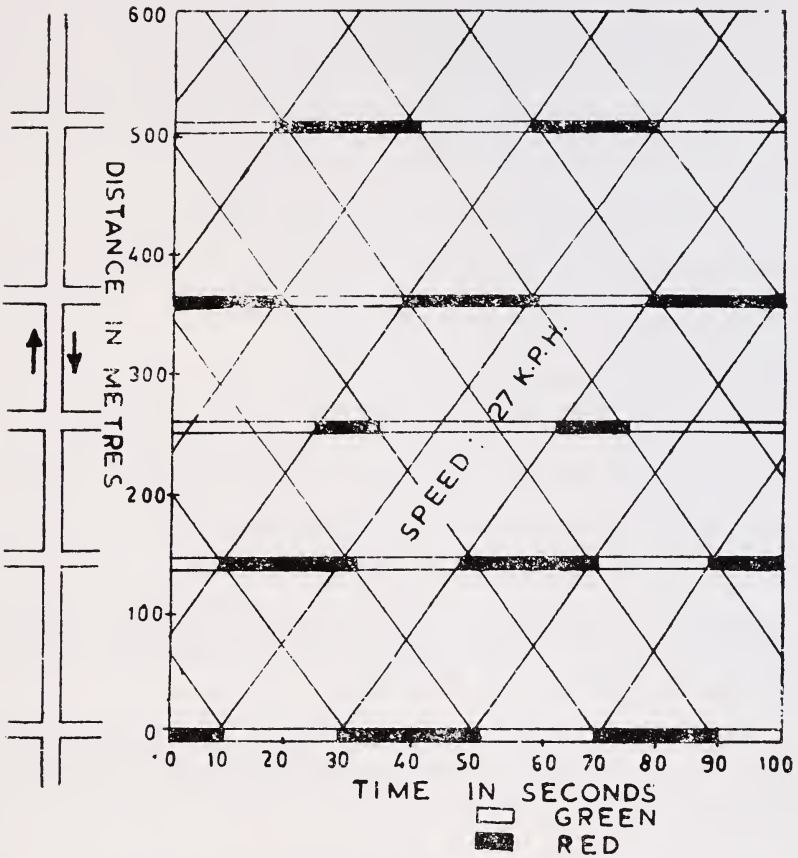


Fig. 8. Typical time and distance diagram for one way streets with linked signals

(ii) Alternate system, or limited progressive system

(iii) Simple progressive system

(iv) Flexible progressive system

SIMULTANEOUS SYSTEM

Under this system, all the signals along a given street always display the same indication to the same traffic stream at the same time. The division of the cycle time is the same at all intersections. A master controller is employed to keep the series of signals in step. The disadvantages of a simultaneous systems are :

(i) It is not conducive to give continuous movement of all vehicles,

(ii) It encourages speeding of drivers between stops.

(iii) The overall speed is often reduced.

(iv) Because the division of the cycle time is the same at all the intersections, inefficiency is inevitable at some intersections.

(v) The simultaneous stoppage of a continuous line of traffic at all intersections often results in difficulty for the side street vehicles in turning into or crossing the main side street.

ALTERNATE SYSTEM (LIMITED PROGRESSIVE SYSTEM)

Under this system, consecutive signal installations along a given road show contrary indications at the same time. This permits the vehicles to travel one block in half the cycle time. This system operates efficiently where the blocks are of equal lengths. It also brings about a certain measure of speed control since speeding drivers are stopped at each signal.

Some of the disadvantages of this system are:

(i) The green times for both the main and side streets have to be substantially equal, resulting in inefficiency at most of the intersections.

(ii) In situations where the block lengths are unequal, the system is not well suited.

(iii) Adjustments are difficult for changing traffic conditions.

SIMPLE PROGRESSIVE SYSTEM

With this system, the various signals along a street display green aspects in accordance with a time schedule to permit, as nearly as possible, continuous operation of platoons of vehicles along the street at a planned rate of motion, which may vary indifferent parts of the system.

The offset at each installation is determined so as to secure the best continuous movement of platoons in both directions. These offsets are fixed and cannot be altered at different periods of the day. Each signal installation may have a cycle division different from the others, but that division remains fixed throughout the day.

FLEXIBLE PROGRESSIVE SYSTEM

This system is an improvement over the simple progressive system with the following provisions:

(i) It is possible to vary the cycle time and division at each signal depending upon traffic.

(ii) It is possible to vary the offset, thus enabling two or more completely different plans.

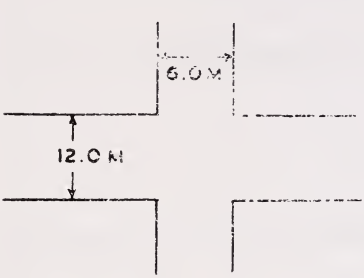
(iii) It is possible to introduce flashing or shut down during off-peak hours.

Flexible progressive systems require a master controller which keeps the local controllers at each intersection in step.

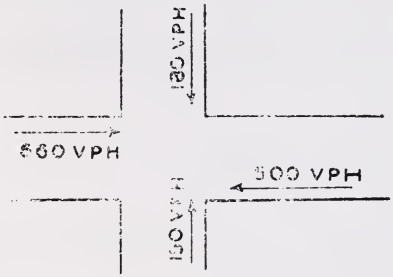
Appendix 2

DESIGN OF SIGNAL TIMING

Data : Right angled intersection (turns prohibited)
Major street 12.0 metre wide (4 lane divided)
Minor street 6.0 metre wide (2 lane)
Peak hour volumes on different approaches shown in sketch 2.



SKETCH-1



SKETCH-2

Pedestrian clearance time for major street = 12.0/1.2 = 10 seconds

Pedestrian green time for crossing major street = 10 + 7 seconds

Pedestrian reactions time = 17 seconds

Therefore minimum green time for vehicle on minor street approach = 17 seconds

Pedestrian clearance for minor street = 6.0 1.2 = 5 seconds

Pedestrian green time for crossing minor street = 5 + 7 = 12 seconds

Therefore minimum green time for vehicle on major street approach = 12 seconds

Critical lane volume on major street = 660/2=330 veh/hour/lane

Critical lane volume on minor street = 180 veh/hour lane

Green time for major street approach = 330/180×17=31.16 seconds say 32 seconds.

Adding initial amber and clearance amber of 2 seconds each for minor as well as major street approaches the minimum cycle length works out to (2 + 17 + 2) + (2 + 32 + 2) = 57 seconds Immediate higher multiple of 5 = 60 seconds. Additional 3 seconds may be apportioned as 2 seconds for major street approach and 1 second for Minor Street approach (Ratio of Volume of Major Street to Volume of Major Street to Volume on Minor Street).

Signal Timing	*Initial Amber*	*Green*	*Clearance Amber*	*Red*	*Cycle length*
Major Street	2	34	2	22	= 60 seconds
Minor Street	2	18	2	38	= 60 seconds

Fig. 9, shows the signal phasing and band diagrams for the designed signal timing.

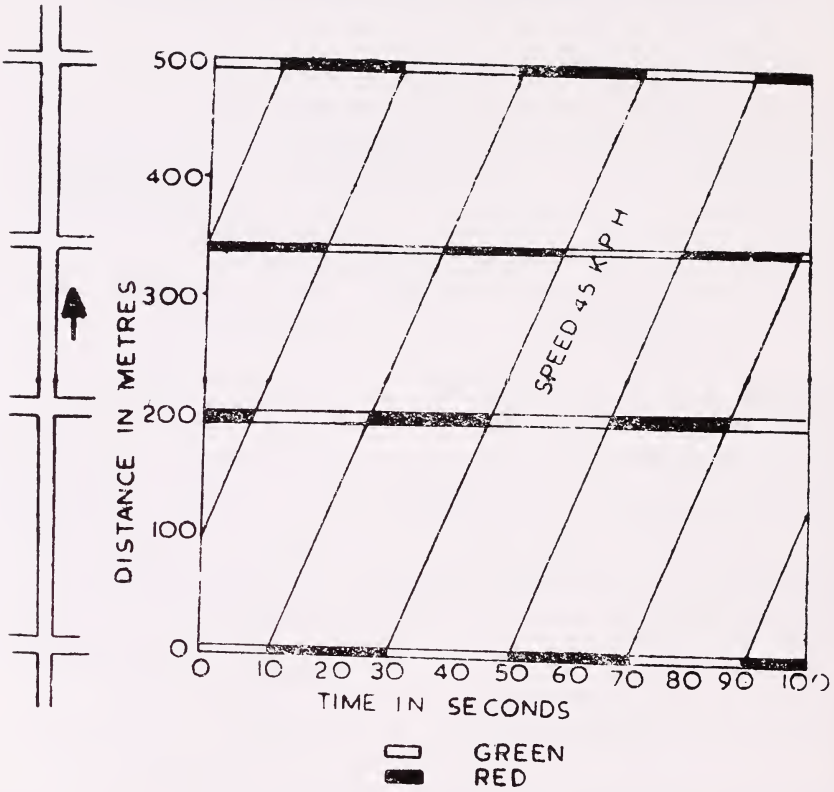


Fig. 9. Typical time and distance diagram for a two way street with linked signals

Appendix 3

CHECK FOR DESIGN OF SIGNAL CYCLE TIMINGS ON THE BASIS OF VEHICULAR VOLUME

It is assumed that the first vehicle on each approach lane will take six seconds reaction time to start after stop and subsequent vehicular in the platoon will follow at a constant headway of 2 seconds each.

It is to be ensured that the minimum time for any vehicular phase is not kept less than 16 seconds so as to provide for built in safety.

Check for major approach

In the above example, the vehicle volume on the major street two lane is equal to 660 vehicles per hour.

Number of vehicles per hour per lane = 330

Number of vehicles per lane per cycle of 60 seconds } 330 60 = 5.5 say 6

Therefore green time required, on the basis of above assumptions for major street approach = 1 × 6 + 5 × 2 = 6 + 10 = 16 seconds

Since 34 seconds green time is provided on the basis of pedestrian clearance period, it is safe.

Check for minor street approach

Number of vehicles per hour per lane = 180 V.P.H.

Number of vehicles per lane per cycle = 180 60 = 3

Therefore green time required on the basis of the above assumption for minor street approach = 1 6 + 2 × 2 = 10 seconds

Since 18 seconds green time is already provided on the basis of pedestrian clearance period, it is safe.

Optimisation of signal timings

Webster's formula, $Co = \frac{1.5 \times L + 5}{1\text{-}Y1\text{-}Y2 \ldots Yn}$

Where

Co = Optimum cycle length in seconds

L = Total lost time per cycle

Y = Volume/Saturation flow for critical approach in each phase.

In the above example, total lost time per cycle is equal to total amber time per cycle i.e. 8 seconds plus 4 seconds reaction time for first vehicle in phase 1 plus 4 seconds reaction time for first vehicle in phase 2 i.e. equal to total 16 seconds. Saturation flow = 525 W p.c.u.s per hour where W is the width of the approach in metre measured from kerb to the inside of the central median or mentioned centre line of the approach. Though above mentioned formula is valid

for widths from 5.5 to 18 metre for lesser widths the values may be obtained from the table given below :

Width W in metres	3.0	3.5	4.0	4.5	5.0	5.5
Saturation flow (p.c.u's) per hour	1850	1890	1950	2250	2550	2990

Saturation flow for critical approach in phase 1 = 525 × 6
= 3150 pcu/hour

Saturation flow for critical approach in phase 2 = 1850 (from table)

$y_1 = 660/3150 = 0.21$

$y_2 = 180/1850 = 0.10$

Optimum cycle length $Co = \frac{1.5 \times 16 + 5}{1\text{-}0.21 - 0.10} = \frac{29}{0.69} = 42.02$ seconds

Say 45 seconds, as the cycle time is expressed in multiples of 5.

The cycle length may be distributed as green time to the two phases on the basis of $g_1/g_2 = y_1/y_2 = \frac{0.21}{0.10}$

Therefore $g_1 = 30.48$ seconds $g_2 = 14.52$ seconds

Effective green after deducting initial and final amber time works out as follows :

$g_1 = 30.48 - 2\text{-}2 = 26.48$ seconds $g_2 = 14.52 - 2\text{-}2 = 10.52$ seconds

But as per pedestrian requirements effective green for minor street to accommodate crossing major street equals 17 seconds.

Therefore total g_2 including amber is equal to 17 + 2 + 2 = 21 seconds

The green for the major street is already kept as 34 seconds which is greater than effective green of 26.48 seconds. As such the signal timings initially worked out are safe.