4.2.2 Reflective Material

The reflective materials should have sufficient retro reflection from a visibility point of view and adequate durability, and they should be easy to maintain.

The visibility of traffic signs using reflective materials is rather less than the lighted traffic signs during night. However, the manufacturing process of this type of signs are simple and installation is also easy. In addition, the total costs is also less expensive.

(1) Type and Characteristics of Reflective Materials

The reflective sheet is usually used for traffic signs. Type and characteristics of the reflective sheet are defined by the Thailand Industrial Standard No. TIS 606-2529. The following summarizes the contents of this industrial standard.

a) Definition

A. A reflective sheet means a reflective material with adhesive backing for attaching onto a flat material.

B. The heat activated adhesive backing means that after peeling off the back sheet, it cannot directly be attached on any material, but it can be attached by heat activation.

C. The pressure sensitive adhesive backing means that after peeling off the back sheet, it can be directly attached on any material.

D. The luminance factor means that the illuminance from reflective sheet and for magnesium oxide by standard light A of CIE.

E. Efficiency of retro-reflection means that the luminous intensity of reflective sheet and illuminance at right angles to the surface ($cd/lx/m^2$).

b) Type of Reflective Sheet

1) Classified by the adhesive backing

- Heat activated adhesive backing.
- Pressure sensitive adhesive backing.

2) Classified by the efficient retro-reflection

- No. 1 : Efficient retro-reflection 1st level.
- No. 2 : Efficient retro-reflection 2nd level.

- No. 3 : Efficient retro-reflection 3rd level.
- No. 4 : Efficient retro-reflection 4th level.

c) Components

A. The coating film should be flexible and transparent with a smooth surface and adequate durability.

B. The reflective layer should be under the coating film and contains reflective materials which reflects the light in the same direction as the incident rays.

C. The adhesive should be on the back.

d) Specification

1) General

The reflective sheet should be a flat sheet, a coating film or a reflective material, and it must be of the same appearance as tested by visual inspection.

2) Color of the reflective sheet

- White
- Gold
- Brown
- Yellow
- Orange
- Red
- Dark red
- Green
- Blue

3) Specification

A. Attachment

The reflective sheet must be a sticky attachment with flat aluminum plate which allows the sheet to be peeled off only 50 mm when it is tested according to this standard.

B. Adjustment

In a case of the heat activated adhesive backing, it should be possible to reattach it in good condition after testing. In addition, the adhesive condition should be the same as before it was peeled off.

C. Flexibility

The reflective sheet should not exhibit any cracks after the test.

D. Chemical resistance

The minimum duration of melting by chemical effects should be more than the duration shown in Table 4.3.

Table 4.3 Minimum Duration for Melting of Reflective Sheet by Chemical Affects

Type of Chemical	Soaking Duration (min.)
Kerosene	10
Turpentine	10
Methanol	1
Toluene	1
Sylene	1

F. Efficient retro-reflection

The efficient retro-reflection of each type of reflective sheet should satisfy the value shown in Tables 4.4 to 4.7. In addition, The efficient retro-reflection at incident angle of 50° and the measuring angle of 0.2° should be a value not less than 1.0% of the fixed value at the measuring angle of 0.2° and the incident angle of -4°.

Table 4.4 Minimum of Efficient of Retro-Reflection of Reflective Sheet Type No. 1

(Unit : cd/lx/m²)

Measuring Angle	Incident Angle	White	Gold	Brown	Yellow	Orange	Red	Dark Red	Green	Blue
0.2°	-4°	70.0	50.0	1.0	50.0	25.0	14.5	14.0	9.0	4.0
0.2°	+30°	30.0	16.0	0.3	22.0	7.0	6.0	6.0	3.5	1.7
0.5°	-4°	30.0	16.0	0.3	25.0	13.5	7.5	7.0	4.5	2.0
0.5°	+30°	15.0	10.0	0.2	13.0	4.0	3.0	3.0	2.2	0.8
2.0°	-4°	1.7	1.2	0.02	1.2	0.6	0.3	0.3	0.2	0.1
2.0°	+30°	1.4	1.0	0.02	1.0	0.5	0.2	0.2	0.14	0.08

Table 4.5 Minimum of Efficient of Retro-Reflection of Reflective Sheet Type No. 2

(Unit : cd/lx/m²)

Measuring Angle	Incident Angle	White	Yellow	Orange	Red	Green	Blue
0.2°	-4°	250.0	170.0	100.0	45.0	45.0	20.0
0.2°	+30°	150.0	100.0	60.0	25.0	24.0	11.0
0.5°	-4°	95.0	62.0	30.0	15.0	15.0	7.5
0.5°	+30°	65.0	45.0	25.0	10.0	10.0	5.0
2.0°	-4°	4.0	3.0	1.1	0.7	0.5	0.3
2.0°	+30°	3.0	1.8	0.5	0.3	0.2	0.1

Table 4.6 Minimum of Efficient of Retro-Reflection of Reflective Sheet Type No. 3

(Unit : cd/lx/m²)

Measuring Angle	Incident Angle	White	Gold	Yellow	Orange	Red	Green	Blue
0.2°	-4°	50.0	25.0	25.0	13.0	10.0	5.0	3.8
0.2°	+30°	12.0	7.0	7.0	4.0	3.0	2.0	1.0
0.5°	-4°	15.0	13.0	10.0	6.5	5.0	3.0	1.0
0.5°	+30°	6.0	3.0	3.0	2.5	1.0	1.0	0.8
2.0°	-4°	4.0	3.2	2.2	1.9	1.6	1.0	0.6
2.0°	+30°	2.2	1.0	1.0	0.7	0.6	0.3	-

Table 4.7 Minimum of Efficient of Retro-Reflection of Reflective Sheet Type No. 4

(Unit : cd/lx/m²)

Measuring Angle	Incident Angle	White	Yellow	Orange	Red	Green	Blue
0.2°	-4°	250.0	170.0	70.0	35.0	30.0	20.0
0.2°	+30°	95.0	64.0	26.0	13.3	11.4	7.6
0.5°	-4°	200.0	136.0	56.0	28.0	24.0	18.0
0.5°	+30°	60.0	40.0	17.0	8.4	7.2	4.8
2.0°	-4°	8.0	6.0	2.2	1.4	1.0	0.8
2.0°	+30°	6.0	3.6	1.0	0.6	0.4	0.2

G. Weather resistance

After the catalysis test of the Fed. Spec. L-S-300C, the condition of a reflective sheet should be;

- When comparing two parts of a reflective sheet, the difference in color on the light side and the dark side must no be under the gray scale grade 4.
- Cracks, twists or shrinkage more than 1mm should not appear on a reflective sheet.
- The efficiency of retro-reflection of a reflective sheet of type No.1 and No.4 must not be less than 50% of the minimum value, while not less than 80% in the case of type No.2.

H. Heat and humidity resistance

After the heat and humidity tests, a reflective sheet should have no cracks or damage.

- Heat test by temperature of 70±3°C for 24 hours.
- Humidity test by the relative humidity of 98±2% at temperature of 40±5°C for 24 hours.

I. Mold resistance

After applying of the mold aspergillus niger on a reflective sheet attached on a aluminum plate for 14

days, a reflective sheet should not be deteriorated affected by the mold. When ethanol is applied to clean a reflective sheet, the efficiency of retro-reflection should be more than the minimum value.

J. Glossiness

The glossiness of a reflective sheet should not be less than 40% at the measuring angle of 40 degrees.

(2) Usage of Reflective Sheet

In principle, the whole surface of the traffic signs should be reflective. However, the black Color part of the warning sign and the supplemental sign should be non-reflective.

4.2.3 Illumination Equipment

The illumination equipment for the traffic sign should have adequate illuminance and durability, and maintenance should be easy.

There are two methods of illumination of traffic signs, i.e. the internal illumination method and the external illumination method. However, the reduced effect due to failure of lighting should be considered. In addition, both production and maintenance costs are high.

(1) Internal Illumination Method

The internal illumination sign consists of a frame, internal illumination equipment and a sign plate made of semitransparent material such as methacrylate plastic. The internal illumination sign can operate on one or both sides.

It is possible to attach an automatic on/off switch for the illumination, if this is required. The basic consideration for designing an internal illumination sign is as follows.

A. During night time, the surface illuminance should be adequate enough to be visible from a distance of approximately 150m.

B. Illumination equipment should be covered by a durable box with anti-corrosive treatment to prevent water and dust. However, it is necessary to be able to easily maintain illumination equipment, such as change of a lamp and for cleaning.

C. The structure of an internal illumination sign should withstand a maximum wind velocity of 50 m/sec.

D. Illumination equipment should function well and also be durable.

(2) External Illumination Method

This method is to illuminate a sign board either from above or from the side and a fluorescent lamp of more than 500 lx is generally used as an illumination source.

The basic consideration for designing an external illumination method is as follows.

A. During night time, the surface illuminance should be adequate enough to be visible from a distance of approximately 150m.

B. Uniform illuminance should be achieved.

C. The illumination source should be placed so that the illumination directly reflects back to drivers.

D. The Illumination should not cause glare for drivers.

E. A supporting arm and accessories should be made of steel pipe or plate with anti-corrosive treatment. Especially, the structure of a supporting arm should withstand a wind pressure as well as the vibration caused by passing vehicles.

F. Illumination equipments should function well and also be durable.

4.2.4 Structure of Traffic Sign Board

The size of the traffic sign board should follow the "The Manual of Traffic Control Devices, 1988" prepared by DOH, while the structure of sign board should be of adequate strength.

(1) Size of Traffic Sign Board

The size of traffic sign boards should follow the specification "The Manual of Traffic Control Devices, 1988" defined by DOH.

In addition, in a case of an information sign board, the size and the arrangement of characters can be obtained by using a computer program developed by the Study Team.

(2) Design Load

A. In designing a traffic sign board, it is necessary to consider the dead load and the wind load as the external force for the design. In this case, the wind load is considered to be a short duration loading.

B. The standard value of the wind velocity for the design are as follows.

- Pedestal type traffic sign : 40m/sec
- Cantilever type traffic sign : 50m/sec
- Overhead traffic sign : 50m/sec
- Road information apparatus : 50m/sec

The wind load can be calculated by the following equation.

$$P = 1/16 \times V^2 \times C_D \times A$$

where;
P : Wind load (kg)
V : Wind velocity for design (m/sec)
A : Surface area of sign board (m^2)
C_D : Standard drag coefficient
for post -- 0.7
for board -- 1.2

(3) Thickness of Sign Board

The desirable thickness of the sign board should be as shown in Table 4.8 according to the material and the size of the sign board.

Table 4.8 Standard Thickness of Traffic Sign Board
(Unit : mm)

Type of Sign	Size	Aluminum Plate	Steel Plate	Plastic Plate	Plywood
Guide Sign	Small Size Large Size	1.6 2.0	1.2 1.6	3.0 4.0	15.0 15.0
Warning Sign	Standard Expansion	1.6 2.0	1.2 1.6	3.0 4.0	15.0 15.0
Regulatory Sign Indication Sign	Standard Expansion	1.6 2.0	1.2 1.6	3.0 4.0	15.0 15.0
Auxiliary Sign		1.6/2.0	1.2/1.6	3.0	15.0

Note -- 1. Thicker materials can be used, if necessary.
2. If it is necessary to bend edges as circular shape, it is possible to use 1.0 mm aluminum plate.

(4) Metal Fittings

On the back of a sign board, it is necessary to attach metal fittings to enable attachment to the post as well as strengthening the sign board itself.

a) Aluminum Board

For an aluminum board, it is desirable to employ the aluminum slide channel method. This type of fitting is not only strengthens a board, but also provides easy attachment to the post. Figure 4.4 shows sections of two types of aluminum fittings. Type I and type II is used for a large size board and a small size board, respectively.

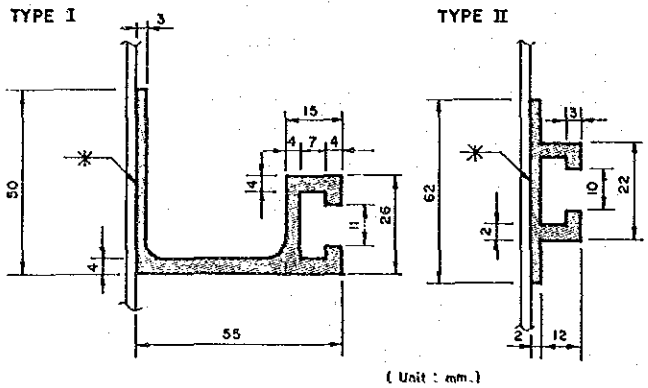


Figure 4.4 Sections of Aluminum Fittings

For attaching an aluminum board to a beam, such as F-shape post, it is necessary to use T-shape aluminum angles, as shown in Figure 4.5.

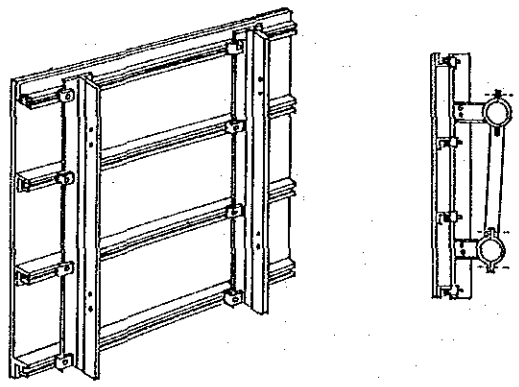
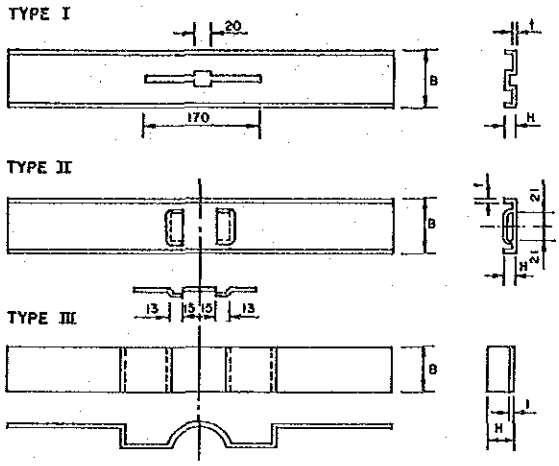


Figure 4.5 Attaching Aluminum Board by Using T-Shape Aluminum Angles

b) Steel Board

Generally, both edges of a steel board are susceptible to external bending stress, since the center part is attached to a post. In order to strengthen the edges, it is necessary to stiffen the outer edges. However, if the size of board is large, it is also necessary to weld metal fittings onto back of a steel board. Figure 4.6 shows some examples of metal fittings for a steel board.



(Unit : mm)

Thickness of Board	Type I			Type II			Type III		
	t	H	B	t	H	B	t	H	B
1.2	1.2	5	80	1.2	5	70	3.2	-	38
1.6	1.6	5	80	1.6	5	70	3.2	-	38
2.0	2.0	5	80	2.0	5	70	3.2	-	38

Note : 1. t --Thickness, H -- Height, B -- width
2. Height of type III depends on type of post.

Figure 4.6 Shape of Metal Fittings for Steel Board

(5) Renewal of Sign Board

If it is necessary to renew a traffic sign board due to modification of the sign or because of damages or weathering of the reflective material, it is economical to attach a new board over an existing board by rivets. An attached board should be an aluminum board with adhered reflective sheet. This treatment can apply to the whole or a part of a board. However, if the renewal area is limited to less than 0.1 m^2, it is possible to only adhere a reflective sheet.

4.2.5 Post of Traffic Sign

The post of traffic sign should have adequate strength in consideration of the size of a sign board and condition of installation location.

(1) Design of Post

The post of a traffic sign should be designed with adequate strength in consideration of the size of a sign board and condition of the installation location.

(2) Method of Attaching Sign Board to a Post

There is the direct method and the indirect method of attaching a sign board to a post. Also, the attaching structure can be classified as the rigid structure and the hinge structure.

An existing facility, such as a lighting pole, a traffic signal pole, an electric pole, a pedestrian bridge, is often used to attach a traffic sign board. In this case, it is necessary to consider the strength of the facility in detail in order to determine the size of a sign board and the furnishing method.

4.2.6 Foundation and Installation

The foundation of the traffic sign should be designed in consideration of the dead load of a sign board and post as well as the wind load. Installation of a traffic sign should be carried out in safety and certainly without effects from other facilities and traffic flows.

(1) Foundation of Traffic Sign

Figure 4.7 shows typical foundation types used for the traffic sign installation. The most suitable foundation type should be selected through examination of type of sign board, dead load, soil conditions, etc.

(2) Installation of Traffic Sign

During installation of a traffic sign, attentions should be paid to the following work items.

a) Foundation Work

The excavation should be properly done at the selected position. In urban areas, special attention should be paid to avoid underground utilities.

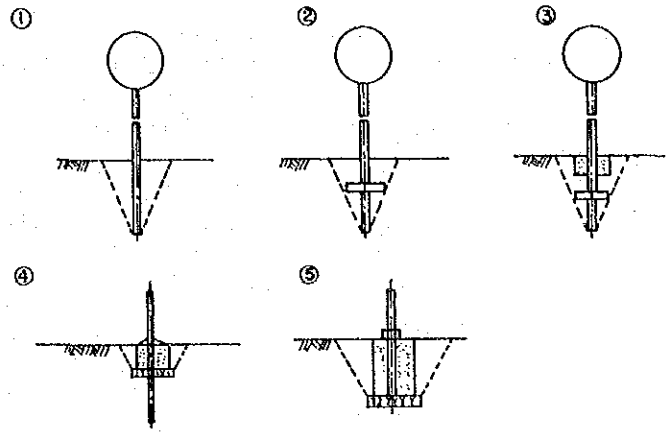


Figure 4.7 Typical Traffic Sign Foundation Types

Special arrangements around an excavated hole is required to avoid confusion by pedestrian traffic. Forms, steel bars and anchor bolts should be fixed appropriately and not moved during pouring of concrete.

b) Installation of Post

A pole should be handled carefully to avoid damage and any necessary protection should be adopted, if there is any danger from overhead electric wires, during installation.

c) Attaching Sign Board

During attachment of a sign board, it is necessary to handle the board carefully, and to avoid damage especially to the surface.

4.2.7 Inspection and Maintenance of Traffic Signs

Routine inspection of traffic signs is necessary to maintain the function of individual traffic sign as well as the function to continuously provide necessary indications to traffic. In addition, it is desirable to carry out additional inspection after the abnormal weather condition, such as typhoon.

When any disorder is found on inspection, it is necessary to repair it immediately. In particular, if any traffic sign has an unsafe clearance, this may result in a bad accident and immediate maintenance is necessary.

An inspection of traffic signs is carried out to detect any disorders and any disorder, such as damage, should be repaired as soon as possible. In general, inspection items on traffic signs are as follows.

- Dirt on the sign board surface.
- Condition of paints on the sign board.
- Bends and twists on the board.
- Looseness and damage on attached part of the sign board.
- Bends and leaning of the post.
- Corrosion of the pole near the ground.
- Condition of paints on the post.
- Stability of foundation.
- Illumination.
- Obstacles which hide the sign board.

4.2.8 Traffic Sign Data Book

In order to carry out rational and speedy maintenance of traffic signs, it is desirable to prepare a traffic sign data book to fill in necessary items at each traffic sign.

The traffic sign data book can clarify the installation condition of each traffic sign, and this information is necessary for rational and speedy maintenance. The contents of this data book can be confined to items, which are fundamentally useful for the road administrators.

CHAPTER 5 PAVEMENT MARKINGS

CHAPTER 5 PAVEMENT MARKINGS

5.1 REVIEW OF TECHNICAL GUIDELINES

A review was made on the "Manual on Traffic Control Devices - Part 2 : Markings", one of the technical standards that were developed by DOH and are currently in use. In this manual, detailed descriptions of pavement markings are found on their types and sizes, the location and method for installation.

Some recommendations are drawn through reviewing on each part of the Manual as seen in the following sections.

5.1.1 Longitudinal Markings

(1) Width of Markings

The width of longitudinal markings is standardized to be 10 cm in general which is adequate for normal condition; however, it will be effectively widen up to 20 cm where special attention of drivers should be called to form an orderly flow at hazardous road sections or intersections.

At this case, attention should be paid for the introduction of anti skidding pavement markings, which is described in Chapter 11, if several accidents occurred due to skidding on pavement markings.

(2) Outer Edge Line

Application of an outer edge line is specified in the Manual in terms of number of lanes, width of carriageway and ADT. According to the traffic volume survey results, 2-lane road length which falls within the warrants accounts for approximately 15% of the total national highways and few recommended at such locations as hazardous intersection approach regardless of ADT and road section where segregation of slow traffic or pedestrian is required.

5.1.2 Markings at Intersection

(1) Right Turn Lane Transition

The following equation, adopted in the Manual for calculating the length of converging lanes at pavement width transition section, will be applicable for obtaining suitable transition length to provide right turn lane at intersection.

$$L = k \cdot V \cdot W$$

where;
- L : Taper length (m)
- V : Prevailing or design speed (km/hr.)
- W : Width of transition (m)
- k : Coefficient
  - (0.6) for normal road section
  - (1/3 - 1/2) for approach of intersection
  - (1/6) for entrance of turning lane at Intersection

(2) Others

There are some controls in which pavement markings are also recommended in addition to primary regulatory signs such as NO U-turn sign and Speed Limit sign.

Some other useful pavement markings are shown below.

A. Symbol marking to guide right turn vehicle at the center of an intersection.

B. Symbol marking for advance notice of crosswalk.

5.2 ENGINEERING SPECIFICATION

5.2.1 Pavement Marking Materials

(1) Basic Requirement for the Material

The basic requirement for the pavement marking materials are as follows.

A. The visibility of the pavement markings should be good throughout the day, especially in rain.

B. The material should have good durability and a quick drying time. In addition, quick application should be possible.

C. The material should have sufficient skid resistance for both vehicular traffic and pedestrian traffic.

D. The cost performance of the material is required to be high. This mean that the life span of the material is sufficient to justify the application cost.

E. For the application of the pavement markings, it is necessary to select the appropriate application method according to the type of material, road and traffic conditions.

(2) Classification of Materials and Application Method

Materials utilized for the pavement markings are classified as the traffic paint and the reflective sheet, while the traffic paint is classified according to the application method.

a) Traffic Paint

The quality of the traffic paint used in Thailand is defined in the Thailand Industrial Standard (TIS) 415-2525 (415-2531 for amendment). In addition, the quality of the reflectorized glass beads is also defined by the TIS 543. Hence the qualities of all traffic paint and reflectorized glass beads used for the pavement markings should satisfy these standardized qualities.

There are two types of traffic paint, i.e. a liquid type and a solid type. The liquid type mainly consists of such raw materials as coloring pigments, extender and synthetic resin varnishes, which is made ready for use by complete mixing and kneading. The solid type mainly comprises such raw materials as coloring pigments, extender, reflectorized glass beads, aggregate and synthetic resin, in which one is premixed with all the materials and the other divided into two parts which are mixed when application is desired.

The traffic paint is classified into the following types, shown in Table 5.1, according to the application conditions.

Table 5.1 Type of Traffic Paint

Types	Condition of Application	Glass Beads Application Method	State of material
Type 1	Cold Application	Glass Beads are not mixed in the paint, but dispensed on to the paint surface	Liquid
Type 2	Hot Application	Glass Beads are not mixed in the paint, but dispensed on to the paint surface	Liquid
Type 3	Melting Application (Thermoplastic Material)	Glass Beads are mixed in the paint by 15 to 18% (by mass). In addition, it is dispensed on to the paint surface when applied in hot melting condition	Solid

Table 5.2 summarizes the characteristics of each type of traffic paint. Since the characteristics as well as the price of each traffic paint is quite different, it is important to select the most suitable traffic paint based on due considerations of the road and traffic conditions, weather condition and economic efficiency.

Table 5.3 shows the applicability of each type of traffic paint according to the road conditions. For the actual installation of road markings, the most suitable type of paint should be selected with reference to this table.

b) Pre-fabricated Tape

Pre-fabricated tape consists of either a rubber or plastic base, coloring pigments, extender, synthetic resin varnishes and reflective materials. There are two adhesive methods for the pre-fabricated tape, i.e. the cold adhesive and the hot adhesive, which requires the pre-painting of the primer on the pavement surface.

Generally, the pre-fabricated tape has the advantage of quick remedial results, higher durability for wearing and easy application. On the other hand, it is difficult to apply a large quantity at once and the cost is high. Hence, application of the pre-fabricated tape is suitable in only the following cases.

- Letters and symbols over a small area.
- Temporary markings.

Table 5.2 Characteristics of Traffic Paint by Type

Item	Type 1 (Cold Paint)	Type 2 (Hot Paint)	Type 3 (Melt Application)
Form	Liquid	Liquid	Powdery bulk materials
Specific Gravity	1.3 to 1.6	1.4 to 1.7	1.8 to 2.3
Heating Residue	60% or over	65% or over	99% or over
Primary Coating	Not required	Not required	Required
Application Temperature	Ambient temp.	Heated to 50 to 80°C	Heated to melting temp. 180 to 220°C
Application Method	-Roller blushing -Brushing -Spraying	-Air spraying -Airless spraying	-Hand pushing screed -Self propelled machine
Skilled Level	Nothing special	Required	Required
Curing	Evaporation of solvent	Evaporation of solvent	Air cooling
Reflection at Night * - White - Yellow	 Good Good	 Excellent Excellent	 Excellent to good Good to excellent
Abrasion Resistance	Low	High	Higher
Interruption to Traffic When It IS Applied	Little	Less	Least
No Pick Up Time	Within 15 min.	Within 10 min.	Within 3 min.
Cost (Thickness)	Least expensive (0.2mm)	Less expensive (0.4mm)	Expensive (1.5mm)
Restriping Required	4 to 8 months	8 to 15 months	10 to 20 months

Note * : Reflection depends on the use and rate of glass beads.

Table 5.3 Applicability of Traffic Paint

Road Type	Surface Condition	Type of Pavement Marking	Heavy Traffic Volume	Light Traffic Volume
Ordinary Highway	Ordinary pavement surface	Line markings	Type 3	Type 3 & 2
		Cross markings Letters & symbols	Type 3	Type 3
	Temporary pavement	-	Type 1	Type 1
	Pavement with many cracks	-	Type 2 & 1	Type 2 & 1
	Stone pavement Brick pavement	-	Type 1	Type 1
Express Highway	Ordinary pavement surface	-	Type 2 & 3	Type 2
Vertical Surface	-	-	Type 1	Type 1

5.2.2 Example of Pavement Marking Installation

(1) Pavement Marking at Intersection

a) Stop Line

A stop line is a marking which indicates that any part of a vehicle should not stop beyond this line. A stop line should be installed at the entrance of signalized intersections, before crosswalks and at non-priority road entrances of stop-control intersections.

Improper installation of a stop line not only results in non-observance of a stop line, but also causes traffic accidents. Hence, in designing an intersection, the location of stop lines should be determined after careful study of the planned traffic operation.

1) Basic concept for the location of stop line

A. In principle, a stop line should be installed at right angles with the center line.

B. A stop line should be located 1m to 2m before a crosswalk.

C. The visibility from a stop line should be sufficient to identify vehicles on a crossing road.

D. Any vehicle stopped at a stop line should not be an obstacle for right/left turn vehicles from a crossing road.

2) Sight distance from a stop line

At unsignalized intersections, it is a general rule that vehicles from non-priority roads must stop before the intersection. In this case, sufficient sight distance over the major road should be assured in order to cross the major road safely. This necessary sight distance is defined by elements, such as stop line location, width of roads, design speed, intersecting angle and design vehicles, as shown in Figure 5.1.

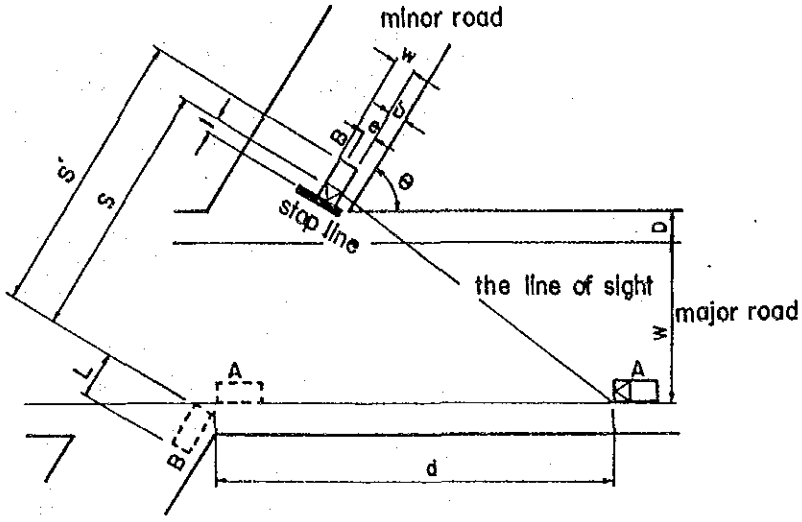


Figure 5.1 Location of Stop Line and Line of Sight

where;
- d : Running distance of vehicle A on major road (m)
- W : Distance between left lane edge and opposite lane edge of main road (m)
- D : Distance between right lane edge of main road and stop line (m)
- S' : Running distance of vehicle B on minor road (m)
- S : One side of sight triangle (=S'-L+l) (m)
- L : Length of vehicle B (m)
- l : Distance between front of vehicle and driver eye position of vehicle B (m)
- w : Width of vehicle B (m)
- b : Distance between road edge of minor road and nearside of vehicle B (m)
- e : Distance between the driver's eye and nearside of vehicle B (m)
- θ : Intersecting angle between major road and minor road (degree)

Running distance of vehicle A $d = \frac{V}{3.6}(T + t)$

where;
- V : Design speed of main road (km/hr)
- T : Reaction time of driver on vehicle B (sec)
- t : Running time for distance S' (sec)

'T' is the reaction time, which is generally two seconds long. Also, 't' is the time in which vehicle B runs distance S' during acceleration. If the rate of acceleration is given, 't' can be calculated.

From Figure 5.1,

$$S = \frac{W + D}{\sin \theta} + \frac{w + b}{\tan \theta} + l$$

By using this equation, 'd' and 'S' can be calculated, and the necessary sight distance is obtained.

3) Treatment on narrow roads

A stop line at an intersection of narrow roads should be located several meters from an intersection, so that

stopping vehicles do not obstruct right/left turn vehicles from the crossing road. However, in this case, there is a problem of not being able to achieve sufficient sight distance to identify vehicles on the crossing road.

The following countermeasures may be applied to solve such problems. However, a careful study of the characteristics of the intersection is required before application of these countermeasures.

A. To take a sufficient corner cut-off to achieve sufficient sight distance.

B. To signalize the intersection, if it is impossible to obtain the necessary corner cut-off due to restricted roadside conditions.

C. To install a road mirror which helps provide a view of the crossing road when the traffic volume of the narrow road is very limited and the corner cut-off is impossible.

b) Intersection Marking

It is desirable to install intersection markings, as shown in Figure 5.2, at intersections between local roads in urban areas and narrow roads in rural areas where the visibility of the intersection is poor.

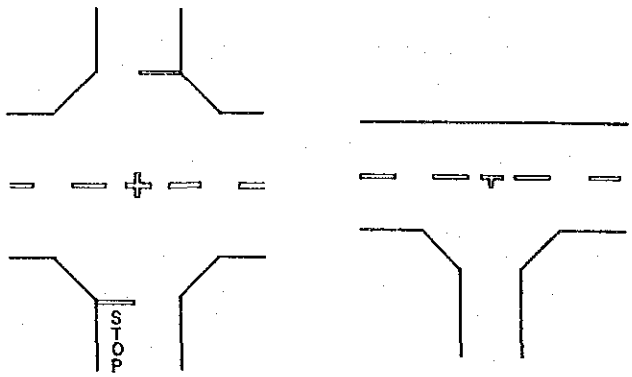


Figure 5.2 Examples of Intersection Marking Installation

c) Right Turn Pavement Marking

There are three methods to indicate the right turn path at an intersection, as shown in Figure 5.3.

d) Channelization Marking

Installation of channelization markings are desirable for the following types of intersections.

1) Intersections with right turn lanes provided by shifted center lines. (see Figure 5.4)

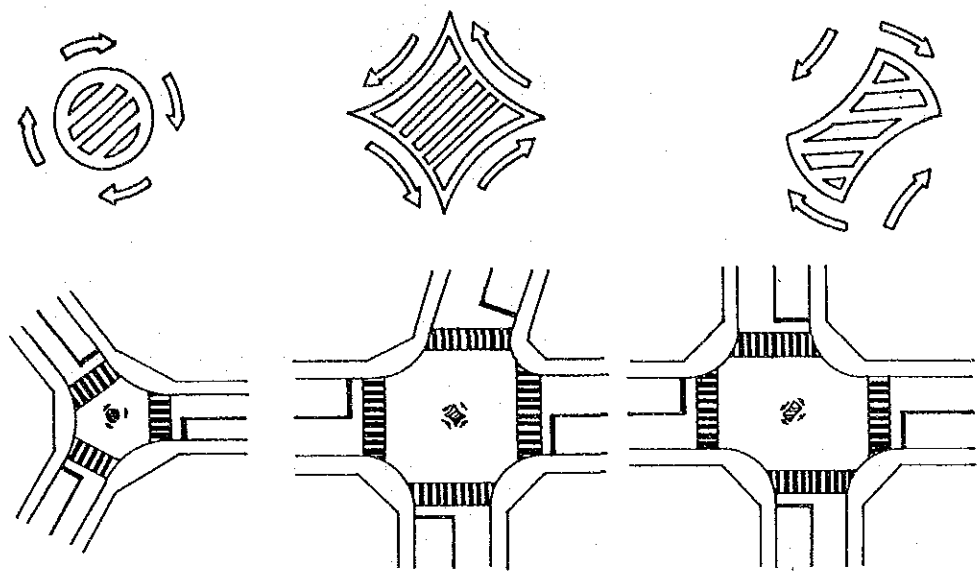


Figure 5.3 Right Turn Pavement Marking

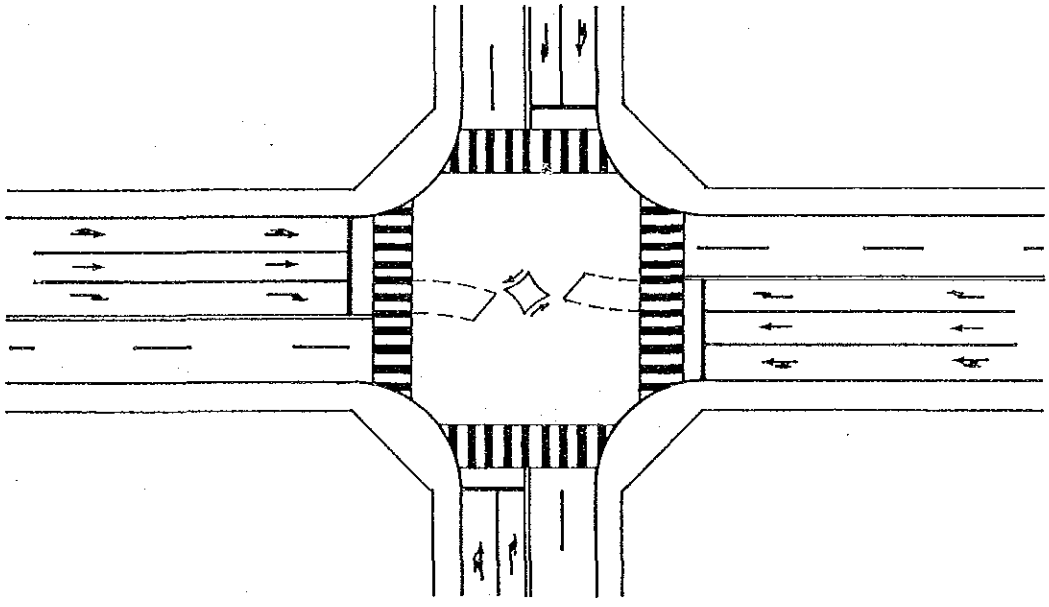


Figure 5.4 Channelization Marking (1)

2) Intersection with wide median. (see Figure 5.5)

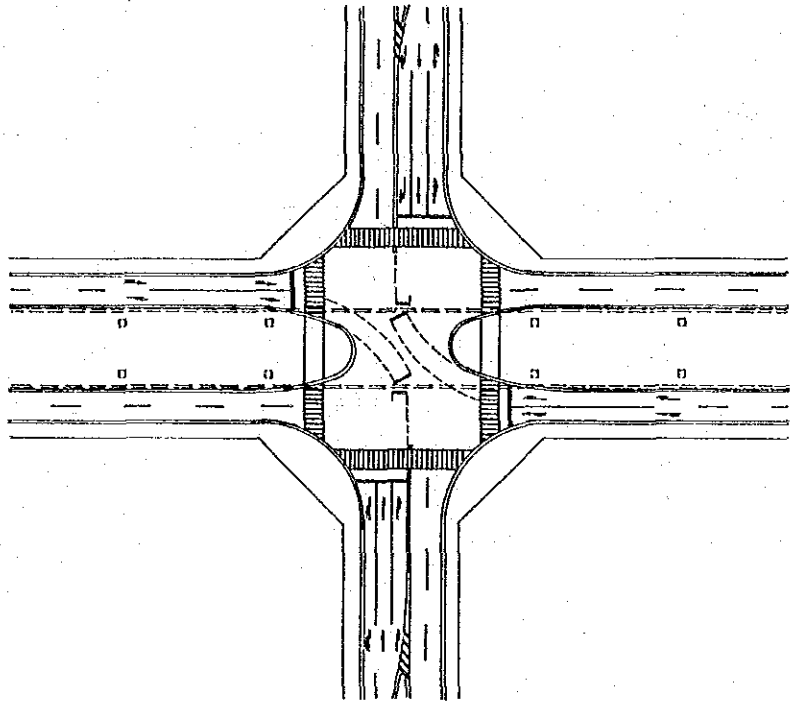


Figure 5.5 Channelization Marking (2)

3) Intersection with more than four legs or with an irregular shape

If there is not enough space to install islands, pavement marking might be used instead as shown in Figure 5.6. In this case, it is not necessary to achieve the set backs.

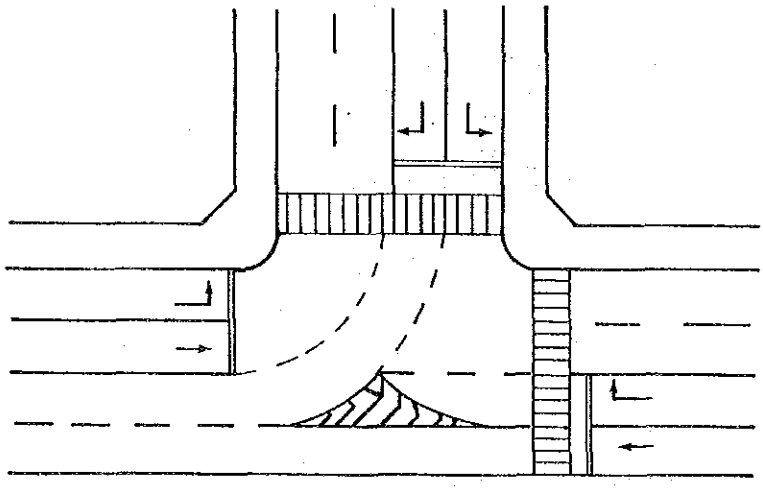


Figure 5.6 Channelization Marking (3)

(2) Pavement Marking at Intersection Approach

a) Lane-use Control

At an intersection approach with several lanes, it is necessary to provide arrow markings which comply with the traffic operation method.

Arrows should definitely be placed just before the stop line (3m to 5m) and at the widening section when added lanes are provided. If the distance between arrows exceeds 30m, extra arrows should be provided for distances between 15m to 30m. In addition, one or two arrows should be provided at the taper section with 30m intervals.

When the distance between intersection is short and it is impossible to maintain enough distance between arrows, the first arrow should be located at least 60m before the stop line, as shown in Figure 5.7.

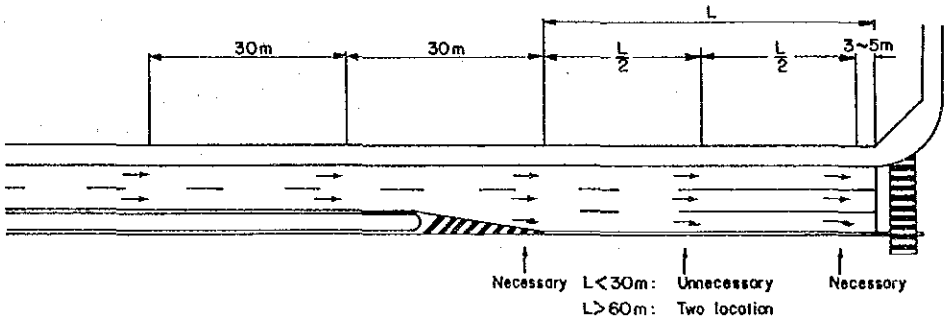


Figure 5.7 Location of Arrows

b) Treatment of Side Strip at Intersection

At a road section with a side strip highlighted in the form of an edge line marking, this marking should be extended into the intersection, as shown in Figure 5.8.

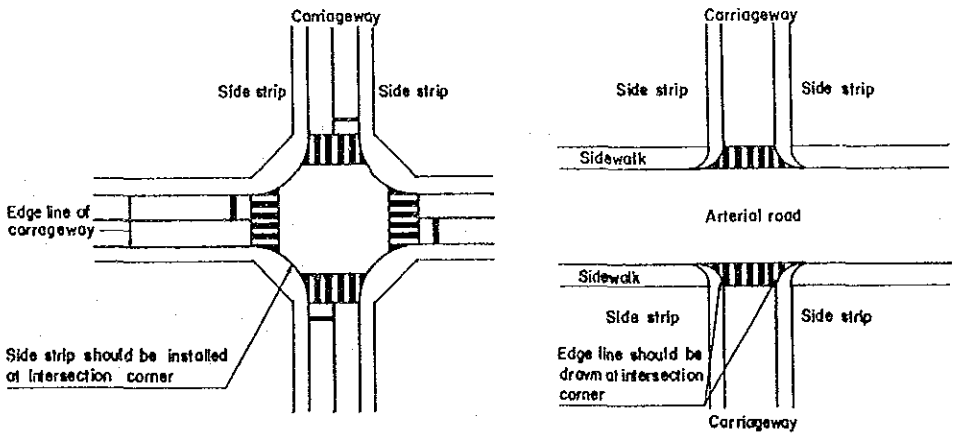


Figure 5.8 Side Strip at Intersection

c) Advanced Warning Marking of Crosswalk

When it is necessary to advice drivers of the existence of a crosswalk, a "Crosswalk Ahead" marking should be installed at the center of each lane. However, this marking is not necessary when the forward visibility is adequate and it is easy to identify the crosswalk, or when a traffic signal can be seen on the road section.

The location of this marking should be 30m to 50m before the crosswalk, and one or two additional markings should be placed at 10m to 30m intervals.

In urban areas, where the density of crosswalks is high, installation of this kind of marking results in confusion and the warning effectiveness declines. Therefore, excessive usage of this marking should be avoided. However, when the crosswalk is located adjacent to a curved section and the visibility is limited, provision of this marking is highly recommended. (see Figure 5.9)

Diamond shape marking is proposed to avoid confusion with the marking at Priority-crossing (triangle shape) although the latter one is widely applied in Bangkok area as advance notice of crosswalk.

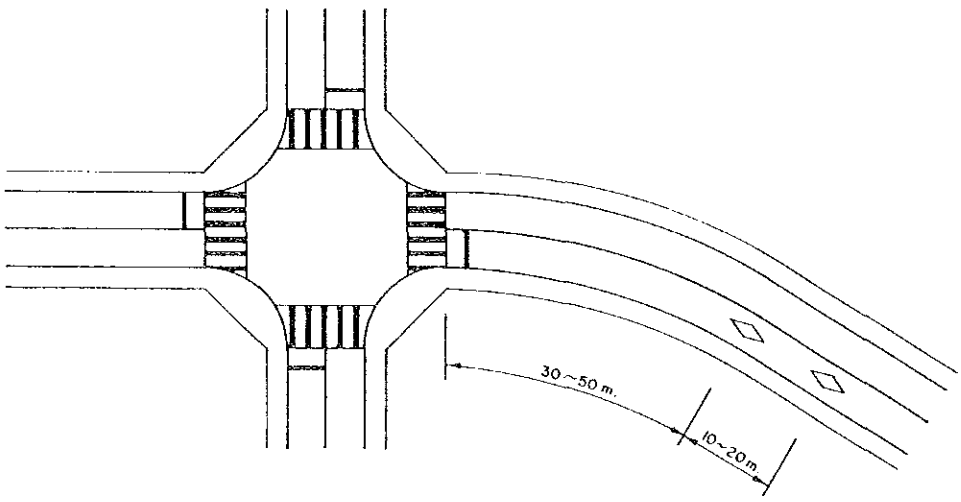


Figure 5.9 Advanced Warning Marking of Crosswalk

CHAPTER 6 CROSSING FACILITY FOR PEDESTRIANS

CHAPTER 6 CROSSING FACILITY FOR PEDESTRIANS

6.1 GENERAL

The main objectives of crossing facilities is to ensure safety of pedestrians when cross roads, through elimination or reduction of conflicts between vehicles and crossing pedestrians. The crossing facilities also contribute to minimize vehicular traffic delays which may be caused by disorderly movements of pedestrians on carriageways without them.

Crosswalks, refuge islands, pedestrian signals, and pedestrian overpasses/underpasses are well known and practical facilities for pedestrian crossing. Since the degree of effectiveness and obstruction to vehicles as well as construction costs varies with types of the facilities, careful considerations should be paid to select best suited facility at a given location.

Although detailed discussions on the features of the crossing facilities are made in the following section, some of them, by the nature of complexity, are rather subjective but neither objective nor conclusive. It should, therefore, be noted that a final decision on selection of type and location of crossing facilities should be made by the concerned engineer who is acquainted with road and traffic conditions at specific locations.

Excluded in the following discussions is the pedestrian signal which has been explained in Chapter 3, "Traffic Signal".

6.2 Crosswalk

6.2.1 Technical Guideline

(1) Summary of Warrant

Crosswalk may be installed where:
1) More than 100 pedestrians cross carriageway per hour.
2) A number of school children cross carriageway.
3) Designated as walking parts within an intersection.
4) Vehicular traffic makes it difficult for a number of pedestrians to cross carriageway.

(2) Warranting Conditions

Crosswalk is a part of carriageway designated as a walking space for pedestrians to cross the carriageway safely. It is particularly desirable to indicate crosswalks by pavement markings so that they are visible by day and by night. The clearly marked crosswalks will attract pedestrians and warn vehicle drivers when they approach to crosswalks.

It is noteworthy that crosswalks accompanied with adequate safety devices like flashing beacons, lightings and warning signs are more effective. Installation of sidewalk guard fences plays an important role to make crosswalk effective, when they are properly erected so as to guide pedestrians into crosswalk preventing jaywalking.

There are no definitely accepted warrants for painted crosswalks, but they should be based upon the following conditions.

A. Pedestrian volume crossing roads.

B. Vehicular traffic volume and speed.

C. Accident frequency.

D. Use as school crossings.

For pedestrian volume, crosswalks are generally warranted at locations where there are at least 100 crossing pedestrians per hour. To ensure sufficient traffic gaps for 100 pedestrians per hour, the maximum traffic volume can be estimated at about 450 vehicles per hour. The minimum intervals of crosswalks should be decided based

upon the requirement of smooth vehicular traffic flow. Although there exist conflicts between pedestrian safety and smooth traffic flow, the minimum interval of around 200m seems to be a reasonable compromise for the conflicts.

6.2.2 Engineering Specification

(1) Planning Methods

a) Type of Markings for Crosswalk

There are three kinds of pavement markings for crosswalks, namely, zebra markings with white color paint, two parallel solid lines with white color paint and two parallel dotted lines with road studs. The zebra markings are superior to other types of marking in visibility of crosswalks existence.

b) Planning Conditions

It is desirable to plan crosswalks in the following manners.

A. The standard width of crosswalks should be 4.0m. The width may be increased or decreased according to pedestrian volume, but the minimum width be 3.0m.

B. Pedestrians should cross the road in one movement.

C. Stop lines should be painted in association with the crosswalk markings.

C. The minimum interval of crosswalks shall be 200m in urban area and 300m in the other areas with exception of the areas in the vicinity of schools, hospitals, and where pedestrian volume is heavy enough to justify installation of other crosswalks in spite of the above minimum intervals.

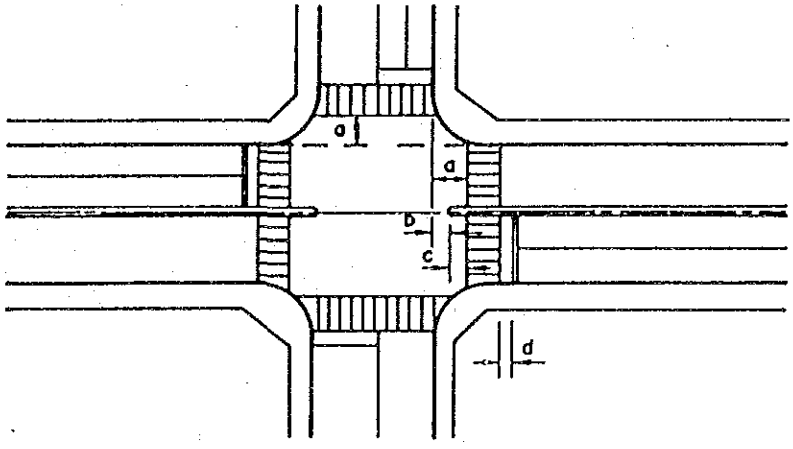


Figure 6.1 Crosswalk Planning at Intersection

(2) Basic Concept for Designing a Crosswalk

Basic concepts for the design of crosswalks are as described below.

A. Location of a crosswalk should comply with the natural pedestrian flow as far as possible.

Installation of a crosswalk with an unnatural detour may lead to crossings by pedestrians other than at a crosswalk and the installed crosswalk becomes useless. This situation is undesirable from a traffic safety point of view.

B. The installation angle of a crosswalk should be at right-angles with the carriageway.

This should reduce the crossing duration for pedestrians by minimizing the carriageway crossing distance. This consideration is also useful for increasing traffic control capacity at an intersection by decreasing necessary signal timing for pedestrians.

C. Location of a crosswalk should be close to the center of an intersection.

Since crosswalks and stop lines form an outline of an intersection, the location of crosswalks should be close to the center of an intersection, in order to minimize the intersection area.

D. Crosswalks should be installed at locations visible to drivers.

E. Length of crosswalk should be desirably less than 15m.

If the crosswalk length is more than 15m, it is necessary to install a refuge island to ensure the safety of crossing pedestrians.

F. In principle, the crosswalk width can be determined in consideration of the traffic condition at an intersection. However, it is undesirable to change crosswalk widths at each intersection according to the traffic volume. Hence, the minimum crosswalk width should be 4m and 2m for major intersection and minor intersection, respectively, and change in the width should be increments of 1m based on this minimum value.

(3) Example of Crosswalk Installation

A. Basically, it is desirable to install a crosswalk as an extension of a sidewalk. However, it is normal practice to locate a crosswalk at 1m (minimum) away from the intersection corner.

At a major intersection where conflicts between pedestrians and left turn vehicles are frequent, a queue of left turn vehicles may disturb the through traffic flow, which results in reduced of traffic capacity at the intersection. In order to solve this problem, it is desirable to install a crosswalk at 4m to 5m further away from the intersection corner. (see Figure 6.2)

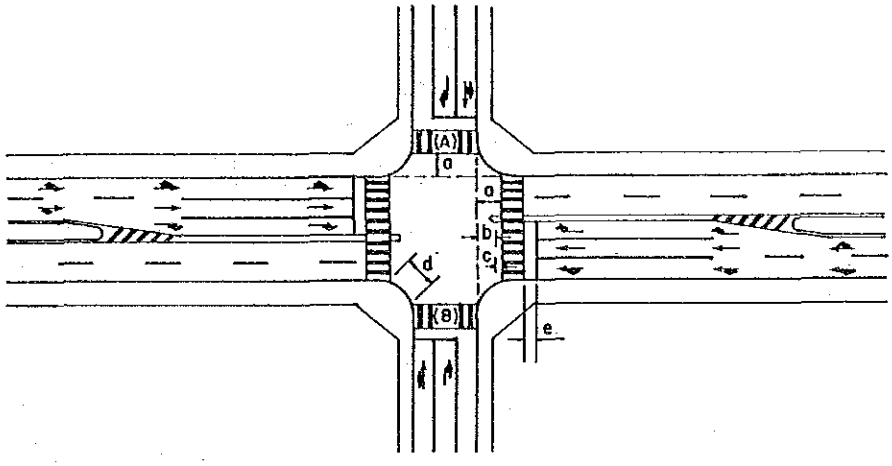


Figure 6.2 Location of Crosswalk

B. The rounded corner of sidewalks (portion 'd' in Figure 6.2) should be carefully designed to increase the quality of the landscape and pedestrian control capability at an intersection by installing well designed guard fences and planting, if possible. Such treatment may prevent random crossing by pedestrians near the corner of an intersection.

C. The position of the nose of a median (portion 'b' and 'c' in Figure 6.2) should be determined based on the calculation of the right turn channel length so as not to obstruct right turn movements. In this case, it is desirable to install a crosswalk 1m to 2m from the nose.

D. Y-shaped intersection.

In the case of Y-shaped intersection shown in Figure 6.3, it is necessary to consider the crosswalk installation as shown in (b) after the channelization.

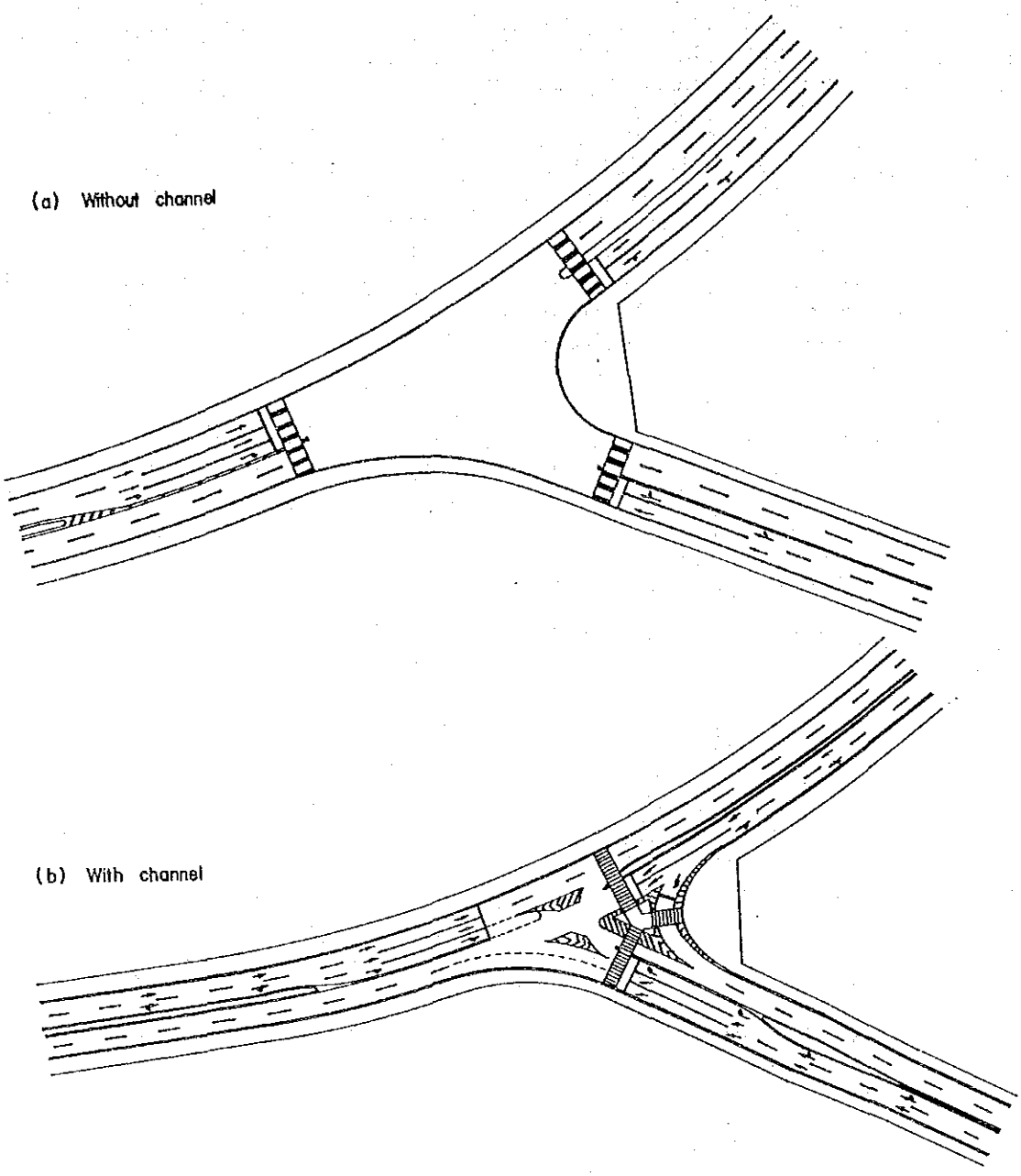


Figure 6.3 Crosswalks at Y-Shaped Intersection

E. T-shaped intersection.

A standard layout of a crosswalk at a T-shaped intersection is shown in Figure 6.4. However, if pedestrian traffic is limited, either the crosswalk 'A' or 'B' in this figure might not be installed.

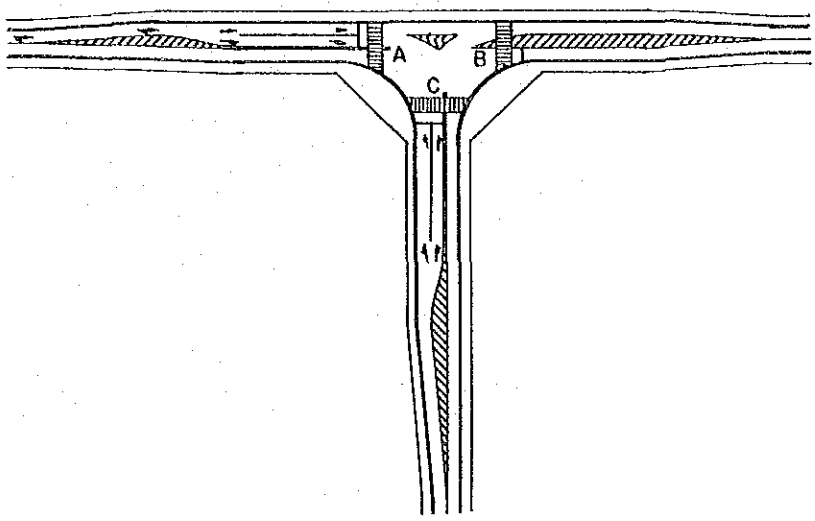


Figure 6.4 Crosswalks at T-Shaped Intersection

F. Intersection under an overpass.

At an intersection under an overpass, the view of drivers is often obstructed by piers, which makes it difficult for drivers to identify crossing pedestrians.

In order to solve this problem, introduction of a crank-shaped crosswalk ('A' in Figure 6.5) is applicable. This type of crosswalk is also able to prevent careless crossing by pedestrians.

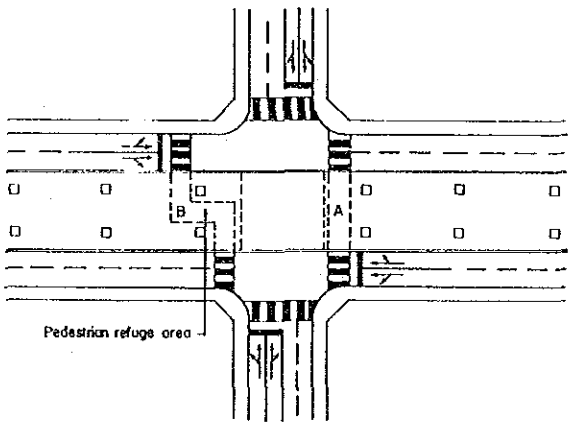


Figure 6.5 Pedestrian Refugee Area with Long Crossing Length

G. Scramble intersection.

Pavement markings of scramble intersection is shown in Figure 6.6.

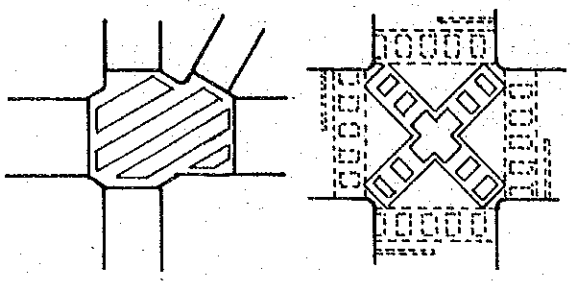


Figure 6.6 Scramble Intersection

H. Guideline marking at crosswalk

A guideline marking for a crosswalk indicated only by two parallel white lines without zebra marking is often installed in Thailand. The visibility of this type of crosswalk marking is lower than the zebra marking. Hence, it is desirable to install zebra marking for crosswalks as much as possible, except for temporary crosswalks during construction and locations where crossing pedestrian volume is very limited.

6.3 PEDESTRIAN REFUGE ISLAND

6.3.1 Technical Guideline

(1) Summary of Warrant

1. Pedestrian refuge island may be installed at the sections where pedestrians can not cross carriageway in one movement of crossing and forced to wait for a traffic gap in the middle part of carriageway with 4 or more lanes.
2. Pedestrian refuge island should, in principle, be installed in combination with a crosswalk.

(2) Warranting Condition

The pedestrian refuge island is a safety zone built in the middle of the carriageway for the exclusive use of pedestrians, where there are heavy traffic volume and heavy volume of pedestrians who would face difficulty and danger in crossing a wide carriageway at on movement. With the provision of a refuge island, in the middle part of the carriageway, pedestrians can safely wait for a traffic gap sufficiently long enough to complete the crossing.

The pedestrian refuge island may also be desirable for wide highways where an intersection is controlled by signals, to reduce the necessary clearance period in accordance with traffic movements without creating dominant gaps for pedestrians to cross the highway.

To increase effectiveness of the pedestrian refuge island, it is preferable to provide a combination of some adequate devices like crosswalks and lightings.

6.3.2 Engineering Specification

(1) Planning Method

It is desirable to plan pedestrian refuge islands in the following manners.

A. The minimum width of island should be 2.0m.

B. The pedestrian refuge island should be protected from direct collisions by vehicles by means of guard fence, curbstone and the like.

C. The pedestrian refuge island should be provided with adequate devices by which the vehicle drivers approaching to or passing by the refuge island, could be warned of the existence of the refuge island. The

following are major warning devices.

- Pavement markings.
- Traffic signs.
- Delineators.
- Flashing beacons.
- Raised pavement markers.
- Street lightings.

6.4 Pedestrian Overpass

6.4.1 Technical Guideline

(1) Summary of Warrant

Pedestrian overpass, at mid-block section or at non-signalized intersection, is warranted under the following conditions.

1. The number of crossing pedestrians per hour exceeds 100 persons at a peak hour, and the condition of traffic volume and the crossing distance meet the range indicated by the oblique line in Figure 6.7. For the crossing of school children, Figure 6.8 should be used.

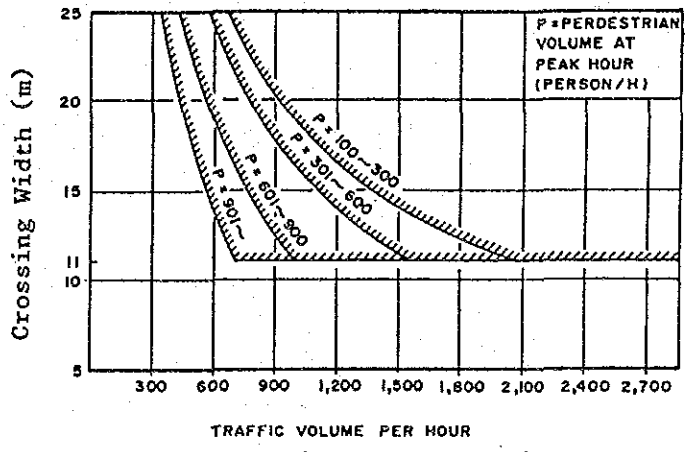


Figure 6.7 Warrant of Pedestrian Overpass

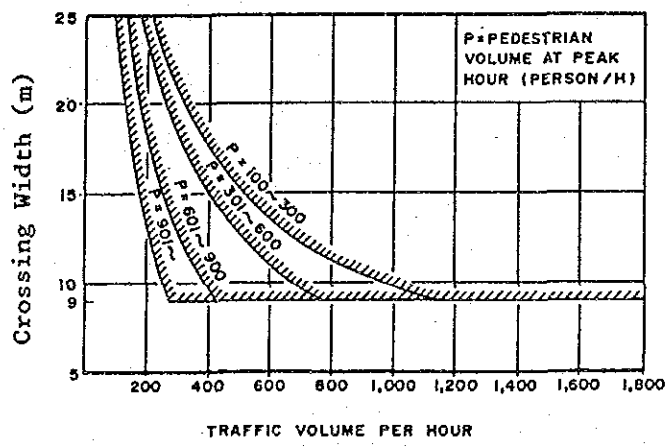


Figure 6.8 Warrant of Pedestrian Overpass for School Children

2. The following conditions are met.

   1) The crossing distance exceeds 25m, and there are no proper space to construct median or refuge island where pedestrians can wait for traffic gap.

2) Pedestrian volume is so heavy that vehicular traffic is affected to a large extent.

3) No pedestrian is allowed to cross to ensure high running speed of vehicles on roads such as expressways.

4) When pedestrian volume is heavy at such as locations, within 200m from railway crossing, immediate vicinity of grade separated road, or sub-standard sight distance, where pedestrian safety cannot be secured by at-grade crossing.

(2) Warranting Condition

The pedestrian overpass is the most effective means to attain the safety of road crossing pedestrians, since it completely separates pedestrians from vehicular traffic on carriageway. However, its high construction cost often restrains the installation of overpasses, and pedestrians sometimes prefer crosswalks because of longer walking distance and extra loss of energy for up and down of steps.

The pedestrian overpass, therefore, may be justified at extremely hazardous locations where there are heavy traffic volumes and pedestrian volumes, and there are high frequency of accidents involving pedestrians which can nor be solved by some simpler or more economical ways. Similar argument is applied to pedestrian underpasses.

A comprehensive evaluation of crosswalk and pedestrian overpass, should be made prior to the installation of an pedestrian overpass. The most fundamental factor in the study is the "time gap" of the traffic flow during which pedestrians can cross carriageway at grade. There exists the following equation between time gap and number of crossing pedestrians.

$$G = \frac{W}{V} + t + f(n) \qquad (1)$$

where;
- G : Necessary time gap for pedestrians to cross carriageway (sec.)
- W : Crossing distance (m)
- V : Walking velocity of pedestrians (m/sec.)
- t : Pedestrian's reaction time (sec.) (usually negligible)
- f(n): Some sort of function. n = pedestrian volume per hour.

From the results of various studies and experiences, the above equation can be simplified as follows.

$$G = \frac{W}{1.3} + 2(N - 1) \qquad (2)$$

where;
N : Number of pedestrian rows. (see Table 6.1 below)

Table 6.1 Number of Rows for Pedestrian

No. of Pedestrian (persons/hr.)	No. of Rows
100 - 300	1
301 - 600	2
601 - 900	4
901 -	6

Note : Prepared based on the assumption that pedestrian cross road five abreast in a row.

Meanwhile, the probability that the number of vehicles which arrive at a certain road section: (TG/3600; T = traffic volume/hr.), can be assumed to follow the Poison's distribution.

$$P(k) = \frac{e^{-TG/3600}(TG/3600)^k}{k!} \qquad (k=0,1,2\ldots) \qquad (3)$$

When traffic volume per hour is T, provided that one vehicle in each direction of road is requested to stop for crossing pedestrians during the time period of G, the traffic volume of T under which G occurs once every 60 seconds, can be obtained from the following equation.

$$\sum_{k=0}^{2} P(k) = \sum_{k=0}^{2} \frac{(TG/3600)^k \cdot e^{-TG/3600}}{k!} \leq \frac{G}{60} \qquad (4)$$

From the equation (2) and (4), and Table 6.1, a warrant for pedestrian overpass can be proposed as shown in Figure 6.7. In this figure, the minimum crossing distance is defined as 11m to ensure the utilization of pedestrian overpass. For these road sections, however, it is desirable to install adequate devices to prevent pedestrians from jaywalking.

6.4.2 Engineering Specification

Because a pedestrian overpass is a permanent structure and its construction cost is high, it is, unlike other crossing facilities, very hard to remodel a pedestrian overpass in accordance with the change of pedestrian volume in the future. Therefore, a thorough study on overpass especially as to structural dimensions is strongly required in advance of construction. The following are standards for overpass designs.

(1) Standard for Pedestrian Overpass Design

a) Width of Footpath, Step and Ramp

1. The minimum width of footpath of pedestrian overpass should be 1.5m; however 2.0m when bicycles, baby carriages and wheelchairs are expected to use the overpass, as shown in Table 6.2.

2. The width of step and ramp should be at least 1.5m and 2.0m, respectively, and a minimum of 1.2m and 1.7m, respectively under very special conditions (see Table 6.2). As for the step with ramp, the minimum width of a portion of ramp should be 0.6m as a standard.

Table 6.2 Minimum Width of Pedestrian Overpass

Unit : m

Method of Access	Minimum Width of Footpath	Minimum Width of Step or Ramp	
		Standard	Reduction
Step	1.5	1.5	1.2
Ramp	2.0	2.0	1.7
Step with Ramp	2.0	2.1	1.8

1) Width of pedestrian overpass

The width of the pedestrian overpass should able to accommodate the design volume of crossing pedestrians in considering the relation between the width and volume of pedestrians, as described below.

In principle, the necessary width of the pedestrian overpass is the multiple value of the standard occupied width of a pedestrian 75cm, and 1.5m is determined as the minimum width in order to allow two pedestrians to pass each other. However, the width of the step can be reduced to 1.2m, if it is difficult to maintain 1.5m width of the step on the sidewalk.

The necessary width is theoretically calculated by the following equation.

$$W = \frac{Q}{V} \cdot D$$

where;
W : Effective width (m)
Q : Pedestrian volume (persons/min.)
V : Walking velocity (m/min.)
D : Space for one pedestrian (m^2/person)

From this equation, the relation between the width of the overpass and the design volume of crossing pedestrians are calculated, as shown in Table 6.3

Table 6.3 Standard Width of Pedestrian Overpass

Width (m)	Design Volume of Pedestrians (Persons/min.)
1.50	Less than 80
2.25	80 - 119
3.00	120 - 159
3.75	160 - 199
4.50	200 - 239

2) Width of pedestrian overpass to accommodate bicycles, baby carriages and wheelchairs

When it is necessary to allow bicycles to use the pedestrian overpass, the minimum width should be widen to 2.0m, since the occupied width of a bicycle is 1.0m.

The same consideration is made for cases where many baby carriages and wheelchairs are expected to use the overpass.

b) Type of Pedestrian Overpass

The type of the pedestrian overpass should be determined with due consideration, such as minimization of climbing height and harmony with adjacent environment.

For the selection of type of a pedestrian overpass, it is necessary to consider not only the construction cost, but also minimizing climbing height. For this purpose, it is desirable to adopt a through bridge type for the pedestrian overpass design.

c) Pier

The location and the structure of piers should be determined from an the examination of the sight distance of vehicular traffic, etc. For a pier susceptible to vehicle collision, it is necessary to install a rigid guard fence, such as a concrete wall.

A pier of a pedestrian overpass should not be an obstacle to pedestrians nor obstruct the sight distance of vehicle drivers. In order to secure these conditions, due consideration should be paid to the location of a pier, such as at a site 50 cm from the carriageway edge or on a median.

A slender type of pier should have adequate strength. In addition, installation of a rigid guard fence is essential for this type of a pier located beside the carriageway.

If a guard rail is used for protecting a pier, it is necessary to study several factors, such as the relation between the direction of moving vehicles and the installation angle of a guard rail, distance between pier and guard rail, and installation location of guard rail, in order to optimize the efficiency of guard rail.

When it is impossible to install a strong guard fence, it is necessary to consider the collision load in the design of a pier.

d) Foundation

The foundation of a pedestrian overpass should be an appropriate structure in consideration of the scale of the superstructure, type of a overpass, the ground conditions, the location, structure and implementation method of the under ground utilities.

Foundation of a pedestrian overpass should be an appropriate structure in consideration of the scale of the superstructure, type of a overpass, the ground conditions, the location, structure and implementation method of the underground utilities.

In an urban area especially, since there are many underground utilities, special attention should be paid in the design and construction of the foundation.

e) Overpass Access Type

1. The most suitable means of access to a pedestrian overpass should be selected.

2. If only pedestrians are supposed to use a pedestrian overpass, these means should be steps in principle.

3. If the passage of bicycles, baby carriages and wheelchairs are considered, it is necessary to provide a ramp. However, if it is difficult to provide a ramp due to the site

condition or for a special reason, steps with a ramp should be provided.

4. The standard gradient of steps should be 50%. On the other hand, the gradient of a ramp and steps with a slope should not be more than 12% and 25%, respectively.

5. Where the vertical climbing height exceeds 3m by steps, it is necessary to provide a landing.

1) Overpass access type

Since a pedestrian overpass imposes inconvenience on pedestrians, it is necessary to select the most suitable means of access to the overpass.

If only pedestrians are supposed to use an overpass, provision of steps is desirable to minimize climbing distance. On the other hand, for a location with more than 300 crossing bicycles per day, or with many baby carriages and wheelchairs, it is desirable to provide a ramp.

2) Structure of steps

The standard value and limitation of the height and step width of a step is shown in Table 6.4. The gradient of steps should not be changed at the halfway point.

Table 6.4 Value of Height and Stepping Width of Step

	Standard Value	Lower Limit
Height	15 cm	not less than 18cm
Stepping Width	30 cm	more than 26cm

Where the vertical climbing height is more than 3m, it is necessary to provide a landing. Figure 6.9 illustrates desirable width of a landing.

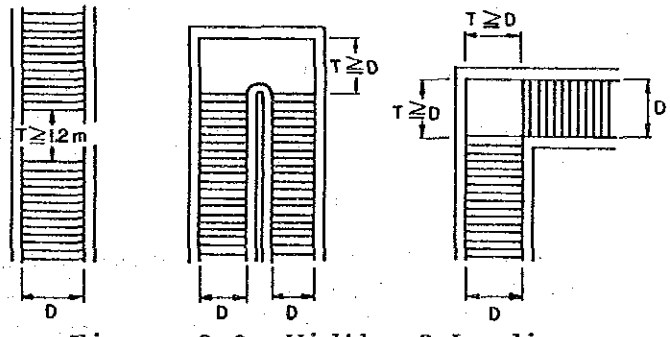


Figure 6.9 Width of Landing

3) Gradient of ramp

A small ramp gradient is desirable for users. However, smaller gradients result in a longer ramp length, which causes user s to avoid using the installation. Hence, 12% is set as the maximum gradient for the ramp.

If there is not sufficient space to provide a ramp, steps with a slope can be provided. In this case, the maximum gradient of step slope can be 25%.

f) Handrail

1. It is necessary to install handrails along steps, a landing and a ramp. For steps with more than 15cm in height or less than 30cm in stepping width and where the width is more than 3m, it is desirable to install a handrail in the center.

2. In an area with many handicapped users, it is desirable to also install handrails other than steps and some special indications for blind users.

A. It is necessary to install handrails along steps, a landing and a ramp from the safety points of view.

B. In an area where many handicapped people are expected to use a pedestrian overpass, it is necessary to provide sufficient facilities for handicapped people in order to make the a pedestrian overpass easy to use.

g) Lighting

In principle, it is necessary to install lighting at a pedestrian overpass. However, where night time use is expected to be very limited, installation of lighting may be excluded.

1) Illumination : Fluorescent lamp or mercury vapor fluorescent lamp.

2) Illuminance : More than 20 lx.

3) Lighting equipments should be designed so as not to adversely affect vehicle drivers.

In order to clearly indicate the location of a pedestrian overpass as well as providing a safe environment for pedestrians to use an overpass, it is necessary to install lighting.

In designing the lighting equipment, due consideration should be given so as not to adversely affect vehicle drivers, such as from glare.

h) Vibration

The vibration of the main girder caused by the live load should not cause an unpleasant experience for pedestrians.

For major trunk roads, large size pedestrian overpasses are often installed. However, in a case of a plate girder of more than 40 m span, if no consideration of vibration is given, unpleasant effects for crossing pedestrians may occur.

The walking pace of pedestrians is generally about 2 Hz and the live load by crossing pedestrians can produce cycle frequency of 2 Hz. Hence, if the deflection vibration of the main girder is nearly 2 Hz, the amplitude of the deflection vibration becomes larger, which increases the unpleasantness for pedestrians as well as undesirable effects on the structure itself.

i) Color

The color of a pedestrian overpass should be selected with due consideration for the harmony with the adjacent environment. In addition, where a pedestrian overpass installed near a signalized intersection, it is desirable not to use color similar to the signal displays.

Pedestrian overpasses are usually installed at urban and suburban areas with high pedestrian flows. In these areas, it is particularly necessary not only to ensure the proper functioning of pedestrian overpasses, but also to choose colors which harmonize with the adjacent environment.

In the case of a metal bridge, the deterioration of the painted surface and the formation of rust are undesirable not only from the visual attractiveness point of view but also from the durability of the overpass. Hence, attentions should be paid in the selection of the paint type, especially for steps.

(2) Maintenance of Pedestrian Overpass

1. In order to maintain a clean condition of the surface, the girder, handrails and etc., it necessary to carry out the regular cleaning of a pedestrian overpass.

2. The routine inspection should be done in order to check the condition of the girder, painting, drain pipes, lighting, etc. If any defect is found, it should be repaired as soon as possible.

3. In the case of metal overpasses, repainting is required after an appropriate period.

a) Cleaning

It is desirable to maintain the beauty of a pedestrian overpass from the road environment maintenance point of view. Hence, regular cleaning of the surface, the girder, handrails of the pedestrian overpass is necessary.

b) Inspection

It is desirable to inspect a pedestrian overpass once a month for the following items. If any defect is found, it is necessary to repair it as soon as possible.

A. Condition of girders and piers, especially damage on a girder and piers caused by vehicle collision.

B. Deterioration of the painted surface and formation of rust.

C. Condition of drain pipes.

D. Condition of lighting equipment, including damage on lines.

c) Repainting

For a metal structure, the deterioration of the painted surface and the formation of rust are undesirable not only from the visual attractiveness point of view but also from the durability of the structure. Hence, repainting after an appropriate period is required. The repainting period differs according to the weather conditions, traffic conditions. etc. However, 7 years is the maximum period, considering the deterioration of paint and the formation of rust.

CHAPTER 7 SIDEWALK AND BICYCLE PATH

CHAPTER 7 SIDEWALK AND BICYCLE PATH

7.1 TECHNICAL GUIDELINES

7.1.1 Summary of Warrants

1. Sidewalk

   Traffic volume on outer lanes of both directions per day is 3,000 or more and pedestrian volume is 250 or more. For the roads in urban areas, it is desirable, regardless of the above traffic volume, to construct sidewalk on any road, when found necessary to do so and no land acquisition problems exist.

2. Bicycle-pedestrian path
   (Bicycle path permissive of pedestrian traffic)

   1) Traffic volume on outer lanes of both directions per day is 2,000 or more and bicycle volume per day is 1,000 or more, or

   2) Traffic volume on outer lanes of both directions per day is 2,000 or more and bicycle volume per day is 500 or more, when vehicle speed is considerably high.

3. Sidewalk plus bicycle path

   The total volume of pedestrians and bicycles exceeds 3,000 per day.

Note : Where two or three of the above warrants are satisfied simultaneously, the priority is in order of 3, 2 and 1.

7.1.2 General

In order to reduce the accidents at locations where their traffic volume are high, it is a general practice to separate the pedestrians and bicycles from the vehicular traffic, by providing exclusive road spaces for pedestrians and bicycles.

The construction of the sidewalk for pedestrians and bicycle path for cyclists does not only contribute to the safety of pedestrians and cyclists, but also enhance the safety of vehicular traffic because it reduces reckless emerging of pedestrians and cyclists. It can also contribute to improving the traffic capacity and travel speed.

In practice, the sidewalk and the bicycle path can be constructed either independently or in the form of their combination. In the Study, warranting conditions on the following paths (hereinafter referred to as slow-traffic path) are prepared.

- sidewalk.
- bicycle-pedestrian path.
- sidewalk plus bicycle path.

The sidewalk is the path for only pedestrians, while the bicycle-pedestrian path is regarded as bicycle path permissive of pedestrian traffic on it. In the case of sidewalk plus bicycle path, where the bicycle path is constructed alongside the sidewalk, they should be exclusive to each other. Figure 7.1 illustrates conceptional cross sections of the slow-traffic paths.

7.1.3 Warranting Conditions

(1) Basic Frame of Warrants

Warranting conditions for slow traffic paths are discussed as to the following.

A. Requirement for segregation of pedestrians.

B. Requirement for segregation of bicycle.

C. Requirement for segregation of pedestrians and bicycles.

Construction of each slow traffic path is justified when:

A. Requirement "A" is met --- Sidewalk.

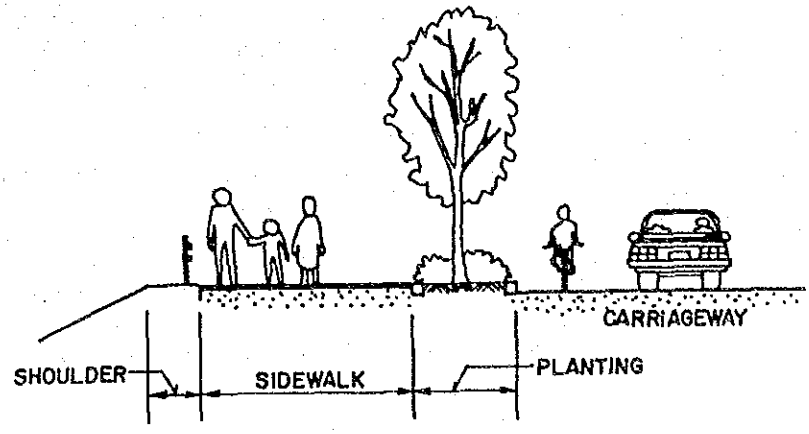
B. Requirement "B" is met --- Bicycle-pedestrian path.

C. Requirement "B" and "C" are met --- Sidewalk plus bicycle path.

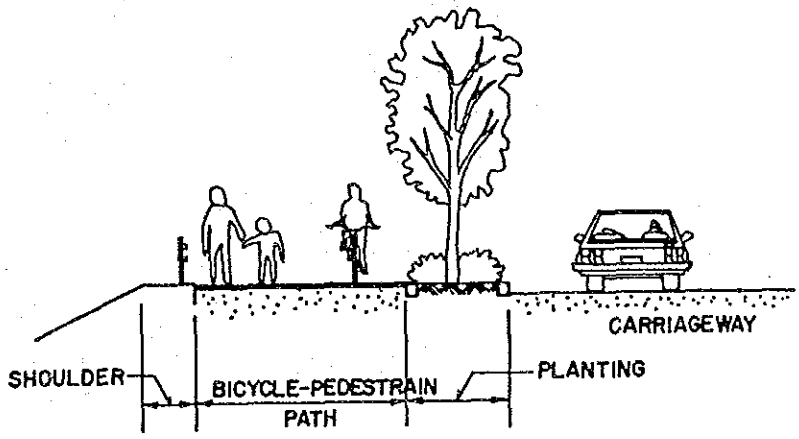
(2) Segregation of Pedestrians

Whether pedestrians should be segregated or not should be determined by considering pedestrian volume and traffic volume.

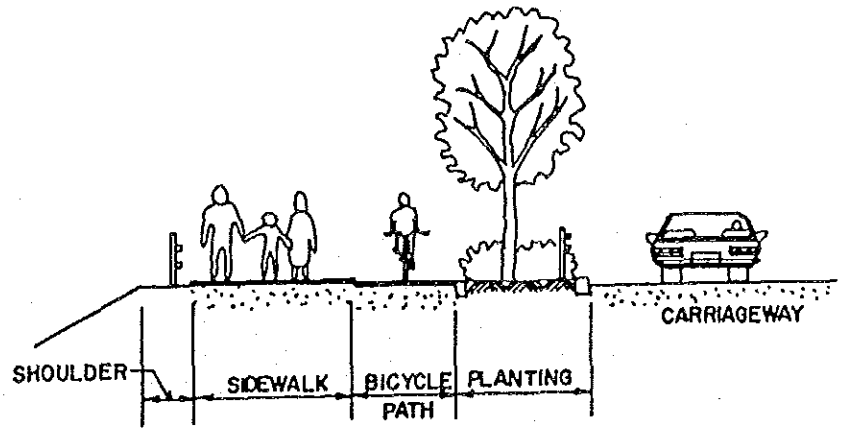
It may be considered rather dangerous if a pedestrian walking on a road is passed by motor vehicles every 30 seconds. When the speeds of vehicle and pedestrian are 60 km/hr. and 4 km/hr., respectively, above situation is created by traffic volume of 260 veh./hr., which corresponds to approximately 3,000 veh./day.



SIDEWALK



BICYCLE - PEDESTRIAN PATH



SIDEWALK PLUS BICYCLE PATH

Figure 7.1 Typical Types of Slow Traffic Path

On the part of a driver, every 15 seconds encounter with pedestrians may be hazardous. 35 persons per hour or 250 persons per day creates such condition.

When above two requirements on traffic volume are satisfied, sidewalk construction may be warranted. This warrant, however, should be applied only to rural roads because sidewalk in urban area should be considered not only from the traffic safety point of view but social requirements as well as city planning. Then, sidewalk construction in builtup areas could be justified at the lower level of traffic volume than rural area.

(3) Segregation of Bicycles

Bicycle volume, traffic volume and vehicle speed should be considered to determine the warrants to segregate bicycles traffic from motor vehicles.

Bicycle traffic often decreases the traffic capacity of road because of its slow speed and unstable riding. The degree of obstruction to the vehicular traffic caused by bicycle increases sharply as the traffic volume increases. It is known that a bicycle is equivalent to one passenger car from the standpoint of traffic capacity when the passenger car volume per hour is 200 to 250 on two-lane road. This volume corresponds to approximately 2,000 vehicles per day. This traffic volume could be a threshold as to vehicle volume. As being the case with the pedestrian, the situation in which vehicle passes bicycles every 30 seconds is assumed as dangerous. Such a situation is created by 120 bicycles per hour or 1,000 bicycles per day.

Even when the bicycle volume per day does not reach 1,000, if the vehicle speed is considerably high and it endangers cyclists, bicycle traffic shall be segregated at the lower volume such as about 500 bicycles per day.

(4) Separation of Pedestrians and Bicycles

The requirement to separate pedestrians and bicycles depends largely on the degree of friction between the two movements. When the total volume of pedestrians and bicycles exceeds 3,000 per day, it is expected that the conflicts between them leads to a confused and dangerous traffic flow. Then, this figure may be the threshold whether pedestrians and bicycles should be separated or not.

(5) Paving the Shoulders

Preceding sections have dealt with warranting conditions of the slow traffic paths. However, their constructions are costly, and it is necessary to consider low cost

alternatives. The simplest method is to draw clear edge lines on the carriageway and designate shoulders as sidewalks or bicycle paths. Installation of raised pavement markers along the edge line might make them clearer and safer. But when the shoulders are not paved, as is often the case with DOH roads, they ought to be paved. Paving the shoulders may make a safer condition not only for slow traffic but also for vehicle traffic.

7.2 ENGINEERING SPECIFICATIONS

7.2.1 Design Information

(1) Cross Section

Several typical cross sections of slow traffic paths are shown in Figure 7.2 for reference. Following discussions deal with three components of cross section, i.e., pathway width, shoulder and vertical clearance.

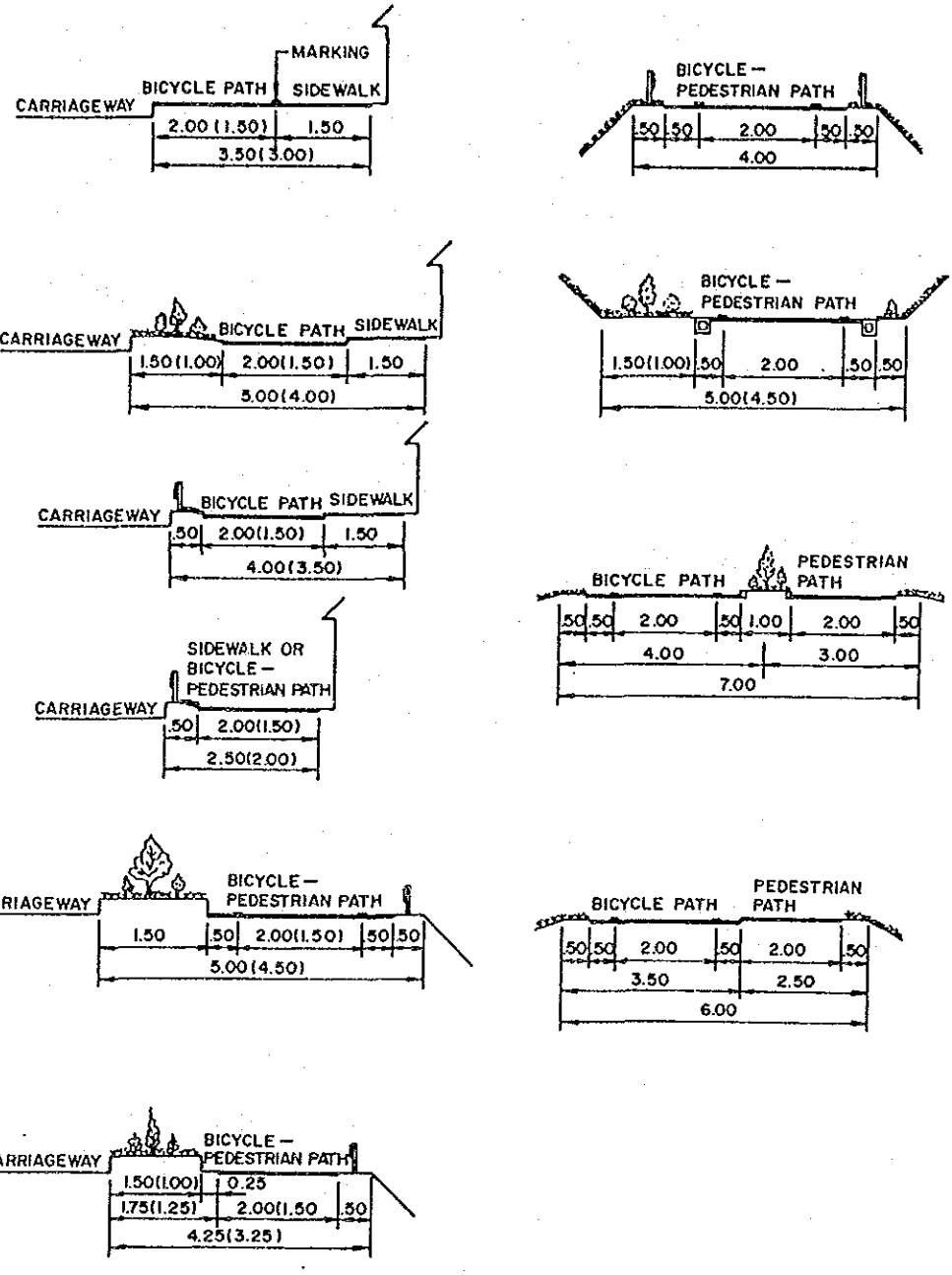


Figure 7.2 Typical Cross Sections of Slow Traffic Paths

a) Minimum Width of Pathway

Assuming the occupied width of a pedestrian is 0.6m, the unit width of a row of pedestrians (that may be called as a "lane") shall be 0.75m including marginal spaces (refer to Figure 7.3 as to the occupied width). Although the occupied width of a bicycle is the same as that of pedestrian, a unit "lane" width of bicycle requires 1.0m because of the unstable lateral positioning.

The width of pathway is to be determined by traffic volume as well as their moving patterns as illustrated in Figure 7.4. The minimum widths are summarized in Table 7.1.

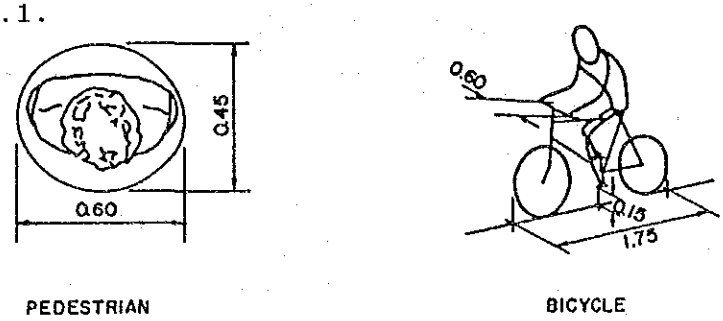


Figure 7.3 Dimensions of Pedestrian and Bicycle

Table 7.1 Minimum Width of Pathway

Unit : m

Slow Traffic Path / Road Class	Bicycle Path	Bicycle-Pedestrian Path	Sidewalk
Urban Road	2.0 (1.5)	3.5 (2.0)	3.0 (1.5)
Other Roads	2.0 (1.5)	2.0 (1.5)	1.5 (1.0)

Note : Reduced values in the parentheses shall be applied when (1) volume of slow traffics (pedestrian or bicycle) are relatively small, or (2) planned on bridge longer than 50m.

The width of a bicycle path should be determined taking the traffic capacity into consideration. "Traffic capacity of bicycle path" means a maximum bicycle volume of a lane which allows the cyclists to ride easily and comfortably. Table 7.2 shows the basic traffic capacity of the bicycle path, which was determined through the experiment and the observation. With this table and the bicycle volume, the width of a bicycle path can be determined; i.e., the bicycle volume less than 2,000 per hour requires 2 lane or width of 2m, 2,000 to 3,000 requires 3m, and more than 3,000 requires 4m wide pathway.

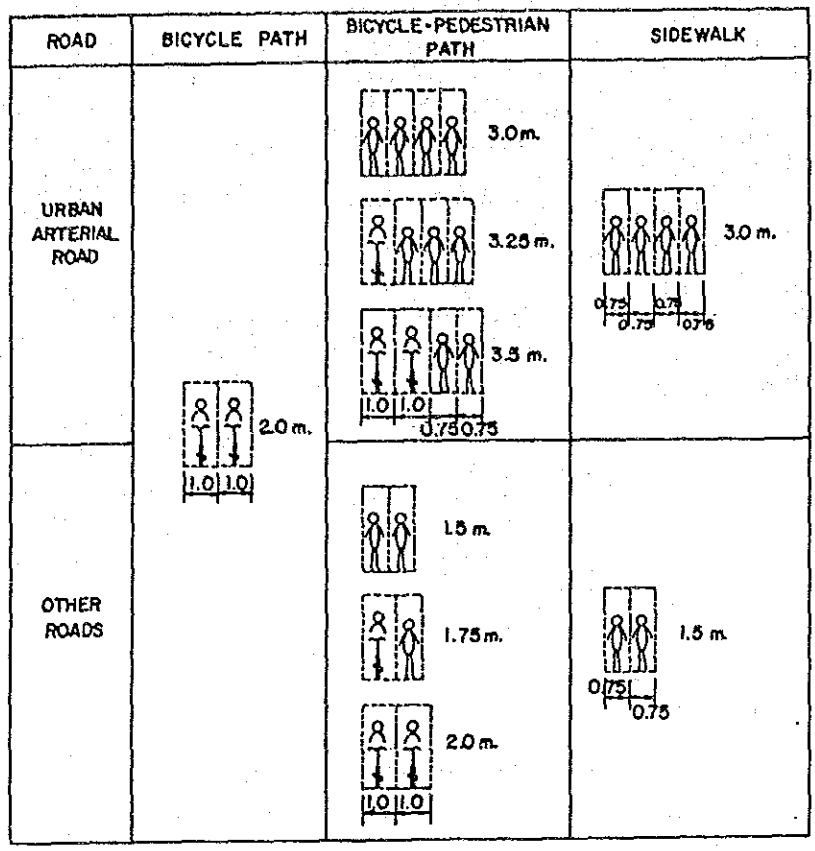


Figure 7.4 Minimum Width of Slow Traffic Paths

Table 7.2 Traffic Capacity of Exclusive Bicycle Path

Lane Number	Bicycle Per Hour
2	2,000
3	3,000

The traffic capacity of the bicycle-pedestrian path is, however, affected by pedestrian volume. The adjustment factor of the capacity for pedestrian volume mixture is assumed as 0.8 when the pedestrian volume is about 200 to 400 per hour. The traffic capacity of the bicycle-pedestrian path is indicated in Table 7.3, from which the width of the bicycle-pedestrian path is determined in the same way as the bicycle path.

Table 7.3 Traffic Capacity of Bicycle-Pedestrian Path

Lane Number	Bicycle Per Hour
2	1,600
3	2,400

As to the sidewalk, it is quite difficult to decide the capacity, because the pedestrian volume varies drastically, even in a five-minute measuring duration, and additionally, pedestrian traffic changes its feature according to the trip purpose, sex and age. Therefore, final decision should be made by concerned engineers, taking account of the characteristics of the pedestrian traffic as well as its volume.

b) Shoulder

Shoulder set out here has following multipurpose functions.

A. To protect the main structure of pathway from erosion.

B. To produce a space for the appurtenances. (e.g. guard fence or traffic sign)

C. To produce a space for planting.

D. To make a lateral clearance for the use of stopping or passing each other.

E. To improve the amenity for users.

Except for the space for planting, 0.5m wide shoulder is enough for respective purposes in most cases. Planting space may require 1.0 to 1.5m. It can be said, however, that the width may be reduced to 0.25m on bridges or on the sections under specific restrictions.

c) Vertical Clearance

The height of a cyclist or a pedestrian can be assumed less than 2.0m. Accordingly, vertical clearance of 2.5m for the bicycle(-pedestrian) path and the sidewalk is recommended.

(2) Separation Methods

There are varieties of measures to separate slow traffic from high speed traffic. They vary from the simple one of edge line marking to the complete one of raised path with a guard fence and planting. Typical measures of separation are exemplified in Figure 7.5.

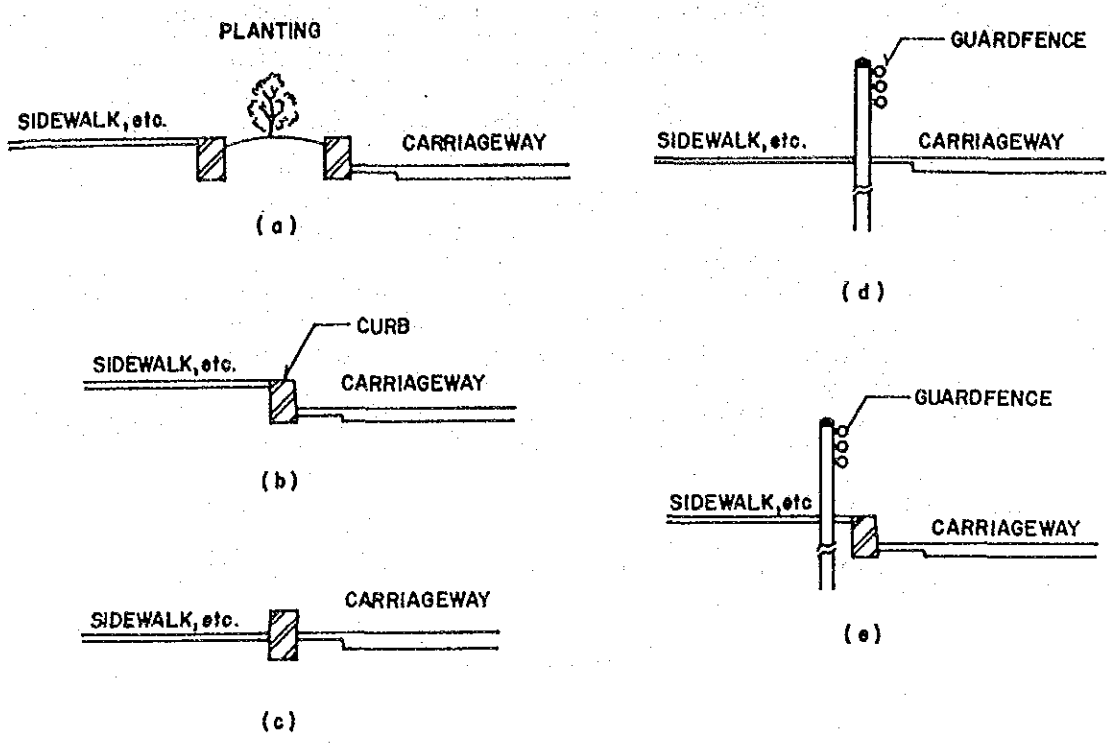


Figure 7.5 Various Methods of Slow Traffic Segregation

7.2.2 Pavement of Sidewalk

In principle, every sidewalk should be paved in order to provide a good walking surface for pedestrians as well as preventing dusts.

Several methods can be used for the pavement of sidewalks as shown below.

- Asphaltic concrete pavement
- Colored asphaltic concrete pavement
- Cement concrete pavement
- Block pavement
- Interlocking block pavement

For the selection of the paving method, due consideration should be paid to the desired environment of sidewalks. In urban and suburban areas especially, provision of a good walking environment becomes important in order to encourage people to walk longer distances and to prevent jaywalking on the carriageway. Hence, introduction of the interlocking block pavement, which can create a beautified walking environment, is desirable for sidewalks installed in some urban and suburban areas.

7.2.3 Treatment for Handicapped People

In parallel with the development of urban and suburban areas, the necessity of the special treatment on pedestrian facilities for handicapped people is gradually increasing, from the social welfare point of view. Hence, the following treatments might be required in areas where some handicapped people are thought to use pedestrian facilities.

(1) Guide Block for Blind People

The guide block for blind people aims to encourage blind people to identify walking location and direction during normal walking condition. This block has a protuberance on the surface, which can be identified by blind people on the sole of their foot. However, for the installation of this type of block, it is necessary that blind people have basic knowledge about roads and roadside conditions.

The guide block is classified into the following two types.

1) Groove type

Groove shape protuberances are attached on the surface and this is mainly used to guide blind people.

2) Dot type

Dot protuberances are attached on the surface and this is mainly used as a warning, advance warning and to get the attention of blind people.

Figure 7.6 shows an example of installation method of guide blocks.

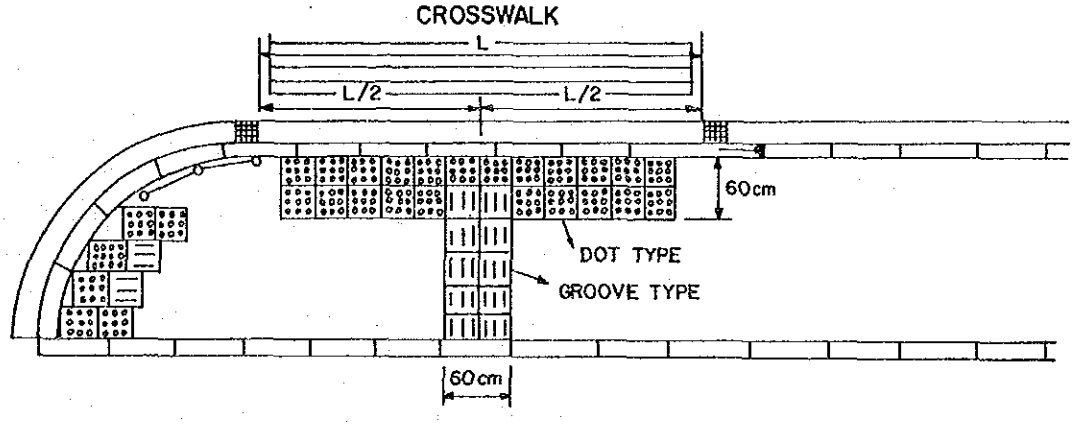


Figure 7.6 Installation Method of Guide Block

(2) Slope on Sidewalk

At the rounded corner or the crosswalk approach on a stepped sidewalk, handicapped people who have to use wheelchairs face a difficulty in maneuvering their wheelchairs due to the different level between the sidewalk and the carriageway.

Hence, it is desirable to provide slopes at the rounded corner or the crosswalk approach on a stepped sidewalk in areas where handicapped people on wheelchairs are supposed to use sidewalks. Typical design of this kind of slope on a sidewalk is shown in Figure 7.7. The standard grade of the slope should be 8%.

In addition, a combination of the slope and the guide block for blind people may also be necessary in certain areas.

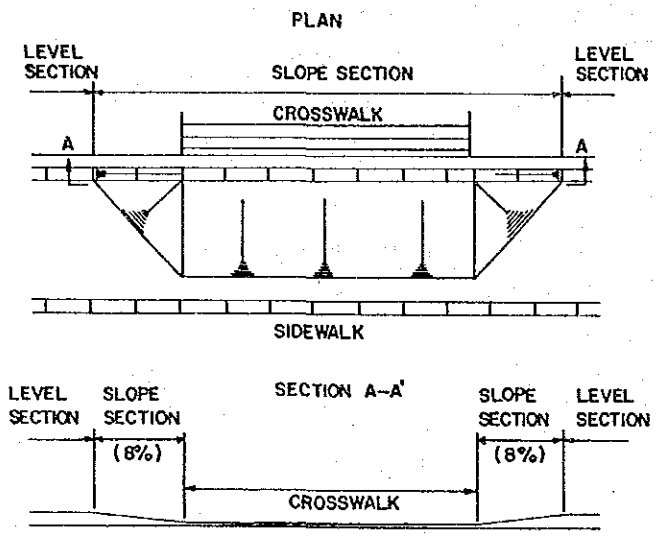


Figure 7.7 Provision of Slope on Sidewalk

7.2.4 Treatment of Bicycle Path at Intersection

Even though the bicycle traffic is segregated from the vehicular traffic by provision of a bicycle path, it is necessary to consider special treatments at an intersection, in order to avoid conflict between bicycles and vehicles. In this case, it is desirable to provide bicycle crossings parallel with crosswalks at intersections.

The concept of the treatment of bicycle path at intersections is summarized below.

A. To clearly show bicycle paths at intersections.

B. To avoid unnatural detours by bicycles.

C. To provide channelization markings for bicycles in order to guide bicycles approaching intersections away from the carriageway.

D. To separate intersecting corners from carriageway as much as possible. This treatment is necessary to avoid accidents between bicycles and left turn vehicles.

E. To clearly mark bicycle paths so that children can easily understand the bicycle path.

(1) Bicycle Path on Sidewalk

When the bicycle path is provided on sidewalks, the treatment at the intersection illustrated in Figures 7.8 and 7.9 are desirable to be employed.

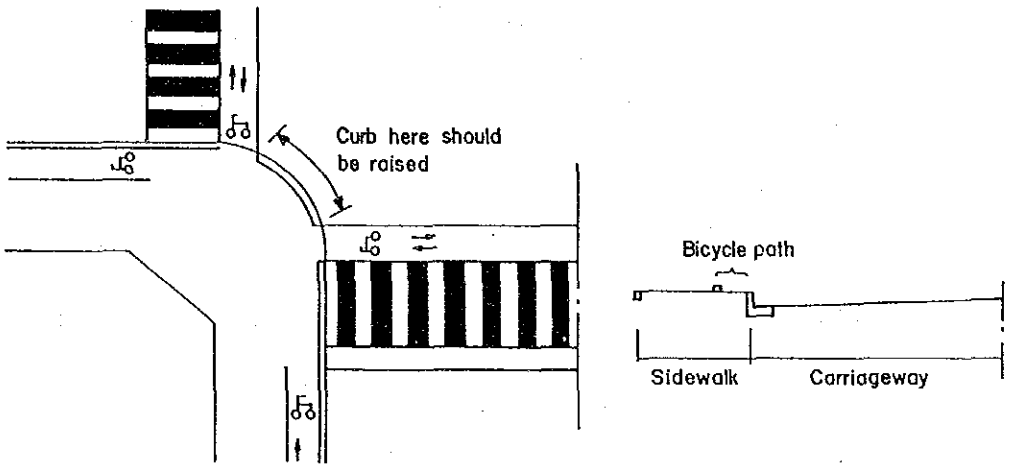


Figure 7.8 Treatment of Bicycle Path at Intersection (1)

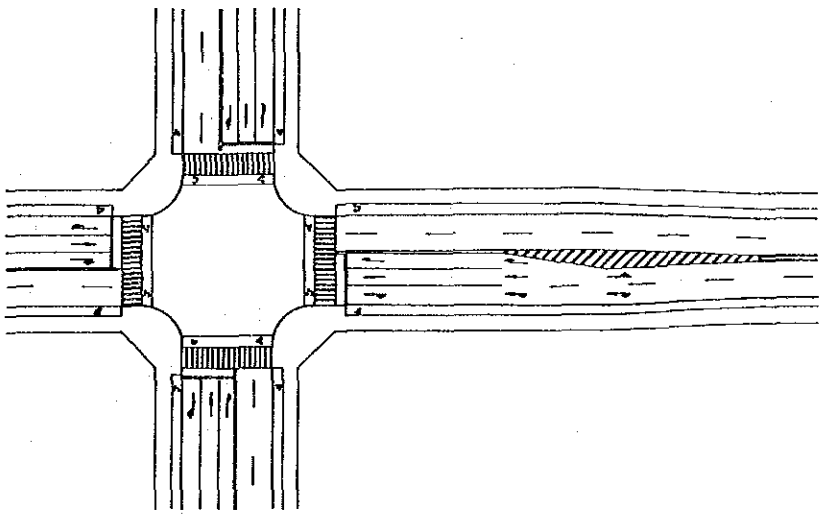


Figure 7.9 Treatment of Bicycle Path at Intersection (2)

(2) Bicycle Lane on Carriageway

When the bicycle lane is provided on the carriageway, it is desirable to shift it onto the sidewalk at large size intersections. The bicycle lane should be shifted near the transition section of the right turn lane, at least 15m from the stop line. (see Figure 7.10)

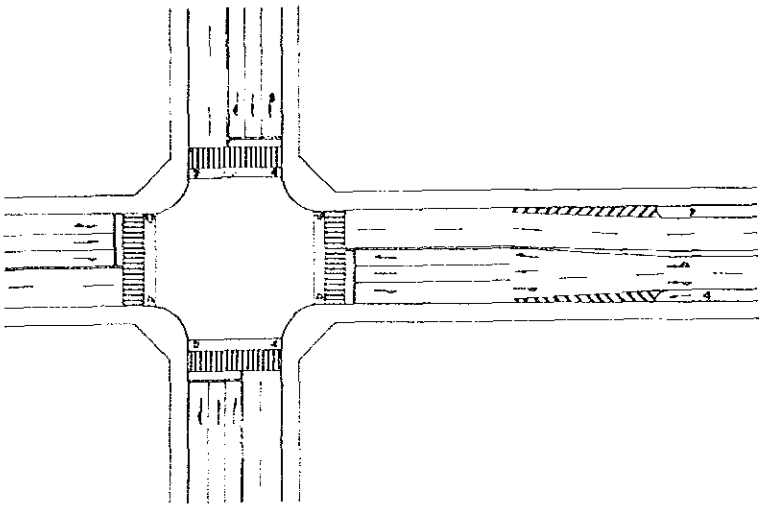


Figure 7.10 Treatment of Bicycle Lane at Intersection

CHAPTER 8 STREET LIGHTING

CHAPTER 8 STREET LIGHTING

8.1 TECHNICAL GUIDELINE

8.1.1 Summary of Warrants

1. Continuous Lighting

   Continuous lightings in urban area are warranted where:

   1) ADT is 25,000 vehicles or more.

   2) Adjacent areas have high illumination levels, which interferes with driver's visibility.

   3) Pedestrian volume at night is considerably heavy.

   4) Road sections shorter than 1 km which are located between two lighted sections.

   Continuous Lighting in rural area may not be warranted.

2. Specific Lighting

   Specific lightings are warranted in principle at:

   1) Intersections where traffic signals are warranted and installed.

   2) Crosswalks where pedestrian signals are warranted and installed.

   3) Long bridges.

   4) Sections where the ratio of night to day accident rate is more than 2.0.

   Specific lightings may be installed at the following locations, if it is necessary.

   1) Unsignalized intersections.

   2) Unsignalized crosswalks.

   3) Road sections where the cross section abruptly changes.

   4) Sharp bend or steep gradient.

   5) Railway crossings.

   6) Toll plaza and its approaches.

   7) Bus stops.

8) Access roads to a public facility such as a station plaza.

9) Other road sections where the installation of a specific lightings are desirable.

8.1.2 Function of Lighting and Visual Information

Nighttime brings increased hazardous to road users through limited visibility. Night driving is considerably more hazrdous than day driving. The main puropose of street lighting is to assure safe driving at nighttime providing increased visibility so that drivers can perceive the following important information as clear as in the daytime.

A. Positional information

Required for steering and speed control

B. Situational information

Required for changes in speed, direction and lateral positions.

C. Navigational information

Required for selecting a route to a destination.

Table 8.1 indictes the major elements required for the safe nighttime driving. Elements in this table should be taken into account for planning of lighting systems.

Table 8.1 Major Elements of the Nighttime Visual Improvment

Kind of Information	Elements
Positional Information	Geometry, Channelization, Lane Markings, Roadside and Roadside objects, Curbs, Vehicles, Pavement edge, Delineation
Situational Information	Geometry, Intersection, Channelization, Lane Markings, Roadside and Roadside objects, Curbs, Pedestrians, Vehicles, Signs, Signals, Delineation, Road objects, Road condition
Navigational	Intersection, Roadside and Roaside objects, Guide Signs

In order to give sufficient visual information to the drivers at night, street lightings should be designed properly in terms of brightness, uniformity of light, glare and so forth. However, it would not be appropri-

ate to furnish street lightings to the whole road network of DOH, because installation and operation of lightings are costly. Therefore, an effective street lighting system should be planned prior to the installation of any lighting unit. The word "effective" used here has two facets as noted below.

A. Superiority over other alternative measures such as delineators, pavement makings, guard gences, etc.

b. Efficient lighting design comprising selection of light source, placement and height of luminaires, glare control and some other important elements.

The requirements for street lighting installation vary with sites according to viaual information elements specifically needed. For example, a certain road sections may need clear road geometry among others, while another sections may require to light up pedestrians. Some of these sections may be substituted by other saftey devices with lower costs than street lightings. Table 8.2 presents possible alternative safety devices which may substitute lightings and should be discussed in advance of the determination of lighting installtion. Installtion should be limited to sections where other safety devices prove to be ineffective.

Table 8.2 Alternative Countermeaures to Street Lighting

Elements	Alternative Countermeasure
Road geometry	- Delineators - Reflective raised pavement markers on center line - Longitudinal markings (edge line, center line)
Intersection channelization	- Flashing beacon - Intersection identification marker for small intersection - Stop control (signs, markings) - Speed control - Channelization by markings - Reflective curb markers - Reflective markers along chevron markings
Roadside objects	- Guard fence with delineators - Object markings - Clearance of roadside objects
Pedestrians	- Guard fence with delineators - Spot lighting of crosswalk
Alignment change	- Guard fence with delineators - Pavement markings and signs - Reflective raised pavement markers

8.1.3 Warranting Conditions

As remarked in the preceding section, determination whether street lighting should be provided or not is to be made through extensive studies. The general principles for lighting instalation are that priority should be placed (1) where a study indicates that street lightings are expected to remarkably improve the nightime safety, or (2) where there are many road users who get benefits from street lightings.

There are two types of installation for street lightings, i.e., the continuous lighting and the specific lighting. When luminaires are placed successively along a certain length of mid-block section, usually more than 0.5 km, such an illumination method is called "continuous lighting". On the other hand, "specific lighting" is a general term for the lighting for specific sites such as intersection, brige, toll plaza, etc.

(1) Continuous Lighting

Continuous street lightings in urban area are generally approved for creation of better enviroments and crime prevention. However, since street lightings of DOH roads are mainly oriented to traffic safety, continuous lightings in urbanized area should be confined to cases where a certain traffic or geometric requirments are met.

Benefits from reduction of accidents are deemed to increase proportionall to traffic volume. A road with more than 25,000 daily traffic volume is expected to yield enough benefit from continuous lightings. But even when continuous lightings where there are considerably heavy pedestrian tvolume at night and are assumed to create dangerous situations.

(2) Specific Lighting

Intersections generally create complicated traffic flows that produce very hazardous spaces for road users. Crosswalks are also dangerous spots where pedestrians and vehicles frequently meet. Therefore, intersections and crosswalks need to be clearly seen by drivers at points with enough distance to assure proper response of drivers.

Warrants of traffic signals (including pedestrian signal) require certain amounts of traffic volume for installation of them. Accordingly, street lightings at intersections and crosswalks where traffic signals are warranted and installed are expected to bring enough economic benefits. On the other hand, specific lightings may be installed at unsignalized intersections and

crosswalks, if it is necessary.

In addition, long bridges should also be illuminated.

Besides above, road sections where the ratio of night to day accident rate is more than 2.0, are generally regarded as seriously dangerous at night an need for lighting.

At nightime, visual information on road alignment and geometry are essential for safe driving. Road sections where alignment or geometry of road change abrupty, may be considered to be illuminated, if it is necessary. Such sections include:

A. Road sections where the cross section abruptly changes.

B. Sharp bend or steep gradient.

C. Railway crossings.

D. Toll plaza and its approaches.

E. Bus stops.

F. Access roads to a public facility such as a station plaza.

G. Other road sections where the installation of a specific lightings are desirable.

In the preceding paragraphs, typical locations which should be lighted are discussed. However, whether a location shall be illuminated or not is, in principle, a matter of engineer's judgement. This leads to a conclusion that sections where a study indicates that street lightings are expected to significantly reduce the nighttime accidents should be warranted.

8.1.4 Desing of Street Lighting

(1) Summary of Design Factor for Street Lighting

1. Average Road Surface Luminance

Table 8.3 Recommended Average Road Surface Luminance

Unit : cd/m²

Road Class \ Roadside Condition	A	B	C
Expressway	1.0	1.0	0.7
Major Trunk Roads	1.0 (0.7)	0.7 (0.5)	0.5 (-)
Major Roads Minor Roads	0.7 (0.5)	0.5 (-)	0.5 (-)

Note : Values in parenthese are applied to roads where median is furnished with glare screen.

2. Light Distribution Type

Table 8.4 Selection of Light Distribution Type

Road Class \ Roadside Condition	A	B	C
Major Trunk Roads	Semi-cut-off	Cut-off	Cut-off
Major Roads Minor Roads	Semi-cut-off	Semi-cut-off	Cut-off

(2) Road and Area Classification

Lighting facilities should be designed taking account of the road class and brightness of surrounding area.

Roads discussed in this section are classified into three categories as follows.

A. Major trunk road

The part of road system which serves as the most principal network mostly for through traffic flow.

B. Major road

The part of road system which serves as the principal network mostly for through traffic flow and supplements the network of major trunk roads.

C. Minor road

The part of road system which serves traffic between major trunk roads or major roads and access roads.

Since this classification is derived from the functional characteristics of road system, it does not directly correspond to DOH road categories. In principle, each road should be classified according to its function. However, following relations may exist between this classifiction and DOH roads if a rough grasp is allowed.

A. Primary national higways which have one- or two-digit route number may correspond to major trunk roads.

B. Secondary national highways which have three-digit route number may correspond to major roads.

C. Provincial highways which have four-digit route number may correspond to the minor roads.

Besides, condition of roadside area shall be classified according to the degree of glare as follows.

A. Rosdside Condition A

Vehicle traffic is continuously affected by roadside illumination.

B. Roaside Condition B

Vehicle traffic is intermittently affected by roadside illumination.

C. Roadside Condition C

Vehicle traffic is scarcely affected by roadside illumination.

(3) Quality of Street Lighting

There are following four fundamentals which influence the quality of highway lighting.

a) Average Road Surface Luminance

Contrast is one of the most important contributors to nighttime visual performance. The recognition of objects is mainly based upon discernment of brightness (luminance) difference between an object and its background.

For night conditions, an obstacle may appear as a dark area against bright background (silhouette) or it may appear as a bright area against a dark background (reverse silhouette). Figure 8.1 shows the relationship between object visibility and brightness. Illumination is essential to enhance the discernment by silhouette.

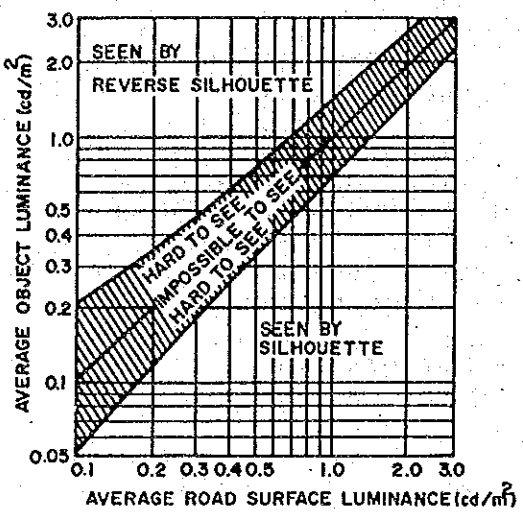


Figure 8.1 Relation Between Visibility and Brightness

Specification of street lighting of DOH has criteria as to average road surface illumination requirements that are shown in Table 8.5. Values of illumination are converted to those of luminance and indicated in parentheses.

Table 8.5 Current Average Illumination (Luminance) Requirements

Unit : lm/m^2 (cd/m^2)

	Urban Areas	Suburban Areas	Rural Areas
High Grade Motorway	21.5 (1.43)	15.0 (1.00)	10.75 (0.72)
At Junctions	21.5 (1.43)	21.5 (1.43)	15.00 (1.00)
Main Routes	21.5 (1.43)	13.0 (0.87)	9.70 (0.65)
Secondary Routes	13.0 (0.87)	9.7 (0.65)	6.50 (0.43)
Local Roads	9.7 (0.65)	6.5 (0.43)	2.10 (0.14)

Note : Conversion from illumination to luminance is done assuming that pavement is asphaltic concrete. ($15\ lm/m^2 = 1\ cd/m^2$)

Generally it is desirable street lighting design be carried out with reference luminance based on a visibility of vehicle drivers. Even though the reference luminance differs by pavement type, it is known that the

relation between reference luminance and average illuminance is relatively simple. Based on practices in Japan, conversion factors between reference luminance and average illuminance is set as shown in Table 8.6

Table 8.6 Conversion Factors between Reference Luminance and Average Illuminance

Type of Pavement	Reference Luminance (cd/m^2)	Average Illuminance (lx)
Asphalt Concrete	1.0	15
Cement Concrete	1.0	10

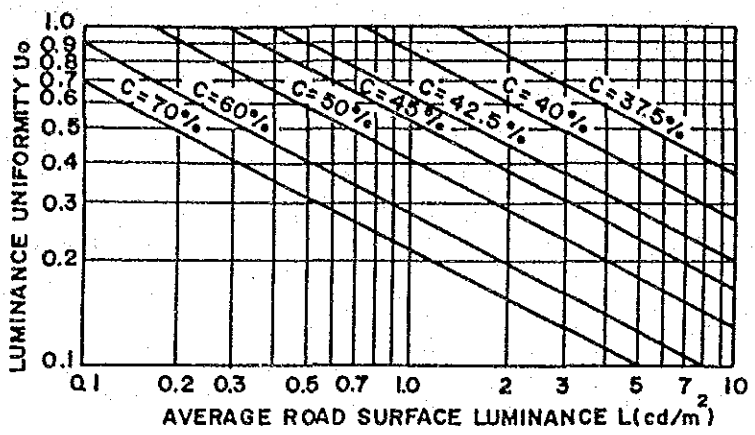
According to the researches and experiments conducted in Japan, the minimum requirement of average road surface luminance (reference luminance) is 1 cd/m^2 when the luminance uniformity is kept to 0.4, while CIE (The International Commission of Illumination) has recommended 2 cd/m^2. DOH specification requires about 1.4 cd/m^2 for "main routes", which is a medial value of Japan and CIE. However, considering the high cost and expenses required for lighting facilities, 1 cd/m^2 is recommended as the reference luminance. Moreover, Japan has lots of practices with the reference luminance of 1 cd/m^2 which proved to be enough for street ligting.

Table 8.3 indicates the recommended reference luminances according to the road classification and roadside condition, where the reference luminance is reduced to 0.5 cd/m^2 which is presumed to be the absolute minimum value to *maintain the minimum visibility*.

b) Luminance Uniformity

Uniformity of luminance is required to provied visibility and visual comfort to the driver. Recognition of obstacles are easy in the area with higher luminance, while it is difficult in the area with lower luminance. Difficulty is derived not only from lower luminance but from the deterioration of visual acuity caused by the light dispersion in the driver's eyes, when the uniformity of brightness is not maintained.

Uniformity ratio is generally expressed as L_{min}/L, where L_{min} is the minimum local luminance and L is the average luminance of the whole carriageway. Relationship between object visibilty and luminance uniformity is shown in Figure 8.2, indicating a great influence of luminance uniformity. It is generally approved tha uniformity ratio of 0.4 is proper for the minimum criterion. Appropriate uniformity of road surface luminance is attained by proper placement of luminaires.



NOTE: C IS "LUMINANCE RATIO", DEFINED AS FOLLOWING:

$$\frac{\text{OBJECT LUMINANCE}}{\text{AVERAGE ROAD SURFACE LUMINANCE}} \times 100\ (\%)$$

Figure 8.2 Thresholds of Object Recognition with Regard to Road Surface Luminance Luminance Uniformity

c) Glare

There are two kinds of glare; discomfort glare and disability glare. Discomfort glare gives the psychological sense of discomfort, while disability glare induces the deterioration of physiological faculty of sight, inducing the light dispersion in eyes which becomes "noise" in sight information. Since enough limitation of discomfort glare can minimize the influence of disability glare, consideration can be concentrated on discomfort glare.

Distribution of glare is affected by mounting height and number of luminaires as well as by the type of lighting apparatus, including cut-off, semi-cut-off and non-cut-off. Cut-off type is suitable for principal road for which limited glare is needed because glare is controlled restrictively for this type. Semi-cut-off type is appropriate for the road where surroundings are comparatively bright, because the light distribution is not so limited as the cut-off type. Non-cut-off type is not generally suitable for street lightings. Table 8.4 is prepared for selection of the light distribution type.

d) Visual Guidance

Drivers need to perceive or know beforehand the information about the change of road alignment and geometry. Longitudinal lane markings and post delineators can give, of course, such information. Appropriately ar-

ranged lighting facilities also produce an outstanding visual guidance, while street lightings arranged improperly many mislead the drivers. Effective placement method of luminaires shall be discussed later.

(4) Street Lighting Design

a) Light Source

Selection of light source should be done taking various aspects into account, i.e., efficacy, lamp life, stability to temperature, color rendering, etc. Following lamps are generally utilized for street lighting purpose.

A. High-pressure sodium lamp.

B. Low-pressure sodium lamp.

C. Mercury vapor fluorescent lamp.

D. Metal halide lamp.

E. Fluorescent lamp.

Characteristics of these lamps are summarized in Table 8.7. Considering the features of each lamp, Table 8.8 is prepared for selection of light source.

In the DOH road network, a lot of lighting facilities seem to be provided to important road sections such as intersections or other hazardous locations. The light source is, in most cases, the low-pressure sodium lamp, which projects orange color light. This color is, however, very similar to that of flashing signal or "yellow" of traffic signal.

Adoption of the low-pressure sodium lamp has advantages of relatively high efficacy and accordingly low operation cost, but also has disadvantages such as lack of color rendition and relatively short lamp life. On the other hand, the high-pressure sodium lamp is characterized by improved color rendering, long lamp life and high efficacy. Therefore, introduction of high-pressure sodium lamp seems to be reasonable.

Table 8.7 Characteristics of Typical Light Sources

Item \ Lamp	High-Pressure Sodium	Low-Pressure Sodium	Mercury Vapor Fluorescent	Metal Halide	Fluorescent
Wattage (W)	220	35	400	400	40
Luminous Flux (lm)*	40,000	4,600	21,000	30,000	3,000
Efficacy(lm/W)	87	78	47	65	55
Lamp Life (hr)	12,000	9,000	12,000	9,000	10,000
Light Color	Hazy Orange	Orange	White	White	White
Color Rendering	Average	Bad	Good	Good	Good
Dimming	Possible	Impossible	Possible	Impossible	Possible
Minimum Temperature for Usage (°C)	-20	-20	-5	-5	5
Maximum Starting Time	8	20	8	8	Negligible
Maximum Re-Starting Time	3	Negligible	10	15	Negligible

*Standard value use for design computation of roadway lighting.

Table 8.8 Suitability of Lamps

Road \ Lamp	High-Pressure Sodium	Low-Pressure Sodium	Mercury Vapor Fluorescent	Metal Halide	Fluorescent
Expressway	◎	◎	○		
Inter-City Road	◎	○	○		
Urban Road	◎		◎	○	
Commercial street			◎	○	◎
Road in Residential Area			◎		○

Legend; ◎ : Recommended ○ : Suitable

b) Arrangement of Luminaires

The position of luminaire is determined by mounting height, overhang, inclination angle and placement type. Figure 8.3 shall be referred to for the explanation below.

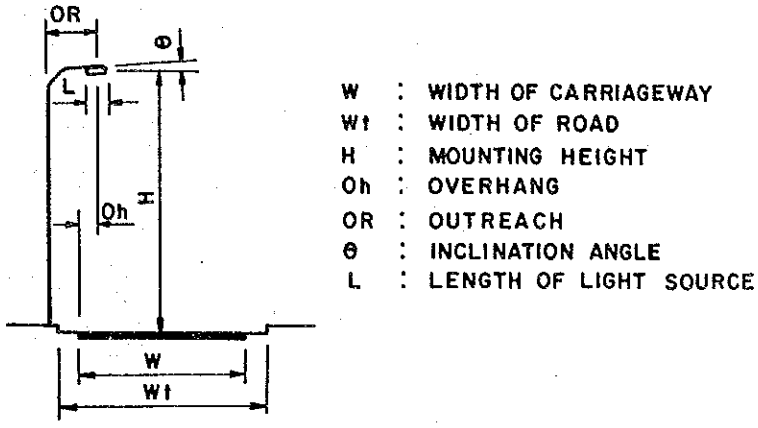


Figure 8.3 Basic Dimensions of Luminaire

1) Mounting height of luminaire

Generally speaking, the higher the luminaire is, the weaker the glare comes out. Also, higher luminaire gives the improved uniformity of luminance, while total construction cost increases. Mounting height of 10 to 15m is generally regarded as economical.

2) Overhang

Larger inclination angle can improve the brightness and luminance uniformity to some extent, but more than that, it increases the discomfort glare. Generally, less than 5 degree is adopted.

3) Placement of luminaire

Basic types of placement comprise one-side placement, staggered placement, opposite placement and median placement, which are illustrated in Figure 8.4.

When the continuous lighting system is planned at a curve section, visual guidance effect of luminaires should be considered. As to the type of placement, staggered placement is not adequate. On the contrary, application of one-side placement to the outer edge of the curve is generally recommended because of its good visual guidance effect. Comparison of perspectives from the driver's eyes is shown in Figure 8.5.

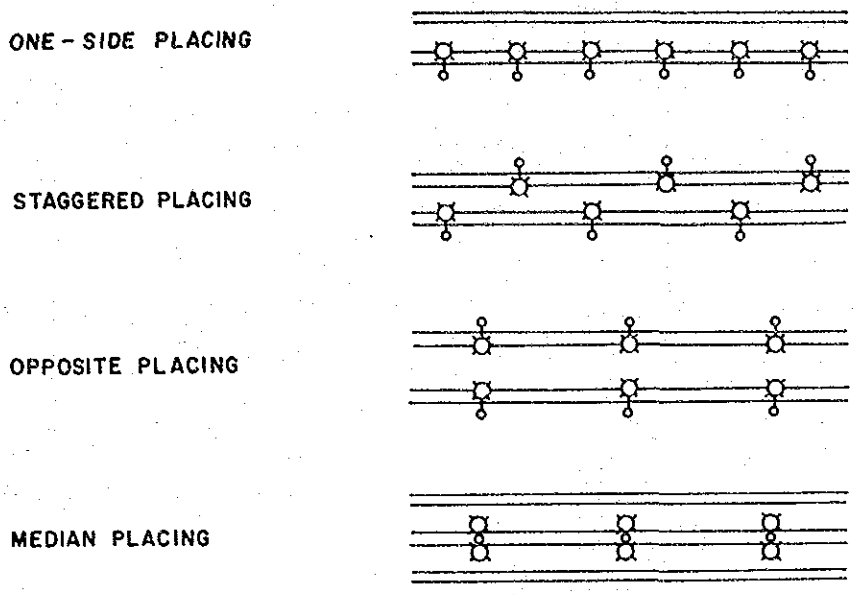
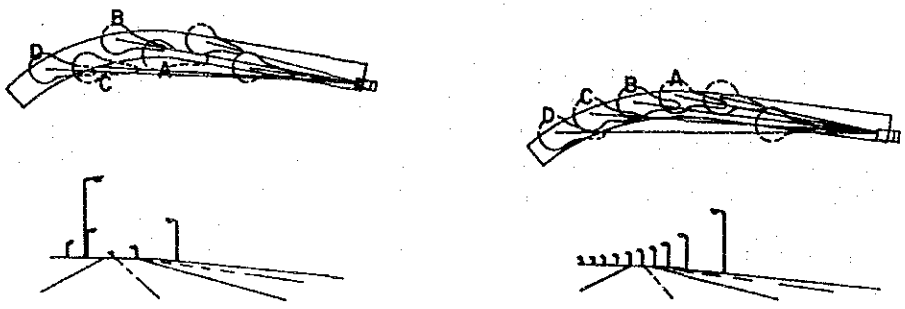


Figure 8.4 Typical Luminaire Placing Arrangements



(a) STAGGERED PLACING AT A CURVE (b) ONE-SIDE PLACING AT A CURVE

Figure 8.5 Lighting Placing at a Curve

c) Design Criteria for Luminaire Positioning

Mounting height, overhang and inclination angle of luminaire shall be conformed to Table 8.9.

Practical mounting height and spacing of luminaire are determined by carriageway width, type of luminaire placement and type of light distribtion. These can be obtained from Table 8.10.

As for the luminaire spacing along the outer edge of the curve, the criteria specified in Table 8.11 shall also be satisfied.

Table 8.9 Mounting Height, Overhang and Inclination Angle of Luminaire

Luminous Flux of a Light Source (lm)	Mounting Height(m) H	Overhang (m) Oh	Inclination Angle (deg.) θ
Less than 15,000	8 or more	$-1 \leqq Oh \leqq 1$ (lamp length < 0.6m) $-1.5 \leqq Oh \leqq 1.5$ (lamp length $\geqq 0.6$m)	5 or less
15,000 ~ 30,000	10 or more		
30,000 or more	12 or more		

Table 8.10 Mounting Height and Spacing of Luminaire

Light Distribution / Height and spacing / Type of placement	Cut-Off		semi-cut-off	
	Mounting Height(m) H	Spacing (m) S	Mounting Height(m) H	Spacing (m) S
One-Side Placement	$\geqq 1.0W$	$\leqq 3.0H$	$\geqq 1.1W$	$\leqq 3.5H$
Medium Placement	$\geqq 1.5W$	$\leqq 3.5H$	$\geqq 1.7W$	$\leqq 4.0H$
Staggered Placement	$\geqq 0.7W$	$\leqq 3.0H$	$\geqq 0.8W$	$\leqq 3.5H$
Opposite Placement	$\geqq 0.5W$	$\leqq 3.0H$	$\geqq 0.6W$	$\leqq 3.5H$
	$\geqq 0.7W$	$\leqq 3.5H$	$\geqq 0.8W$	$\leqq 4.0H$

Note; W is width of carriageway.

Table 8.11 Spacing of Luminaires along Outer Edge of Curve

Curve Radius (m) / Mounting Height	300 or more	250 to 300	200 to 250	Less than 200
No more than 12m	35 or less	30 or less	25 or less	20 or less
More than 12m	40 or less	35 or less	30 or less	25 or less

d) Design Method of Street Lighting

For the design of continuous lightings, it is possible to calculate a desirable spacing of luminous flux using the following formula.

$$\frac{F}{S} = \frac{W \times K \times L}{N \times U \times M}$$

where;
F : Luminous flux (lm)
S : Spacing of luminaire (m)
W : Carriageway width (m)
K : Conversion factor of illuminance to luminance (lx/cd/m²)
L : Reference luminance (cd/m²)
N : Coefficient by the type of placing
One side or staggered placement -- N = 1
Opposite placement ---------- N = 2
U : Utilization factor
M : Maintenance factor

The utilization factor can be obtained from the Figure 8.6. In this figure, the horizontal axis is the ratio of carriageway width and mounting height of luminaire.

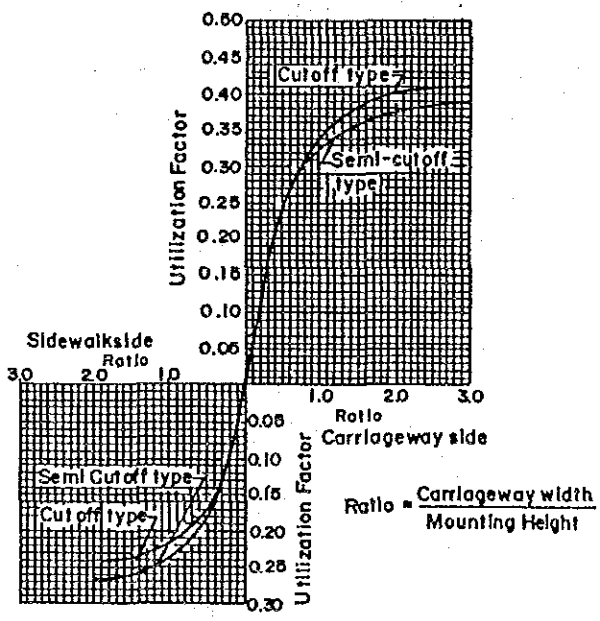


Figure 8.6 Relation Between Utilization Factor and Ratio of Carriageway Width and Mounting Height of Luminaire

The maintenance factor is the diminution rate of reference luminance due to the decline of luminous flux capacity and contamination on luminaires. For the continuous lightings, 0.65 - 0.75 is used as the maintenance factor depending on traffic condition, road condition. etc.

(5) Arrangement of Luminaires for Specific Lighting

a) Inersection

Luminaires at intersection should be placed so that the driver approaching to the intersection can easily recognize the vehicles and pedestrians in and near the intersection, and besides, the existence of the intersection can draw an attention of the driver from a distance.

Figure 8.7 shows examples of luminaire arrangement at a T-junction and a 4-leg intersection. The luminaire placements in this figure are determined so as to illuminate the turning vehicles clearly in particular.

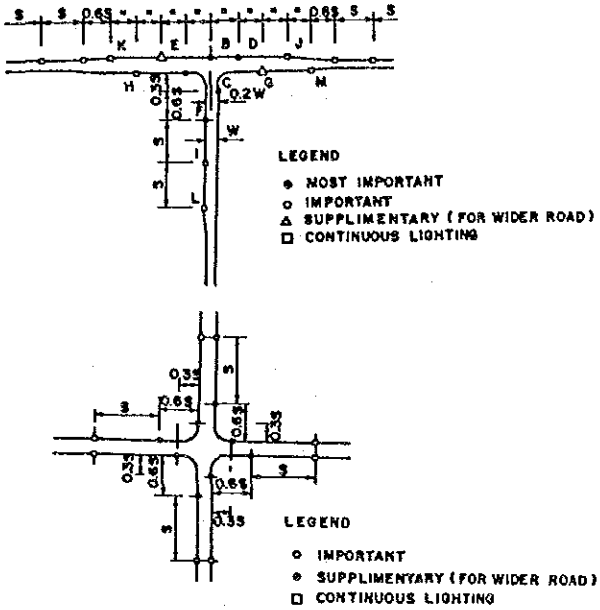


Figure 8.7 Typical Luminaire Arrangement (Intersections)

When the road has a median, two kinds of typical luminaire arrangement can be considered, as shown in Figure 8.8. If continuous lightings are furnished along the median, opposite placing of luminaires at the intersection is recommended because such an arrengement gives the approaching drivers an information of the existence of an intersection.

On the contrary, if continuous lightings are furnished along both sides of carriageway, the median placing at an intersection is recommended.

b) Crosswalk

Lighting at crosswalks should be furnished so that the pedestrians are clearly lighted up. To assure the safety of pedestrians, they must be recognized by driv-

ers from a distance of minimum 50m, and this can be realized by illuminating the 35m zone ahead from the crosswalk. In addition, to lighten the crosswalk itself is not considered effective because the silhouette effect is impaired, unless the crosswalk is directory illuminated. Figure 8.9 shows the typical arrangement of luminaires for the crosswalk lighting.

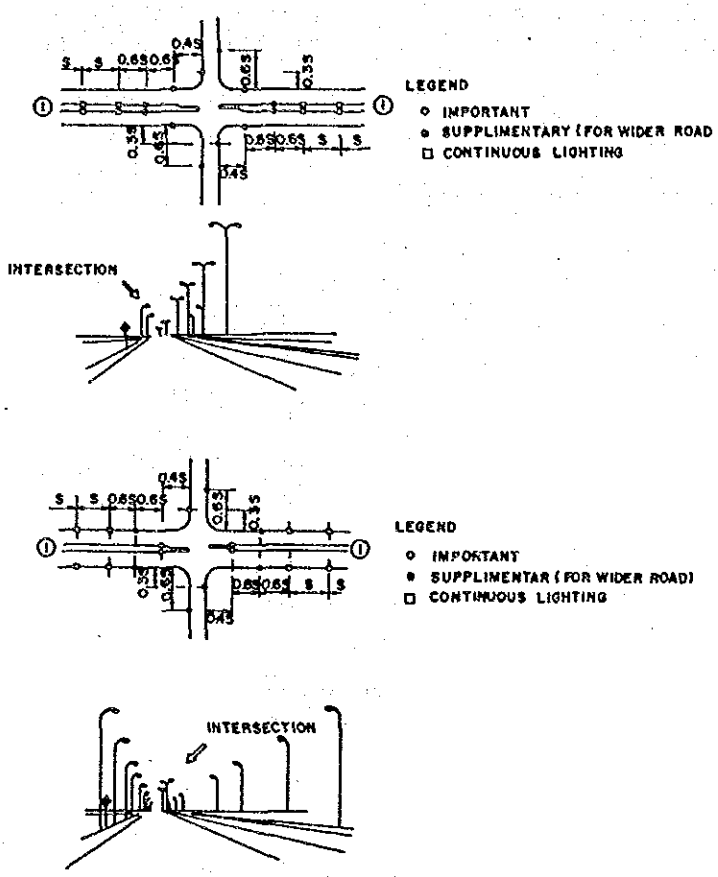


Figure 8.8 Typical Luninaire Arrangements (Indication of Intersection)

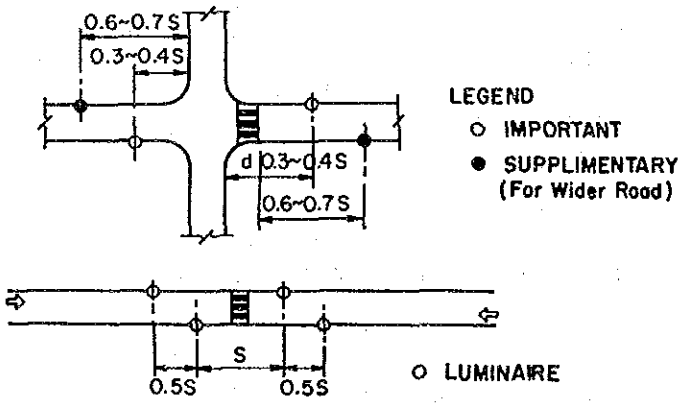


Figure 8.9 Typical Luminaire Arrangement (Crosswalk)

c) Pavement Width Transition

Specific lightings at pavement width reduction are exemplified in Figure 8.10. Identification of such a hazard is to be made easily.

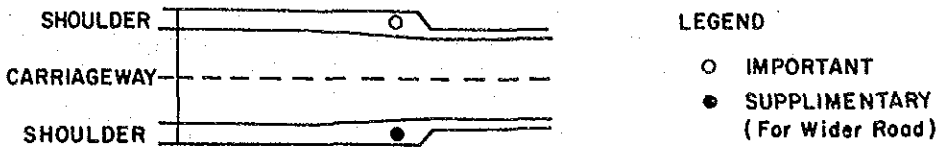


Figure 8.10 Typical Luminaire Arrangement (Width Transition)

d) Other Places

Specific lightings at a curve are explained in preceding paragraph. Lightings for other places such as bridge, gradient, toll plaza, rest area, etc. can also be correspondingly applied in the same manners as discussed above.

8.2 ENGINEERING SPECIFICATION

8.2.1 Lighting Apparatus

1. Performance

   1) The lighting apparatus should have good light distribution characteristics able to achieve high coefficient of utilization with limited glare.

   2) The lighting apparatus should contain the necessary electrical, mechanical, water proof and anti-corrosive efficiencies, in order to achieve a satisfactory working order over a long period.

2. Mechanism

   1) The mechanism of the lighting apparatus should permit easy inspection. In addition, beautification of lighting apparatus should also be considered in the same way as road apparatus.

   2) The joint connecting the lighting apparatus with lighting poles or other road apparatus should have adequate strength. However, the works required to attach the lighting apparatus should be simple.

3. Material

   Materials used for the lighting apparatus should be of good quality, with long durability and efficiency against anti-corrosion and anti-deterioration.

(1) Performance

A. The most important performance required for the lighting apparatus is the light distribution characteristics, which greatly affects the quality of street lightings and economics. In addition, provision of the cut-off or the semi-cut-off types lighting apparatus are effective in minimizing glare.

B. Lighting apparatus with high efficiency should desirably used. The efficiencies of equipments differ according to the reflection ratio of the reflector, and the transmittance and the shape of the cover of the lighting apparatus. Hence, it is necessary to select the lighting apparatus with good light distribution characteristics as well as high efficiency.

C. It is essential that the resistance and durability for the insulation of the lighting apparatus should be satisfactory over a long period.

D. Mechanical efficiency against vibrations and shocks under ordinary conditions are required of the lighting apparatus in order to avoid loosening and damage to equipment, including lamps.

E. Since the lighting apparatus experiences bad weather, such as rain and strong gusts, adequate waterproof efficiency is necessary.

F. The lighting apparatus often faces corrosive circumstances, such as vehicle exhausts, sulfurous acid gas in industrial areas and the salt particles in coastal areas. In order to use the lighting apparatus for a long period, adequate anti-corrosive efficiency is required to prevent reduction of optical, electrical and mechanical efficiency as mentioned above.

G. The lighting apparatus experiences heat effects caused by sunshine as well as heat generated during the lighting period. In order to prevent deformation and deterioration in the performance of equipment, and deteriorations of insulation capability caused by the temperature increase inside equipment, heatproof efficiency is also required.

(2) Mechanism

A. The lighting apparatus consists of the reflector, the cover of the luminaire, the mechanism to open/close the cover, the socket to install a lamp, the connector for electric cable connection and the main frame. Some types of the lighting apparatus also contain a stabilizer. Any part of the lighting apparatus should not be detached from the main component by opening of the cover. Also, waterproof packing material should be put at the joint surface of the main component and the cover.

B. Since most of the installation work of the lighting apparatus should be carried out above ground level, the attachment procedure of the lighting apparatus is desirably should be easy, but also possess adequate strength. The lighting apparatus used for the lighting pole should have a mechanism to insert a part of the equipment into a lighting pole in order to prevent the fall off and the distortion.

(3) Material

A. Aluminum plate of high quality is used for the reflector and special treatment is carried out on the surface in order to obtain a high reflection ratio.

B. Clear glass or formed plastic with good transmittance is used for the cover. In order to increase

the light distribution characteristics, the inside of the cover has a as prism shape, if this is required.

C. The sponge made from the chloroprene rubber is widely used as the waterproof packing material.

D. An aluminum alloy die cast product is usually used for the frame of the lighting apparatus. When the steel plate product is used for the frame, the zinc coating or anti-corrosive painting is required in order to prevent corrosion and maintain the appearance.

8.2.2 Lighting Pole

1. Structure

1) The lighting pole should hold the lighting apparatus properly in order to fully maintain the efficiency of the lighting apparatus. Hence the shape and the structure of the lighting pole should satisfy this condition. In addition, due consideration should also be paid to the economics and the appearance in accordance with the illumination distribution.

2) The lighting pole should have adequate strength against external forces to both the lighting apparatus as well as the lighting pole.

3) The structure of the lighting pole should be able to accommodate the stabilizer, etc.

2. Material

The material utilized for the lighting pole should have adequate strength and be of good quality in order to hold the lighting apparatus properly.

3. Anti-Corrosive Treatment

Hot-dip zinc coating or anti-corrosive painting is required on the lighting pole in order to prevent corrosion and to keep the appearance.

(1) Structure

A. The tapered pole (tapered ratio of 1/100) is generally used as the lighting pole. In addition, the long circular arm for attachment to the electric pole, and the knockdown pole can also be used according to the site conditions.

B. The lighting pole should have adequate strength not

only to hold the weight of the lighting apparatus but also against external forces, such as the overturning moment and the torsion generated by the wind pressure and vibrations.

C. There are two types of lighting poles. One is a standard type for attaching one lighting apparatus and the other is a Y-type for attaching two sets of lighting apparatus on each side. These two types of lighting pole are further classified by the installation method, i.e. the buried method and the base plate method.

(2) Material

A. As a standard, the lighting pole should be made from rolled steel. In addition, cast iron and aluminum alloy can also be used in some cases, however; their strength should be as same as the rolled steel.

B. In order to minimize the shrinkage stress and welding strain during the welding work, it is necessary to pay attention to the sequence of welding as well as the welding method.

C. Anti-corrosive treatment
Hot-dip zinc coating or anti-corrosive painting is required on the lighting pole in order to prevent corrosion and to maintain appearance. In the case of anti-corrosive painting, however, a special type of paint might be required in certain areas with corrosive circumstances, such as along the seaside and in industrial areas, in order to achieve satisfactory durability.

8.2.3 Other Equipments

1. Stabilizer

The stabilizer should have high efficiency and conformity with the luminaire used. When it is necessary to control illuminance, a stabilizer with dimmer should be used.

2. Automatic Switching Controller

The automatic switching controller should function with high reliability over a long period with a stable condition.

3. Distribution Board

The distribution board should contain the necessary functions either to switch on/off a lamp or control illuminance. The shape and the structure of the distribution

board should suit the conditions of the installation site.

4. Electric Cable

The electric cable used for the wiring should have sufficient thickness in consideration of the allowable electric current and the voltage drop. The electric cable should be covered by insulation or the equivalent according to the site condition.

5. Duct

The duct should have sufficient diameter and strength in order to protect the electric cable to be installed. Also, it should have anti-corrosive and installation efficiencies suitable to the site condition.

(1) Stabilizer

A. The stabilizer is used in order to continuously stabilize the electric discharge of the lamp. The stabilizer should conform with the type of the luminous source and its power, since it directly affects the efficiency of the lighting apparatus and its durability. In addition, it is also necessary to consider the variation of supplied voltage and the surrounding temperature.

The stabilizer is classified according to the associated lamp, the supply voltage and frequency, installation location and the electric current efficiency.

B. The stabilizer is usually installed in the lighting pole. However, it is necessary to consider measures to prevent harmful temperature increases, which may result in damage or deterioration of the insulation.

(2) Automatic Switching Controller

The automatic switching controller controls (opens/closes) the circuit of the street lighting in response to the level of natural light by using a photoelectric cell. The function of the automatic switching controller should be reliable, while the mechanical durability is required. Also, a waterproof mechanism to prevent the mal-function caused by water invasion and vibration-proof under ordinary operating condition are required.

(3) Distribution Board

In order to control many luminaires by distributing them to the appropriate number of separate circuits, it is necessary to install a distribution board equipped with a breaker, electromagnetic control switch, etc.

Where a distribution board is installed in the open-air, it should have waterproof mechanism, especially for the packing on the front door and holes to accommodate electric cables. In addition, the anti-corrosive treatment either by the hot-dip zinc coating or painting might be necessary according to the corrosive atmosphere.

Inside of distribution board, it is necessary to consider heat radiation and the ventilation to prevent the harmful temperature increases.

(4) Electric Cable

A. The electric cable used to connect between the electric distribution point and the lighting apparatus should be suitable for the wiring method applied at the installation site.

B. The electric cable should consist of stranded wire, which should be able to prevent damage and disconnections caused by the tensile forces during installation as well as the expansion stress in use.

(5) Duct

The duct facilitates wiring works and guards the electric cables in order to maintain electrical efficiency. Hence, the following points should be considered in the selection of the material used for the duct.

A. The duct should have sufficient mechanical strength to protect the electric cables from the external loads, impacts and vibrations.

B. The duct should not induce bending and tensile stresses in the electric cable through temperature extension of the duct and structure, nor any elongation caused by the land subsidence.

C. When the communication cable is installed in parallel with the wiring, the duct should be screened to prevent electrostatic induction.

D. The duct should have adequate durability for bad environmental conditions, such as corrosive gases, salty air and ultraviolet rays.

E. Installation as well as preparatory works on electric cables should be easy.

8.2.4 Installation Process of Street Lighting

The rational and the economical design of street lighting and wiring as well as installation are desirable based on the preliminary installation planning of street lighting.

The procedure generally used for the design of street lighting is summarized in Figure 8.11. The main work items in this procedure are as follows.

A. Analysis of installation condition based on the preliminary study results.

B. Determination of the arrangement of luminaires after selection of the luminous source and the lighting apparatus.

C. Setting up the condition for the calculation of the utilization factor and the maintenance factor.

D. Determination of the spacing of the luminaire and the wattage of the luminous source based on the luminous flux method.

E. Determination of the method of electric supply and design of wiring based on result of calculations, such as the voltage drop.

F. Installation of street lighting at the site according to the specification prepared based on the above items.

8.2.5 Design of Street Lighting

The luminance source, the light distribution type and the arrangement of the luminaire should be determined in order to maintain the standard illuminance.

The procedure to calculate the spacing of the luminaire is presented in the section 8.1.4, while some examples of the illuminance distribution contour of various lighting apparatus available in Thailand are attached in Appendix 8.1.

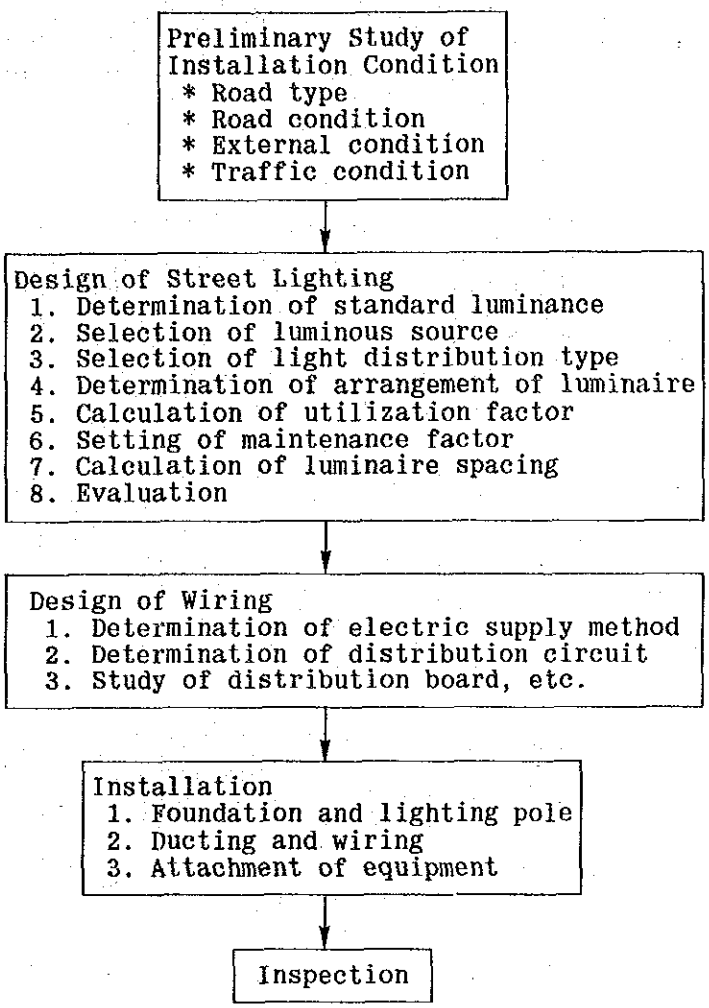


Figure 8.11 Summary of Street Lighting Installation

8.2.6 Design of Wiring

1. The most economical electricity supply method to the luminaire should be used in consideration of the supply distance, the wattage of luminaire, number of luminaires, and the arrangement of the distribution circuit.

2. The voltage drop due to the wiring should be within a range able to maintain the stable lighting of the luminous source as we as to prevent drastic reduction of the luminous flux and efficiency.

(1) Electricity Supply Method

The installation cost of the wiring depends on the electricity supply method, the supply electric current,

the voltage drop and the supply distance on each distribution circuit. Hence, the most economical electricity supply method and distribution circuit should be selected.

(2) Voltage Drop

The voltage drop at the extremity of the distribution circuit should be within a range able to start lighting and to maintain the stable lighting of the luminous source without variation of the luminous flux or blackout. In addition, since reduction of the luminous flux and efficiency are unavoidable, it is necessary to maintain the voltage drop within a certain range.

The allowance of the voltage drop during normal lighting conditions should be within 6% in consideration of the voltage drop due to the starting electric current in lighting and the voltage variation of lamps affected by temperature.

8.2.7 Installation

1. The foundation of the lighting pole should be constructed properly in order to firmly support the lighting pole at the fixed point and to prevent harmful sinking or tilting.
2. The lighting pole should be installed by the vertical angle facing to the fixed direction.
3. The lighting apparatus should be firmly attached to the fixing position and angle.
4. The wiring should be properly carried out in order to maintain electricity supply and protect the insulation.

(1) Foundation

A. In the design of the foundation, the dead load of the lighting pole and the wind load should be considered. In this case, the wind load is considered as a short term load.

B. In the construction of the foundation, it is necessary to avoid adversely affecting road traffic and other structures.

C. When the foundation is constructed on a filled section or embankment section, it is desirable to examine the soil condition, such as by the experimental digging or boring. Then, it is also desirable to replace the soil up to depth about two times that of the foundation width with gravel or sandy soil.

D. In order to maintain a dry condition at the bottom of the lighting pole, it is desirable to raise the upper part of the concrete foundation about 5 to 10cm. In addition, the base of the concrete foundation should be compacted by applying rubble and chippings.

(2) Base Plate Type Lighting Pole

The base plate type lighting pole is installed on a structure such as a bridge and wing wall, with the foundation for the base plate type lighting as shown in Figure 8.12. For this type of foundation, it is desirable to use an anchor bolt 25mm in diameter and to consider the safety factor required for the pull-out stress.

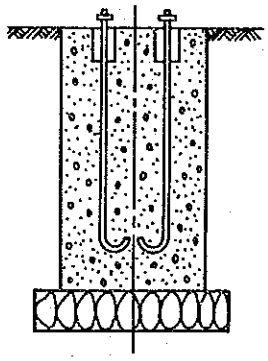


Figure 8.12 Foundation for the Base Plate Type Lighting Pole

(3) Installation of Lighting Pole

A. The lighting pole should be installed facing in the proper direction in order to maintain the balance of light distribution as well as the appearance.

B. For the installation of the lighting pole, a crane vehicle can be used according to the road conditions. Also, a mobile hydraulic platform can be used to attach the lighting apparatus on to the lighting pole.

(4) Installation of Lighting Apparatus

Improper installation of lighting apparatus results in a reduction of light distribution efficiency. Also, as accidental dropping of a lighting apparatus could cause a big accident, special attention should be paid to the installation method of the lighting apparatus.

8.2.8 Inspection

It is desirable to carry out routine inspection of the street lighting for the following items.

1) Lighting condition

- Failure to light up during night time and light operation during daylight hours.
- Measurement of illuminance.

2) Lighting apparatus

- Condition of the cover attachment and the luminaire.
- Condition of the lighting apparatus attachment with the lighting pole.
- Presence of dirt both inside and outside the lighting apparatus.

3) Lighting pole and foundation

- Tilting and bending of the lighting pole.
- Condition of the join between lighting pole and foundation.
- Condition of paint on the lighting pole.

4) Wiring and electricity distribution equipment

- Measurement of the insulation resistance.
- Condition of the distribution board.
- Condition of the stabilizer.
- Drainage condition in the manhole or the hand hole.

In addition to the routine inspection, it is desirable to carry out an inspection after a natural disaster, such as a typhoon.

Prior to the inspection, the inspector should have a sufficient understanding the mechanism, functions and maintenance record of the lighting pole and to be aware of important points for the inspection.

The frequency of inspection can be determined according to the location, the weather conditions and the traffic conditions. However, it is desirable that the inspection of failure to light up during night time and light operation during daylight hours be carried out once a month and other items once a year.

It is desirable to carry out an extra inspection after a natural disaster. In addition, it is also effective to carry out an extra inspection and maintenance just before expected bad weather in order to minimize damage.

The basic consideration for the inspection are as follows.

(1) Lighting Condition

When failure to light up during night time or light operation during daylight hours is found or a reduction in the illuminance is identified by eye inspection, it is necessary to find out the cause.

In order to objectively identify the required illumination effects, measurement of the illumination level is generally carried out. Even though the illumination level is determined by the surface luminance, it is quite difficult, however, to measure the surface luminance by routine inspection. In stead, it is possible to measure the average surface illuminance. Prior to the operation of the lights, it is necessary to measure the surface illuminance in detail. After that, it is possible to measure the surface illuminance at representative points in order to determine sufficiently well the illumination of the whole lighting.

(2) Lighting Apparatus

It is possible that the attachment bolts may become loose due to vibration resulting in a discrepancy of the installation angle of the lighting apparatus. During inspection, attention should be paid to this point.

(3) Lighting Pole and Foundation

For the base plate type lighting pole, attention should be paid during inspection for looseness of attachment bolts connecting the lighting pole and the foundation.

(4) Wiring and Electricity Distribution Equipment

Improper waterproofing may decrease the durability of the distribution board, resulting deterioration of wiring in various equipment and inferior connection. Hence, special attention should be paid during inspections.

Improper drainage in the manhole or the hand hole may also result in the deterioration of wiring.

8.2.9 Cleaning and Maintenance

1. Cleaning

Dirt inside and outside of the lighting apparatus results in a reduction of the surface luminance. Based on eye inspection or the measurement of the surface illuminance, it is necessary to carry out cleaning of the lighting apparatus.

2. Maintenance

If any fault is found during inspection, it is necessary to rectify it.

1) Change of luminous source

After consideration of the inspection results of lighting condition and the life span of the luminous source, it is necessary to determine the procedure for changing the luminous source. According to this procedure, the luminous source is then changed.

2) Painting

Repainting should be carried out according to the deterioration of the paint. When the painted surface is removed by damages, it is necessary to repaint as soon as possible.

3) Wiring and Electricity Distribution Equipment

Inadequate insulation and a fault in the control function of the electricity distribution equipment directly result in non-performance of the street lighting. Hence, it is necessary to locate the cause and rectify it.

When any damage on the lighting facilities, such as failure to light up during night time, light operation during daylight hours and dirt on the lighting apparatus are found by inspection, it is necessary to carry out cleaning or maintenance, in order to maintain the design function of the street lighting.

(1) Cleaning

The lighting apparatus becomes dirty by dust or exhaust gas from vehicles. Based on the level of dirt, the cleaning method should be determined. During cleaning, care should be taken not to damage the cover, the reflector, etc.

(2) Method to Change Luminous Source

There are several methods to change the luminous source as shown below. For the actual work, the most suitable method should be adopted having consideration to each method and the life span of the luminous source.

A. Individual changing method :
To change individual bad luminous sources one by one.

B. Total changing method :
To change every luminous source after a certain period regardless of their condition.

C. Individual and total changing method
To change individual bad luminous sources and to change every luminous source after a certain period.

D. Partial changing method
To change a certain number of bad luminous sources.

(3) Repainting

At locations with heavy traffic volumes, in urban areas and along the seashore with possible damage from salt, it is necessary to increase the frequency of repainting, since the speed of deterioration of painted surfaces is faster than in other areas. Prior to the repainting, it is necessary to completely remove rust.

8.2.10 Record

1. When the street lighting facility is installed, it is desirable to prepare a record, containing the structure and the mechanism of the lighting apparatus, the lighting pole, the foundation, the electricity distribution equipments and the street lighting number.

2. When the cleaning and the maintenance is carried out, date, cause of fault and contents of works should be recorded.

Since the installation record of the street lighting is very important for the future maintenance works, a record should be prepared with the details of equipments, etc. The cleaning works and the maintenance works should also be recorded. In addition, it is desirable to prepare an inspection list to properly carried out the inspection.

CHAPTER 9 DELINEATOR

CHAPTER 9 DELINEATOR

9.1 DELINEATION OF CARRIAGEWAY

Nighttime brings increase hazards to road users through limited visibility and night driving is considerably more hazardous than daytime driving. The main purpose of carriageway delineation is to assure safe driving at nighttime providing various visual information, especially when carriageway is not illuminated or the illumination is insufficient. Effective delineation will improves the road safety and ease the driving task.

Substantial delineation treatments include the following.

- Post delineators.
- Raised pavement markers.
- Longitudinal pavement markings.
- Curbs.
- Guard fences.
- Colored pavement.
- Rows of luminaires

Among these treatments, post delineators and raised pavement markers are taken up in this chapter, while other important delineation treatments such as pavement markings, guard fences and row of luminaires are discussed in their respective chapters in this report.

9.2 POST DELINEATOR

9.2.1 Technical Guideline

(1) Summary of Warrants

Post delineators may be installed along the following sections except where guard fences are installed.

1) Curve sections of which radius is 400m or less, and approaches to the curve.

2) Sections where number of lanes or width of carriageway changes abruptly.

3) Sections where there are many accident records of run-off type at nighttime or where found as necessary by engineering study to ensure safe traffic flow.

(2) Type of Post Delineator

DOH has erected a large number of so-called "guide posts" at curves, approaches to bridges and other selected places. The guide post, made of concrete in a shape of quadrangular column, painted in white and black zebra with the height of about 0.8m, is regarded as one form of post delineator when it is reflectorized at the top. Types of post delineators varies in shape and material, some examples are illustrated in Figure 9.1.

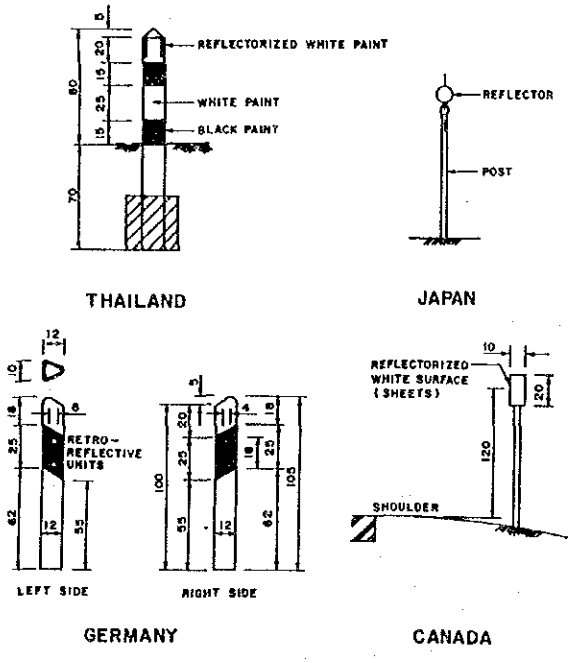


Figure 9.1 Various Types of Post Delineators

(3) Warranting Conditions

Following remarks are found in "Manual on Traffic Control Devices" of DOH.

In general, the delineators are used for the case of the horizontal or vertical change of route alignment, or where the pavement width is changed. However, the delineator could be considered to be used in tangent road section, if necessary.

In this manual of DOH, delineator is prescribed as a reflective material (it is usually a white reflective paint) placed on top of guide post. Since non reflectorized guide posts can be nothing but hazards to traveling vehicles at night, except when they are installed in illuminated area, following discussion will not apply to non-reflectorized guide posts.

There are three types of road sections where delineators may be erected, as described in the manual, which are:

A. Horizontal or vertical curve sections.

B. Sections where pavement width changes.

C. Tangent sections.

As there is a part of common roles between guard fences and post delineators, the warranting conditions for post delineators shall be discussed, referring to those of guard fences. It should, however, be noted that post delineators are not so effective when guard fences are installed, because guard fences have high visual guidance effect especially when they are reflectorized partially.

According to warrants of guard fences, they are to be installed at curve sections having radius of 200m or less or downgrades of 4% or more. As to post delineators, they can be applied more widely, because of their relatively low cost. Post delineators are generally recommended to curve sections having radius of 400m or less, while grades are not necessarily provided with post delineators.

Post delineators are also to be installed along sections where number of lanes or width of carriageway changes abruptly because substantial guidance for drivers are needed peculiarly at such sections. The installation of post delineators to tangent road sections is justified only when vehicle speed at night is relatively high and such installation is expected to effect a smooth and safe traffic flows or where there are many experiences of run-off type accidents at nighttime.

(4) Application

a) Horizontal Curve

In the Manual of DOH, spacing of delineators at a horizontal curve is determined under the condition that the motorist can observe at least 5 delineators. These criteria shown in Figure 9.2 together with those of employed in Japan. Since both seem similar to each other, the spacing criteria of DOH are considered as adequate.

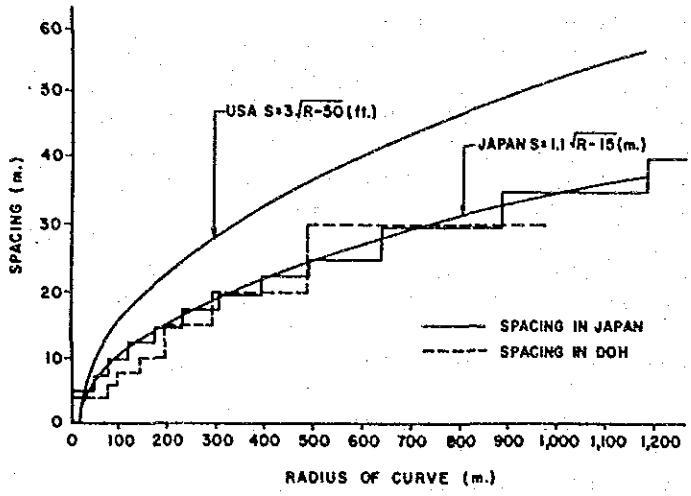


Figure 9.2 Spacing of Post Delineators

From the visual standpoint, use of post delineators on the outside of curve is effective enough. However, post delineators used on both sides make the carriageway clearer. In this case, two-color system, i.e. white for left hand side and orange for right hand side from the driver, may be more effective. However, as long as the current shape of post delineator in DOH is employed, introduction of two-color system has a difficulty. Therefore, single color (i.e. white) is recommended except for warning purpose.

b) Pavement Width Transition

Changing the color of reflective units (from white to orange) and shortening of the spacing of post delineators in the area where the pavement width reduces will provide advance warning of change. Use of post delineators on both sides of the road may further emphasize hazardousness, and promote slower and more attentive approaches.

c) Tangent Section

Post delineators should be installed along the left hand side of roads of with a spacing of 40m.

9.2.2 Engineering Specification

The post delineator consists of several parts as shown in Figure 9.3.

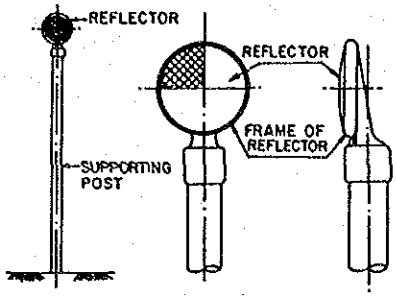


Figure 9.3 Component of Post Delineator

(1) Reflector

1. Reflector

1) The reflector is the main part of the post delineator and it reflects light from the headlight of the vehicle.

2) The shape of the reflector should be circular with diameter of between 70 and 100mm. The back of the reflector should sealed in order to prevent water and dust intrusion.

3) The color of the reflector should be white or orange.

4) The reflective capability of the reflector should be more than the value shown in Table 9.1.

Table 9.1 Standard Reflective Capability of Reflector
(Unit : cd/lx·m²)

Color	White			Orange		
Incident Angle / Observation Angle	0°	10°	20°	0°	10°	20°
0.2°	850	680	510	530	430	310
0.5°	410	340	240	270	220	140
1.5°	13	11	8	8	7	5

2. Frame of the reflector

The frame of the reflector is used to attach the reflector on to the supporting post. Also, it protects the back of the reflector from the atmosphere.

a) Reflector

1) Function of reflector

The reflector is the main part of the post delineator and it reflects light from the headlight of the vehicle. The reflector should have a durable reflective capability, while it should not easily become discolored or break.

2) Mechanism of reflector

The diameter of the reflector mentioned above means the inner diameter of the effective reflective part. Hence, when the effective reflective part is reduced such as by the attachment hole, it is necessary to increase the inner diameter in order to compensate for this reduced area.

Since the bigger size of reflector has better visibility at greater distances, it is desirable to install bigger size of reflector on road sections where the velocity of vehicles is high or conditions hazardous.

Basically, the shape of the reflector should be circular. However, when an other shape of reflector (rectangular shape) is used, it is necessary to achieve the required effective reflective area.

The back of the reflector should be properly sealed in order to prevent the invasion of water and dust.

3) Color of reflector

- It is desirable to install a white color reflector in most cases.

- It is desirable to install an orange color reflector on the right side of the carriageway and the median, and at particularly hazardous locations. Even though the reflective capability of the orange color reflector is less than the white one, this color is usually used to attract people's attention.

4) Reflective capability

The reflective capability of the reflector largely affects the visibility of the post delineator. When the reflective capability is not good, it is difficult to ensure proper visual guidance. Hence the reflective capability of the reflector should satisfy the standard values shown in Table 9.1. As a reference, the relation between the incident angle and the observation angle is illustrated in Figure 9.4.

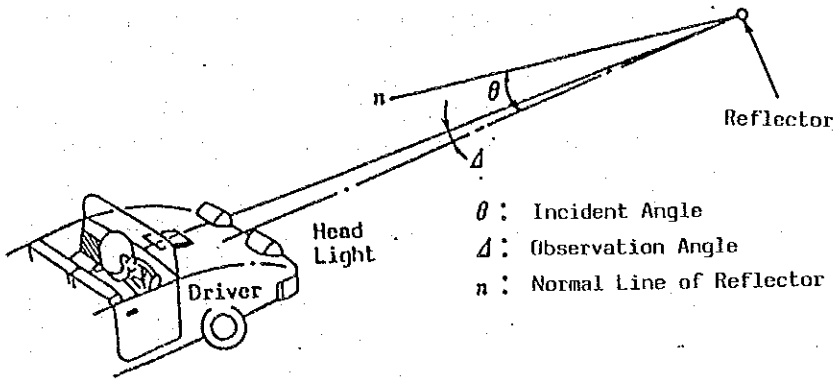


Figure 9.4 Relation between Incident Angle and Observation Angle

b) Frame of Reflector

The frame of the reflector is used to attach the reflector on to the supporting post. Also, it protects the back of the reflector and from the surrounding atmosphere. Hence, the frame structure should able to reliably attach the reflector on to the supporting post. However, when the mechanism of the reflector is able to directly attach on the supporting post or adhesive is applied onto the back of the reflector, a frame is unnecessary.

(2) Supporting Post

1. The structure of the supporting post should be able to reliably fix the reflector at prescribed position.
2. The color of the supporting post should be white or similar color.
3. When steel material is used for the supporting post, it is necessary to carry out anti-corrosive treatment.

a) Structure of Supporting Post

The structure of the supporting post should be able to reliably fix the reflector at the prescribed position. Where a guard fence, handrail or wing wall exists, it is possible to attach the reflector onto these using an attachment.

b) Specification of Supporting Post

The standard shape of the supporting post is cylindrical. The specification of the supporting post should

differ according to the installation location, the installation condition and the material. Table 9.2 shows a standard specification of the supporting post.

It is desirable that the supporting post has sufficient strength against external forces, such as contact by pedestrians, to assure the position of the reflector is maintained.

Table 9.2 Standard Specification of Supporting Post

Installation Condition		Length (mm)	Material		
			Steel	Aluminum Alloy	Plastic
Height of Reflector (cm)	Type of Foundation		Size* (mm)	Size* (mm)	Size* (mm)
90	Concrete Foundation	1,150	exceed 34 X 2.3	exceed 45 X 3	exceed 60 X 4.5 (89)**
	Planted Foundation	1,450			

Note * : Size means outer diameter times thickness.
** : When the polyethylene resin is used.

c) Anti-Corrosive Treatment

1) By painting

When steel pipe is used as the supporting post, it is desirable to carry out shot blasting or phosphate treatment on hot-dipped zinc coating steel pipe in order to increase the adhesion of the paint.

2) By membrane treatment

Membrane steel pipe can be produced by either of the following methods.

- Carry out shot blasting and then paint the adhesive on the steel pipe, after which make a membrane of about 0.5mm thickness with chloroethyle.

- Apply polyethylene resin of about 2.0mm thickness to formulate the membrane.

3) By hot-dipped zinc coating

Not only the supporting post, but also the attachment, bolts and nuts should be treated by hot-dipped zinc coating.

(3) Installation

During installation of the post delineator, it is necessary to pay attention to traffic safety and the effects of other structures.

During installation of the post delineator, it is necessary to consider measures to attract the attention of drivers and pedestrians. Also, it is necessary to consider the effects of the underground utilities and other structures.

In order to properly maintain the function of the post delineator, the following points should be taking into consideration.

a) Installation of Supporting Post

1) Installation in the ground

A. By digging and filling

In order to prevent sinking, impact compaction should be adequately carried out at the base of the post as well as after filling.

B. By driving

During driving of the post, attention should be paid to keep the post vertical as well as the underground utilities. In addition, the head of the post should not be damaged by driving.

Figure 9.5 shows an example of supporting post installation by both this and above methods.

C. Concrete foundation

The foundation of the supporting post should be an adequate structure to prevent the tilting and sinking, while the surrounding area should adequately apply the impact compaction. Figure 9.6 shows an example of supporting post installation using a concrete foundation.

2) Installation in concrete structure

A. Installation in concrete structure

When the supporting post is installed in a concrete structure, it is necessary to consider the effects on the structure itself. In addition, rotation and pulling out of the post should also be considered.

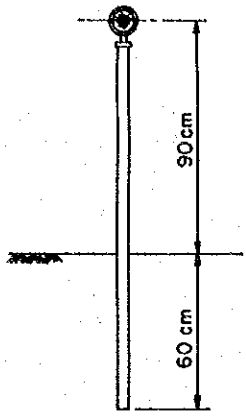


Figure 9.5 Supporting Post Installation by Planting

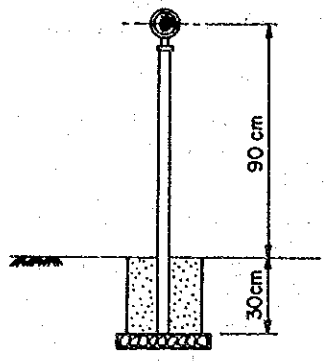


Figure 9.6 Supporting Post Installation by Concrete Foundation

B. Installation by base plate method

The fixing of the anchor should be properly done and it is desirable to properly join the base plate and the structure.

3) Installation on guard fence

When the supporting post is installed on a guard fence or other apparatus, it is necessary to select a suitable attachment having consideration for the shape of apparatus. The installation of the attachment on such apparatus should not produce an obstacle to traffic. Figure 9.7 shows an example of installation of post delineator on a guard fence.

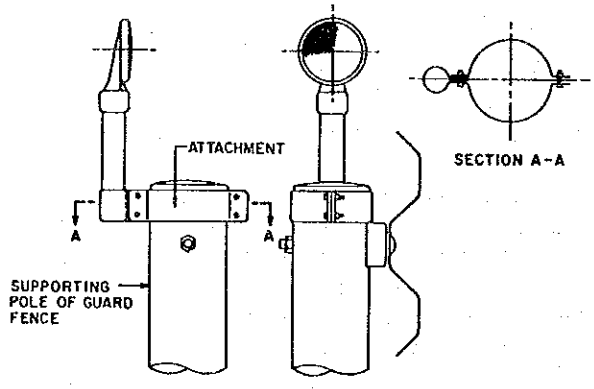


Figure 9.7 Installation of Post Delineator on Guard Fence

b) Inspection after Installation

After the installation of the post delineator, it is necessary to inspect for the following points.

A. Installation location

B. Attaching condition of the reflector

C. Height and angle of the reflector

D. Flaws and dirt on the reflector

E. Angle of the reflector
F. Foundation installation

(4) Routine Inspection

Routine inspection of the post delineator should be carried out in order to check for any faults of the post delineator. In addition, it is also necessary to carry out inspection for the following items, if it is required. 1) Reflective condition. 2) Fixing condition of the reflector and the supporting post, damage and dirt. 3) Fixed angle of the reflector. 4) Visibility of the reflector.

The routine inspection of the post delineator should be carried out in order to check for any faults. In addition, it is also necessary to carry out inspection for the following items, if it is required.

A. Reflective condition.

B. Fixing condition of the reflector and the supporting post.

C. Damage of the reflector and the supporting post.

D. Dirt on the reflector.

E. Fixed angle of the reflector.

F. Bent supporting post or reflector.

G. Obstruction covering the reflector.

Since the objective of the post delineator is the visual guidance during night time, it is desirable to occasionally carry out an inspection during night time in order to examine the function of the post delineator.

(5) Cleaning and Maintenance

1. Cleaning

Since dirt on the reflector reduces the visual guidance effect, it is necessary to clean the surface of the reflector according to the result of an inspection.

2. Maintenance

When any damage is found through inspection, maintenance should be done as soon as possible.

a) Cleaning

Based on the results of the inspection, the cleaning of the reflector should be done. During cleaning, attention should be paid not to change the angle nor to damage the surface of the reflector.

If the reflector becomes dirty very quickly due to heavy traffic volumes or dust, installation of the dirt prevention type post delineator, as shown in Figure 9.8 might be considered.

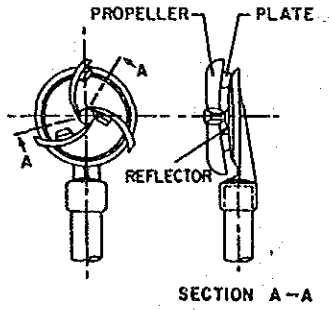


Figure 9.8 Dirt Prevention Type Post Delineator

In addition, it is desirable to clear the area around the post delineator, when visibility of the post delineator is reduced by weeds or undergrowth.

b) Maintenance

When damage on the post delineator is small, it is possible to leave it at the site. However, replacement will be necessary if damage is severe. Hence, it is desirable for the field district office to stock extra post delineators.

The decay of the supporting post and the deterioration of reflective capability of the reflector results after use over a long period. Hence, renewal of the post delineator is necessary after a certain period.