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Third Edition

Highway - Specifications for Design

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Foreword

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Highway - Specifications for Design

1. Scope of Application

1.1 This standard sets out requirements for the design of the public highway network, including new construction, rehabilitation and improvement projects. The design of specialized roads such as Freeway/Expressway, Urban roads, Industrial district roads, Forestry roads and other roads etc. should comply with the respective sectional standards. When designing rural roads, provisions for appropriate road class in this standard could be applied.

In the case of highway design involving other works such as railway, irrigation work, or the highway passing over residential area, urban area, cultural and historic relics etc. the highway design should follow not only this standard but the existing regulations of the State for the related works also.

1.2 In special case, it's possible to apply technical specifications in other standards but only after has technical and economic analysis been done.

Highway sections which are followed other technical specifications should be designed concentratively along the alignment and the total length of the sections should not exceed 20% total length of the designed alignment.

2. Reference Materials

The following reference materials are very important in applying the standard. It's possible to apply the cited reference materials with issuance date. The materials without issuance date might be applied with the latest edition including revised editions.

TCVN 5729: 1997 Freeway/Expressway - Specifications for Design

22TCN 16: Specification for measuring smoothness of pavement surface by 3m length straight edge

22TCN 171 Specification for surveying geological conditions and designing stabilized method for embankment in the landslide and settlement area

22TCN 211 Flexible pavement specifications

22TCN 211	Standard for transportation work design in seismic zone
22TCN 223	Rigid pavement specifications
22TCN 237	Roadway traffic signal regulations
22TCN 242	Specification for environmental impact assessment when preparing project feasible report and design
22TCN 251	Testing specifications for determining general elastic modulus of the flexible pavement by Benkelman level beam
22TCN 262	Highway embankment on soft soil design survey standard
22TCN 272	Bridge design standard
22TCN 277	Standard for testing and evaluating pavement surface by international roughness IRI
22TCN 278	Testing specification for determining pavement roughness by blinding
22TCN 332-05	Testing specification for determining CBR of soil, crushed stone in laboratory
22TCN 333-05	Specification for soil, crushed stone compaction in laboratory
22TCN 334-05	Technical specification for construction and acceptance of macadam foundation in highway pavement structure

3. General Specifications

3.1 Specifications for design

3.1.1 When carrying out highway design, not only provisions stipulated in this standard must be followed sufficiently but comprehensive study should be done also to have safe, effective and sustainable highway.

3.1.2 The elements of alignment such as horizontal alignment, vertical alignment, and cross-section should be coordinated closely together with taking the most use of topographic conditions in order to make a spatially well-proportioned route assuring both favorable sight distance and intrinsic mechanical stability for obtaining following objectives:

- satisfying traffic volume properly in order to ensure appropriate traffic flow;
- ensuring maximum safety and comfortableness for vehicles and road users;
- having highly economical effectiveness by evaluation norms regarding work construction cost, maintenance cost, expense for transport price, transport duration and traffic accident forecast;
- mitigating negative impacts to environment, creating properly ecological equilibrium in order for the road to become a positively integral part of the landscape in the locality.

3.1.3 In principles, high- class highways (of category I, II and III) shall not be planned running through urban centers. When designing, following considerations should be made:

- connection between the road with the urban area especially large urban area
- method for separation of the local traffic, particular from high- class highway in order to ensure mobility of the traffic.

The highway shall ensure two functions, these are:

- mobility presenting by high speed, cut-down of travel time and safety during traveling
- accessibility i.e. vehicle can reach the destination favorably.

These two functions are incompatible. Therefore, it's necessary to limit accessibility of the high-level highway with high traffic volume and long distance in order to ensure mobility; in contrast for the low-level highway (of category IV, V, VI) the accessibility shall be ensured.

For the high- level highway, it's necessary to ensure:

- separation of the local traffic from the through traffic on the high-level highway.
- detour residential area, but taking into consideration of the connection with the urban area especially large urban area requiring radial traffic

3.1.4 For highway design, staged construction shall be considered based on long-term master plan. The option of staged construction should be suitable with the recently estimated traffic volume and a part of the master plan. That means the master plan shall take full or most use of the works built in previously staged construction. When executing the staged construction plan, provision of land reservation for future construction shall also be considered.

3.2. Design Vehicles

The design vehicle shall be the prevailed vehicle type in the traffic flow used for calculating highway factor.

The dimensions for design vehicles are given in Table 1.

Table 1 - Dimensions for design vehicles

Dimensions are in meters

Vehicle Type	Overall Length	Overall Width	Height	Front Overhang	Rear Overhang	Wheel base
Car	6.00	1.80	2.00	0.80	1.40	3.80
Truck	12.00	2.50	4.00	1.50	4.00	6.50
Semi-trailer	16.50	2.50	4.00	1.20	2.00	4.00 ÷ 8.80

3.3. Design Traffic Volume

3.3.1 Design traffic volume is defined as the total number of passenger car equivalent vehicles that pass over a given cross section during a given time interval, estimated for the future year. The future year is defined as the 20th year after putting into operation of the Class I and II highways and the 15th year for the Class III and IV highways; the 10th year for the Class IV and VI and rehabilitation ones.

3.3.2. The equivalent factors for converting various sized vehicles to passenger car units can be obtained from Table 2.

Table 2 - Passenger Car Equivalent factors

Terrain	Type of vehicles					
	Bicycle	Motorbike	Car	Trucks of 2 axles and mini bus with less than 25 seats	Truck of more than 3 axles and large bus	Trailer and bus with trailer
Flat and rolling	0.2	0.3	1.0	2.0	2.5	4.0
Mountainous	0.2	0.3	1.0	2.5	3.0	5.0
NOTE: <ul style="list-style-type: none"> - Classification of the terrain is based on common natural slope of the hill side and mountain side as follows: flat and rolling $\leq 30\%$; Mountains $> 30\%$. - For the highway having separated bicycle lanes, the number of bicycles is not converted. 						

3.3.3 Design volume characteristics:

3.3.3.1 The Annual Average Daily Traffic Volume in the future year (abbreviated N_{AADT}) has its unit as PCU/daily (passenger car unit/ daily).

This traffic volume could be used to determine technical classification for highway and to calculate other elements.

3.3.3.2 The peak-hour traffic volume in the future year (abbreviated $N_{Peak-hour}$) has its unit as PCU/hour (passenger car unit/hour). This traffic volume is used for determining and arranging the number of lanes, forecasting the quality of traffic flow, traffic organization, etc.

$N_{Peak-hour}$ could be determined as follows:

- For statistical data available, it can be computed from $N_{average\ daily}$ using the time variation factors.
- For annual hourly volumes available, using the 30th highest hour volume of the statistic year;
- If there is no special study, it's possible to apply $N_{Peak-hour} = (0.10 \div 0.12) N_{average\ daily}$

3.4 Design categories for highway

3.4.1 Design classification is the highway technical specifications criteria in order to satisfy:

- traffic requirement proper to the function of the highway in the transport network;
- requirement on design traffic volume (this criteria is extendable because there are cases of important road with low traffic volume or temporally low traffic).
- based on terrain, each design category has particular standard requirements for appropriate investment and economic effectiveness.

3.4.2 Technical classification is based on function and design traffic volume of the highway in the network and stipulated in the Table 3

Table 3 – Highway Technical Classification according to function and design traffic volume

Design categories	Design traffic volume (PCU/daily)	Major functions of highway
Expressway	> 25.000	Arterial road, in compliance with TCVN 5729:1997
I	> 15.000	Arterial road, connecting large national economic, political, cultural centers National Highway
II	> 6.000	Arterial road, connecting large national economic, political, cultural centers National Highway
III	> 3.000	Arterial road, connecting large national and regional economic, political, cultural centers National Highway or Provincial Road
IV	> 500	Highway connecting regional centers , depots, residential areas National highways, Provincial road, District roads
V	> 200	Road serving for local traffic. Provincial road, district road, communal road
VI	< 200	District road, communal road
* These values are for reference. Selection of road classification should base on road function and terrain type.		

3.4.3 Each highway section must cover a minimum length as stipulated in its category. This minimum length is 5km for the Class IV downward, and 10km for the other categories.

3.5 Design speed, (V_{tk})

3.5.1 Design speed is defined as the speed used for the calculation of major technical elements of each highway in difficult situations. This speed differs from the permitted operating speed on the roadway stipulated by road management agency. The permitted operating speed is dependent on the actual condition of the road (climate, weather, road condition, traffic condition etc.)

3.5.2 Design speed of each road category is based on its topographic condition and stipulated in the Table 4

Design categories	I	II	III		IV		V		VI	
Topography	flat	flat	flat	mountain	flat	mountain	flat	mountain	flat	mountain
Design speed, V_{tk} (km/h)	120	100	80	60	60	40	40	30	30	20
NOTE: Classification of the terrain is based on common natural slope of the hill side and mountain side as follows: flat and rolling $\leq 30\%$; Mountain $> 30\%$.										

4. Cross sections

4.1 General requirements for design of highway cross- sectional layout

4.1.1 Layout of highway components including traveled way, shoulder, separator, frontage road and auxiliary lanes (climbing lane, speed-change lane) on the highway cross- section shall in compliance with traffic organization requirements in order for all vehicles (all type of automobiles, motorbikes, non-motorized vehicles) to operate safely, comfortably and to take the most use of the road serviceability.

Based on design category and design speed of the highway, the layout of the cited components must comply with traffic organization alternatives stipulated in the Table 5.

Table 5- Traffic Organization Alternatives on the roadway cross-section

Design categories		I	II	III	IV	V	VI
Design speed, V_{tk} (km/h)	Mountainous area	-	-	60	40	30	20
	Flat and rolling	120	100	80	60	40	30
Frontage road*		exist	exist	None	None	None	None
Separated lanes for bicycles and		Bicycles and non-motorized vehicles are arranged on		- arrange on stabilized	No separated lane; bicycles and non-motorized vehicles		Bicycles and non-

Design categories	I	II	III	IV	V	VI
non-motorized vehicles	frontage road (refer to 4.6.2 and 4.6.6)		part of shoulder - side separator ** by line marking	travel on stabilized part of shoulder		motorized vehicles travel on traveled way
Separation between 2 traffic direction	With separation band between 2 traffic direction		Two lanes without median separator. Four lanes with double lines marking for separation			
Turnaround loop	To cut the median separator for turnaround loop according to 4.4.4		No limitation			
Limited access	Frontage road is parallel to the main road. Distance between entrance and exit is at least 5km and traffic organization is reasonable.		No limitation			
* For frontage road, refer to Article 4.6.						
** For side separator, refer to Article 4.5.						

4.1.2 The minimum width of cross- sectional elements of highway categories is given in Table 6 applied for flat and rolling terrain, and in Table 7 applied for mountainous terrain.

Table 6- Minimum width of cross-sectional elements applied for flat rolling terrain

Design categories	I	II	III	IV	V	VI
Design speed, (Km/h)	120	100	80	60	40	30
Minimum number of lanes for motorized vehicle, (nos)	6	4	2	2	2	1
Width of a lane, (m)	3.75	3.75	3.5	3.5	2.75	3.5
Width of traveled way for motorized vehicle, (m)	2 × 11.25	2 × 7.50	7.00	7.00	5.50	3.50
Width of median separator ¹⁾ , (m)	3.00	1.50	0	0	0	0
Width of shoulder and stabilized part of shoulder ²⁾ , (m)	3.50 (3.00)	3.00 (2.50)	2.50 (2.00)	1.00 (0.50)	1.00 (0.50)	1.50
Width of roadbed, (m)	32.5	22.5	12.00	9.00	7.50	6.50

- 1) Width of median separator for each structure is defined in Article 4.4 and Figure 1. The minimum value is applied for separator made of pre-cast concrete or curb stone with cover and without constructing piers (poles) on separated bands. In other cases, separator width must comply with provisions in Article 4.4.
- 2) Number in the bracket is the minimum width of stabilized part of shoulder. If possible, it suggests to stabilize the whole shoulder width, especially when the highway without side lane for non-motorized vehicles.

Table 7- Minimum width of cross-sectional elements applied for mountainous terrain

Design categories	III	IV	V	VI
Design speed, (Km/h)	60	40	30	20
Number of lanes for motorized vehicle, (nos)	2	2	1	1
Width of a lane, (m)	3.00	2.75	3.50	3.50
Width of traveled way for motorized vehicle, (m)	6.00	5.50	3.50	3.50
Width of shoulder*, (m)	1.50 (stabilized 1.0m)	1.00 (stabilized 0.5m)	1.50 (stabilized 1.0m)	1.25
Width of roadbed, (m)	9.00	7.50	6.50	6.00
* Number in the bracket is the minimum width of stabilized part of shoulder. If possible, it suggests to stabilize the whole shoulder width, especially when the highway without side lane for non-motorized vehicles.				

4.1.3 When designing highway cross-section, it's necessary to study carefully land use plan of the area where the highway passes through, to consider staged construction alternatives of the cross-section (as for road of class I and II) and to take into consideration the land reservation for future road improvement; and to determine right-of-way according to the existing State regulations as well.

4.2 Traveled Ways

4.2.1 Traveled way consists of an integral number of lanes. This number should be an even number, except for cases that traffic volume in each direction has a significant difference or there is a special traffic control on the highway.

4.2.2 The number of lanes on the cross section is determined by the road category given in Tables 6 and 7, and must be checked by the formula:

$$n_{\text{lane}} = \frac{N_{\text{rush-hour}}}{Z \cdot N_{\text{ltth}}}$$

Where:

n_{lane} = required number of lanes, rounded up as per Article 4.2.1;

$N_{\text{rush-hour}}$ = rush-hour design traffic capacity, which is determined as per Article 3.3.3;

$N_{\text{actual capacity}}$ = actual capacity of through traffic flow, which is determined, if there is no study and calculation, as follows:

- When there is median separator between the vehicles in opposite directions and side separator between motor vehicles and non-motorized ones, it is 1800 PCU/h/lane;
- When there is median separator between the vehicles in the opposite directions but no side separator for motor vehicles and non-motorized ones, it is 1500 PCU /h/lane;
- When there is no separator between the vehicles in the opposite directions and motor vehicles use the same lane with non-motorized ones, it is 1000 PCU /h/lane;

Z = volume-to-capacity ratio:

when $V_{\text{tt}} \geq 80\text{km/h}$, $Z = 0.55$;

when $V_{\text{tt}} = 60\text{km/h}$, $Z = 0.55$ for the flat area and $Z = 0.77$ for the rolling-mountainous areas;

when $V_{\text{tt}} \leq 40\text{km/h}$, $Z = 0.85$

The above-mentioned calculation method shall be applied for the expected traveled way with number of lane more than that given in the Tables 6 and 7.

4.2.3 Lane width.

In common case, the lane width for each highway categories is stipulated in the Tables 6 and 7.

4.3 Shoulders

4.3.1 Dependent on highway category, the shoulders have a stabilized part whose width is prescribed in Tables 6 and 7 (value in the bracket). Structure of the stabilized part is regulated by Article 8.8.

4.3.2 For highway with design speed of 60km/h or more, there must be a direction guiding stripe (edge line). It is a continuous yellow or white color stripe, 20cm wide, placed on the stabilized shoulder and close to the edge of pavement. At places for passing such as intersections, merging and diverging maneuvers etc., this stripe is broken line in accordance with the regulations on road signs. In case that there is a side separator on the road class III to separate bicycle lane on the stabilized part of the shoulder, the direction guiding stripe can

be replaced with double continuous white line, width of each line is 10cm and distance between each line is 10cm (total width of the double line is 30cm).

4.3.3 At places where there are auxiliary lanes such as climbing lane, speed-change lane etc., these lanes will replace the stabilized part of shoulder. If the width of remaining soil shoulder is not wide enough, it is necessary to widen the roadbed in order to ensure that the remaining shoulder is not less than 0.5m in width.

4.3.4 Road for non-motorized vehicles

For the highway class I and II, non-motorized vehicles must be separated from the motorized lanes (as stipulated in the Table 5) in order to travel on the same frontage road with the local traffic. As for road class III, the non-motorized vehicles travel on the stabilized part of the shoulder, which is separated from the motorized lane by a side separator; refer to Article 4.5).

The width of bicycle pavement in one direction is calculated by the formula:

$$b = 1 \times n + 0.5 \text{ m} \quad (\text{in which } n \text{ is number of bicycle lanes in one direction})$$

The through capacity of a bicycle lane is 800 bicycles/hour/one direction. In case that the bicycle lane is arranged on the stabilized part of the shoulder, when the stabilized part is required widening for sufficient width b (width of the stabilized part of the shoulder shall be equal to b plus width of side separator). The width of bicycle pavement must be sufficient to account for passing capacity of other non-motorized vehicles.

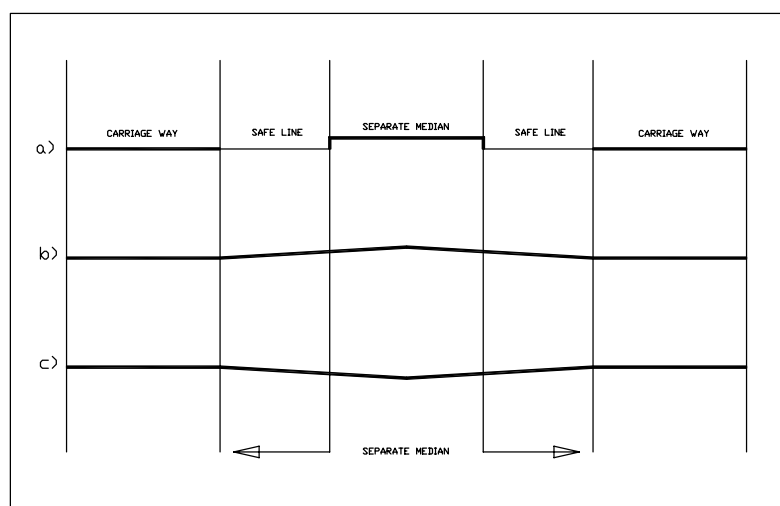
4.3.5 Surface of the non-motorized way must be as smooth as the adjacent motorized lane.

4.4 Median Separator.

4.4.1 Median separator shall only be arranged for the 4-lane highway upward (refer to Table 5), including separator and two safety parts (stabilized) on both sides. The minimum dimensions of the separator are given in Table 8, and Figure 1.

Table 8 - Minimum dimensions of a median

The structure of separator	Separated part (m)	Safety part (stabilized) (m)	Minimum width of a median (m)
Pre-cast concrete, curb stones with covers; no constructing piers (poles) on separator	0.50	2×0.50	1.50
Curb stones, with covers, piers (poles) on separator	1.50	2×0.50	2.50
Without covers	3.00	2×0.50	4.00



Legend:

- a. Raised medians;
- b. Flush medians, with the pavement surface;
- c. Depressed medians, collected storm water to the middle.

Figure 1. Structure of median

4.4.2 When the roadbed is divided into two separated parts, the one-way roadbed consists of traveled lane and shoulders. The formation of right shoulder is shown in Table 6 or Table 7 depending on the terrain; the left one has the same width as the right shoulder but the width of stabilized part can be reduced to 0.50m. The edge striping of 0.20m wide is still placed on the stabilized part of shoulder close to the pavement.

4.4.3 When the width of separating bands is less than 3.00m, the separating parts must be surfaced and rounded by curbstone.

When the separating bands is from 3.00 to 4.50m in width:

- if it is protected by curbstone, it is necessary to ensure that soil in the separated area does not cause dirt to the pavement (soil surface is lower than curbstone); the curb stone is at least 18cm in height and must have compacted clay layer to prevent water from seeping to the underneath pavement.
- it is necessary to grow grass or shrubs for soil protection, height of the shrubs should not be more than 0.80m.

When the width of separated band is over 4.50m (to reserve land for widened lanes or separate one-way roadways), it should be depressed and has drainage facilities to protect the roadbed from water infiltration. The formation of shoulder is prescribed as in Article 4.4.2.

4.4.4 The median should be cut to provide the path for turnaround loop. The turnaround loop is arranged as follows:

- The interval between turnaround loops is not under 1.0km (when the width of median is less than 4.5 m) and not over 4km (when the width of median is more than 4.5 m).
- near (approaching) tunnels and long bridges.

The length and the edge of cutting place on the separator must be large enough for three-axle truck to turn around. The cutting edge shall be trimmed by the truck's orbit to prevent the truck from hitting the edge of curbstone.

4.5 Side separator

4.5.1 Side separator shall only be arranged in cases mentioned in Table 5, in order to separate bicycle and non- motorized vehicle lane on the stabilized part of the shoulders (or widening stabilized part) from the traveled way for motorized vehicle.

4.5.2 Arrangement and structure of the side separator can be one of the following alternatives:

- By two continuous line in compliance with 22TCN 237 (only for road class III);
- By guardrail (made of corrugated iron). Height from the shoulder's surface to crest of the guardrail is 0.80m.

The above-mentioned cases are placed on the stabilized part, but the side safety part must be at least 0.25m far from the edge of the nearside motor lane.

Width of the side separator consists of width of the guardrail (or marking line) and width of the side safety part.

4.5.3 The side separator shall be cut for water drainage with the interval of less than 150m. The turnaround loop for non-motorized vehicles shall be arranged so as to coincide with that for the motorized vehicles, according to the Article 4.4.4.

4.6 Frontage road

4.6.1 Frontage road is the auxiliary road arranged along both sides of the road class I and II, has following functions:

- To prevent traffic (motorized, non-motorized vehicles and pedestrians) from accessing freely the road class I and II;
- To meet the traveling demand of the cited vehicles in local scope (local traffic) in one-way or two- way (in the scope between the permitted accesses to the road class I and II)

4.6.2 On the road class I and II, frontage road shall be arranged on the sections having significant local traffic such as sections through residential areas, industrial zones, tourism landscape, forestry and agricultural

farm etc. When it's impossible to arrange frontage road (in staged construction, or having difficulties etc.) provisions in Article 4.6.6 shall be applied.

Determination of above-mentioned local traffic demand is required surveying, forecasting by socio-cultural-economic development plan for each section to be arranged frontage road.

4.6.3 Frontage road shall be arranged separately from the main roadway of the road class I and II. Length of each frontage road (i.e. interval between permitted accesses to the road class I and II) is equal or larger than 5 km. Frontage roads can be arranged at both sides of the main line and it can be one-way or two-way road each side (in order to facilitate the local traffic). If there are frontage roads at both sides of the main line, it's possible to organize traffic from frontage roads by grade-separated underpass or overpass structures (do not cross the main line) at the locations of the permitted accesses to the main line only when it's really necessary.

4.6.4 Frontage road can be arranged right at the right-of-way of the main road class I and II. In this case the ROW shall be in compliance with the existing regulations taking account of the boundary of the edge side structure of the frontage road.

4.6.5 Frontage road is designed by category V and VI (for flat or rolling terrain) but its roadbed width can be reduced minimally to 6.0m (if two-way frontage road) and 4.5m (if one-way frontage road). Cross-sectional arrangement of the frontage road shall be selected by Design consultant depending on the actual requirements.

4.6.6 As for sections without frontage road, on the road class I and II it's necessary to arrange bicycle and non-motorized vehicles lane on the stabilized part which is separated by guardrail with height of at least 0.80m from the road surface.

4.7 Climbing auxiliary lanes

4.7.1 Climbing auxiliary lane is considered to be placed only when having enough the three following conditions:

- Climbing traffic flow exceeds 200 vehicle/h, in which volume of truck exceeds 20 vehicle/h;
- when grade is over 4% and;
- length of grade is more than 800m;

As for road sections expected to be arranged climbing lane, it's necessary to make comparison on economic and technical norms of the two alternatives, i.e. arrangement of climbing lane or road grade deduction.

The climbing lane is usually taken into consideration for two-lane roadway without median separator and with constraint passing condition.

4.7.2 Formation and arrangement of climbing lanes:

- The width of a climbing lane is 3.50m and can be reduced to 3.00m in difficult cases.
- Climbing lanes should be located separately, if impossible, the climbing lane shall be placed on stabilized part of the shoulder; if the stabilized part width is not adequate, it needs widening to sufficient width of 3.5m and soil shoulder width must be 0.5m (at this climbing segment bicycles and non-motorized vehicles shall travel on the same climbing lane with trucks).
- A transition part for vehicle to enter the climbing lane must be placed 35m prior to the entrance of the climbing lane and widened in tapered shape with enlarged width of 1:10; a transition part for vehicle to exit the climbing lane must also be widen in tapered shape from the top point of the grade with narrow width of 1:20 (length of the taper is 70m)

4.8 Speed- change lanes

Speed- change lane is arranged at entrance and exit of frontage road to road class I and II. Formation of the speed- change lane is provided in Article 11.3.5.

4.9 Cross- slope

Cross slope of cross- sectional elements of the straight line is prescribed in Table 9. The cross slope in curved sections must follow regulation on super-elevation (refer to Article 5.6).

Table 9 - Cross slope rate of cross-sectional elements

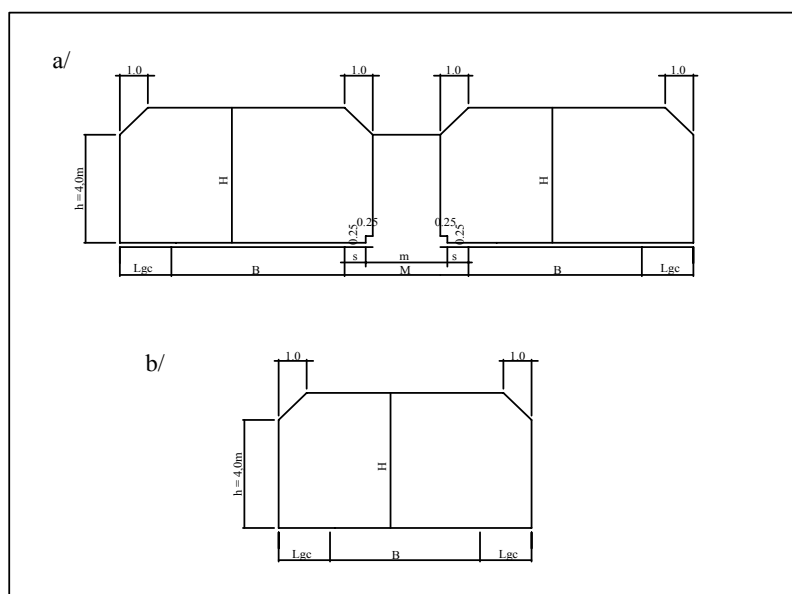
Cross- sectional elements	Cross Slope Rate, %
1. Pavement and shoulder stabilized part	
Cement concrete and asphalt concrete	1.5 - 2.0
Other types of road surface, good and flat rock paved surface	2.0 - 3.0
Medium- quality rock paved surface	3.0 - 3.5
Gravel macadamized, aggregate, low-type surface	3.0 - 3.5
2. Non-stabilized shoulder part	4.0 - 6.0
3. Separator	Depending on covering material, applied correspondingly to 1.

4.10 Clearances.

4.10.1 Clearance is defined as a space limit to ensure traveling of all types of vehicles. In the clearance area no obstacle, including highway facilities such as road signs, lighting poles, etc. is allowed to be placed.

4.10.2 The minimum clearance of highway categories is prescribed in Figure 2. On the improved highway, in case of difficulty rising, it's possible to keep the old clearance but not less than 4.30m. In this case, it's required to design gantry for clearance limitation, which is placed before the limited clearance of at least 20m.

For highway passing over railway, clearance height shall follow the standard 22 TCN272 (depending on railway gauge and type of locomotive)



a- Highways of $V_{tk} \geq 80$ km/h with median;

b- All types of highway without median;

B - Width of traveled way;

L_{gc} - width of stabilized shoulder part (see Table 7);

m - Separated part;

s - Safety part (stabilized);

M - width of separator;

M, m, s- minimum values (see Tables 6 and 7)

H - Clearance height from the highest point of traveled lane (the height does not take into account of the reserved height for pavement raising when repairing or improvement);

h - Clearance height at the edge of stabilized shoulder

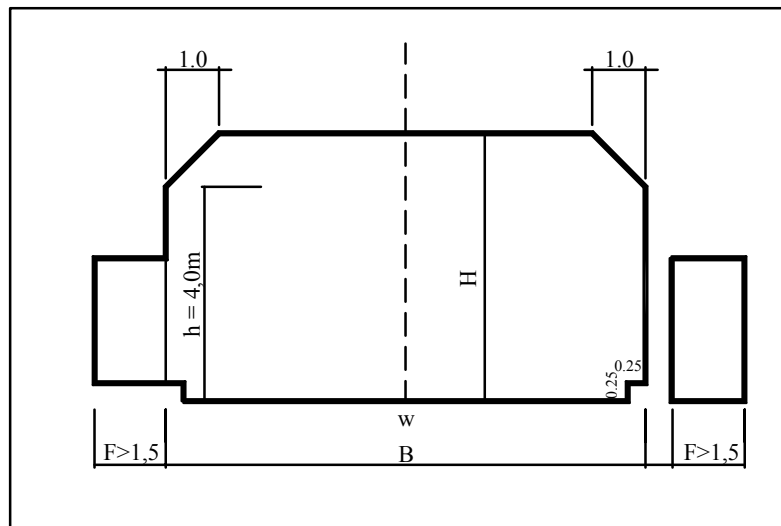
$H = 4.75$ m $h = 4.00$ m for highway class I, II, III

$H = 4.50$ m $h = 4.00$ m for remaining highway classes

Figure 2. Highway Clearances

4.10.3 In case of bicycle (or pedestrian) traffic is separated from traveled way, minimum clearance of for non-motorized vehicle way and walkway is a rectangle of 2.50m high and minimum 1.50m wide. This clearance may be placed close to the clearance of traveled way or separated by a side separator, same as clearance in tunnel (Figure 3).

4.10.4 The clearance in tunnel is in compliance with the existing specifications for tunnel design and showed in Figure 3. The soil shoulder part is transformed into space for placing guardrails.



F - width of bikeway or walkway; G - width for placing highway facilities.

NOTE: The left part is the case of walkway and bikeway close with traveled way, the right part is the case of separation

Figure3. Clearances in the tunnel

4.10.5 The width of roadway on the bridge:

- For bridge length $L \geq 100$ m, the width of roadway follows clearance standard of the bridge design.
- For bridge length $L < 100$ m, the width of roadway is determined by the width of traveled way and the width required for pedestrians and non-motorized vehicles movement combined. However, it must not be larger than the roadbed width.
- For bridge length $L < 25$ m, roadway width is equaled to the bridge width.

5. Horizontal alignment and Vertical alignment

5.1 Sight Distance

5.1.2 Sight distance on the roadway must be necessarily ensured to improve operating safety and psychological reliability for driver to travel at design speed.

Minimum value on stopping sight distance, opposing sight distance and overtaking sight distance are given in the Table 10.

Table 10 - Minimum sight distance on roadway

Design categories	I	II	III		IV		V		VI	
Design speed, V_{tk} , km/h	120	100	80	60	60	40	40	30	30	20
Stopping sight distance (S1), m	210	150	100	75	75	40	40	30	30	20
Ahead opposing sight distance (S2), m	-	-	200	150	150	80	80	60	60	40
Overtaking sight distance S_{xv} , m	-	-	550	350	350	200	200	150	150	100

Sight distances are calculated from the driver's eye sight with height of 1.00m above road surface; to opposing vehicle with height of 1.20m, to object on the roadway with height of 0.10m.

5.1.2 When designing, it's necessary to check sight distance. At locations with insufficient sight distance, it's necessary to remove all obstacles (clearing trees, excavating side slope etc.). After removing, obstacles must be 0.30m lower than sight line. In difficult cases, it's possible to use convex mirror, signs, speed limit sign or prohibited passing sign

5.2 Highway elements on horizontal alignment

5.2.1 On the horizontal alignment, the alignment consists of tangents continued with circular curvature sections. When the design speed $V_{tk} \geq 60$ km/h, it is necessary to provide a clothoid transition curve between tangent and curvature.

5.2.2 The length of straight line between two reverse curvatures must be sufficient for placing of the transition curve or super-elevation runoff.

5.3 Curvature on horizontal alignment (Horizontal curve)

5.3.1 Only in difficult situations, the minimum radius of horizontal curvature may be applied. The use of normal minimum radius upward should be encouraged; topographic condition should be taken advantages in order to ensure the best quality of vehicle operation.

Provisions on radius of horizontal alignment are given in Table 11.

Table 11 - Minimum radius of horizontal alignment

Highway categories	I	II	III		IV		V		VI	
Design speed, km/h	120	100	80	60	60	40	40	30	30	20
Radius of horizontal alignment, m										
- limited minimum	650	400	250	125	125	60	60	30	30	15
- normal minimum	1000	700	400	250	250	125	125	60	60	50
- non-superelevation minimum	5500	4000	2500	1500	1500	600	600	350	350	250

5.4 Traveled way widening on curvatures

5.4.1 It's required to widen the traveled way if vehicle traveling on curvature. When curvature radius is $\leq 250\text{m}$ the traveled way shall be widened as shown in Table 12.

5.4.2 When the traveled way has more than two lanes, each lane is widened by a half of the value recognized in Table 12 and its multiple is 0.1m.

As for traffic flow with special vehicle, it's necessary to check the values given in the Table 12.

Table 12- Extra width allowance on curve of two-lane traveled way on plan

Units are given in millimeter

Traffic flow	Radius of horizontal curvature							
	250 ÷ 200	<200 ÷ 150	< 150 ÷ 100	<100 ÷ 70	<70 ÷ 50	<50 ÷ 30	<30 ÷ 25	<25 ÷ 15
Car	0.4	0.6	0.8	1.0	1.2	1.4	1.8	2.2
Truck	0.6	0.7	0.9	1.2	1.5	2.0	-	-
Trailer	0.8	1.0	1.5	2.0	2.5	-	-	-

5.4.3 The widening part is on both sides, crest and sag side of the curve. In difficult conditions, it's possible to place the widening part on one side, sag or crest side of the curve.

5.4.4 The widening part is placed in the area of stabilized shoulder. The direction guiding stripe (and the others such as the auxiliary lanes for non-motorized vehicle etc.) must be placed on the right side of the widening part. When it is necessary, the roadbed must be widened to ensure the remaining part of soil shoulder is not less than 0.50m.

5.4.5 The widening section totally coincides with the super-elevation section and transition curvature. When these two elements are absent, it is formed as follows:

- a half of widening section is placed on the straight line, other half on the curvature.
- on the widening section, the enlargement is even (linear). Widening 1m on the minimum length of 10m;

5.5 Super-elevation rate and tangent runoff

5.5.1 Super-elevation is the one-side cross slope of traveled way grading toward the sag side of the curve.

The super-elevation rate is based on the horizontal curve radius and design speed given in Table 13. The maximum super-elevation rate does not exceed 8% and the minimum super-elevation rate is not smaller than 2%.

5.5.2 The stabilized part of the shoulder has the same grade and direction with super-elevation, the non-stabilized part of shoulder on back of the curve grades toward back of curve.

5.5.3 When there are separated traveled ways, the super-elevation can be made for each way separately.

5.5.4 The length of super-elevation runoff (in curve section with super-elevation) shall not be smaller than value given in Table 14.

Table 13 – Super-elevation rate corresponding with horizontal curve radius and design speed

Design	Super-elevation Rate, %							Normal cross-fall
	8	7	6	5	4	3	2	
Speed, V_{tk} , km/h	Horizontal curve radius, m							
120	650÷ 800	800÷ 1000	1000÷ 1500	1500÷ 2000	2000÷ 2500	2500÷ 3500	3500÷ 5500	≥ 5500

100	400÷ 450	450÷ 500	500÷ 550	550÷ 650	650÷ 800	800÷ 1000	1000÷ 4000	≥ 4000
80	250÷ 275	275÷ 300	300÷ 350	350÷ 425	425÷ 500	500÷ 650	650÷ 2500	≥ 2500
60	-	125÷ 150	150÷ 175	175÷ 200	200÷ 250	250÷ 300	300÷ 1500	≥ 1500
40	-	-	60÷ 75		75÷ 100		100÷ 600	≥ 600
30	-		30÷ 50		50÷ 75		75÷ 350	≥ 350
20	-		25÷ 50		50÷ 75	75÷ 150	150÷ 250	≥ 250

Table 14 – Super-elevation rate (i_{sc}) and tangent runout length

Design Speed, V_{tk} , km/h											
120			100			80			60		
R, m	i_{sc}	L, m	R, m	i_{sc}	L, m	R, m	i_{sc}	L, m	R, m	i_{sc}	L, m
650÷ 800	0.08	125	400÷ 450	0.08	120	250÷ 275	0.08	110	125÷ 150	0.07	70
800÷ 1000	0.07	110	450÷ 500	0.07	105	275÷ 300	0.07	100	150÷ 175	0.06	60
1000÷ 1500	0.06	95	500÷ 550	0.06	90	300÷ 350	0.06	85	175÷ 200	0.05	55
1500÷ 2000	0.05	85	550÷ 650	0.05	85	350÷ 425	0.05	70	200÷ 250	0.04	50
2000÷ 2500	0.04	85	650÷ 800	0.04	85	425÷ 500	0.04	70	250÷ 300	0.03	50
2500÷ 3500	0.03	85	800÷ 1000	0.03	85	500÷ 650	0.03	70	300÷ 1500	0.02	50
3500÷ 5500	0.02	85	1000÷ 4000	0.02	85	650÷ 2500	0.02	70	-	-	-
Design speed, V_{design} , km/h											
40			30			20					
R, m	i_{sc}	L, m	R, m	i_{sc}	L, m	R, m	i_{sc}	L, m			
65÷ 75	0.06	35	30÷ 50	0.06	33	15÷ 50	0.06	20			
	0.05	30		0.05	27		0.05	15			
75÷ 100	0.04	25	50÷ 75	0.04	22	50÷ 75	0.04	10			

	0.03	20		0.03	17			
100÷600	0.02	12	75÷350	0.02	11	75÷150	0.03	7

NOTE:

1) L- Length of the superelevation section or transition curve is determined according to the Article 5.5.5 and 5.6.1.

2) Value L given in the table is applied for dual carriageway road. As for road class I and II, if the road is double lanes the above values shall be applied; as for three lanes the above value is multiplied by 1.2; multiplied by 1.5 for four- lane road; and by 2 for six- lane road.

5.5.5 Super-elevation runoff

Super-elevation shall be done by revolving the traveled way on the crest side of the curve about centerline profile to the cross slope of traveled way, and then continue revolving about the centerline profile to the full rate of super-elevation. In case of divided highway, super-elevation is attained by revolving about the inside and outside edges of the pavement.

5.5.6 Super-elevation runoff, widening runoff shall be placed coincidently with the transition curve. When there is no transition curve, the runoff will be half on the circular curve and half on the tangent.

5.6 Transition curves.

5.6.1 When design speed $V_{tk} \geq 60$ km/h, transition curves are placed so as to connect the tangent to the circular curve and vice versa.

5.6.2 Super-elevation rate (i_{sc}) and length of super-elevation runoff (L) depend on radius of horizontal curve (R) and design speed (V_{tk}), and shall not be smaller than values given in the Table 14.

5.6.3 Transition curve can be a clothoid curvature, third-degree parabolic curvature or compound circular curves.

5.7 Longitudinal Grade.

5.7.1 Depending on highway category, the maximum grade is indicated in Table 15. In difficult cases, the maximum gradient may be about 1% steeper but shall not exceed 11%.

For the highway in areas with elevation of 2000m above mean sea level, the maximum gradient is not to exceed 8%.

5.7.2 When the highway runs through residential areas, a grade shall not exceed 4%.

5.7.3 Longitudinal gradient in tunnel is not steeper than 4% and not flatter than 0.3 %.

5.7.4 On excavation sections, minimum longitudinal grade is 0.5% (in difficult situation, it may be allowed to use the grade of 0.3% but the gradient length is not over 50m).

Table 15 - Maximum longitudinal grade of highway categories

Design categories	I	II	III		IV		V		VI	
Topography	flat	flat	Flat, rolling	Mountain	Flat, rolling	Mountain	Flat, rolling	Mountain	Flat, rolling	Mountain
Maximum longitudinal grade	3	4	5	7	6	8	7	10	9	11

5.7.5 When the section length with grade exceeds the values given in Table 16, it's necessary to have a straight line with grade of 2.5% and sufficient length for vertical curve.

Table 16 - Maximum length of longitudinal grade (Unit is given in meter)

Grade	Calculated speed, V_{tk} , (km/h)						
%	20	30	40	60	80	100	120
4	1200	1100	1100	1000	900	800	-
5	1000	900	900	800	700	-	-
6	800	700	700	600	-	-	-
7	700	600	600	500	-	-	-
8	600	500	500	-	-	-	-
9	400	400	-	-	-	-	-
10 and 11	300	-	-	-	-	-	-

5.7.6. The minimum length of the grade change section must be sufficient for arrangement of vertical curve and not less than the values given in Table 17.

Table 17 - Minimum length of grade change section

Design speed, V_{tk} , (km/h)	120	100	80	60	40	30	20
Minimum length of grade change section, m	300	250	200 (150)	150 (100)	120 (70)	100 (60)	60 (50)
NOTE: values in bracket are applied for improved, upgraded roads when quantity of compensated pavement is large.							

5.7.7 On horizontal curvatures with small radius, the gradient given in the Table 16 must be decreased by a reduction value given in Table 18.

Table 18 - Reduction value of grade on the horizontal curves of small radius

Radius of horizontal curve, m	15 - 25	25 - 30	30 - 35	35 - 50
Reduction value of maximum grade, %	2.5	2	1.5	1

5.8 Vertical curve

5.8.1 Grade change section on vertical alignment (larger than 1% when design speed ≥ 60 km/h, larger than 2% when design speed < 60 km/h) must be continued by vertical curves (crest and sag) – These curves can be circular curves or second-degree parabolic curvature.

5.8.2 Vertical curve radius must be in compliance with topography in order to provide favorable conditions for traveling and highway landscape, but not less than the values given in Table 19.

Table 19 - Minimum radius of the crest and sag vertical curves

Design speed, km/h	120	100	80	60	40	30	20
Radius of crest vertical curvature, m							
- Limited minimum	11000	6000	4000	2500	700	400	200
- Normal minimum	17000	10000	5000	4000	1000	600	200
Radius of sag vertical curvature, m							
- Limited minimum	4000	3000	2000	1000	450	250	100
- Normal minimum	6000	5000	3000	1000	700	400	200
Minimum length of the vertical curvature, m	100	85	70	50	35	25	20

5.9 Curves in zigzag.

5.9.1 The use of curves in zigzag should be limited except in case of alignment development on the complicated mountainous terrain.

5.9.2 Technical specifications at turning path on the zigzag curve are shown in Table 20

Table 20 - Technical specification at turning path on curves of zigzag

Design speed, V_{tk}	60	40	30	20
Calculated speed for turning, km/h	25	20	20	20
Minimum radius of horizontal curve, m	20	15		
Maximum super-elevation rate, %	6	6		
Widening value of two-lane traveled way part	2.5	3.0		
Maximum gradient at turning part	5.0	5.5		

6. Combination of highway elements

6.1 Combination of highway elements is to:

- Create good sight distance, provide adequate information for driver to have prompt actions in any situation;
- Create confidence, comfortableness for driver to have good, effective and tireless environment ;
- Avoid hidden place, place causing illusion for driver resulting in disruption and wrong actions.
- Create aesthetic structure contributing in the landscape of the highway area.

6.2 All requirements given in the Article 6.1 are compulsory for highways with design speed over 80km/h, are encouraged with for those with design speed over 60km/h and oriented for other categories.

6.3 When designing, it's necessary to consider the combination of elements on horizontal alignment for ensuring cost-effectiveness.

6.4 Elements on horizontal alignment

6.4.1 On the horizontal alignment, the alignment on various curves with maximum radius is better than on the long, straight lines placed between short curves; the alignment taking the most advantage of the terrain (running along the forest boundary, along hill and river) is better than that crossing or requiring construction of special structures (retaining wall, viaduct etc.)

6.4.2 Small deflection angle shall require large radius of horizontal curve. See Table 21.

Table 21 - Minimum radius of horizontal curves depending on deflection angle

Deflection angle (degree)		1	2	3	4	5	6	8
Minimum radius of horizontal curve, m	Grade I and II, $V_{tk} \geq 100\text{km/h}$	20000	1000	8000	6000	4000	2000	1500
	Other categories	10000	6000	4000	3000	2000	1000	800

6.4.3 When designing, sudden changes should be avoided:

- Adjacent horizontal curves radius should not be twice bigger than each other;
- At the end of a straight line, minimum radius of horizontal curve should not be placed;
- Length of curve should be approximately equal or bigger than length of straight line placed before.

6.4.4 When the highway is dual carriageway with divided two directions, it's necessary to design as two routes with independent roadbed, and the median is widened for harmony of landscape; it's possible to design as two separated roadbeds for saving quantity and having more beautiful and stable structure.

6.4.5 On high category roads, it's encouraged to place continuous clothoids between horizontal curves.

6.5 Coordination of horizontal and vertical alignment

6.5.1 Various vertical curves should not be placed on one long tangent (or horizontal curve with large radius) in order to prevent the alignment from having many hidden places.

To avoid bending alignment, various horizontal curves should not be placed on a flat alignment section.

6.5.2 Number of horizontal curve should be equal to that of vertical curve and their vertices should be coincided to each others. When it's required to shift, the shift of the two vertices of the curves (horizontal and vertical) should not be one forth bigger than length of the horizontal curve.

6.5.3 It should be designed long horizontal curves covering outside of the vertical curve.

6.5.4 It should not be designed vertical curve with small radius to be inside the horizontal curve in order to avoid crests or sags. Radius of sag vertical curve (R_{sag}) should be ensured to be bigger than that of the horizontal curve ($R_{\text{horizontal}}$).

6.6 Coordination with landscape

6.6.1 It's necessary to study carefully all topographical and natural factors of the region for reasonable combination which shall not break natural law, and avoid any structures of deep excavation and high embankment, and special structures.

6.6.2 Regulation on slope (Table 24 and 25) shall be obtained by mechanical principles of soil. The slope could be:

- Changed for consistency with common cross fall on the terrain;
- Rounded at the top of slope and widened at both ends of slope;
- As for slope under 1m, due to requiring less quantity, the slope should be 1:4÷ 1:6 and rounded at top and toe of slope;
- As for high slope, it's necessary to build berm that shall stabilize the slope and a part that prevent slope scour, and to plant shrubs.

7. Roadbed

7.1 Basic requirements and design principles

7.1.1 Roadbed shall be ensured stability maintaining geometric dimensions, strong enough for bearing impacts of traffic loading and natural factors during its serviceability.

In order to have appropriate design method, it's necessary to conduct topographic, geological and hydrological surveys (especially with presence of water sources, factors causing scouring and pavement destruction) and study carefully related data.

Roadbed construction shall be ensured not to damage the natural equilibrium, cause negative impacts on environment and destroy regional landscape. It's necessary to take notice that once the environment is damaged, the roadbed itself shall be destroyed too resulting in instability of the roadbed.

7.1.2 Design principles

7.1.2.1 Effective area of the roadbed shall be ensured (when there is no special calculation, this area can be 80cm downward from subgrade) to obtain the following requirements:

- Not to be too wet and not to be affected by the external damp source (rain-water, underground water, water beside roadbed);
- 30 cm uppermost shall ensured minimum bearing capacity CBR^* of 8 for highway category I, II and of 6 for other categories;
- Subsequent 50 cm shall ensured minimum bearing capacity CBR^* of 5 for highway category I, II and of 4 for other categories;

In which: CBR - California Bearing Ratio is determined in laboratory with soil specimen to be compacted by standard compaction according to 22TCN 332-05 and saturated in 4 days and nights.

7.1.2.2 Embankment on soft soil shall be applied according to 22TCN 262.

7.1.2.3 Roadbed on the complicated geological condition shall be applied according to 22TCN 171.

7.1.2.4 Roadbed on seismic area shall be applied according to 22TCN 221.

7.1.2.5 In order to mitigate negative impacts on environment and landscape, it's necessary to take into consideration the following principles:

- Limit damage to vegetation. If possible, organic soil in the excavation should be collected for backfilling the borrow pits and slope sides;
- Limit damage to natural equilibrium, avoid deep cutting and high filling and cut and fill quantity should be equilibrated. In complicated terrain, it's necessary to make comparison on alternatives of viaduct, tunnel, and roadbed of balcony. Roadbed slope height should not higher than 20m;
- On the slope above 50%, it's necessary to consider alternative of two separated roadbeds;
- The low cutting and filling should have alternative of sloping (1:3 ~ 1:6) and rounding for consistency of topography and traffic safety;
- Limit negative impacts on socio- economy of residence such as flooding to fields and houses. Locations and openings of drainage facilities should be adequate not to obstruct flood flow causing embankment destruction at other location, avoid obstruction to the local circulation and respect the local drainage plan.

7.2 Roadbed width

Roadbed width and width of roadbed's elements given in Table 6 and 7 is minimum values. In such cases as designing more lanes, placing median with cover but constructing piers (poles) on separated bands or without cover, placing side separator and increasing bicycle lane width (b) by calculation, designer has to determine width of the designed roadbed.

7.3 Design elevation of roadbed

7.3.1 Design elevation of roadbed is the elevation of centerline. When there are two separated roadbed, there will be two design elevations on the two profiles separately.

7.3.2 The design elevation of pavement edge of the sections running along the rivers bank, approaches of small bridges, culverts and flooded fields must be at least 0.50m higher than the flooded water level of design frequency given in Table 30. Flooded water level includes the height of backwater and waves hitting to the surface of foreslope).

In difficult circumstances, especially case of road running through sections with crowded population and inundated water maintaining less than 20 days, determination of calculated flooding frequency shall be

considered in terms of technical, economical points and environmental point also. In such case, when designing, the long-term stability of the structure should be checked and decision making are responsibility of investment decision- makers.

7.3.3 Elevation of the subgrade must be higher than calculated underground water level (or permanent standing water level) according to provisions in Table 22.

**Table 22 - Minimum height from calculated under ground water table
(or permanent stagnant water) to the subgrade**

Units are given in centimeter

Types of filling soil	Number of consecutive days maintaining water level per year	
	Over 20 days	Under 20 days
Silty sand, fine sand, lean clayey sand	50	30
Pumice sand, ponderous clayey sand	70	40
Silty clay sand	120 - 80	50
Pumice sandy clay, ponderous sandy clay, fat clay, ponderous clay	100 - 120	40

7.3.4 The elevation of pavement at the pipe culvert location must be higher than the top of pipe by a minimum height of 0.50m. When the thickness of pavement is more than 0.50m, this difference in height must be enough for construction of the thickness of pavement.

7.4 Filling soil

7.4.1 Filling soil is taken from excavation borrow-pits, digging pits. Soil taken shall comply with principle of mitigating negative impact on environment as mentioned in the Article 7.1.2.5. Digging pits must be designed with a form that will not be detrimental to the surrounding landscape and can be used after completing the construction when necessary.

Soil obtained from all sources must undergo testing and must be placed layer by layer, without mixing up.

All layers are filled interposingly. However, when the drainage layer is put above the layer of difficult drainage, the surface of the below layer must have a cross slope from 2% to 4% for removal of water from the road itself.

7.4.2 Do not use salty and plastered soil (over 5%), mud, peat, alluvium and humus (over 10% of organic composition) for filling soil.

Inside effective area (see 7.1.2.1), do not use ponderous sand with free expansion over 4%.

Do not use silty soil and weathered rock for filling roadbed located in flooded area.

At the location behind abutment and retaining wall, filling material should be granular soil with large internal friction angle.

When using filling material of disposal rock or gravel soil, allowable maximum particle size is 10cm for filling scope inside effective area which is 80cm from subgrade and 15cm from the underneath area; however the largest size shall not be exceed 2/3 depth of compaction layer (depending on type of equipment used for compaction).

7.4.3 Do not use weathered rock and rock likely to be weathered for embankment.

7.4.4 When the embankment is filled by sand, roadbed must be covered at both sides of the slope and the top of embankment to prevent erosion of the surface and facilitate traveling of machines, equipment for embankment construction. Soil covered at slope sides must have plasticity index of equal or over 7; the soil for filling top of the embankment should be hilly aggregate. Do not use loose material for top of the embankment to prevent rain-water, surface water from penetrating into the sand filling.

The minimum coverage thickness at the slope sides and embankment top (subgrade) is 1.0m and 0.3m correspondingly.

When the requirements are not met, the followings should be done:

- To reduce thickness of filling to 0.5m (perpendicular to the slope surface), and to design stability method for preventing slope scouring and anti-penetration method for inside of the roadbed.
- To design method for replacing covering soil on the top of embankment.

7.5 Treatment method for natural ground before filling

7.5.1 Where the natural ground has a cross slope less than 20%, it is a must to remove the organic soil layer, and then filled up the natural ground directly.

Where the natural ground has cross slope from 20% to 50%, it is necessary to bench before filling.

Where the natural ground has a cross slope steeper than 50%, the support works (such as: toe wall, retaining wall, viaduct, balcony bridge etc.) must be considered to be included.

7.5.2 In the area of the embankment bottom, it's necessary to design drainage method for preventing flow on upper side of slope from concentrating on toe of the embankment slope.

In case of the embankment located on field or permanently inundated area, it has to dredge for mud and change the soil. When possible, it's necessary to use loose filling material with filter layer (such as geotextile) for filling in the area of permanent inundation or use lime mixed soil which has cohesiveness for changing soil.

7.5.3 Treatment for weak soil before filling shall comply with 22TCN 262.

7.5.4 Geological investigations and testing must be undertaken in special areas such as soft soil/sand-moving/karst areas, complicated geological area for calculating and finding the structural solutions to ensure roadbed stability. These solutions must be fit with the highway category, structural works and geological condition of the highway location.

7.6 Density of roadbed compaction

7.6.1 Roadbed must be compacted to the standard compaction state as given in Table 23. Besides, the body of embankment which is affected by inundated water or underground water shall obtain the minimum compaction state of 0.95 regardless of highway category. At the location behind the abutment and retaining wall, the required compaction state should be increased from 1% to 2% in comparison with the values given in Table 23.

Table 23 - Standard compaction of roadbed (standard compaction according to 22TCN 333-05)

			Depth below	Compaction state	
Types of roadbed			Pavement bottom (cm)	Highways category I to IV	Highways category V, VI
	When the thickness of pavement is more than 60cm		30	≥ 0.98	≥ 0.95
Embank- ment	When the thickness of pavement is less than 60cm		50	≥ 0.98	≥ 0.95
	Below the above depths	Newly filled		≥ 0.95	≥ 0.93
		Natural ground*	Up to 80	≥ 0.93	≥ 0.90
Cutting and no-cut/no-fill sections (natural ground)**			30	≥ 0.98	≥ 0.95
			30- 80	≥ 0.93	≥ 0.90

* This is a case of low embankment, the effective area of 80cm as mentioned in the Article 7.1.2 with a part inside natural ground area. In such case, the natural soil part of the effective area shall have the minimum compaction state of 0.90;

** If the natural ground does not meet the required compaction state in Table 23, it's necessary to remove the unsatisfied soil and compact again to the required state.

7.6.2 In the effective area, the soil after being compacted must have bearing capacity according to the required CBR mentioned in the Article 7.1.2.1. If the compacted soil does not meet the requirements given in Table 23, or does not obtain the required CBR even after compaction, it's necessary to design soil improvement, strengthening or changing in order to meet both mentioned requirements (testing for determining ratio of lime, ratio of appropriate improvement must be conducted).

7.7 Design of cut slope

7.7.1 Gradient of cut slope

Side slope rate can be selected from Table 24 on the basis of geological structure condition and the height of slope. It's necessary to make investigations on cut slope and natural slope which is stable for a long time with similar geological condition and located in the area adjacent to the designed highway area, in order to have firm basis for determination of the designed cut slope.

Table 24 – Slope of cut sections

Types and condition of soil/rock	Rate of cut slope when height of slope (m)	
	$\leq 12\text{m}$	$\geq 12\text{m}$
- Cohesive soil or incohesive soil having medium dense to dense state	1 : 1.00	1 : 1.25
- Granular soil	1 : 1.50	1 : 1.75
-Lightly weathered rock	1 : 0.30	1 : 0.50
- Highly weathered rock	1 : 1.00	1 : 1.25
- Lightly weathered soft rock	1 : 0.75	1 : 1.00
- Highly weathered soft rock	1 : 1.00	1 : 1.25
NOTE: As for soil excavation, height of the slope should not be over 20m. As for soft rock excavation, if the surface of the rock layer slopes outward with the slope angle above 25° , the design slope should be as steep as the rock layer surface and the height of the slope should be limited less than 30m.		

7.7.2 When the slope height is over 12m, it's necessary to conduct the analysis to check stability by appropriate method corresponding to the most unfavorable state (weathered soil, rock saturated with water). As for slope of loose, cohesionless material, a flat sliding surface method should be applied; as for cohesive soil a circular sliding surface method should be applied, the minimum stability coefficient should be equal or bigger than 1.25

As for rock slope, it's necessary to have comparison analysis with gradient of other stable slopes (embankment/ structural slope or natural slope) that exist in the adjacent area.

7.7.3 When the slope has several layers of different types of soil and rock, it is necessary to design various gradients correspondingly making a terraced slope; or at the gradient changing location a berm with width in a range of 1.0m to 3.0m and gradient of 5% to 10% should be placed sloping inward to the gutter; on the berm it's required to build rectangular or triangular drainage gutter ensuring capable to drain water from the upper talus. When the cut slope has not several layers of different types of soil and rock but it is high, it is necessary to design the similar berm as mentioned above, with height between the berms ranging from 6m to 12m.

7.7.4 When the slope structure involves easily falling soils, a berm with a minimum width of 1.0m should be placed between the outer edge of the side ditch and the toe of cut slope. However, there is no need to place this berm when there is a protected wall, or the height of cut slope is lower than 12m.

7.7.5 It's necessary to have improvement methods for preventing slope surface scouring, weathered soil and rock from causing local scour (such as planting grass, shrubs or concrete grid etc.) and when required, it's necessary to construct retaining wall, foot curbs for enhancing stability of the slope.

7.7.6 It's required to have plan for disposing waste soil from the excavation, not to dispose the waste soil randomly to the under slope side resulting in unstable to natural slope, not to dispose to the under fields, garden or watercourses. The disposed area shall be leveled as a plain for planting protective vegetation and considered to have suitable drainage method.

7.8 Design of embankment slope

7.8.1 Depending on the height of the embankment and type of filling material, slope of the embankment is given in Table 25.

Table 25 - Slope of the fill sections

Type of soil/rock	Slope of the embankment when height of fill slope	
	under 6m	from 6m to 12m
Lightly weathered rocks	1 : 1 ÷ 1 : 1.3	1 : 1.3 ÷ 1.5
Slightly weathered rock with size more than 25cm, dry rip rap	1 : 0.75	1 : 1.0
Crushed stone, graveled stone, sand mixed with gravel, clinker.	1:1.3	1:1.3 ÷ 1.5
Large and medium size sand, clay, clayey sand, easily weathered rock	1:1.5	1:1.75
Silty soil, fine sand	1:1.75 ÷ 2	1:1.75 ÷ 2
* See more in the Article 7.8.2		

7.8.2 If the embankment has stone slope, stone size shall be more than 25cm and stacked as dry rip- rap (with small size stone for wedge) in thickness ranging from 1.0m – 2.0m with gradient as given in the Table 25; depending on the gradient of the slope, stone can be stacked in terraced slope (no need uniform slope). Inside the dry rip-rap, stone can be stack as follows: rip-rap a lift of large- size stones, then place a lift of small- size stones above and compact by vibrated heavy roller to make the top stone stable. Trial should be made to determine thickness of the stone lifts, quantity of the inserted stone and number of necessary rolling. Trial result shall be a basis for checking and acceptance (including compaction state) of the stone embankment.

7.8.3 In case of the embankment (if sand) is located on inundated area. Gradient of the embankment slope must be 1:2 – 1:3 for the roadbed under normally inundated water level and 1:1.75 – 1:2.0 for the roadbed under the design water level.

7.8.4 When the embankment slope is relatively high, a berm with width from 1.0 to 3.0m shall be placed for each 8m- 10 m high; there must have cross- fall and masonry gutter on the berm as given in the Article 7.7.3. Besides, the surface of high slope should be strengthened with stone or pre-cast concrete slab.

7.8.5 In case of the slope height is more than 12.0m, checking must be done as stipulated in the Article 7.7.2. When checking the stability of the inundated embankment it's necessary to consider the hydrodynamic pressure caused by hydraulic gradient. Height of soil slope should not be higher than 16.0m and 20.0m for stone slope.

7.8.6 In case that the embankment is high and located on slope side, if the stability checking results are not ensured, treatment methods shall be designed to increase stability (foot curbs or shoulder curbs) by dry rip-rap, masonry or cement concrete.

7.8.7 Embankment slope shall be strengthened with appropriate methods taking into account of the regional hydrological condition and climate to prevent scouring caused by rainfall, water run off, wave and changes of the inundated water level.

7.8.8 Earth borrow pit for embankment shall be planned beforehand and accepted by local authority according to the following principles:

- Taking the most use of the fallow, earth with suitable quality and exploitation condition;
- Not impact on the environment and saving land;
- Combining the earth exploitation with aqua-agricultural works (creating reservoir, fish breeding pond etc.)

8. Pavement and structure of the stabilized shoulder (to be translated)

8.5 Roughness

8.5.1 The top layer, in case of need, should have one more surface roughness layer with a suitable structure to ensure the average sand filling depth H_{tb} (mm) as prescribed in the Standard 22TCN278 depending on the designed speed and/or dangerous level of the designed section as shown in Table 28.

Table 28 Requirement of road surface roughness

Designed speed, V_{tk} , km/h or dangerous level	Sand filling average depth, H_{tb} , mm	Characteristic of surface roughness
<60	$0.25 \leq H_{tb} < 0.35$	Smooth
$60 \leq V < 80$	$0.35 \leq H_{tb} < 0.45$	Smooth
$80 < V < 120$	$0.45 \leq H_{tb} < 0.80$	Average
Road passing the dangerous difficult topographical area (bendy road, curve radius is less than 150m and without speed limit, vertical slope)	$0.80 \leq H_{tb} < 1.20$	Rough

8.5.2 Its able to apply the methods assessing roughness as the ...factor by using immediately-breaking specific vehicle when design the top layer of the pavement.

8.5.3 The sections with disqualified roughness should be designed by installing signs of slippery road and speed limit.

8.6 Flatness

8.6.1 The flatness of road surface should be ensured as the international roughness index IRI (m/km) prescribed in the Standard 22TCN 277 and shown in Table 29.

Table 29- Requirement of road surface flatness as IRI

Designed speed, V_{tk} , km/h	Required IRI, m/km	
	Newly-constructed road	Improved, upgraded road
120 and 100	≤ 2.0	≤ 2.5
80	≤ 2.2	≤ 2.8
60	≤ 2.5	≤ 3.0
From 40 to 20 (asphalted road surface)	≤ 4.0	≤ 5.0
From 40 to 20 (low-grade road surface)	≤ 6.0	≤ 8.0

8.6.2 Flatness shall be also assessed as 3m long ruler as regulated in 22 TCN16

As for high-grade road surface A1 (asphalt concrete, cement concrete), 70% of air gap should be less than 3mm and 30% of the remaining ones should be less than 5mm. All air gaps should be less than 5mm and 10mm as for high-grade road surface A2 (refer to Table 26) and for low-grade road surface B1 and B2, respectfully.

8.7 Bridge surface

8.7.1 It's required to make a specified design for surface layer of bridge and viaduct and have a similar type of surface layer for the adjoining sections.

8.7.2 It's required to have design method to ensure a safety, smooth traffic circulation on bridge, especially on bridge approach road.

8.8 Pavement Structure

8.8.1 In case there is no central reservation or there is a side median by two markings between the motorized lane and consolidation shoulder (refer to the item 4.5.2), namely the motorized vehicle may encroach or park/stop on the permanent consolidation shoulder, if using soft pavement structure for shoulder, it should be calculated to design as the current pavement standard to satisfy the following requirements:

- Bearing the calculated traveling traffic volume (standardized vehicle/lane/day, night) from 35% to 50% against that of the adjoining motorized lane;
- The top layer of consolidation shoulder should be as the same as the one of the adjoining motorized lane;
- The consolidation structure should be studied in order to be utilized as maximum when proceeding improvement, expanding and upgrading of road surface;
- Satisfying the required minimum numeric value of elastic module as regulated as 22 TCN251;
- Auditing the tension-bending strength and skidding condition of the heaviest wheel possibly parking on the consolidation shoulder (not considering the impulse factor and repeat factor during auditing);
- The consolidation structure of shoulder should be designed as that of pavement in a possible economic condition.

8.8.2 In case there is a side median between the motorized lane and consolidation shoulder of 1st and 2nd grade road to stop the motorized vehicle encroaching or parking on the shoulder (the side median should be 30cm to 80cm higher than road surface, refer to Item 4.5.2), the pavement type and numerous value elastic module shall be applied in accordance with 22TCN211, but reduce one grade, (for example, as for 1st grade road, the shoulder is able to apply the pavement type of both A1 and A2 grade road of which the required minimum elastic module value is corresponding to that of 2nd grade road.

8.8.3 In case the motorized lane is designed as a rigid pavement (cement concrete) and there is no side median to stop the motorized vehicle encroaching or parking on the shoulder, the pavement structure for shoulder should be as cement concrete, but the cement concrete slab of shoulder is 18cm thick as minimum. The cement concrete for shoulder shall be closely jointed at longitudinal joints (connecting the cement concrete slab of the adjacent motorized lane) and at horizontal joints.

9. Design of drainage facilities system

9.1 Planning of drainage facilities system

First of all, a master plan of completed drainage system should be done, including drainage facilities such as intercepting ditch, side ditch, and water receiving ditch, bridge, culvert, underground drain, pit, and evaporation pond etc., these facilities must cooperate closely to each other. Locations, dimensions of the drainage facilities must be reasonable and suitable with the regional drainage plan in order to ensure high effectiveness and low cost.

Arrangement of ditches and canals for subgrade drainage must ensure ability to receive and collect water in order to prevent water from running freely into the subgrade; must incorporate with arrangement of drainage culvert and bridge on the highway, and determine direction of runoff from ditch and canal draining to bridge, culvert or watercourses; methods for connecting drainage ditches with bridge, culvert or watercourses are necessary needed. In contrary, when arranging bridge, culvert, it's necessary to consider requirement of fast draining from ditches and canals.

Arrangement of the drainage facilities on the highway shall take irrigation and drainage requirements into consideration. At the same time flood drainage after highway construction must be considered as well.

9.2 Highway surface and shoulder drainage

9.2.1 On the tangents and curves having radius requires no superelevation (Table 11), highway cross section is designated as a type of two slope with cross- fall values as given in the Article 4.9.

On the curves with radius as given in the Table 13 needs superelevation, the elevation gradient shall comply with the values given in the Table 11 and longitudinal gradient of the section must be 1% to ensure highway drainage and subgrade drainage.

9.2.2 For highway class I and II with median, it's necessary to design gutter near median side to collect rain- water on the superelevation curves. If the median is uncovered, flush type, drainage ditch shall be provided (open or with cover) at the lowest location of the median (dimension of the ditch is 20cm- 30cm wide

and 20cm- 30cm deep). If the median is covered and curbed type higher than road surface, inlet hole and pipe with radius from 20 to 40 cm for carry water from roadbed area to the drainage facilities shall be provided near the median curb, minimum gradient of the drainage pipe is 0.3%. At the location of longitudinal pipe connecting with cross culvert, connecting hole (manhole) shall be provided.

9.2.3 In case of uncovered, curbed and raised separator, inlet shall be provided either on tangent or curve to collect seepage water on the separator and drain out of the roadbed area. It's possible to provide permeable material under the subgrade and placed in the middle of the median, and to place drainage pipe with diameter from 6cm to 8 cm covered with filter material.

9.2.4 On the multi- lane highway class I and II, rain- water on the carriage way is very large, it's necessary to stabilized high embankment sections and slope for protection from scouring or to design 8cm- 12cm high retaining wall of concrete or masonry along out edge of the stabilized parts in order to prevent water from running directly onto highway slope; rain-water from highway pavement shall run along the retaining wall and concentrate on the chute placed on highway slope, and drain out of the roadbed area.

9.3 Side ditch (longitudinal ditch)

9.3.1 Side ditch is constructed to drain rain- water highway surface, shoulder, cut slope and area of two sides of highway on cut subgrade, part- cut and part- fill subgrade, fill subgrade lower than 0.60m.

9.3.2 Dimension of side ditch under normal conditions is designed by fixed form, not need hydraulic calculation. Only if the side ditch is used to drain not only surface water on the pavement, shoulders and right-of- way but also water on the catchments on highway sides, shall side ditch dimension be calculated by hydraulic formula, but depth of ditch shall not be over 0.80m.

Ditch cross- section can be trapezium, triangular, rectangular or semi- circular. The common use is trapezium ditch with bottom width of 0.04m, minimum depth from natural ground is 0.30m, and ditch slope of cut roadbed is equal to that of the cut roadbed slope based on geological structure, ditch slope of cut roadbed is 1: 1.5 ÷ 3. It can be used triangular ditch with depth of 0.30m, slope toward carriage way is 1:3 and the opposing side is 1:1.5 as for fill roadbed, and 1: m based on slope m of the cut roadbed; at the location with geological condition of rock, it can be used rectangular or triangular cross-section.

9.3.3 In order to avoid mud and debris deposition on ditch bed, ditch bed gradient shall not be less than 0.5%; in special case, it's possible to be 0.3 %.

9.3.4 When planning the surface water drainage system, it's noted that drainage water is prevented from draining from ditch of fill roadbed to cut roadbed, except case of the roadbed length is shorter than 100m, water from intercepting ditch, directing ditch etc must be prevented from running into longitudinal ditch and water in the longitudinal ditch must be drained to hollow place, watercourses near the highway or through across drainage facilities. Culverts with minimum diameter of 0.75m shall be placed at maximum 500m away from the trapezium ditch and at 250m away from the triangular ditch to drain water from side ditch to adjacent mountain sides. As for fix form culvert, no hydraulic calculation is required.

9.3.5 A place where water drains from side ditch shall be far away from the road embankment. If there is a pit hole near fill roadbed, longitudinal ditch of the cut roadbed is designed toward the pit hole. If there is no pit hole, longitudinal ditch of the cut roadbed is placed parallel to highway centerline, until reaching the location where fill roadbed is higher than 0.50m, the ditch shall be designed so as to separate from the roadbed until its depth is zero.

9.3.6 As for agricultural land, if the ditch is used as an irrigation/ drainage canal, its dimension shall be increased and at the same time roadbed needs treatment methods to avoid sliding and scouring.

9.3.7 Through residential area, side ditch should be designed as masonry or concrete type and paved with closed grate, and provided with inlet system.

9.3.8 Side ditch in tunnel should be bigger in dimension compared with normal one in order to increase drainage capacity and should be of masonry or concrete type.

9.3.9 At the sections with gradient of ditch steeper than gradient value causing ditch bed scouring, it's necessary to base on runoff velocity to design suitable stability method (stone patching, masonry, concrete). In possible condition, ditch should be stabilized by dry rip-rap or masonry, independent to ditch gradient in order to ensure drainage capacity of the ditch and to minimize maintenance works.

9.4 Intercepting ditch

9.4.1 When catchment area of the mountain side running toward the highway or cut slope height is $\geq 12\text{m}$, intercepting ditch shall be provided to receive water running down to highway and to carry water to drainage facility, and watercourses or hollow area near the highway; do not let the water running directly onto the side ditch.

9.4.2 Intercepting ditch shall be planned suitably with alignment, longitudinal gradient and drainage cross-section. Intercepting ditch must be designed as triangular cross-section, minimum bottom width of 0.50m and slope of ditch bank is 1: 1.5, depth of ditch is determined by hydraulic calculation and calculation water level in the ditch must be ensured to be at least 20cm lower than ditch edge, it should not be deeper than 1.50m.

9.4.3 When intercepting ditch is remarkable long, it should be divided into short segments. Calculated discharge of each section is equal to the discharge volume through its last section, it means that discharge volume of the catchment running directly to the calculated ditch segment plus all discharge volume of the catchment of the upper segments.

9.4.4 Gradient of the intercepting ditch is normally selected by area condition so that runoff velocity shall not cause ditch bottom scouring. Under compulsory circumstance required by area topography, intercepting ditch must be designed with big steep, it's necessary to have suitable stabilized method for ditch bottom. It's best to stabilize by block stone or concrete slab, or to design the ditch having chute or drop water. To avoid mud and debris depositing in the ditch, gradient of the ditch shall not be less than $3\text{‰} \div 5\text{‰}$.

9.4.5 At the area with steep mountain side, large catchment area, sliding-prone geology, it's possible to build two or more intercepting ditches. In contrary, if the cross slope of hill side is small and catchment area of

water running to the longitudinal ditch is not large, it need not to build intercepting ditch but drainage capacity of the side ditch should be checked.

9.4.6 Location of intercepting ditch is at least 5m away from edge of cut roadbed slope. And soil taken from intercepting ditch excavating shall be used to embank a small dyke in the direction toward the terrain slope (lower side); dyke surface has cross slope of 2% toward the ditch and dyke foot is at least 1m away from edge of the cut roadbed slope.

In case of intercepting ditch is provided to prevent water from running to fill roadbed, the ditch shall be at least 5m away from the edge of side ditch if having side ditch, otherwise shall be at least 2m away from toe of fill roadbed slope; soil taken from intercepting ditch excavating shall be used to embank a small dyke in the direction toward the roadbed; dyke surface has cross slope of 2% toward the ditch.

Intercepting ditch should not be placed too far away from the roadbed because effectiveness of the ditch shall be limited.

9.4.7 At deep cut section, terraced slope shall be applied to prevent water from causing scour on slope, it's necessary to arrange drainage ditches along slope berms and at the end of the ditch, water is concentrated in the chute or drop water to drain to watercourses or bridge, culvert of chute or drop water type.

9.4.8 Frequency for calculating discharge of intercepting and side ditch is 4%.

9.5 Drainage ditch

9.5.1 Drainage ditch is designed to carry water from local hollow area to the nearest drainage facility or from longitudinal ditch intercepting ditch to hollow area or bridge, culvert, or to connect watercourses with culvert downstream.

9.5.2 Drainage ditch should not be longer than 500m. Soil taken from intercepting ditch excavating shall be used to embank a small dyke along the ditch. If the drainage ditch is arranged along roadbed, edge of ditch shall be at least 3m and 4m away from toe of slope, there shall be a 0.50m – 0.60m high protecting dyke between ditch and roadbed.

9.5.3 Ditch direction should be selected as straight as possible. At direction change locations, curve radius shall be 10 to 20 times as much as the surface width of the ditch, but not less than 10m.

9.5.4 Cross- section of the ditch is determined by hydraulic calculation, but ditch depth should not be less than 0.50m and ditch bottom should not be less than 0.40m; edge of the ditch shall be at least 0.40m higher than flowing water level in the ditch.

9.5.5 Frequency for calculating discharge of the drainage ditch is equal to that of relevant drainage structure.

9.6 Chute and drop water

9.6.1 At the location drainage ditch having big slope, it's necessary to make chute or drop water in order to prevent structure from scouring caused by runoff. Selection of drainage facility is based on comparison of alternatives depending on specific conditions. Chute and drop water are normally used at ditch having big slope, connecting between culvert upstream, downstream and natural watercourse bed; at section with drainage

ditch from drainage facility running along cut or fill roadbed slope, section connecting intercepting ditch with watercourse or bridge, culvert.

9.6.2 Cross- section the chute is commonly rectangular type, its width and depth is calculated by hydraulic condition, depending on design discharge, slope of chute and velocity permitted for non- scouring of the material for chute and depending on dimensions of structure connecting with the chute.

9.6.3 Chute structure can be concrete, reinforcement concrete, masonry. In order to reduce runoff velocity of the chute, chute bottom shall be made rough and at the end of the chute there is commonly energy dissipation pond (well) or energy dissipation wall.

9.6.4 Drop water with energy dissipation pond is normally used when drainage canal and ditch gradient is very steep. Drop water cross- section is rectangular, made of concrete or reinforcement concrete, stone. Drop water width and height; pond depth and length; and energy dissipation wall height and thickness are calculated by hydraulic formula and depending on dimension of the adjacent structure to the drop water.

9.6.5 Structure of chute and drop water is designed by typical designing. In case of suitable typical designs are unavailable, it's possible to refer to the following regulations.

- Height of chute and drop water is higher than the minimum calculated water level of at least 0.20m.
- In order to be skid- resistant, the chute bottom shall be designed so as to be embedded about 0.30- 0.50m into the ground per each interval of 2.5- 4.0m;
- Gradient of the chute should not steeper than 1:1.5. If the gradient is more than that, drop water shall be designed;
- Drop water is normally designed with the height of each berm is 0.30m- 0.60m and gradient of berm surface is 2%- 3%.

9.6.6 Frequency for calculation of design discharge of chute and drop water is adopted the calculated discharge frequency of the structures relating to the chute and drop water.

9.7 Under- ground drainage facilities

9.7.1 On the highway sections with high underwater level or underground water running down from slope and the highway has possible risk of unstable roadbed must have appropriate treatment methods.

9.7.2 Depending on particular case, following type of under- ground drainage facilities can be used:

- Under- ground ditch is placed deeply under longitudinal ditch, shoulder, subgrade in order to reduce under- ground water level under the carriage way.
- Under- ground ditch is placed inside the cut roadbed slope in order for the highway slope to be ensured unwetted and to prevent the under- ground water from seeping through foreslope to outside;
- Under- ground ditch is placed behind retaining wall, and wing of tunnel and abutment.

9.7.3 Under- ground drainage ditch can be in form of open or close ditch. The open type is only be used when the under- ground water level is high; and the close type is normally used when the under-ground water

level is deep. Bottom width of the under-ground ditch is from 0.30m to 1m depending on depth of the ditch and construction conditions.

9.7.4 Structure of the close under- ground drainage ditch is designed according to general diagram as follows: The uppermost top of the ditch is cover by impermeable material (soil) compacted closely to prevent rain water from seeping into the ditch; after that is the 2 layers of reversed turfs to prevent soil from dropping to underneath filter material; under the turf is sand layer and then a layer of crushed stone or cobble stone; the undermost bottom is provided with pipe or drainage tunnel to increase drainage capacity.

9.7.5 In case of using under-ground drainage ditch at positive slope of cut roadbed to prevent under-ground water from running outside, it's necessary to use under-ground drainage ditch with impermeable retaining wall one side running along the ditch, and reverse filter layer at the other side.

9.7.6 Stone used for covering the ditch is un-weathered and undissolved (in water) type, pipe commonly used for the under- ground ditch is concrete pipe with minimum diameter from 15cm to 20cm or can be terracotta, brick or stone with diameter of 30cm – 50cm, length of each segment of the drainage pipe is 0.3m – 0.6m; drainage pipe is placed next to each other with clearance of 1cm- 0.5cm to allow water to run into the drainage pipe.

10 Bridges, Culverts, Tunnels and other water crossing structures

10.1 The various types of bridges (river bridge, railway bridge, flyover, viaduct, etc.), culverts and tunnels on highway is designed as the sectional standards.

10.2 Cross-section of the various bridges and tunnels on highway should satisfy the requirements of traveling vehicle, as specified in the Article 4.10.5

Dimension, shape and characteristic of cross-section of bridge and tunnel should be suitable with their approach roads; dimension of the traveled way on the bridge is unchanged; in a difficult condition, its allowed to narrow the different elements of bridge cross-section, but do not change the cross-section of approach road toward bridge and tunnel. As for small-sized bridges, its cross-section is not allowed to be narrowed in comparison with the highway design standards.

10.3 The central reservation on bridge is composed as follows:

- In case the width of central reservation is less than 3m, the composition of its surface should be similar to that of traveled way on bridge deck, and provided with separated fence and safety equipments;
- In case the width of central reservation is more than 3m, it's able to keep space, arrange a lane of 0.75 wide and 0.25 high covered by a separated fence and safety equipments.

10.4. The horizontal and vertical alignment of bridge and tunnel such as minimum curve radius, super-elevation curve, transition curve, super-elevation, expansion, maximum gradient, minimum vertical curve radius, etc., should comply with the design standards prescribed to each type of road class. However, as for large-sized, medium-sized bridge and tunnel, it should not be designed with the gradient more than 4% to

increase the traffic capacity and convenience as well as the traffic safety; and with small curve radius, it's necessary to arrange an extension section for roadway.

In case there are vertical crest curve at both approach roads, in order to make transition of the section from elevation of bridge surface to elevation of embankment passing river plain, it's required to arrange one section near the bridge approaches with the same elevation of bridge profile to create a vertical curve, and ensure the connection point of the vertical curve is 10m far from bridge as minimum.

10.5 The selection of river bridge location should satisfy the economic, technical, geological, hydrological requirements, convenience and traffic safety as well as make a comparison with the following criteria:

10.5.1 The economic, technical criteria and environment protection

- Total construction cost
- Minimum construction time;
- Utilizing local material;
- Navigation clearance under bridge is convenient and safe;
- Minimum affect of bridge construction on surrounding environment;
- Convenience and traffic safety.

10.5.2 Hydrological, topographical and geomorphologic condition

- Riverbed should be stable, straight;
- River width should be the narrowest, with small floodplain, deep water, no branch, without old tributary and marsh;
- Flow regime is less changeable;
- Direction of flow in the flood season and dry season is nearly parallel to each other;
- As for large and medium bridges, bridge centerline must be perpendicular to the main channel. In difficult circumstances, it's possible to be skewed with the main channel but must ensured safety for navigation river; or to be perpendicular to the valley and skewed with the main channel if no navigation clearance is required. The bridge opening shall not be designed so as to contract the main channel width.

10.5.3 About geology, location which is be selected, shall has rock layer condition basically similar to the riverbed condition, good and stable river bank soil, and avoid scouring, karst and plaster area.

10.6 Calculated hydrological frequency for structures on the highway is given in Table 30

Table 30- Calculated hydrological frequency for structures on the highway (Unit is given in %)

Structure Name	Highway category		
	Expressway	I, II	III to VI
Embankment, protection work	According to calculated frequency for bridge and culvert		
Large and medium bridge	1	1	1
Small bridge and culvert	1	2	4
Intercepting and side ditches	4	4	4

NOTE:

- 1) Generally, the improved and upgraded highway shall comply with regulations on design flood frequency as same as to the newly- constructed one. In case of technical difficulties and large quantity requirements rising, specification for calculated frequency given in the Table 30 is allowed to be reduced, but need approval from relevant authorities.
- 2) If during surveying, it has investigated the historic flood water level that is higher than flood water level calculated by frequency given in the above table, it's necessary to use historic flood water level as a value for calculation for large bridge.
- 3) On the highway running through urban and residential areas, design elevation of roadbed shall comply with design elevation of the master plan for the area and calculated flood frequency of drainage facilities and roadbed shall be in accordance with design standard for urban road.
- 4) With large bridge, $L_c \geq 100\text{m}$; medium bridge, $25\text{m} \leq L_c < 100\text{m}$; small bridge, $L_c < 25\text{m}$. Where: L_c is drainage opening clearance.

10.7 Culverts constructed under embankment must be as long as the roadbed width, there is head wall and wing wall at the top of culvert to prevent embankment slope stability from sliding, resulting in roadbed scour by water penetration. Minimum thickness of the embankment above pipe culverts and box culverts without reinforcement but under truck loading is given in the Article 7.3.4.

Compaction of embankment over culvert shall ensure the same compaction of roadbed; soil filling for embankment on the culvert shall be the same type of the roadbed.

Culverts constructed on upstream excavation section must have receiving hole to collect runoff from side ditches and watercourses. In case that the culvert is placed deeply and high runoff, receiving hole shall be replaced with energy-dissipation structures, and chute for directing runoff from watercourse to the culvert shall be provided. In case the deep excavation crossing with runoff, it's necessary to consider aqueduct installation alternative to carry water across the highway.

Minimum opening regulated is 0.75m with length not more than 15m. To facilitate repair and maintenance works, culvert with opening of 1m and length less than 30m is necessarily used. Culvert with opening of 1.25m and 1.5m its permitted length must be more than 30m.

In general, culvert opening is selected under unpressured regime. Pressure and semi-pressure regime is only applied for high embankment section, and section with soil filling is not a permeable type to which water from culvert upstream is difficult to penetrate into the roadbed. Longitudinal gradient of the culvert should not be

steeper than that of runoff at culvert downstream. Culvert gradient shall be from 2% to 3% to prevent mud and debris from collecting on the culvert bed.

10.8 At river crossing sites, if it is not yet possible to build a bridge, a ferry or a pontoon bridge can be installed. Roads approaching to ferry or pontoon bridge must have normal slope of 8% to 12% depending on area condition, and must be at least 9m wide, paved by cement concrete or block stone.

10.9 On the low category highway, if it is allowed to be closed traffic, it's possible to construct submersible road or tunnel for the following cases:

- Over wide, flat river plain, with water depth is mostly not high.
- Over slow watercourse;
- Over hollow area at the mountain foot;
- Submersible road can be combined with culvert or submersible bridge in order to limit standing water at the upstream of the submersible road and increase drainage capacity of the submersible road when high flood occurs;
- Maximum inundated water depth that allow vehicle to travel on the submersible road is given in Table 31.

Table 31 - Permitted value of inundated water depth above submersible road
(with design flood frequency of 4%)

Water velocity, (m/sec)	Permitted maximum inundated water depth (m)		
	Car	Chained vehicle	Non-motorized vehicle
< 1.5	0.5	0.7	0.4
1.5 - 2.0	0.4	0.6	0.3
> 2.0	0.3	0.5	0.2
* In special case, determination of design flood frequency might be considered for selection as mentioned in the Article 7.3.2			

Minimum traveled way of the submersible and underpass roads is 7m; its pavement is of cement concrete or block stone. Gradient of the submersible road slope at upstream side is 1: 2 and 1: 3 to 1:5 at downstream. Slope surface must be protected from scouring by concrete or masonry. Toe of slope at downstream side must have anti- scouring method which is retaining wall made of block stone with minimum depth of 0.70m. Along

toe of highway slope, riverbed must be protected from scouring. Width of protected area is 2m toward upstream side and (2.5- 3) times of water flowing velocity toward downstream. Projecting materials commonly used are dry riprap or cement mortar.

Two approach roads of the submersible and underpass roads must have guide signs for indicating water level permitted for vehicle travel through. System of marker post shall be placed along submersible road to guide traveled way area and inundated water depth gauge on the submersible road, which can be viewed by drivers.

11. Intersections.

11.1 General requirement

11.1.1 Intersection is a place where are many traffic conflicts, accidents causing in congestion. Task of intersection design is to solve the traffic conflicts (absolute or limited) in order to obtain the following objectives:

- to ensure capacity through the intersection appropriately and ensure quality of the traffic flow;
- to ensure traffic safety;
- cost-effectiveness;
- to ensure landscape and environment hygiene;

In which the two first objectives are very important, need being complied.

11.1.2 When designing intersection, following factors are necessarily taken into consideration:

a) Traffic factors:

- Function of the existing cross roads in the road network;
- Traffic volume of: vehicles entering the intersection, vehicles of turning movement at present (existing intersection), and anticipated (20 years for basic construction, 5 years for short- term traffic organization); daily average traffic volume, peak hours volume;
- Composition of traffic flow, typical characteristics of special vehicles;
- Pedestrians volume;
- Parking stations in the intersection area (if any).

b) Physical factors:

- Topography of the intersection location and natural conditions;
- Regional planning and drainage conditions;
- Angle of intersection and improvement possibility;

- Environmental and aesthetic requirements.
- c) Economic factors:
 - Construction, maintenance costs;
 - Land acquisition costs and compensation costs;
 - Norms of technical- economic analysis.
- d) Landscape factors;
- e) Human factors:
 - Habits, disciplines, skills of the drivers;
 - Disciplines, social knowledge of road users and roadside residents.

11.1.3 Intersection classification

Intersection classification is based on conflict solving methods:

- a) Grade-separated intersection, using structures (tunnel or bridge) to separate traffic flow for conflict solving. Two main types are:
 - Interchanges: there are ramps in the interchange for vehicles to change direction;
 - Flyover: without ramps. The main traffic movement passes through the intersection via structures to separate from other traffic movement.
- b) At-grade intersection:
 - Simple intersection: conflicts might be acceptable (when traffic volume less than 30 PCU/h and speed of turning vehicle under 25km/h). This type can be widened or not;
 - Channelized intersection when some traffic movements having requirements (about turning volume and turning speed), these turning lane shall be separated, have protection (by island, marking and called channelized intersection). The channelized intersection shall define intersection angle which is advantage for conflict, create area for waiting vehicles before crossing other traffic flow.
 - Roundabouts: to transfer dangerous conflicts of crossing type to conflicts of weaving type.
- c) Signal controlled intersection: conflicted traffic movements are separated by time- divided. This type is not recommended for highway, especially when the design speed is more than 60km/h.

11.1.4 Selection of intersection. Selection is mainly based on factors (in the Article 11.1.2), technical-economic norms, taking the most use of designer's creativeness, when necessary it's possible to refer to data of traffic volume in intersection given in Table 32.

Table 32- Scope of application of intersections

Traffic volume on main highway, PCU/day and night	Traffic volume on side road, PCU/day and night			
	Simple intersection	Intersection with island on side road	Intersection with island, waiting lane and lane for left- turning movement on main highway	Other types
≤ 1000	≤ 500	$500 \div 1000$	-	-
≤ 2000	≤ 500	$500 \div 2000$	-	-
≤ 3000	≤ 450	$450 \div 1000$	$1000 \div 1700$	≥ 1700
≤ 4000	≤ 250	≤ 250	$250 \div 1200$	> 1200
≤ 5000	-	-	≤ 700	> 700
> 5000	-	-	≤ 400	> 400

11.2 Grade- separated intersection

11.2.1 Structures and clearances

Determination of using structure (over or under) is based on following principles:

- Giving priority for priority direction;
- Taking the most advantages of topography and favorable conditions when construction;
- Harmony with other intersection on the alignment;
- Through technical- economic analysis.

The structures should follow the clearances stipulated in the Article 4.7.

11.2.2 Carriage way on the main line of the grade- separated intersection.

In the grade- separated intersection, the carriage way of the main line should not be narrowed down in comparison with that at near (approach) and far (exit) side of intersection. Besides, considering:

- The median of underneath road must be widened adequately for providing structural supports and safety devices if over-passing having pier;

- Each direction should be added with one 3.75m wide collector lane at the right side of the traveling direction- The collector lane should be length enough to be a speed change lane for vehicles from ramps entering into the main line and vice versa (according to Article 4.8);

- One more 1.5h wide part should be added (where h is curb height of the sidewalk)

11.2.3 Left- turning ramp is classified into 3 types:

- Indirect left- turning type (turning head through 270^0)
- Semi- direct left- turning type (turning head through 90^0 on three quadrants);
- Direct left- turning type (turning head through 90^0 on one quadrant).

The indirect left- turning type is taken into consideration when left- turning volume is less than 500 PCU/h.

The semi- direct left- turning type is taken into consideration when left- turning volume is more than 500 PCU/h.

The direct left- turning type is taken into consideration when left- turning volume is more than 1500 PCU/h.

11.2.4 Cross- section of the left and right turning ramps

Cross- section of the ramps (left and right turning) is determined according to the Article 4.2. However it's necessary to follow the minimum provisions as follows:

- When ramp length is more than 80m, dual lane shall be placed.
- When ramp length is less than 80m, single lane might be designed but it's necessary to arrange stabilized shoulder under circumstance that a truck overtakes another truck parking on the road.

11.2.5 Design speed in the grade- separated intersection is given in Table 33.

11.2.6 Distance between interchanges with ramps must be not less than 4km.

Table 33 - Design speed of turning ramps (Units are given in kilometer per hour)

Maximum design speed *	With the speed-change lane at the entrance and exit of turning ramp		Without the speed-change lane at the entrance and exit of turning ramp		Design speed of ramp
	Recommended minimum speed	Absolute minimum speed	Recommended minimum speed	Absolute minimum speed	

120	90	80	80	60	50
100	80	70	70	50	45
80	65	55	55	40	40
60	50	40	40	30	30
* Selecting the higher speed in the design speeds of intersecting roadways					

11.3 At-grade intersection

11.3.1 Alignment and intersection angle

- Alignment on the intersection should avoid curvature, when curvature is necessarily used its radius should not be smaller than common minimum radius of the highway category;
- The best angle of intersection is square angle. When the intersection angle is smaller than 60° alignment improvement should be considered to improve the intersection angle;
- Intersection point should be located on flat place. When gradient is over 4%, sight distance should be corrected;
- Profile of the side road should not interfere or change the cross- section of the main line. When the two highways are at the same category, priority should not be given unequally; vertical alignment shall be designed so as to ensure good traffic continuity and water drainage.

11.3.2 Design vehicle and design speed

11.3.2.1 Design vehicle: when volume of passenger car is more than 60% and less than 60%, design vehicle can be passenger car and truck correspondingly. Trailer can be used as design vehicle when the volume of trailers is more than 20%.

11.3.2.2 Design speed at turning path:

- a) With straight movement, using design speed of the main highway;
- b) With right turning movement, design speed is 60% less than that of the main highway.
- c) With left turning movement, design speed has two cases:
 - Minimum design speed is not more than 15 km/h;
 - Higher design speed is not more than 40% of the design speed on the open-road.

11.3.3 Super-elevation and side friction factor

Maximum super-elevation at intersections is 6% and not over 4% when crossing residential area.

Side friction factor permitted to be used at intersections is 0.25.

11.3.4 Sight distance at intersections

There must be a field of vision at intersection (as illustrated in Figure 4), which is limited to:

- vehicles on the no-priority roadway is away from the conflict point at a distance of stopping sight of

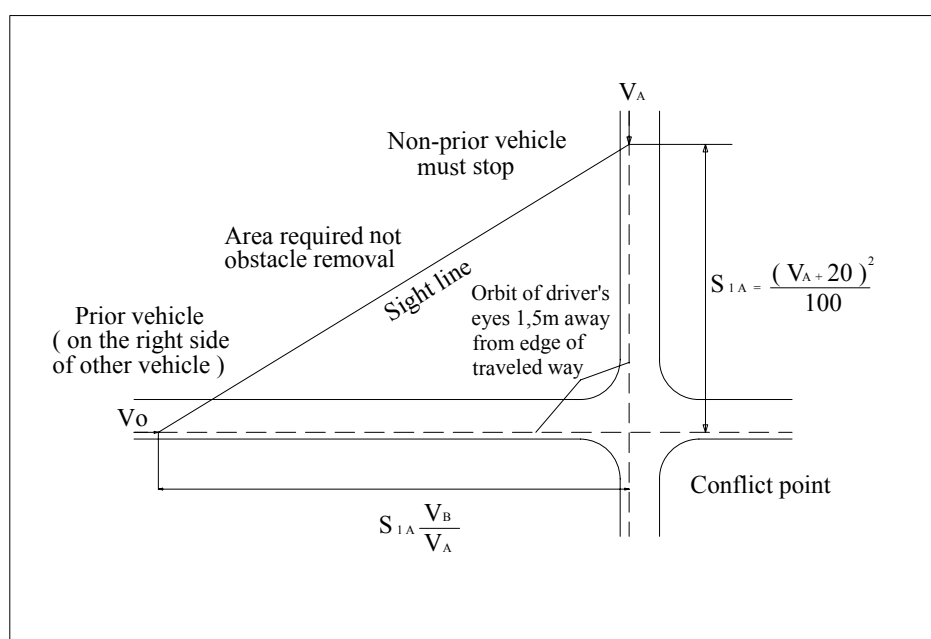
$$S_{1A} = \frac{(V_A + 20)^2}{100} \text{ m};$$

vehicle operator on the no-priority roadway observes a priority vehicle approaching (on the right hand) when it is far from the conflict point at a distance of $S_{1A} \frac{V_B}{V_A}$

in which:

V_A is design speed of no-priority vehicles, in kilometer per hour;

V_B is design speed of priority vehicles, in kilometer per hour;



NOTE - the hatched section means area required not to remove obstacles

Figure 4 - Sight distance at four-leg intersection, the predominant is on the right

11.3.5 Speed change lane

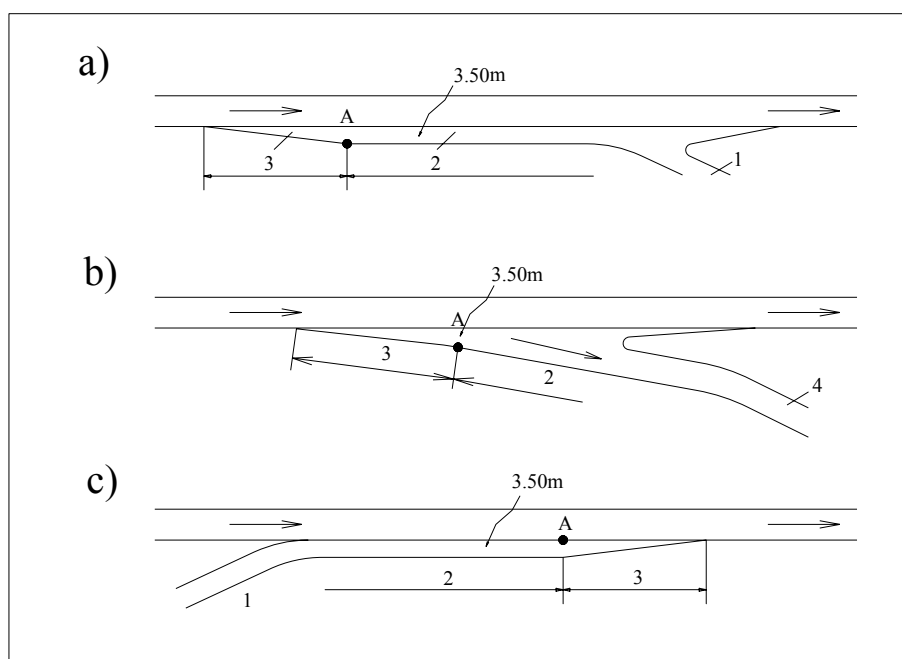
Speed change lane is provided at location where vehicle turns into the other highway category. Acceleration lane shall be provided at the location where vehicle on the low design speed highway entering into the higher one. On contrary, deceleration lane shall be provided.

11.3.5.1 Deceleration lane is parallel or direct connected (see Figure 5a and 5b) and acceleration lane is parallel (see Figure 5c).

11.3.5.2 Speed change lane is 3.50m wide. Minimum length of the taper is 35m (1m of widening on 10m length). Length of the speed change lane is 1m/s^2 and 2 m/s^2 according to positive acceleration and negative acceleration correspondingly. Length of the deceleration lane and the acceleration lane is not less than 30m, and 120m correspondingly.

11.3.5.3 Speed change lane should be located on the longitudinal grade of less than 2%. When grade is compulsory more than 2%, correction by grade or multiplying with 1.2 should be considered.

11.3.5.4 Sight distance should be ensured at the exit and entrance of the speed change lane to the main lane to which vehicles shall enter.



NOTE:

a) Parallel exit

b) Direct connected exit;

- c) Entrance to the expressway;
Parallel type
- 1- Ramp;
- 2- Speed- change section (Figure a) and b): deceleration; Figure c): acceleration)
- 3- Tapered lane change section;
- 4- Ramp acting as speed change lane and lane change

Figure 5- Diagram of speed change lane arrangement

11.3.6 Island in at-grade intersection

a) An island is a defined area for the following purposes:

- Reduction of excessive pavement areas between turning lanes;
- Clear channelization of turning movement;
- Fixing conflict points and providing advantageous intersection angle for conflicted movements;
- Providing a protection area for stopping vehicles to wait for turning or entering the main movement;
- Providing a refuge area for pedestrian;
- Location of traffic control devices.

b) Principles of arrangement and forms of islands:

- Fewer islands are preferred;
- Large islands are preferred to small one;
- Islands should be placed so as to: provide an advantage for the predominant traffic directions, obstruct traffic directions where the slow movement is needed, prevent prohibited traffic directions, and provide clear arrangement on intersection, help unhesitant continuity of traffic.

c) Offset of the island:

In order to prevent vehicles from colliding to island, the island needs offsetting to the edge of the nearside lane providing the island offset. The offset at the entrance direction of the island is regulated from 1.0m to 1.5m. The offset at the exit is 0.5m. The island periphery is obtained by connecting even curves; island nose is rounded with radius of 0.5m.

Pavement at the island offset is similar to that of the carriageway, and marked with zebra-marking.

11.4 Railroad grade crossing

11.4.1 A railroad-highway grade crossing must be placed outside the range of railroad stations, wagon gathering track, entry of railroad tunnel and signal lighting poles at the station entrance. The best intersecting angle should be a right one, it must not be smaller than 45^0 .

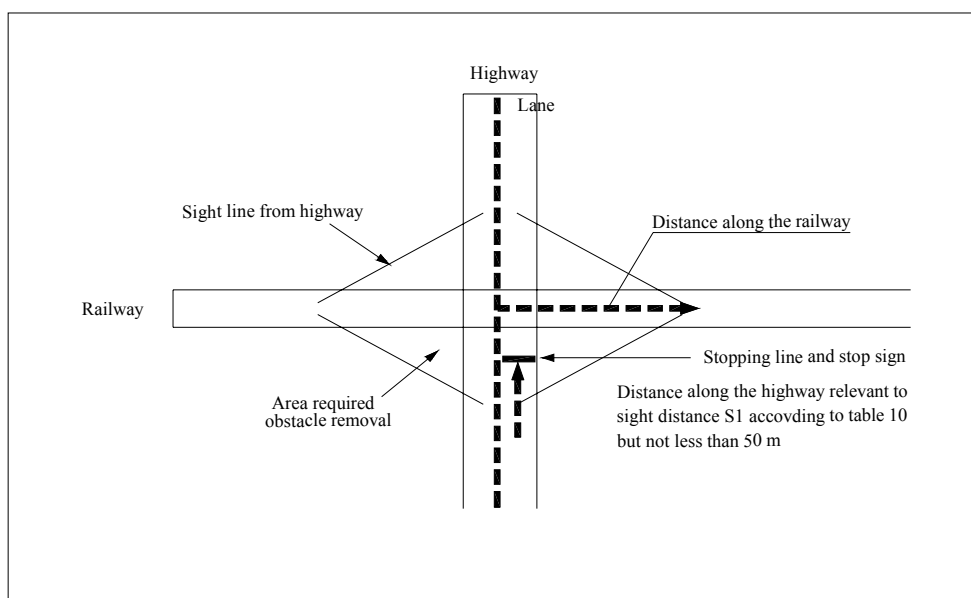
11.4.2 Railroad-highway grade crossing should not be applied in the following cases:

- Highway with design speed $V_{\text{design}} \geq 80\text{km/h}$ crossing a railroad;
- Highway with design speed $V_{\text{design}} < 80\text{km/h}$ crossing a high-speed railroad (120km/h), especially where adequate sight distance is not available.

11.4.3 An adequate sight distance must be ensured at railroad-highway at-grade crossing (where there is no barrier or flagman) so that the highway driver can observe the approaching train. Particularly, unobstructed area for sight distance availability should be ensured, as shown in Figure 6 and Table 34.

Table 34- Distance required obstacle removal along the railroad from the crossing

Maximum speed of the train on the crossing section, km/h	120	100	80	60	40
Distance along the railroad, m	400	340	270	200	140



* When the actual area is limited, it's possible to provide "Stopping line" and "Stop sign" on the highway, placing 5m away from the edge of the outside rail according to the 22TCN 237. Sight distance of 5m must be ensured along the highway and along the railroad with the values given in the Table 34.

Figure 6 - A sketch of unobstructed area for sight distance availability at railroad-highway at-grade crossing

11.4.4 Width of highway carriageway at a railroad at-grade crossing to both sides should not smaller than 6m with length of a stopping sight distance S_1 in Table 10 calculated from the outside rail edge plus 5m.

11.4.5 At a railroad crossing, the highway must be made level (0% gradient) or provided the same longitudinal gradient as the superelevated rate of railroad in the minimum area of 16m (in which successive vertical curve is excluded), or it is allowable to reduce to 10m in difficult case.

11.4.6 Highway structure at the intersection should be reinforcement concrete slabs with minimum length of 2.0m each side from the outside rail edge; it's allowable to reduce to 1.0m in difficult case.

11.5 Other intersections

11.5.1 In the range of electricity lines, telephone lines, the highway design must follow the requirements of the respective management departments and following instructions:

- Minimum vertical distance from the road surface to telegraph/telephone lines crossing highway is 5.5 m;
- Horizontal distance from the edge of roadbed to the posts of above-mentioned lines must be not less than four-third of post height and not lower than 5m.

11.5.2 Horizontal and vertical distances from the highway to the electricity lines are in accordance with the existing regulations.

11.5.3 When the highway crosses with pipes such as water pipe, gas pipe, oil pipe, energy pipe, underground power lines, it's necessary to comply with the existing regulations of the relevant section.

12. Traffic Safety Devices on highways

12.1 Signs

The 22TCN 237 shall be applied.

12.2 Traffic Pavement Markings

The 22TCN 237 shall be applied.

12.3 Guide posts, guardrails.

12.3.1 Guide post functions as direction guiding, Guide posts are necessarily placed on the ea soil part of shoulder when the down slope is high from 2m upward on the curve with small radius and approach roads of bridge; guide posts spacing are given in Table 35. When there are guardrails, guide posts need not to be placed.

Table 35 - Spacing of guide posts on horizontal curvature radius

Units are given in meter

Horizontal curve radius	Distance between guide posts
on the tangent	10
> 100	8-10
from > 30 to 100	4-6
from > 15 to 100	2-3

The cross section of guide posts may be circular, square, and triangular but its dimension must not be less than 15cm. The height of guide posts is 0.60m above shoulder elevation and that of the underground section is not less than 35cm.

Painting colors used for guide posts follow the instructions of the regulation on road signs. It is recommended to use reflectorizing paint, or to paint at least a reflectorizing stripe of 4cm wide, 18cm long at about 30 to 35cm beneath the top of posts and towards traveling direction.

12.3.2 Guardrails must be placed on the highway where the embankment height is over 4m, on bridges, viaducts, overflies, location of piers and abutments of underpass/overpass, pedestrian paths in tunnels etc.

Railings may be made of concrete or corrugated steel may be used. The cross section of steels is at least 4mm in thickness, 300 to 350mm in height and it should be formed in corrugated shape for increasing rigidity.

Railing bars and posts are designed and checked based on strength requirements given in Table 36.

Railings must extend over the protection areas by at least 10m on both sides.

12.3.3 When railing bars and posts are made of equivalent materials, mechanical conditions must be checked following the requirement in Table 36

Table 36 - Minimum requirements for guardrail

Force elements	Calculated force, kN
Corrugated iron for railing under flexural force between two posts:	
- in the direction from the centerline to the edge	9
- in the direction from the edge to the centerline	4.5
Steel for post, expulsive force at the top of it	
- in the direction of traffic movement	25
- in the perpendicular direction to traffic movement	35
Bolt: All directions	25

Push force at each railing section	400
------------------------------------	-----

12.4 Lighting

Highways are not artificially lighted on their alignment, except some particular circumstances that artificial lighting may be considered at the following places: large intersections, long bridges, tunnels and residential areas. The difference in illumination between lighted place and unlighted one is not more than 1 candela/m² over the 100m long for preventing glare.

13. Auxiliary works

13.1 Planting

13.1.1 Planting is the must of the highway project. Planting has the following purposes: protecting works, providing shade zone, creating landscape, guiding direction etc. At the same time, it can reduce traffic noise and dust, and prevent the glare for opposing vehicles.

13.1.2 Turf: turf must be grown on separators and islands without covers, dikes which are left over near the highways.

Fill slopes and cut slopes must be grown with turf by ways of seeding or assembling grass pieces etc. for preventing erosion and improving highway landscape.

The selection of seed species must follow consultation with agronomists, and combination various grass varieties should be considered so as to ensure year-round greenery. The height of turf is not over 5cm. Turf height over 5cm must be trimmed away.

13.1.3 Shrubs

Shrubs have the following effects: create landscape, prevent the glare from head-light of opposing vehicles, and reduce traffic noise and dust.

Shrubs can be grown at medians, berms of cut and fill slopes. It must not be grown at small islands.

It is necessary to prune down shrubs, prune off branches, replace the dead ones and trim the top of shrubs so that their height will not be over 0.80m

13.1.4 Big trees

Big trees must be planted outside the soil shoulder. They can be planted on both sides along the roadway or made into a clump of trees beside the road.

The selection of tree species must follow consultation with agronomists. Tree species should be suitable to the habitat, their roots do not spoil highway structures, trees should not fall down easily, their branches should not be fragile, and they should serve good decorative effect.

13.2 Bus stops

13.2.1 Bus stops can be classified into three types:

- Simple stops: Buses stop located on the part of traveled way, close to the right edge. Buses decelerate or accelerate right on the outer lane;
- Avoiding stops: Buses use a part of traveled way and a part of shoulder for stopping. Buses decelerate or accelerate right on the outer lane;
- Separating stops: Buses stop at the area which is outside the traveled way and separated by level, curbs, railings, separators. Buses decelerate or accelerate on a part of outer lane and a part of lane which is separated from main traveled way.

13.2.2 The scope of bus-stop application is as follows:

- a) When the frequency of buses is smaller than the value given in Table 37, a simple stop can be used; when it is bigger, an avoiding stop must be used.

Table 37 - The scope for applying bus- stop

Average Daily Traffic Volume in future year $N_{\text{average annual}}(PCU/daily)$	1000	2000	3000	4000	5000
Anticipated frequency of bus, <i>buses/hour</i>	5	2,8	1.6	1.2	1.0

Besides the instructions in Table 37, avoiding stops must be placed in the following cases:

- When the shoulder is more than 3.0m wide;
- When the width of shoulders is from 2.0m to 3.0m and the volume of two-wheel vehicles is more than 50 vehicles/ hour in one direction;
- When the above-mentioned conditions are not available but the bus stop is 15m away from the pedestrian crossing.

- b) Separating stops must be provided on the highway with the calculated speed $V_{\text{design}} \geq 80$ km/h.

13.2.3 Bus stop arrangements:

- Simple stop: Buses stop on the carriage way, and the stabilized shoulder is used for loading;
- Avoiding stops: Minimum width from the edge of carriage way is 3.0m. The dimension of loading platform is 1.5m wide and 15m long. Its arrangement is illustrated in Figure 7

- Separation stops must have entrance and exit roads and speed-change lanes must be taken into consideration.

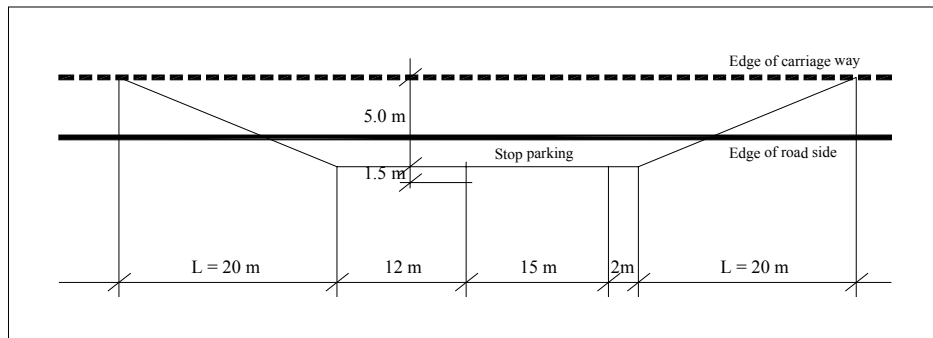


Figure 7 - Minimum arrangement of an avoiding bus stop

132.4 Location of bus stops

- Bus stops are placed on the right hand side of traveled way and in the same direction of the traffic movement.
- The spacing of bus stops is 300 to 500m at least. The bus stops must be not located on curvatures with radius value smaller than the normal minimum horizontal curve radius.
- Bus stops are located on both sides of roadway, the distance between the starting point and the ending point of bus stops must be at least 10m;
- Bus stops may be located on the near (approach) side or the far (exit) side of intersections. The distance from bus stop to intersection must be in consideration of accelerated section, observation time (when bus stop is located on near side), deceleration section (when it is located on the far side), and the impact of bus stop to through traffic capacity of intersection. When bus stop is located on far side, it must be at least 50m far from the center of intersection.

When bus stop is placed on the near side, it must be at least 40m away from the center of intersection for the highway with the calculated speed $V_{\text{design}} \leq 60$ km/h, and 60m away for the highway with $V_{\text{design}} \geq 80$ km/h.

At intersections with the pavement markings for pedestrian crossings, bus stop must be placed at least 10m away from that crossing.

13.3 Rest and other service areas

13.3.1 It is necessary to provide rest and other service areas on highways with the calculated speed $V_{\text{design}} \geq 60$ km/h. The rest areas serve the following purposes: to reduce the fatigue of highway users, increase traffic safety and make better use of the country's tourism potentials.

13.3.2 Rest and other service areas must be separated from the roadway. The acceleration and deceleration factors must be included in the design of entrance and exit roads. Guide signs must be installed on the main roadways in accordance with the instructions in 22 TCN 237.

13.3.3 Rest areas.

Small rest areas: having the area of 3000 m² more or less, with parking areas; fixed facilities for the rest area may be provided (less than 10 places together with tables and chairs, roofs, taps for drinking water, information boards about locality's history and geography).

Large rest areas: having the area of more than 5.000 m². Parking areas for cars, trucks and buses are provided. It may include following services, which are managed by local authorities: medical stations, petrol stations, car services, soft drink bars and shopping counters, public telephone points (or post offices).

13.3.4 The spacing of large rest areas is 60km to 100km.

The spacing of small rest areas is 15km to 30km

On highways of more than 100km in length, it might be necessary to consider providing motels.

The selection of rest area location, service capacity must be consulted with local authorities.

13.3.5 Parking areas must be paved with adequate strength. Minimum dimensions of parking areas are as follows:

- For cars: 2.5m x 5.00m;
- For trucks: 4.0m x 20.00m;
- For buses: 5.0m x 15.00m.

13.3.6 It is important to plant trees at rest areas, in order to:

- Separate rest areas and roadways; provide the relaxing surroundings for highway users to take a rest;
- Separate parking areas and among sections in the rest areas. High trees should be grown at parking areas to provide the shadow zones.

13.4 Toll plaza

13.4.1 Toll plaza is placed at the following locations:

- Near the approach to large bridges or tunnels;

- At interchanges;
- Appropriate locations;
- Spacing of toll-plazas should not be less than 70 km.

13.4.2 Toll station lanes

13.4.2.1.1 The number of the toll lanes of a station depends on the followings:

- Peak hour volume of the design year;
- Length of the waiting line should not be over 500m;
- Time needed for toll collection. This is dependent on toll types: manual, semi- automatic or automatic collection’
- Separated lane shall be provided if having simultaneously various payment methods (cash, ticket, e-card etc. or with various vehicles such as motorbikes, trucks, containers etc.)
- Near urban area, it’s possible to provide some lanes which are reversible to accommodate heavy peak traffic volume (high volume in the morning and low volume in the afternoon).
- A lane shall be designed to accommodate over-size vehicles to detour the toll gate.

13.4.2.1.2 Toll lane width:

- Non- motorized lane is 3.8m in width and provided with vehicle counting device;
- Lanes are separated by islands of 30m long and 2m wide. On the island, there are booth for toll collection staff, lifting barriers between lanes, and devices and equipment installation such as toll collector, vehicle counting device, guide signs etc.;
- Separated lanes, at least 2 lanes should be provided for motorbikes with dimension of $(2 \times 1\text{m}) + 0.5\text{m}) = 2.5\text{m}$;
- Pavement of the toll lanes (on the lane for queuing also) is paved with cement concrete.

13.4.3 Other regulations

13.4.3.1 Clearance of the toll gate is at least 5.0m. The width is adequate for exit and entrance vehicles (including separation island and reserved lane for future widening). The length is adequate for vehicles to queue with the possible queuing length is as long as 800m.

13.4.3.1.1 Toll plaza shall not be placed at the end of the slope with gradient more than 3%.

13.4.3.1.2 The toll plaza shall be lit, provided with telecommunication system (radio, telephone etc.) and ventilation system and sound proof.

13.4.4 As a minimum the station building shall include the following rooms and systems:

- Managers office;
- Security officers office;
- Strong room for storing currency and goods;
- Locker room and lockers for staff;
- Canteen;
- Male and Female toilets;
- Generator station for stand by power.

14. Environmental protection

14.1 During design stage, it's necessary to analyze and evaluate environmental impacts resulting from highway construction and operation, with aims to find out mitigating measures and to comply with the existing legal documents;

14.2 Environmental impacts analysis is conducted by 2 steps:

- During basic design: preliminary evaluation on environmental impacts is to study and select alignment alternative, refer to the 22TCN 242;
 - During technical design and final drawing design: detailed study on environmental impacts is to analyze economic benefits and loss with the aims of recommending and deciding the suitable treatment methods for highway construction and operation
-