IMPROVED GEOMETRIC DESIGN OF EXISTING HILL ROAD

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Name of Student: ANKIT THAKUR(091647)

KINLEY WANGCHUK(091617)

DAKSH SHARMA(091625)

AKSHAY VERMA(091618)

RAHUL TEGTA(091629)

SIDHANT DOGRA(091643)

Name of Guide: Dr. AMIT GOEL

Mr. KUSHWANT SINGH

DEPARTMENT OF CIVIL ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY, WAKNAGHAT

CERTIFICATE

This is to certify that project report entitled “Improved Geometric Design of Existing Hill Road”, submitted by Kinley Wangchuk, Ankit Thakur, Daksh Sharma, Rahul Tegta, Akshay Verma and Sidhant Dogra in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

Date: **Dr. Amit Goel**

Mr. Khushwant Singh

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Date: Kinley Wangchuk (091617)

Ankit Thakur (091647)

Daksh Sharma (091625)

Akshey Verma (091618)

Rahul Tegta (091629)

Sidhant Dogra (091643)

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Chapter 1: INTRODUCTION

The geometric design of any road deals with the dimensions and layout of visible features of the road. The emphasis of the geometric design is to address the requirement of the driver and the vehicle such as safety, comfort, efficiency, etc. The features normally considered are the cross section elements, sight distance consideration, horizontal curvature, gradients, and intersection. The design of these features is to a great extend influenced by driver behavior and psychology, vehicle characteristics, traffic characteristics such as speed and volume. Proper geometric design will help in the reduction of accidents and their severity. Therefore, the objective of geometric design is to provide optimum efficiency in traffic operation and maximum safety at reasonable cost.

Hilly regions, generally, have extremes of climatic conditions, difficult and hazardous terrain, topography and vast high altitude area. The roads are affected by flood consequent to torrential rainfall, land slide, snow fall, avalanche, etc. For the geometric design of hill road design specification are given separately from that of in plane for the provision of safety and comfort to the road users. The specification for the design is explained in chapter 2.

In this project, an existing hill road stretch is chosen and is studied and checked against required geometric design standards as specified by the Indian Roads Congress (IRC). For any short comings in the geometric design of the chosen road stretch, an improved geometric design is proposed; which is done using MXROAD™ software and also by hand calculations. The cost analysis for implication of this improved geometric design for this road stretch is also done.

1.1 Objectives

(i) To check the geometric design of existing road stretch against the specifications of IRC standards,

(ii) To do an improved geometric design for this road stretch, and

(iii) To estimate cost of implication of improved geometric design.

1.1Organization of the report

This report is organized into four chapters. The first chapter of the report gives the brief introduction about the geometric design, hill road and the selected road stretch. Objective of the project is also included in this chapter. In the second chapter of the report, it explains the terminology related to our project and table of IRC recommendation is also included. Third chapter of the report shows the method and equipment used by the author. Methodology of the work and the detail working of the instruments are also included in this chapter. The last chapter of the report shows the results and the problems faced by the authors. References and appendix are placed after fourth chapter subsequently.

Chapter 2: LITERATURE REVIEW

2.1 INTRODUCTION

The geometrics of the highway should be designed to provide optimum efficiency in the traffic operations with maximum safety at reasonable cost. It is possible to design and construct the pavement of the road in stages; but it is very expensive and rather difficult to improve the geometric elements of the road in stages at a later date. Therefore it is important to plan and design the geometric features of the road during the initial alignment itself taking into consideration the future growth of the traffic flow and possibility of the road being upgraded to a higher category or to a higher design speed standard at a later speed.

Geometric design of highway deals with following elements:

1) Cross section elements
2) Sight distance considerations
3) Horizontal alignment details
4) Vertical alignment details
5) Intersection elements

Under the cross section elements, the consideration for the width of the pavement, formation and land, the surface characteristics and cross slope of the pavement is included. The sight distance or clear distance visible ahead of a driver at horizontal and vertical curves and at intersections governs the safe movements of vehicle.

The change in road directions is made possible by introducing horizontal curves. Super-elevation is provided by raising the outer edge of pavement to counteract the centrifugal force developed on a vehicle traversing a horizontal curve; extra pavement width is also provided on horizontal curve. In order to introduce the centrifugal force and super-elevation gradually, transition curves are introduced between the straight and circular curves.

2.2 DESIGN OF HORIZONTAL ALIGNMENT

Horizontal alignment is one of the most important features influencing the efficiency and safety of a highway. A poor design will result in lower speeds and resultant reduction in highway performance in terms of safety and comfort. In addition, it may increase the cost of vehicle operations and lower the highway capacity. Horizontal alignment design involves the understanding on the design aspects such as design speed and the effect of horizontal curve on the vehicles.

Design elements to be considered under Horizontal Alignment are as follows:

1) Design speed
2) Horizontal curve
3) Super-elevation
4) Type and length of Transition curve
5) Extra widening
6) Set-back distance

2.2.1 Design speed

The design speed is the most important factor in the design of horizontal alignment. The design speed depends on the type of road. For e.g., the design speed expected from a National highway will be much higher than a village road, and hence geometry will vary significantly. The design speed also depends on the type of terrain. a plain terrain can afford to have any geometry, but for the same standard in a hilly terrain requires substantial cutting and filling implying excessive cost as well as safety concern due to unstable slopes. Therefore, the design speed is normally reduced for terrains with steep slopes.

For instance, Indian Road congress (IRC) has classified the terrains into four categories, namely plain, rolling , mountainous, and steep based on the cross slope given in Table 2.1.

Based on the type of road and type of terrain the design speed varies. The IRC: 52-2001 has suggested desirable or ruling speed as well as minimum suggested design speed for hill roads and is tabulated in Table 2.2.

Table 2.1: Terrain classification [4]

Terrain classification	**Cross slope (%)**
Plain	0 - 10
Rolling	10- 25
Mountainous	25 -60
Steep	>60

Table 2.2: Design speed (km/hr) [4]

Sr.No.	Road Classification	Mountainous Terrain		Steep Terrain	
		Ruling	Minimum	Ruling	Minimum
1.	National and State Highways	50	40	40	30
2.	Major District Roads	40	30	30	20
3.	Other District Roads	30	25	25	20
4.	Village Roads	25	20	25	20

2.2.2 Horizontal Curve

When a vehicle traverses a horizontal curve, the centrifugal force ($P=Wv^2/gR$ or Mv^2/R) acts horizontally outward through the centre of gravity of the vehicle. Centrifugal force depend on speed and radius of the horizontal curve and is counteracted to a certain extend by transverse friction between the tire and the pavement surface. On a curve road, this force tends to cause the vehicle to overturn outward about the outer wheels or skid the vehicle laterally outward.

Various forces acting on the vehicle is illustrated in Figure 2.1. Force consists of centrifugal force (P) acting outward, weight of the vehicle (W) acting downward, and the reaction of the ground on the wheels (RA and RB). The centrifugal and weight is assumed t be from the centre of gravity which is at h units from the ground. Let the wheel base be assumed as b units. The centrifugal force P in kg/sq. m is given by

$$P=Wv^2/gR$$

Where W is the weight of the vehicle in kg, v is the speed of the vehicle in m/sec, g is the acceleration due to gravity in m/sq.sec and R is the radius of the curve in m.

So centrifugal ratio or impact factor is given by

$$P/W = v^2/gR$$

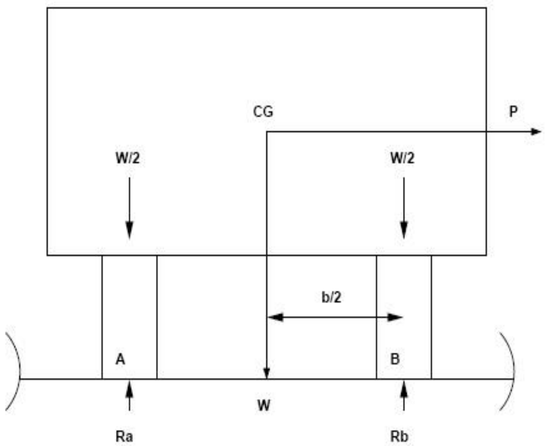


Figure 2.1: Effect of horizontal curve

The centrifugal force has two effects

1) Tendency to overturn the vehicle about the outer wheel.
2) Tendency to skid the vehicle laterally outward.

Taking moments of the force with respect to the other when the vehicle is just about to override is given as

$$Ph = Wb/2 \text{ or } P/W = b/2h$$

At the equilibrium over turning is possible when

$$v^2/gR = b/2h$$

And for safety the following condition must be satisfy:

$b/2h > v^2/gR$ (if the equation is violated, vehicle will overturn at the horizontal curve)

The second tendency of the vehicle is for transverse skidding. i.e. when the centrifugal force P is greater than the maximum possible transverse skid resistance due to friction between the pavement surface and the tire.

The transverse skid resistance (F) is given by

$$\begin{aligned} F &= FA + FB \\ &= f\,(RA + RB) \\ &= fW \end{aligned}$$

Where FA and FB are the frictional force at tire A and B, RA and RB are the reaction at tire A and B, f is the lateral coefficient of friction and W is the weight of the vehicle. This is counteracted by centrifugal force P, and equating:

$$P = fW \text{ or } P/W = f$$

At equilibrium when skidding takes place

$$P/W = f = v^2/gR$$

And for the safety the following condition must be satisfy:

$F > v^2/gR$ (if the equation is violated, vehicle will skid at the horizontal curve)

Some of the DONT's to be considered while designing horizontal curve are as follows:

1) Should be fluent and blend well with the surrounding topography.
2) Short curves for small deflection angle (kinks) should be avoided.
3) Curves in same direction separated by short tangents should be avoided and replaced with a large single curve.
4) Sharp curves should not be introduced at the end of long tangents.
5) Compound curve should be avoided. When unavoidable limiting value of ratio of flatter curve radius and sharper curve radius is 1.5:1 (IRC).

The ruling and absolute minimum value of radii of horizontal curve of various classes of roads in different terrain as per IRC: 52-2001 are given in Table 2.3. [4]

Table 2.3 Minimum radii of horizontal curves for different terrain conditions

Classification of roads	Mountainous terrain				Steep terrain			
	Areas not affected by snow		Snow-bound areas		Areas not affected by snow		Snow-bound areas	
	Ruling Min. (m)	Absolute Min. (m)	Ruling Min. (m)	Absolute Min. (m)	Ruling Min. (m)	Absolute Min. (m)	Ruling Min. (m)	Absolute Min. (m)
1. National Highway and State Highway	80	50	90	60	50	30	60	33
2. Major District Roads	50	30	60	33	30	14	33	15
3. Other District Roads	30	20	33	23	20	14	23	15
4. Village Roads	20	14	23	15	23	14	23	15

2.2.3 Super-elevation

To counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge. This transverse inclination to the pavement surface is known as super-elevation or cant.

Analysis of super-elevation

The force acting on a vehicle while taking a horizontal curve with super-elevation is shown in Figure 2.2. The force acting on horizontal curve of radius R m at a speed of v m/sq.sec is:

1) Centrifugal force (P) acting horizontally outward through the center of gravity,
2) Weight of the vehicle (W) acting downward through the center of gravity, and
3) Frictional force (F) between the wheel and pavement, along the surface inward.

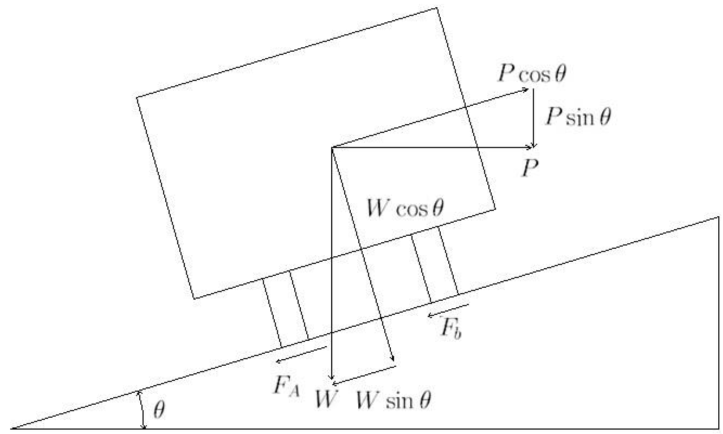


Figure 2.2.Analysis of super-elevation

At equilibrium, by resolving the forces parallel to the surface of the pavement we get:

$$P\cos\theta = W\sin\theta + F_a + F_b$$

$$= W\sin\theta + f\,(R_a + R_b)$$

$$= W\sin\theta + f\,(W\cos\theta + P\sin\theta)$$

Where W is the weight of the vehicle, P is the centrifugal force, f is the coefficient of friction, θ is the transverse slope due to super-elevation. Dividing by W cosθ, we get:

$$P\cos\theta / W\cos\theta = W\sin\theta / W\cos\theta + \{f\,(W\cos\theta + P\sin\theta) / W\cos\theta\}$$

$$P/W = \tan\theta + f + f\,P/W \tan\theta$$

$$P/W\,(1 - f\tan\theta) = \tan\theta + f$$

$$P/W = (\tan\theta + f) / (1 - f\tan\theta)$$

Since $P/W = v^2/gR$,

$$v^2/gR = (\tan\theta + f) / (1 - f\tan\theta)$$

This is an exact expression for super-elevation. But normally $f = 0.15$ and $\theta < 4^o$ and $1-f\tan\theta$ approximately equal to 1, and for small θ, $\tan\theta = \sin\theta$ $E/B = e$, so we have:

$$e+f = v^2/gR = V^2/127R$$

Where e is the rate of super-elevation, f is the coefficient of friction; v is the speed in m/sq.sec, R the radius of curve in m and g the acceleration due to gravity in m/ sq.sce.

Three specific cases that can arise from equation $e+f = v^2/gR$ is as follows:

1. If there is no friction due to some practical reason, then $f = 0$ and equation becomes $e = v^2/gR$. These results in the situation where the pressure on the outer and the inner wheels are same; requiring very high super elevation e.
2. If there is no super-elevation provided due to some practical reason, then $e = 0$ and equation becomes $f = v^2/gR$. This results in very high coefficient of friction.
3. If $e = 0$ and $f = 0.15$ then for safe traveling speed from the equation is give by $v' = \sqrt{fgR}$, where v' is the restricted speed.

Maximum and minimum super-elevation (IRC)

Maximum allowable super-elevation of

1) 7% for plain and rolling terrain.
2) 10% for mountainous terrain not bounded by snow.

Minimum super-elevation

If the calculated super-elevation is equal or less then camber, then minimum elevation equal to camber should be provided from drainage consideration.

The IRC recommendation giving the radii of horizontal curves beyond which normal cambered section may be maintained and no super-elevation is required for curves, are presented in Table 2.4, for various design speed and cross slope.

Table 2.4 Radii beyond which super-elevation is not required [4]

Design Speed(km\h)	Radii (meters) for camber of				
	4%	3%	2.5%	2%	1.7%
20	50	60	70	90	100
25	70	90	110	140	150
30	100	130	160	200	240
35	140	180	220	270	320
40	180	240	280	350	420
50	280	370	450	550	650

Steps for super-elevation design

Various steps in the design of super-elevation in practice may be summarized as given below:

1. Super-elevation for 75% of design speed is calculated neglecting the friction

$$e_{cal} = V^2/225R$$

2. If e_{cal} is less than e_{max} then provide e_{cal}. If e_{cal} is greater than e_{max} then provide e_{max} and proceed with step 3 and step 4

3. Check the coefficient of friction developed with e(max) at full value of design speed

$$f = \{(V^2/127R) - 0.07\}$$

   if the value of 'f' thus calculated is less than 0.15 then ok, else calculate the restricted speed as given in step 4.

4. Calculate the allowable speed.

$$e+f = 0.07+0.15 = 0.22 = V^2/127R$$

2.2.4 Transition curve

A transition curve has a radius which decreases from infinity at the tangent point to a designed radius of the circular curve. When a transition curve is introduced between a straight and circular curve, the radius of the transition curve decreases becomes minimum at the beginning of the circular curve. The rate of change of radius of the transition curve will depend on the equation of the curve or its shape.

Objective of providing Transition Curve

The functions of transition curves in the horizontal alignment of highway are as follows:

1) To introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding sudden jerk on the vehicle.
2) To enable the driver turn the steering gradually for his own comfort and security.
3) To enable gradual introduction of the design super-elevation and extra widening of the pavement at the start of the circular curve.
4) To improve the aesthetic appearance of the road.

Calculation of Length of Transition Curve

The length of the transition curve is designed to fulfill three conditions, viz.:

1) Rate of change of centrifugal acceleration to be developed gradually
2) Rate of introduction of the designed super-elevation to be at a reasonable rate
3) Minimum length by IRC empirical formula.

1. Based on the rate of change of centrifugal acceleration
   - Time taken to traverse transition length(L_s) in design speed V

     $t = L_s/V$
   - Max centrifugal acceleration V^2/R is introduced in time 't' through the transition length Ls

     $C= V^2/R_t = V^2/R\ (L_s/V) = V^3/L_s\ R$

- If speed is V km/hrs then,

  $L_s = V^3/ 3.6^3 CR = 0.0215 V^3/CR$

- IRC value for C,

  $C = 80/75+V$ where C is in m/sec³ and R is in meter.

  $[0.5 < C < 0.8]$

2. Based on the rate of change of super-elevation:

   Let ‘e’ be the rate of super-elevation designed for the highway curve having normal pavement width W. Let ‘W_e’ be an extra widening provided at a circular curve so that the total width B of pavement = $(W+W_e)$ and the total raising of the pavement with respect to the inner edge = e.B = e. $(W+W_e)$ = E. If it is assumed that the pavement is rotated about centre line after neutralizing the camber,(maintaining the vertical alignment of the centre line) then the maximum amount by which the outer edge is to be raised at the circular curve with respect to the centre = E/2. Hence allowing a rate of change of super-elevation of 1 in N (where minimum value of N = 150 to 60), the length of transition curve L_s is given by:

   $$L_s = EN/2 = [e. (W+W_e).N]/2$$

   However if the pavement is rotated about the inner edge, the length of transition curve is given by:

   $$Ls = EN = e. (W+W_e).N$$

3. By empirical formula: According to the IRC standards, the length of horizontal transition curve Ls should not be less than the value given by the following equations for the terrain classifications:

   a) For plain and rolling terrain (1 in 150)

   $$L_s = 2.67 V^2/R_c$$

   b) For mountainous and steep terrain (1 in 60)

   $$L_s = 1.0 V^2/R_c$$

The length if transition curve for the design should be the highest of the three values mentioned above.

The minimum length of transition curve for various value of radius of curve and design speeds recommended by the IRC: 52-2001 is given in Table 2.5.

Table 2.5 Minimum transition length for different speeds and curve radii [4]

Curve Radius (m)	Design Speed (km/h)				
	50	40	30	25	20
15				NA	30
20				35	20
25			NA	25	20
30			30	25	15
40		NA	25	20	15
50		40	20	15	15
55		40	20	15	15
70	NA	30	15	15	15
80	55	25	15	15	NR
90	45	25	15	15	
100	45	20	15	15	
125	35	15	15	NR	
150	30	15	15		
170	25	15	NR		
200	20	15			
300	15	NR			
400	15				
500	NR				

NA =not applicable NR= Transition not required

2.2.5 Set-back distance

It is an essential consideration to have an adequate sight distance on horizontal curve from obstruction like building, trees, cut slope, etc, along the inner side of the horizontal curves. The absolute minimum sight distance which is the safe stopping sight distance should be available at every section of the highway for safety point; these values may be adopted as given in Table 2.6 for the design speed.

The set back distance depends upon the following factors:

- Required sight distance
- Radius of horizontal curve
- Length of curve

Table 2.6 Design value of stopping and intermediate sight distance for various speeds [4]

Speed (km/h)	Design Values-meters	
	Stopping Sight Distance	Intermediate Sight Distance
20	20	40
25	25	50
30	30	60
35	40	80
40	45	90
50	60	120

Two cases are considered for analysis

- Sight distance is less than length of curve (S<L)

Refer Figure 2.3. Let C be the obstruction to vision on the inner side of a horizontal curve of radius R, ABC the line of sight and arc be the sight distance S.

Let the length of curve L be greater than the sight distance S. The angle subtended by the arc length S at the centre be α. On narrow road such as single lane roads, the sight distance is measured along the centre line of the road and the angle subtended at the centre, α is equal to S/R radians.

Therefore half central angle is given by:

$$\alpha/2 = S/2R \text{ radians} = 180S / 2\pi R \text{ degrees}$$

The distance from the obstruction to the centre is R cos $\alpha/2$. Therefore the set-back distance, m required from the centre line is given by:

$$m = R - R\cos\alpha/2$$

- Sight distance is more than length of curve (S>L)

If the sight distance required is greater than the length of curve L, then the angle α subtended at the centre is determined with reference to the length of the circular curve, L and set-back distance is worked out in two parts as given below: see Figure 2.4

$$\alpha/2 = 180L / 2\pi(R-d) \quad \text{degrees}$$

$$m' = R - (R - d)\cos\alpha'/2 + (S - L)/2 \sin\alpha'/2$$

The clearance of obstruction upto the set-back distance is important when there is cut slope on the inner side of the horizontal curve.

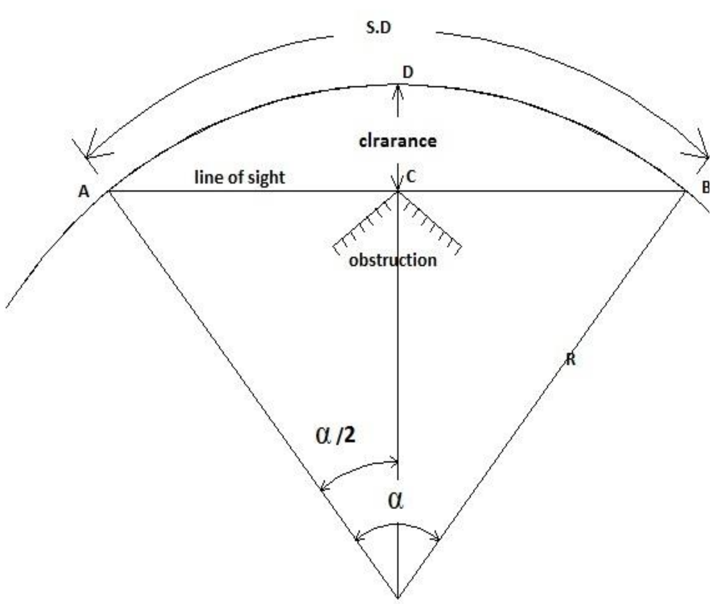


Figure 2.3 Set-back distance for S<L

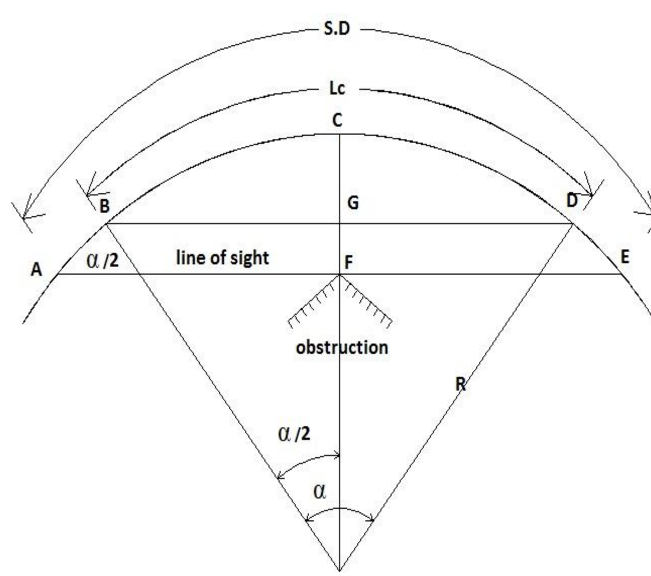


Figure 2.4 Set-back distance for S>L

2.2.6 Extra Widening

On horizontal curves, especially when they are not of very large radii, it is common to widen the pavement slightly more than the normal width. The objectives of providing extra widening of pavements on horizontal curves are due to the following reasons:

- Off- tracking of vehicle

Automobile with rigid wheel base on horizontal curve, the rear wheel do not follow the same path as that of the front wheel (only the front wheel are turned).

At low speed and up to the design speed with no lateral slipping of rear wheels, rear wheel follow the inner path of the curve as compared with the corresponding front wheel(if inner front wheel on inner edge of the pavement then inner rear wheel on shoulder).

Super-elevation and side friction developed are not adequate to counter act the outward thrust due to centrifugal force for vehicle travelling at higher speed then the design speed, transverse skidding is possible and rear wheels may follow the outer path as compared with corresponding front wheels.

- Psychological reasons

At the beginning of the curve, drivers have tendency to follow the outer side of the lane so as to take a path with larger radius and to have greater visibility.

Crossing or overtaking maneuver on curve, drivers tend to maintain greater clearance between vehicles then on tangents.

The extra width recommended by the Indian Roads Congress for single and two lane pavements are given in Table 2.7.

Table 2.7 Extra width of the pavement at horizontal curves [4]

Radius of Curves	Up to 20	20-40	41-60	61-100	101-300	Above 300
Extra Width (m) Two lane	1.5	1.5	1.2	0.9	0.6	Nil
Single-lane	0.9	0.9	.6	Nil	Nil	Nil

2.3 DESIGN OF VERTICAL ALIGNMENT

The vertical alignment should provide for a smooth longitudinal profile consistent with category of road and the terrain. Grade changes should not be too frequent as to cause kinks and visual discontinuities in the profile. Grade should be carefully selected keeping in view the design speed, terrain conditions and the nature of traffic expected on the road. It is difficult and costly to flatten the gradients later.

Recommended gradient for different terrain conditions are given in Table 2.8;

Table 2.8 Recommended Gradients for Different Terrain Conditions [4]

Classification of gradient	Mountainous terrain and steep terrain having elevation more than 3000m above the mean sea level	Steep terrain up to 3000m height above the sea level
(a) Ruling gradient	5% (1 in 20)	6% (1 in 16.7)
(b) Limiting gradient	6% (1 in 16.7)	7% (1 in 14.3)
(b) Exceptional gradient	7% (1 in 14.3)	8% (1 in 12.5)

2.3.1 Vertical Curve

Vertical curve are introduced fir smooth transition at grade change. Both summits curves (i.e., convex vertical curve) and valley/sag curves (i.e., concave vertical curves), should be designed as square parabolas. The length of vertical curve is controlled by sight distance requirements, but curves with greater length are aesthetically better. Curves should be provided at all grade changes exceeding those indicated in Table 2.9;

Table 2.9 Minimum Length of Vertical Curve [4]

Design speed (km/h)	Maximum grade change (per cent) not requiring a vertical curve (m)	Minimum Length of vertical curve (m)
Up to 35	1.5	15
40	1.2	20
50	1.0	20

2.3.1.1 Summit Curve

The length of summit curve is governed by the choice of sight distance, whether stopping site distance or the intermediate sight distance.

The required length may be calculated from the following formulae:

1) For safe stopping sight distance

Case (1) when the length of the curve exceeds the required sight distance, i.e., L is greater than S

$$L=NS^2 / 4.4$$

where N = Deviation angle, i.e., the algebraic difference between the two grades

L = Length of parabolic vertical curve in meters

S = Sight distance in meters

Case (2) when the length if curve is less than the required sight distance, i.e., L is greater than S

$$L = 2S – 9.6 / N$$

2.3.1.2 Valley Curve

The length of valley curve should be such that for night travel, the headlight beam distance is equal to the stopping sight distance. Base on this criterion, the length of curve may be calculated as under:

Case (1) when the length of the curve exceeds the required sight distance, i.e., L is greater than S

$$L = NS^2 / (1.50+0.035S)$$

Case (2) when the length of curve is less than the required sight distance, i.e., L is less than S

$$L = 2S - (1.50+0.035S) / N$$

The above formulae have been derived with the following assumptions;

1) Headlight height = 0.75 m
2) Upward divergence of the light beam from the longitudinal axis of the vehicle = 1 degree.

2.4 Drainage in Hill Road

Surface water flowing from the hill slope towards the road way is one of the main problems in drainage of hill roads. Side drain is provided only on the hill side of the roads and not on both side. Due to the limitation in the formation width, the side drains are constructed to such a shape that at emergency the vehicles could utilize this space for crossing at low speed or for parking. The usual type of side drains are angle, saucer and kerb and channel drains.

2.5 Retaining Wall

Retaining walls are most important structure in hill road construction to provide adequate stability to the roadway and to the slope. Retaining walls are constructed on the valley side of the roadway and also on the cut hill side to prevent land slide towards the roadway.

2.6 Closing Remark

All the geometric features mentioned above are considered for our design work and some special features for hill road like drainage consideration and retaining walls are also considered.

Chapter 3: METHODS AND EQUIPMENT

In this chapter, the methodology and equipment/software used by the authors for project work have been described along with their working principle, stepwise procedures, etc.

The road stretch selected for our project (improved geometric design for existing hill road) falls under village road category in hilly area, which is 3.5 km (Waknaghat chausa road) starting from Jaypee University of Information Technology gate till Waknaghat Chowk. Construction of this road was started on Gandhi Jayanti i.e. 2nd October, 1962 and was completed on 31st march, 1963, when the area was under Punjab.

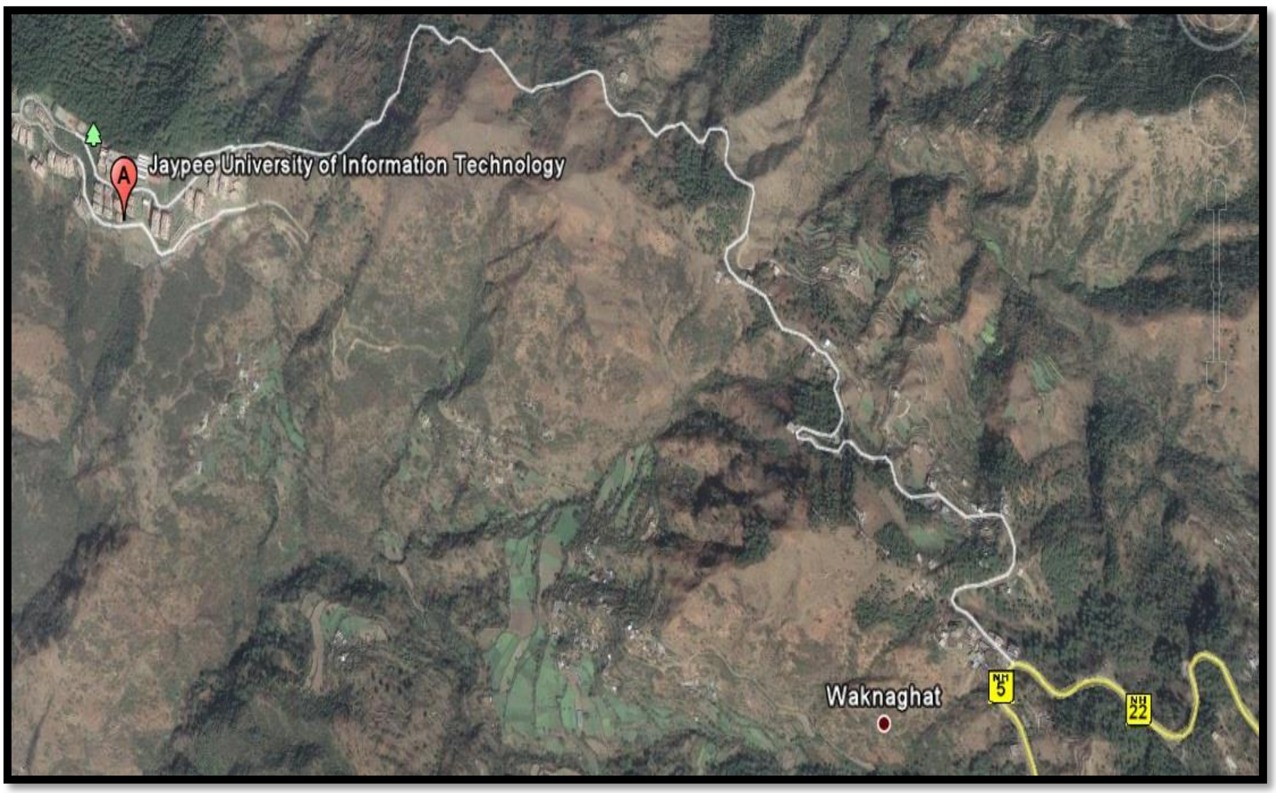
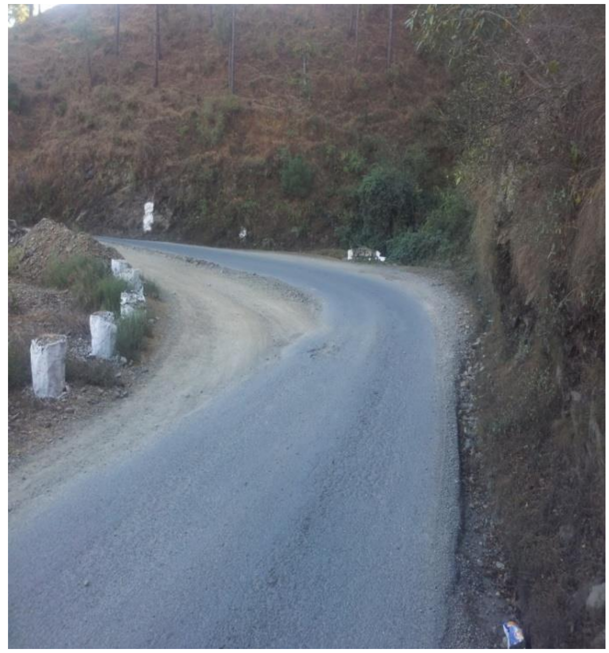


Figure 3.1 Alignment of the selected road stretch from Google Earth [2]

(a) Hair-pin Bend



(b) Approximately 1.3 km from JUIT

(c) Near Destiny Restaurant towards Waknaghat

(d) Near Destiny Restaurant towards JUIT

Figure 3.2 Photos of existing road stretch

3.1 Methodology

To check the geometric design of existing road stretch against the specifications of IRC standards. A fly leveling survey has been done for the selected road stretch to generate the topography of the road. Data obtain from the survey has been inputted in excel sheet manually and alignment corresponding to the data obtained has been drawn in AutoCAD^{TM} software for required feature check like horizontal alignment, section of the alignment, carriageway width, roadway width, shoulder, drain, etc as per recommended standards.

To do an improved geometric design for selected road stretch. Data obtained has been checked for any short comings in the geometric design of the chosen road stretch, an improved geometric design are proposed; which is done using MXROAD^{TM} software and also by hand calculations.

Cost estimation for the road stretch designed by the authors for implication.

3.2 Total Station

A total station is an electronic/optical instrument used in modern surveying. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read slope distances from the instrument to a particular point.

Sokkia Total Station (SET610) version has been used (Figure 3.3 Sokkia total station SET610).

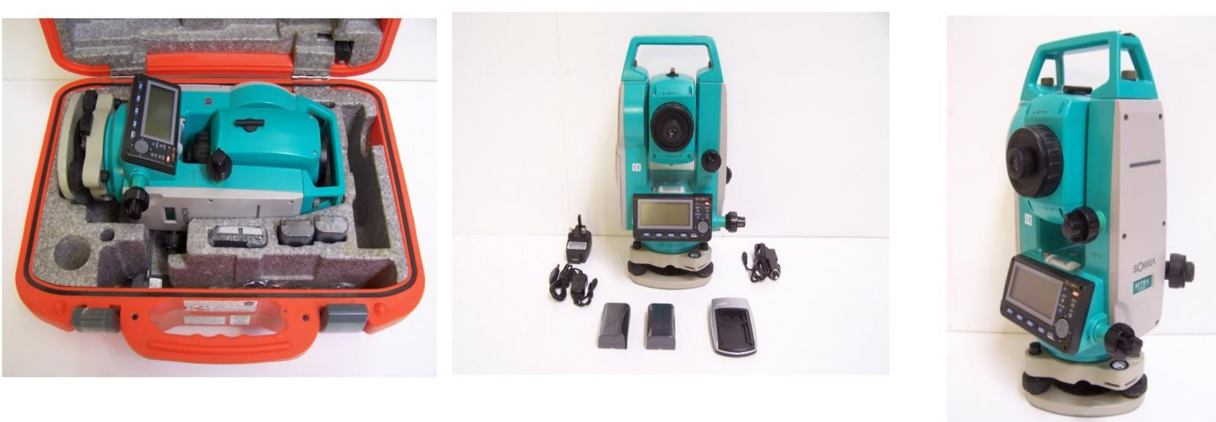


Figure 3.3 Sokkia Total Station SET610 [1]

3.2.1 Parts of Total Station

Figure 3.4 (A)

Figure 3.4: (B) Tripod Figure 3.4: (C) Reflector & stand Figure 3.4: (D) Plum bob

Figure 3.4: Parts of total station [1]

3.2.2 Working steps

(Refer section 3.2.1: Parts of total station, for any term related to total station mentioned below)

1. Level the instrument using bubble on the base and then bubble above the screen. The bubble on the base is used for leveling the tripod and bubble above the screen is used for leveling the instrument.
2. For centering the instrument Plum bob is used.
3. After the instrument have been centered and leveled, press turn ON button on the operation panel.
4. From operation panel press **MEAS** followed by **TILT** which are displayed on the display screen (press **FUNC** key on the operational panel to scroll menu) – complete fine leveling adjustments if needed.
5. Prior to the start of survey one either need to fit the back sight coordinate of the previous point in the instrument or one have to set north angle.
6. For our survey work we have oriented north angle.
7. North angle is oriented using compass fitted on the top of total station, press **OSET** on operational panel and set the horizontal angle to zero.
8. After setting the north angle one need to input certain specific information's about the bench mark (northing, easting & elevation coordinate), height of instrument and height of reflector in total station instrument.
9. To do this one need to press **COORD – Stn. Orientation – Stn. Coordinate** on optional panel.
10. Once all the required information has been entered and the instrument is well leveled, one is ready to proceed with the survey by sighting on the reflector.

3.2.3 Trial survey using total station in JUIT campus

Figure 3.5 Trial survey using total station in JUIT campus, under progress

3.3 MXROAD™ Software

MXROAD™ is an advanced, string based modeling tool that enables the rapid and accurate design of all road type. With MXROAD™ one can quickly create design alternatives to achieve the ideal road system. Upon selection of the final design alternatives, MXROAD™ automates much of the design detailing process, saving the user time and money.

3.3.1 Basic concepts of MXROAD™

- A system for the collection, generation, analysis and display of three dimensional data.
- All data are stored in the MX data base.
- 3D surface are stored as models in MX data base.
- Each model has a model name, 28 characters maximum in range 0 to 9, A to Z and space only.
- One model per surface, such as
    - → Existing ground
    - → Design
    - → Contours through the survey or design
    - → Long and cross section
- No practical limit on number of models.
- Surface features and break lines stored as strings.
- Each string has string name which is 4 characters long alphanumeric and are user defined in both the survey and in design.
- String are the list of points- surveyed, designed or from analysis.
- Three essential files of MXROAD™ are as follows:
    - → model.fil – the database (hold the project design and survey model information).
    - → "projectname".mmd – the project file (holds project parameters, library locations etc,.).
    - → Defmods.txt – the association file (holds model types and model style set or feature set associations)
- Survey input file type are as follows; DWG,DXF,GENIO,NTF and Land XML
    - → GENIO is the MX standard method of data transfer.

3.3.2 Working steps

3.3.2.1 Survey Input

Survey data may come from a number of sources like DWG, DXF, GENIO, NTF and Land XML. GENIO is the MX standard method of data transfer. For our project we have used DWG survey data.

To load the survey data use either *File > Open* or *File > Import* to select required file from CAD Menu.

For example, import CAD file from CD (All Survey Data-Survey 5 data) as shown in Figure 3.6 and after importing the CAD file one should get a screen as shown in Figure 3.7.

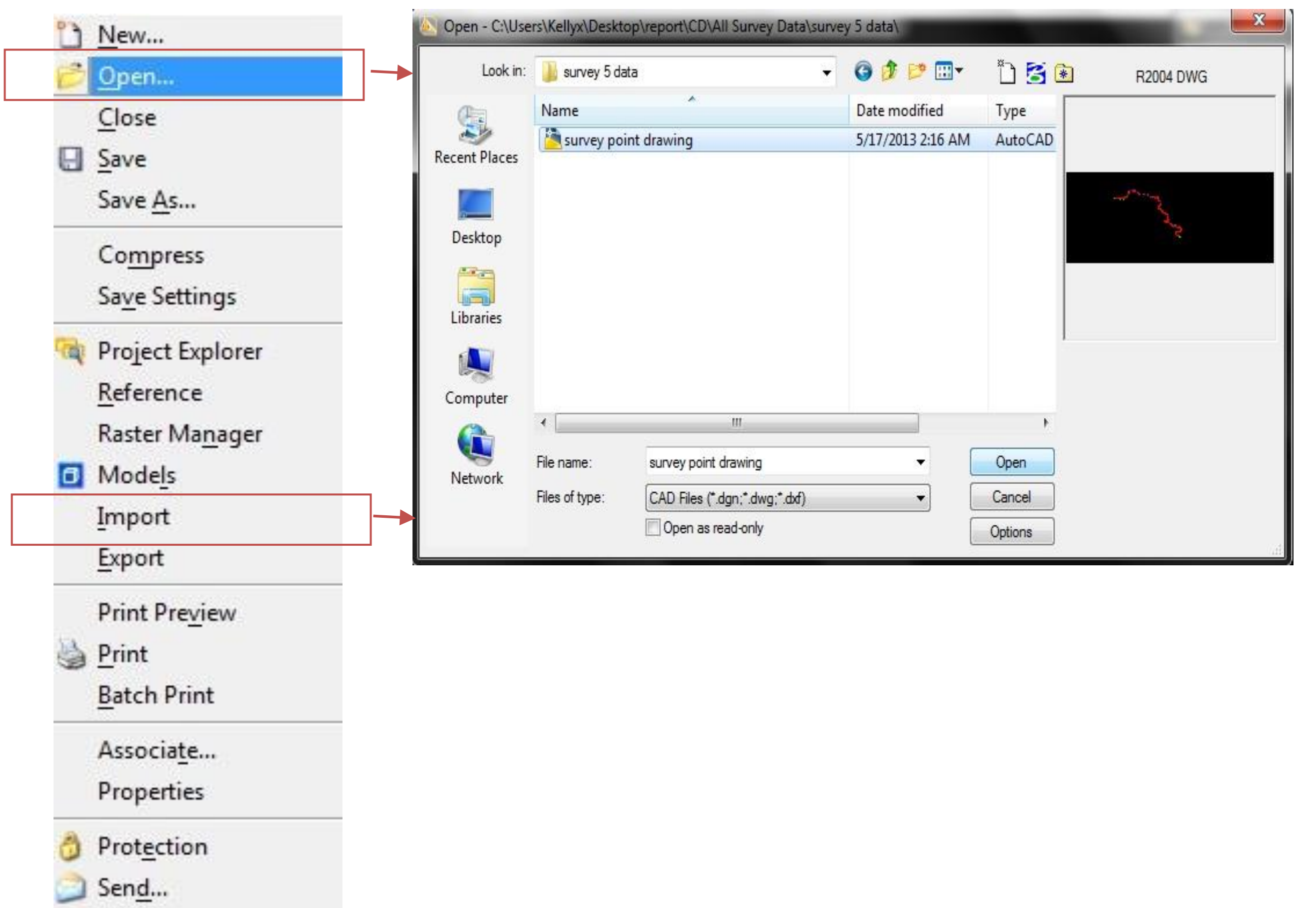


Figure 3.6 Survey Data Input

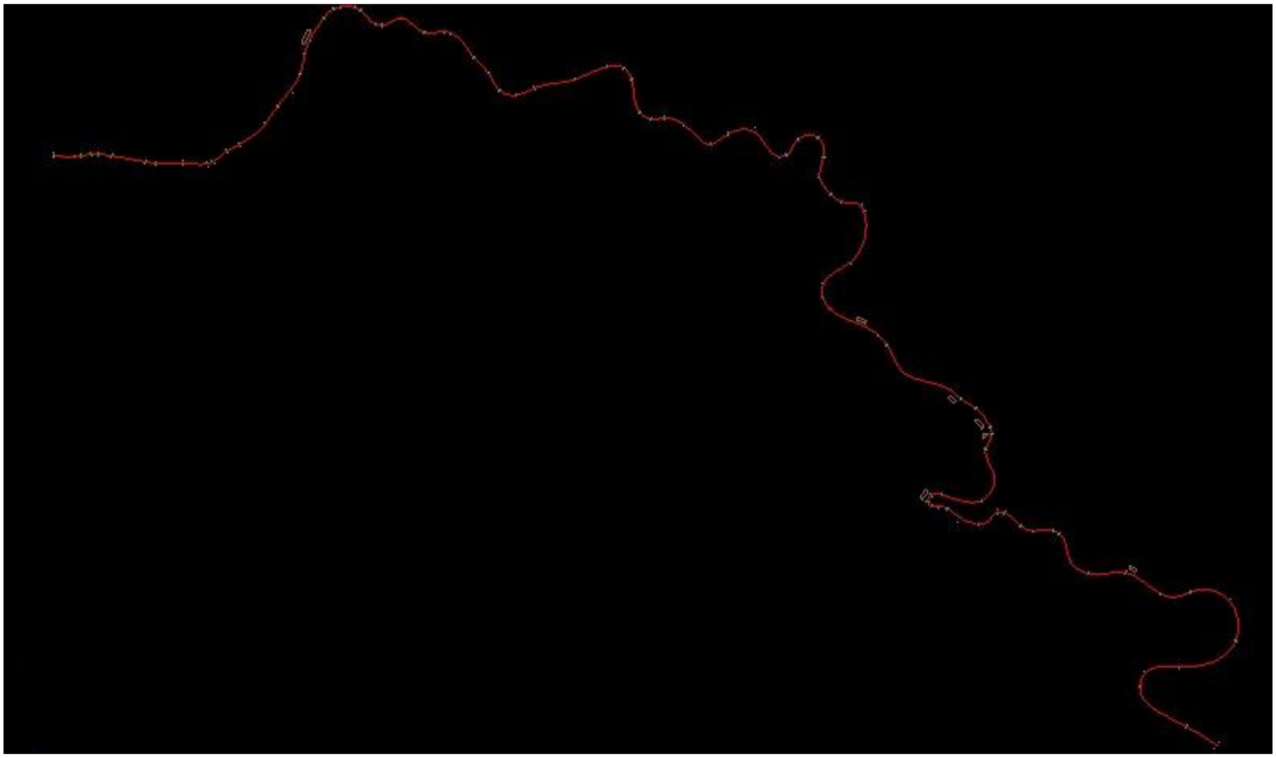


Figure 3.7 Screen shot of a display window after importing survey data

3.3.2.2 Creating model and assigning model defaults:

String names and drawing styles are controlled by assigning model defaults. Model defaults have a two set of features which are Feature Set and Style Set name.

Feature name set offers string name by the type of features used and it controls the use of string type throughout MX.

Style set name defined the drawing style of the various model types and it ensure the consistent style of presentation.

From MX Menu, *select Modify - Edit models – Create models*

Every model created should be related to the style set name and feature set name at the earliest opportunity.

For example, create a model name called GROUND SURVEY and assign the model defaults as shown in figure 3.8.

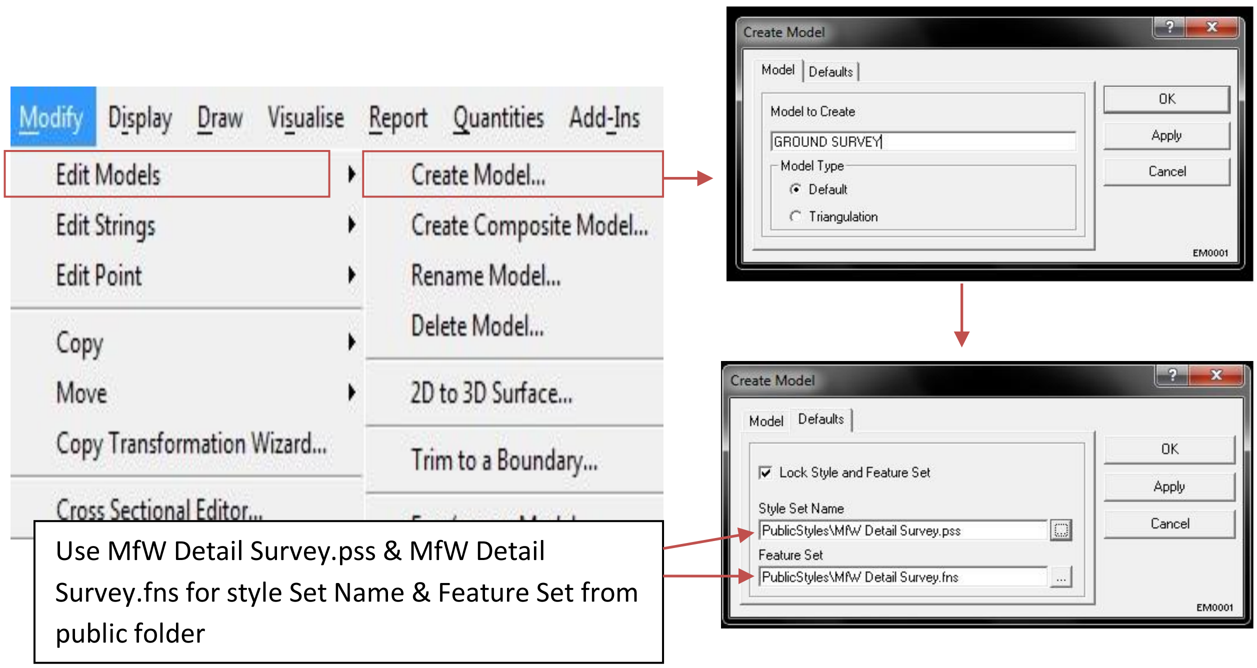


Figure 3.8 Creating model and assigning model default

3.3.2.3 Conversion of CAD file to MX file

All we have done so far is to open a CAD drawing; MX has no information at all in its database (the mode file), and does not know anything about the drawing. We now need to create a link between the MX model and the information in the CAD drawing.

For example, on MX Conversion Toolbar (refer Appendix A for the detail of MX Conversion Toolbar), select the arrow on the feature list to display the entire feature associated with the model. Scroll down the list and select point feature as shown in Figure 3.9. A corresponding level is created with the same name in the level manager as shown in Figure 3.10.

Now select all the point, make Point Features level active (refer Appendix A for active level toolbar) and press convert element icon. After conversion it should look like Figure 3.11.

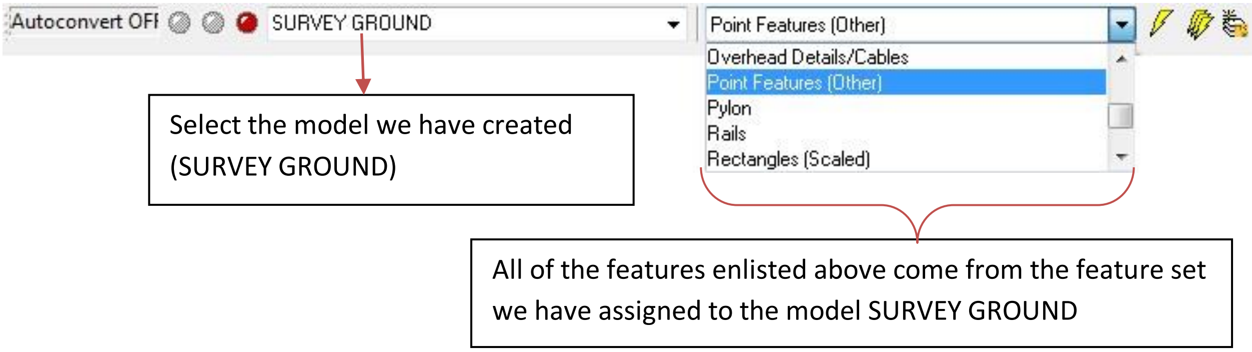


Figure 3.9 Creating MX level from MX Conversion Toolbar

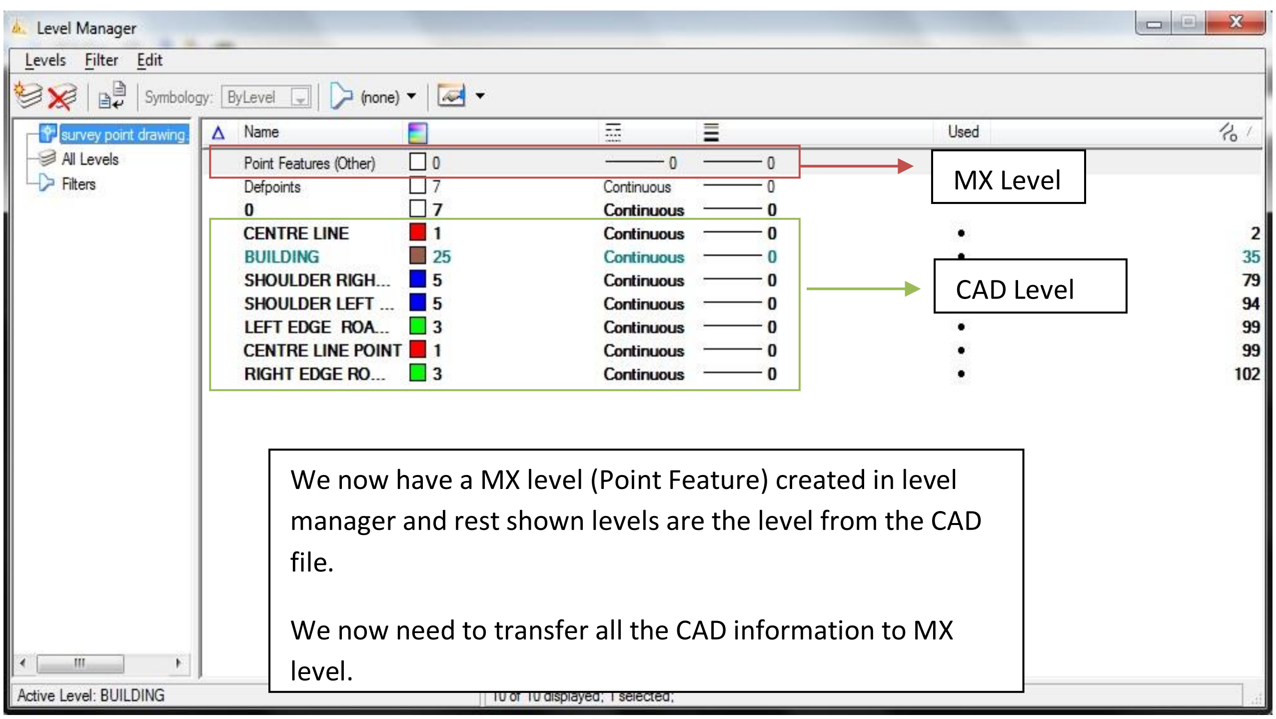


Figure 3.10 Level Manager

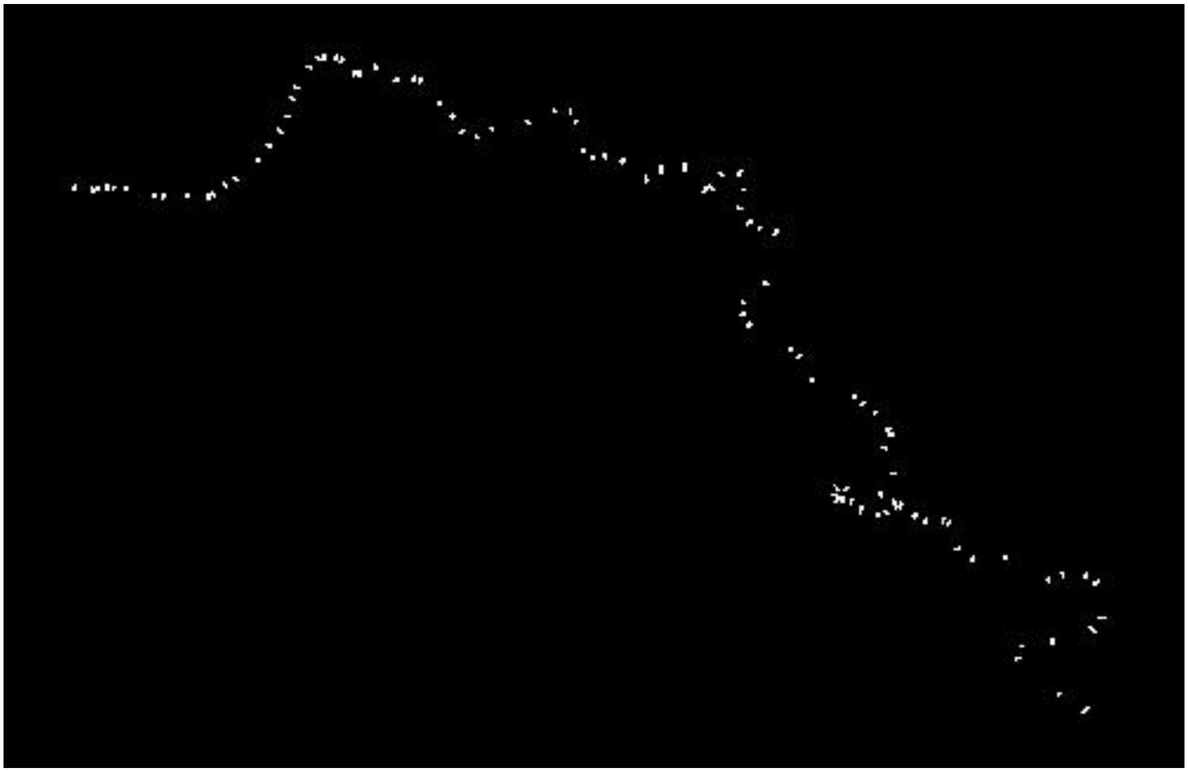


Figure 3.11 Screen shot showing MX strings

3.3.2.4 Analysis

The survey file is critical to the design and one must check that it contain no serious errors.MX provides two type of analysis; Surface Analysis and Surface Checker. Surface analysis checks level for serious errors and are use to create Triangulations (MX automatically creates a number of triangle connecting every string, triangulation is very much important while designing vertical alignment as it forms a surface connecting every point), Contours, Depth Bands etc. Surface checker search for the standard errors.

It can be accessed from the main menu (*Analysis-Surface Analysis*) or from the application toolbar as shown in the figure 3.12A.

For example, from application toolbar go to Surface Analysis as shown in Figure 3.12A. Select the appropriate model name to be analyzed (GROUND SURVEY) as shown in Figure 3.12B. Press *Next*, new panel will come as shown in Figure 3.12C. Select Display Triangulation and hit next. Final model should look like Figure 3.13.

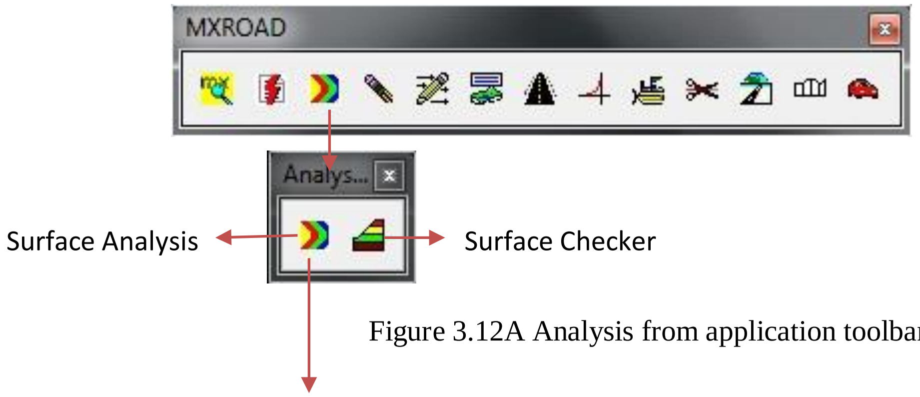


Figure 3.12A Analysis from application toolbar

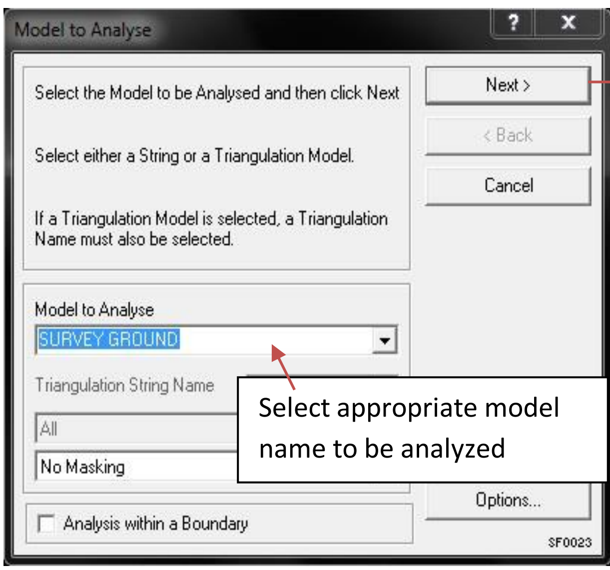


Figure 3.12B Model to Analyze

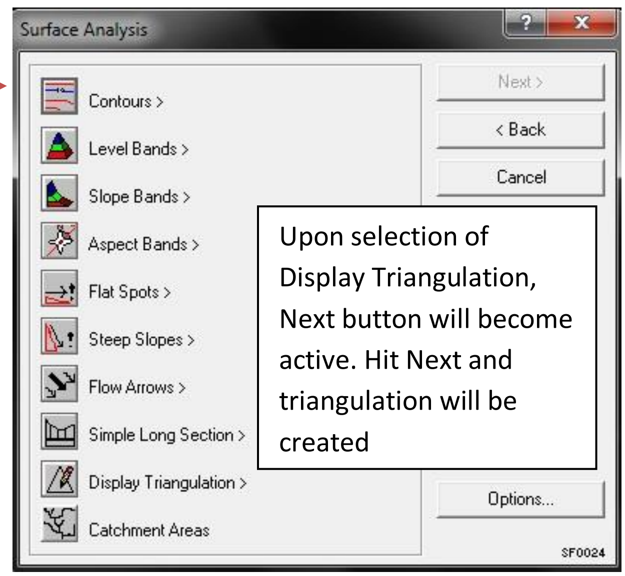


Figure 3.12C Surface Analysis

Contours are also generated from the same step that we did for the Triangulation and Contour Model generated in shown in Figure 3.14.

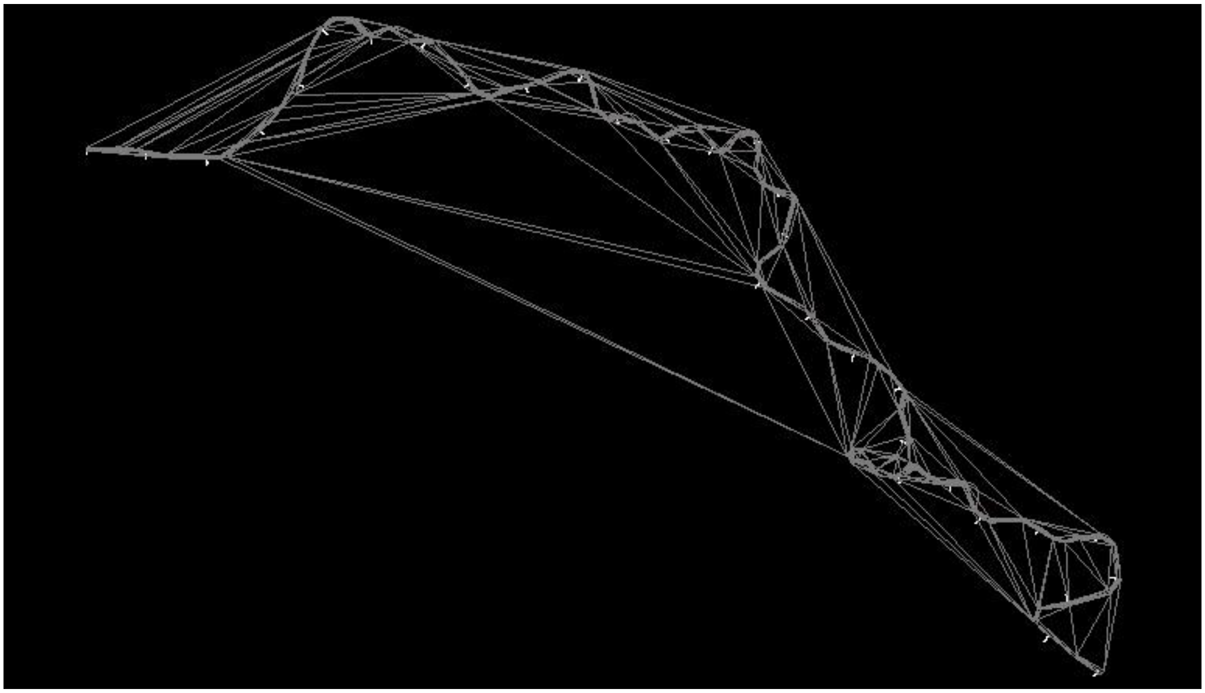


Figure 3.13 Triangulated Model Generated

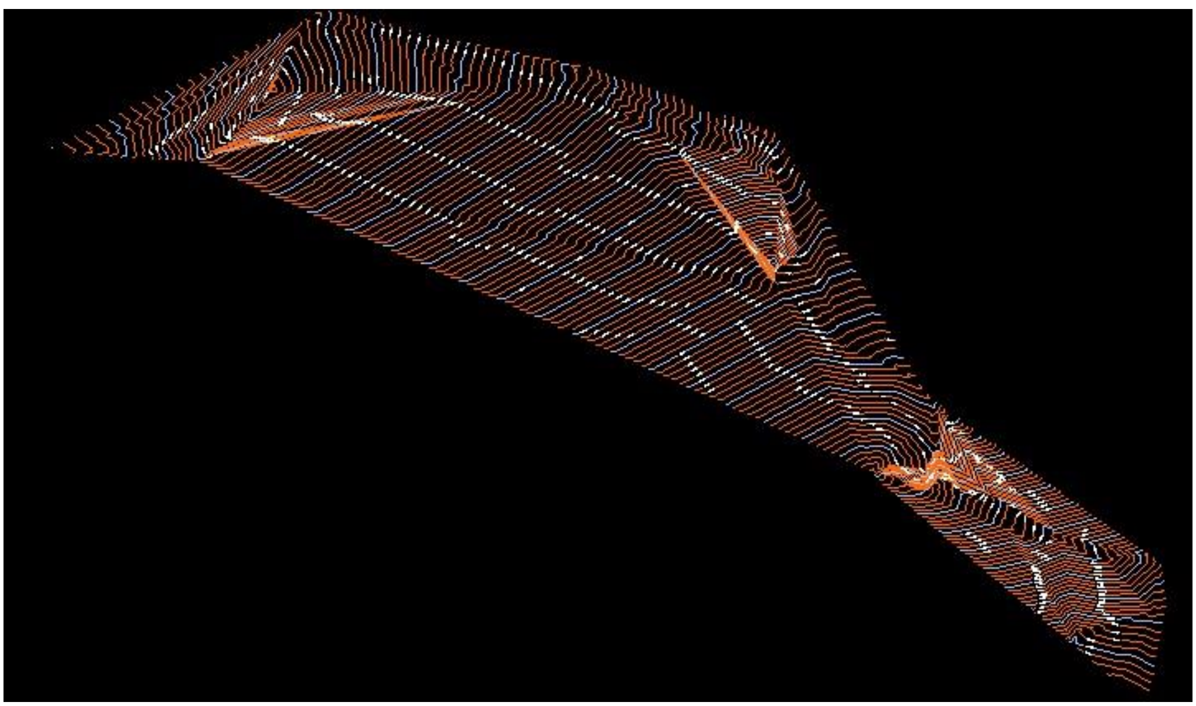


Figure 3.14 Contour Model Generated

3.3.2.5 HORIZONTAL ALIGNMENT

For the design of horizontal alignment we have used quick horizontal alignment method and it can be accessed from either the main menu; *Design-Quick Alignment-Horizontal Design*, or if you are using one of the MX applications then Quick Horizontal Design can be accessed from the toolbar.

For example, go to Quick Horizontal Design as shown in Figure 3.15A. Model Selection panel will come up, name a model 'Design' and string name 'MC10' (M stands for master string, C stand for road center line and 10 is road identity) as shown in Figure 3.15B and press Next.

On pressing Next, Quick Horizontal Alignment Toolbar will come (refer Appendix A for detail of Quick Horizontal Alignment Toolbar) as shown in figure 3.14C.

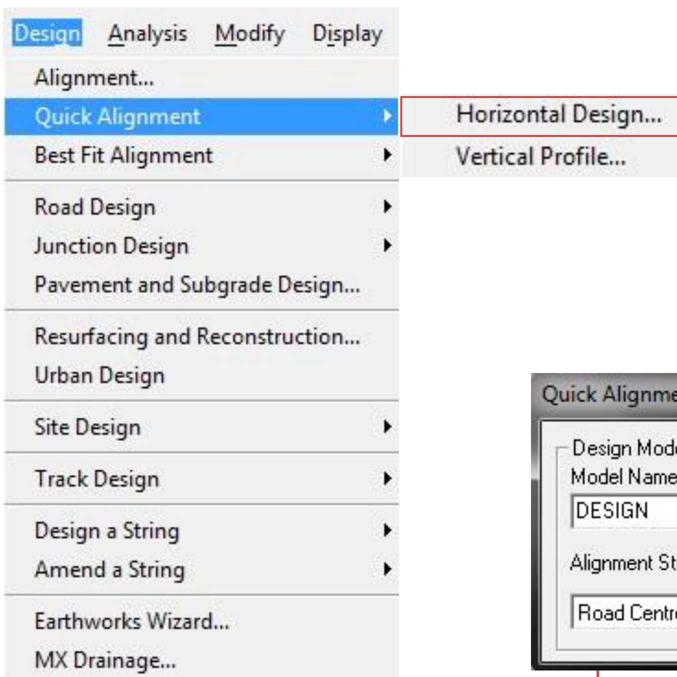


Figure 3.15A Horizontal Design from

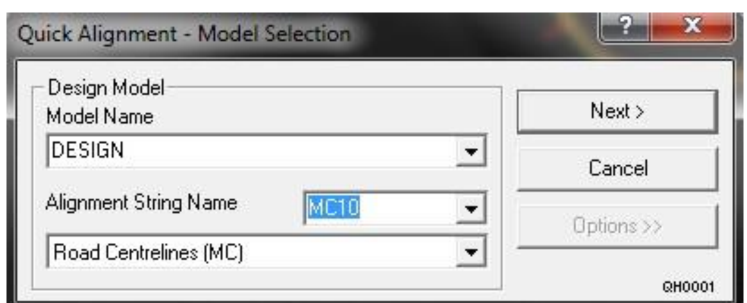


Figure 3.15B Model Selection

Figure 3.15C Quick Horizontal Alignment Toolbar

Go to XY Keyboard Entry on Quick Horizontal Alignment Toolbar and enter the value of X=3.280 and Y=871.646 for the construction of 1st IP (intersection point) as shown in the Figure 3.16

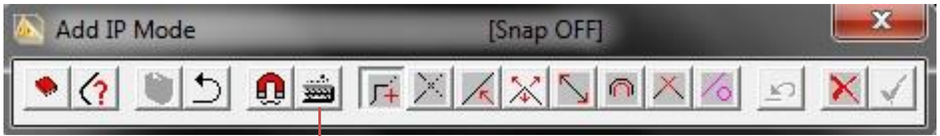


Figure 3.16A QHA Toolbar

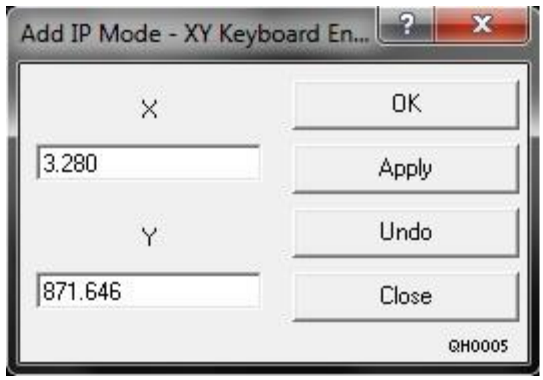


Figure 3.16B XY Keyboard Entry

1st IP constructed

Figure 3.16C Plan

Figure 3.16 Construction of 1st IP

For 2nd IP, enter X=27.191, Y=867.952 in XY Keyboard Entry and Radius 80m, transition length of 15m in Parameters as shown Figure 3.16.

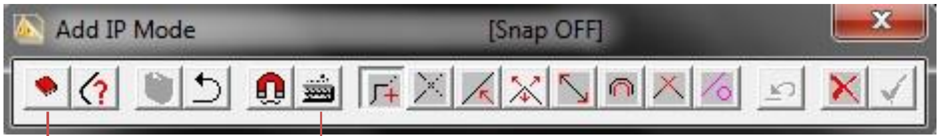


Figure 3.17A QHA Toolbar

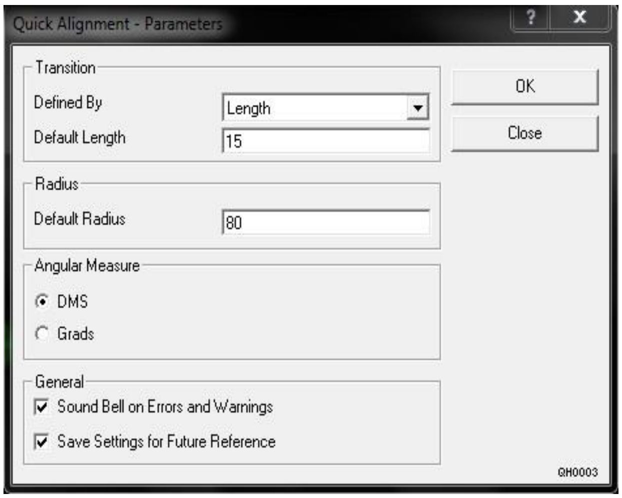


Figure 3.17B Parameters

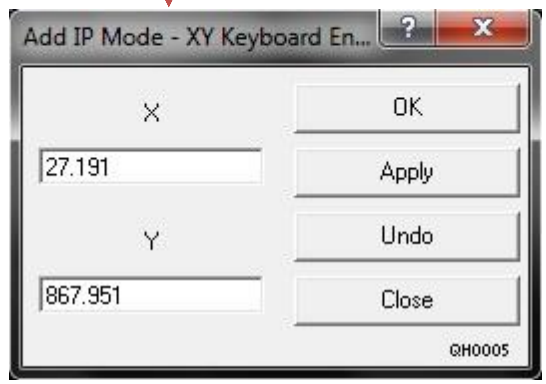


Figure 3.17C XY Keyboard Entry

2nd IP Constructed

Figure 3.17D Plan

Figure 3.17 Construction of 2nd IP

Go on constructing IP following the centre dote of survey point till the end and when done press OK button on QHA Toolbar to accept the horizontal design. Figure 3.18 shows the complete horizontal alignment designed by the authors.

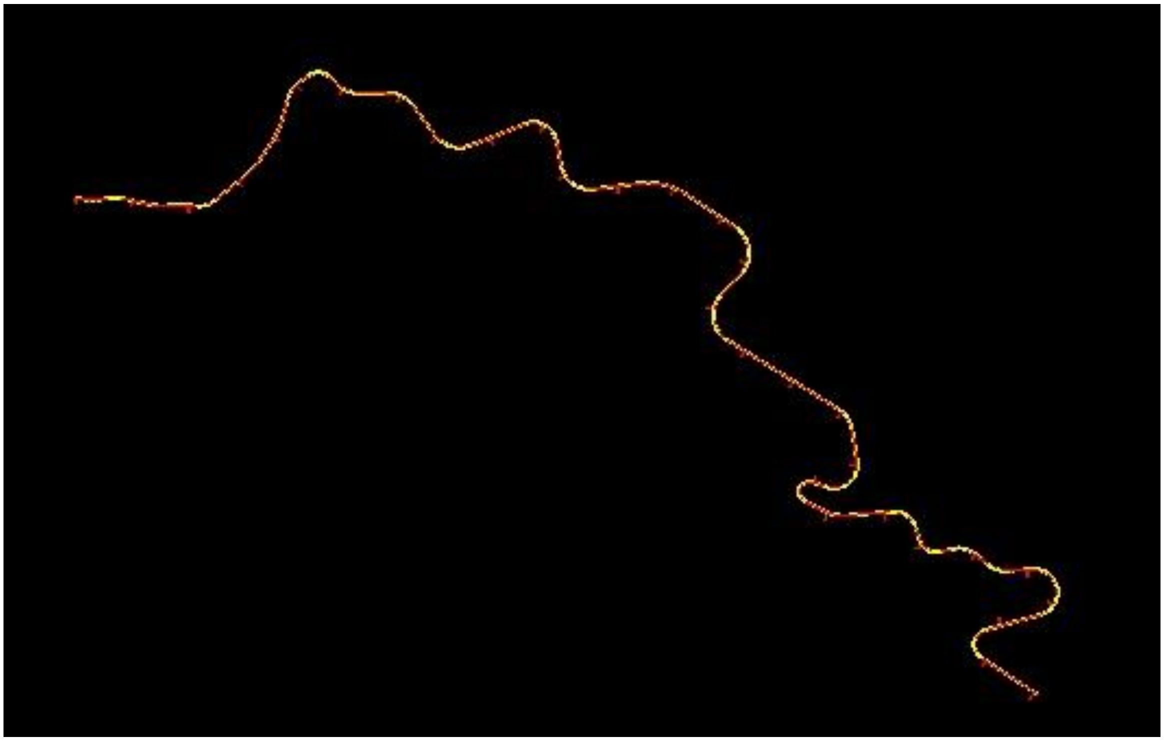


Figure 3.18 Designed Horizontal Alignments for JUIT-Waknaghat

3.3.2.6 VERTICAL ALIGNMENT

For the design of vertical alignment we have used quick vertical alignment method and it can be accessed from either the main menu; *Design-Quick Alignment-Vertical Design*, or if you are using one of the MX applications then Quick Vertical Design can be accessed from the toolbar.

For example, go to vertical profile as shown in Figure 3.19A. Select the appropriate model name called DESIGN from the list and selects the model GROUND TRIANGULATION as the reference model. Press *Next*, a Quick Vertical Alignment Toolbar (QVH Toolbar) will appear as shown in the Figure 3.19B (refer appendix A for the detail of Quick Vertical Alignment Toolbar).

Add IP as shown in the Figure 3.19C (it has four IP) by using Add IP icon on the QVH Toolbar, go to Lock IP on the QVH Toolbar as shown in the Figure 3.19D and select First and Last X-Z, which will snap to the starting and the end of horizontal alignment.

Now go to Table View and enter the Out Grade as shown in Figure 3.19E. The final drawing should look like Figure 3.20.

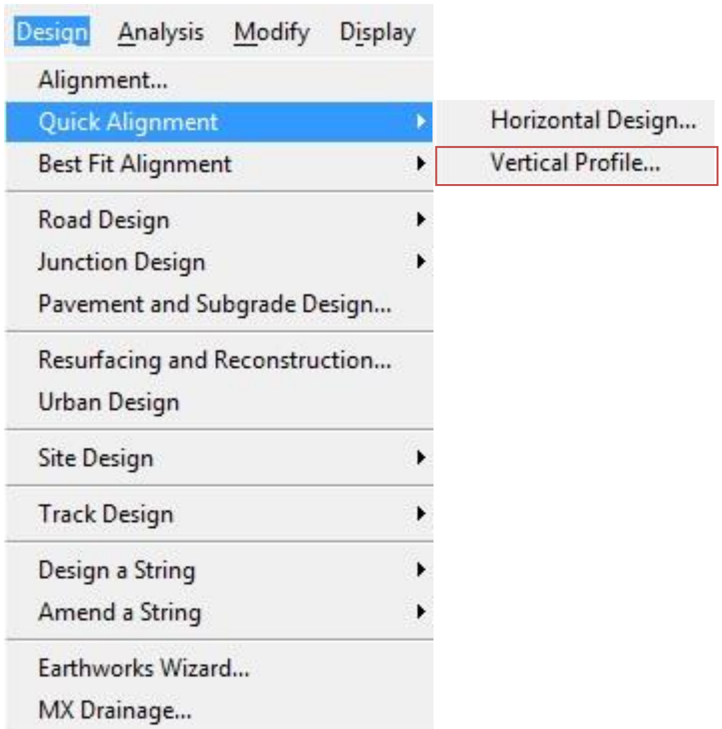


Figure 3.19A Vertical Profile from main

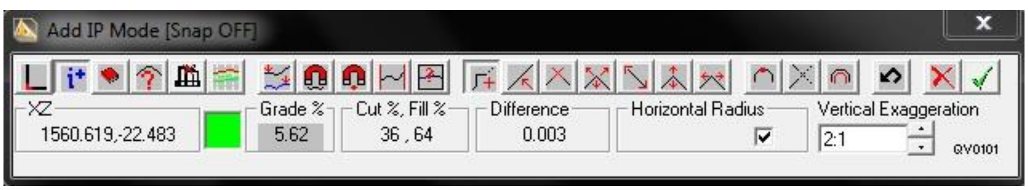


Figure 3.19B QVA Toolbar

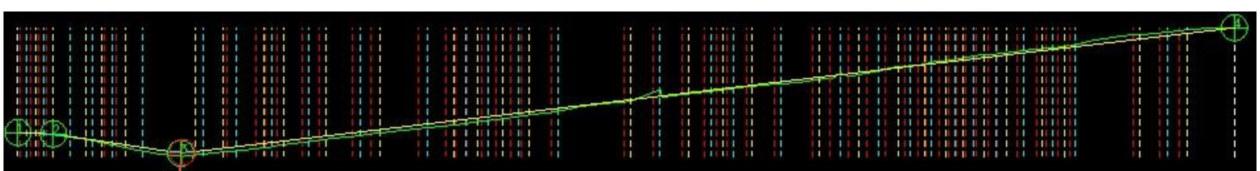


Figure 3.19C Add IP

These IP's are constructed using Add IP icon and readjustment is done by Add, Move, and Delete icon on QVH Toolbar.

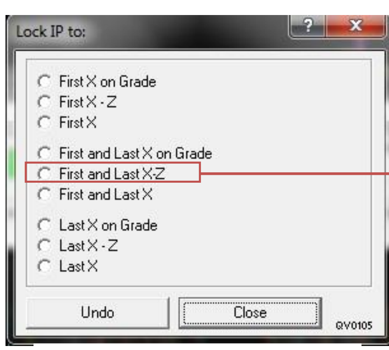
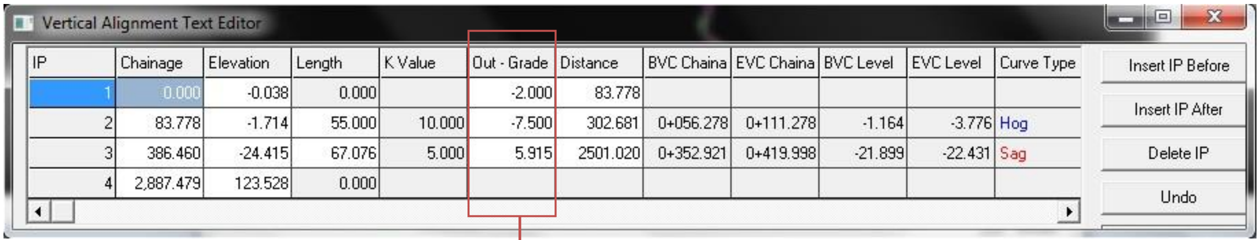


Figure 3.19D Lock IP

This one will lock the position of first and last IP to the starting and end of horizontal alignment



Vertical Alignment Text Editor

IP	Chainage	Elevation	Length	K Value	Out - Grade	Distance	BVC Chaina	EVC Chaina	BVC Level	EVC Level	Curve Type
1	0.000	-0.038	0.000		-2.000	83.778					
2	83.778	-1.714	55.000	10.000	-7.500	302.681	0+056.278	0+111.278	-1.164	-3.776	Hog
3	386.460	-24.415	67.076	5.000	5.915	2501.020	0+352.921	0+419.998	-21.899	-22.431	Sag
4	2,887.479	123.528	0.000								

Use these gradients

Figure 3.19E Table View

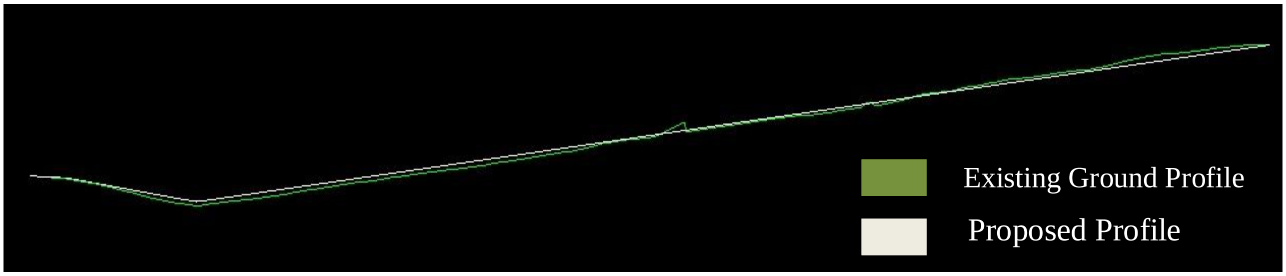


Figure 3.20 Designed Vertical Profile

3.3.2.7 CARRIAGEWAY DESIGN

Carriageway design is a template-based design using library of road categories. It can be accessed from the main menu; *Design-Road Design-Carriageway*.,

For example, go to carriageway design as shown in Figure 3.21A. Select the model name DESIGN and model string name MC10 from the list as shown in Figure 3.21B. Press Next, Library of Standard Road Template will appear, select the template MfW Single Two Lane 7.3m from the list and edit the width to 3m as shown in the Figure 3.21C. Press Next and the carriageway should look like Figure 3.22.

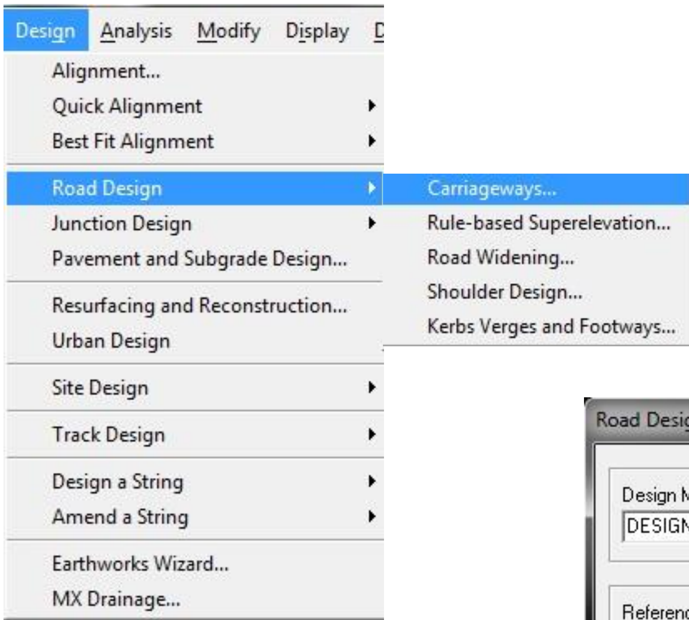


Figure 3.21A Carriageway design

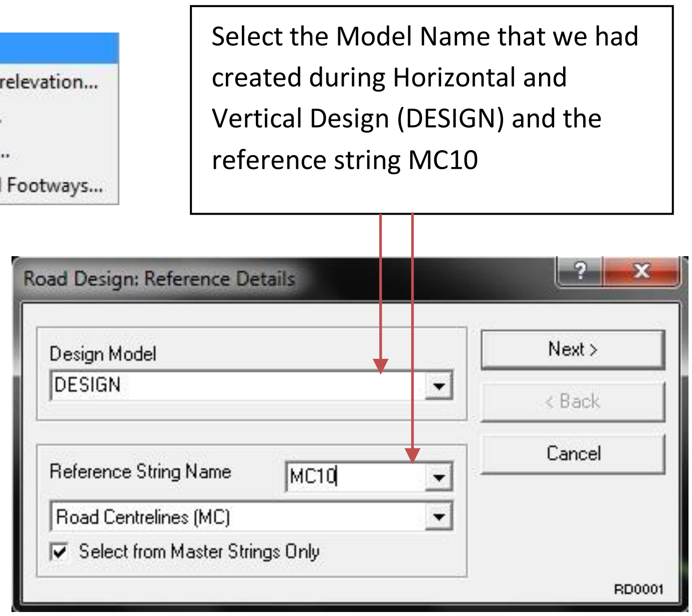


Figure 3.21B Reference Detail

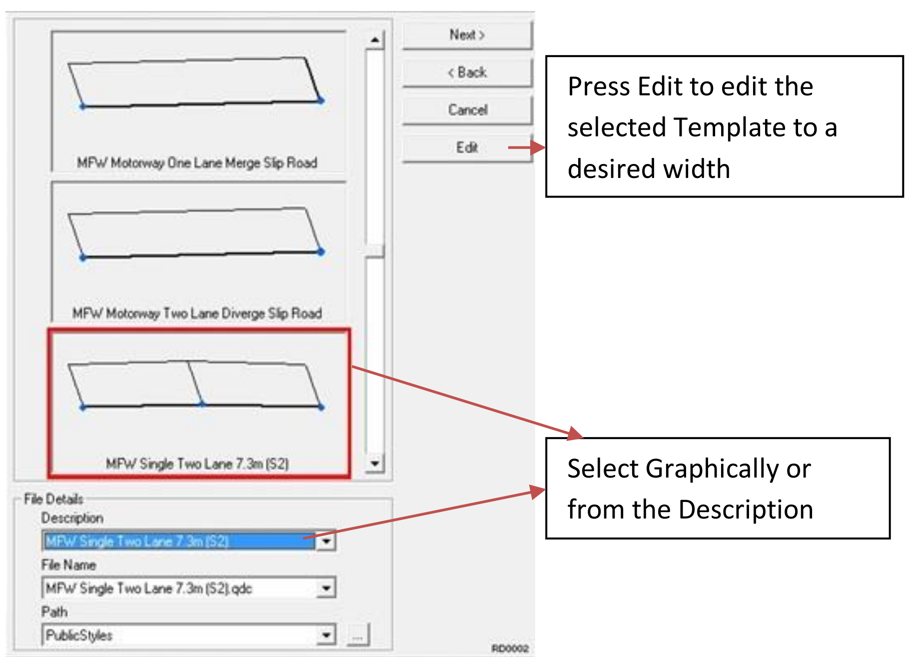


Figure 3.21C Standard Road Template

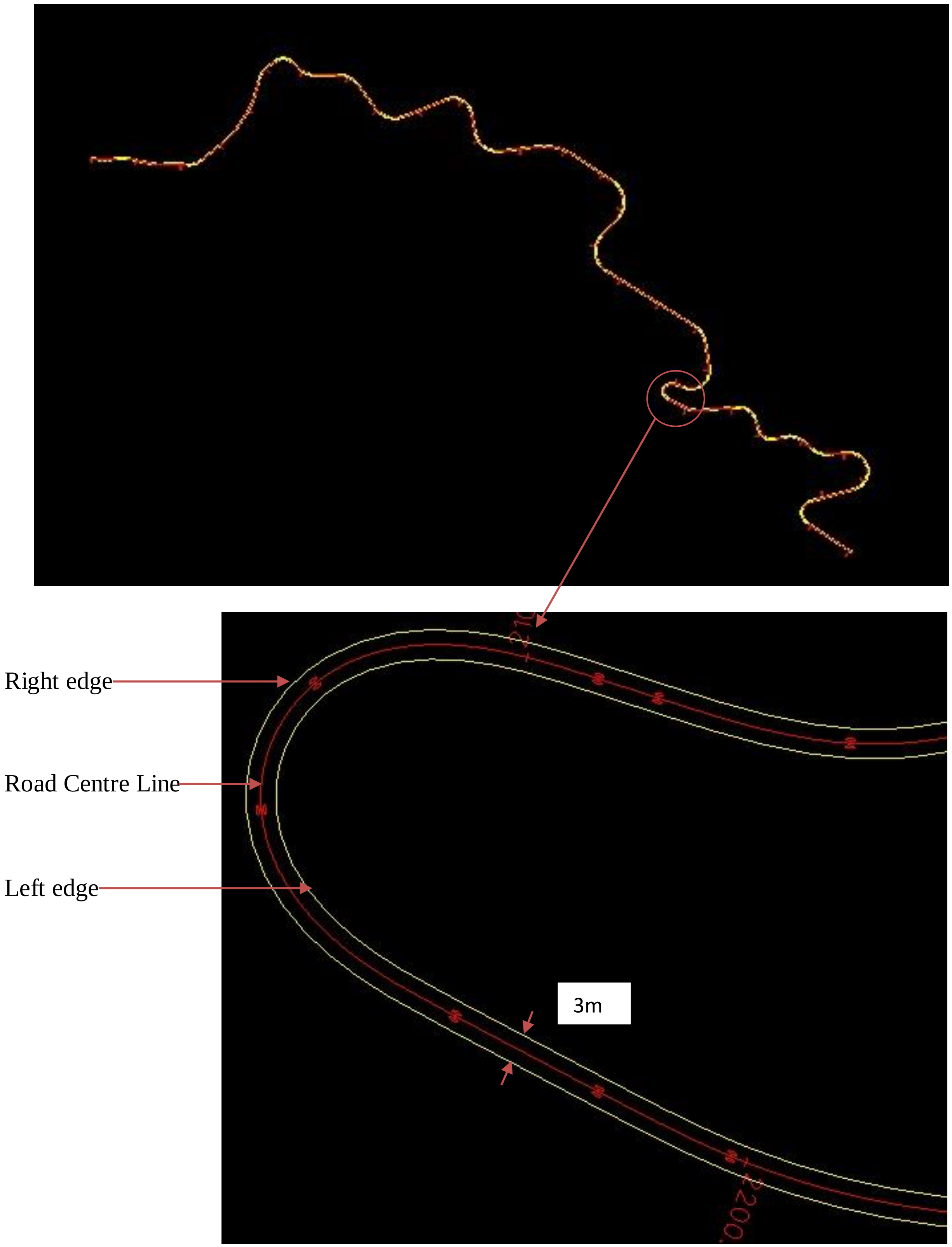
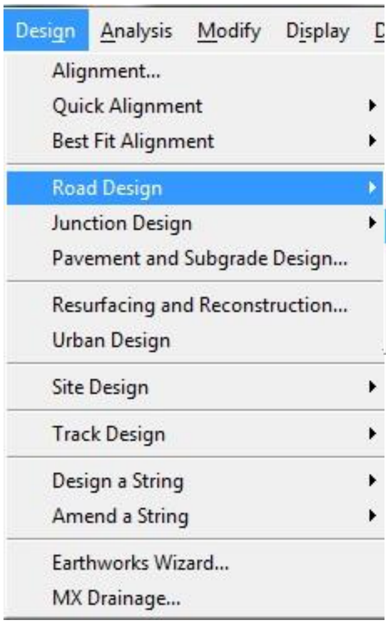


Figure 3.22 Designed Carriageway

3.3.2.8 SUPER-ELEVATION AT CURVES

It can be accessed from the main menu; *Design-Road Design-Super-elevation*. Refer MX manual given in CD for the detail working.

For example, go to super-elevation as shown in Figure 3.23A. Select the appropriate model name and string name to be super-elevated as shown in Figure 3.23B. Press Next, Super-elevation Wizard will come, use India 2 lane Motorway hill.srl as a rule and select the design speed 20 as shown in the Figure 3.23C. Press *Next*, super-elevation will be loaded and on applying the super-elevation check, it should look like Figure 3.24 at curve and straight.



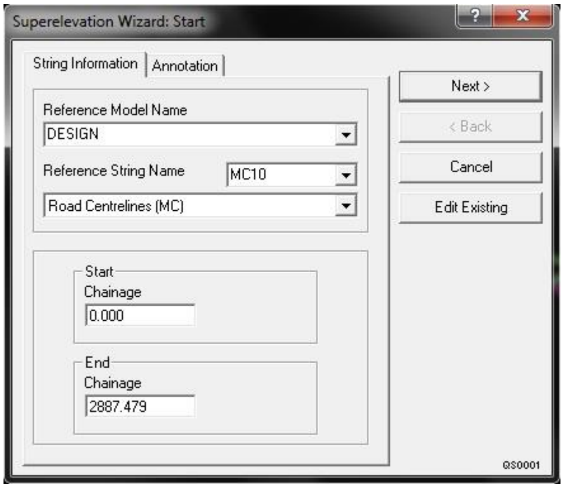


Figure 3.23B Super-elevation Wizard

Figure 3.23A Super-elevation from main

Figure 3.23C Super-elevation Wizard Rule

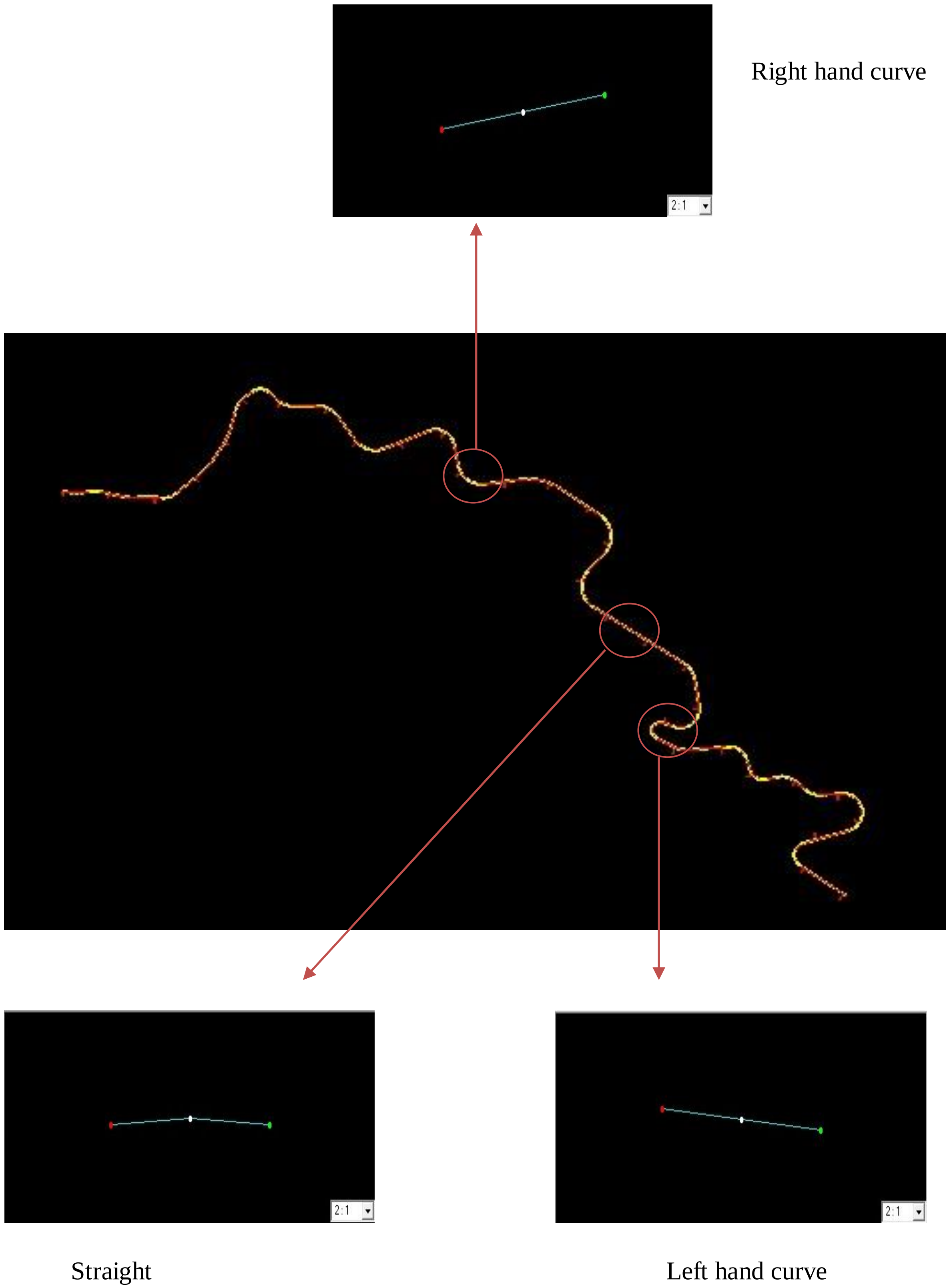


Figure 3.24 Cross fall section of road

3.3.2.9 EXTRA WIDENING AT CURVES

It can be accessed from the main menu; *Design-Road Design- Road Widening*, IRC: 52-2001 recommendation for road widening for varying curve radius is given in Table 2.7 (Extra width of the pavement at horizontal curves).

For example, go to Road Widening from main menu as shown above. Widening Start Wizard will appear, select the model name (DESIGN), reference string name (MC10) and name of the string to be widened (this string will be carriage way edges). Press *Next*, one panel will appear, enter the start chainage and end chainage in the panel as shown in the figure 3.25.

Refer Table 2.7 for recommended value of road widening.

Screen shot of road after widening is shown in figure 3.26.

Widening will increase gradually between In-Start-Chainage and In-End-Chainage. Full width widening will be between In-End-Chainage and Out-Start-Chainage, and widening will decrease gradually between Out-Start-Chainage and Out-End-Chainage.

Figure 3.25 Road Widening

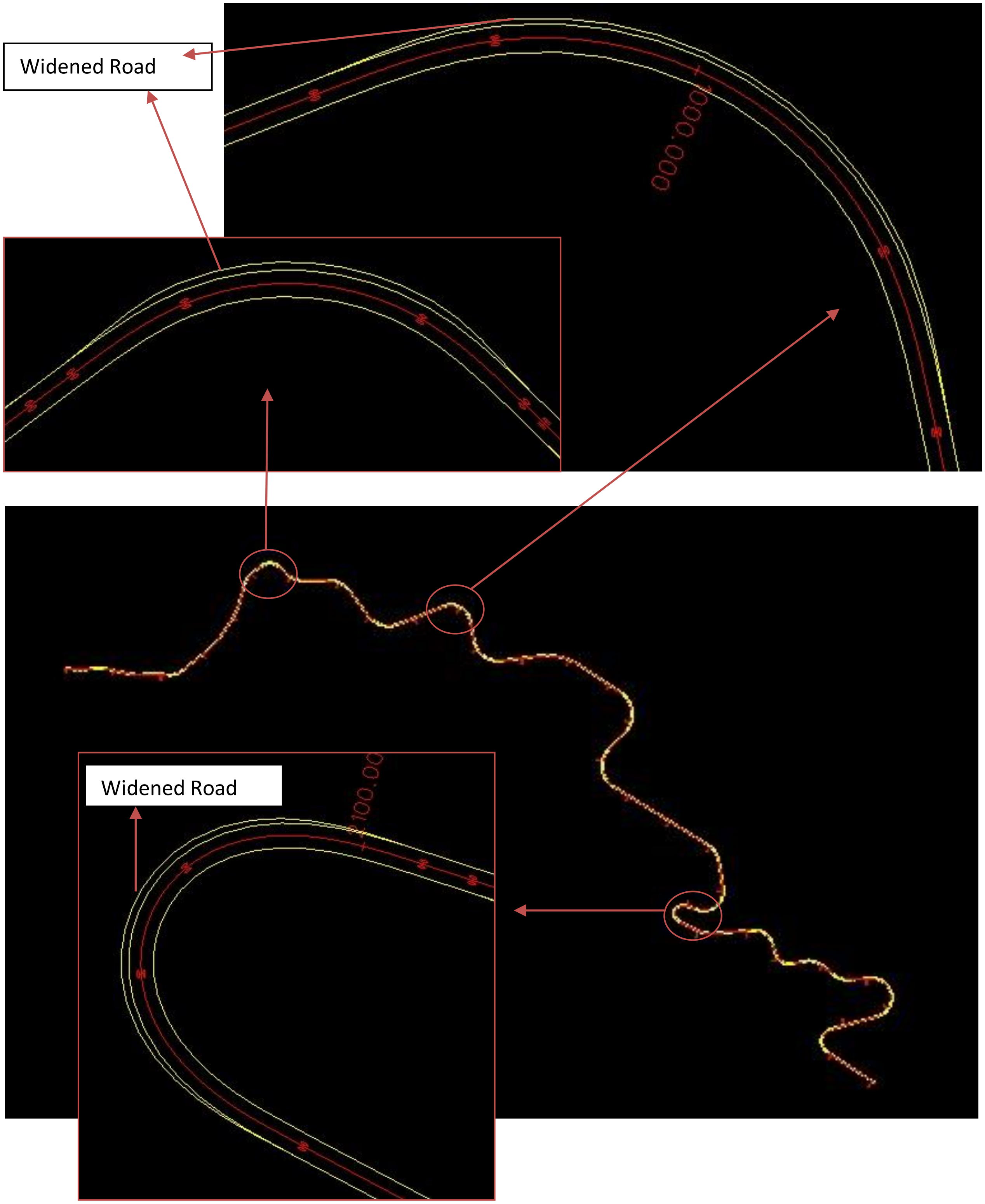


Figure 3.26 Screen shot of extra widened road for a selected road

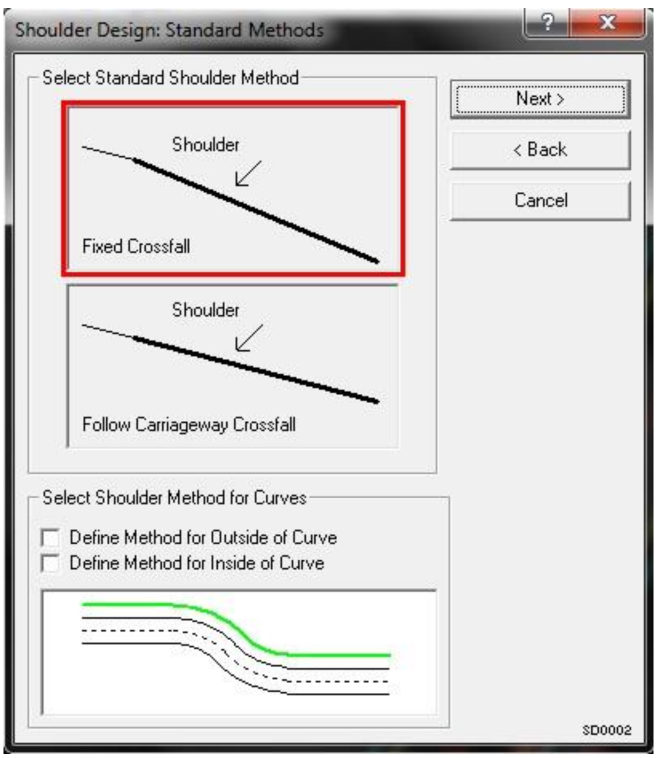
3.3.2.10 SHOULDER DESIGN

It can be accessed from the main menu; *Design-Road Design- Shoulder Design*.

For example, go to shoulder design as shown above from the main menu. To begin with the shoulder design, select the model name (DESIGN), reference string name (MC10) and name of the string for which the shoulder is to be designed i.e. either the left side of the carriageway or the right of the carriageway string name.

After assigning all required string name, press *Next*, select the Fixed Cross-fall method for the design as shown in the figure 3.27A. A new panel will come on pressing *Next.* Input 0.5m for the width and 0.025 for cross fall as recommended by IRC: 52-2001 (refer figure 3.27B).

Screen shot of the designed shoulder for the selected road is shown in the Figure 3.28



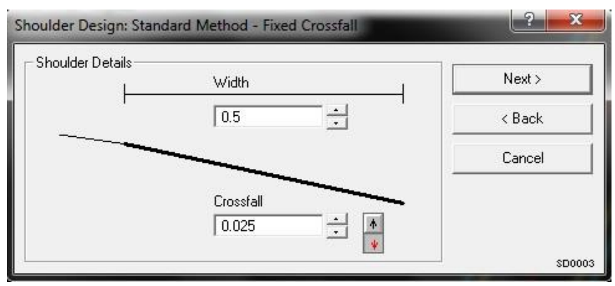
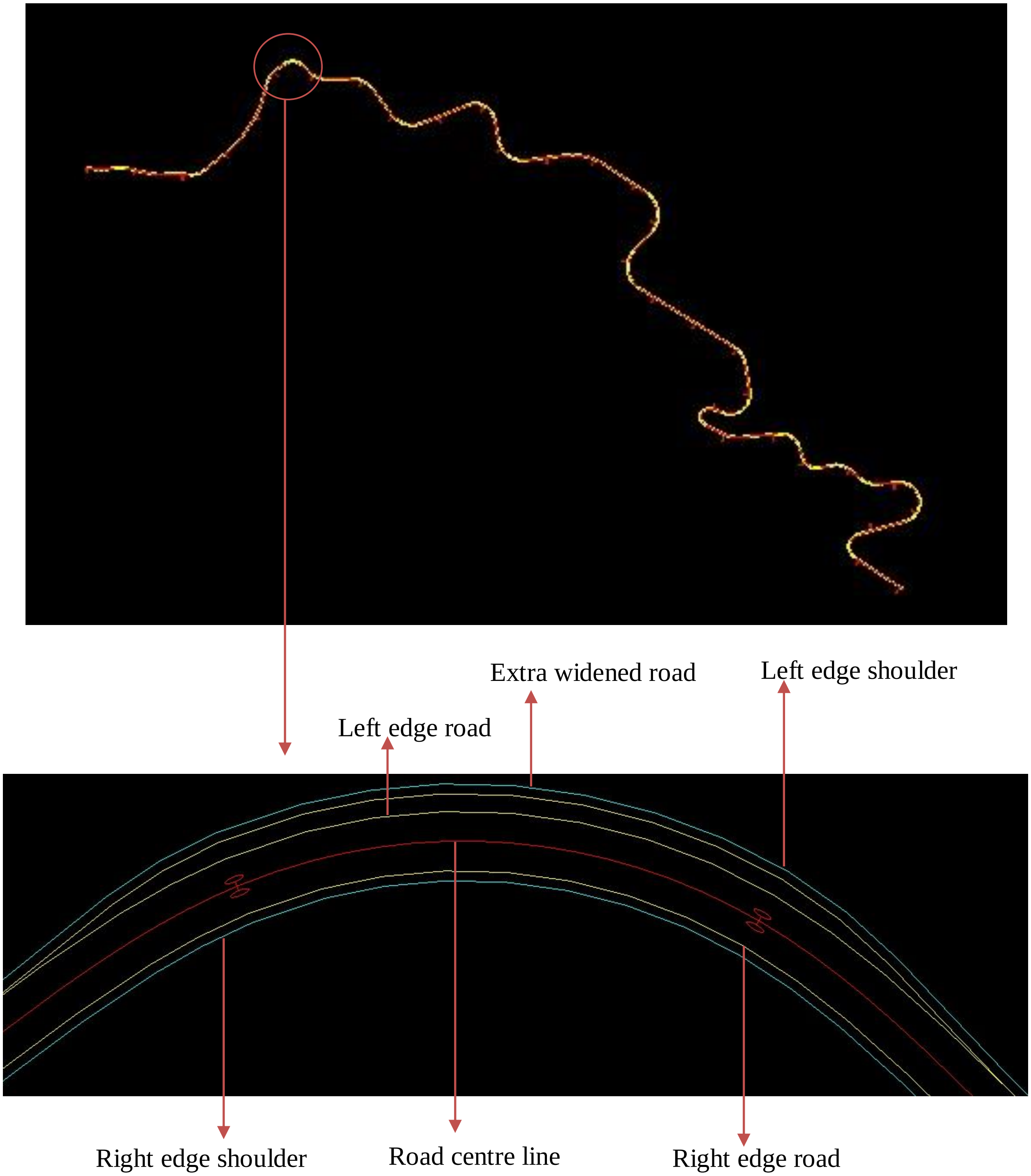


Figure 3.27B Data Input

Figure 3.27A Standard Method


Extra widened road
Left edge shoulder
Left edge road
Right edge shoulder
Road centre line
Right edge road

3.3.2.11 EARTHWORK

The earthwork wizard gives us a choice of how we want to cut/fill. We have used a slope of 2:1 for both cut and fill work. It can be accessed from the main menu; *Design-Earthwork Wizard.* Refer MX manual given in CD for the detail working.

Screen shot of the earth work for the selected road is shown in the Figure 3.29

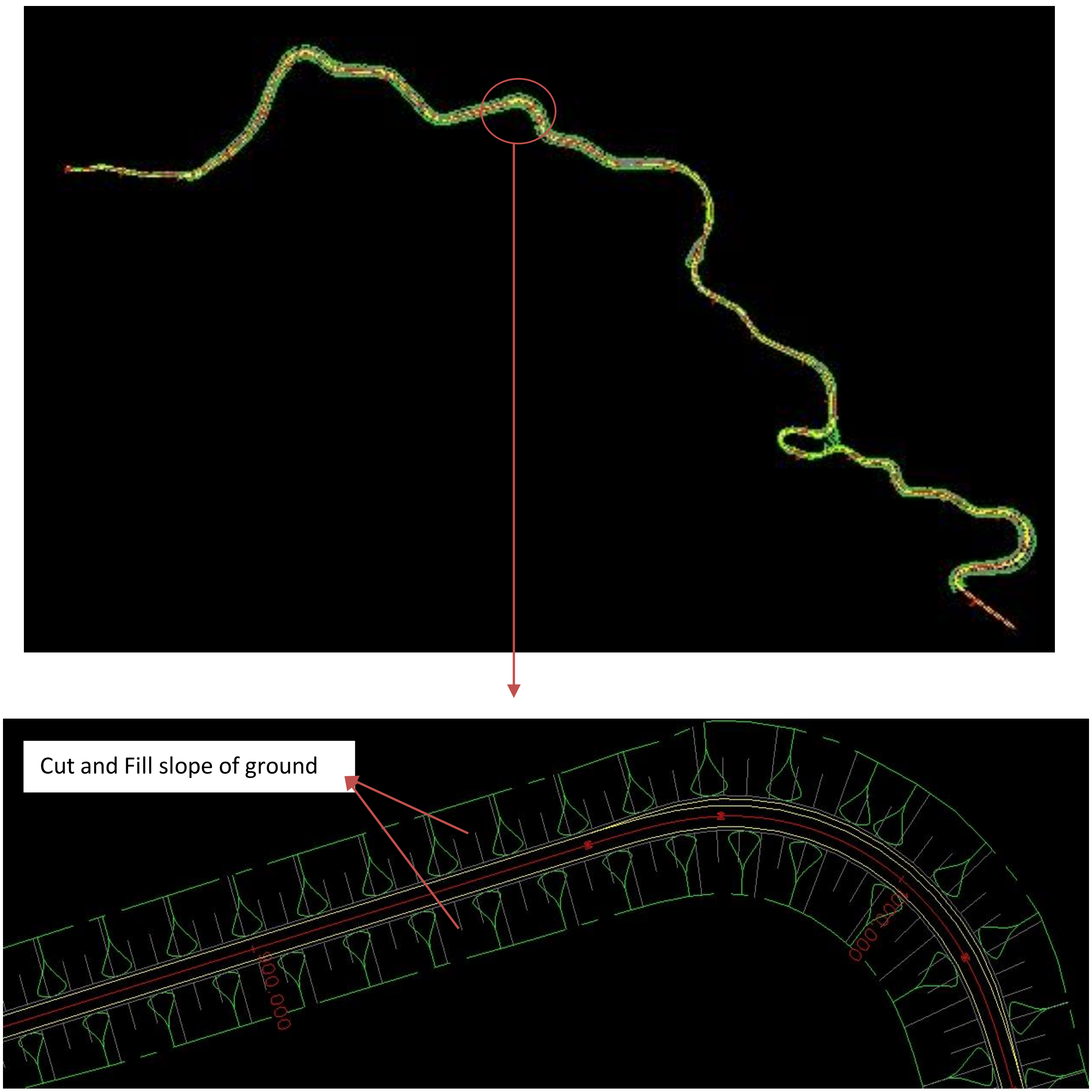


Figure 3.29 Earthwork

3.4 Closing Remark

All the above designed geometric features has been designed in MXROAD^{TM} taking into consideration the standards recommended by IRC (Indian Road congress).

Design speed of 20-25kph has been considered for our design work.

Chapter 4: RESULTS AND DISCUSSION

4.1 Survey Data

We have used total station for the survey of the selected road; we have done five set of survey due to the problems mentioned in section 4.1.1(problem faced during surveying by total station). Sample of survey data collected is given in Table 4.1(sample of survey data) and its corresponding alignment is given in Figure 4.1.

Detail of the survey data is given in CD attached along with the book in folder 'All Survey Data'

Survey data 5 is the final survey file.

Below shown is the sample of the survey data for the chainage of 0-000 to 0-0470.

Table 4.1 sample of survey data

Chainage	Northing	Easting	Elevation	Remark
0+000CL	2.009	3.28	-0.038	OK
0+000LE	4.151	3.78	0.027	OK
0+000RE	0.204	2.844	-0.049	OK
0+0030CL	-1.13	33.108	-0.686	OK
0+0030LE	-0.823	33.232	-0.621	OK
0+0030RE	-2.74	33.096	-0.733	OK
0+0040CL	0.182	42.866	-1.101	OK
0+0040LE	2.24	42.476	-1.051	OK
0+0040RE	-1.575	43.512	-1.185	OK
0+0055CL	3.568	57.422	-1.791	OK

0+0055LE	5.612	57.455	-1.812	OK
0+0055RE	1.422	57.561	-1.864	OK
ELECTRICAL POLE	4.453	68.664	-2.075	OK
0+0065CL	3.309	67.838	-2.103	OK
0+0065LE	5.312	68.021	-2.061	OK
0+0065RE	1.473	67.791	-2.154	OK
0+0085CL	0.345	87.552	-2.701	OK
0+0085LE	2.222	87.724	-2.695	OK
0+0085RE	-1.486	87.288	-2.733	OK
ELECTRICAL POLE	-6.009	110.623	-4.116	OK
0+0135CL	-8.519	136.579	-6.235	OK
0+0135LE	-6.476	136.957	-6.229	OK
0+0135RE	-11.004	135.99	-6.232	OK
0+0150CL	-11.683	151.281	-7.21	OK
0+0150LE1	-9.747	151.56	-7.136	OK
0+0150LE2	-8.54	151.568	-7.138	OK
0+0150RE1	-13.503	151.095	-7.202	OK
0+0150RE2	-14.382	151.034	-7.208	OK
ELECTRICAL POLE	-8.235	153.552	-7.181	OK
0+0190CL	-9.864	191.079	-10.817	OK
0+0190LE	-7.385	191.151	-10.768	OK
0+0190RE	-12.27	191.054	-10.819	OK
0+0225CL	-11.584	225.738	-14.704	OK
0+0225LE	-8.634	225.219	-14.793	OK
0+0225RE	-14.664	226.259	-14.602	OK
0+0235CL	-8.23	234.653	-15.35	OK
0+0235LE	-6.283	232.997	-15.545	OK
0+0235RE	-10.359	236.456	-15.424	OK
0+0260CL	7.633	253.809	-18.003	OK
0+0260LE	9.754	252.294	-17.85	OK
0+0260RE	5.746	254.995	-18.054	OK

0+0280CL	16.922	271.543	-20.375	OK
0+0280LE	19.277	270.451	-20.451	OK
0+0280RE	14.383	272.401	-20.376	OK
0+0330CL	47.637	310.196	-25.035	OK
0+0330LE	49.565	308.272	-25.16	OK
0+0330RE	46.167	132.083	-24.191	OK
0+0360CL	72.614	327.266	-26.704	OK
0+0360LE	73.812	325.52	-26.692	OK
0+0360RE	71.634	328.875	-26.692	OK
0+390CL	96.313	345.497	-28.116	OK
0+0390LE	95	347.231	-28.258	OK
0+0390RE	93	350.241	-28.078	OK
CONNECTING ROAD LE	97	345.317	-28.384	OK
SHOULDER LE	99.245	343.948	-28.398	OK
DRAIN CL	93.164	350.768	-28.228	OK
0+0420CL	121.044	360.625	-26.426	OK
0+0420LE	121.182	358.946	-26.467	OK
0+0420RE	121.002	361.998	-26.383	OK
SHOULDER LE	121.386	357.833	-26.484	OK
DRAIN CL	120.956	362.545	-26.505	OK
0+0450CL	150.177	366.812	-24.964	OK
0+0450LE	150.835	365.414	-24.952	OK
0+0450RE	149.626	368.352	-24.953	OK
SHOULDER LE	150.99	364.71	-24.945	OK
SHOULDER RE	149.402	369.295	-24.939	OK
DRAIN CL	149.259	369.558	-24.938	OK
0+0470CL	168.736	374.191	-23.803	OK
0+0470LE	169.383	372.88	-23.807	OK
0+0470RE	168.31	375.577	-23.786	OK
SHOULDER LE	169.795	371.82	-23.757	OK

SHOULDER RE	167.744	376.982	-23.795	OK
DRAIN CL	167.69	377.169	-23.748	OK
ELECTRICAL POLE	163.935	369.183	-24.112	OK
HPEJ BUILDING START	164.159	366.748	-23.971	OK
HPEJ BUILDING END	184.158	375.739	-22.986	OK

Alignment corresponding to the above survey data generated from Auto CAD is shown below:

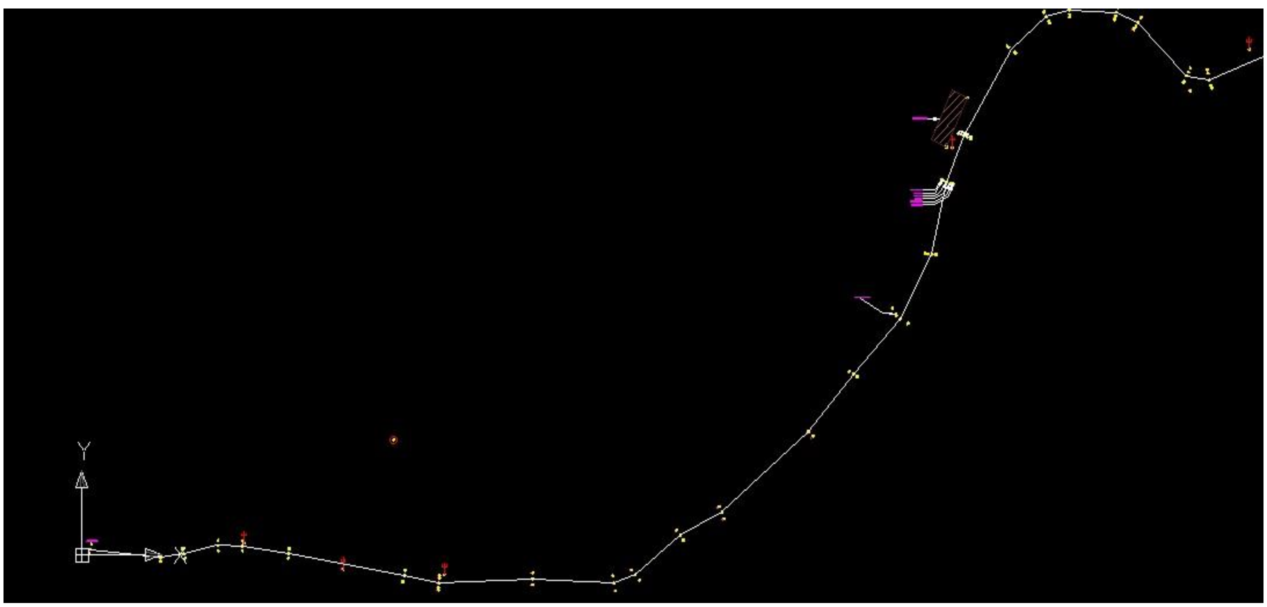


Figure 4.1 Corresponding Alignment for sample data.

4.1.1 Problem faced during surveying by total station

1. Surveying was delayed due to unfavorable climatic condition and traffic disturbance.

2. While changing the bench mark, one either needs to input the back sight coordinate of the previous point or set north angle.

3. We proceeded the survey without fixing either of the two.

4. Without transferring the data to PC from total station, data saved in the total station cannot be deleted.

4.2 Short coming of the selected road

1. Absence of Traffic Sign.

Traffic sign are very much important to warn drivers about the danger ahead.

2. Radius of Horizontal Curve and Transition Length.

Village road are generally designed for the speed of 20kph-25kph. On checking against the standard recommendations provided in IRC: 52-2001 (Table 2.5 Minimum transition length for different speeds and curve radii) we found out that some stretch of road does not have the adequate length of transition provided as shown in the Figure 4.2

3. Drainage System

We found out that existing drainage system were poorly maintained, drains were solid covered with trash and debris.

4. Retaining Walls

We found out that no retaining walls are provided on the hill side and cut side of the mountain for the selected road stretch.

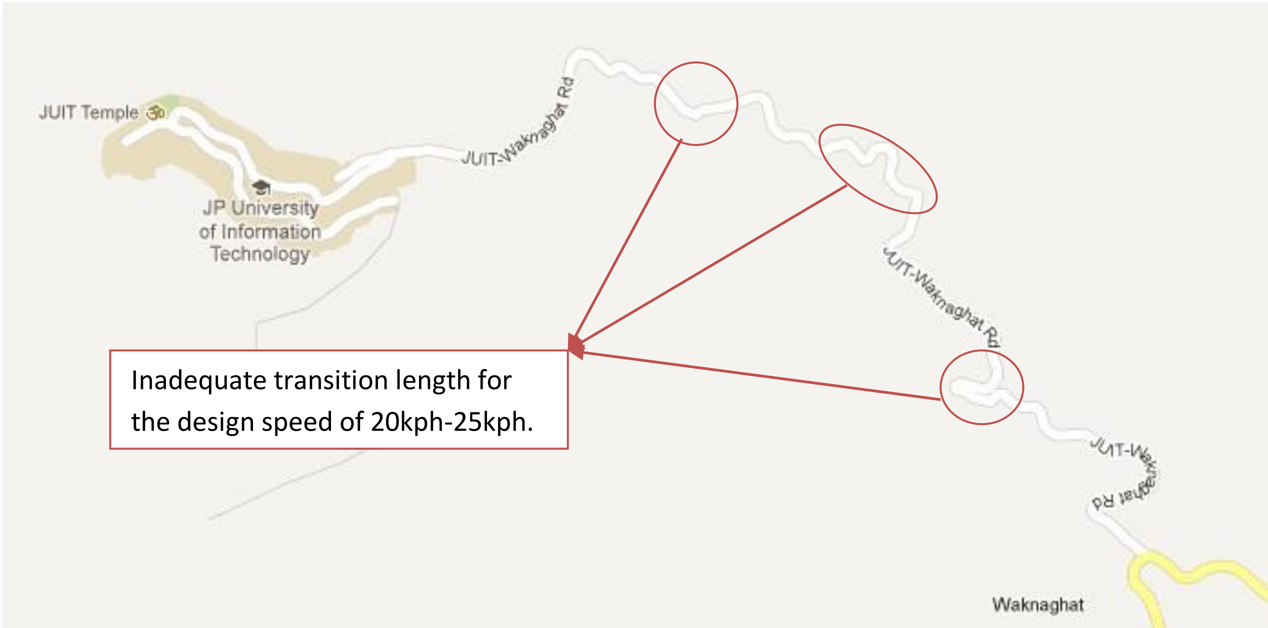


Figure 4.2 Inadequate transition length for the selected road stretch

5. Grade of Vertical Curve.

The existing road has a gradient of -9.35% for the chainage of 0100-0380, which violates the standard recommendation provided by IRC. IRC: 52-2001 recommends a gradient maximum of 8% for mountainous terrain and steep terrain. (Refer Figure 4.3)

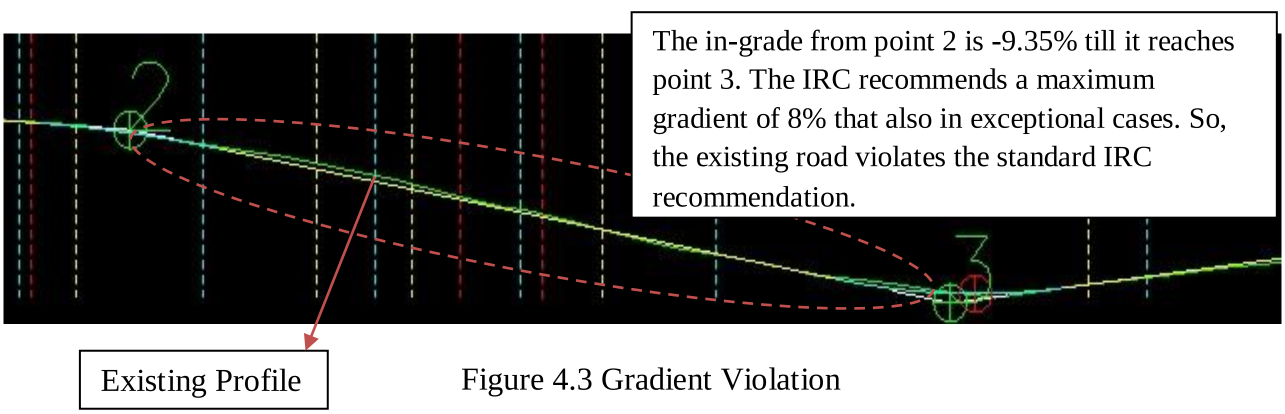


Figure 4.3 Gradient Violation

6. Set-Back Distance

We found out inadequate set back distance for some curve of the road stretch.

4.3 Geometric Alignment Design Results

Following are the summery of the result generated from MXROAD^{TM}, detail of the result are given in the CD attached along with the book. The result attached in CD includes Horizontal Alignment Report, Vertical Alignment Report and Super-elevation Report.

Horizontal Alignment

Width of Carriage-way provided 3m

Width of Shoulder provided...0.5m on either side

Design Speed Considered...20 -25kph

Total Length of Road...2888m

Total Length of Straight provided..867.445m

Total Transition Length provided...960m

Total no. of Curve provided...32nos.

Vertical Alignment

Hog Curve Start Gradient..-2

Hog Curve End Gradient...-7.5

Hog Curve Radius..1000m

Hog Curve Length..55m

Sag Curve Start Gradient...-7.5

Sag Curve End Gradient..5.915

Sag Curve Radius...500m

Sag Curve Length...67.076m

4.4 Cost Estimation

Cost Estimation for Earth-work

Total Cut Volume ....31633.557m^3

Total Fill Volume...67776.34m^3

Rate for Cut and Fill Considered...80 Rs / m^3

Total Cut Cost..2530685/-

(Rs Twenty Five Lakh Thirty Thousand Six Hundred Eighty Five)

Total Fill Cost..5422107/-

(Rs Fifty Four Lakh Twenty Two Thousand One Hundred Seven)

Total Cut and Fill Cost..7952792/-

(Rs Seventy Nine Lakh Fifty Two Thousand Seven Hundred Ninety Two)

Cost Estimation for Pavement Layer

Total Plan Area for Wearing Course..11662.66m^2

Total Plan Area for Base Course...11663.15m^2

Total Plan Area for Upper Road Base..11663.69m^2

Total Plan Area for Sub Base...11663.51m^2

CONCLUSION

We have completed an analysis and geometric design of selected road stretch, i.e. Waknaghat Chausha Road. The following recommendations are based on physical inspections of the existing road, official records, hand calculation, software (MXROAD^{TM}) analysis and design, interviews with road users and person's knowledge about the design criterion.

Recommendations

To increase the safety for the road users, Waknaghat Chausha Road should make the following changes:

- Reduce the gradient of the road to acceptable value as recommended by IRC: 52-2001 for a chainage of 0100m – 0380m.
- It is recommended to maintain the existing drainage system properly as the existing drains were solid covered with trash and debris.
- Provide traffic signs at desirable places.
- Provide adequate transition length for the varying horizontal curve as recommended by IRC: 52-2001.
- Provide retaining walls on the hill side and cut side to protect road from land slide.
- Provide adequate set back distance.

REFERENCES

1. Photos of total station, http://www.sealandsurvey.co.uk/used-total-stations/553-sokkia-set610-reflectorless.html (last accessed date is 24/09/2012)
2. Photo of Road Alignment of selected stretch from Google Earth (last accessed date is 24/09/2012)
3. S.K Khanna & C.E.G.Justo, “Highway Engineering”, 2011, Ninth Edition.
4. IRC: 52 2001 “Recommendations about the alignment survey and geometric design of hill road”, second edition.
5. Bentley MX Road official site, http://www.bentley.com/en-US/Products/Bentley+MXROAD/ (last accessed date is 2/05/2013)

APPENDIX A

A.1 CAD Environment

MX Menu contains a CAD menu. The menu can be switched between the MX and CAD by selecting CAD and then CAD Menu.

CAD toolbar loaded by default are Attributes, Primary and Main Toolbox.

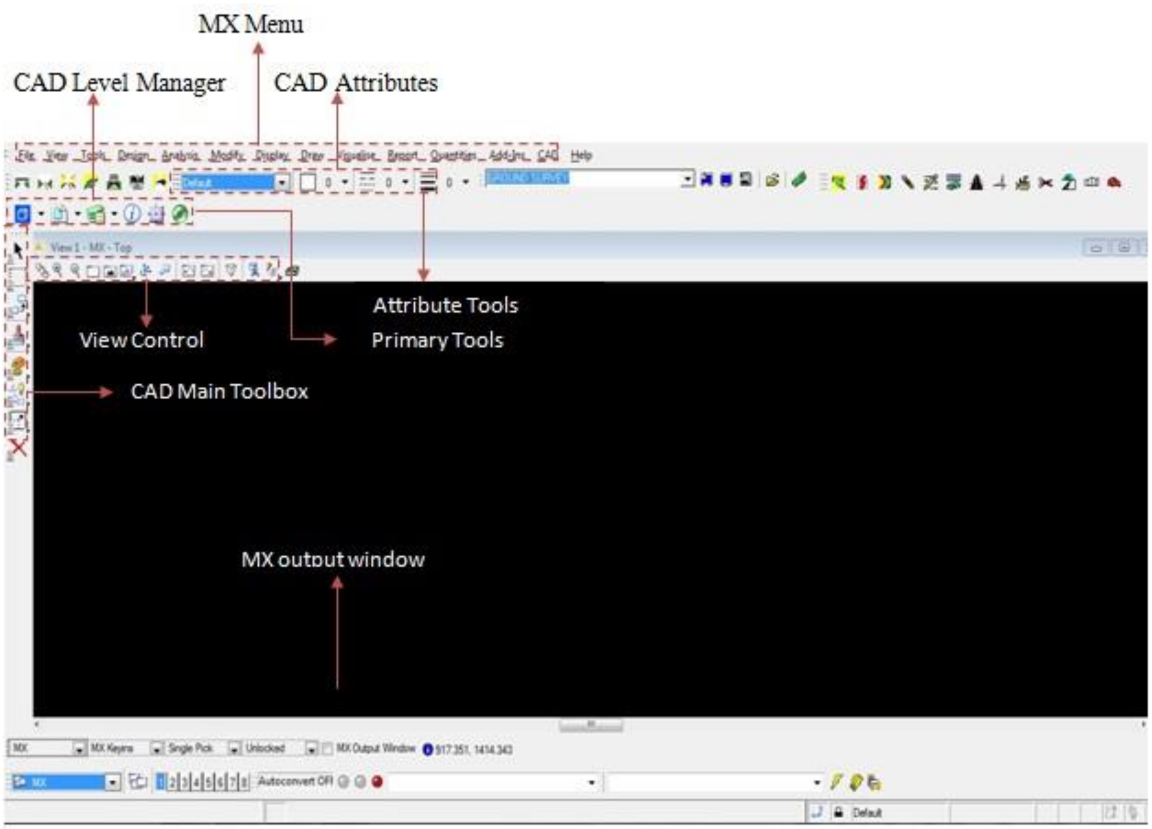


Figure A1 CAD Environment

A.2 CAD TOOLS

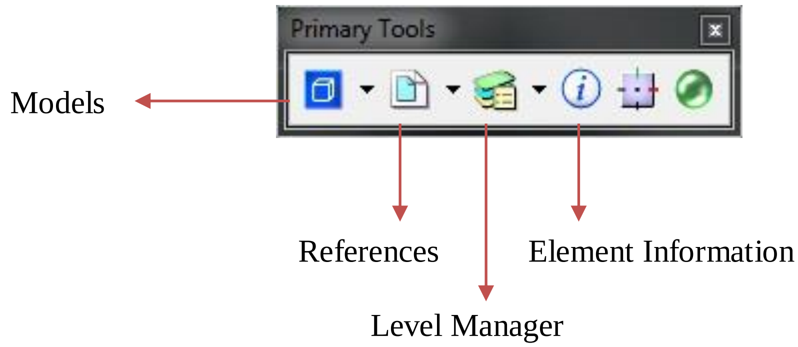


Figure A2 Primary Toolbox

Primary toolbox consists of Models, References, Level Manager and Element Information.

- Models dialog manages CAD models.
- Reference dialog is used to attach and detach reference models.
- Level Manager consists of a list of models and levels name on the left and its detail on the right.
- Element Information display element information such as its type, attribute and geometry and permits modification.

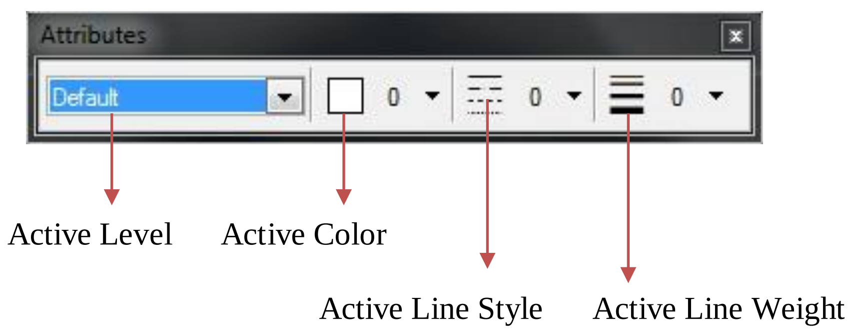


Figure A3 Attribute toolbox

Attributes toolbox sets the properties of an element and applies them to a new element or one or more elements.

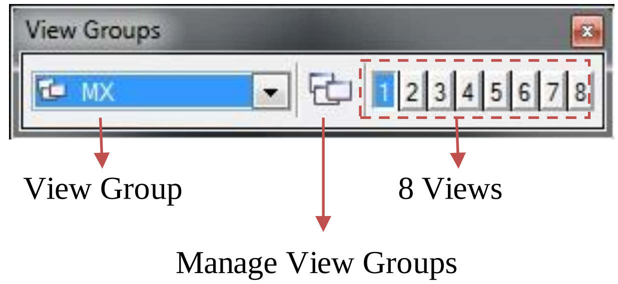


Figure A4 View Groups Toolbox

View Groups toolbox allows you to manage view groups. There are eight available view windows which allow you to setup your desktop to display your preferences including number of open view windows, window size and orientations.

A.3 MX TOOLS

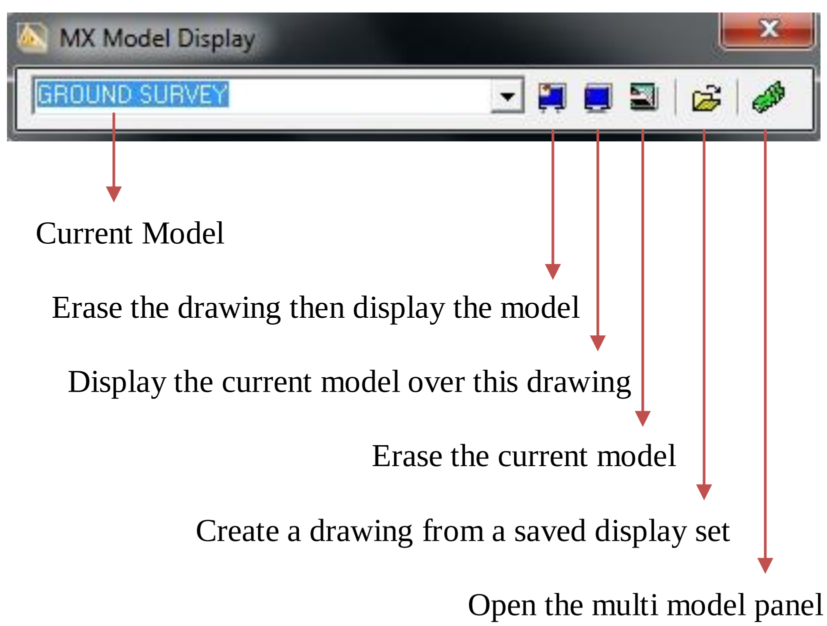


Figure A5 MX Model Display

MX model display toolbar provides quick access to most of the display manipulation options you will need to make the display meet your requirement.

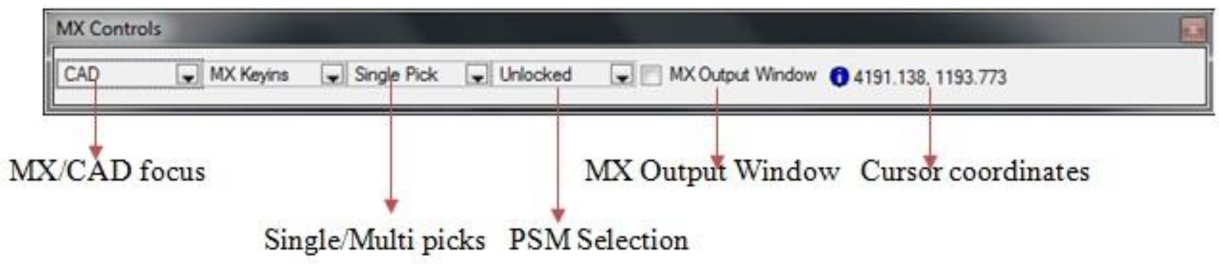


Figure A6 MX Controls

- MX/CAD focus – indicates which program currently has focus, either MX or CAD. Toggle the box to override the settings if you wish to use a CAD when you are in the middle of an MX options and vice-versa.
- PSM Selection – the point selection method mode controls how points are selected from an MX option on MX strings. Allows you to modify the current point selection method. The pull down list contains; Unlocked, Points, Chainage, Intersect, Normal and Trig XY. Generally this should be left in the unlocked mode to permit the use of native CAD snap options.
- Single/Multi picks – allow you to toggle between single and multi picks.
- MX Output Window – when checked the MX Output Window is displayed.
- Cursor Coordinates – this displays the current cursor coordinates.

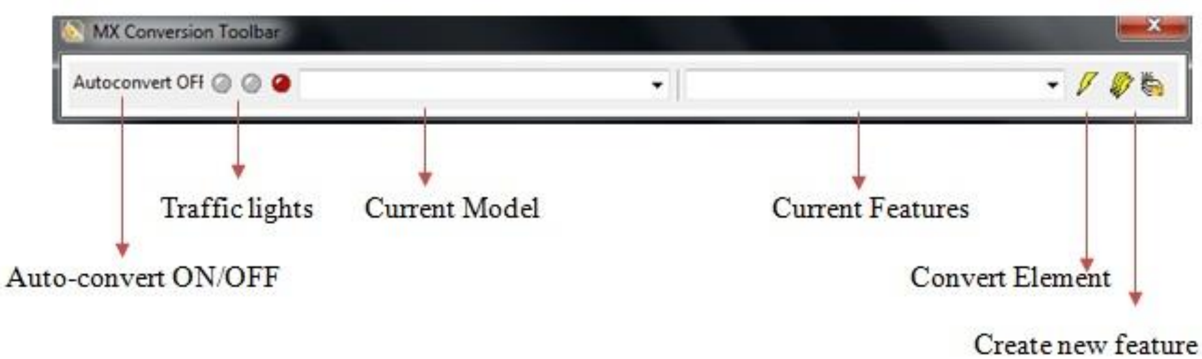


Figure A7 MX Conversion Toolbar

The traffic light provides a visual indication of whether you can create MX string using CAD or Micro Station tools.

- If a green light is displayed, then when you create a CAD or Micro Station elements on an MX level it will be automatically converted to MX string in the current displayed model.
- If an amber light is displayed, then when you create a CAD or Micro Station element you

can manually convert it to an MX string by clicking the Convert Element and then selecting the element to be converted.

To switch between automatic and manual conversion, you click and toggle the Auto-Convert ON/OFF box.

The current model is the model in which MX stings will be created. If you select an element, the current model is updated to reflect the model containing the element you have selected.

The current features are the feature type which is given to any MX string you creates using CAD or Micro Station tools. The field lists all the features in the feature set associated with the current model. If you create a CAD element, it will be created on level associated with this features.

If an amber light is displayed, select an element to be converted to MX string, then click convert element button. The element will be converted to the MX features corresponding to the level that the element is on.

A.4 Quick horizontal alignment Toolbar

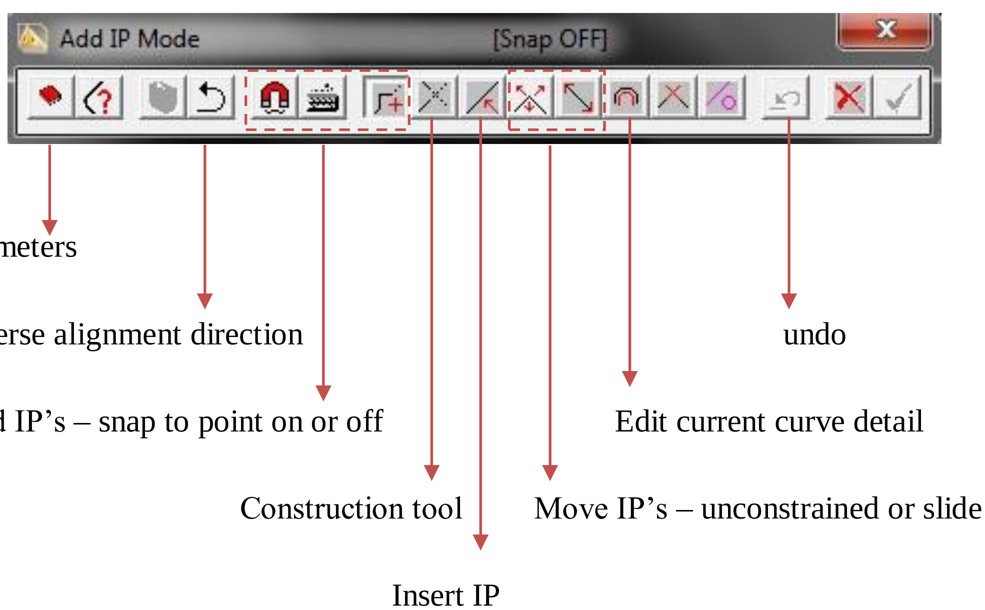


Figure A8 Quick Horizontal Alignment Toolbar

Parameter – here one can set default radius and transition parameters. Use a standard value for the scheme and change individual curves as necessary. Transition can be defined by length, A

Value or RL value. Most commonly they are defined by length and derived from the formula;

Transition length = V^3 / (46.7*0.3*radius of curve), where V= Design speed.

There is two ways of adding IP's, they are as follows:

- Select the IP position with the cursor, with snap off the selection is anywhere in the display; turn snap on and the selection will be the nearest string point when the cursor is covering a string. As one add IP's the default curve radius and transition will be added between the IP locations.
- IP's can also be added by typing in the Easting and Northing locations. This can be done by selecting the keyboard icon from the toolbar.

To amend a curves values, select the curve details icon and select the curve you wish to amend by clicking on it on the display. The current value will appear, just amend the values and select OK.

To amend an IP location by free drag, select it from the screen and with the left hand mouse button depressed move the IP to the location of your choice. Note any curves or transition associated to that IP will move along with it.

An IP location can be moved relative to a bearing of a straight you have already positioned. Click before or after the IP you wish to move and keep the left hand mouse button selected, the IP will move relative to the bearing depending on which side of the IP you have chosen.

A.5 Quick Vertical Alignment Toolbar

The vertical alignment toolbar is similar to the horizontal, but has additional functions relating to IP movement and surface snapping. In addition, you may adjust the horizontal-vertical scale relationship to suit the need of the site.

As the cursor is moved over the drawing its chainage and level shown, and the running cut-fill balance is displayed dynamically on the toolbar. If the gradient exceeds the default set by you the value is displayed on a red background, immediately drawing attention to the infringement.

You can snap to the surface-current snap surface is indicated by the colored square on the toolbar.

Change the required surface as necessary.

The vertical profile will be built using the default K-value or radii for both summit and valley curves. You may amend any individual curves, either to a new K-value or radius or by supplying the new length of the curve.

You will be advised of any curve that overlap, or extend beyond the limits of the ground profile when one attempts to finish the profile design phase. These conflicts must be resolved before the vertical design can be completed.

Curve data can be supplied through the tabular input button (Table View) if required. This data may be for a new curve or for modifying an existing one. As you supply the data the graphical display is automatically updated. Also you can leave the Table View panel active while you make changed to the positions of existing IP's graphically.

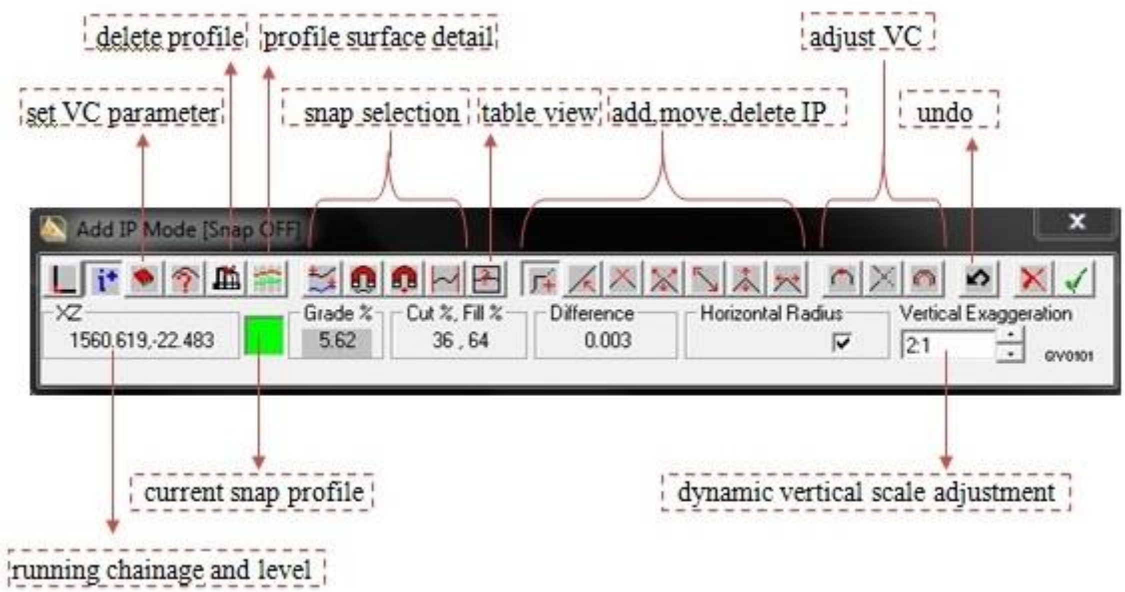


Figure A9 Quick Vertical Alignment Toolbar