9.3 RAISED PAVEMENT MARKER

9.3.1 Technical Guideline

(1) Summary of Warrant

Series of raised pavement markers may be installed along:
1) Curve sections of which curve radius is 150m or less.
2) Sections where center line crossing by vehicles is to be prohibited.
3) Boundary of chevron marking which is drawn on the pavement near to rigid hazards, e.g., raised traffic island, pier in the carriageway, etc.

(2) Type of Raised Pavement Marker

Raised pavement markers, meanwhile, include various types employed for guidance of vehicles, as exemplified in Figure 9.9. While shape, color and material vary extremely, raised pavement markers may be roughly classified as follows:

- Non-reflective marker.
- Reflective button.
- Reflective raised bar.
- Reflective curb marker.
- Intersection identification marker.
- Other reflective marker.

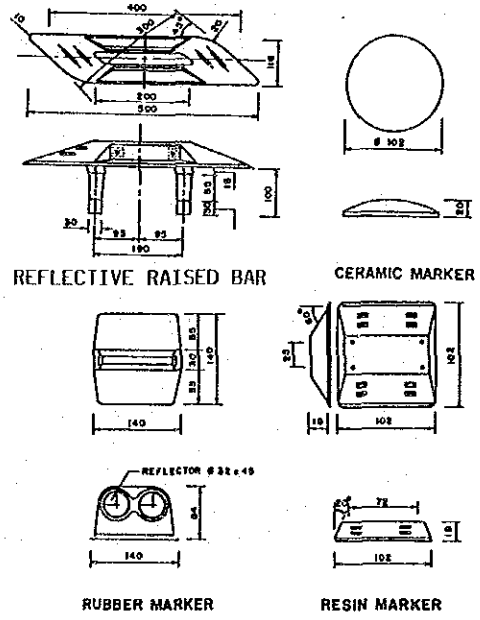


Figure 9.9 Various Types of Raised Pavement Markers

From the standpoint of applications, several aims of raised pavement markers are listed as follows.

- to amplify longitudinal pavement marking.
- to restrain overtaking.
- to delineate curb line.
- to control vehicle speed.
- to channelize traffic.
- to identify intersection.
- to identify hazardous location.

As there is no established practice for the selection of raised pavement markers, engineers are requested to select an adequate so as to get sufficient efficacy of them, considering the characteristics of each type.

In this section, reflective raised bar will be mainly discussed since they are utilized and applied to various purposes and win general appreciation in Japan.

(3) Warranting Condition

Reflective raised bars have been placed in various cases in Japan. They have two aspects in effectiveness, one is delineation effect by reflective unit, and the other is rumble effect which alerts inattentive drivers. Reflective raised bars are very effective when applied to road sections where traffic is to be channelized and visually guided at nighttime.

As a small radius curve, vehicle running on inside lane often drives on a part of opposing lane to avoid intense centrifugal effect, which possibly leads to a disastrous head-on collision. Installation of reflective raised bars along center line at such small radius curve is very effective. This has been proved effective through the experimental work on Route 306 in the Phase I Study. The inclination to drive on opposing lane is related to "easiness of driving". Assuming that approaching speed is 60 km/hr, 150m of curve radius is considered as a minimum limit for easy driving according to lateral force calculation.

Even the tangent road sections sometimes should be divided physically along the center line. One case is undivided multilane road, and the other is section where overtaking is prohibited. Roads having 4 lanes or more are, in principle, to be divided by median to prevent intensive head-on collision accidents. Installation of reflective raised bars are effective when construction of mounded and curbed median is restricted or when access and egress traffics frequently cross the center line.

Another effective use of reflective raised bar is to

stress the boundary of chevron markings. To mark clearly channelization at night and to alert careless drivers by rumble effect, the placement of reflective raised bars along the boundary of chevron markings contributes to safety, especially when such markings are drawn closely to rigid hazards, e.g., raised traffic island, pier in the carriageway, etc.

(4) Application

a) Horizontal Curve

Positive application of reflective raised bars along the center lines of sharp curves will have a remarkable effect on safety improvement. Spacing of reflective raised bars should comply with figures in Table 9.3.

Table 9.3 Spacing of Reflective Raised Bars

Curve Radius (m)	Spacing (m)
Less than 50	2
50 to 300	3
300 or more	4

b) Use as Substitute for Median

One effective usage of reflective raised bar is to install along center line to make it work as a simple median. The height of reflective raised bar is about 5cm from the pavement surface, and it may give the vehicle running in considerable speed an intense rumble effect which discourage the driver to cross the center line, while it allows the vehicle to cross the line of reflective raised bars easily when moving slowly.

Simple median comprised of reflective raised bars, therefore, is useful and effective when it is applied to sections where separation, of counter-directional traffic is required and besides, access and egress of vehicles from and to the neighboring areas should be visible. Figure 9.10 is a typical application for above usage.

c) Enhancement of Zebra Markings

Zebra markings to channelize the traffic flow are one of the principal measures to enhance the safety and capacity of intersections. But as is often the case with the channelization only by markings, drivers tend to disobey their way indicated by means of zebra markings, and this leads to restricted efficiency of channelization.

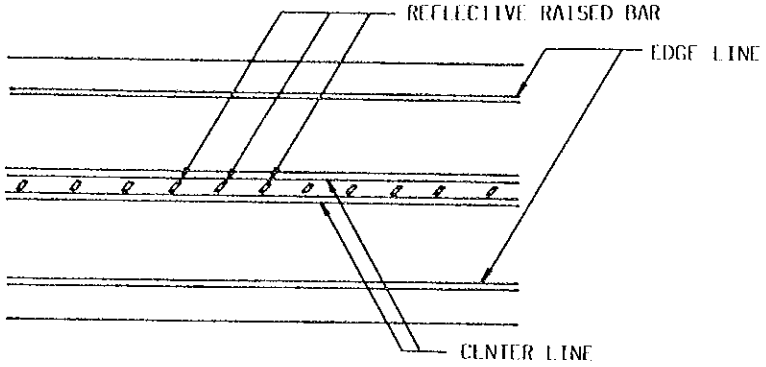


Figure 9.10 Example of Simple Median Marking Use of Reflective Raised Bars

In such case, installation of reflective raised bars along the boundary of zebra markings is recommended. Reflective raised bars installed as indicated in Figure 9.11 will guide and delineate the way of drivers effectively through its rumble effect and optical guidance by reflective unit.

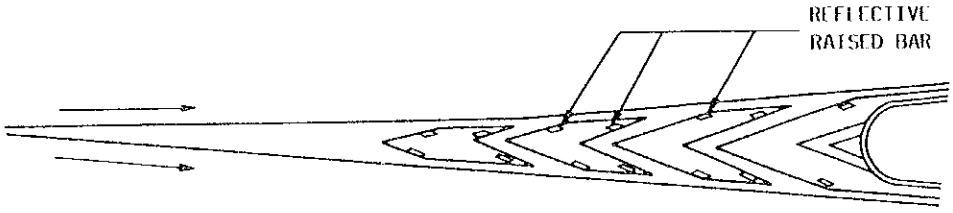


Figure 9.11 Enhancement of Channelization by Reflective Raised Bars

CHAPTER 10 GUARD FENCE

CHAPTER 10 GUARD FENCE

10.1 TECHNICAL GUIDELINE

10.1.1 Summary of Warrants

1. Roadside Guard Fence

(1) Sections Having Serious Roadside Hazards

- Sections which height and side slope combinations are fallen above the line in Figure 10.1.
- Sections which have obstacles, such as big rocks, big trees, traffic signals and houses, in the 2m zone to the carriageway.
- Sections along the water such as sea, lake, pond, river and ditch, which depth is more than 1.5m.
- Sections on bridges and flyovers.

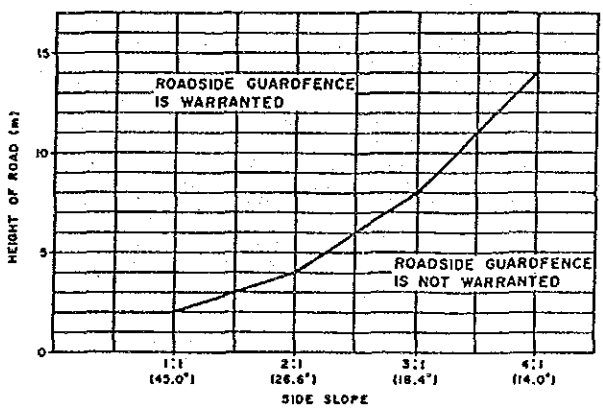


Figure 10.1 Guard Fence Warrant for Road Height and Side Slope

(2) Low-standard Design Sections

- Curves having radius of 200 m or less.
- Down slopes having 4% or more gradient.
- Sections where the carriageway width or number of lanes is reduced abruptly.

(3) Proximities to Bridges, Culverts, etc.

- Approaches to bridges, viaducts, tunnels or culverts.
- Sections where pier, abutment, retaining wall or other rigid structure is in the 2m zone to the carriageway.

(4) Sections which have numbers of accidents

- Sections where considerable number of run-off-road accidents happened or are suspected to happen.

2. Median Guard Fence (width of less than 10m)

- Sections where 85 percentile speed is 80 km/h or more and meet one of the following conditions.
  * Longitudinal gradient is 3% or more.
  * Curve radius is 750 m or less.
- Sections where median guard fence installation is necessitated because of high running speed.
- Sections where carriageway crossing by pedestrians should be prohibited.
- Sections where prevention of glare by headlight (high-beam) of vehicles from the opposite direction are desirable.

3. Sidewalk Guard Fence

(1) Guard Fence to Restrain the Errant Vehicle

- Sections where vehicles are suspected to run into pedestrians on sidewalks due to poor horizontal alignment.
- Sections where prevailing speed is considerably high and safeguard of pedestrians or bicycles is considered to be requisite.
- Sections on bridges with sidewalk.

(2) Guard Fence to Discourage Pedestrians from Crossing

- Sections where carriageway crossing by pedestrians should be prohibited.

(3) Guard Fence to Prevent Pedestrians or Cyclists from Dropping Off

- Sections along the roadside hazard such as ditch, river or low-height ground.

10.1.2 Function and Classification of Guard Fence

(1) Function

The main function of guard fence is to restrain errant and uncontrolled vehicles from running into the hazards and getting severe damages. In addition, there are following other functions:

A. To minimize damage to vehicle as well as its occupants.

B. To redirect errant vehicle without endangering other traffic.

C. To ensure pedestrian safety.

D. To restrain pedestrians from crossing carriageway recklessly.

There are a number of papers reporting that guard fences which are designed and placed in appropriate manners bring delightful results to road safety. Guard fences, on the contrary to the multi-purpose functions as mentioned above, can also be serious roadside hazards to the drivers when improperly installed. Hence, the study leads to an understanding that guard fences shall be a great help to road safety, only when installed by "sound engineering judgment". This also requires the need of a careful and comprehensive guideline for guard fences as regard to warranting conditions, design and material.

(2) Classification by Type

Since there are various sorts of guard fences, classification and definition are attempted for better understanding of guard fences. Among many kinds of guard fences, following five (5) types of guard fences are in general use, i.e., guard rail, guard pipe, box-beam guard fence, guard cable and rigid guard fence. The major features of each type of guard fence are briefly described below. Examples of these types of guard fences are illustrated in Figure 10.2

A. Guard rail, as defined in this report, is a fence of which rail is made of corrugated steel beam in a shape of "W", being supported by a row of steel or wooden posts. Guard rail absorbs collision energy with plastic deformation of "W" beam and deformation of posts.

B. Guard pipe, which is used mainly aiming at pedestrian safety, is composed of plural number of steel pipes and supporting posts. Collision energy is absorbed in plastic deformation of pipes.

C. Box-beam guard fence is composed of fabricated box-section steel beams and supporting posts. This type of guard fence possesses an advantage to be installed on median, because of its symmetrical cross section. Box-beam guard fences cope with collision impact by bending resistance.

D. Guard cable consists of strained steel cables, and supporting posts. It resists collision impact by elastic tension of steel cables.

E. Rigid guard fence is usually constructed by the reinforced concrete, hence collision impact fully affects the collided vehicle.

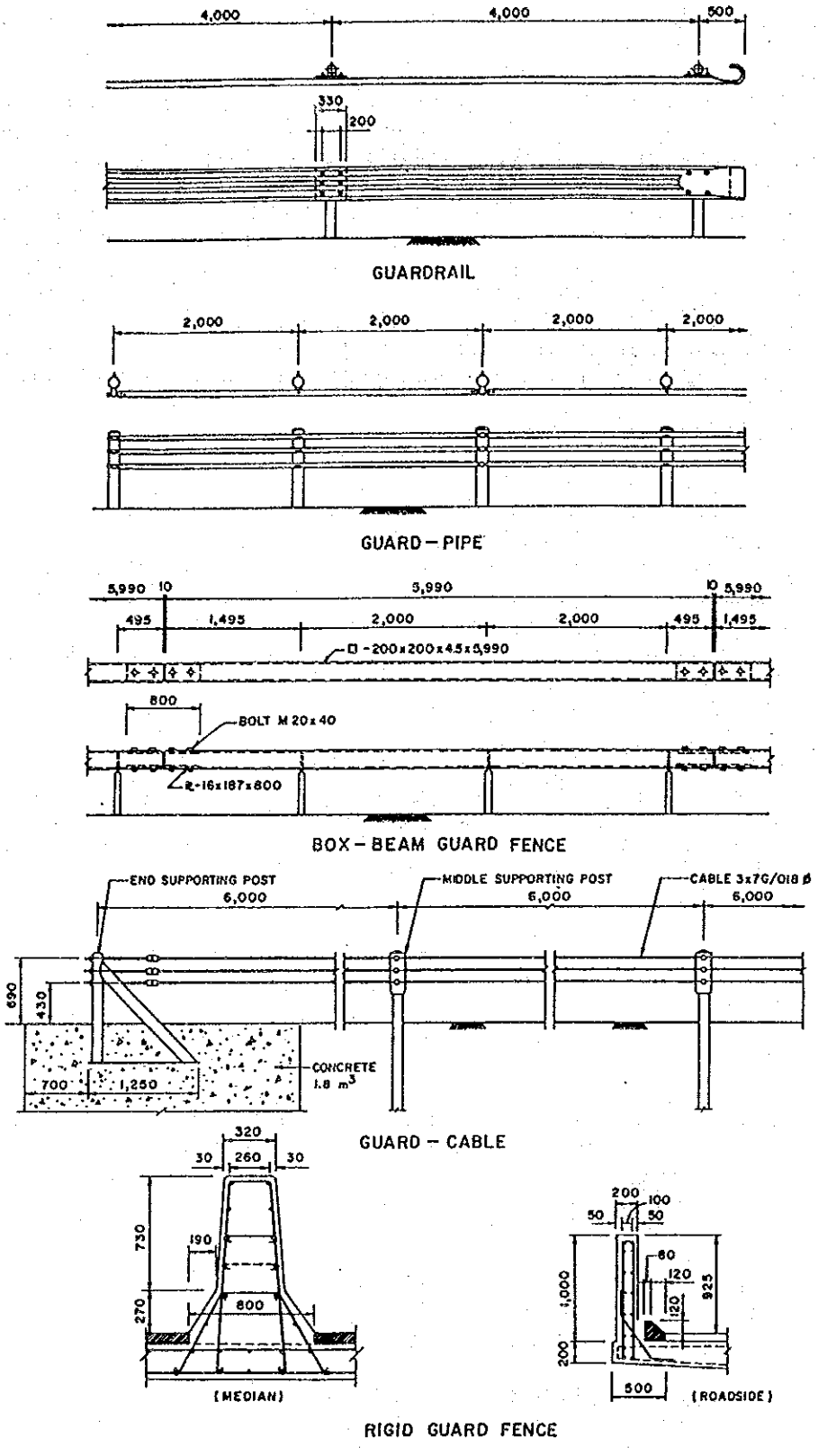


Figure 10.2 Example of Various Types of Guard Fence

Guard fences are further divided into three categories by purpose of installation, i.e., roadside guard fence, median guard fence and sidewalk guard fence.

Roadside guard fence is installed mainly to protect the uncontrolled vehicle from lateral drop off where sidewalk is not existing. Median guard fence installation aims at decreasing head-on collision between contra-flow vehicles, while sidewalk guard fence is to assure pedestrian safety.

10.1.3 Warranting Conditions

(1) Roadside Guard Fence

Roadside guard fences are needed where errant or uncontrolled vehicles are apt to run into roadside hazards resulting in serious damage if guard fences are not installed. Road sections that justify guard fence installation are as follow. However, based on practices in Japan, priority should be given to selected road sections adjacent to water, while a second priority for selection should be the traffic volume.

A. Sections where roadside areas could be serious hazards.

B. Low-standard design sections.

C. Proximity to bridges, culverts, etc.

D. Sections which have the experiences of a number of accidents.

a) Sections Where Roadside Areas Could Be Hazards

Typical road section in this category is that with high road surface level to ground such as embankment roads or cut roads on a hillside. Degree of hazardousness at such road sections varies according to its steepness of side slope and height of road; i.e., the gentler the side slope is, the safer situation it gives. The oblique line in Figure 10.1 is a threshold for warrant to install roadside guard fence. The line is regarded as "equi-damageable" for lateral drop off of vehicle, and it is determined by reference to the technical information in other countries.

In addition, degree of hazardousness at flyovers and bridges are very high, since lateral drop off of vehicles from a flyover/bridge causes serious accident. Therefore, it is definitely necessary to install guard fence, particularly rigid guard fence, along these road sections in order to absolutely prevent drop off type of accidents.

Even when road height and side slope combination does not meet the above criterion, the existence of hard obstacles in the very proximity to the carriageway such as big rocks, big trees, sign supports, lighting poles, traffic signals, houses, etc., can generally justify the guardfence erection.

Besides, sections along the water such as sea, lake, pond, river, canal, ditch, etc., are generally regarded as the dangerous sections which require the provision of guard fences, when they have a certain depth. One and a half meter (1.5m) of depth is considered as a limit whether passengers are relieved or not from the vehicle sunk in water.

b) Low-standard Design Section

Relations between geometric parameters of roads and traffic accidents have been widely examined and reported on many occasions, indicating that smaller radii of curves and steep downgrades make the roads more hazardous.

Regarding curve radius, the curves with radii of less than 200m are considered as dangerous as shown in Figure 10.3, while moderate curve sections produce safer driving conditions.

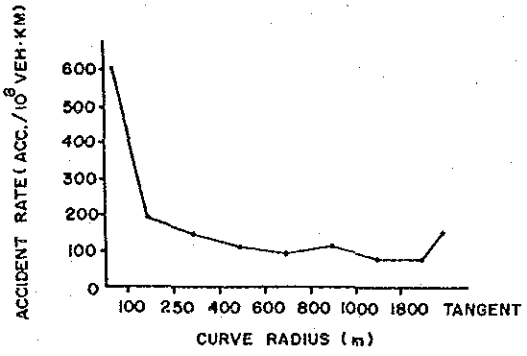


Figure 10.3 Relation Between Curve Radius and Accident (Ordinary Road, Japan)

On the other hand, the value of "safe" curve radius can be calculated, i.e., the following equation gives a limit value of a vehicle's lateral slip.

$$R = \frac{V^2}{127(e+f)}$$

where;
R : Limit curve radius.
V : Driving speed.
e : Superelevation.
f : Lateral force coefficient.

When 80 km/hr for "V", 0.06 for "e", and 0.2 for "f" are substituted in the equation, the resultant curve radius "R" comes out to be 194m. This indicates the curve of which radius is less than 200m is rather dangerous to a vehicle running at 80 km/hr or more, especially in a bad weather such as heavy rainfall.

In respect to the relation between roadway gradient and traffic accidents. The down slopes having 4% or more gradient are highly dangerous as shown in Figure 10.4. This is because drivers are apt to speed up and lose vehicle control at such down slopes.

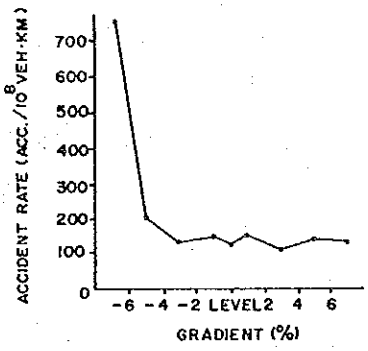


Figure 10.4 Relation Between Gradient and Accident (Ordinary Road, Japan)

The sections where the effective width of carriageway or number of lanes is reduced abruptly (rate of transition is larger than 1:2), are also dangerous, especially at nighttime and need for guard fence.

c) Proximity to Bridges, Culverts, etc.

Approaches to bridges, flyovers, or culverts where carriageway width changes sharply, require guard fences. Collisions with those structures are expected to induce severe damage to the passengers as well as structures themselves.

Sections where bridge pier, abutment, retaining wall or other rigid structure exists in the very vicinity (within about 2m zone) to the carriageway are regarded hazardous and require guard fences.

d) Sections Which Have Experience of a Number of Accidents

The determination whether guard fence should be installed or not requires, in most cases, a close examination by highway/traffic engineers on a case-by-case basis. In other words, it depends on "sound engineering judgement" of concerned engineers.

However, it is supposed that such sections which have the experiences of a considerable number of run-off-road accidents should be provided with roadside guard fences.

(2) Median Guard Fence

Effectiveness of median guard fence in traffic safety may be a somewhat controversial subject. There are some papers reporting that median guard fence increases the number of accidents. These prove that guard fence itself can be a hazard to vehicles. Nevertheless, most of reports stress that run-over-median accidents, which are mostly fatal, would notably decrease after construction of median guard fences. There is a report that run-over-median accidents with median guard fence is reduced to one third in Japan.

It is desirable that the road sections with anticipated frequent head-on collisions, e.g, sections of high vehicle speed, considerable amount of vehicular traffic, relatively narrow median, and poor geometrical alignments, are provided with guard fences on the median.

An example of a relation between curve radii and traffic accidents of expressways is shown in Figure 10.5. It indicates that when vehicle speed is relatively high, curve radius of less than 750m produces increased danger to the drivers. An example showing ratios of head-on collision accidents to all accidents at gradients is presented in Figure 10.6. This example indicates that the gradient of more than 3% induces higher ratio of head-on collision. Thus median guard fences are advisable at the sections mentioned above.

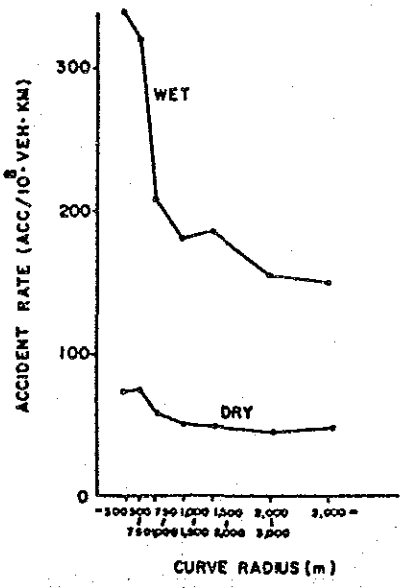


Figure 10.5 Relation Between Curve Radius and Accident (Tomei Expressway, Japan)

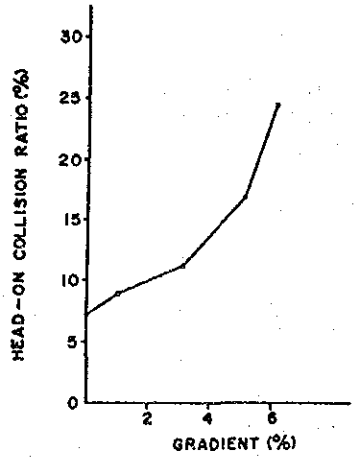


Figure 10.6 Relation Between Gradient and Head-on Collision Ratio (Ordinary Road, Japan)

Median guard fences are also very effective to prevent pedestrians from crossing carriageway at random and it is possible to reduce conflict points between vehicle traffic and pedestrians.

In addition, median guard fences can prevent glare by headlight (high-beam) of vehicles from the opposite direction, as a supplemental effect.

(3) Sidewalk Guard Fence

The objectives of sidewalk guard fences are as follows.

A. To safeguard pedestrians from uncontrolled vehicles.

B. To prevent pedestrian or cyclist from dropping off the sidewalk or bicycle path.

C. To prevent vehicles from running off the road.

D. To discourage pedestrians to cross carriageway.

E. To separate pedestrians from vehicular traffic.

At the sharp curvature of road, it is possible for errant vehicle to run off the road onto the sidewalks bringing calamity to pedestrians and passengers. Such road sections, where the drivers are inclined to improperly operate their vehicles because of road geometry, need for the provision of guard fences.

For the roads, it is desirable to install guard fences on sidewalks at the sections where considerably high speed vehicles endanger pedestrians or cyclists.

On a bridge with sidewalks, it is desirable to install sidewalk guard fences other than handrails of a bridge, in order to prevent vehicles from drop off.

The guard fences on sidewalks, where pedestrians jaywalk carriageways to jeopardize traffic and endanger themselves, are very effective.

10.1.4 Selection of Guard Fence Type

In selection of guard fence, information on merit and demerit of each type of guard fence will be of a great help. Characteristics of five (5) types of guard fences are described in Table 10.1. This table suggests that careful and sound judgement is necessary in guard fence selection since each type has distinctive characteristics.

Table 10.1 Characteristics of Various Guard Fences

Type of Guard Fence	Advantage	Disadvantage	Usage
Guard Rail	- Appropriate rigidity and tenacity - Easy replacement of damaged part - Good visual guidance to drivers - Good adaptability to small-radius curve	- Easily stained	Roadside Median Sidewalk
Guard Pipe	- Good adaptability to small-radius curve - Good scenic view from passengers	- Difficulty in pipe connection	Sidewalk
Box Beam Guard Fence	- Good adaptability to narrow median - Good scenic view from Passengers	- Difficulty to install to small radius curve	Median
Guard Cable	- Easy rehabilitation through reusing the steel cable - Better scenic view from passengers - Free placement of supporting posts - Allowable to differential settlement of posts	- Difficulty to install to small radius curve - Uneconomical to short section - Difficulty in repair of cable terminals	Roadside Median
Rigid Guard Fence	- Perfectly prevent run-off type of accident - Good lastingness for corrosion resistance	- Difficulty in construction and maintenance - Collision impact fully affect collided vehicle	Roadside Median

Table 10.2 is prepared for practical use so that engineers can easily get the information regarding which guard fence has a suitability for a certain road section. It is obvious that the final decision shall be made based on thorough field investigations and taking economical and social conditions into consideration.

Table 10.2 Applicability of Various Guard Fence to Specific Road Sections

Type of Guard Fence / Road Section of ...	Guardrail	Guard-Pipe	Box-beam Guard Fence	Guard-Cable	Rigid Guard Fence
Small-radius (R=300m) Curve	◎	○	▲	△*	▲
Visual Guidance Required	◎	▲	△	▲	○
Good Scenic View Required	▲	○	△	◎	▲
Narrow Median	△	▲	◎	○	◎
Big Differential Settlement	▲	△	▲	◎	▲
Corrosion Resistance Required	△	○	△	○	◎
Long Tangent Road	○	○	○	◎	▲
Bridge/Flyover (important)	△**	▲	▲	▲	◎

LEGEND ; ◎ : Highly Applicable.
○ : Applicable.
△ : Applicable under the certain condition.
▲ : Unsuitable

NOTE ; * : Shorten the distance of supporting poles are required.
** : Certain types (A or S type), described in the Engineering Specification, are applicable.

10.2 ENGINEERING SPECIFICATION

10.2.1 Classification of Guard Fence

1. The guard fence is classified as shown in Table 10.3 according to the road type applying to the guard fence.

Table 10.3 Classification of Guard Fence Application

Guard Fence Type	Guard Fence Class	Guard Fence Application According to Road Type	Applicable Design Speed (km/hr)
Roadside Guard Fence	A	Expressway Motorway Major Trunk Highway (Important)	60 - 120
	B	Major Trunk Road Major Road Major Trunk Road in Urban Area	60
	C	Other Road	20 - 50
	S	Road section where run-off type of accident should be completely prevented	20 - 120
Median Guard Fence	Am	Expressway Motorway Major Trunk Highway (Important)	60 - 120
	Bm	Other Road	30 - 60
Sidewalk Guard Fence	Ap	Major Trunk Highway (Important)	80
	Bp	Major Trunk Road Major Road Major Trunk Road in Urban Area	60
	Cp	Other Road	20 - 50
	P	Installation on simple sidewalk Prevention of random crossings Prevention of falling onto roadside by by pedestrians and bicycles	20 - 80

2. At road sections where the composition of heavy vehicles is high, the roadside is particularly hazardous, velocity of vehicles is very high and all run-off type of accidents should be prevented, it is desirable to use the higher rank class of guard fence.

3. Each class of guard fence should be designed according to the design condition as shown in Table 10.4.

4. At a road section where the design speed is set because of special considerations, the same class of guard fence should be applied on both sides of this section.

Table 10.4 Design Condition of Each Class of Guard Fence

Guard Fence Class	Collision Speed of Vehicle (km/hr)	Weight of Vehicle (t)	Collision Angle (Degrees)	Vehicle Deceleration (g)	Maximum Allowable Run-Off Distance by Vehicle	
					Post Planted in the Ground (m)	Post Installed in Concrete Structure (m)
A	60	1.4 and 3.5	15	Not exceed 4	Not exceed 1.1	Not exceed 0.3
B	40					
C	35					
S	80			-		
Am	60	1.4 and 3.5	15	Not exceed 4	Not exceed 1.5	Not exceed 0.5
Bm	40				Not exceed 1.1	Not exceed 0.3
Ap	60	1.4 and 3.5	15	Not exceed 4	Not exceed 0.75	Not exceed 0.3
Bp	40					
Cp	35					
P	-	-	-	-	-	-

In this specification, the guard fence is classified into several classes according to the type of road. This classification is set in consideration of the road type and the speed of collision with the guard fence, which effects are closely related with damage in accidents, etc.

The design of the guard fence is not aimed at preventing all run-off type accidents. Hence, at road sections, where the composition of heavy vehicles is high, the roadside is particularly hazardous, velocity of vehicles are very high and all run-off type accidents should be prevented, it is desirable to use higher class of guard fence or to shorten the distance between supporting posts.

10.2.2 Specification of Each Type of Guard Fence

(1) Guard Rail for Roadside Installation

The specification of the guard rail to be installed on the roadside should be as shown in Table 10.5.

a) Beam

The specification of two classes of guard rail, i.e. class B and Class C, follow the basic specification of the corrugated steel beams used for the guard rail defined under the TIS 248-2531. In the Study, introduction of class A and class S (combination of classes A and C guard rails) guard rails are recommended. Figures

10.7 and 10.8 show basic dimensions of the corrugated steel beam used for the guard rail and the end beam defined by the TIS 248-2531, respectively.

Table 10.5 Specification of Guard Rail for Roadside

Guard Rail Class	Beam			Supporting Post			Bracket			Height of Beam Center	Maximum Space of Post
	Width (mm)	Corrugation (mm)	Thickness (mm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (cm)	Width (mm)	Corrugation (mm)	Thickness (mm)	(cm)	(m)
A	310	80	4.0	139.8	4.5	165 (40)	70	31	4.5	60	4.0 (2.0)
B	310	80	3.2	114.3	4.5	150 (40)	70	31	4.5	60	4.0 (2.0)
C	310	80	2.5	114.3	4.5	140 (40)	70	31	4.5	60	4.0 (2.0)
S	310 310	80 80	4.0 2.5	139.8	4.5	165 (40)	70	31	4.5	80 40	2.0 (1.0)

Note -- 1 : Value in parenthesis is the specified value when the supporting post is connected to a concrete structure, such as bridge, retaining wall and box culvert.
2 : The height of the beam center is measured from the pavement surface. However, when a curb exists, the height is measured from the upper side of the curb.
3 : Upper and lower values of Class S means the value for the upper and the lower beams respectively.

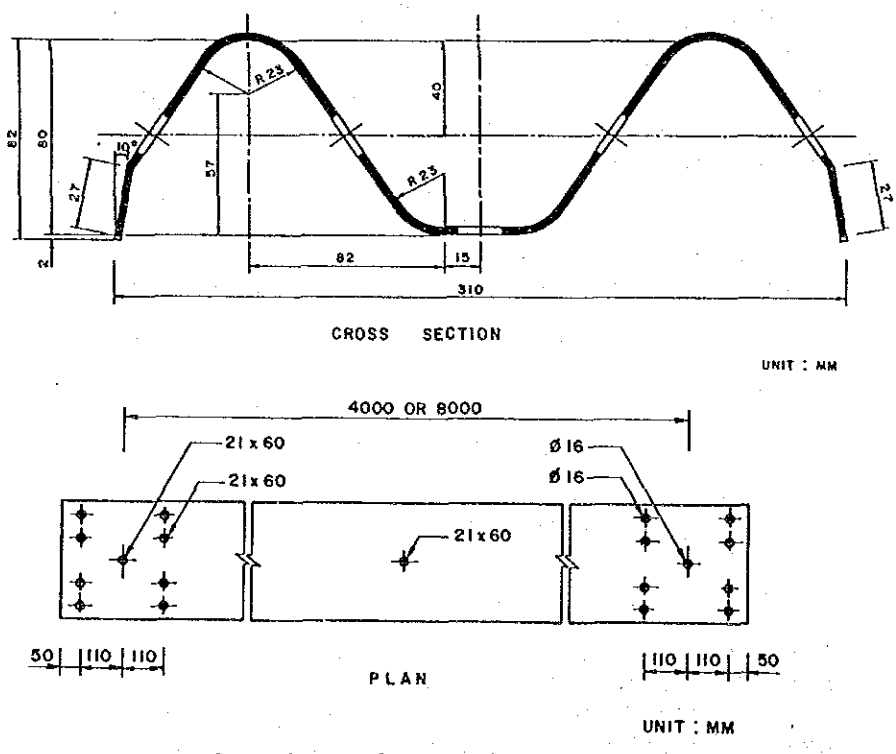


Figure 10.7 Basic Dimensions of Corrugated Steel Beam Used for Guard Rail

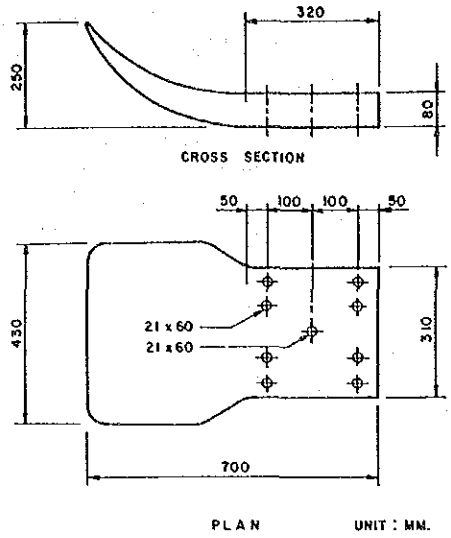


Figure 10.8 Basic Dimension of End Beam for Guard Rail

Figure 10.9 illustrates the components of the guard rail used for roadside installation.

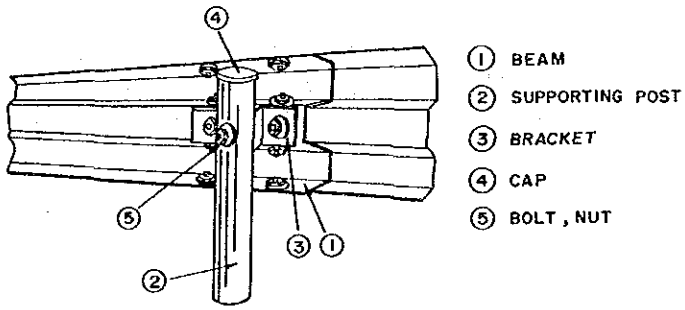


Figure 10.9 Components of Guard Rail for Roadside

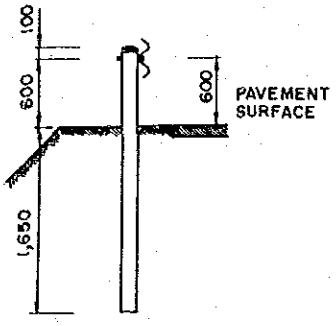
b) Supporting Post

The planting depth of the supporting post should be a uniform value regardless of the distance from the top of a slope. When the supporting post is connected to a concrete structure, the depth should be 40cm in consideration of the pull-out resistance and the effects on the concrete structure.

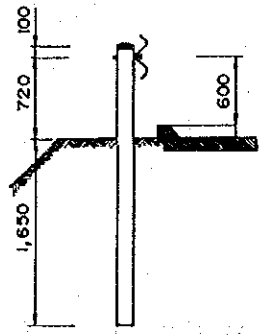
The space between posts in the case of planting in the ground is determined as 4m in consideration of the function of the guard rail, installation and transport of materials. On the other hand, the space is determined as 2m in the case of connection to a concrete structure, in consideration of the prevention of partial deformation of the beam resulting from an increase of resistance and the over driving of vehicle on the guard rail. In addition, it is necessary to shorten the space

of posts at a curved section, sections with less soil bearing resistance and the protection of bridge piers.

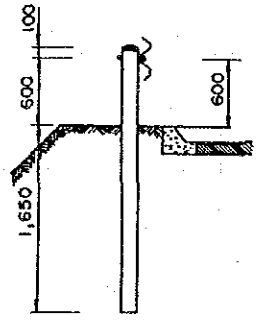
The height of the beam center should be measured from the pavement surface. However, where a curb exists, the height is measured from the upper side of the curb. The relation between the height of the beam center, the formation in the planting part and the planting depth is shown in Figure 10.10.



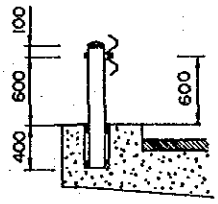
(1) Planting in the Ground



(2) Planting in the Ground (Where curb exists)



(3) Planting in the Ground (Planting point is stepped--up from pavement surface)



(4) Connection to Concrete Structure

Figure 10.10 The Method to Determine the Beam Center

c) Bracket

The space between the beam and the supporting post is determined as 110mm, 84mm and 83mm for Classes A, B and C guard rails, respectively. The dimension of the bracket defined by the TIS 248-2531 is shown in Figure 10.11.

d) Others

On the top of the supporting post, it is necessary to install a cap in order to prevent the intrusion of rain and dust.

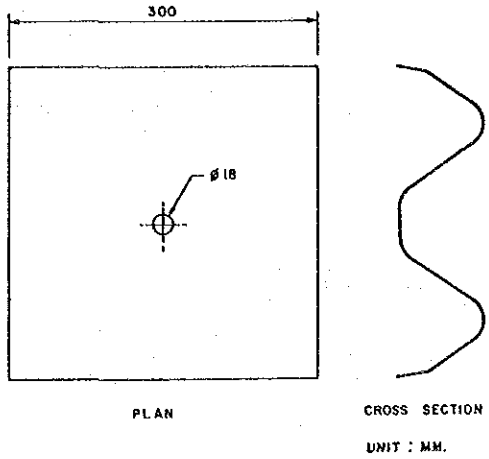


Figure 10.11 Dimension of Bracket

(2) Guard Rail for Median Installation

The specification of the guard rail to be installed on the roadside should be as shown in Table 10.6. However, when it is impossible to maintain the space between the outer edge of the beam at 75cm, this space can be reduced using the supporting post as for a roadside installation.

Table 10.6 Specification of Guard Rail for Median

Guard Rail Class	Beam			Supporting Post			Bracket		Height of Beam	Maximum Space	Space between Outer Edge of Beam
	Width (mm)	Corrugation (mm)	Thickness (mm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (cm)	Cross Section (mm)	Thickness (mm)	(cm)	(m)	(cm)
Am	310	80	4.0	114.3	4.5	150 (40)	2[—200 x50	4.5	60	4.0 (2.0)	75
Bm	310	80	3.2	114.3	4.5	150 (40)	2[—160 x50	4.5	60	4.0 (2.0)	75

Note -- 1 : Value in parenthesis is the specified value when the supporting post is connected to a concrete structure, such as bridge, retaining wall and box culvert.
2 : The height of the beam center is measured from the median surface.

The objectives and function of the guard rail installed in the median are different from that of roadside installation; hence it is not appropriate to employ the same specification.

The block-out double face type guard rail is accordingly recommended. This type is installed using a bracket attached on the supporting post to connect two beams. Since the two beams are overhung from the supporting post, direct collision on the post and the reduction in height of the beam center by tilting of the post can be prevented. Also, the rigidity of this type of structure is greater and it is possible to smoothly alter the collision direction of a vehicle. In order to increase this tendency, the strength of the supporting post is reduced.

Figure 10.12 illustrates the components of the guard rail used in a median installation.

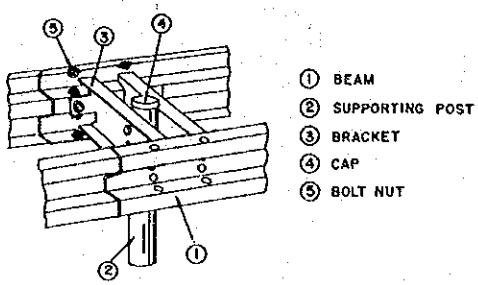


Figure 10.12 Components of Guard Rail for Median

Figure 10.13 shows the shape of the bracket to maintain the space between beams. When application of the block-out double face type is impossible, it is necessary to apply the guard rail with same strength as for road side installation and to widen the space between the post and the beam as much as possible.

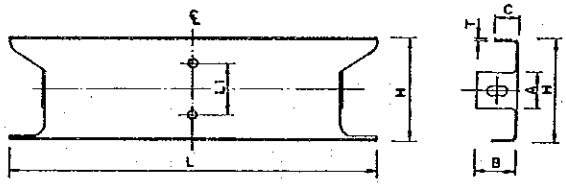


Figure 10.13 Shape of Bracket for Median Guard Rail

(3) Guard Rail for Sidewalk Installation

The specification of the guard rail to be installed on the sidewalk should be as shown in Table 10.7.

Table 10.7 Specification of Guard Rail for Sidewalk

Guard Rail Class	Beam			Supporting Post			Bracket			Height of Beam Center	Maximum Space of Post
	Width (mm)	Corrugation (mm)	Thickness (mm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (cm)	Width (mm)	Corrugation (mm)	Thickness (mm)	(cm)	(m)
Ap	310	80	4.0	139.8	4.5	165 (40)	70	31	4.5	60	2.0
Bp	310	80	3.2	114.3	4.5	150 (40)	70	31	4.5	60	2.0
Cp	310	80	2.5	114.3	4.5	140 (40)	70	31	4.5	60	2.0

Note -- 1 : Value in parenthesis is the specified value when the supporting post is connected to a concrete structure, such as bridge, retaining wall and box culvert.
2 : The height of the beam center is measured from the pavement surface. However, when a curb exists, the height is measured from the upper side of of the curb.

Basically, the specification of this type of guard rail is the same as the roadside guard rail, except the space between posts for planting in the ground. This is to limit the allowable vehicle run-off distance which is not to exceed 75cm. In addition, bolt faces should be on the sidewalk side in order to prevent damage to pedestrians' clothing, etc.

(4) Guard Cable for Roadside Installation

The specification of the guard cable to be installed on the roadside should be as shown in Table 10.8.

Table 10.8 Specification of Guard Cable for Roadside

Guard Cable Class	Cable			Middle Supporting Post			Bracket		End Supporting Post			Height of Lowest Cable	Maximum Space of Post	Space Between Cable & Post
	No. of Cable (No.)	Initial Tension (t)	Space of Cable (cm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (mm)	Width (mm)	Thickness (mm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (mm)	(cm)	(m)	(mm)
A	5	2	13	139.8	4.5	165 (40)	210 420	3.2	165.2	5.0	50	43	7.0 (4.0)	110
B	4	1	13	114.3	4.5	150 (40)	210 290	3.2	114.3	4.5	45	43	7.0 (4.0)	110
C	3	1	13	114.3	4.5	140 (40)	420	3.2	114.3	4.5	40	43	7.0 (4.0)	110
S	6	2	13	139.8	4.5	165 (40)	340 420	3.2	190.7	5.3	55	43	4.0 (2.0)	110

Note -- 1 : Value in parenthesis is the specified value when the supporting post is connected to a concrete structure, such as bridge, retaining wall and box culvert.
2 : The height of the lowest cable is measured from the pavement surface. However, when a curb exists, the height is measured from the upper side of the curb.
3 : Upper value and lower value for the width of bracket indicate the width of the upper bracket and the lower bracket, respectively.

Figure 10.14 illustrates the components of the guard cable for roadside installation.

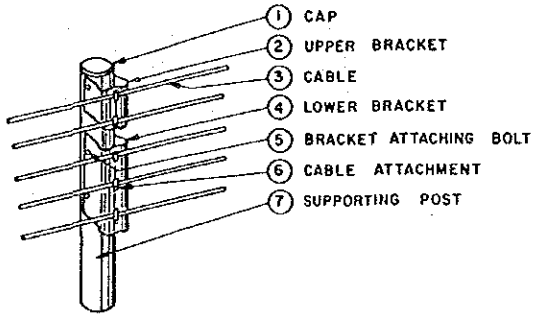


Figure 10.14 Components of Guard Cable for Roadside

a) Cable

The cable used for the guard rail should have appropriate rigidity and anti-corrosive efficiency, and the outer diameter of the cable should be 18mm.

b) Supporting Post

The planting depth of the middle supporting post should be as same as the supporting post of the guard cable.

The maximum space between posts in the case of planting in the ground is determined as 7m in consideration of the function of the guard cable. On the other hand, the space is determined as 4m in the case of connection to a concrete structure, in consideration of prevention of the partial deformation of the beam resulting from an increase of resistance and the over driving of vehicle on the guard rail. In addition, it is necessary to shorten the space of posts at a curved section, sections with less soil bearing resistance and the protection of bridge piers.

The standard shape of the end supporting post is shown in Figure 10.15.

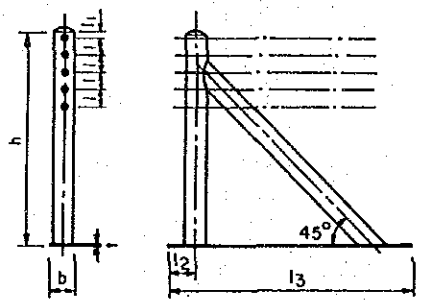


Figure 10.15 Standard Shape of End Supporting Post

c) Bracket

The bracket combination for each class of guard cable is illustrated in Figure 10.16 and the shape of the bracket to attach guard cable is shown in Figure 10.17.

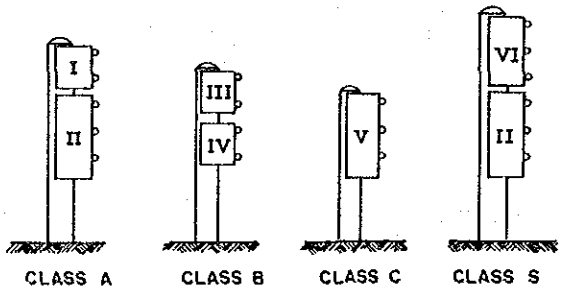


Figure 10.16 Combination of Bracket by Guard Cable Class

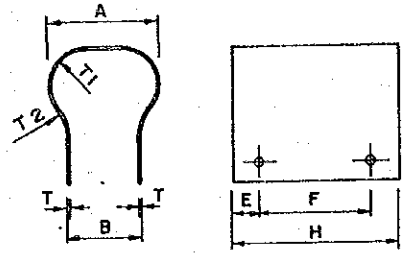


Figure 10.17 Shape of Bracket for Guard Cable

(5) Guard Cable for Median Installation

The specification of the guard cable to be installed on the median should be as shown in Table 10.9.

Table 10.9 Specification of Guard Cable for Median

Guard Cable Class	Cable			Middle Supporting Post			Bracket		End Supporting Post			Height of Lowest Cable	Maximum Space of Post	Space Between Both Side Cables
	No. of Cable (No.)	Initial Tension (t)	Space of Cable (cm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (cm)	Width (mm)	Thickness (mm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (cm)	(cm)	(m)	(mm)
Am	8	2	17	114.3	4.5	150 (40)	250 420	4.5	139.8	4.5	50	44	6.0 (4.0)	110
Bm	6	1	17	114.3	4.5	150 (40)	520	3.2	114.3	4.5	45	44	6.0 (4.0)	110

Note -- 1 : Value in parenthesis is the specified value when the supporting post is connected to a concrete structure, such as bridge, retaining wall and box culvert.
2 : The height of the lowest cable is measured from the median surface.
3 : Upper value and lower value for the width of bracket indicate the width for the upper bracket and the lower bracket, respectively.

Objectives and function of the guard cable installed in the median are different from that of a roadside installation; hence it is not appropriate to employ the same specification. Figure 10.18 illustrates the components of the guard cable used for median installation.

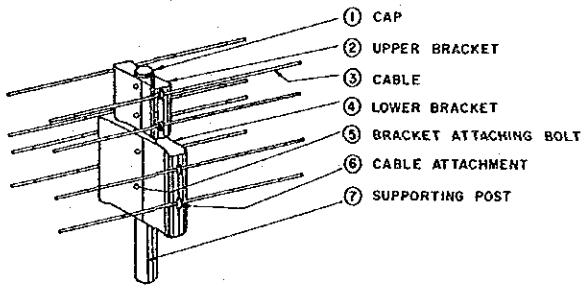


Figure 10.18 Components of Guard Cable for Median

A specific consideration of the guard cable for a median installation is the longer space of 250mm between the supporting post and cables. Direct collision on the post and overturning by tilting of the post can be

prevented by this structure; hence it is possible to smoothly alter the collision direction of vehicle.

When application of double side type guard cable is impossible, it is necessary to apply only one side of the guard cable for median installation. In this case, the outer diameter and the thickness of the supporting posts should be equal to or greater than that of a roadside installation. In addition, the number of cables for the median guard cable is one cable less than the roadside installation, the maximum spacing should be not exceed 4.0m in order to supplement the strength.

(6) Box Beam Guard Fence for Median Installation

The specification of the box beam guard fence to be installed in the median should be as shown in Table 10.10.

Table 10.10 Specification of Box Beam Guard Fence for Median

Box Beam Guard Fence Class	Beam		Supporting Post			Height of Beam Center (cm)	Maximum Post Space (m)
	Dimension (mm)	Thickness (mm)	Dimension (mm)	Planting Depth (cm)	Planting Plate (mm)		
Am	□—200 x200	4.5	H—125 x60x6x8	150 (40)	PL—4.5 x300x500 (-)	60	2.0
Bm	□—200 x150	4.5	H—100 x50x5x7	150 (40)	PL—4.5 x300x500 (-)	60	2.0

The box beam guard fence was developed for the narrow median installation. The basic concept of this type of guard fence is to strengthen the beam and weaken the supporting post. The characteristics of this guard fence are as follows.

A. Due to high rigidity of the beam, the performance to distribute the load and to smoothly alter the collision direction of vehicle are high.

B. The impact of a colliding vehicle is less, since the supporting post is easily detached from the beam.

C. It is able to prevent vehicle run-off even though the supporting post breaks, due to high rigidity of the beam.

The components of the box beam guard fence after the installation are shown in Figure 10.19.

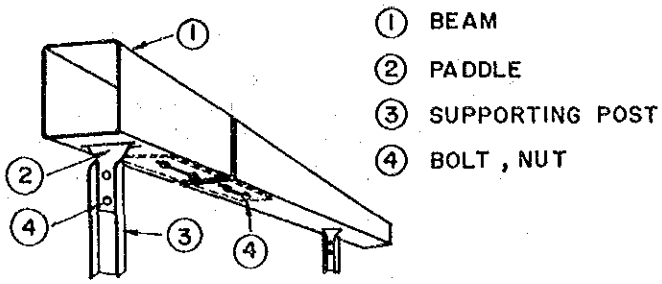


Figure 10.19 Components of Box Beam Guard Fence for Median

a) Beam

The standard shape of the box beam is shown in Figure 10.20. The height of the center of the box beam follows the specification of the guard rail for roadside installation.

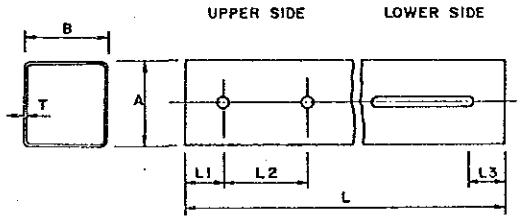


Figure 10.20 Standard Shape of Box Beam

b) Supporting post

Since direct impact of a vehicle wheel on the supporting post is possible, the cross sectional shape of the supporting post should have be weaker in the vehicle direction and of greater strength at right angles with the box beam, in order to minimize damage to the vehicle wheel. Hence, the H-steel was employed.

In order to increase the bearing capacity at right angles to the supporting post, the flange plate should be attached on the post. The attaching position of the flange plate is determined to maximize the resisting moment. Figure 10.21 illustrates the standard shape of the supporting post, together with the flange plate.

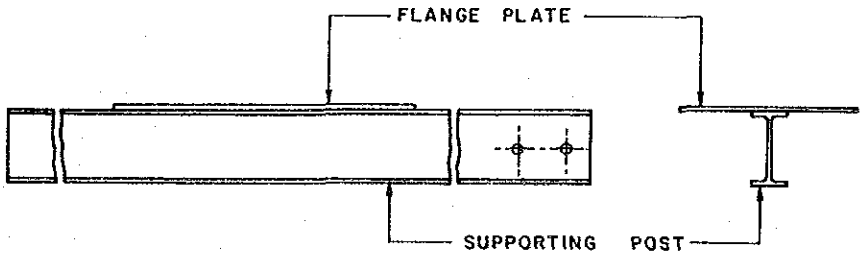


Figure 10.21 Standard Shape of Supporting Post for Box Beam Guard Fence

The space between posts is set as 2m regardless of the method of planting in consideration of the function of the box beam guard fence, such as the displacement value, vehicle loading capacity, etc.

c) Joint

The structure of the joint of the box beam guard fence should adequately transmit the bending stress of the box beam as well as the tensile stress, when the beam receives a large bending deformation or plastic deformation. Figure 10.22 shows an example of the joint for the box beam guard fence.

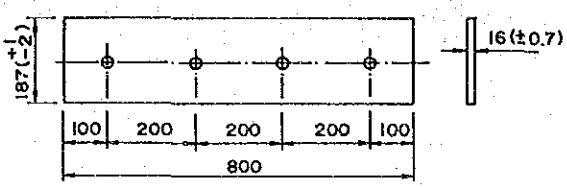


Figure 10.22 Example of Joint for Box Beam Guard Fence

d) Paddle

In order to attach the box beam to the supporting post, it is necessary to use a paddle as shown in Figure 10.23.

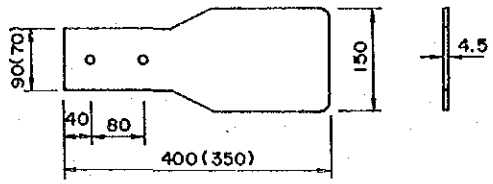


Figure 10.23 Shape of Paddle for Box Beam Guard Fence

(6) Guard Pipe for Sidewalk Installation

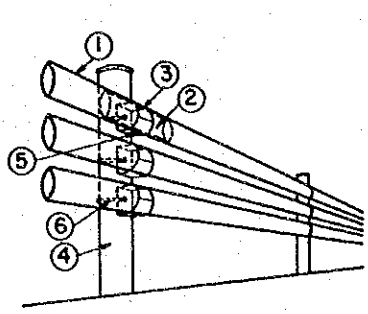
The specification of the guard pipe to be installed on the median should be as shown in Table 10.11.

Table 10.11 Specification of Guard Pipe for Sidewalk

Guard Pipe Class	Pipe				Supporting Post			Joint Pipe			Height of Center Pipe (cm)	Maximum Post Space (m)
	Outer Diameter (mm)	Thickness (mm)	No.of Pipe (No.)	Pipe Space (mm)	Outer Diameter (mm)	Thickness (mm)	Planting Depth (cm)	Outer Diameter (mm)	Thickness (mm)	Length (mm)		
Ap	60.5	3.8	3	175	139.8	4.5	165 (40)	51	5.0	324	60	2.0
Bp	48.6	3.2	3	150	114.3	4.5	150 (40)	40	4.3	264	60	2.0
Cp	48.6	2.4	3	150	114.3	4.5	140 (40)	42	3.0	264	60	2.0

Note -- 1 : Value in parenthesis is the specified value when the supporting post is connected to a concrete structure, such as bridge, retaining wall and box culvert.
2 : The height of the center pipe is measured from the pavement surface. However, when a curb exists, the height is measured from the upper side of the curb.

The components of the guard pipe after the installation is shown in Figure 10.24.



① PIPE
② JOINT PIPE
③ BRACKET
④ SUPPORTING POST
⑤ BOLT, NUT
⑥ BRACKET ATTACHING BOLT

Figure 10.24 Components of Guard Pipe for Sidewalk

The standard shape of the pipe used for the guard pipe is shown in Figure 10.25.

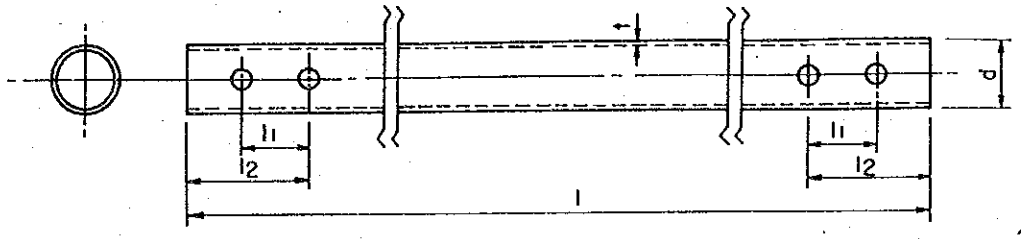
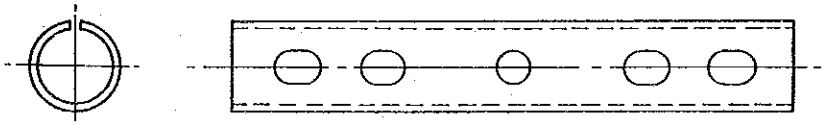
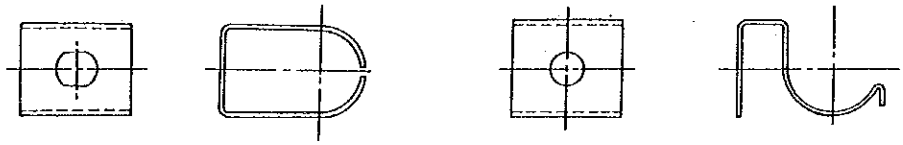


Figure 10.25 Standard Shape of Pipe for Guard Pipe

The inner sleeve type joint is often used as a joint structure. Figure 10.26 illustrates the standard shape of the joint, the joint bracket and the middle bracket.



Joint Pipe



Joint Bracket Middle Bracket

Figure 10.26 Standard Shape of Joint Pipe, Joint Bracket and Middle Bracket

(7) Guard Fence to Prevent Crossing of Pedestrians

Table 10.12 shows the specification for the guard fence to prevent random crossing on the carriageway by pedestrians.

Table 10.12 Specification of Guard Fence to Prevent Crossing of Pedestrians

Guard Fence Class	Shape	Standard Height		Space Between Posts
		Upper Edge	Lower Edge	
P	Free	70 - 80cm	20 - 40cm	Free

The guard fence to prevent random crossing on the carriageway by pedestrians should not present an obstacle of the urban landscape and pedestrians' view. There are several types of guard fence, such as the fence, the pipe, the chain, etc. For any case, the structure of the guard fence should be easy to maintain.

The height of the guard fence should prevent the crossing of pedestrians in normal circumstances; however, it should not be too high to prevent crossing underneath in unavoidable circumstances.

The strength of the guard fence is not specified under the specification. However, as pedestrians may sit down on the guard fence, it is desirable to ensure that the strength of the upper edge of the guard fence is 60kg/m for the vertical direction and 40kg/m for the horizontal direction.

10.2.3 Color and Anti-Corrosive Treatment

(1) Color

The color of the guard fence should be as defined below.

1. In principle, the color of the guard fence should be white. However, a zinc coated guard fence may be able to be used without painting.

2. Any color can be used for the guard fence to prevent crossing by pedestrians.

a) Color of Guard Fence

In principle, the color of the guard fence should be white having consideration for visual guidance.

However, on an intercity highway where the visual guidance effect is not required, due to the good alignment, and there is no necessity to consider the appearance or provision of delineators or marginal strips, the unpainted zinc coated guard fence may be used.

b) Color of Guard Fence to Prevent Crossing by Pedestrians

The color of the guard fence to prevent crossing by pedestrians should be determined in consideration of landscaping aspects; hence any color can be used for this type of guard fence. However, it is desirable to use a white color, if possible, from the visual guidance point of view.

(2) Anti-Corrosive Treatment

1. Beam, Pipe, Bracket and Paddle

Beams, pipes, brackets and paddles used for the guard fence should be hot-dipped zinc coated, and then painted at the factory. In this case, surface treatment, such as the phosphate treatment, is necessary to increase the adhesive efficiency of the paint.

The minimum weight of zinc coating for the material used for the guard fence should be 381 g/m^2. The paint used on the guard fence should be the thermosetting acryloyl resin paint or equivalent and the minimum paint thickness should be 20μ.

2. Supporting Post

The zinc coating and the painting of the supporting post should follow the process described above. However, after zinc coating, it is necessary to use an oil varnish paint on the lower part of the supporting post to be planted.

3. Bolts, Nuts and Joints

Bolts, nuts and joints used for the guard fence should be hot-dipped zinc coated.

4. Guard Fence without Painting

When guard fence is used without painting, the minimum weight of zinc coating should be 550 g/m^2, as defined in TIS 248-2531.

a) Beam, Pipe, Bracket and Paddle

The painting of guard fence materials should be done at the factory.

The hot-dipped zinc coating is the most economical and effective anti-corrosive treatment for steel; hence it is desirable to do this treatment for every materials used for the guard fence.

After the zinc coating, materials should be painted white in considering the following effects.

A. Visual guidance effect.

B. Additional anti-corrosive efficiency.

C. Appearance.

In order to increase the adhesive efficiency of the paint, it is necessary to carry out phosphate treatment on the zinc coated surface. Also, the paint used for coloring the guard fence should be the thermosetting acryloyl resin paint or equivalent, which has less deterioration and weather proofing capability. The minimum paint thickness is determined to be 20μ, in order to completely cover the zinc coating.

Cables used for the guard cable should also be zinc coated, but the minimum weight of the zinc coating can be 300 g/m^2.

In addition, if the hot-dipped zinc coating is unsuitable for those materials used for the guard fence which prevent crossing pedestrians because of their shape, galvanizing can be done instead. In this case, the minimum thickness of coating should be 8μ.

b) Supporting Post

In order to prevent corrosion of zinc coated material at the planted part of the supporting post, it is necessary to use an oil varnish paint on the lower part of the supporting post after zinc coating.

c) Guard Fence without Painting

On an intercity highway where the visual guidance effect is not required, due to the good alignment, and there is no necessity to consider the appearance or provision of delineators or marginal strips, the unpainted zinc coated guard fence may be used. In addition, usage of the zinc coated materials are effective in the corrosive circumstances, as the minimum weight of the zinc coating is increased, because zinc coat thickness and the weather proofing are proportionately related.

Hence, the minimum weight of the zinc coating is defined as 550 g/m^2 for materials without painting.

Also, guard fence without painting may reduce maintenance cost of the guard fence, since repainting work is not required.

10.2.4 Installation Method

The guard fence should be installed in order to achieve the functions based on the road condition survey result.

1. When two or more road sections, with similar road and traffic conditions, are closely located, the same type and class of guard fence should be installed.

2. The guard fence should be installed continuously at a road section with same road and traffic conditions throughout the whole section, except in unavoidable cases.

3. When there is any small structure, such as short span bridge, within a road section constructed on earth works, the same guard fence installed on the earth works section should also be installed on the structure.

4. At road sections where it is necessary to install guard fence, it is necessary to extend the installation length of guard fence 20m beyond each end of the road section.

5. The supporting post of the guard fence should be installed vertically.

6. A guard rail should be installed at the edge of road reserve where it is possible to provide the allowable run-off distance.

7. The end of the guard fence facing oncoming vehicles should be aligned away from the edge if the road as much as possible.

8. The end of the guard fence should be installed having consideration for the geometric design of the road, such as a median opening, an intersection with an approach road, etc.

9. The median guard fence should be installed at the center of the median.

10. The maximum extent of the guard cable should be 500m.

(1) Installation of Same Type/Class of Guard Fence

When two or more road sections, with similar road and traffic conditions, are closely located, a different type and class of guard fence should not be installed, having regard to the function, maintenance, visual guidance and the appearance points of view.

(2) Continuation of Guard Fence Installation

The characteristic of a guard fence is to absorb the collision impact by spreading the force in the longitudinal direction. Hence, any discontinuity of installation reduces this function and the smooth visual guidance effects.

In particular, any discontinuity part of the guard fence should be located at a curved section. In addition, if discontinuity is necessary at an intersection, it is necessary to extend the guard fence into the approach road.

(3) Installation of Guard Fence on a Small Structure

Since the continuous installation of guard fence is desirable from a functional and visual guidance point of view, it is necessary to continuously install guard fence even on small structures in a road section constructed on earth works.

If a large settlement is expected at the interface of earth works section and a structure, installation of guard cable is applicable.

(4) Extension of Guard Fence End

The end of the guard fence cannot satisfy the same functions as for the mid section. Hence, it is necessary to extend the guard fence about 20m on each end.

(5) Installation of Supporting Post

In principle, a supporting post should be installed vertically. However, when a supporting post must be installed in a tilted position, it is necessary to either shorten the space between supporting posts or strengthen the foundation, since the collision force exceeds the design condition.

(6) Allowable Run-off Distance

It is necessary to achieve the allowable run-off distance behind the installed guard fence within the road space.

(7) End Alignment of Guard Fence

At the end of the guard fence facing oncoming vehicles, it is desirable to install guard fence by changing alignment, as shown in Figure 10.27.

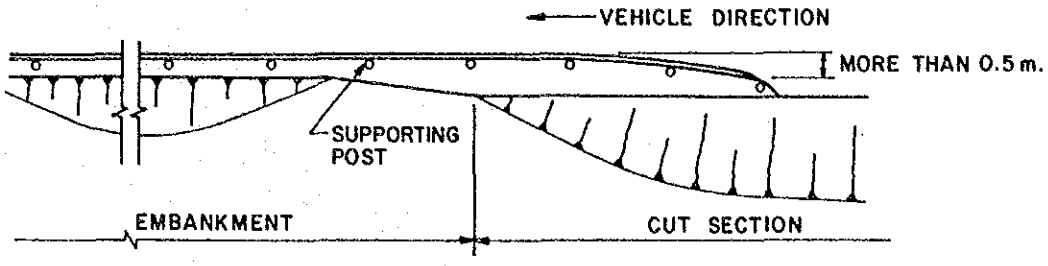


Figure 10.27 End Alignment of Guard Fence

(8) End Treatment of Guard Fence

At the median opening and at intersections, it is necessary to consider the end treatment of a guard fence, in order to prevent the direct collision of a vehicle onto the supporting post with penetration of the beam into the vehicle. Some example of end treatment of various types of guard fence are shown in Figure 10.28.

(9) Installation of Guard Fence on Median

In principle, a guard fence should be installed at the center of the median. However, if any obstruction exists, such as a bridge pier, a lighting pole or traffic sign, the single-face type guard fence can be installed only at that section.

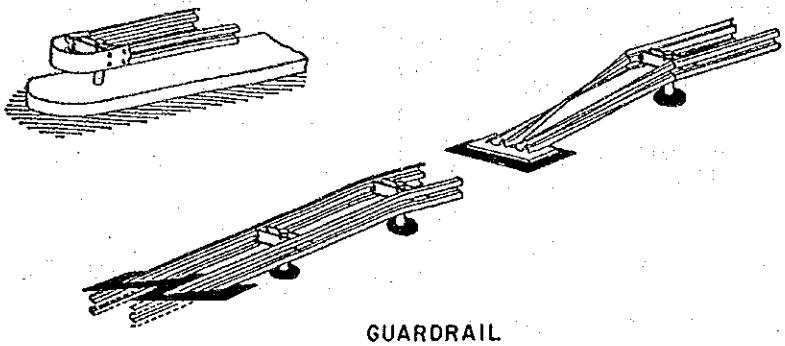
When guard fence installation is necessary on the median on grade, it is desirable to install guard fence as follows.

A. The grade is between 4:1 and 2:1

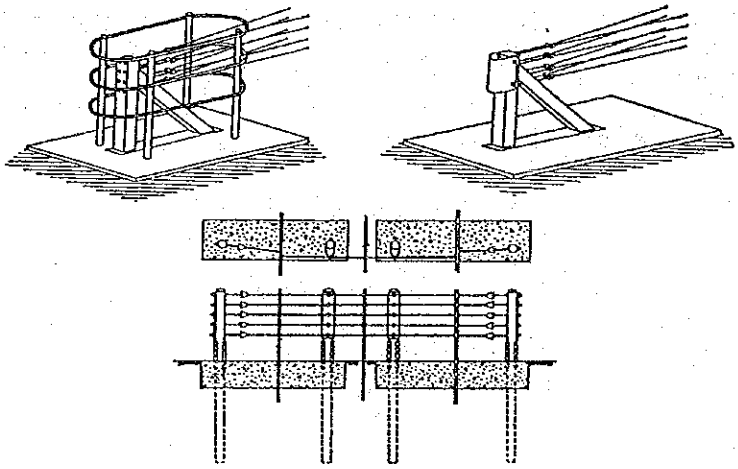
When grade is less than 4:1, the ordinary installation method can be applied. However, when the grade is between 4:1 and 2:1, it is necessary to install guard fence as shown in (1) of Figure 10.29.

B. The grade is more than 2:1

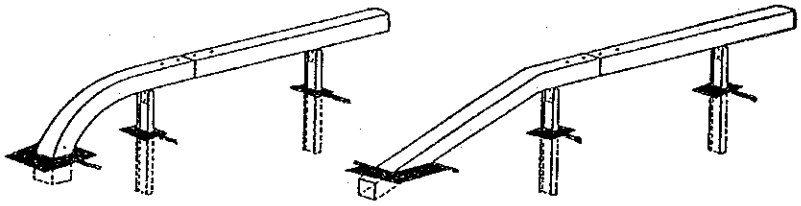
When grade is more than 2:1, it is necessary to install single-face types as shown in (2) of Figure 10.29.



GUARDRAIL



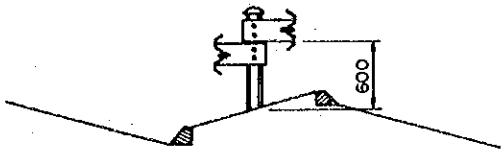
GUARD – CABLE



BOX – BEAM GUARD FENCE

Figure 10.28 End Treatment of Guard Fence

(1)



(2)

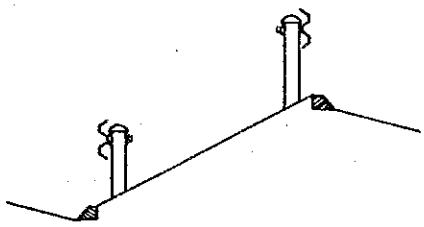


Figure 10.29 Installation of Guard Fence on Median with Grade

(10) The maximum extent of the guard cable is determined as 500m, in consideration of the difficulty for transport of cable, installation and maintenance. If the extent of guard cable exceed 500m, it is necessary to consider the mid-block treatment as shown in Figure 10.30.

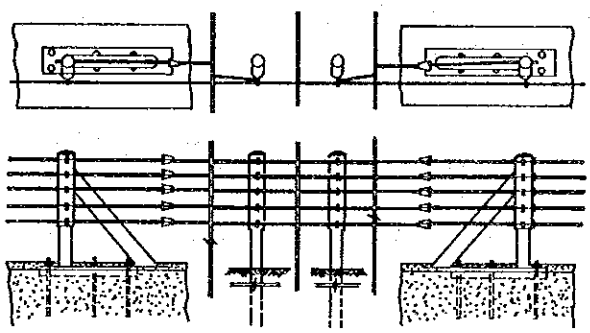


Figure 10.30 Mid-Block Treatment of Guard Cable

10.2.5 Inspection

It is desirable to carry out routine inspection of the guard fence at least once every two months. In addition to the routine inspection, it is desirable to carry out an inspection after a natural disaster, such as a typhoon, together with an inspection of road structure. The necessary inspection items are as follows.

1. Guard Fence

   - Condition of the join between the supporting post and the horizontal component.
   - Subsidence, tilting and bending of the supporting post.
   - Dirt and condition of paint.
   - Deformation and damage of horizontal component of the guard rail and the guard pipe.
   - Damage on the join part of the beam and paddle of the box beam guard fence.
   - Condition of cable slackening of guard cable.

2. Shoulder and Slope

   - Condition of the shoulder and slope.
   - Condition of the drainage facility.

It is important to carry out routine inspection in order to maintain the effectiveness of guard fence. Prior to the inspection, the inspector should have a sufficient understanding of the mechanism, functions and maintenance record of the guard fence and to be aware of important points for the inspection. During routine inspection of the road, it is necessary to check damage and height of the guard fence.

Since the joint strength affects the function of the box beam guard fence, it is necessary to pay attention to any looseness of bolts and nuts and tighten then if necessary.

Since the tensile force of the cable greatly affects the efficiency of the guard cable, it is necessary to inspect the slackening of cable.

It is desirable to carry out an extra inspection after a natural disaster to check the condition of the shoulder and the slope. When any looseness, collapses or cracks are found on the shoulder or the slope during the inspection, it is necessary to repair immediately to maintain the function of the guard fence.

10.2.6 Maintenance

1. Maintenance

   If any damage or deformation on the guard fence is found during inspection achieve the function of the guard fence is impaired, it is necessary to rectify it as soon as possible.

2. Cleaning

   It is desirable to carry out cleaning of the guard fence monthly along an unpaved road and once or twice a year along a paved road.

3. Painting

   When the paint surface is removed by damage or deterioration, it is necessary to repaint as soon as possible.

When any damage on the guard fence is found during the inspection, it is necessary to carry out maintenance, in order to maintain the design function of the guard fence. If the height between the pavement surface and the guard fence is changed due to pavement overlay works, it is necessary to adjust the height or install another guard fence on outside of the existing one in order to maintain the proper function.

It is desirable to carry out cleaning of the guard fence monthly along an unpaved road and once or twice a year along a paved road.

Prior to repainting of the guard fence, it is necessary to completely remove rust and to carry out phosphate treatment. If any components suffers a large deformation through vehicle collision, that part should be replaced. However, light damage can be repaired by repainting.

10.2.7 Record

When the guard fence is damaged, it is necessary to record the damaged extent, the road condition at the damaged location and cause of the damage.

When the guard fence is damaged, it is necessary to record the damaged extent, the road condition at the damaged location and cause of the damage. It is important for the road authority to examine the road structure and traffic control based on this record.

CHAPTER 11 PAVEMENT TREATMENT

CHAPTER 11 PAVEMENT TREATMENT

11.1 TECHNICAL GUIDELINE

11.1.1 General

The characteristics of the pavement surface will influence its trafficability. The trafficability is classified into riding quality, traffic safety and comfortability. In addition, it is also necessary to consider environmental aspects at the same time. The environmental aspect usually covers noise, air pollution and vibration.

The relationship between a pavement surface characteristic and trafficability or environmental aspect is shown in Table 11.1.

Table 11.1 Pavement Surface Characteristics and Trafficability or Environment

Trafficability/ Environment		Surface Characteristics
Trafficability	Riding Quality	- Surface roughness - Evenness of surface * Longitudinal * Transversal - Faulting - Disruption
	Traffic Safety	- Skid resistance - Rutting of pavement - Faulting - Disruption
Environment	Noise	- Surface roughness (texture)
	Vibration	- Evenness of surface - Faulting - Disruption

To secure these trafficability and environmental conditions, the recommended target value for the characteristics of the pavement surface are as shown in Tables 11.2 and 11.3.

Table 11.2 Recommended Target Value for Pavement Rehabilitation (Asphalt Pavement)

Item / Road Classification	Rutting Depth (mm)	Bump(mm)		Skid Resistance Coefficient	Longitudinal Roughness (mm)	Pot Hole Diameter (cm)
		Abutment	Culvert Box			
Express Highway	25	20	30	0.25-0.3**	90 (PrI cm/km) (8m Profile meter) 3.5(σ) (3m Profile meter)	20
Highway with Heavy Traffic	30-40	30 (60)*	40 (60)*	0.25-0.3**	4.0-5.0(σ) (3m Profile meter)	20
Other Highways	40	30 (60)*	-	-	-	20

Note : * (σ) Soft ground with heavy displacement, suburb of Bangkok.
** Measuring speed on Express Highway 80 km/hr, on Highway 60 km/hr.

Table 11.3 Recommended Target Value for Rehabilitation (Cement Concrete Pavement)

Item / Road Classification	Rutting Depth (mm)	Bump (mm)	Skid Resistance Coefficient	Longitudinal Roughness (mm)
Express Highway	25	10	0.25-0.3**	90 (PrI cm/km) (8m Profile meter) 3.5(σ) (3m Profile meter)
Highway with Heavy Traffic Vol.	30-40	15	0.25-0.3**	5.0(σ) (3m Profile meter)
Other Highways	40-50	-	-	-

Note : * (σ) Soft ground with heavy displacement, suburb of Bangkok.
** Measuring speed on Express Highway 80 km/hr, on Highway 60 km/hr.

11.1.2 Treatment of Pavement

(1) Skid Resistance

The skid resistance of a pavement surface is very important for traffic safety. Especially in situations when a vehicle needs deceleration - at an intersection approach, a curved section etc. The coefficient of skid

resistance is shown in Tables 11.2 and 11.3 for the recommended target value for pavement rehabilitation. The coefficient of skid resistance is small when the pavement surface is wet and the running speed is high.

a) Survey of Slippery Road

It is not unusual for hazardous road sections which are selected by the identification method and accident pattern analysis, to find the cause of accident at some of the road segments is found to be attributable to the skidding of vehicle.

For the determination of the slipperiness of the road surface, the following reviews are generally made.

1) Wet Accident Ratio

The wet accident ratio is normally calculated by the following equation;

$$\text{Wet accident ratio} = \frac{\text{Wet Accident}}{\text{Wet Accident + Dry Accident}} \times 100\%$$

If this ratio is more than 30-50%, the cause of accident is considered to be the slipperiness of road surface.

2) Wet Skid Resistance Coefficient

If it is possible, it is recommended the wet skid resistance coefficient of a road be measured. When the coefficient of friction is small (refer to Table 11.4 and following table), it should be decided whether the cause of accident on such a road segment is the slipperiness.

Table 11.4 Recommended Minimum Interim Skid Numbers (Proposed, H R B, U.S.A.)

Main traffic speed V (mph)	Skid number	
	SN_b	SN_{40c}
0	60	–
10	50	–
20	40	–
30	36	31
40	33	33
50	32	37
60	31	41
70	31	46
80	31	51

Note :
1. On the basis of the measuring method of ASTM E-274.
2. SN_b is the measured value at mean traffic speed.
3. SN_{40} is the measured value at 40 mph speed.
4. Skid number is 100 times the coefficient of skidding friction. The same applies for others.

b) Countermeasures

As countermeasures for the skidding of a road surface, there are several elements to be considered.

1) Binding Materials

For both asphalt pavements and cement concrete pavements, the content of binding material (asphalt bitumen, portland cement) should be minimized. For cement concrete pavements, a cement content less than 300 kg/m^3 is preferable and a maximum of 330 kg/m^3 is recommended for skidding prevention. When more than 330 kg/m^3 is used, it is advisable to test the skidding resistance before construction. For asphalt pavements, the content of asphalt should be minimized within the limits of Marshall Stability Test.

It is also recommended to use special binding materials (rubber-mixed asphalt, high molecular polymerized), if available.

2) Aggregate

Limestone and metamorphic rock are not ideal for skid resistance. Slag, sandstone, emery, silica sand are good materials for skid resistance.

3) Mixture

For anti-skid asphalt pavements, open graded asphalt concrete is recommended, as shown in Table 11.5.

Table 11.5 Mix Proportion of Aggregates for Open Graded Asphalt Concrete

Compacted Thickness (cm)		3 - 4
Max Particle Size (mm)		13
Weight percent Passing sieve	26.5 mm	-
	19	100
	13.2	95 - 100
	4.75	23 - 45
	2.36	15 - 30
	0.6	8 - 20
	0.3	4 - 15
	0.15	4 - 10
	0.075	2 - 7
Asphalt Content (%)		3.5 - 5.5

4) Surface Treatment

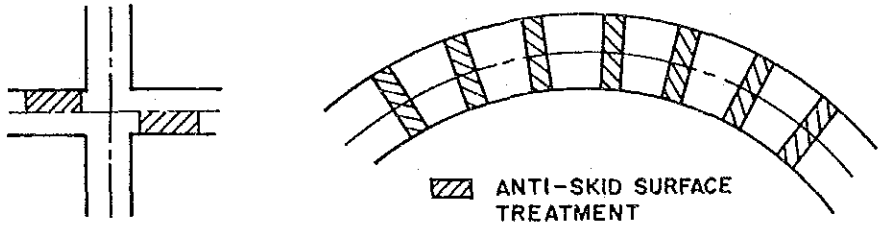
For anti-skid surface treatments, the following methods are recommended;

A. The spread of hard aggregates over the sphalt mixed layer and compact (rolled asphalt).

B. The spread of asphalt coated gravel over the asphalt mixed layer.

C. Surface dressing; the spread of epoxy resin 1.5 kg/m² (standard case) and the spread of aggregate (1.2 - 3.2 mm) 7 kg/m² over the epoxy resin.

These treatments are not only useful for anti-skid pavements, but also useful for speed control. These forms of pavement generate about 3-5 dBA higher noise levels compared with dense graded asphalt concrete pavements. These pavements are useful at an intersection approach or curved section where control of a high running speed is desirable, as shown in Figure 11.1.



(a) Intersection (b) Curved Section

Figure 11.1 Application of Anti-Skid Surface Treatment

5) Grooving on the Surface of Pavement

The grooving method is also used for anti-skid purposes. This method is particularly effective for hydroplaning on high-speed highways. Nowadays, the tine grooving method is also used as a simple and cheap grooving procedure. The tine grooving method involves scratching a fresh concrete pavement surface with a steel wire.

c) Skidding on the Pavement Marking

The coefficient of skid resistance on several markings have been tested in Japan, as shown in Figures 11.2 and 11.3. These figures show that the coefficients of skid resistance on cold paintings are very small. On deposited paintings, they are slightly higher, but compared to ordinary pavement surfaces, they are half or 2/3 of the values indicated.

These show that the surface of markings is very slippery under wet conditions. From the view point of slipperiness, a deposited painting is better than a cold painting. If possible, a sand (abrasive material such as silica sand etc.) mixed marking is recommended, but it is expensive. From the view point of safety, wide markings should not be used, particularly where the vehicle will run on a curved path. (curved section, turning lane etc.)

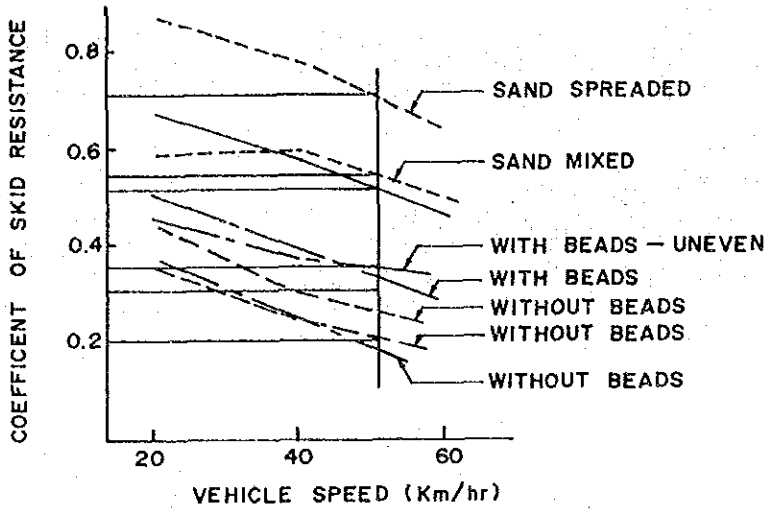


Figure 11.2 Coefficient of Skid Resistance on Pavement Markings Just after Painting

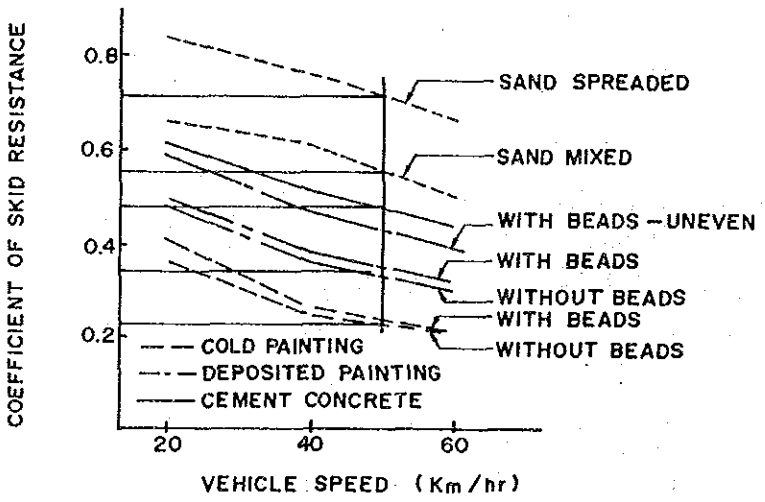


Figure 11.3 Coefficient of Skid Resistance on Pavement Markings 17 Months after Painting

11.1.3 Evenness of the Pavement Surface

The macro roughness of a pavement surface is called the evenness of the pavement. The evenness of the pavement contains longitudinal evenness, transversal evenness and pot hole or stripping.

(1) Longitudinal Evenness

The longitudinal evenness of a pavement is measured in terms of profile. The profile index is used as the target value for rehabilitation work from the view point of traffic safety and comfortability. Countermeasures for longitudinal evenness are overlay, armor coat or carpet coat.

(2) Transversal Evenness (Rutting)

The transversal evenness is measured in terms of the cross-sectional profile. The main cause of rutting is excessive traffic of heavy vehicles. A road with deep rutting creates water splashing during rainy periods and vehicle operations become dangerous. Countermeasures for rutting are milling of protruded sections, carpet coat or overlay.

(3) Pot Hole or Stripping

Pot holes not only detract from the travelling comfortability, but they are also dangerous to vehicle operation. Countermeasures are patching or partial reconstruction.

11.1.4 Roughness (Surface Texture)

The micro roughness of a pavement surface is named as surface texture. The surface texture influences the riding quality - comfortability and traffic noise. Measuring methods of a pavement surface texture are roughness meter, micro profilograph, stereophotograph, sand patch method and water out flow meter. General relationships between the pavement roughness and power level of traffic noise are shown in Figure 11.4. Countermeasures for surface texture are armor coat or carpet coat.

11.1.5 Faulting

Faulting is an irregularity in the vicinity of structures. Figure 11.5 shows the measuring method of the faulting.

Faulting influences the riding quality, safety of vehicle operation and traffic vibration. Countermeasures are patching or partial reconstruction.

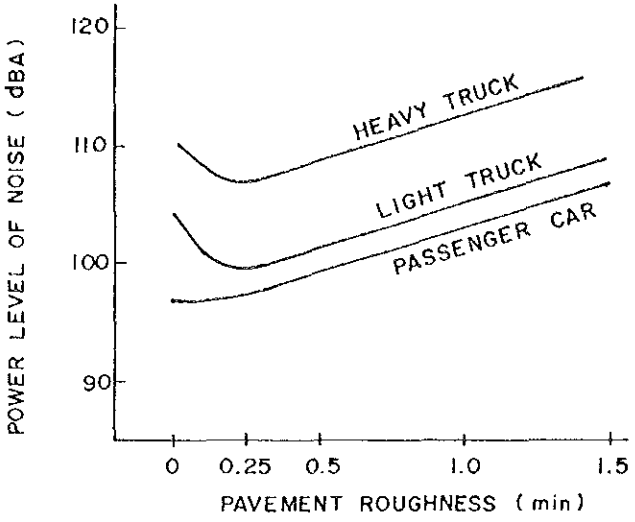


Figure 11.4 Power Level of Noise and Pavement Roughness (Pavement roughness by sand patch method)

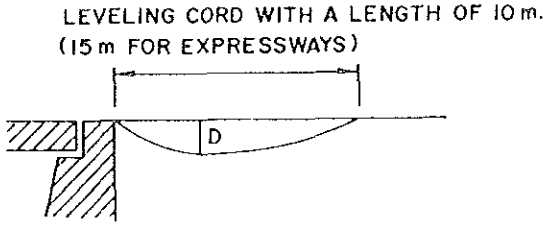


Figure 11.5 Method of Measuring Faulting

CHAPTER 12 OTHER FACILITIES

CHAPTER 12 OTHER FACILITIES

12.1 VEHICLE DETECTOR

12.1.1 Technical Guideline

1. It is desirable to install vehicle detectors for continual traffic surveys at most suitable locations for traffic data collection.

2. Vehicle detectors for traffic signal operation should be installed at appropriate locations which have been designed under the traffic signal installation plan.

(1) Vehicle Detector for Continual Traffic Survey

In order to maintain the efficiency of the continual traffic surveys, whose main objectives are "Identification of traffic congestion", "Identification of traffic fluctuation" and "Collection of basic data for traffic engineering", it is a requisite to select the most suitable locations to install vehicle detectors.

Basically, guidelines for the selection of locations for the installation of vehicle detectors can be summarized according to the object of the continual traffic survey. However, a final decision should be made after comparisons of preliminary traffic survey results at proposed road sections.

a) Collection of Basic Data for Traffic Engineering

Vehicle detectors for the purpose of collection of basic data for traffic engineering should be installed at road sections where data collection is very useful for traffic operation planning.

b) Identification of Traffic Fluctuation

Vehicle detectors for the purpose of identification of traffic fluctuations should be installed at road sections where the difference of the number of traffic congestions between an ordinary working day and a holiday are 3 times or more, based on the results of traffic congestion survey.

c) Identification of Traffic Congestion

Vehicle detectors for the purpose of identification of traffic congestion should be installed at road sections where traffic congestions are observed at least 3 times in an ordinary working day, based on the results of

traffic congestion surveys.

(2) Vehicle Detector for Traffic Signal Operation

This type of vehicle detector should be installed based on traffic signal operation planning. This will differ at each location and guidelines for the installation are discussed in Chapter 1.

12.2 ROAD INFORMATION SYSTEM

12.2.1 Technical Guideline

1. If it is required to inform the latest and accurate information to road users, such as road, weather and traffic conditions, or traffic control, installation of apparatuses for traffic information is desirable in order to maintain a safe and smooth road traffic.

(1) Variable Message Signs

Installation of variable message signs are aimed to inform to road users the latest and accurate road, weather and traffic conditions, or traffic control, in order to maintain a safe and smooth traffic. This information will differ hour to hour and from day to day.

Prior to the installation of variable message signs, it is necessary to prepare an installation plan for determining the type and location of installations. This will depend on the contents of information provided for road users, in order to secure an effective use of information and to maintain the safe and smooth traffic.

It is desirable to install variable message signs at locations such as both sides of a traffic control section and at bottleneck road sections for unusual weather conditions: at entrance and exit points of an urban area: at major points in urban areas: at intersections of major trunk roads, etc. It is also desirable to install variable message signs along major trunk roads at appropriate intervals.

The types of signs should be determined in due consideration of the contents of information to be provided; the road structure required for installation; location and management system; to take into consideration the characteristics of the various types of signs. Variable message signs can be classified into the following types;

A. Classification by display method:

Slide-in type, Scroll type, Lens matrix type,
Bulb matrix type, Magnet reverse type

B. Classification by control method:

Manual type, Remote control type

C. Classification by installation method:

Pedestal type, Overhang type, Overhead type

D. Classification by display capability:

Fixed pattern type, Free pattern type

(2) Apparatuses for Weather Observation

Bad weather conditions, such as rainfall, strong gusts and fog, may cause slope failures, slipperiness, anxiety of vehicle operation and obstruction of the visual field. These situations may obstruct traffic operations as well as the road structure itself. It is desirable to install apparatus for weather observations, such as a pluviometer, a wind gauge and a thermometer, in order to monitor bad weather conditions, accordingly.

(3) Apparatuses for Traffic Interception

At a road section where there is possibility of rock erosion, slope failures and landslides resulting from heavy rainfall, washout by waves along the seaside which would be a hazard for vehicles and pedestrians under abnormal weather conditions, it is desirable to install apparatuses for traffic interception which could stop vehicle and pedestrian traffic entering a possible hazardous or actual disaster area.

This apparatus for traffic interception is either a manual or electrical control bar. It is also desirable to install an information board indicating standards for traffic control as well as the reason for the control.

12.3 BUS STOP FACILITY

12.3.1 Technical Guideline

(1) Bus Stop Facility

The determination of the size and location of bus stop facilities should depend on the type of bus and take into due consideration the needs of smooth stopping and acceleration.

A bus stop facility consists of a bus bay and a bus stop.

- Bus bay : Exclusively utilized for stopping buses by a separation from the carriageway.
- Bus stop : Outside lane is utilized for stopping buses.

(2) Bus Bay

1. A bus bay should be provided on highways with a design speed of more than 80 km/h. 2. A bus bay should be provided on other types of highways, if necessary, when the stopping of a bus on the carriageway would disturb the main traffic flow, and/or reduce the traffic capacity to be less than the design traffic capacity.

For highways with a high running speed, bus bays separated from the carriageway should be provided in order to avoid confusion of traffic flow. This may also cause traffic accidents where buses stop on carriageway.

For other types of highways, provision of bus bays are desirable, when the stopping of a bus on the carriageway would disturb the main traffic flow, and/or reduce the traffic capacity to be less than the design traffic capacity. However, the provision of only bus stops might be sufficient for these road sections, if smooth traffic flow and increased traffic capacity are secured by traffic regulations, such as parking prohibition during peak hours.

(3) Location of Bus Bay

A bus bay should be located along a straight road section or curved road section where the curve is less than the standard radius of curve in order to secure a suffi-

cient sight distance as well as provide for a smooth maneuvering of buses.

In addition, a bus bay should not be provided on a steep gradient section. If provision of a bus bay is necessary on a steep gradient section, a grade value of less than 2% (or 3% for an unavoidable case) should be secured for at least a bus stopping lane, by separating the vertical alignment of a bus bay from the main carriageway, as shown in Figure 12.1. For this case, it is necessary to provide sufficient vertical curves at speed change lanes.

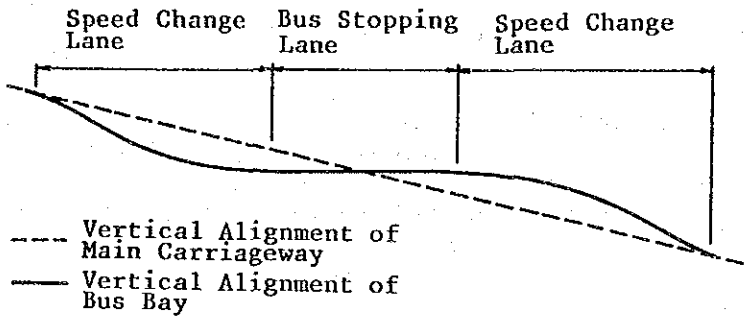


Figure 12.1 Separation of Vertical Alignment at Bus Bay

(4) Element of Bus Bay on Highways with Design Speed of more than 80 km/hr

Bus bays on these type of highways should principally be separated from the main carriageway by an outer separator, with provision of speed change lanes, in order to minimize the effects of stopping buses on the main traffic flow.

A bus bay consists of speed change lanes and a stopping lane as shown in Figure 12.2. The standard length of a bus bay should be determined by referring to Table 12.1 in consideration of the traffic volume, the frequency of bus bay utilization and roadside conditions.

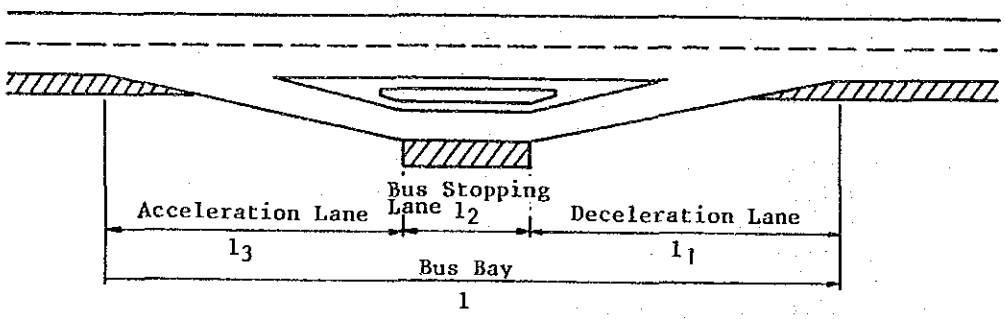


Figure 12.2 Element of Bus Bay on Highways with Design Speed of More Than 80 km/hr

Table 12.1 Length of Bus Bay on Highways with Design Speed of More Than 80 km/hr

Unit : m

Design Speed (km/hr		80	60	50
Deceleration Lane Length	l_1	35	25	20
Bus Stopping Lane Length	l_2	15	15	15
Acceleration Lane Length	l_3	40	30	25
Bus Bay Length	l	90	70	60
Weaving Length		80	50	40

As a general rule, the width of the speed change lane and stopping lane should be 4.0m. Even in a very unfavorable situation, the width of the bus lane including shoulder must be a minimum 4.0m. It is desirable the width of an outer separator to be 2.00m. The minimum value of the sidewalk width along the bus stop should be 2.75m.

(5) Element of Bus Bay on Other Highways

Bus bays on other types of highways should be separated from the main carriageway by a lane line marking of 1.00m width.

A bus bay consists of speed change lanes and a stopping lane as shown in Figure 12.3. The standard length of a bus bay should be determined by referring to Table 12.2 in consideration of the traffic volume, the frequency of bus bay utilization and roadside conditions.

When a bus bay is provided near an intersection, the bus bay should be kept at a distance from an intersection to secure the necessary weaving length.

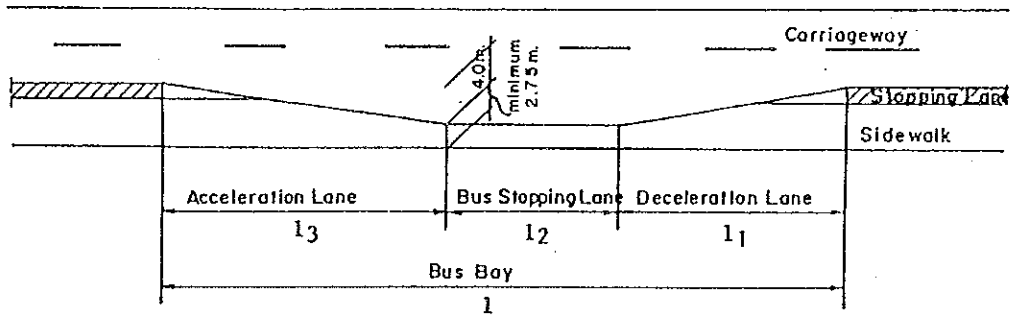


Figure 12.3 Element of Bus Bay on Other Types of Highways

Table 12.2 Length of Bus Bay on Other Types of Highways

Unit : m

Design Speed (km/hr)		80	60	50	40
Deceleration Lane Length	l_1	30	20	15	12
Bus Stopping Lane Length	l_2	15	15	15	15
Acceleration Lane Length	l_3	30	25	20	13
Bus Bay Length	l	80	60	50	40
Weaving Length		80	50	40	30

As a general rule, the width of the speed change lane and stopping lane should be 4.0m. Even in a very unfavorable situation, the width of the bus lane including shoulder must be at minimum 4.0m. It is desirable the width of an outer separator to be 2.00m. The minimum value of the sidewalk width along the bus stop should be 2.75m.

(6) Bus Stop

It is desirable to indicate the location of a bus stop by pavement markings at a bus stop without provision of a bus bay.

It is desirable to indicate the location of a bus stop in order to exclude illegal parking vehicles at a bus stop. Such parking vehicles at a bus stop force bus drivers to load/unload passengers on the carriageway, which may cause confusion to the main traffic flow.

The size of a bus stop marking is principally 2.5m in width and 20m in length. However, the length can be extended depending on the volume of bus traffic by 10m for each bus space. It is also desirable to indicate "BUS STOP" in Thai to be included with the bus stop marking.

12.4 GRADE SEPARATION AT RAILWAY CROSSING

12.4.1 Technical Guideline

1. Road and railway crossing should be grade separated in principle.
2. For the planning of a grade separation, it is necessary to consider the future plan of both road network and railway. In addition, it is also necessary to consider the road network configuration in the area.

(1) Standard of Grade Separation at Railway Crossing

At present, one cause of traffic bottlenecks is at-grade railway crossings; hence exclusion of at-grade railway crossings is considered to contribute to the better road traffic operation.

Therefore, in principle, it is desirable to provide grade separation at railway crossings, except in the following cases;

A. "Traffic Movement" (T.M.) value, which is the value obtained by multiplying the ADT on DOH road and number of passing trains at railway crossing for 24 hours, is 100,000 or less.

B. The location where provision of grade separation is economically unfeasible.

C. Difficulty of grade separation due to site condition.

D. Temporary railway crossing.

E. Near a railway station, where the efficiency of roads or railway may reduced due to provision of grade separation.

Concerning the 1st and the 2nd items, there is an agreement between DOH and the State Railway of Thailand about the guidelines for constructing a grade separation at railway crossings. In this agreement, the T.M. value is employed as an index to determine the necessary measure for the railway crossing. According to this guideline, where the T.M. value is more than 100,000, construction of a grade separation should be considered, if it is economically feasible. Hence the guideline in the Study also follows the concept of this agreement.

As a reference, the kinds of benefits considered to be used in the economic evaluation and the concept of the construction cost burden employed in Japan are described

at the end of this chapter.

Generally, the structure of a grade separation is a permanent structure and it is difficult to modify it after completion. Therefore, for the planning of grade separation, it is necessary to consider the existing situation as well as future plan of both road network and railway prior to the final decision.

In addition, it is also necessary to study the road network configuration including the project road for the grade separation, and elevation of a certain portion of railway can be considered, if it will be appropriate from the technical and economical point of view.

(2) Reference

a) Item of Benefits

The following benefits are considered to be used in the economic evaluation of construction of a grade separation at a railway crossing.

A. Time saving benefit of vehicles.

B. Fuel saving benefit of vehicles.

C. Benefit from reduced accidents between the vehicle and the train.

D. Benefit from reduction in security personnel at the railway crossing.

E. Benefit from reduced the maintenance cost of railway crossing facilities.

b) Construction Cost Burden Employed in Japan

A. When a railway crossing is removed either by construction of a road flyover or the construction of a bypass, the construction cost burden between the road administrator and the railway administrator should follow the concept shown in Table 12.3.

In this concept, the amount borne by the railway administrator is defined by number of tracks, type of railway crossing to be removed and number of lanes on the crossing road. This amount is calculated based on the benefits for railway administrator due to the removal of a railway crossing. These benefits are mainly a saving in maintenance cost of the railway crossing, such as the personnel expenses, expenses of facilities, maintenance cost and the amount of damage caused by accidents at the railway crossing.

Table 12.3 Construction Cost Burden of Grade Separation of Railway Crossing

Item		Road	
		Existing	Widening
Railway	Existing	Railway : Certain Amount Road : Remaining Cost	Road : 100%
	Additional Track	Railway : 100%	Road : 50% Railway : 50%

B. When an existing railway crossing remains after construction of a road flyover or a bypass, the entire construction cost should be borne by the road administrator.

C. When a railway crossing is removed by construction of a railway flyover, the burden of the construction cost should be determined through the discussion of the road administrator and the railway administrator.

12.4.2 Engineering Specification

1. It is desirable to construct a grade separation of a railway crossing at a location where the horizontal and vertical alignments are good for both road and railway.

2. For design of a grade separation, it is necessary to pay attention to the railway structural profile (clearance), the sight distance, the drainage, safety facilities, the land use adjacent to the grade separation, etc.

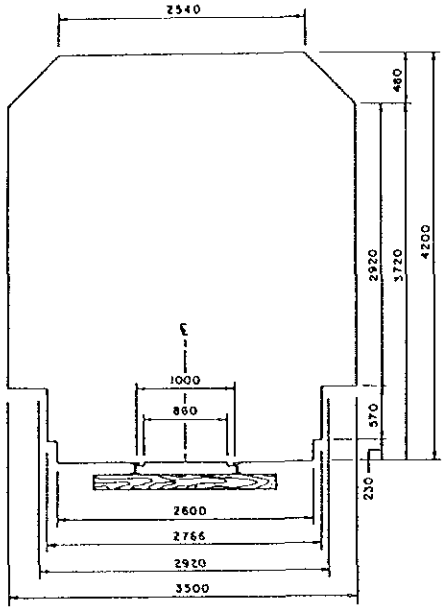
The structural profile defined by the State Railway of Thailand (SRT) is shown in Figure 12.4 for the single track and double track sections. Also, it is necessary to ensure additional clearance in the construction for maintenance requirements.

When it is necessary to include a horizontal or vertical curve on the grade separation for both an overpass or an underpass, it is necessary to ensure adequate sight distance.

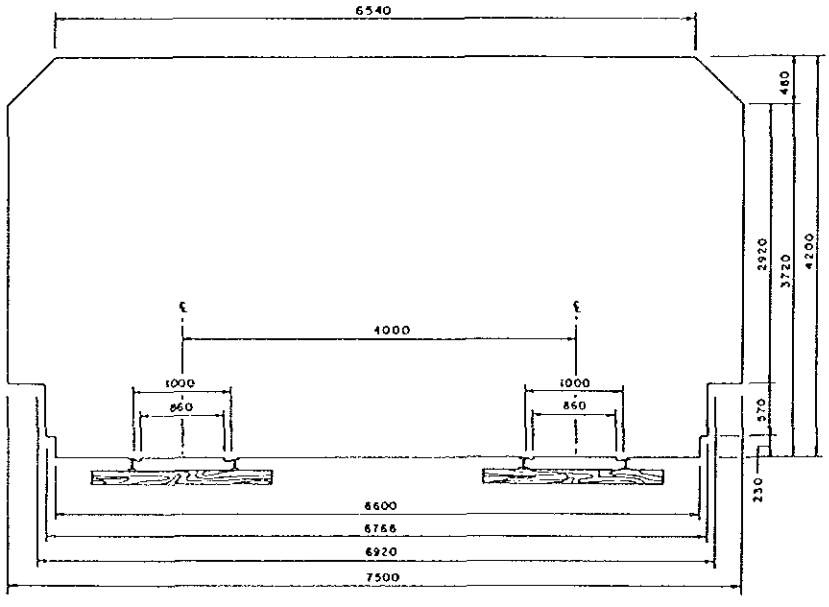
When the road underpasses the railway, it is necessary to install a proper drainage system, in order to avoid water lying at the bottom of the underpass and concentration of drainage water from railway facilities.

For installation of a guard fence, particularly on an overpass, it is necessary to consider the height and structure of curb and strength of the handrail.

In urban areas, it is necessary to pay attention not only to through traffic, but also for traffic related to the roadside area. Generally, an additional road or a frontage road is constructed. In this case, the geometric design of these roads should not permit a level crossing of the railway, but provide an U-turn facility only.



SINGLE TRACK



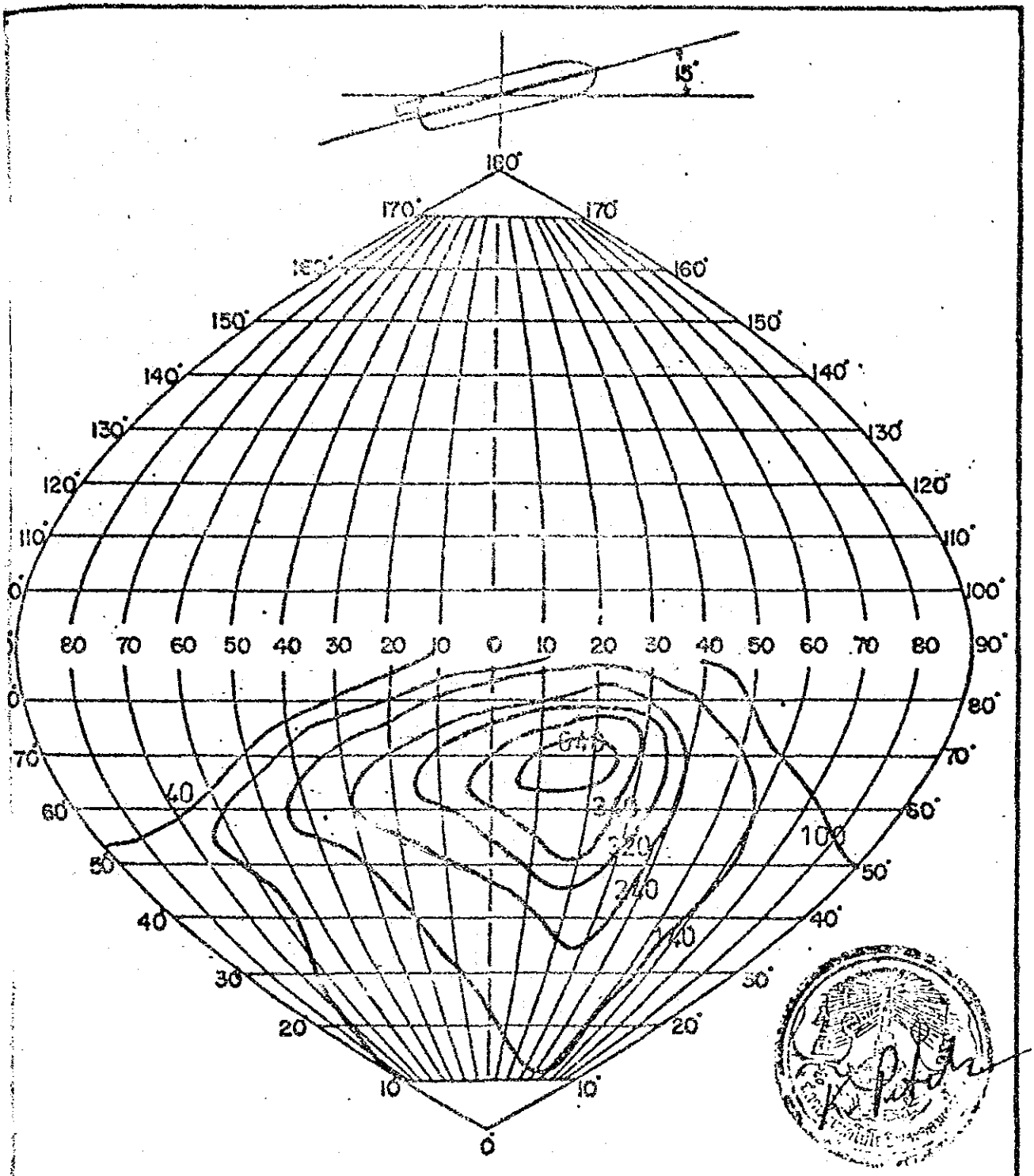
UNIT : MM.

DOUBLE TRACK

SOURCE : STATE RAILWAY OF THAILAND

Figure 12.4 Structural Profile Defined by SRT

APPENDIX



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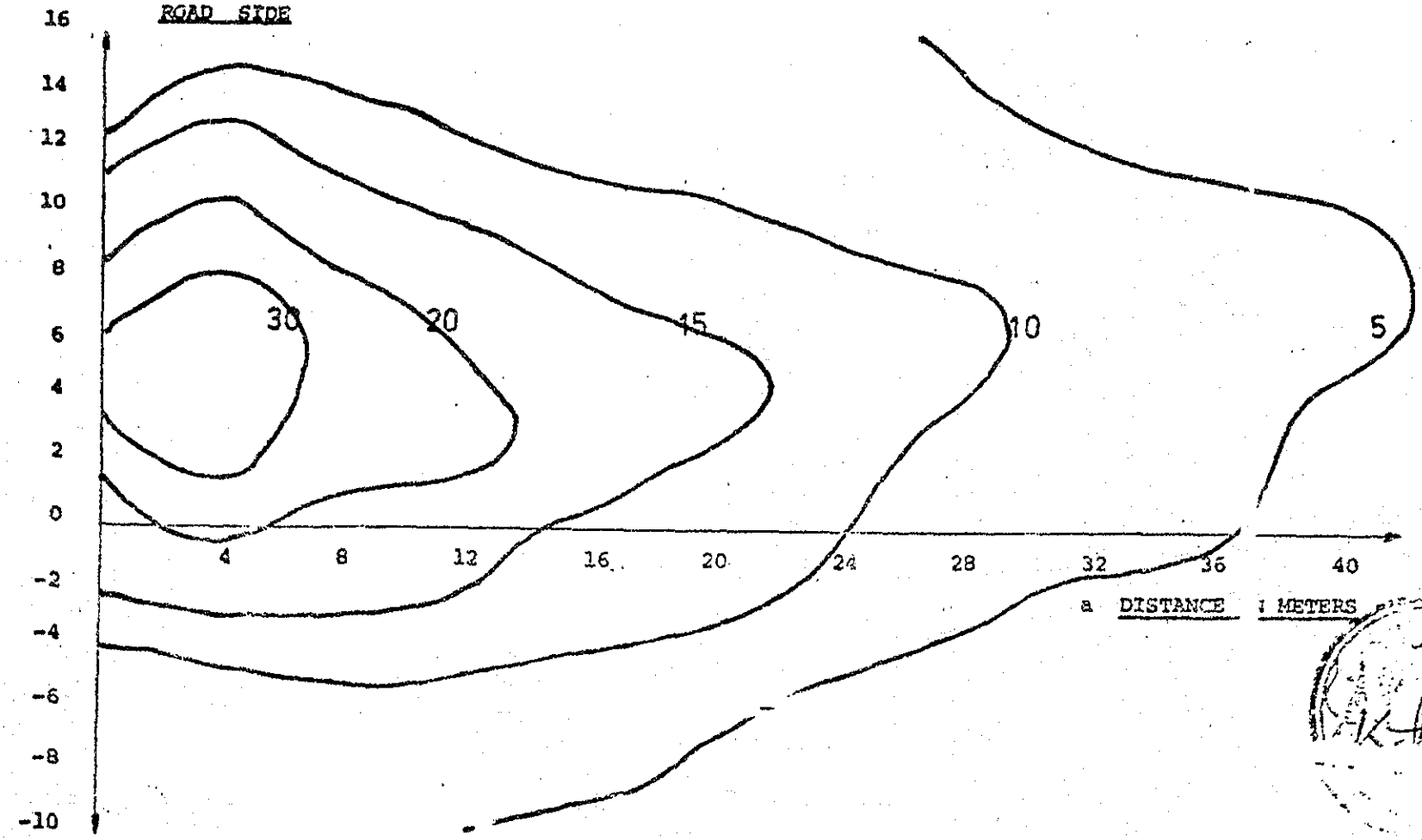
MP	: SYLVANIA LU400	CHECKED BY	K. Patel
TTS	: 400 W. 50,000 LUMENS		
ST DISTANCE	: 4 M. 15° TILT	DATE	JULY 25, 1980
PPLY VOLTAGE	: 220 V 50 Hz.		
NE CURRENT	: A. INPUT WATTAGE W.		

ISOLUX CURVES
In Lux



LUMINAIRE : CDC TYPE HPS 1.400C

LAMP : SYLVANIA LU400 - 50,000 Lumens

MOUNTING HEIGHT : 14.0 M TILT 15°

FACULTY OF ENGINEERING - KMIT LADKRABANG	
TESTED BY	S Bunyong-it
CHECKED BY	K. Petch
DATE	JULY 25, 1980

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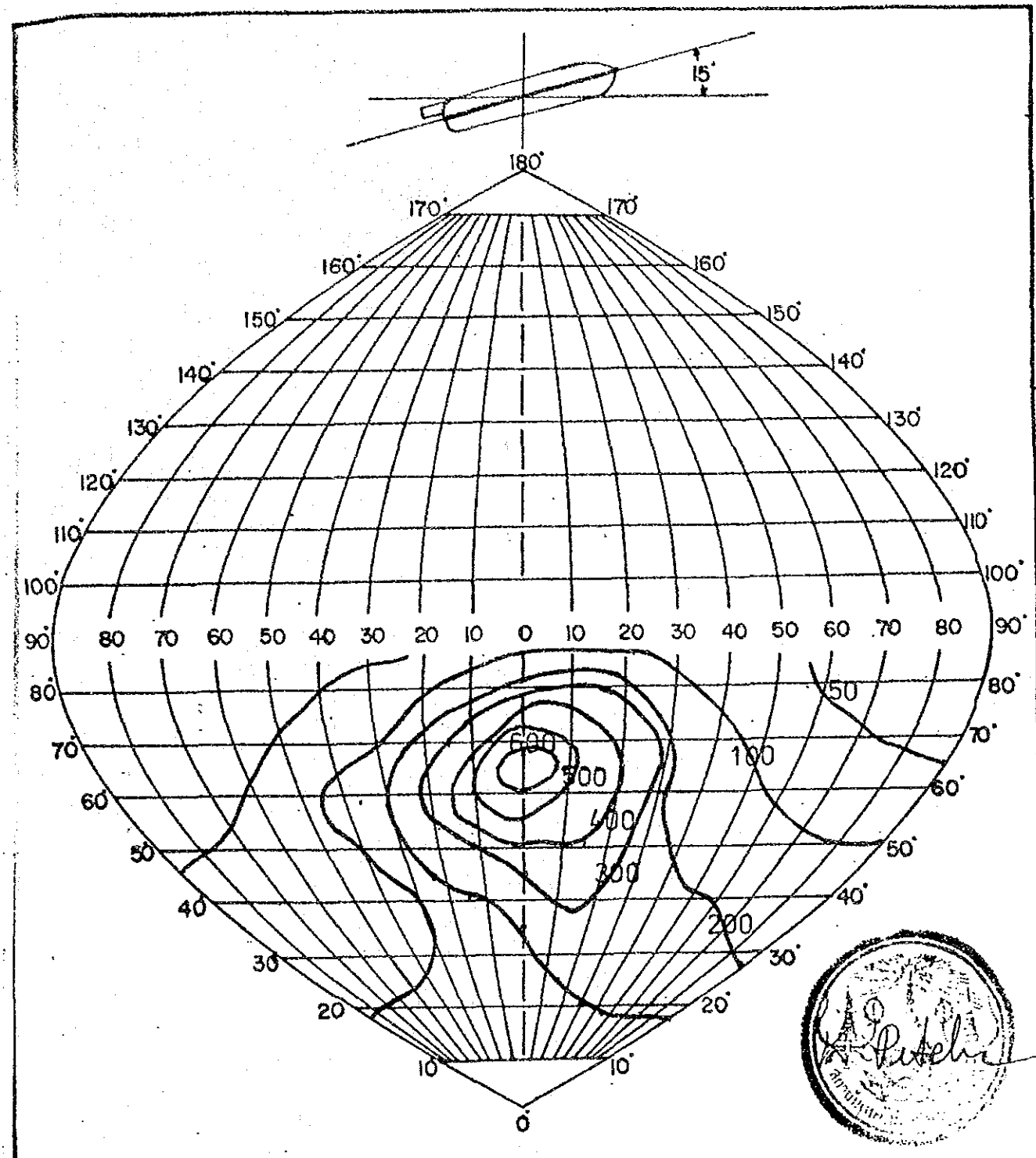
8.1 (2)



ISOCANDELA LINES ON SANSON'S NET		FACULTY OF ENGINEERING KMIT LADKRABANG	
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LAMP	: SYLVANIA LU250	DRAWN BY	/
WATTS	: 250 W 25,500 LUMENS	CHECKED BY	K. Petch
TEST DISTANCE	: 4 M. TILTING 15°	DATE	July, 30, 1980
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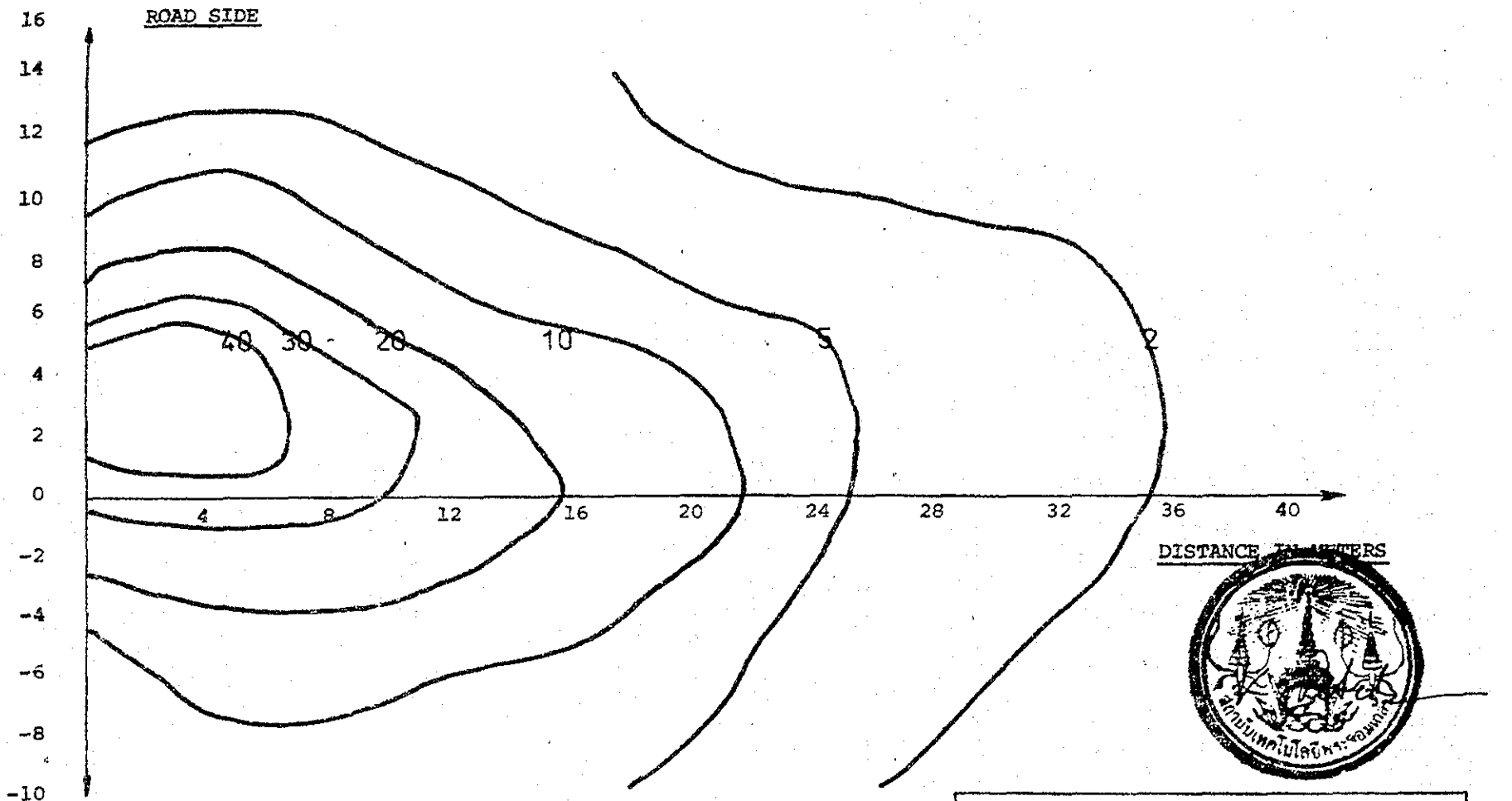
LINE CURRENT	: A INPUT WATTAGE W		

ISOLUX CURVES

In LUX



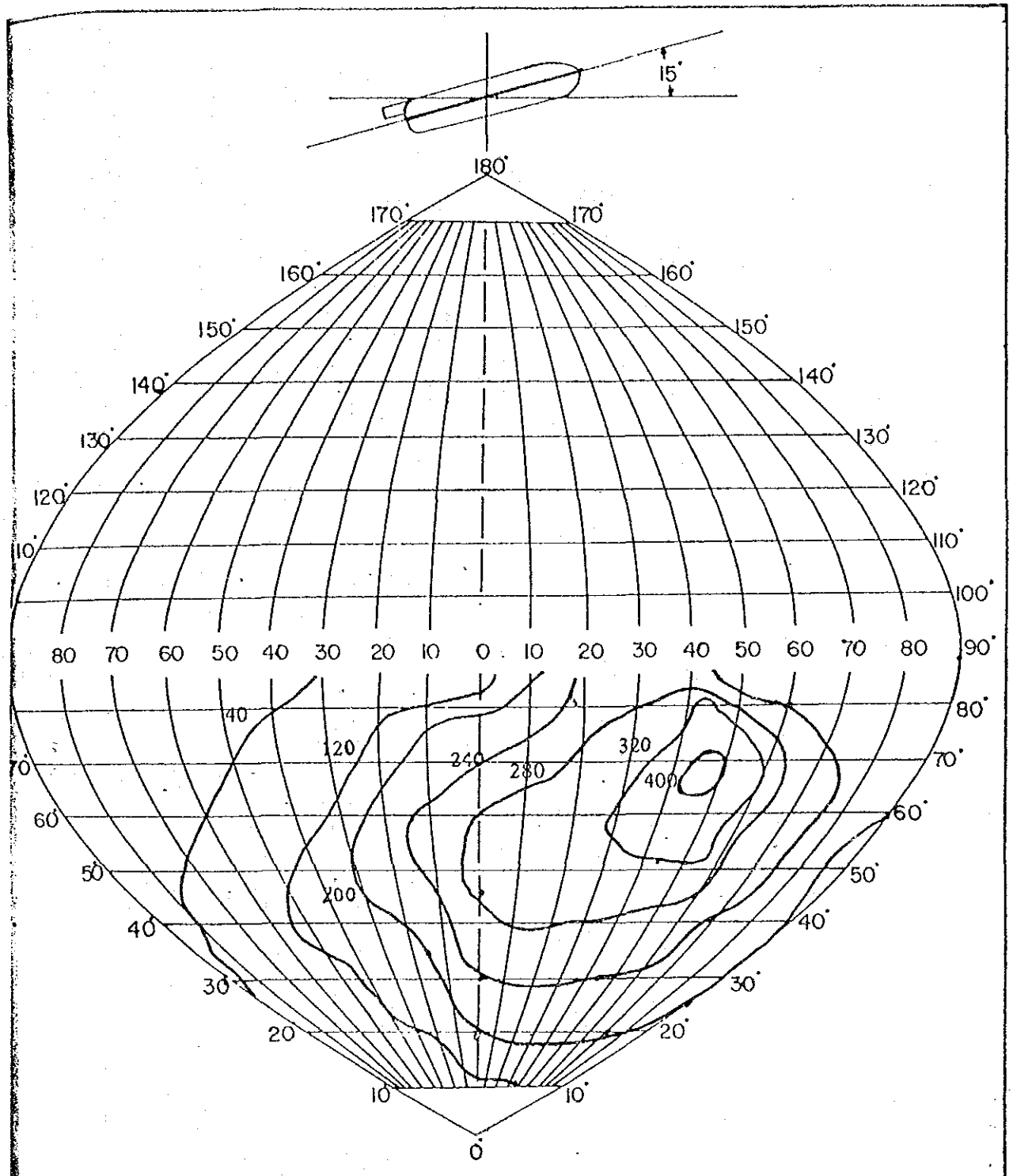
KERB SIDE

LUMINAIRE	: CDC TYPE HPS 1.250C
LAMP	: SYLVANIA LU250
MOUNTING HEIGHT	: 9 M. TILT 15°

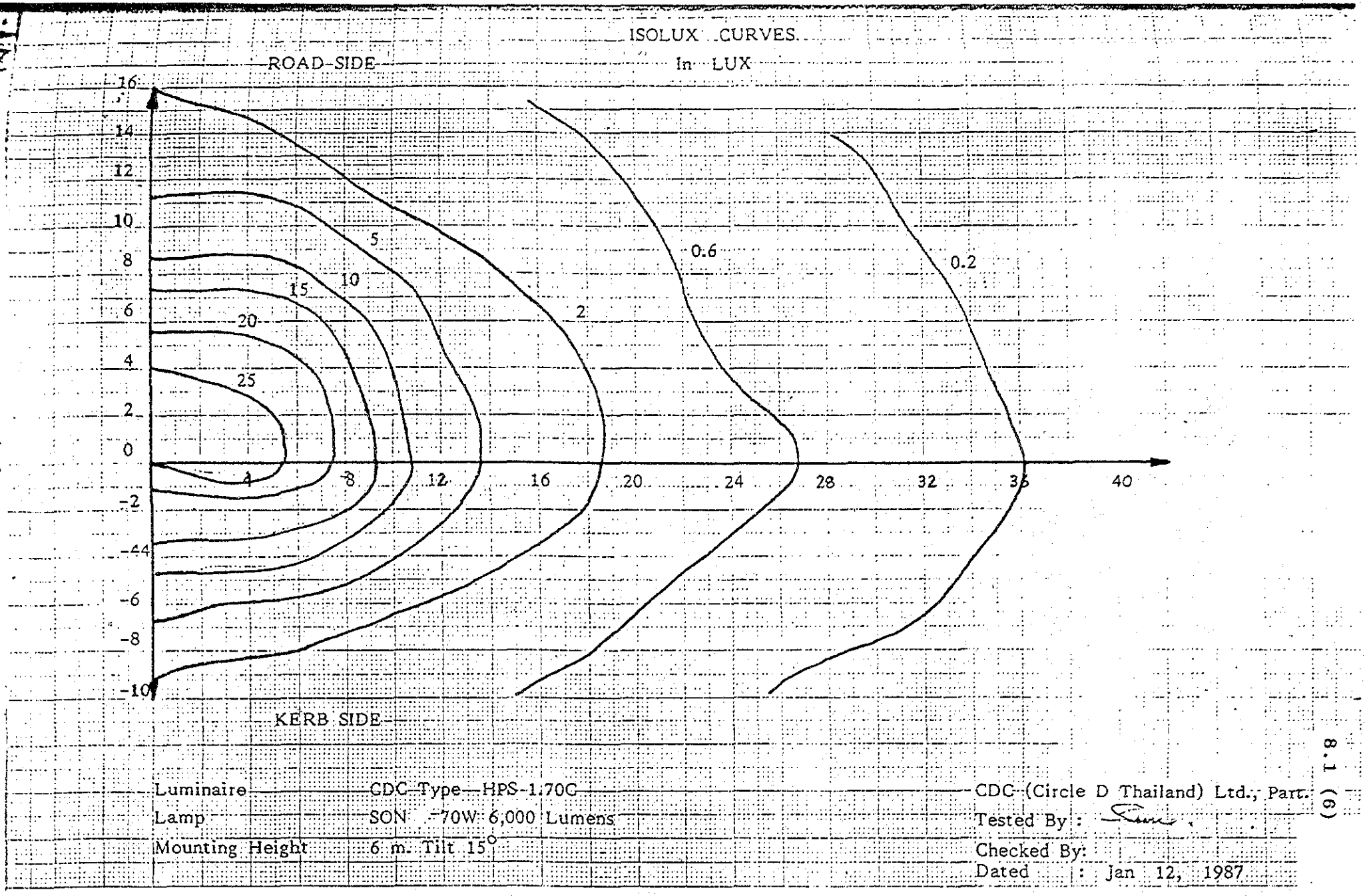
FACULTY OF ENGINEERING KMIT LADKRABANG	
TESTED BY	S. Bunjonggit
CHECKED BY	K. Patel
DATE	JULY 30, 1980

A-4

8.1 (4)



ISOCANDELA LINE ON SANSON'S NET		CDC (Circle D Thailand) L.P.
inaire	CDC Type HPS 1.70C	Tested By:
np Distance ply Voltage e Current	SON 70W 6,000 Lumens 6 m. Tilt 15° 220V 50 Hz. A Input Wattage W	Drawn By: Checked by: Dated: Jan 12, 1987



Luminaire ——— CDC Type HPS-170C

Lamp ——— SON 70W: 6,000 Lumens

Mounting Height 6 m. Tilt 15°

CDC (Circle D Thailand) Ltd., Part.

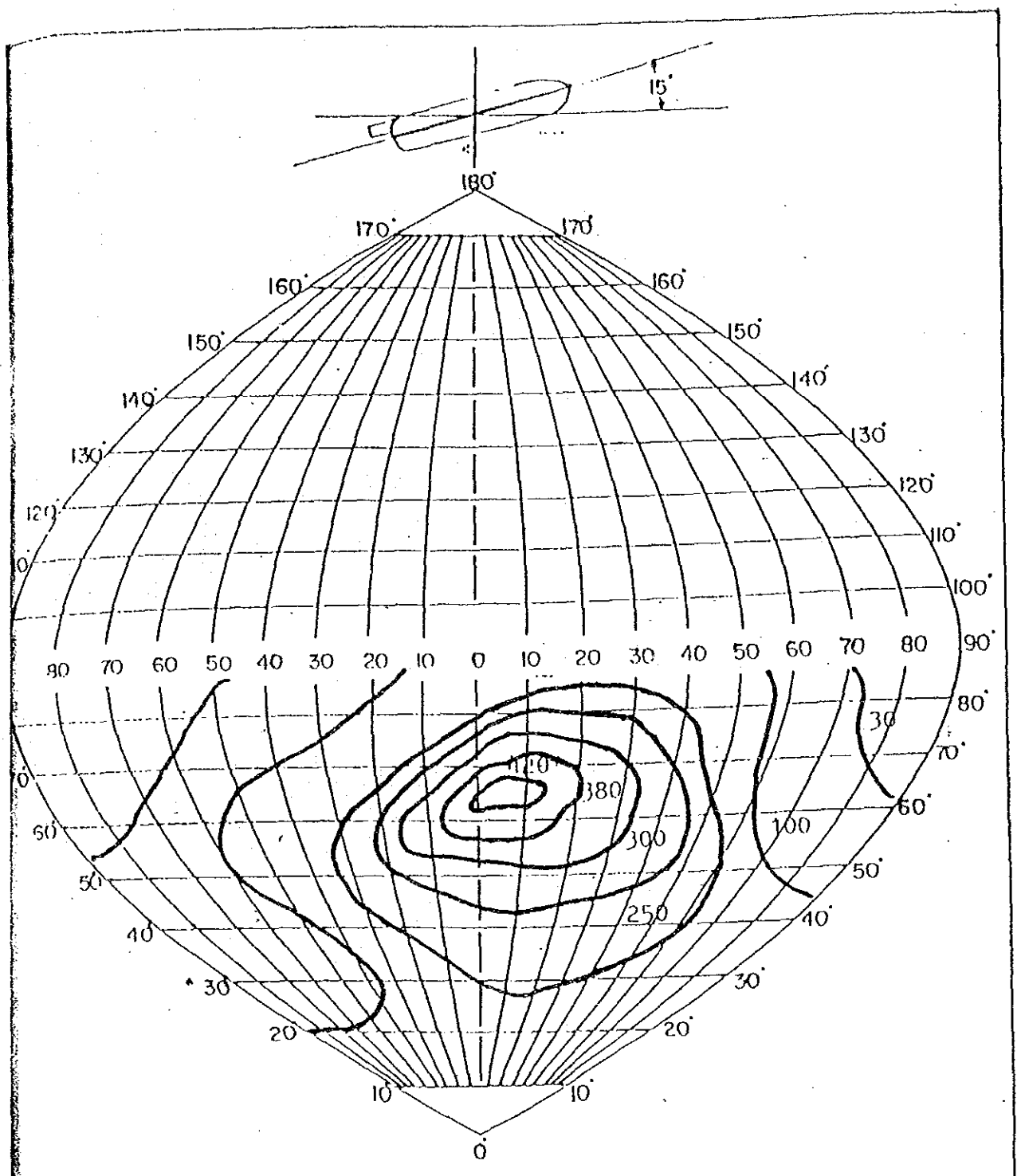
Tested By :

Checked By:

Dated : Jan 12, 1987

A-6

8.1 (6)



ISOCANDELA LINES ON SANSON'S NET	C.D.C.(CIRCLE D.THAILAND) LTD.,PART. BANGKOK, THAILAND.	
LUMINAIRE : CDC TYPE HPS 1.150C	TESTED BY	
LAMP : OSRAM NAV-T 150	DRAWN BY	
LAMP : 150 WATTS 14,500 LUMENS	CHECKED BY	
MOUNTING DISTANCE : 4 M. TILTING 15°	DATED	JULY 12, 1987
SUPPLY VOLTAGE : 220 V 50 Hz.		
LAMP CURRENT : A INPUT WATTAGE W