CHAPTER 3

HIGHWAY & INTERCHANGE DESIGN

CHAPTER 3 HIGHWAY & INTERCHANGE DESIGN

3.1. Introduction

3.1.1. Background

The JICA Study Team has studied the expected geometric design standards of OCH during the basic design period taking into account the following policies.

- To ensure necessary levels of safety and comfort for drivers by the provision of adequate sight distances, coefficients of friction and road space for vehicle maneuvers;
- To ensure that the road is designed economically
- To ensure uniformity of the alignment
- To determine geometric design criteria applicable for use in Sri Lanka.

From the engineer's points of view, the JICA Study Team recommended the RDA to adopt the Japanese Standards as a basic standard taking into account similar geography and topography in Sri Lanka. The RDA agreed with this recommendation however the standards should be rectified to suit for local conditions if necessary.

Various studies have been conducted, which include comparative studies on the geometric design standards adopted for highways linking to the Outer Circular Highway, such as Colombo-Katunayake Expressway and Southern Highway and other matters of influence to the Project.

The details given below in this chapter describes the analysis and various parameters involve in the geometric design of OCH.

Table 3.1.1 Adopted Design Standards and Major Design Elements

Project Name	Standards	Design Speed (km/h)	Number of lanes in ultimate Stage (lane width)	Max Grade (%)	Radius (m)	Max. super elevation (%)	Remarks
Colombo. Katunayake Expressway	NAASRA & RDA	110	4 (3.6m)	3 (Des) 5 (Abs)	*1500* *600*	*5*	
Outer Circular Highway .	Japanese *amended to suits local conditions*	80	6 (3.5m)	4(Des) 7(Abs)	*400* *280*	*6*	
Southern Highway	AASHTO	120	6 (3.6m)	3 (Des) *4 (Abs)*	1250 *755*	*4* *6*	

Notes: Figure in parenthesis show actually adopted values.

3.1.2. Definition of Terms

The following technical terms as defined below are used in this Report

- **Roadway:**
  A highway cross section including shoulders, provided for vehicular use.

- **Carriageway:**
  The portion of the roadway cross section provided for the movement of vehicles, exclusive of shoulders.

- **Shoulder:**
  The portion of the roadway contiguous with carriageway for accommodation of stopped vehicles, for emergency use and also for lateral support of Sub base, base, and surface courses. Hard Shoulder is the portion to be paved or surface treated and the soft shoulder is the portion to be covered by sod or turf.

- **Marginal Strip:**
  The portion of the shoulder with the same pavement structure of the traveled way extended usually 0.25m – 0.3m. This is also the space for road marking at both ends of carriageway.

- **Median (Center Strip):**
  A cross section element provided to separate a lane by directional separation and ensure lateral clearances.

- **Traffic Lane:**
  A strip section of the carriageway (except for the service road) provided for safe and smooth traffic by directional separation of a row of vehicles.

- **Service road (Frontage Road):**
  A carriageway parallel provided to applicable sections to ensure access of vehicles to roadsides where access is prevented for the reason of embankment and cut, or other.

- **Approach road:**
  The existing roads, which are non accessible once the OCH is constructed, shall be compensated to ensure the existing access. An overpass or underpass structure shall be constructed in order to cross the OCH.

3.2. Geometric Design Criteria for Main Carriageway

3.2.1 Design Vehicle

The size and physical characteristic of the vehicles essentially form geometric features, such as cross section elements, widening on curve, and corner treatment at intersection, grade, sight distance and so forth. In the feasibility study, the AASHTO design vehicles are recommended to be used for designing of OCH, since it is specified in the Geometric Design Standards produced by RDA 1998. However, it seems that the Japanese design vehicles are more appropriate to apply taking into account various usage of Japanese vehicles in Sri Lanka. In addition, the design vehicle for STDP is applied to Japanese design vehicle for the economic and practical reasons. Accordingly, the JICA Study Team recommended using the Japanese design vehicles in the study.

The figures in **Fig.3.2.1.** shows design vehicles are, which quoted from the Japan Road Ordinance says that the dimensions of the vehicles are conformed to the relevant laws and regulations of transportation enforced in Japan.

The design vehicles shown in **Fig.3.2.1.**, the semi-trailer is almost similar to AASHTO design vehicle type WB – 15. Therefore, the proposed Japanese design vehicles are appropriate for use in designing of OCH. The minimum turning path will follows AASHTO design vehicle type WB –15.

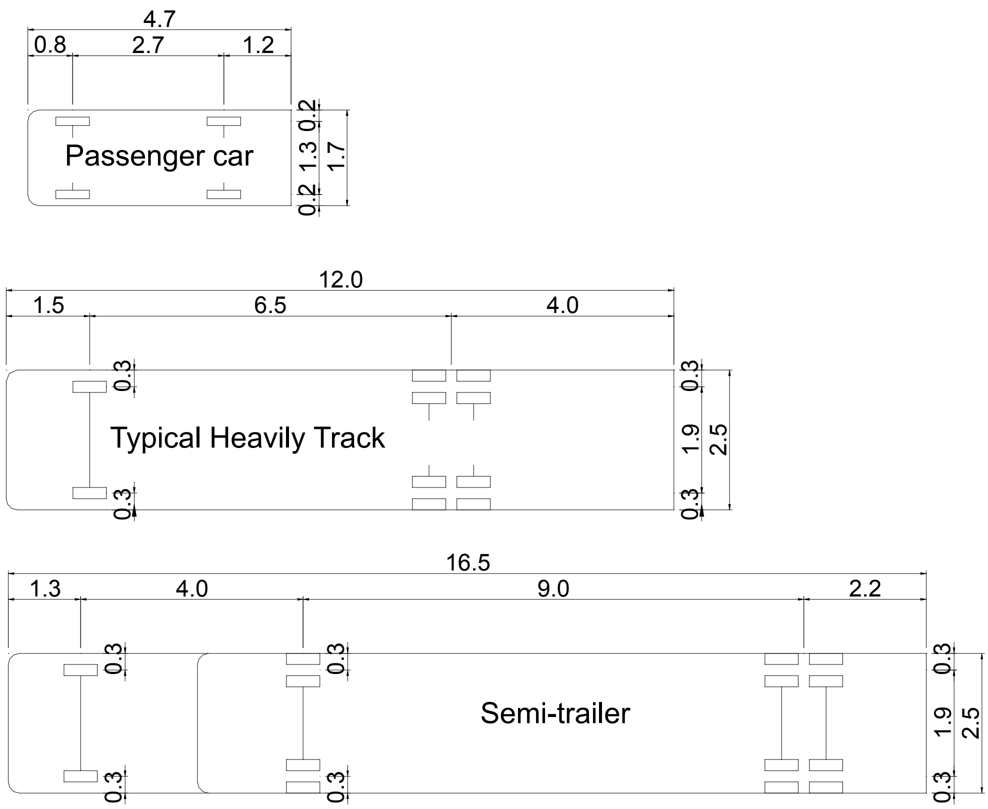
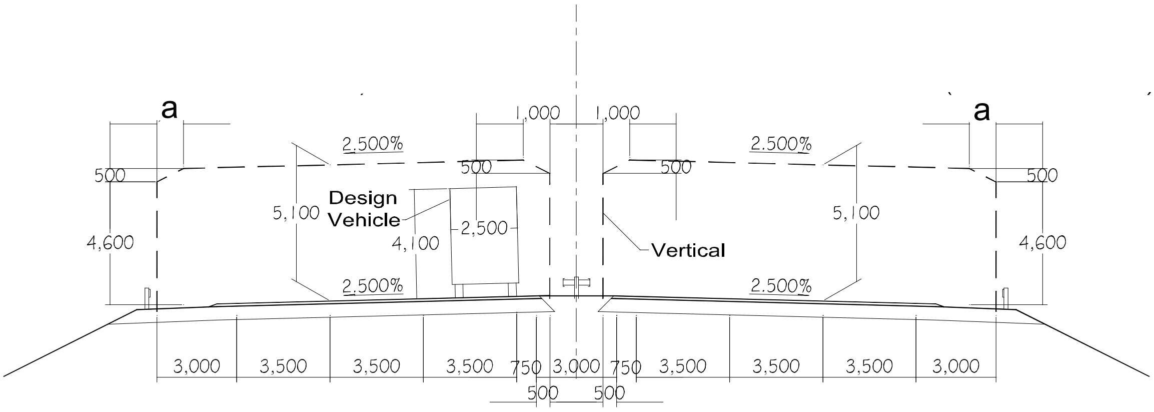


Fig. 3.2.1 Design Vehicles

3.2.2 Clearances

(i) Clearances for Main Carriageway

The vertical clearance and lateral clearance for OCH given in **Fig. 3.2.2**. & **Fig.3.2.3**. as discussed with RDA. The both top side end of clearance shall be shaped same as the hunch to reduce concise the clearance by economic reasons in Japan.



a: the width varies depending on the width of shoulder but not more than 1.0m

Fig. 3.2.2 Lateral Clearance

(ii) Clearances for National Roads and Railways

Minimum vertical clearances for the existing national roads are determined after the series of discussions with RDA in 2001. However, the RDA requested JICA Study Team to rectify the vertical clearance for C and D class roads by the letter issued on 9th September 2003.

As for the clearance of railways, it was given by the letter dated on 20th from RDA attached with the clarification from SLR (Sri Lanka Railways).

The vertical clearances applied to the study are as shown in **Fig. 3.2.3.**

The vertical clearances, which have been shown in the **Fig. 3.2.3.**, conform to the AASHTO standard, which requires min. clearance of 4.3m for minor roads and 4.9m for major roads. NAASRA specifies a vertical clearance of 5.5m for service wires, 5.4m preferred and 4.6m minimum clearances for highways.

The clearances for the overhead signs and pedestrians are specified according to RDA standards as below.

Overhead Signs : 5.7m

Pedestrian Bridges : 5.7m

These clearances are provided for design of national highways should be taken into consideration.

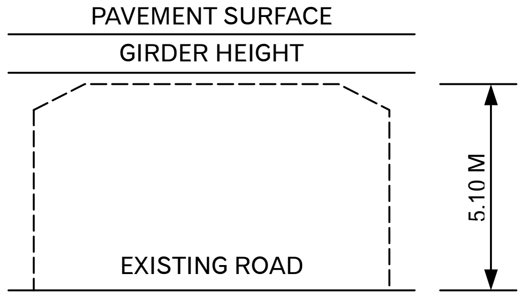
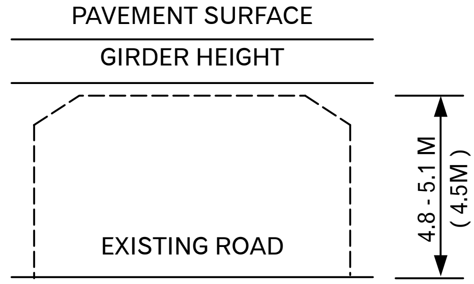
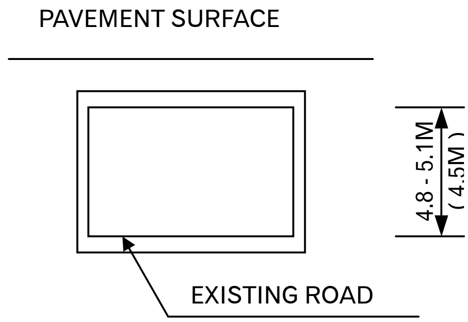
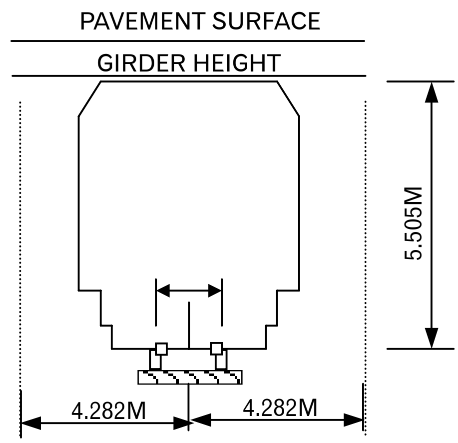
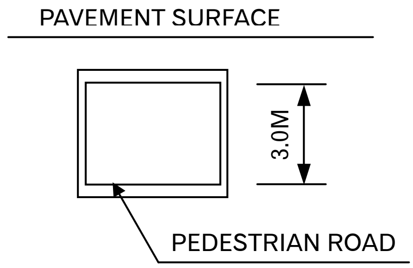
Type of Crossing	Classifications	Sketch
Crossing with Major Roads	- Expressways - A3 - A1 - B214 - A110 - B240 - A4	
Crossing with Minor Roads	- C, D, E - Other Provincial (Gravel) Roads	 ( ): E class and Other Road)
Crossing with Minor Roads	- C, D, E - Other Provincial (Gravel) Roads	 ( ): E class and Other Road)
Crossing with Railways	- Sri Lanka Railways	
Crossing with Pedestrian Roads		

Fig. 3.2.3 Vertical Clearance

3.2.3 Design Speed

The range of design speeds are provided in Japan by the different road classifications, depending mainly on terrain and traffic volume, and that the standards used should be consistent on long length of roads. Consideration should be given to the economic tradeoffs between the increased construction costs of higher standards and the saving in operation costs which result. Most of these savings in operating costs will be saving in travel time from higher speeds of travel.

According to the feasibility study, the Outer Circular Highway will serve slight different role of general expressway linking among urban cities. It should play a role of an intercity expressway in which dispersing the traffic centralizing to Colombo should be more important than the benefit of time saving. Therefore, it is important to improve the mutual accessibility between arterial roads and economic growth zones through Outer Circular Highway.

Hence, the design speed adopted for OCH is 80km/h, which the speed categorized to meet the requirements of an expressway.

Expressways in Sri Lanka	Design Speed
Outer Circular Highway	80km/h
Southern Highway	120km/h
Colombo-Katunayake Expressway	110km/h

(i) Restriction of Applicable Different Design Speeds

The design speed may vary within a short distance due to the changing zone, topography, planning and traffic volume in a given section.
If the design speed changes in a short distance, it is undesirable for the users in terms of traffic safety and driver's comfort. Therefore, it is recommended that the minimum distance for a design speed should be determined and consistently maintained. The minimum distance stipulated in Japan is given below for reference.

	Standard	Special Case
Minimum distance for one design speed	30 – 20 km	5 km

(ii) Transition Between Different Design Speeds

The difference in design speeds at connection points normally need to be kept within 10-20 km/h. The design speed is changed according to variations in topography and zone, or at interchanges. The transition between OCH (80km/h) and STDP (120km/h) is over 20 km/h. Section for transition (operation speed: 100km/h) will be required at the south of Kottawa Interchange when STDP starts 6-lane operation.

3.2.4 Cross Section Elements

The typical cross sections of OCH have been determined with the agreement of RDA. The cross section consists of lanes, center median, shoulders, etc. This cross section width has been established based on Japan Highway Design Manual in relation to design speed and traffic demand forecast. The determination of width of each element and the concept in relation to expressway standard is presented hereinafter. Note that the cross-section of the OCH will ultimately have three lanes per direction and total six lanes, while the initial OCH will have two lanes per direction and total four lanes.

(1) Traffic Lane

The standard lane width for Japanese expressway is 3.5 m. When the first expressway (Meishin Expressway) in Japan was constructed, a lane width of 3.6 m was adopted in accordance with the practices in various foreign countries. Based on the lane studies done on the operation of the representative expressways, a lane width of 3.5 m has been found to be adequate to adopt as the standard width for the expressway in Japan.

The Southern Highway (AASHTO) recommends, 3.60m (App. 12ft) lane widths for the main carriageway. However, the design speed adopted for Outer Circular Highway is different from that of STDP (as per section 3.2.3 Design Speed), so that it doesn't warrant a consistent lane width of 3.60m for the OCH as the direct linking expressway.

The volume of traffic and the type of vehicle in the traffic stream are the main factors affecting pavement width. According to the traffic demand forecasts for the Outer Circular Highway, the lane widths of 3.50m to 3.65m, are desirable considering the reductions in capacity, driver comfort and safety associated with narrower lanes.

The JICA Study Team, based on the feasibility study, recommends a lane width of 3.5m to adopt at OCH for the following reasons.

- Conformity of design standard
  3.50m lane width that conforms to the design standards in Japan can lead to a safe and economical design.

- Classification of the highway:
  OCH is classified as the intercity expressway that does not require high traveling speed, as the Southern Highway.

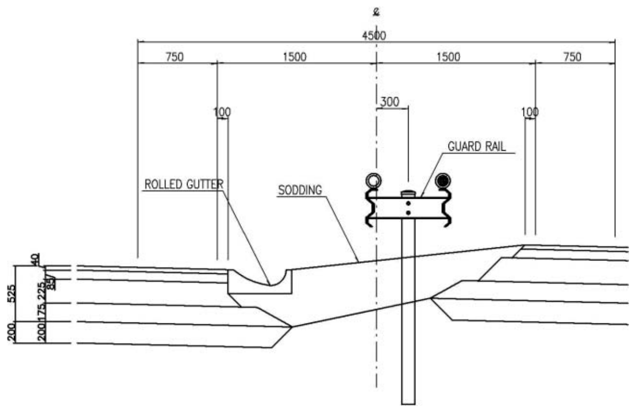
- Vehicle speed:
  OCH is applied to different design speed of 80km/h that the required circumstance may be considered as providing acceptable levels of service.

(2) Center median

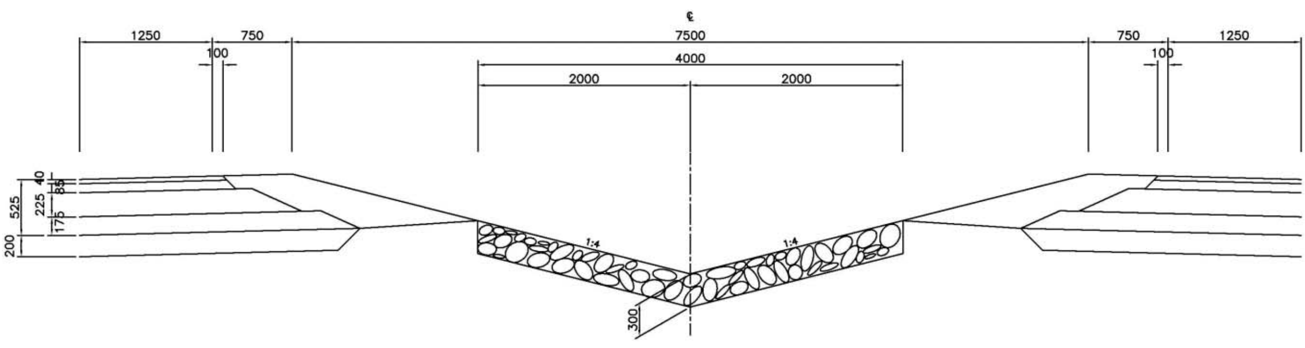
This consists of a median and a marginal strip. The median separates the two-way traffic flow to prevent turns and minimize disorder in the traffic flow in order to ensure safety environment. The center median for OCH will be provided with a guardrail to facilitate these functions at the ultimate stage of six traffic lanes. The marginal strip provided in center median has the function of maintaining the lane effect by indicating clearly the external line of the traffic line, guiding the driver's vision, increasing driver's safety and providing a lateral clearance.

In order to improve the visibility, a white marking line with 20cm wide indicating the outer line of the carriageway is commonly drawn on the marginal strip. The basic width of the center median is 3.0 m in Japan. This is sufficient to ensure the lateral clearance and it should not be affected by the installation of guardrail or by the landscape within the median.

The minimum width of the center median for expressways in Japan is 2.0 m as it requires sufficient width to accommodate any facilities installed within the median. Under clearance to the structures that NAASRA recommends lateral clearance from shoulder to guard fence to be 0.3m. This could be taken into consideration at the ultimate stage where the guard fence is to be placed in the center of the median.
The center median at ultimate 6 lanes (flat type) given as follows, which has been adopted and agreed by the RDA at the feasibility study. The center median at initial 4 lanes given below as well.



Ultimate 6 Lane



Initial 4 Lane

Fig. 3.2.4 Center Median

(a) Median Opening (Emergency Crossing)

Necessary opening of median shall be applied at required interval for the maintenance purpose, to transact the traffic during maintenance works. The location of median opening has specified as follows:

- where the alignment secure enough visibility at grade section (over 600 m radius of horizontal curve)
- before and after interchange
- standard interval is about 2 km

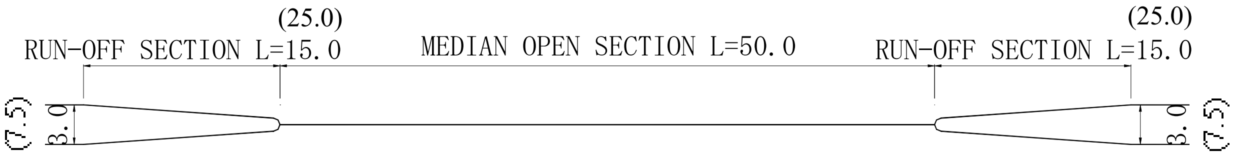


Fig. 3.2.5 Median Opening (Emergency Crossing)

(3) Shoulder

The shoulder for the expressway should play the following roles.

- To provide the space for the treatment of traffic disturbances caused by the disabled cars.
- To secure the traffic safety and driver's comfort by providing lateral clearance.
- To protect the carriageway.

The shoulder width should be determined taking into account the functions above. In Japan, the standard width of passenger car is 1.70m and the truck is 2.50m. Accordingly, 2.50m wide shoulder is sufficient to provide the adequate space off the traffic lanes for any kind of disabled vehicle; the width should be at least 1.70 m, assuming only passenger cars. The basic concept is that the shoulder installed to the left of the outer lane should provide space for a disabled car.

The inner shoulder is not installed in cases of standard cross section has center median. However, roads with grade separation and those where the two way directions of traffic are separated by means other than a center strip, the inner shoulder is installed. As for pavement structure of the shoulder, the surface course could eliminate to reduce the construction cost, as the vehicle is not running frequently.

The gap should be treated as tapered to the shoulder not to require suddenly drivers maneuver. Also, there is a marginal strip if 0.75m out side of traffic lane, therefore it could be affectivity on safety.

In comparison with other international standards, the 3.00m wide inner shoulder, which is applied to OCH (including marginal strip of 0.75m and stabilized median of 1.25m) is compatible to AASHTO and NAASRA."

		Shoulder Width	
		Inner	Outer
AASHTO		1.2 -2.4m	3.0m
NAASRA	4 Lanes	1.2 m	3.0 m
	6&8 Lanes	2.4 m	3.0 m
OCH	Initial 4 lanes	1.25 m	3.0 m
	Ultimate 6 lanes	*0.75 m (1.25m) *Marginal strip for center median ( ):lateral clearlance	3.0 m

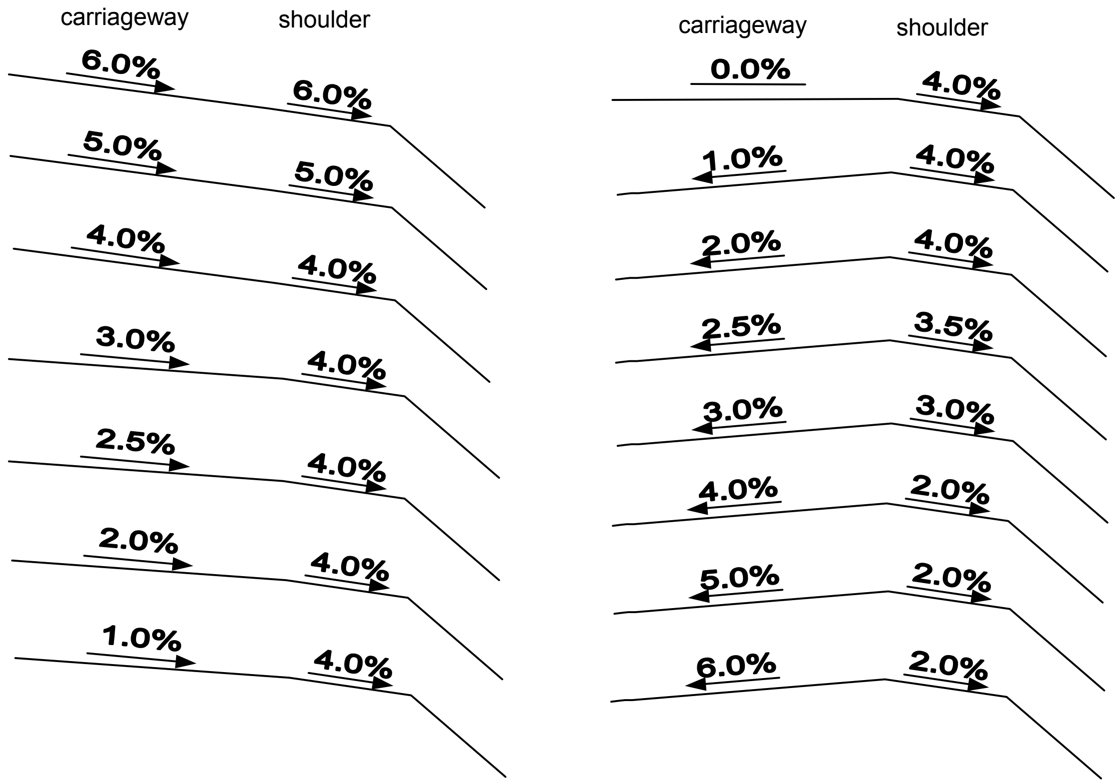
(4) Verge Width

The desirable standard of 0.75 m width of outer verge specified in Japanese Standards has been adopted. Also, 0.75m width of inner verge will be adopted at the initial stage of four lanes.

(5) Crossfall

The crossfall of main carriageway adopted is 2.5% at the feasibility study as the normal crossfall. To facilitate discharging run-off-water, the crossfall of 4.0% on shoulder is recommended which is steeper than normal crossfall of 2.5%. "In case that algebraic difference between superelevation of main carriageway and crossfall of shoulder is over 6%, the shoulder superelevation shall be adjusted up to the algebraic difference is 6%. However, when the superelevation of the main carriageway becomes more than 4%, it is allowed to adopt algebraic difference 8%."

Superelevation runoff for shoulder depending on the superelevation of main carriageway shows in figure below.



3.2.5 Proposed Height and Axis of Rotation

The proposed height (PH) which is indicated in the design profile is the point about which the crossfall is rotated to develop the superelevation. The position of the axis of rotation on the cross section of OCH has been placed at the center of three lanes in ultimate 6 lane carriagway as shown in **Fig. 3.2.6.**

3.2.6 Right of Way Setting

For the setting of the right of way, the reservation that be applied to STDP is commonly adaptable to use for OCH taking into account the consistency between the projects directly linking each other. At the normal earthworks section except the some constraints as below, 5.0 m reservations even from the edge of cut and fill slope will be kept, in order to accommodate the side storm drainage, boundary fencing and other necessary facilities. The reservation will be also used for the temporary yard at the construction stage and landscaping or other buffer zone at the operation stage.

- boundary at the high- density urban area
- specific circumstances concerning land acquisition
- reduced 2.0 m reservations at the frontage section along OCH
- extra reservation needed adjacent to high cut slope to allow for the erosion

For the approach roads crossing OCH, 2.0 m reservations will be secured at both road sides.

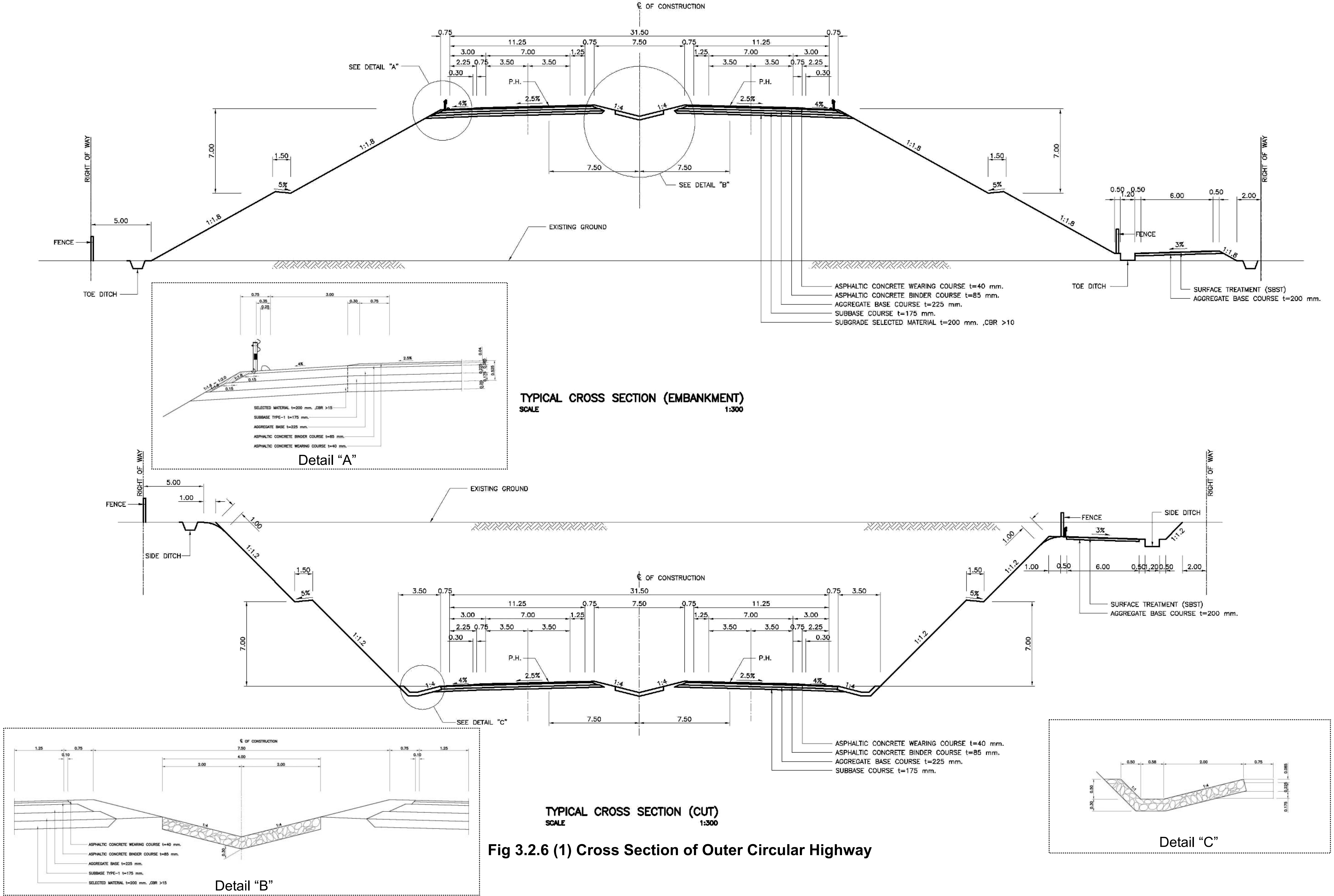


Fig 3.2.6 (1) Cross Section of Outer Circular Highway

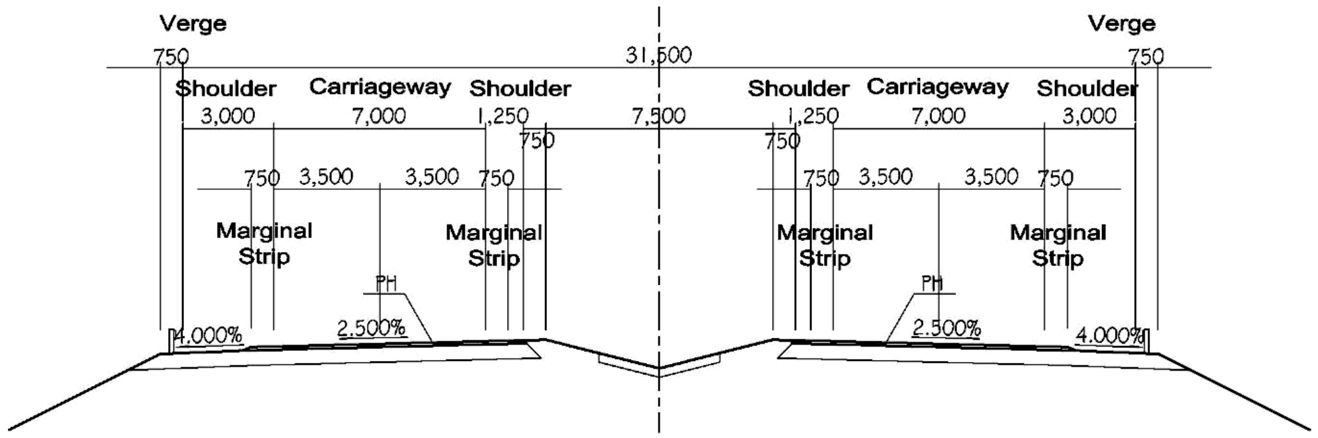
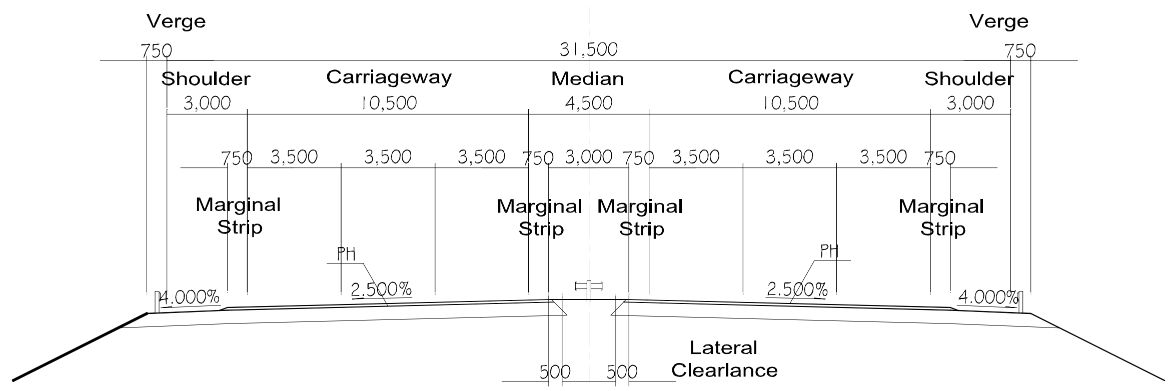
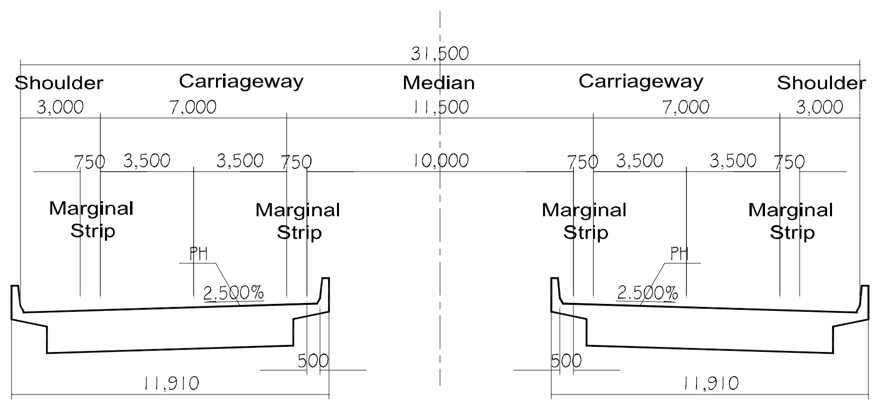
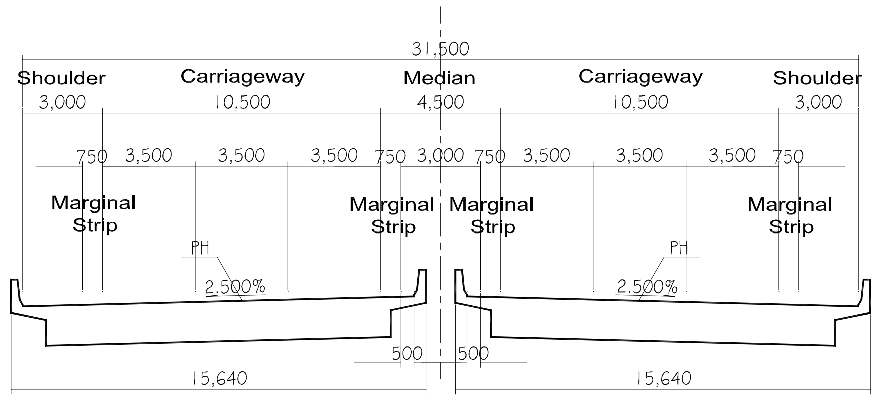
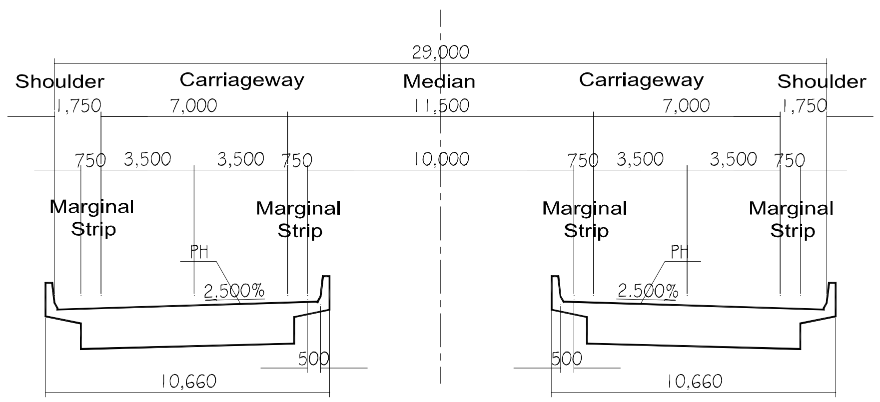
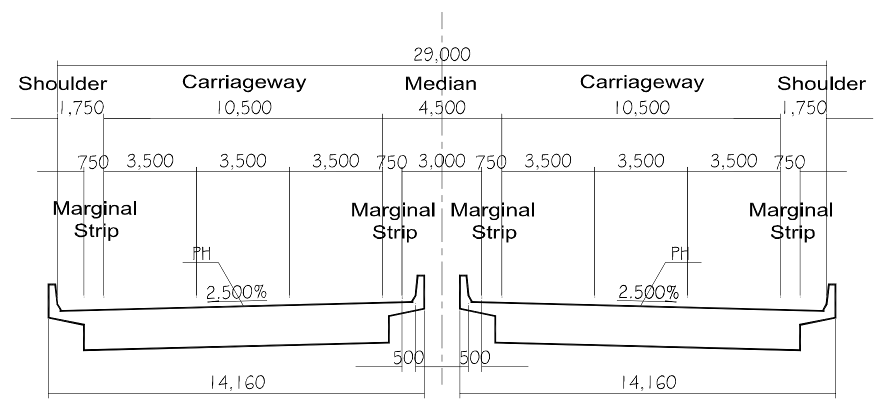
	Initial Stage	Ultimate Stage
Unseparated Road Section		
Minor Bridge		
Major Bridge (KELANI RIVER)		

Fig 3.2.6 (2) Cross Section of Outer Circular Highway

3.2.7 Road Alignment

Road alignment includes horizontal and vertical alignment; the horizontal alignment is composed of straight lines, circular curves and transition curves, and the vertical alignment is composed of straight lines and vertical curves. The standard minimum values for these elements are described below.

3.2.8 Horizontal Alignment

This consists of straight lines, circular curves and spiral (clothoid) curves to be used as transition curves. The general policy for horizontal alignment design is as follows;

(a) The alignment should be suitable to the topography.
(b) The alignment should be continuous with no rapid changes.
(c) Sufficient curve length should be maintained to prevent an illusion in which the curve looks less sharp than it actually is. This is a particular problem where the radius of the curve is small.

(1) Minimum Radius of Horizontal Curve

The radius of the circular curve given is the minimum for guaranteeing driving safety and comfort and the applicable radius is generally far bigger than this value.
Minimum curve radius (R min.) for the Outer Circular Highway given by design speed (v= 80 km/h) can be determined using the following equation.

$R_{min} = v^2 / 127 * (e_{max} + f_{max})$

Where e_{max} … maximum superelevation
f_{max} … maximum side friction factor

Summary of the above factors are given as follows

Table 3.2.1 Desirable Minimum Radius of Horizontal Curve

Design Speed (km/h)	80
Max. Allowable Side Friction Factor (f)	0.05
Max. Superelevation (i max) %	6.0
Desirable Minimum Radius (m)	400

Table 3.2.2 Minimum and Absolute Minimum Radius of Horizontal Curve

Design Speed (km/h)	80 - Expressway -		
	AASHTO	NAASRA	JAPANESE
f max	0.14	0.14	0.12
i max	8-12	6-10	10
min.Radius (m)	250	300	280 (230)

( ) means absolute value

The Japanese Standard defines lower value for maximum side friction and for the maximum super-elevation than those values given in AASHTO. However, the minimum radius of 280m is also governed by AASHTO standard. Therefore, It is safe and appropriate to adopt the Japanese Standard for the detail design of OCH.

Table 3.2.3 Values of Superelevation related to Horizontal Curve

Design Speed	80	Superelevation (%)
Radius of curve (m)	Less than 710	6.0
	From 710 to 790	5.5
	From 790 to 900	5.0
	From 900 to 1030	4.5
	From 1030 to 1190	4.0
	From 1190 to 1400	3.5
	From 1400 to 1680	3.0
	From 1680	2.5

The values of superelevation related to horizontal curve shown in the above table is a little more conservative than the AASHTO standard. It is slightly safer than the AASHTO. Therefore, the proposed superelevation development of horizontal curve is appropriate.

(2) Horizontal Curve Length

In order to ensure comfortable driving, the minimum horizontal curve brings into sufficient length to allow secure comfort steering for the drivers at the change of curve.

(a) Minimum Horizontal Curve Length by the Required Steering Time on Curve

In Japan, the minimum required steering time on curve should be more than 6 seconds that may not incur any drivers' stress practically. Accordingly, the equation imply to the OCH design speed has given following figures.

$$L = t*v$$

Where t : the required steering time on curve (sec)
v: design speed (m/s)

(b) Minimum Horizontal Curve Length in Practical Appearance

For small deflection angles, curves should be sufficiently long to avoid the appearance of a kink. Curves should be at least 150 m long for a central angle of 5° and the minimum length should be increased 30 m for each 1° decrease in the central angle. The minimum length of horizontal curve on main highways, L, should be about 3 times the design speed, or $L_{o\ min} = 3V$. On high speed controlled-access facilities that use flat curvature, a desirable minimum length of curve for aesthetic reasons would be about double the minimum length, or $L_{o\ des} = 6V$.

Therefore, $L_{o\ des}$ = 6 x 80 km/h = 480 m, $L_{o\ min}$ = 3 x 80 km / h = 240 m

Design Speed (km/h)		80
Minimum required steering time on curve (sec)		6
Minimum horizontal curve length by the required steering time on curve (m)	Calculated	133
	Rounded	140
Minimum horizontal curve length is Practical Appearance (m)	Desirable	480
	Minimum	240

(c) Minimum Transition Curve Length

Transition curve are inserted between tangents and circular curves, or between circular curves of substantially different radius for the following reasons:

- to provide a gradual increase or decrease in the radial acceleration when a vehicle enters or leaves a circular curve.
- to provide a length over which the superelevation can be applied.
- to facilitate pavement widening on curves.
- to improve the appearance of the road by avoiding sharp discontinuities in alignment at the beginning and end of circular curve.

The type of transition curve, which is normally used in practice, is euler spiral, or clothoid. This spiral is defined by the degree of curvature at any point on the spiral being directly proportional to the distance along spiral.

In Japan, the minimum transition curve length required steering time on curve should be more than 3 seconds that may not incur any drivers' stress practically. Accordingly, the equation implying the OCH design speed has given following figures.

$$L = t*v$$

Where t : the required steering time on curve (sec)
v: design speed (m/s)

Design Speed (km/h)		80
Minimum required steering time on curve (sec)		3
Minimum transition curve length by the required steering time on curve (m)	Calculated	67
	Rounded	70

The minimum transition curve length is derived from the formula above and which conforms to that of AASHTO . Therefore, the proposed minimum transition curve length of 70m for the design speed of 80 km/hr is appropriate.

When the length of the superelevation run-off is over the value, the transition curve length shall comply with the length of the superelevation run-off.
In the actual design, the parameter of spiral curve shall be set to satisfy necessary transition curve length, but it will also determine the conditions for obtaining a visually smooth alignment (select from the range of 1/1 to 1/3, of circular curves, for parameters of spiral curve). Generally, the length becomes far longer than that of the steering time on curve.
Further to this, the length of transition curve, as determined by rotation angle and changing ratio of centrifugal acceleration, will become shorter, as the radius of the

circular curve becomes larger. Visually desirable transition curve length characteristically becomes longer as the circular curve radius becoming bigger.

(d) Minimum Radius of Curve Omitting Transition Curve

The Japan Highway Design Manual recommends that for appearance purposes, length of transitions should be sufficient to provide a shift of 0.2 meters. If the shift is less than 0.2meters, the transition curve is omitted.

When continuing straight line and circular curve; if size of the circular curve is more than R=2000m at the design speed 80km/h shown in the table, transition curve can be omitted.

$R= 1/24*L^2/S$

Where

S: Shift in meters between curve and tangent
L: Transition curve length (m)
R: Radius of circular curve (m)

Shift in meters between curve and tangent (m)		0.2
Minimum transition curve length (m)		70
Minimum radius of circular curve (m)	Calculated	900
	Rounded	2000

From the above, 900 m is calculated by using minimum transition curve length. However, from experience in Japan, this value of circular curve is not sufficient visually. Therefore, the desirable radius of curve is recommended to use about twice of calculated value.

3.2.9 Vertical Alignment

(1) Grade

In Japan Highway Design Manual, it is recommended to apply the desirable maximum grade given in **Table 3.2.4** as far as possible. The critical gradient is defined that a typical truck is able to climb up on that gradient with a half of design speed (App. 40km/h). In some instances, a grade higher than the desirable maximum may be applied but the length of that segment should be limited to the specified value.
In a flat area, the minimum gradient is specified at 0.5 – 0.3% to ensure drainage. The gradient of 0% could be applied in some cases but the road surface drainage must be considered carefully. It is preferable to limit the length of level gradient to be as small as possible.

Japanese standards regulates and controls the absolute limit length at maximum grade, so that no extreme difficulty is caused by the traffic where a steeper grade than the desirable steepest grade, is applied.

When limiting grade length, it can be eased to apply a climbing lane, however when each absolute limit length is controlled, in most cases a climbing lane is needed, except when the traffic volume is very small.

The critical lengths of grade determined by AASHTO and RDA (not for expressway) given in **Table 3.2.4** as well. Length on the Japanese Standard is longer than the RDA Standard, and Length on AASHTO for the maximum speed reduction of 15 km/h is the shortest of all.

Therefore the Length on AASHTO shall be adopted for OCH. However, there will be no section applied through the OCH.

Table 3.2.4 Limit of Length to Maximum Grade

Design Speed (km/h)	Maximum Grade (%)	Absolute Maximum Grade (%) ** limit of length shown in parenthesis		
		Japanese (50% speed reduction allowed)	AASHTO (15km/h speed reduction allowed)	RDA (Reference)
80	4	5 (600) 6 (500) 7 (400)	5 (210) 6 (180) 7 (80)	5 (250) 6 (200) 7 (170)

Note: Limit of length is shown in the parenthesis

(2) Minimum vertical Curve

Vertical curves effect gradual change between tangent grades in crest and sag curves and should result in a design that is safe, comfortable in operation, pleasing in appearance and adequate for drainage.

The major control for safe operation on crest vertical curves is provision of ample sight distance for the design speed and rider comfort, while headlight sight distance and rider comfort govern the length of a sag vertical curve.

The following equations are used for the calculation of required vertical curve length and radius of vertical curve, of which longer length is applicable.

(a) Pleasing in Appearance

$L = Vd * t/3.6$

Where

L : Vertical curve Length (m)
Vd : Design Speed
t : Minimum required time, (t= 3 sec from AASHTO).

Design Vd (km/h)	On Crest Curve Min. Vertical Curve Length (m)
80	70 (67)

(b) Crest Curve (object height : 0.12 m , eye- height : 1.05m) * Recommended by RDA

$L = D^2 i / 433$ or $R = 100* D^2 / 433$

Where
L : Vertical curve length(m)
R : Radius of vertical curve (m)
D : Sight distance(m)
i : Algebraic different in grade (%)

The following table gives some values for the design speed of 80km/h.

Design Speed vd (km/h)	Sight Distance (m)	On Crest Curve	
		Min. Radius (m)	
		Calculated	Rounded
80	140	4526	4500

(c) Sag Curve

The length of Sag curve is based on head light sight distance, rider comfort, drainage control and a rule of thumb for general appearance.
In general use, head light height is taken as 600mm and 1^o upward divergence.

$L = D^2 I / 150+3.5*D$ or $R = 100* D^2 / 150+3.5*D$

Where L: Vertical curve length (m),
D: Sight Distance (m)
R: Radius of vertical curve (m)
I: Algebraic difference in grade (%)

Design Speed Vd (km/h)	Sight Distance (m)	On Sag Curve	
		Min. Radius (m)	
		Calculated	Rounded
80	140	3062	3100

(d) Definition of K

The parabolic vertical curves are defined by the length of curve required for a change of grade of 1%. This constant for the parabola is K.

$K = L / G$ where, L = length of vertical curve (m),
G = Algebraic difference in Grade (m per %)

The K- values for the OCH for the given criteria are as follows:

Criteria	K-value (Calculated)	K-value (Adopted)
Pleasing Appearance	17.8	17.8
Crest Curve (Stopping Sight distance: 140m)	45.27	45
Sag Curve (Head light sight distance)	30.63	31

(3) Composite Gradient

This criteria, which includes checking whether the combined grade value, which is the value of superelevation and the grade, is suitable or not when the section overlaps a grade and a horizontal curve.

Design Speed (km/h)	Maximum Grade (%)
80	10.5

(4) Minimum Radius without Superelevation

In accordance with AASHTO, the minimum radius without superevevation of R=5,100 m is recommended when the 2.5%-crossfall is adopted. The OCH is also adopted with 2.5%- crossfall, therefore, minimum radius without superelevation on 2.5% normal crossfall as per AASHTO should be calculated as below:

$$R = V^2 / 127 (i + f)$$

Where			
	v:	Design Speed	80 (km/h)
	i:	Superelevation	-2.5 (%)
	f:	Longitudinal Friction Factor	0.04 (AASHTO)

Design Speed (km/h)	Minimum Radius without superelevation (m)		
	Calculated	Rounded	Desirable
80	3,359	3,500	5,100

(5) Superelevation Run off

In accordance with the Japanese Standards, the superelevation runoff value should be 1/200 where the position of the rotation axis is at center of lane (OCH: Center of 6 lane). Superelevation runoff should be done along the whole length of the transition curve, and its ration should not exceed the appearance value above.

The point of 0 % cross fall corresponds to the start of the transition (for a vehicle entering the curve) and the full super elevation for the curve (e%) is attained at the end of the transition. The super elevation development is extended back from the start at the same rotation to the point of normal cross fall on the approach tangent.

Design Speed (km/h)	Superelevation runoff
80	1/200

3.2.10 Sight Distance

Sight distance is an important factor in highway design. Two different kinds of sight distance will be considered, stopping sight distance and passing sight distance. As the OCH is proposed to be a single way traffic highway, the passing sight distance is irrelevant.

(1) Stopping Sight Distance (SSD)

Sight distance is defined as the distance along a roadway that an object of specified height is continuously visible to the driver with eye- height above the road surface. The height of 0.15 m of object height is recommended by AASHTO. The height of driver's eye ranges 1.07m to 1.2m in international standards. 1.05 m as the eye-height and 0.2m as the object height are used for our work as followed to RDA. The following table gives the eye and object height specified in other standards.

Table 3.2.5 Criteria of Stopping Sight Distance

Standards	AASHTO	NAASRA	RDA	JAPANESE
Driver's eye height (m)	1.07	1.15	1.05	1.20
Object Height (m)	0.15	0.2	0.2	0.10

Stopping sight distance is the sum of two distances:

The distance traversed by the vehicle from the instant that the driver sight an object necessitating a stop to the instant that break are applied (Break reaction time), and the distance required to stop the vehicle from the instant that break application begins (Breaking distance).

2.5 seconds is used for the former and the later is dependent on the initial speed and coefficient of friction between tires and pavement. The following equation is used for the calculation of stopping sight distance;

$$d = 0.278 * t*v + v^2/254f$$

Where

d: Stopping Sight distance (m)
t : Break reaction time, generally assumed to 2.5sec.
v: Initial Speed (km/h)
f :Coefficient of Friction between Tires and pavement

The minimum stopping sight distance of 140m is longer than that of AASHTO standard (av.120m.). The distance depends on driver's eye height, object height and coefficient of friction on wet condition. The minimum stopping sight distance according to the RDA standard is proposed safer than that of other standards. Therefore, the JICA Study Team recommends to adopt the sopping sight distance of 140 m in the OCH as well as that is adopted in other highways in Sri Lanka.

Stopping Sight Distances for design speed under wet conditions are shown in table as follows.

Table 3.2.6. Stopping Sight Distance on Wet Pavement

Design Speed (km/h)	80			
Standard	AASHTO	NAASRA	RDA	JAPANESE
Coefficient of Friction	0.30	0.43	0.3	0.31
Stopping Sight Distance	112.8 –139.4	120	140	110

3.2.11 Comparison of Japanese Standards and Other Standards

In order to select an optimum design standard for OCH, a comparative study among widely used standards in the world (AASHTO & NAASRA) and the Japanese standard has been carried out as shown in **Table 3.2.7**

Table 3.2.7 shows the various parameters used for the design of highways based on standards widely practiced around the world. It is very clear from the table that the values obtained by Japanese Standard are mostly in agreement with all other standards although we find a variation in some parameters. In cases, where there are major variations in parameters, the Japanese standard gives the safest values for the design. The condition prevailing in Sri Lanka in every aspect of highway design such as the terrain, type of vehicle and the design speed mostly suits to some existing highways in Japan. Therefore, it is strongly recommended to adopt the design criteria quoted on the Japanese Standard and suitably modified to suit for the Outer Circular Highway in regard to the Sri Lankan conditions.

Table 3.2.7 Comparisons of Japanese Standards and Other Standards

	Item	Unit	Design Criteria											
	Design Speed	Km/h	60				**80**				100			
			A	N	R	J	A	N	R	J	A	N	R	J
1.	Maximum Superelevation	%	6	5 -7	6	8	**6**	5 -7	**6**	8	6	5 -7	6	8
2.	Minimum Radius	m	125	105	130 (6)	150	250	300	255 (6)	**280**	435	450	420 (6)	460
3.	Desirable Minimum Curve Radius	m	-	130	155	200	-	350	310	**400**		550	515	700
4.	Maximum Grade	%	5	6	4	5	4	3	4	**4**	3	3	4	3
5.	Stopping Sight Distance	m	74 -85	80	85	75	112 -139	120	**140**	110	157 -205	180	205	160
6.	"K" value of Vertical Curves — Crest	m	14 -18	14	17	20	32 -49	31	**45**	45 30	62 -105	70	97	100
	"K" value of Vertical Curves — Sag	m	15 -18	15	17	15	25 -32	25	**31**	30 20	37 -51	42	50	45
7.	Minimum Horizontal Curve Length	m	360 180	-	-	700/θ 100	**480** **240**	-	-	1000/θ 140	600 300	-	-	1200/θ 170
8.	Minimum Transition Curve Length	m	75	-	50	50	85	-	60	**70**	187	-	80 90	85
9.	Minimum Radius Without Transition curve	m	1700	-	-	1000 500	2100	-	-	**2000** 900	7300	-	-	3000 1500
10.	Minimum Radius Without Superelevation	M	1300	900	810	2900	**3500**		1440	5100	5000	2700	2250	7900

Where, A – AASHTO, N-NAASRA, R-RDA, J-Japan Highway's Design Manual
Figure in ( ) is superelevation %, which determines the radius of curve
Note: RDA standard is not for expressway, and given for references.

Table 3.2.8 Summary of the Geometric Design Criteria for OCH Project.

Item		Desirable Value	Criteria	Absolute Value	Adoption
Design Speed		80km/h			
Min. Radius to Horizontal Curve		400m	280m	230m	700m
Min. Horizontal Curve Length		480m	240m		246m
Min. Transition Curve Length			70m		229m
Min. Radius Without Transition Curve			2000m		2000m
Min. Radius Without Superelevation		5100m	3500m		3600m
Max. Grade			4%	5 – 7%*	2.850%
Min. Vertical Curve Length			70m		200m
Min."K" value of Vertical Curves	Crest		45		70
	Sag		31		46
Crossfall of Carriageway		2.5%			
Crossfall of Outer Shoulder		4.0%			
Max. Superelevation			6%		6%
Max. Composite Gradient			10.5%		6.011%
Stopping Sight Distance			140m		142m**
Traffic Lane Width		3.5m			
Outer Shoulder Width		3.0m			
Marginal Strip Width (at Shoulder and Center Median)		0.75m			
Right (Inner) Shoulder		1.25m***			
Center Median Width		4.5m** / 3.0m** (without marginal strip)			

*: Limit Length is regulated **: Ultimate Stage: 6 lanes ***: Initial Stage: 4 lanes

3.3. Route Selection and Alignment Setting

3.3.1 General

The alignment of OCH had been preliminary set out during the feasibility study in 1998-2000. Since the basic design was started July 2001, the alignment has been practically reviewed with respect to various aspects under the close coordination with RDA.

While the basic design study was being carried out, the JICA Study Team had encountered considerable protests from the residents. The study therefore had to be suspended under the Agreement concluded between RDA and JICA end of January 2002.

According to the said Agreement, the RDA carried out the public consultations at their efforts to convince the residents for a viable expressway in Sri Lanka to expedite the soonest design works to be resumed.

In the meantime, there had lots of controversial subjects arisen in the public consultation, particularly for possible alternative alignment instead of the current OCH alignment. In this respect, JICA Study Team supported with the activities of RDA particularly to prepare the technical view papers corresponding to each subject.

3.3.2 Vertical Alignment

(1) Concept to Fix the Vertical Alignment

Under the above factors, JICA Study Team was studied to find the optimal vertical alignment considering concepts described as below.

- Embankment Height should be low to save construction cost.
  - To be free from High Flood Level (50 years return period).
  - Minimum vertical clearance for underpass.
    A&B class Road: 5.1m
    C&D class Road: Minimum 4.8m, Desirable 5.1m
  - Select the appropriate crossing points at some Overpass and Underpass locations to lower OCH Embankment Height. (Minor road would be able to detour up to 500m if necessary)
- Minimum vertical gradient of 0.3% is maintained for drainage on road surface.
- Minimize Land Acquisition.

(2) Control of High Flood Level

After Detailed Design Study was suspended in 2002, some hydrological study regarding Kelani River basin was carried out by other organization. By considering these studies and discussing with SLLR&DC, flood water level was given in **Table 2.4.10.**

The criteria for control on High Flood Level was described in Chapter 2.4. and is showed again as follows:

- Under steady state conditions, the structures across the road embankment shall cater to a 50-year return period flood with a free board of 300 mm to the top of the sub-grade at the shoulder.

- Flood waters may be allowed to reach to the edge of the carriageway for short durations in case of a 100-year return period flood.

However, Exceptional value for control flood level was used in particular after study and discussion with RDA as described at 3.3.2 (5).

(3) Vertical Clearance for C & D Class Roads

The RDA instructed the JICA Study Team to revise the criteria of vertical clearance for C and D class road as below. This revision was introduced taking into account the height of double-deck bus and Light Rail Transit (LRT) proposed under the study for the future development plan of Colombo Metropolitan Region.

	*Basic Design Study (**2001**)*	*Basic Design Study (**2004**)*
Vertical Clearance for C & D Class Road	*Minimum: 4.5m*	*Desirable: 5.1 m* *Minimum: 4.8 m*

(4) Study to lower the Vertical Alignment

In order to hold down the increase in construction costs, JICA Study Team was studied to find the optimal vertical alignment and following conditions were adopted.

1) Application of Overpass

At the some crossing points with minor road, overpass was adopted instead of underpass. This is to lower the vertical alignment of main carriageway at that points. The points are showed as below.

Package-1	Package-3	
STA. 3+714	STA. 23+940	STA. 26+299
	STA. 25+650	STA. 26+684

2) Vertical Clearance for Underpass

At the underpass with C and D class road, vertical clearance is adopted 5.1m generally. However, 4.8m are adopted when little traffic volume for heavy vehicle was expected at the crossing point. 4.8m of vertical clearance are adopted at the points as follows.

Package-1	Package-2	Package-3
STA. 0+192	STA. 10+950	STA. 16+990
STA. 7+850	STA. 13+327	STA. 20+105
	STA. 14+615	STA. 21+640
	STA. 15+233	

3) Crossing Point for Underpass

Generally, crossing point for underpass or overpass shall be original road location. However, according to the concept, shifting of crossing points was adopted at some underpass locations to lower the embankment height. Shifting locations and shifting distances are as below.

Package-1	Package-2	Package-3
STA. 1+545: 60m	STA. 10+950: 20m	STA. 16+990: 220m

4) Interval of VPI (Vertical Point of Intersection)

Minimum vertical gradient would be adopted at flat area. When flat area is quite longer, interval of VPI should be short distance due to lower the vertical alignment. However, If interval of VPI is very short, road surface would be undulate and drivability would not be good. Therefore, around 500m was adopted to minimum distance for interval of VPI.

Selected vertical alignment for entire OCH is shown in **Fig. 3.3.1.**

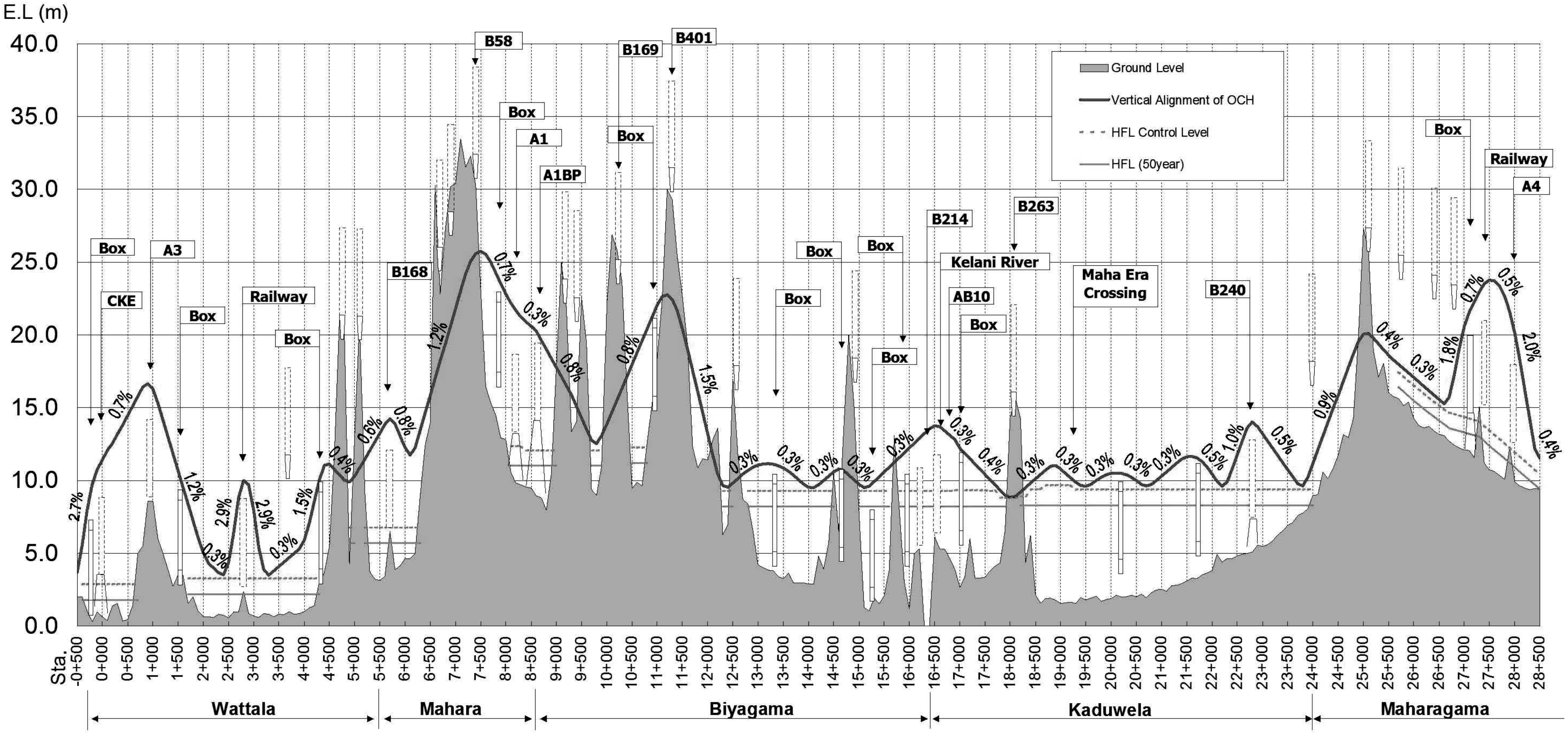


Fig. 3.3.1 Vertical Alignment of OCH

(5) Vertical Alignment at the crossing with Malabe - Kaduwela Road

Exceptional value for control from high flood level was used at the crossing with Malabe – Kaduwela road. Details are shows as below.

In the Basic Design Study, carried out in 2001, the 50-year return period flood level has been taken as 7.5 m MSL and the 100-year return period flood level as 7.9 m MSL. The formation level of the embankment is taken as 300 mm from the 50-year flood level, which is the top of the sub grade at the shoulder.

After the basic design was suspended January 2002, the recent study was carried out by the LHI for NWS & DB has predicted that the 100-year return period flood level as 9.05 m MSL. Accordingly the SLLR&DC has requested to maintain the road embankment level at 8.0 m MSL by their letter ref.RD/PROJ/70 dated August 25, 2004 addressed to D/PMU [OCH].

In this respect, the JICA Study Team reviewed their model study and has established the 50-year return period flood level and the 100-year return period flood level as 8.3 m MSL and 8.6 m MSL respectively.

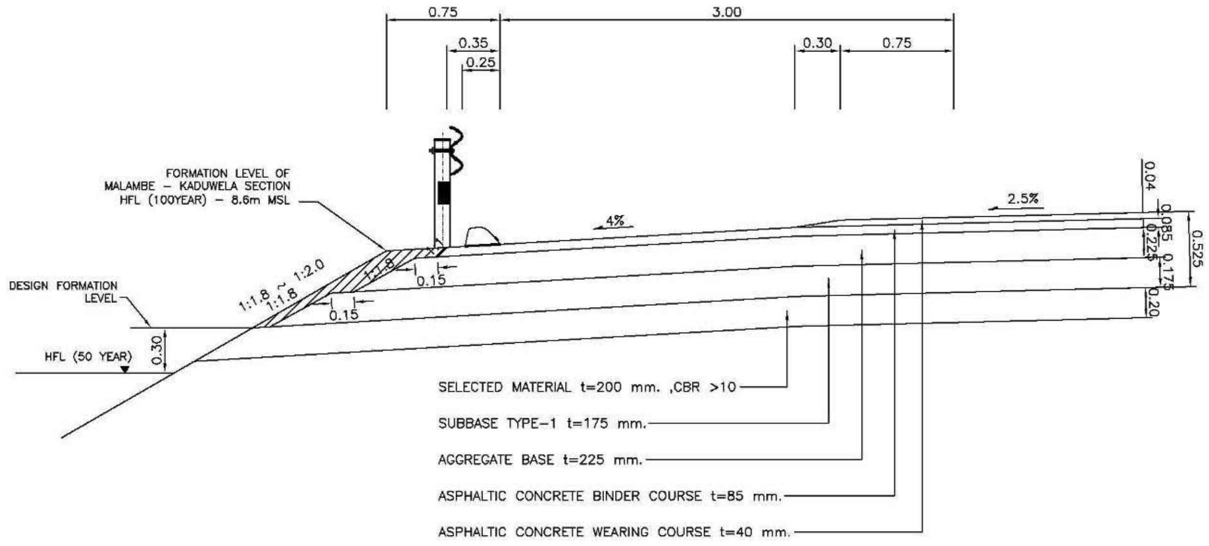
As such the RDA requirements, the formation level of the embankment is to be maintained at 300 mm above the present value of the 50-year return period flood level the Malabe – Kaduwela road has to be raised further by approximately 0.8 m. This will increase the construction cost and require additional land acquisition to accommodate the increase in height.

RDA by their e-mail dated December 02, 2003 has requested the JICA Study Team to reduce the formation level and hence the fill height and there by reduce the number of residents affected due to OCH main trace and the Malabe – Kaduwela Road.

To overcome the increase in the finished level of the Malabe – Kaduwela Road the JICA Study Team proposed to maintain the 50-year return period flood level at the edge of the shoulder and reduce the finished level of the Malabe – Kaduwela Road by the pavement structure height of OCH [0.792 m].

It has been conveyed to the JICA Study Team by D/PMU [OCH] that the 100-year return period flood level of 8.6 m MSL proposed by the JICA Study Team has been confirmed by the information obtained from long term inhabitants in the Kaduwela existing bridge location. It has also been conveyed that the increase in height has to be accommodated within the exiting acquisition boundary and the edge of the shoulder to be maintained to the 100-year return period flood level of 8.6 m MSL for this section only.

Figure given below shows the formation level of OCH at other sections and OCH Sta.18 + 013.



Accordingly, the JICA Study Team has fixed the vertical alignment of the Malabe – Kaduwela Road with maximum possible reduction in OCH formation level for this section. With this alignment, it has proposed retaining walls on either side of the Malabe – Kaduwela Road to be within the available acquisition boundary as given in **Fig. 3.3.2.**

The JICA Study Team also proposes that if the alignment of Malabe – Kaduwela Road could be fixed as in **Fig. 3.3.3** and a pedestrian under – pass provided as shown will compensate the loss of access to the residents on the LHS of the OCH.

Proposal on **Fig 3.3.2** was selected through the Technical Committee Meeting.

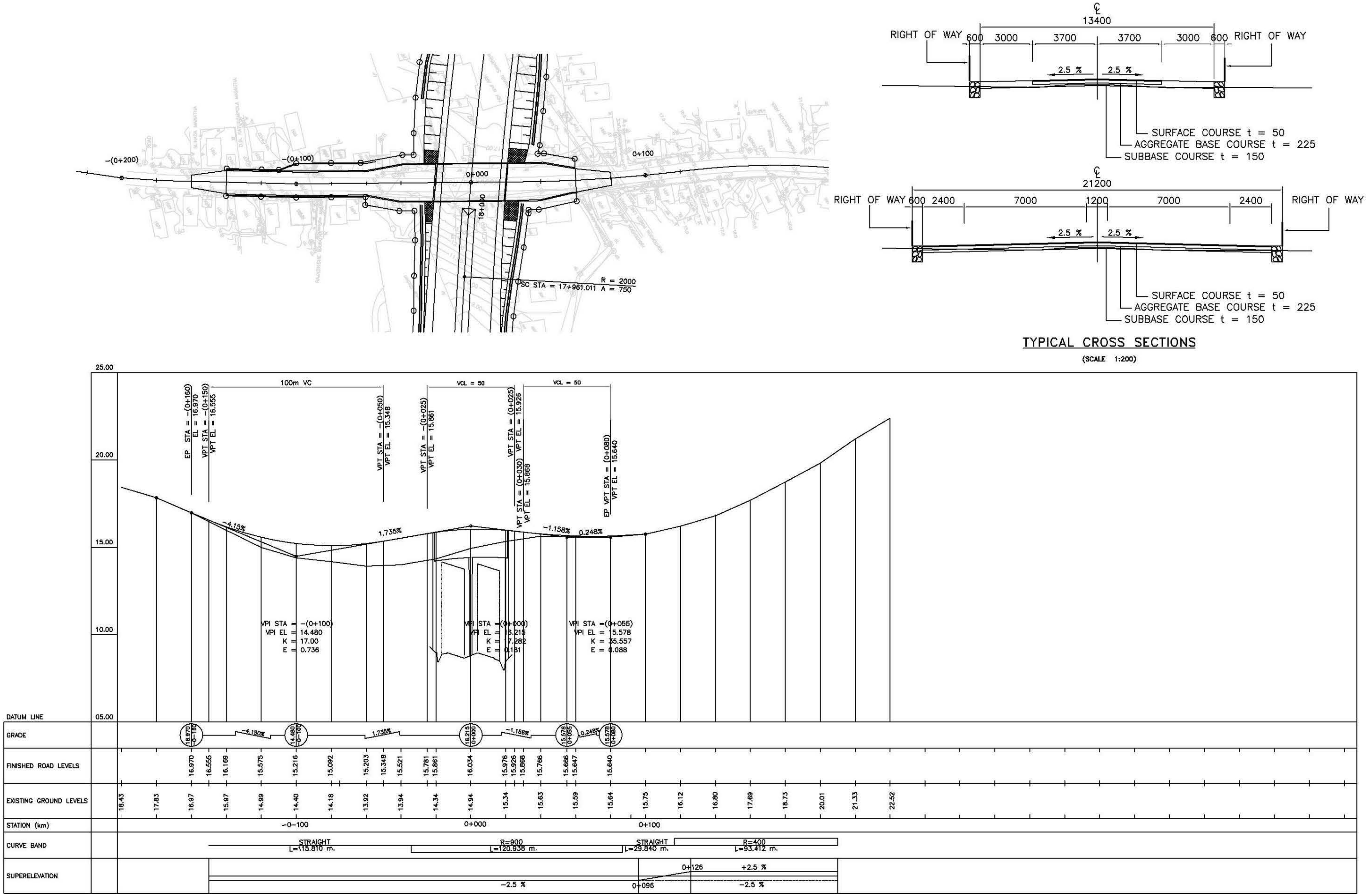


Fig. 3.3.2. Proposed Plan for Improvement of Malambe – Kaduwela Road (Opt.1)

Fig. 3.3.3. Proposed Plan for Improvement of Malambe – Kaduwela Road (Opt.2)