

## **CHAPTER 6**

### **BRIDGES**

## CONTENTS

Section	Title	Page
6-01	GENERAL	1
6-02	DESIGN CRITERIA	1
	6-02.01 Concrete Design	1
	6-02.02 Prestressed Concrete	1
	6-02.03 Earthquake Stresses	4
	6-02.04 Earth Pressure	4
	6-02.05 Design Flood Frequencies	4
	6-02.06 Bridge Cross Sections	5
	6-02.07 Horizontal Clearances at Underpasses	5
	6-02.08 Vertical Clearance	9
6-03	GENERAL AND SPECIAL DETAILS	9
	6-03.01 Bearings	9
	6-03.02 Attachment of Utilities	9
	6-03.03 Railings	9
	6-03.04 Guard Rail Tie to Bridge Parapet	9
	6-03.05 Sidewalks in Rural Areas	18
	6-03.06 Lighting Supports	18
	6-03.07 Impact Attenuator Reserve Areas	18
6-04	PRELIMINARY DESIGN PROCEDURES	18
	6-04.01 Site Data	21
	6-04.02 Hydrologic and Hydraulic Analysis	21
	6-04.03 Site Inspections	21
	6-04.04 Coordination with Other Agencies	24
	6-04.05 Preliminary Design Report	25
	6-04.06 Soils Study	26
	6-04.07 Advance Plans	26
6-05	FINAL DESIGN AND PLANS	26
6-06	REFERENCES AND GUIDES	27

## LIST OF FIGURES

Figure No.	Title	Page
6-A	Bridge Cross Sections—Expressways	6
6-B	Bridge Cross Sections — Rural Two-lane Roads and Ramps	7
6-C	Bridge Cross Sections — Avenues, Principal and Local Streets	8
6-D	Underpass Clearances — Divided Highway with Pier in Median	10
6-E	Underpass Clearances — Divided Highway with No Pier in Median	11
6-F	Underpass Clearances — Two-lane Rural Arterials and Collectors	12
6-G	Underpass Clearances — Local Rural Roads and Ramps	13
6-H	Underpass Clearances — Other Urban Highways and Streets	14
6-I	Typical Treatment of Side Slopes at Underpasses	15
6-J	Typical Barrier Installations at Underpasses with Restricted Right Side Clearance	16
6-K	Typical Barrier Installations at Underpasses with Piers in Median	17
6-L	Typical Railings	19
6-M	Typical Transition of Approach Guard Rail to Bridge Railing	20
6-N	Impact Attenuator Reserve Area	22

## LIST OF TABLES

Table No.	Title	Page
6-1	General Bridge Design Standards — Rural Highways	2
6-2	General Bridge Design Standards — Urban Highways	3
6-3	Guide for Hydraulic Studies and Reports	23

## CHAPTER 6

### BRIDGES

#### 6-01 GENERAL

This chapter covers design policies and criteria for bridge structures including bridges over waterways and grade separation structures (overpasses and underpasses) but excluding pedestrian bridges which are covered in Chapter 15. By AASHTO definition a bridge is a structure having an opening measured along the center of the roadway of more than 6.1 meters (20'). Culverts, which are structures with clear openings of 6.1 meters or less, are discussed in Chapter 11.

#### 6-02 DESIGN CRITERIA

The current edition of the AASHTO "Standard Specifications for Highway Bridges", as supplemented by this Manual and the directives and guides issued by the Design Area and its Structural Design Office covers the basic criteria and allowable factors governing bridge designs for the Department.

The general bridge design standards for the various highway design classes are included in Tables 6-1 (Rural) and 6-2 (Urban). These general bridge standards complement the general highway design standards given in Tables 1-11 through 1-15 of Chapter 1.

##### 6-02.01 CONCRETE DESIGN

1. CONCRETE (Non-Prestressed)—Design on the basis of an ultimate cylinder compressive strength at 28 days of 4,000 psi. (Class A 4) for bridge deck slabs and 3,000 psi. (Class A) for all other members. Design prestressed concrete members as per 6-02.02.

2. REINFORCING STEEL—Design on the basis of Grade 60 with a yield strength of 60,000 psi.

3. LOAD FACTOR DESIGN—Do not use except with the prior approval of the Structural Design Office.

##### 6-02.02 PRESTRESSED CONCRETE

1. BEAM SHAPES—Use standard AASHTO sections unless another type of section can be justified and specific prior approval is obtained from the Structural Design Office.

2. CONCRETE—Design for a compressive strength of 5,000 psi at 28 days. Design for compressive strength at time of stress transfer of 4,000 psi except for beam types V and VI for which 4,500 psi should be used.

#### NOTES — TABLES 6-1 AND 6-2

- ( 1 ) For ramp widths see Chapter 2 and Table 2-2.
- ( 2 ) Medians 9.0 M. or less in width shall normally be covered unless special conditions require separate structures. Dual structures will be used where the median width exceeds 9.0 meters. See Figure 6-A.
- ( 3 ) These are highway over highway clearances. Use a minimum clearance above highway of 5.25 M. for overhead signs and pedestrian overpasses, see Chapters 9 and 15 respectively. Above private industrial railroads, provide minimum vertical clearances as agreed upon with owners. See Section 6-02.08.

TABLE 6-1

## GENERAL BRIDGE DESIGN STANDARDS - RURAL HIGHWAYS

DESIGN CLASS		EXPRESSWAYS					OTHER ARTERIALS AND COLLECTORS				LOCAL ROADS		
		RE-1	RE-2	RE-3	RE-4	RAMPS	R-5	R-6	R-7	R-8	R-9	R-10	R-11
TRAVELED WAY WIDTH		2 AT 10.95	2 AT 7.30	2 AT 7.30	7.30	VAR. <sup>(1)</sup>	2 AT 7.30	7.30	6.70	6.10	6.10	6.10	6.10
MIN. MEDIAN WIDTH <sup>(2)</sup>		9.0	9.0	6.0	—	—	6.0	—	—	—	—	—	—
SHOULDER WIDTH	RIGHT	3.0	3.0	3.0	3.0	VAR. <sup>(1)</sup>	3.0	3.0	2.4	1.8	1.8	1.8	1.8
	LEFT	1.8	1.2	1.2		VAR. <sup>(1)</sup>	1.2						
RAIL OFFSET FROM OUTSIDE EDGE OF SHOULDER	RIGHT	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	LEFT	0.6 IF DUAL STRUCTURES <sup>(2)</sup>				0.6	0.6 <sup>(2)</sup>						
MIN. BRIDGE WIDTH F.-F. OF RAILINGS	SINGLE	38.10	30.80	27.80	14.5	VAR. <sup>(5)</sup>	27.80 <sup>(4)</sup>	14.50	12.70	10.90	10.90	10.90	10.90
	DUAL <sup>(2)</sup>	16.95 EA.	12.70 EA.	12.70 EA.			12.70 EA.						
MIN. VERTICAL CLEARANCE		4.95 <sup>(3)</sup>								4.40 <sup>(3)</sup>			
HORIZONTAL CLEARANCES AT UNDERPASSES		SEE FIGURES 6-D AND E			FIG. 6-F	FIG. 6-G	FIGS. 6-D & E	FIG. 6-F			FIG. 6-G		
DESIGN LIVE LOAD		HS 20-44											
MIN. DESIGN FLOOD FREQ. <sup>(7)</sup>		100 YR. <sup>(6)</sup>											
MIN. CLEAR. ABOVE DESIGN H.W.		0.60 FOR 100 YR. , 0.30 FOR GREATER FLOODS <sup>(9)</sup>											
		0.60 <sup>(10)</sup>											

ALL DIMENSIONS IN METERS. FOR NUMBERED NOTES REFER TO PAGE 6-4.

TABLE 6-2

GENERAL BRIDGE DESIGN STANDARDS - URBAN HIGHWAYS												
DESIGN CLASS		EXPRESSWAYS						AVE- NUES	PRINCIPAL STREETS		LOCAL STS.	
											COMM.	RES.
		UE-1	UE-2	UE-3	UE-4	UE-5	RAMPS		U-6	U-7	U-8	U-9
PAVEMENT WIDTH		2 AT 14.60	2 AT 10.95	2 AT 7.30	2 AT 10.95	2 AT 7.30	VAR. <sup>(1)</sup>	2 AT 11.00	2 AT 7.30	14.60	8.0-12.0	8-11.0
MIN. MEDIAN WIDTH <sup>(2)</sup>		6.6	5.4	4.2	6.0 <sup>(11)</sup>	6.0 <sup>(11)</sup>	—	6.0 <sup>(12)</sup>	4.25 <sup>(12)</sup>	—	—	—
SHOULDER WIDTH	RIGHT	3.0	3.0	3.0	3.0	3.0	VAR. <sup>(1)</sup>	—	3.0 <sup>(13)</sup> PARK. LANE	3.0 <sup>(13)</sup> PARK. LANE	—	—
	LEFT	3.0	2.4	1.8	—	—	VAR. <sup>(1)</sup>					
SIDEWALK WIDTH <sup>(14)</sup>		—	—	—	—	—	—	4.0	3.0	2.5	2.5	2.5
RAIL OFFSET FROM OUTSIDE EDGE OF SHOULDER	RIGHT	0.6	0.6	0.6	0.6	0.6	0.6	SIDEWALK WIDTH				
	LEFT	0.6 IF DUAL STRUCTURES <sup>(2)</sup>				COVERED MEDIAN		0.6	COVERED MEDIAN		—	—
MIN. BRIDGE WIDTH F.-F. OF RAILINGS	SINGLE	43.0 <sup>(4)</sup>	34.5 <sup>(4)</sup>	26.0 <sup>(4)</sup>	35.1 <sup>(4)</sup>	27.8 <sup>(4)</sup>	VAR. <sup>(5)</sup>	36.0 <sup>(15)</sup>	30.85 <sup>(15)</sup>	25.60 <sup>(15)</sup>	13.5-17.0 <sup>(15)</sup>	13.0-16.0 <sup>(15)</sup>
	DUAL <sup>(2)</sup>	21.8 EA.	17.55 EA.	13.3 EA.								
MIN. VERTICAL CLEARANCE		4.95 <sup>(3)</sup>									4.40 <sup>(3)</sup>	
HORIZONTAL CLEARANCES AT UNDERPASSES		SEE FIGURES 6-D AND E					FIG. 6-G	FIGURE 6-H				
DESIGN LIVE LOAD		HS 20-44										HS 20-44
MIN. DESIGN FLOOD FREQ. <sup>(7)</sup>		100 YR. <sup>(6)</sup>										
MIN. CLEAR. ABOVE DESIGN H.W.		0.60 FOR 100 YR., 0.30 FOR GREATER FLOODS <sup>(9)</sup>										

ALL DIMENSIONS IN METERS. FOR NUMBERED NOTES REFER TO PAGE 6-4.

- ( 4 ) These widths are based on a covered median of standard minimum width. However, the bridge median width shall match that on approach roadway and the required bridge width shall be determined accordingly.
- ( 5 ) Required ramp width plus a minimum clearance of 0.6 M. to bridge railing on each side. See Figure 6—B.
- ( 6 ) Greater historical floods may be considered if economically feasible and whenever a similar flood would cause extensive damage to adjoining property or the loss of a costly structure.
- ( 7 ) For definition and application see Section 6—02.05.
- ( 8 ) On low volume R—10 and R—11 design class roads encroaching on flood plains, lower design flood frequencies may be warranted by economic considerations provided that the 100-year flood can be conveyed over the highway and structures without causing significant damage to the structures and to existing or reasonably anticipated future development upstream or downstream.
- ( 9 ) The designer should exercise his judgment and assume both buoyancy forces and current pressure at the deck, specially whenever a clearance under 0.60 meters is provided.
- (10) May be reduced to 0.30 M. in special cases covered under Note (8) above and for greater floods.
- (11) Raised median normally used with curb offset from through lanes. See Figure 2—G.
- (12) Raised median, see Figure 6—C.
- (13) If provided on approach roadways, see Figure 2—H. May be omitted on long bridges even if provided on approaches.
- (14) Sidewalk widths may be reduced in special cases but to not less than 1.5 meters.
- (15) These width are based on normal cross sections. However, when a reduction in sidewalk width and/or elimination of parking lane is authorized, the bridge width will vary accordingly. See Figure 6—C.

#### 6—02.03 EARTHQUAKE STRESSES

Design for Seismic Zone 3 requirements using the latest AASHTO criteria.

#### 6—02.04 EARTH PRESSURE

Structural elements which retain fills, such as abutments and wingwalls, shall be designed for earth pressures as recommended by soils study but in no case less than an equivalent fluid pressure of 35 pounds per cubic foot.

#### 6—02.05 DESIGN FLOOD FREQUENCIES

The term "design flood" means the peak discharge, volume (if appropriate), and stage or wave crest elevation of the flood associate with the frequency interval selected for the design. It is necessary to make an evaluation, using the 100-year flood or the maximum flood or record, whichever is greater, of the flood hazard to other property, stream stability, and the stream and flood plain environment.

In any case, the overall design must permit the conveyance of the 100-year or greater floods without increasing flood heights or velocities to an extent which would cause significant damage to upstream or downstream existing or reasonably anticipated future development.

## 6-02.06 BRIDGE CROSS SECTIONS

Bridge cross sections for the various design classes of highway are illustrated in Figures 6-A, B and C. The basic criteria is to provide a bridge section that matches the approach highway traveled way and shoulder widths plus a clearance of 0.6 meter to the bridge railings or parapets on structures without sidewalks.

On urban highways with sidewalks, the full sidewalk width plus planting strip width, if any, will normally be carried on the bridge section. However, in the case of undivided principal (U-8) and local (U-9, 10) streets with light pedestrian traffic, the bridge sidewalk width may be reduced by eliminating the planting strip width but in no case to less than 1.5 meters.

On some urban bridges serving large pedestrian volumes adjacent to highspeed roadways it is desirable to physically separate the pedestrian from the vehicular traffic by providing a parapet between the roadway and the sidewalk. These special cases are discussed in Chapter 8.

When an auxiliary lane with a partial shoulder is carried across the structure, the bridge rail may be placed at the outside edge of the partial shoulder without the additional offset of 0.6 M. provided that the bridge section is consistent with that on the approaches to provide roadway continuity.

## 6-02.07 HORIZONTAL CLEARANCES AT UNDERPASSES

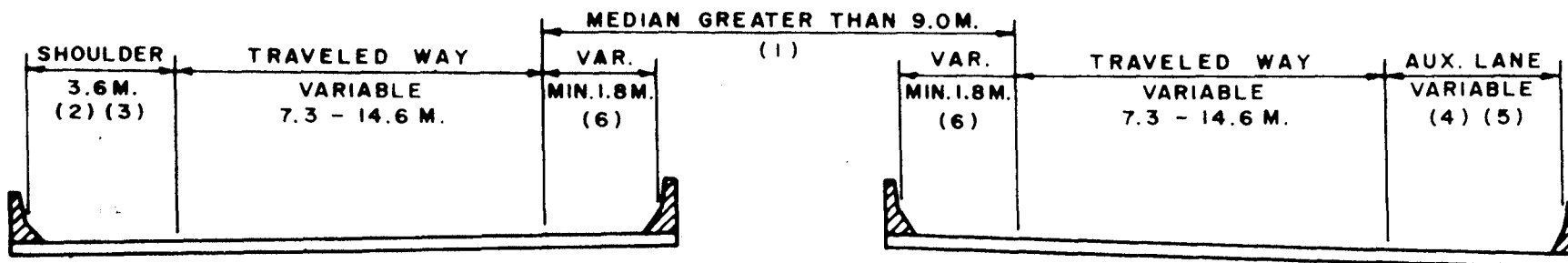
The basic principle in designing structures over highways is to normally provide for the entire roadway section of the underpassing highway including the traveled way, median, shoulders and clear recovery area. The normal minimum underpass clearances for the various highway design classes are illustrated in Figures 6-D through 6-H.

Underpasses for expressways and other highways with design speeds of 50 mph or greater, shall normally provide a horizontal clearance between the right edge of through pavement and adjacent pier or abutment of at least 9.0 meters. Exception to this policy may be made when the approach roadway is restricted and does not itself provide a 9.0 M. clear recovery area due to right-of-way or other physical considerations. In such cases there shall be continuity between the lateral clearances on the approaches and those at the underpass with a minimum of 4.2 M. normally provided to accommodate the full shoulder and guardrail or concrete barrier protection. Exception may also be made for extreme skew crossings where the 9.0 M. right side clearance would result in very long spans or in very high unit cost structures but in no case shall the clearance be less than 4.2 meters.

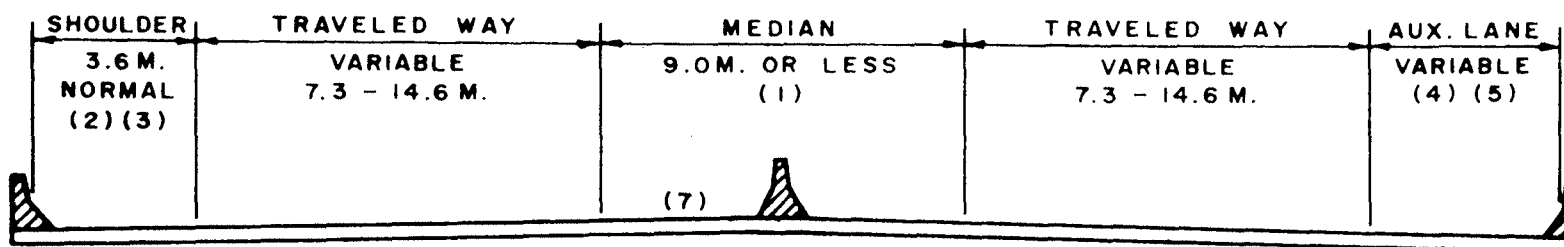
Figure 6-I illustrates typical treatment of the side slopes at underpasses. By careful slope transitioning and design of drainage facilities it is possible to provide a clear recovery area with traversable side slopes at underpasses on high speed highways without unduly lengthening the spans. It is desirable that whenever possible the back slope to the side pier or abutment not exceed 3:1.

Auxiliary lanes may be accommodated within the 9.0 M. right side clear space except for high-speed (50 mph or greater) auxiliary lanes which should be provided with 9.0 M. clearance from the right edge of the lane to pier or abutment. In no case shall this clearance be less than the width of the shoulder adjacent to the auxiliary lane plus 1.2 meters.

On divided highways with median widths of 6.0 M. or wider it is normally necessary to accommodate a pier in the median. In such cases the pier should be located at the center and preferable parallel to the underpassing roadway. The clearance from the left edge of the travel way to the pier should be no less than 2.4 meters and barrier protection provided. For structures over highways with narrow medians consideration should be given to a design without a median pier but maintaining the required minimum right side clearances.



### DUAL STRUCTURES - OPEN MEDIAN



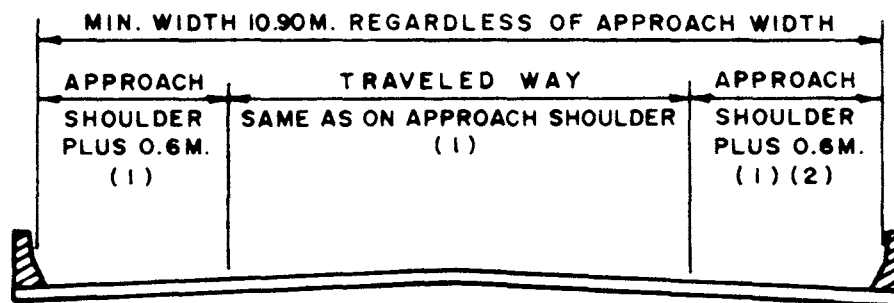
### SINGLE STRUCTURE - CLOSED MEDIAN

#### NOTES:

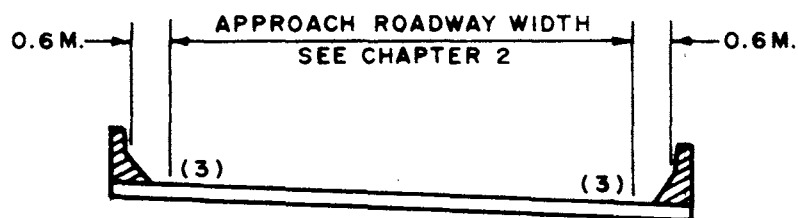
- (1) MEDIAN WIDTH SAME AS ON APPROACH ROADWAY.
  - (2) APPROACH SHOULDER WIDTH PLUS 0.6 M. CLEARANCE TO UPPER FACE OF RAILING.
  - (3) IF AUXILIARY LANE PRESENT, TREAT AS IN (4).
  - (4) AUXILIARY LANE WIDTH PLUS APPROACH SHOULDER, IF ANY, BUT AT LEAST AUXILIARY LANE WIDTH PLUS 0.6 M.
  - (5) IF NO AUX. LANE PRESENT, TREAT AS IN (2).
  - (6) SAME WIDTH AS INSIDE SHOULDER ON APPROACH ROADWAY PLUS 0.6 M. CLEARANCE TO UPPER FACE OF RAILING.
  - (7) MEDIAN FLUSH WITH TRAVELED WAY SURFACE EXCEPT ON DESIGN CLASSES UE-4 AND 5. SEE CHAPTER 2.
- \* ALSO APPLICABLE TO OTHER DIVIDED MULTILANE RURAL HIGHWAYS.

## BRIDGE CROSS SECTIONS - EXPRESSWAYS \*

FIGURE 6 - A



## RURAL TWO-LANE ROADS



## RAMP STRUCTURE

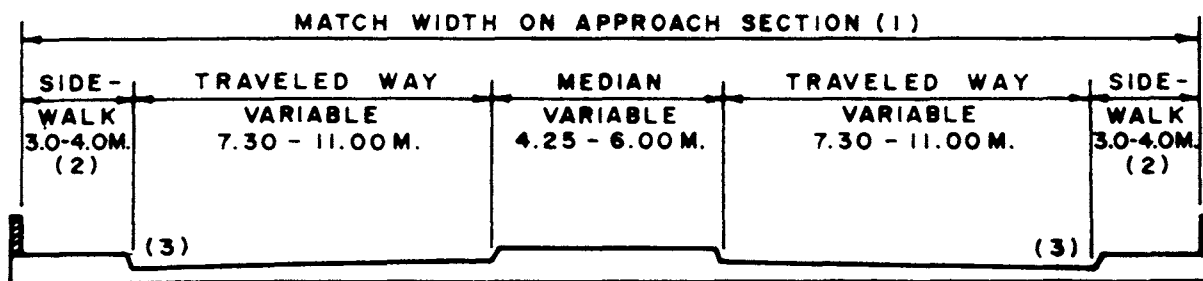
### NOTES:

- (1) SEE CHAPTERS 1 AND 2 FOR TRAVELED WAY AND SHOULDER WIDTHS FOR THE VARIOUS HIGHWAY DESIGN CLASSES.
- (2) IF AUXILIARY LANE PRESENT, USE AUXILIARY LANE WIDTH PLUS APPROACH SHOULDER WIDTH PLUS 0.6 M. TO RAILING.
- (3) IF APPROACH ROADWAY IS CURBED, ALIGN APPROACH CURB WITH BASE OF RAILING.

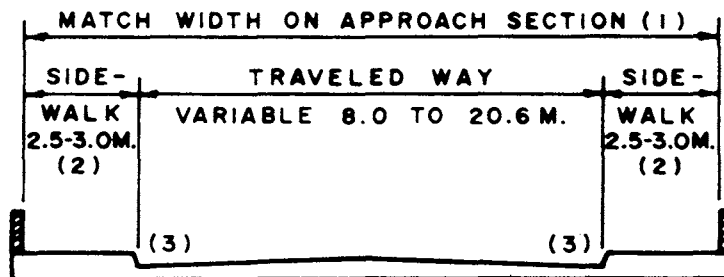
## BRIDGE CROSS SECTIONS

## RURAL TWO-LANE ROADS AND RAMPS

FIGURE 6-B



## AVENUES AND DIVIDED PRINCIPAL STREETS



## UNDIVIDED PRINCIPAL AND LOCAL STREETS

### NOTES:

- (1) SEE CHAPTERS 1 AND 2 FOR CROSS SECTION WIDTHS FOR THE VARIOUS HIGHWAY DESIGN CLASSES.
- (2) SIDEWALK WIDTH MAY BE REDUCED IN SPECIAL CASES WHEN AUTHORIZED BY CENTRAL OFFICE BUT IN NO CASE TO LESS THAN 1.5 M.
- (3) BARRIER CURB AS ON APPROACH ROADWAY.

## BRIDGE CROSS SECTIONS AVENUES, PRINCIPAL AND LOCAL STREETS

FIGURE 6 - C

Figures 6—J and 6—K illustrate typical barrier installation where restricted right side or left side clearances require their use to shield piers or abutments. Details on barrier types, lengths, approach transitions, end treatments, etc. are discussed in Chapter 8.

#### **6—02.08      VERTICAL CLEARANCE**

The required vertical clearance for all new structures spanning the various highway design classes are given in Tables 6—1 and 6—2 and illustrated in Figures 6—D through 6—H.

The standard vertical clearance for new highway over highway structures is 4.95 meters except for design classes R—8, 9, 10, 11 and U—9, 10 for which a 4.40 M. clearance is normally provided. However, on some urban expressways and avenues a minimum clearance of 4.40 meters may be considered when there are alternate routes available for an occasional high body vehicle. Under urban conditions, the 0.55 M. difference between a 4.40 M. and a 4.95 M. clearance may represent a substantial reduction in cost.

#### **6—03            GENERAL AND SPECIAL DETAILS**

##### **6—03.01      BEARINGS**

Elastomeric bearing pads shall be used unless another type of bearing is justified or required and approval is obtained from the Structural Design Office. All superstructures shall be securely anchored to the substructure at both fixed and expansion ends unless otherwise herewith indicated. Except at stream crossings, anchorage may be omitted over continuous supports if not required to resist uplift or to secure against horizontal crawling.

##### **6—03.02      ATTACHMENT OF UTILITIES**

Attachment of utilities to structures on controlled access highways is not permitted except in very special cases and on other highways should be avoided since such attachment can materially affect the structure, its appearance and its maintenance. When utility attachments to a structure is permitted, the installation must comply with the requirements of the DTPW "Policy on the Accommodation of Utilities on Highway Rights-of-Way" as supplemented by Chapter 13 of this Manual.

##### **6—03.03      RAILINGS**

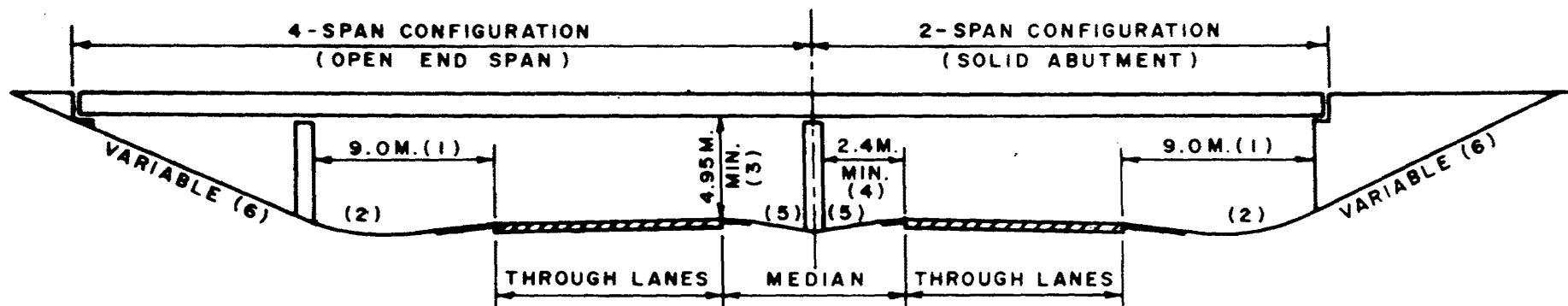
The typical railing types used by the Department are illustrated in Figure 6—L. On structures without sidewalks the standard railing is a sloped concrete parapet which follows the New Jersey barrier contour.

On bridges with sidewalks, a combination traffic-pedestrian railing is used. Two of the most commonly used types are illustrated in Figure 6—L, and all concrete type and another that combines a concrete parapet with single aluminum rail on top.

##### **6—03.04      GUARD RAIL TIE TO BRIDGE PARAPET**

The transition from an approach guard rail to a bridge parapet is a key safety element. A typical design of such transition is illustrated in Figure 6—M. In the design of these transitions the following items must be considered:

1. **STRENGTH OF CONNECTION**—At the connection point the attachment must have the strength of at least the strength of the weaker of the two barriers, usually the guard rail on the approach. In the case of the W-beam type commonly used in Puerto Rico, the connection should at least equal the tensile strength of the beam.



#### NOTES:

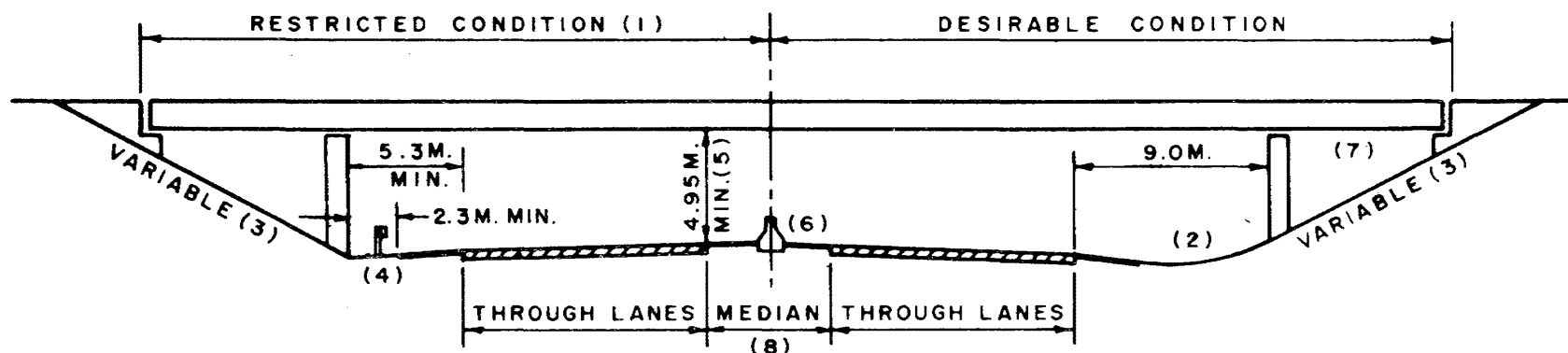
- (1) A RESTRICTED MINIMUM CLEARANCE OF 4.2M. WITH GUARD RAIL PROTECTION MAY BE AUTHORIZED WHERE SPECIAL APPROACH OR SITE CONDITIONS MAKE A 9.0M. IMPRACTICAL. SEE FIG. 6-J.
- (2) FOR TYPICAL SIDE SLOPE TREATMENTS SEE FIG. 6-I.
- \* (3) MINIMUM VERTICAL CLEARANCE TO BE PROVIDED OVER ENTIRE ROADWAY SURFACED WIDTH.
- (4) FOR MEDIANS WIDER THAN 19.2M. USE 9.0M. MINIMUM CLEARANCE.  
FOR MEDIANS UNDER 19.2M. PLACE PIER IN CENTER OF MEDIAN.  
WHERE CONTINUOUS MEDIAN BARRIER IS PRESENT ON HIGHWAY, MIN. CLEARANCE MAY BE THE SAME AS ON HIGHWAY. SEE FIG. 6-K.
- (5) USE GUARD RAIL OR BARRIER PROTECTION WHERE CLEARANCE IS UNDER 9.0M. SEE FIG. 6-K.
- (6) VARIABLE SLOPE AS PER HIGHWAY SECTION, SEE CHAPTER 2. NORMAL MAXIMUM 2:1.
- \* TO BE PREDICATED ON FUTURE PAVEMENT WIDENINGS IN THE CASE OF EXPANSIBLE MEDIANS.

### UNDERPASS CLEARANCES

### DIVIDED HIGHWAYS WITH PIER IN MEDIAN

### EXPRESSWAYS AND OTHER HIGH-SPEED HIGHWAYS

FIGURE 6-D

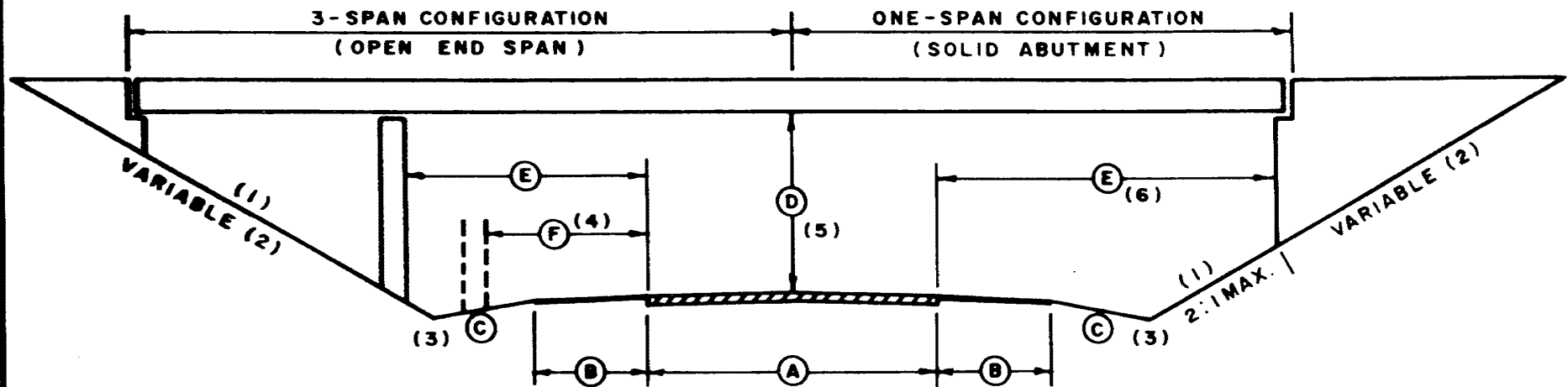


#### NOTES:

- (1) TO BE USED ONLY WHERE TERRAIN OR SPACE LIMITATIONS, SKEW CONDITIONS, OR STRUCTURE COSTS MAKE A 9.0M. CLEARANCE IMPRACTICAL.
- (2) FOR TYPICAL SIDE SLOPE TREATMENTS SEE FIG. 6-I.
- (3) VARIABLE SLOPE AS PER HIGHWAY SECTION. SEE CHAPTER 2. NORMAL MAXIMUM 2:1.
- (4) GUARDRAIL OR BARRIER PROTECTION REQUIRED. SEE FIG. 6-J.
- \* (5) MINIMUM VERTICAL CLEARANCE TO BE PROVIDED OVER ENTIRE ROADWAY SURFACED WIDTH.
- (6) MEDIAN BARRIER WHEN REQUIRED. SEE CHAPTERS 2 AND 8.
- (7) OPEN SPAN OR SOLID ABUTMENT.
- (8) NORMALLY UNDER 6.0M. WIDE BUT NOT LESS THAN ON APPROACH ROADWAY.
- \* TO BE PREDICATED ON FUTURE PAVEMENT WIDENINGS IN THE CASE OF EXPANSIBLE MEDIANS.

## UNDERPASS CLEARANCES DIVIDED HIGHWAYS WITH NO PIER IN MEDIAN EXPRESSWAYS AND OTHER HIGH-SPEED HIGHWAYS

FIGURE 6-E



#### NORMAL DIMENSIONS (METERS)

DESIGN CLASS :	RE-4	R-6	R-7	R-8
(A) PAVEMENT WIDTH	7.30	7.30	6.70	6.10
(B) SHOULDER WIDTH	3.00	3.00	2.40	1.80
(C) MAX. INSLOPE	6:1	6:1	4:1	4:1
(D) MIN. VERT. CLEAR.	4.95	4.95	4.95	4.40
(E) NORMAL LATERAL CLEAR.	9.00	9.00	6.00	6.00
(F) MIN. LATERAL CLEAR.	5.30	5.30	5.60*	5.90*

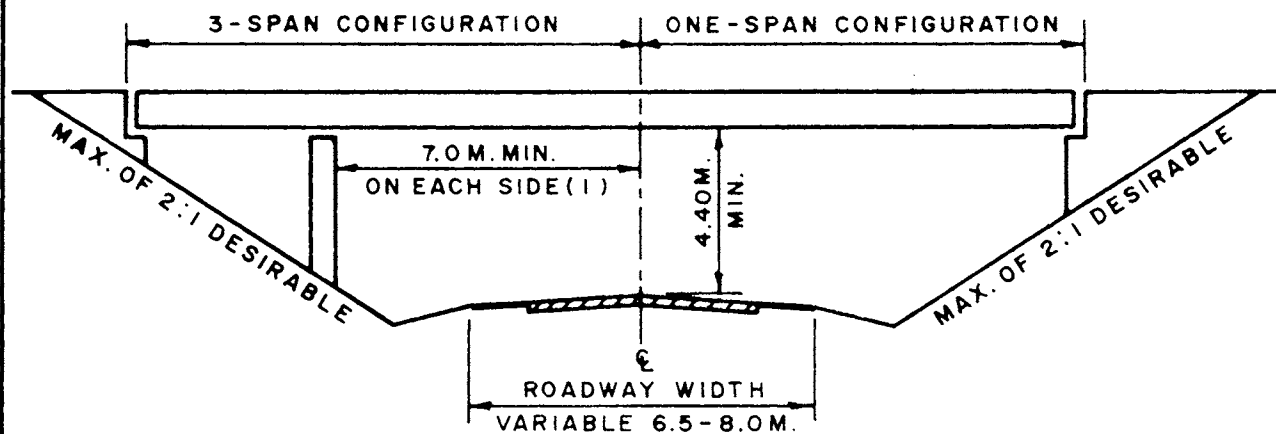
\* TO ALLOW FOR POSSIBLE WIDENING TO R-6 SECTION

#### NOTES :

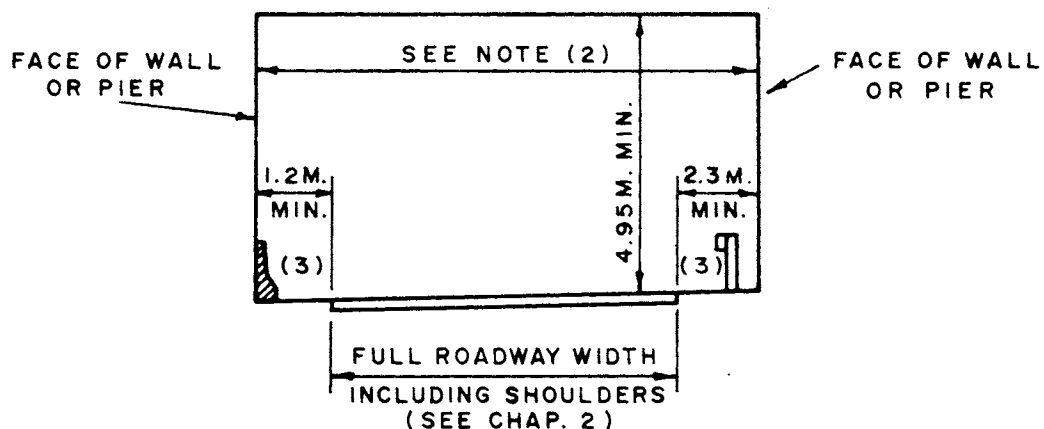
- (1) PROVIDE SLOPE PAVING.
- (2) VARIABLE SLOPE AS PER HIGHWAY SECTION.  
SEE CHAPTER 2. NORMAL MAXIMUM 2:1.
- (3) ROUNDED DITCH SECTION. SEE CHAPTER 2 AND FIG. 6-I.
- (4) RESTRICTED MINIMUM CLEARANCE TO BE USED ONLY  
WHERE CONDITIONS MAKE THE NORMAL CLEARANCE  
IMPRACTICAL. GUARDRAIL PROTECTION REQUIRED,  
SEE FIG. 6-J.
- (5) MINIMUM VERTICAL CLEARANCE TO BE PROVIDED  
OVER ENTIRE ROADWAY WIDTH.
- (6) AUXILIARY LANES MAY BE INCLUDED WITHIN "E".

## UNDERPASS CLEARANCES TWO-LANE RURAL ARTERIALS AND COLLECTORS

FIGURE 6-F



## LOCAL RURAL ROADS, DESIGN CLASSES R-9, 10, 11



## INTERCHANGE RAMPS

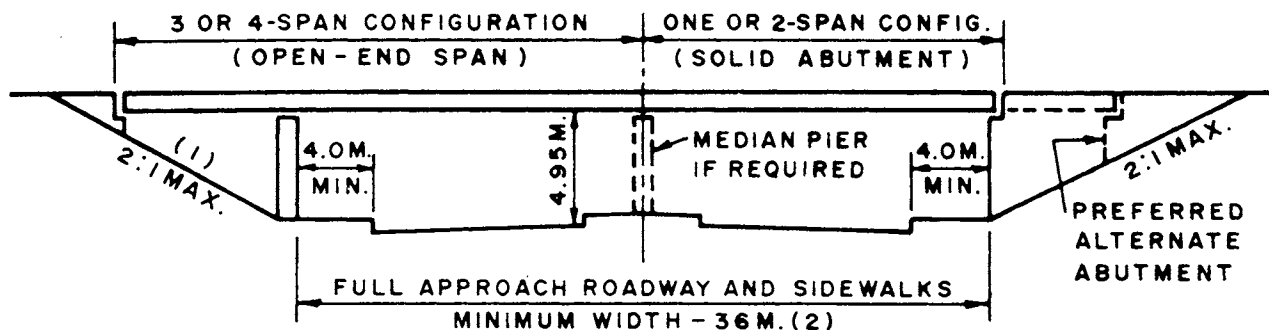
### NOTES:

- (1) TO ALLOW FOR POSSIBLE FUTURE WIDENING OF ROAD.
- (2) ON MAJOR TURNING ROADWAYS APPLY SAME CLEARANCES AS ON CONNECTING MAIN LINES.
- (3) BARRIER OR GUARD RAIL AS REQUIRED. SEE FIGS. 6-J AND 6-K.

## UNDERPASS CLEARANCES

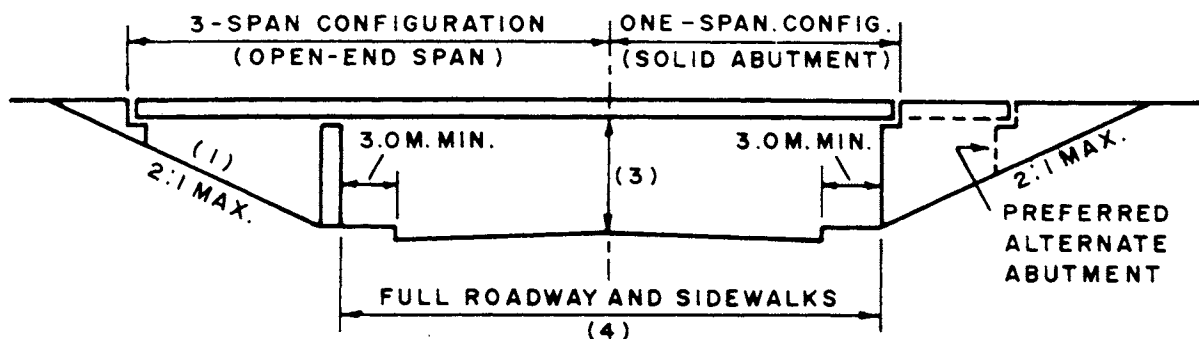
## LOCAL RURAL ROADS AND RAMPS

FIGURE 6-G



## AVENUES

( DESIGN CLASS U-6 )



## PRINCIPAL AND LOCAL STREETS

( DESIGN CLASSES U-7, 8, 9, 10 )

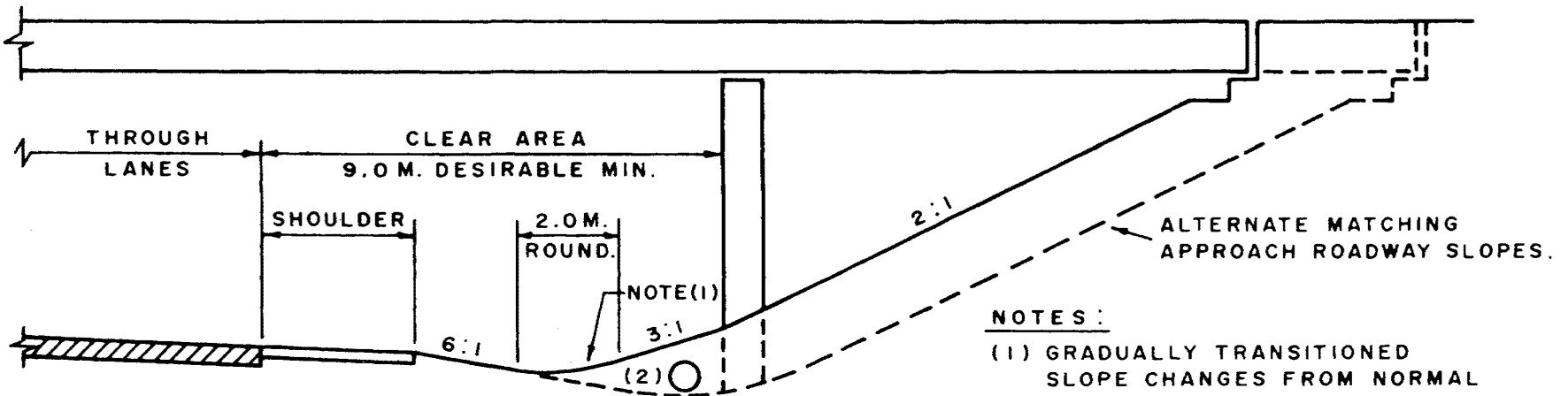
### NOTES:

- (1) PROVIDE SLOPE PAVING.
- (2) INCREASE AS REQUIRED FOR ANY AUXILIARY LANES.
- (3) MINIMUM VERTICAL CLEARANCE :  
 4.95M. FOR PRINCIPAL STREETS (U-7, 8).  
 4.40M. FOR LOCAL STREETS (U-9, 10)
- (4) WHERE FUTURE WIDENING OF STREET IS POSSIBLE, PROVIDE AT LEAST THE MIN. WIDTH NECESSARY FOR FINAL TYPICAL SECTION.

## UNDERPASS CLEARANCES

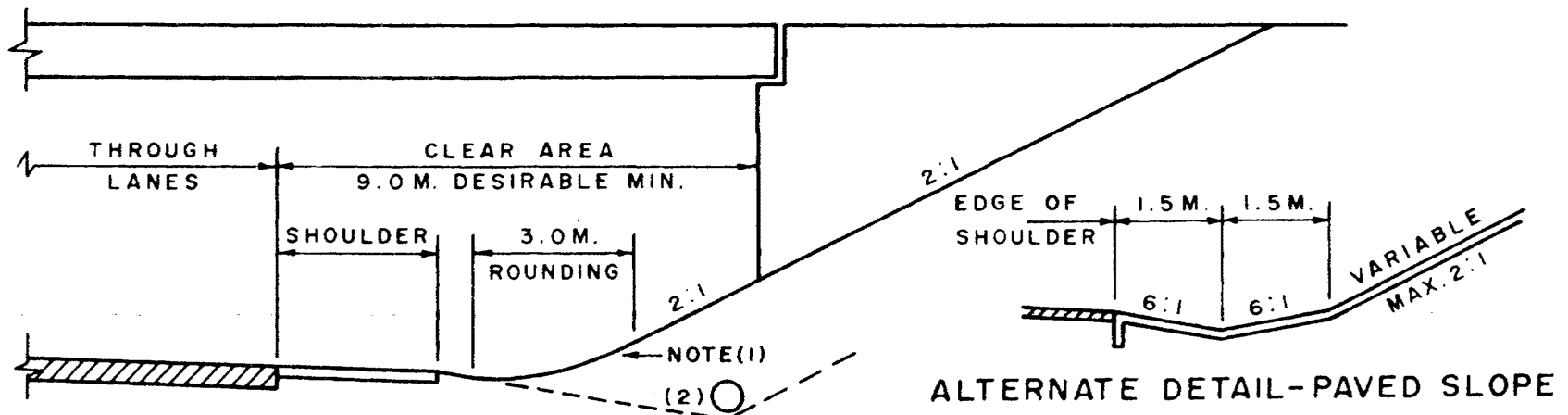
## OTHER URBAN HIGHWAYS AND STREETS

FIGURE 6-H



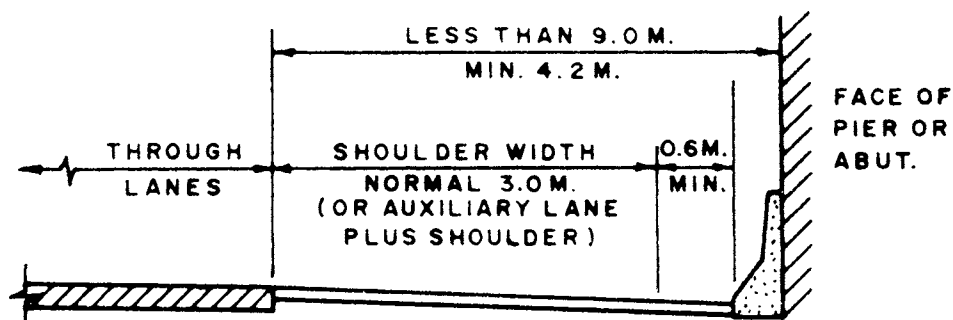
**NOTES:**

- (1) GRADUALLY TRANSITIONED SLOPE CHANGES FROM NORMAL APPROACH CROSS SECTION.
- (2) CULVERT IF REQUIRED FOR DRAINAGE CONTINUITY BUT AVOID IF POSSIBLE.

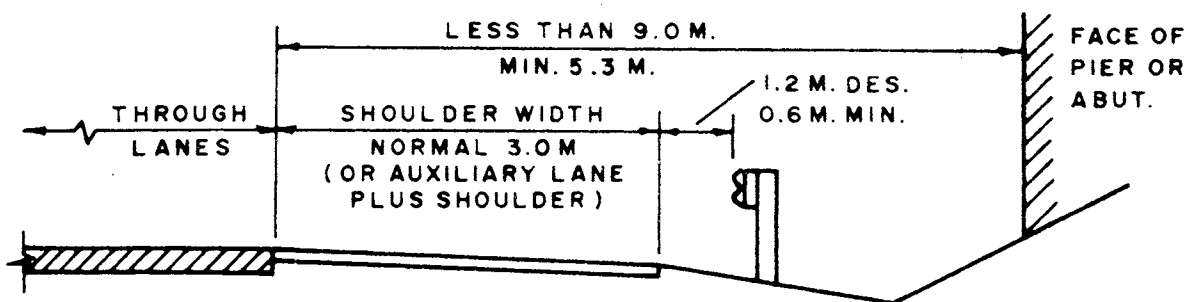


**TYPICAL TREATMENT OF SIDE SLOPES AT UNDERPASSES**

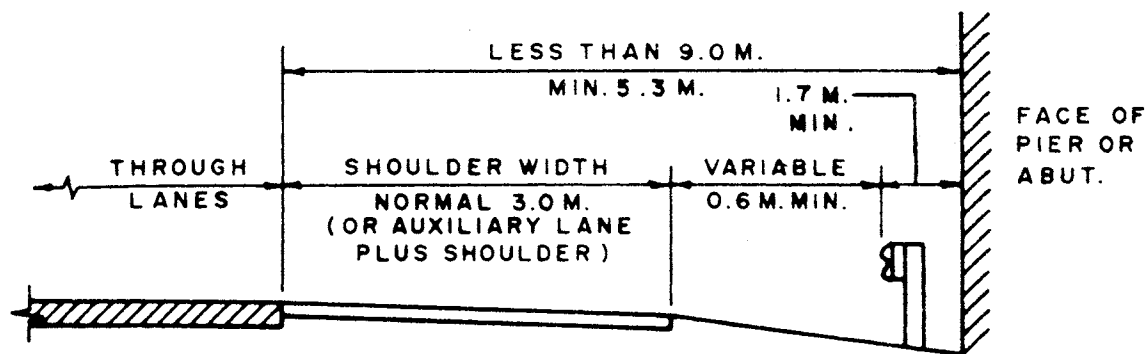
FIGURE 6-I



INTRODUCED CONCRETE BARRIER



GUARD RAIL ON BROKEN SIDE SLOPE

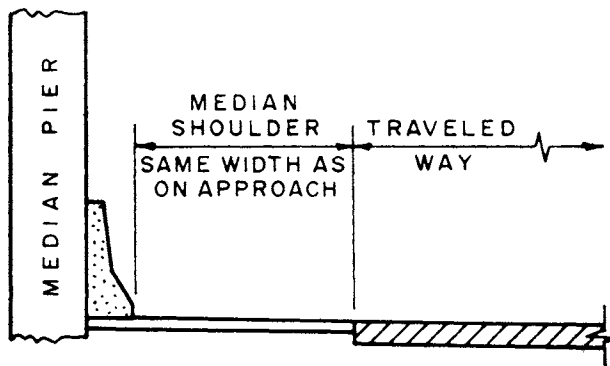


GUARD RAIL ON UNIFORM SIDE SLOPE

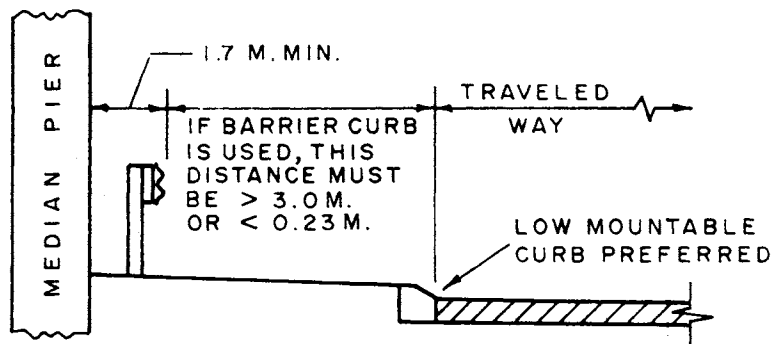
NOTE: REFER TO CHAPTER 8 FOR APPROACH TRANSITION  
AND END TREATMENT DETAILS OF BARRIERS.

TYPICAL BARRIER INSTALLATIONS AT UNDERPASSES  
WITH RESTRICTED RIGHT SIDE CLEARANCE

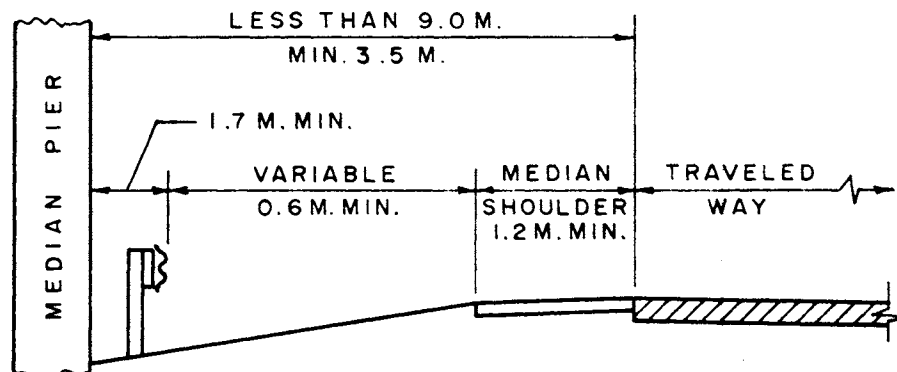
FIGURE 6-J



NARROW MEDIAN WITH CONTINUOUS MEDIAN BARRIER



CURVED MEDIAN WITH INTRODUCED GUARD RAIL



INTERMEDIATE MEDIAN WIDTHS  
WITH INTRODUCED GUARD RAIL

NOTE: REFER TO CHAPTER 8 FOR APPROACH TRANSITION  
AND END TREATMENT DETAILS OF BARRIERS.

TYPICAL BARRIER INSTALLATIONS AT UNDERPASSES  
WITH PIERS IN MEDIAN

FIGURE 6-K

2. **ALIGNMENT OF BARRIER FACES**—The alignment and transition of the two barriers should be such as to allow an impacting vehicle to slide smoothly along from one barrier to the other without snagging on projecting parts.

3. **CHANGE IN FLEXIBILITY**—The approach guard rail is purposely designed as a flexible barrier which will deflect 0.60 M. or more depending on the type. Since it is to be connected to a rigid bridge parapet, a transition must be made to develop a gradual stiffening that will prevent pocketing of an impacting vehicle. This gradual stiffening may be accomplished by decreasing the post spacing or strengthening the posts as the guard rail approaches the bridge parapet.

#### **6-03.05      SIDEWALKS IN RURAL AREAS**

No sidewalks are provided on expressways and none are normally provided on other rural highway and local roads. However, there may be instances along some non-controlled access rural highways where existing development, such as a school or factory, may generate sufficient pedestrian traffic to justify providing a sidewalk on one or both sides of the structure and its corresponding accesses. Such sidewalk shall be placed beyond the normal approach shoulder width so that the full approach roadway is carried on the structure. The determination of need for such sidewalks is made during the planning stage.

#### **6-03.06      LIGHTING SUPPORTS**

When the highway lighting design calls for locating lighting units on a bridge superstructure, the poles shall be installed on special supports back of the bridge railing. The installation of lighting poles on top of railings or at breaks in the railing will be avoided.

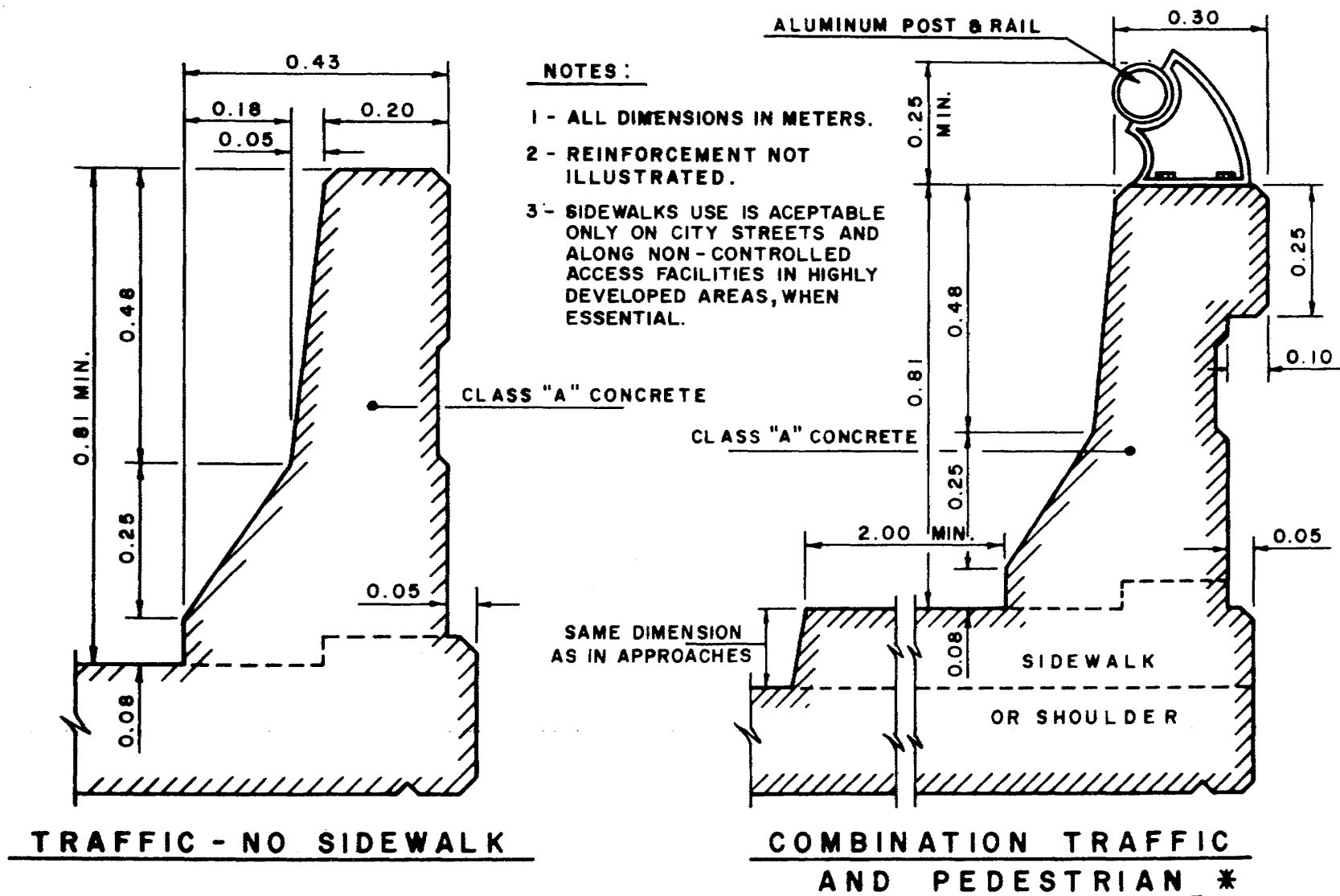
#### **6-03.07      IMPACT ATTENUATOR RESERVE AREAS**

When fixed obstructions must be placed in a gore area, such as the bridge railings at the exit ramp terminals on an elevated structure or when a bridge pier in a gore cannot be avoided, a reserved area for the installation of an impact attenuator (energy dissipating device) must be provided. The details for these impact attenuator reserve areas are illustrated in Figure 6-N. The various energy dissipation devices are covered in Chapter 8.

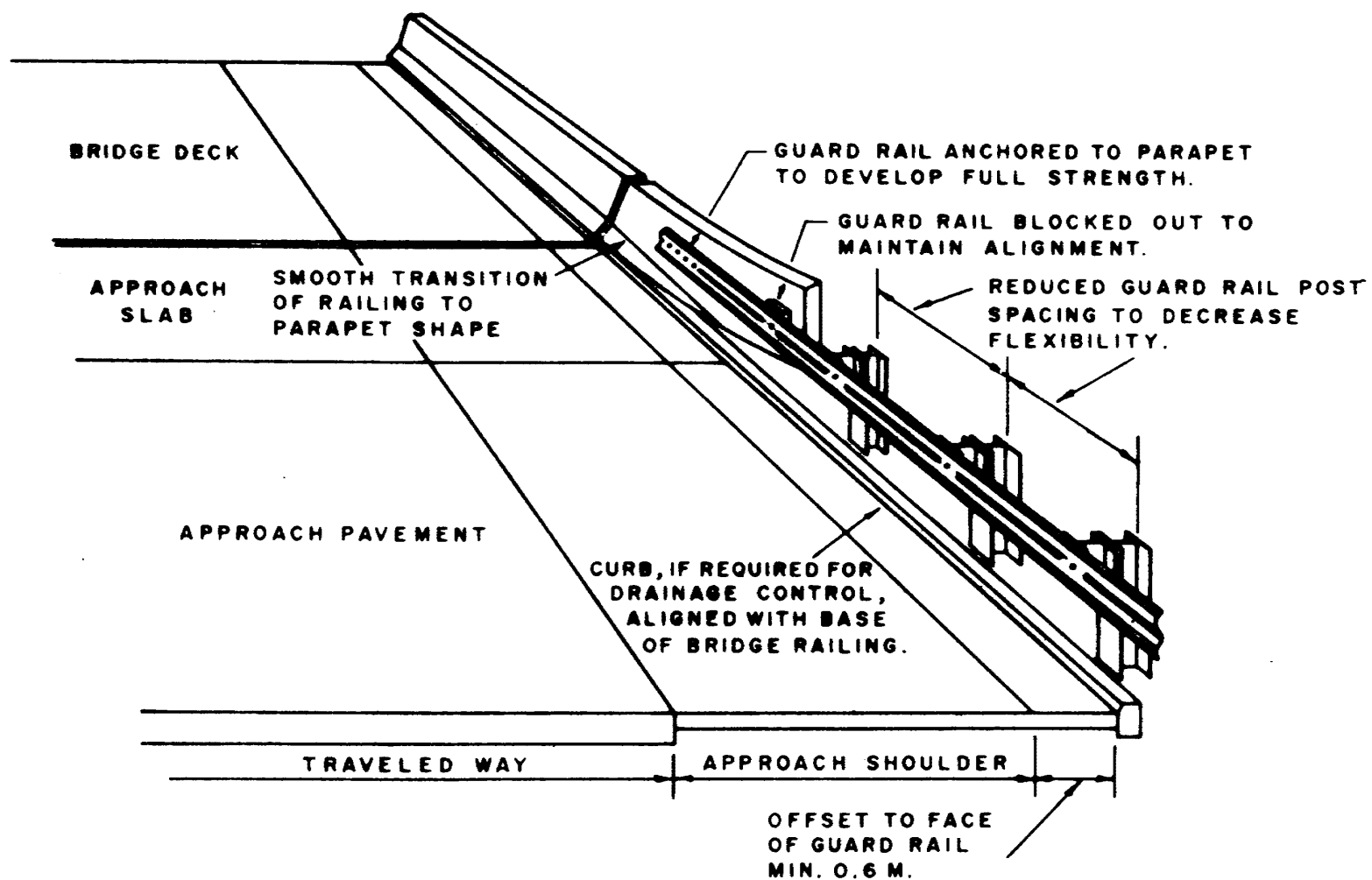
In selecting the dimensions to be applied to new designs from the tabulation shown in Figure 6-N, the minimum values for unrestricted conditions should be used. The restricted conditions minimum values should not be used except when there are extremely tight geometric conditions and the use of the greater values would result in unreasonably higher costs. The preferred values may be applied when their use would only result in minor increases in project costs.

#### **6-04              PRELIMINARY DESIGN PROCEDURES**

The general design requirements for bridges on a particular route are established during the route location studies which include the investigation of alternate routes and their evaluation on the basis of service, socio-economic, environmental and cost factors. During this planning phase consideration is given to the location and costs of structures required with particular emphasis on waterway crossings because of their possible effects on drainage areas, flood plains, navigation, fish and wildlife, and water pollution. The planning phase and the subsequent preliminary and final design involve the consultation and coordination with, and in some cases approvals by, a number of agencies as appropriate. For waterway crossings these may include the Department of Natural Resources, the Planning Board, the Flood Control Area of the DTPW, the U.S. Corps of Engineers, the U.S. Geological Survey and the U.S. Coast Guard.



\* SEE NOTE #3 AND  
SECTION 6-03-05



TYPICAL TRANSITION OF APPROACH GUARD RAIL TO BRIDGE RAILING

FIGURE 6-M

After the route location has been approved, the preliminary design of the highway and bridge structures is initiated including further evaluation and expansion of the design requirements previously established during the initial planning stages. The activities described below are undertaken during the preliminary design phase.

#### **6-04.01 SITE DATA**

Complete site data is necessary for the proper selection and development of plans to provide a structure that best fits the location. Initial site data is available from the route location studies which normally include topographic maps obtained by aerial survey and photogrammetric methods. Additional data is provided by field surveys made by the Surveying Division, see Chapter 16.

The site data for grade separation structures is presented in large scale topographic maps (1:200 to 1:500, depending on site) showing the existing topography, base lines, stationing, control points, existing roads and structures, bench marks, existing utilities, and other pertinent information that will have a bearing on the design of the proposed structure. In addition, data is provided on the approach highways including all elements of the highway sections, horizontal alignment and proposed profiles.

Bridges over waterways require all of the above site data plus additional information necessary for the hydraulic analysis as indicated in the next section.

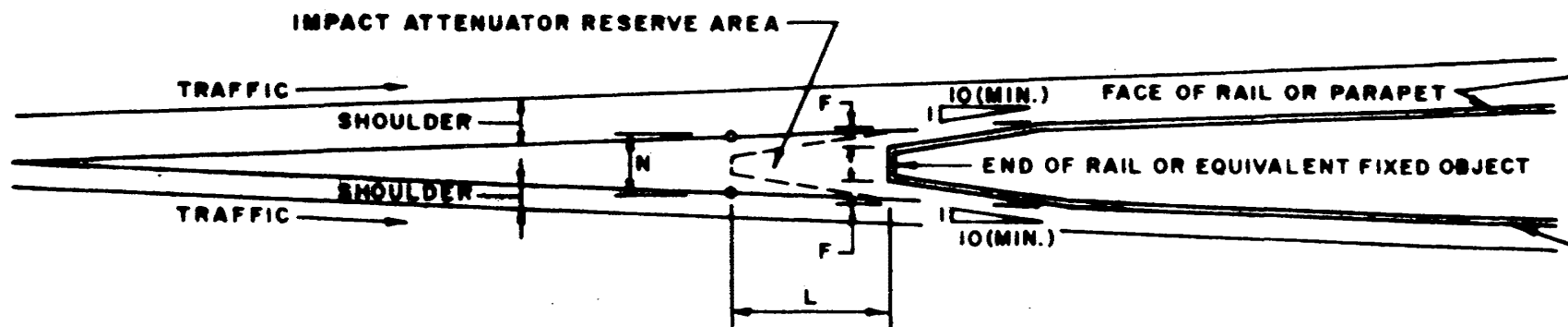
#### **6-04.02 HYDROLOGIC AND HYDRAULIC ANALYSIS**

The determination of adequate waterway opening for stream crossings is essential to the design of safe and economical bridges. In addition, whenever a highway encroaches on a flood plain an evaluation of the flood hazard is required as indicated in Section 6-02.05. Thus, hydraulic studies of bridge sites for stream crossings are a necessary part of the preliminary design phase.

An outline guide for hydraulic studies and reports is shown in Table 6-3. The extent of the study should be commensurate with the importance and magnitude of the project, the complexity of the problems encountered, and the risk to life and property. Less comprehensive studies are appropriate for minor stream crossings and at locations where the risk of property damage or loss of the highway is small. In all cases a written report shall be prepared including the hydrologic and hydraulic data, the design computations, the analysis of the effect on the stream stability, and the favorable or adverse effects on the stream environment.

#### **6-04.03 SITE INSPECTIONS**

It is expected that the designer and the design reviewer in the case of consultant's design shall visit and become familiar with the site during the preliminary design phase and prior to the selection of the possible bridge types. These field visits provide the opportunity to review field reports previously submitted by others, determine what additional site data may be necessary, consider possible shifts in alignment and profile, ascertain foundation data requirements, and inspect any special topographic or other features which may have an important influence on the design or construction requirements.



DESIGN SPEED ON MAINLINE (M.P.H.)	DIMENSIONS FOR IMPACT ATTENUATOR RESERVE AREA ON NEW DESIGNS (METERS)								
	MINIMUM						PREFERRED		
	RESTRICTED CONDITIONS			UNRESTRICTED CONDITIONS					
	N	L	F	N	L	F	N	L	F
30	1.8	2.4	0.6	2.4	3.3	0.9	3.6	5.2	1.2
50	1.8	5.2	0.6	2.4	7.6	0.9	3.6	10.0	1.2
70	1.8	8.5	0.6	2.4	13.7	0.9	3.6	16.8	1.2

NOTE - SEE TEXT FOR GUIDANCE ON APPLICATION

## IMPACT ATTENUATOR RESERVE AREA

FIGURE 6-N

TABLE 6-3  
GUIDE FOR HYDRAULIC STUDIES AND REPORTS

A. SITE DATA

1. Vicinity map — use a USGS quadrangle, an aerial photo, or map of similar detail to show proposed highway alignment and reach of river, bends and stream meanders, and general flow directions.
2. Site map — specially prepared map showing contours (0.5 or 1.0 M. interval), vegetation and manmade improvements. In some cases, cross sections normal to flood-flow are acceptable in lieu of a map. At least 3 cross sections are desirable — upstream, at crossing and downstream.
3. Existing structures, including relief or overflow structure —
  - a. Locate on map existing structures upstream and downstream from proposed crossing.
  - b. Describe each structure fully, giving —
    - (1) Type, number of spans and length of each, pier design and orientation. For culverts give size and number of cells.
    - (2) Foundation type (spread footing, piling) and depth.
    - (3) Scour history at abutments and piers or culvert outlets; stream aggradation or degradation.
    - (4) Cross sections beneath structure, noting clearance to superstructure and skew with direction of current during extreme floods.
    - (5) Flood history, high water marks (elevations) with dates of occurrence, nature of flooding including overtopping, damages and sources of information.
    - (6) Damage from abrasion, corrosion, wingwall failure, culvert end failure.
4. Locate and determine elevations of high water marks along stream, giving dates of occurrence. Describe or list critical flood elevations of interest in evaluating possible damage and indicate datum used. Refer to any available flood hazard studies for the area.
5. Comment on drift, nature of stream bed, bank stability, bends, meanders, vegetative cover and land use.
6. Include photographs of existing structures, past floods, main channel and flood plain to help in evaluating a location and documenting conditions existing prior to construction.
7. List factors affecting water stages —
  - a. High water from other streams.
  - b. Reservoirs — existing or proposed and date of construction.
  - c. Flood control projects — give status.
  - d. Tides.
  - e. Other controls.

## **B. HYDROLOGICAL ANALYSIS**

1. List available flood records.
2. Determine drainage area above proposed construction.
3. Evaluate potential for changes in watershed characteristics which would change magnitude of flood peaks such as urbanization, channelization, etc.
4. Plot flood — frequency curve for site.
5. Plot stage — discharge — frequency curve for site.
6. Determine distribution of flow and velocities for several discharges or stages in natural channel for existing conditions.

## **C. HYDRAULIC ANALYSIS**

1. Determine permissible upstream water surface elevations.
2. Compute backwater for various trial bridge lengths and discharges.
3. Select design flood and waterway design.
4. Provide for conveyance of 100-year flood or maximum flood of record, whichever is greater.
5. Estimate scour depth at piers and abutments.
6. Design riprap for bank protection and scour attenuation devices, if required.
7. Investigate need for spur dikes.
8. Show final layout in plan and profile —
  - a. Show design discharge, elevations and frequency.
  - b. Show discharge and elevations for 100-year flood (or max. flood of record).
9. Comment on —
  - a. Selection of design flood.
  - b. Conveyance of 100-year flood (or max. flood of record).
  - c. Channel change, if provided.
  - d. Effects of construction.
  - e. Need for stream controls to protect the highway.

NOTE — See Section 6—06 for suggested references.

## **6—04.04 COORDINATION WITH OTHER AGENCIES**

Approval and/or permits from various agencies are required in the case of most stream crossings and in the case of some grade separation structures. Initial coordination with and identification of their specific requirements will have been made during the planning and route location studies. Follow up and required permit applications should be completed during the preliminary design phase.

### **1. AIRWAY—HIGHWAY CLEARANCES**

Highway projects in the vicinity of airports must be designed to provide minimum clearances between the highway and the navigable airspace. This may have an influence in the design of the project structures, particularly grade separation structures. The coordination and requirements for airway-highway clearances should be available to the bridge designer in the location report as discussed in Chapter 18.

### **2. FLOOD CONTROL AREA, DTPW**

The flood Control Area of the Department of Transportation and Public Works is responsible for the design, construction and maintenance of flood control works. Coordination with them on highways encroaching on flood plains is initiated during the route location study

phase. They are to be consulted during the preliminary design stages on the hydrologic and hydraulic aspects of the stream crossings and agreement with them reached on the hydraulic design features of the bridges.

### 3. NAVIGABLE WATERS

Bridges over navigable waters require a permit from the U.S. Coast Guard and also from the U.S. Corps of Engineers for all work affecting the navigable waterway (other than the bridge itself) such as channel relocations. Although there are very few rivers and streams in Puerto Rico that are navigable in fact, the Coast Guard has not as yet identified all of those which they consider navigable for which a permit is required. The questions of identifying crossings over waterways which are considered navigable should be completed during the route location study and the navigation requirements established in coordination with the Coast Guard and the Corps of Engineers. The formal applications for permits for the construction of such bridges should be submitted to the Coast Guard and the Corps of Engineers during the preliminary design phase. Detailed design should not be initiated until the required permits have been obtained.

### 4. WATER POLLUTION

The Corps of Engineers has been given control over the discharge of dredge material and placement of fill material over practically all lakes, streams, rivers, coastal water and contiguous wetlands under the Federal Water Pollution Control Act. Therefore, any bridge project involving the discharge of dredged material or placement of fill material over practically any body of water will require an application for a permit by the Corps of Engineers. The regulations of the Corps provide for the implementation of these permit requirements by phases. Coordination with the Corps of Engineers and identification of water bodies subject to Corps' control should be completed during the route location study phase. The bridge designer should become familiar with the permit conditions and detailed design should not be initiated until the permit has been obtained.

## 6-04.05 PRELIMINARY DESIGN REPORT

On the basis of the site data, site inspection, hydraulic report highway requirements and design criteria, and other agencies' requirements (if applicable), the designer will select alternate structure types for consideration. Dimensioned sketches will be prepared showing plan, elevations and typical sections. Approximate detailed cost estimates will be made based on estimated quantities of principal construction items and current unit price data.

At least two alternate types or layouts should be worked for each site. In the case of major structures several alternates may need to be considered to help arrive at the most appropriate solution.

A report shall be prepared and submitted to the Director of the Structural Design Office. The report shall include the sketches and estimates of the various alternate considered, a discussion of major elements considered and recommendations as to which alternate should be selected and why. In evaluating the various alternates under review the designer should consider estimated construction costs, aesthetics, time and ease of construction, availability of materials, future maintenance requirements and costs, and special conditions such as maintenance of traffic during construction. In addition, the report should include a section on specific additional site data required for the design including soil information and borings for the foundations design.

Because of any number of conditions peculiar to each site it is not practical to furnish blanket recommendations on structure types. In general concrete construction is favored in Puerto Rico and in particular prestressed concrete beams. However, it should be remembered that cost trends, new materials, and new design and construction procedures influence the

economy, aesthetics and maintenance of structure types and that basic materials are subject to constant cost fluctuations.

#### **6-04.06 SOILS STUDY**

After agreement has been reached on the alternate design proposed for the site, the designer will prepare a memorandum to the Soils and Materials Office requesting the sub-surface explorations and soils reports needed for the foundation design. A standard format for this memorandum is available in the Structural Design Office. The request will include a layout of the structure showing the location of each pier and abutment tied to the survey line stationing and the suggested boring locations. As a minimum, at least one boring should be requested at each pier and abutment. In addition borings are required on the approaches unless already available from the roadway soil survey. However, although suggested boring locations are indicated, the soils engineer may alter the number and locations of borings in line with his judgement of the site conditions. The soils report will provide specific data and recommendations for the design of the foundations. Soils investigations and reports are discussed in Chapter 12.

#### **6-04.07 ADVANCE PLANS**

After approval of the preliminary design report, the preparation of advance plans at full scale will be initiated. These advance plans will eventually develop into the final detailed construction plans. However, miscellaneous details such as access slab, reinforced steel tables etc., may be omitted at this stage.

The advance plans should include all geometric data such as vertical and horizontal clearances, profiles, superstructure depth, cross sections, waterway information, and typical piers which will enable the necessary agencies to make a proper review of the plans. It is essential that the designer maintain coordination with the roadway designer during the development of the advance plans to insure continuity of design and avoid discrepancies in the overall final project plans. The designer should also be cognizant of any special requirements affecting the structure which may have evolved from the environmental evaluation, the public hearings, and the review and approval by other agencies.

Consultants doing design work for the Department shall submit the advance plans for each bridge for review and approval by the Structural Design Office. The consultant should refrain from further development of the final construction plans until he has received comments and recommendations from the Department and agreement has been reached.

Advance plans shall be submitted to the FHWA Division Administrator for review and approval for all bridges financed under the Federal-aid program. Further work in the development of these final bridge plans should normally be withheld until agreement has been reached with the FHWA.

#### **6-05 FINAL DESIGN AND PLANS**

An explanation of the procedures for detailed design of the structural elements of bridges is beyond the scope of this Manual. The bridge designer must combine education, experience and judgement in order to develop designs that provide durable and economical structures that best meet the requirements of the individual sites.

It is the bridge designer's responsibility to correlate all available data and develop a design that will provide the most efficient construction procedures and staging. He must include in the final plans all necessary notes, instructions, details and construction controls that will insure that the structure when built will be consistent with the design.

A copy of all the design computations, after checking, shall be filed in the permanent project file. After the detailed plans have been developed they are made into reproducible plans. Basic final construction plans requirements and what should be included in the plan set for each bridge are covered in Chapter 19 on "Contract Plans, Specifications and Estimates".

In the case of design by consultants, a copy of the design computations and prints of the detailed plans shall be submitted for review through the Design Area following approval of the preliminary plans for the structure. The Highway Design Office makes a general review to insure that the structure is properly coordinated into the total project. The Structural Design Office makes a more thorough examination for structural adequacy, material economy, completeness of information and compliance with the Department design criteria. However, although the Structural Design Office spot checks dimensions and elevations, makes a cursory review of quantities, and reviews other features of the design, the consultant remains responsible for the completeness and accuracy of the design and final plans. The consultant shall submit a reproducible copy in mylar or approved equal of all the final plan sheets after approval.

## **6-06 REFERENCE AND GUIDES**

Chapter I on "General Design Criteria" includes a listing of selected references that highway designers should have access to and be familiar with. Several of these are repeated herein in addition to other references and guides of particular interest to bridge designers.

### **1. AASHTO Publications:**

- a. A Policy on Geometric Design of Rural Highways — 1965
- b. A Policy on Design of Urban Highways and Arterial Streets — 1973
- c. Standard Specifications for Highway Bridges—1973 and subsequent amendments
- d. Standard Specifications for Welding of Structural Steel Highway Bridges — 1977
- e. Highway Drainage Guidelines, Volumes I, II and III, 1973
- f. Standard Specifications for Transportation Materials, Part I, 1974

### **2. FEDERAL HIGHWAY ADMINISTRATION**

- a. Hydraulic Design Series
  - No. 1 — Hydraulics of Bridge Waterways, 1970
  - No. 3 — Design Charts for Open-Channel Flow, 1961
  - No. 4 — Design of Roadside Drainage Channels, 1965
- b. Standard Plans for Highway Bridges
  - Vol. 1 Concrete Superstructures — 1976
  - Vol. 2 Structural Steel Superstructures — 1968
  - Vol. 4 Typical Continuous Bridges — 1975
- c. Handbook of Highway Safety Design and Operating Practices — 1973

### **3. Transportation Research Board—**

- a. NCHRP Report No. 149 — Bridge Rail Design—Factors, Trends and Guidelines
- b. NCHRP Synthesis No. 5 — Scour at Bridge Waterways

### **4. Reinforcing Steel Welding Code, AWS D12.1-75**

### **4A. Structural Welding Code AWS D1.1-75**

### **5. P.R. Planning Board — Planning Regulation No. 13, Regulation on the Control of Buildings and Land Development in Areas Suceptible to Flooding, 1971.**

6. U.S. Water Resources Council — Flood Hazard Evaluation Guidelines for Federal Executive Agencies, 1972
7. U.S. Department of Commerce, National Weather Service — Technical Paper No. 42 on Generalized Estimates of Probable Maximum Precipitation and Rainfall—Frequency Data for Puerto Rico and Virgin Islands, 1961
8. U.S. Geological Survey — Hydrologic Investigation Atlases and Map Series for various river basins in Puerto Rico.
9. U.S. Corps of Engineers — Flood Plain Information Reports for various rivers in Puerto Rico.
10. Bureau of Structural Design, DTPW
  - a. Procedural Memorandums
  - b. Design Policy Memorandums
  - c. Guide Detail Sheets covering such items as parapets and railings, embankment cones at grade separation structures, deck drainage, wingwalls, rip-rap protection, AASHTO beams, deck slabs, diaphragms, spur dikes, etc.
11. Other References
  - a. "Standard Specifications for Structural Support for Highway Signs, Luminaries and Traffic Signals" — 1975
  - b. "Highway Design and Operational Practices Related to Highway Safety" (Yellow Book) — 1974
  - c. "Guide for Selecting, Locating and Designing Traffic Barriers" — AASHTO — 1977