DESIGN OF SUB-ARTERIAL URBAN ROAD USING MXROAD SOFTWARE

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Abstract – *The project is about Design of Urban Road using MXROAD Software and is done for a stretch of 1.51 km from Devegowda Circle to Nice Road via Kerekodi Road. The intention of this study is to import road design into the software as well as relate with design standards applied into the software. To know the existing condition of the road cross sectional elements, road inventory is done. Survey data is extracted from GIS i.e., Google Earth and road design is done using MXROAD software which is an advance string base tool that enables rapid designing of all road type with accuracy. In road design, geometric design which consists of alignment (both horizontal and vertical), carriageway, super elevation and extra widening along with road cross sectional elements which consists of shoulder, kerbs, verges and footpath followed design standard as per IRC: 86-1983. Earthwork is done in such a way that the cut and fill percent gets roughly matched. The flexible pavement design is carried out as per IRC: 37-2012 and for that traffic volume survey and CBR test is done. A detailed report of each segment is generated with great ease using MXROAD. As 27 km of road is build each day in India. So, adopting software in this practice will optimize accuracy and safety while minimizing the cost and time.*

***Key Words*: MXROAD, Google Earth, Geometric Design, Flexible Pavement, Traffic Volume Survey, CBR Test**

1. INTRODUCTION

Bengaluru is home to 2nd highest number of vehicle in India having vehicle population of about 8.4 million [1]. Statistics says that the number has more than doubled in the past 10 years, with the addition of 4 million new vehicles. There are 4.86 million two wheelers and 1.35 million four wheelers. BMTC provides transport facilities to over 5 million commuters. These buses depend on urban roads which are maintained by BBMP to carry out these populations. Total area of Bengaluru covers 741 sq.km and road length of 13000 km, increment of 1,254 percent from 1976. Roads are just developed over time but no improvements were done in order to ensure safe pedestrian traffic and non motorized facility. So, a sub arterial road is selected from a place where population of both vehicle and people has seen an enormous growth. Since growth was not planned, transport planning was also not controlled.

1.1 Project Location

The stretch selected is 1.51 km and is from *Devegowda Circle to Nice Road via Kerekodi Road*. As it covers shortest distance and connects outer ring road traffic to Raja Rajeshwari Nagar in the right via Legacy Road which makes it an important road. At the start of road up to 100m there are lots of shops and pedestrian traffic is high and PES University back gate is 400m from starting point. At 600m the road is connected to legacy road which creates three way intersection over there. From that three way intersection to Hayagreeva Temple, it is 600m. And there are residential area on both side of the road. From Hayagreeva Temple till the end of the stretch , there is low line area on the right and Hosakerehalli Lake on the left which 59.25 acre in the area where recently Chola structure is found.

Fig -1: Existing site location

1.2 MXROAD Software

MXROAD software has been created by a UK based company, Bentley System in the year 1996 which is upgraded later on as per the requirement. It is an advance string based modeling tool which enables rapid and accurate design of roads. Using MXROAD, highway engineers can finalize design alternatives and automate design and detailing processes, saving time and money as well. It uses 3D string modeling technology which is a powerful and simple method of creating 3D surface. Its database allows engineers to create and annotate 3D project models in AEC or in Windows platform. From past so many years' highway projects in India are mostly public private partnership in which private investors are challenged to maintain high standards in design and construction, because of which design engineers needs to use specially designed software like MXROAD. Its dynamic placement and functionality speeds creation of 2D and 3D alignment. The flexibility promotes design creativity and assessment of alternatives with cut/fill calculation and end result will be better quality design and its built in design rules allows to apply local, company and project standards which saves time and provide greater flexibility. Various design elements like carriageway, shoulder, kerb or verges, footways can be design effectively using MXROAD. Other design controlling pattern such as design speed, horizontal alignment, super elevation and widening can be effectively designed and controlled by MXROAD software. Earth work calculation and pavement design are also carried out and done to high accuracy by using MXROAD.

1.3 Project Objectives

- Road inventory to know the existing condition of road.
- Producing proper horizontal and vertical alignment.
- Providing proper carriageway, shoulder, kerbs, verges or footways wherever required based on IRC.
- Providing widening wherever required.
- Introducing super elevation on curves.
- Cut and fill data extraction based on earth work.
- Traffic Volume survey.
- Pavement design based on CBR value and average daily traffic.

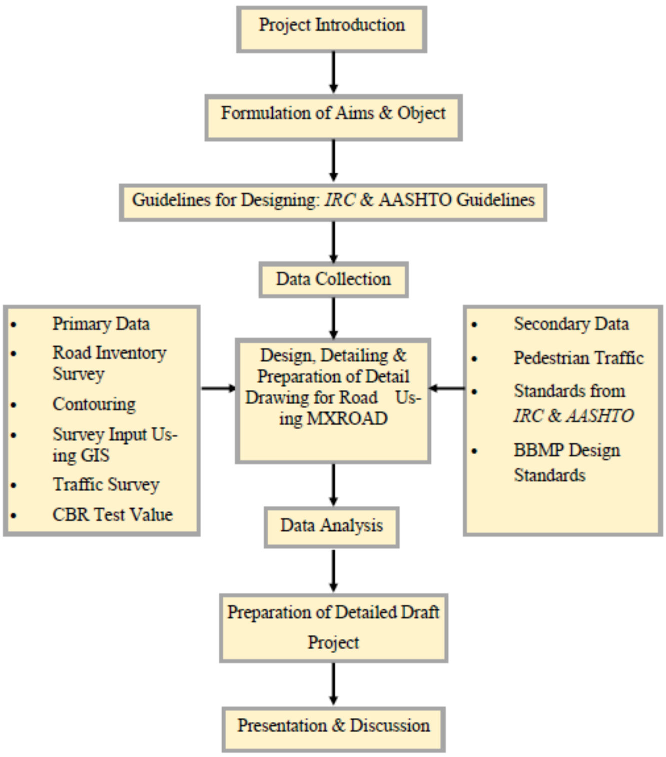

Fig -2: Flow chart of methodology

2. Field and Laboratory Investigation

In this project following surveys is conducted as listed below.

2.1 Collection of 4 Soil sample from 350m each.

Fig -3: Collection of soil sample

2.2 Road inventory

In this road inventory length of road is measured along with the land used and terrain up to that particular length. Road component like width of the carriageway and shoulder along with its present condition and type is checked.

Table -1: Summary of road inventory

Geometric features	Project Road
Length	1510 m
Width	6.92 m
Number of lanes	Two lane
Traffic movement	2-way
Divided/undivided	Undivided
Shoulder type	Unpaved
Pavement drainage condition	Poor
Road side drainage	Poor
Land use	Commercial & Residential

2.3 Traffic volume survey

Traffic volume is defined as number of vehicles crossing a section of road per unit time at any particular period. It is conducted to collect data on number of vehicles or pedestrians that pass a point on a road facility during a specified time period.

- **Average daily traffic**

We calculated the average daily traffic for a design of pavement. For design of pavement only number of commercial vehicles i.e., vehicles of gross weight of 30 KN or more will be considered [3]. For the design of two lane single carriageway road, the design should be based on 50 percent of total number of commercial vehicle in both directions [3].

According to equation [5],

ADT= 10 * No. of Commercial Vehicle in peak hour

Table -2: Number of commercial vehicle

Time	Car	Mini Bus	Bus	2-Axle Truck	3-axle Truck	JCB 3dx	Tracktor	Total
MORNING PEAK HOUR								
A to B								
08:30 to 08:45 am	38	2	3	3	2	0	0	48
08:45 to 09:00 am	48	2	2	4	2	0	2	60
09:00 to 09:15 am	58	1	1	2	1	0	0	63
09:15 to 09:30 am	43	1	1	2	0	0	0	47
09:30 to 09:45 am	46	0	2	5	1	0	0	54
09:45 to 10:00 am	42	2	2	3	1	0	0	50
10:00 to 10:15 am	47	4	1	1	2	0	1	56
10:15 to 10:30 am	56	1	2	1	2	0	0	62
B to A								
08:30 to 08:45 am	54	3	1	6	0	0	0	64
08:45 to 09:00 am	58	1	1	1	0	0	0	61
09:00 to 09:15 am	43	3	0	4	0	0	0	50
09:15 to 09:30 am	52	0	3	1	0	0	0	56
09:30 to 09:45 am	58	0	3	1	2	0	1	65
09:45 to 10:00 am	49	5	2	4	0	0	0	60
10:00 to 10:15 am	53	1	0	2	0	0	1	57
10:15 to 10:30 am	37	2	1	1	0	0	1	42
EVENING PEAK HOUR								
A to B								
Time	Car	Mini Bus	Bus	2-Axle Truck	3-axle Truck	JCB 3dx	Tracktor	Total
05:30 to 05:45 pm	25	0	0	0	0	0	0	25
05:45 to 06:00 pm	27	1	0	0	0	0	0	28
06:00 to 06:15 pm	21	0	1	2	0	0	0	24
06:15 to 06:30 pm	31	3	0	1	1	0	0	36
06:30 to 06:45 pm	25	0	2	0	0	0	0	27
06:45 to 07:00 pm	23	1	1	1	1	0	0	27
07:00 to 07:15 pm	28	1	1	1	0	0	0	31
07:15 to 07:30 pm	32	1	0	1	0	0	0	34
B to A								
05:30 to 05:45 pm	48	2	2	4	0	1	0	57
05:45 to 06:00 pm	33	0	1	0	0	0	0	34
06:00 to 06:15 pm	35	0	1	0	2	0	0	38
06:15 to 06:30 pm	29	1	0	3	0	0	1	34
06:30 to 06:45 pm	34	2	1	1	1	0	0	39
06:45 to 07:00 pm	36	0	0	0	0	1	0	37
07:00 to 07:15 pm	30	1	0	1	0	0	0	32
07:15 to 07:30 pm	31	1	1	0	1	0	0	34

No. of Commercial Vehicle in both

the direction for peak hour = 241 + 251 = 492

50% of the above value = 246

Average daily traffic = 2460 vehicle/day

2.4 Laboratory investigations

In the evaluation level laboratory description is an important feature. This would help in the field at the time of construction to know the properties of materials. For road construction works, properties of soil at subgrade level are required to be known. Soil testing is done in the laboratory as per IRC-37-2012. The laboratory tests that were conducted on soil samples are :

Table -3: Determination of OMC

Sl No.	Particulars	Unit	Mould 1	Mould 2
Determination of Bulk Density of Soil				
1	Volume of mould	cm3	1001.38	1001.38
2	Weight of Empty Mould	gm	1992	1992
3	Weight of Mould + Compacted Soil	gm	4374	4368
4	Weight of Compacted Soil	gm	2387	2376
5	Weight Density (w/v)	gm/cm3	2.376	2.376

Sl No.	Particulars	Unit	Mould 1	Mould 2
Determination of Moisture Content and Dry Density of Soil				
1	Cup Number		7-1	5-3
2	Weight of Empty Cup	gm	23.4	23.5
3	Weight of Cup + Wet Soil	gm	29.4	30.3
4	Weight of Cup + Dry Soil	gm	28.8	30.2
5	Weight of Dry Soil	gm	5.4	6.7
6	Moisture Content	%	10.3	10.4
7	Dry Density	gm/cm3	2.164	2.151

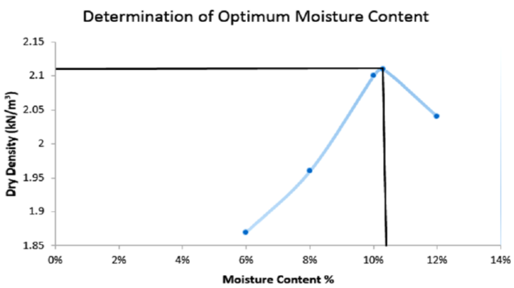

Chart -1: Moisture Content vs Dry Density

OMC = 10.3%

MDD = 2.11 kN/m^{3}.

- California Bearing Ratio

Fig -4: Making of Mould and taking reading from CBR reading

Table -4: Proving Ring Road

Penetration (mm)	Mould 1	Mould 2	Average
	Proving Ring Reading	Proving Ring Reading	Proving Ring Reading
0.0	0	0	0
0.5	5	4	5
1.0	10	9	10
1.5	15	13	14
2.0	18	14	16
2.5	20	18	19
3.0	22	20	21
4.0	25	23	24
5.0	32	30	31
7.5	37	42	40
10.0	39	52	46
12.0	54	46	50

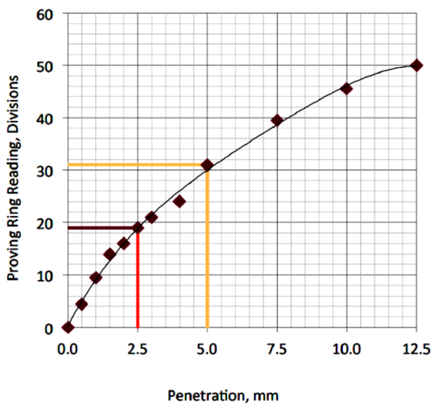

Chart -2: Penetration vs PRR Graph

From the Above Figure	PRR	Load	CBR
At 2.5 mm Penetration	19	106	8%

3. Design Proposal

3.1 Importing Survey Data from Google Earth to MXROAD

3.1.1 Creating path in Google earth

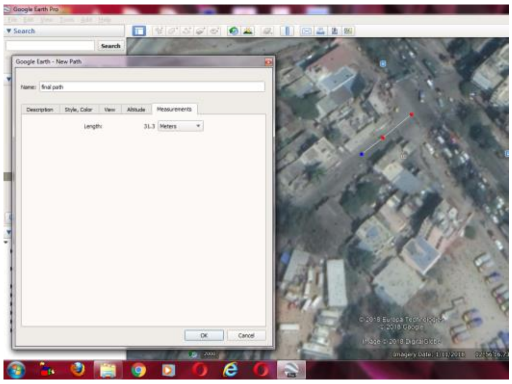

Fig -5: Creating path in Google earth

3.1.2 Adding Elevation Using GPS visualizer

- Open gpsvisualizer.com and add elevation
- File can be downloaded in gpx format

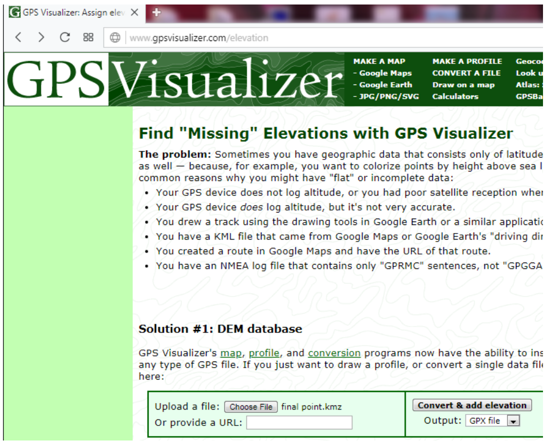

Fig -5: Adding Elevtion

3.1.3 Changing gpx to csv format using TCX convertor

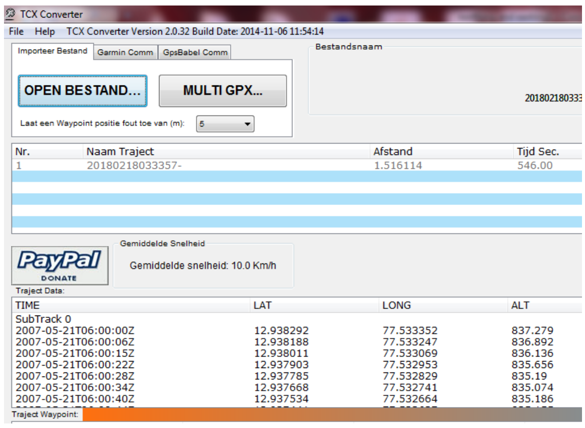

Fig -6: Converting File in Csv

3.1.4 Converting Latitude, Longitude to Northing and Easting using UTM convertor

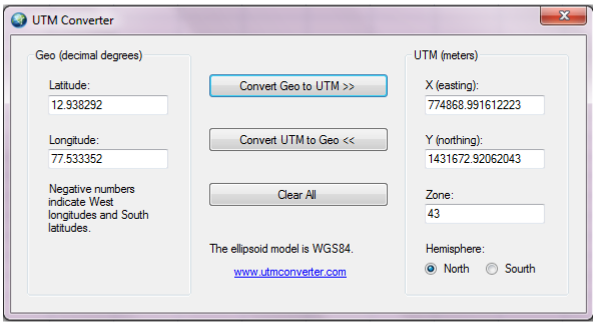

Fig -7: Changing GEO Coordinates to UTM

After that in csv file string name of centerline is included and by using ASCII import command, it is imported.

774869	1431673	837.279	C001

Fig -8: Northing, Easting, Elevation &String name

3.2 Geometric design using MXROAD

3.2.1 Sight distance

For Sub-arterial road [4],
Design speed = 60 km/h
So, SSD = 80m
As road is dual lane single carriageway,
ISD = 2*SSD = 160m
By using equation,
$OSD = 0.28V_bt + 0.28V_bT + 2S + 0.28VT$
OSD = 376m

3.2.2 Horizontal alignment

Radius of curve,
$r = V^2/127(e+f)$
Minimum radius = 40m

Maximum radius = 150m

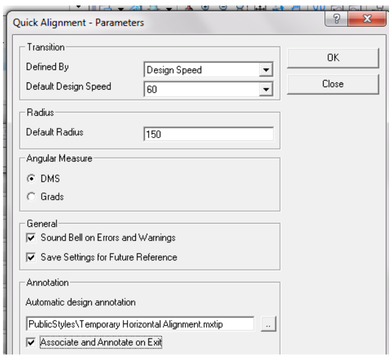

Fig -9: Parameters in Horizontal Alignment

3.2.3 Vertical Alignment

From page no. 23[4],
Maximum grade % for urban road = 4%
Minimum grade % for urban road = 0.5%
From Exhibit 3-77[6],
Hog curve K value = 195
From Exhibit 3-79[6],
Sag curve k value = 18
Minimum Length of vertical curve = 40m(From Table 14[4])

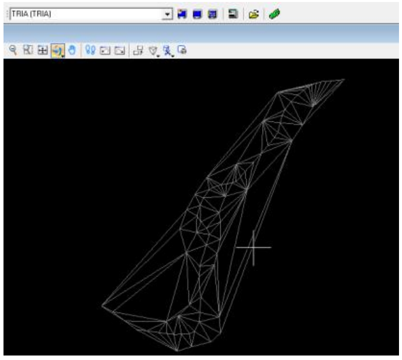

Fig -10: Traingulation model

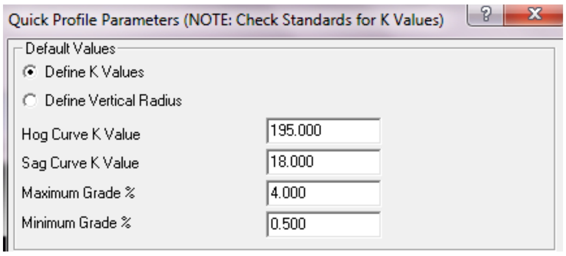

Fig -11: Parameters in Vertical alignment

Creating Vertical Alignment using Add IP mode:

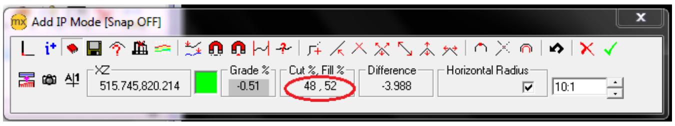

Fig -12: Add IP mode

3.2.4 Carriageway

From Table 5[4],

Width of Carriageway

2- Lane with Kerbs = 7.50m

Camber should be between 1.7 – 3.0 %

In urban roads of Bengaluru = 2%

No median is provided because IRC suggest median in urban road should be provided in 4 to 6 lanes.

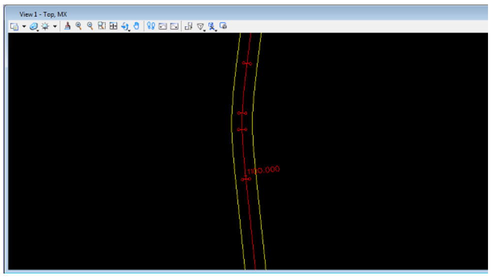

Fig -13: Carriageway design

3.2.5 Super elevation

Maximum Super elevation is calculated using,
Design of Super elevation concept by considering 75% of design speed,

$R_{ruling} = (0.278V)^2 / g(e+f)$

$R_{ruling} = 130\text{m}$

And $e = (0.75*0.278*V)^2 / gR$

$e = 0.1222 > 0.07$

So, maximum SE = 0.07 provided if f < 0.15
and f came out to be = 0.148 .
So, Maximum e = 0.07
Radius beyond which no super elevation is required = 800m

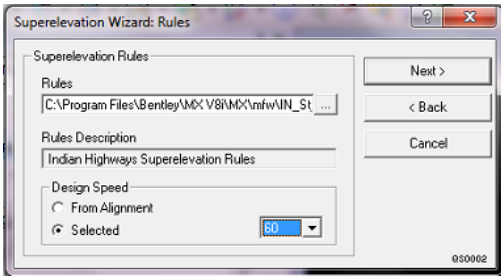

Fig -14: Super elevation Rules

3.2.6 Widening

It is calculated using,

$$w = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

So, it is different for different speed and curve radius

- Taper

TD = VW/3.6 TM = VW/2.16
where V is taken as 85% of v.

- When R>300m no widening is provided

Fig -15: Widening parameter

3.2.7 Road cross sectional element

- Shoulder:

Width of shoulder = 2.5m
Camber for shoulder = 2.5% (2.0%+0.5%)
Stretch where there is valley ,
Shoulder width provided = 2m

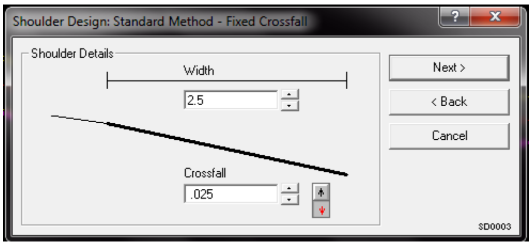

Fig -16: Shoulder parameters

- Kerbs, Verges and Footways:

Where Pedestrian traffic is high,
Kerbs = 20 cm (Barrier)(0 to 120m & 610 to 1140m)
And Footpath = 2m
Where Pedestrian traffic is medium,
Kerbs provided = 10cm (Mountable)(140 to 530m)
Where Pedestrian traffic is low and valley on side,
Verges provided = 2.5m (1160 to 1510m)

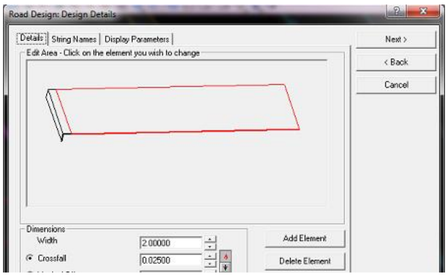

Fig -17: Kerbs, Verges and Footway parameter

3.3 Earthwork

Embankment slope provided = 1 in 2

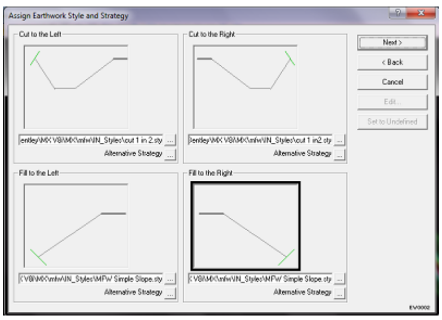

Fig -18: Cutting & Filling Style

3.4 Pavement design

Traffic in msa,

$$N = \frac{365((1+r)^n - 1)}{r} * A * D * F$$

N = 55.66msa

And CBR is taken as = 8%

As per Chart given in Page 27 [3],

Binder Course = 41 mm

Dense Bituminous Macadam = 102 mm

Granular Base = 250 mm

Granular Sub Base = 200 mm

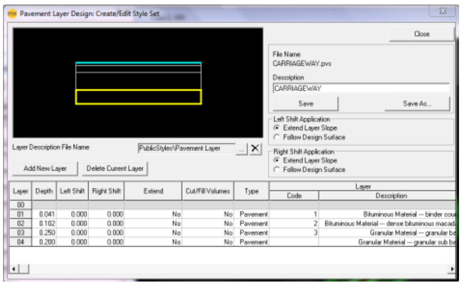

Fig -19: Pavement Design Parameters

4. Output from Software

- Horizontal Alignment

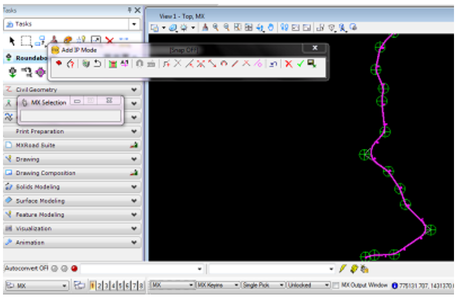

Fig -20: Horizontal Alignment Preview

Table -5: Horizontal Report Curve 1

Horizontal Alignment Report Model: DESIGN String: MC00 Units: Metric Date: 16/04/2018 at 10:48:07 AM
********Element 1 Straight********
Bearing 77 59 33.866
Length 25.619
********Transition********
Long Tangent 12.073
Short Tangent 6.032
Chord Bearing 79 38 13.695
Chord Length 18.076
Transition Start X 774751.651
Transition Start Y 1430543.108
Transition End X 774769.433
Transition End Y 1430546.359
********Element 2 Arc********
Chord Length .706
Radius 105.000 Chord Bearing 83 07 08.295
Arc Length .706
Tangent .353
Included Angle 00 23 07.655
********Transition********
Long Tangent 12.073
Short Tangent 6.032
Chord Bearing 86 36 02.894
Chord Length 18.076
Transition Start X 774770.134
Transition Start Y 1430546.444
Transition End X 774788.178
Transition End Y 1430547.516

- Vertical Alignment

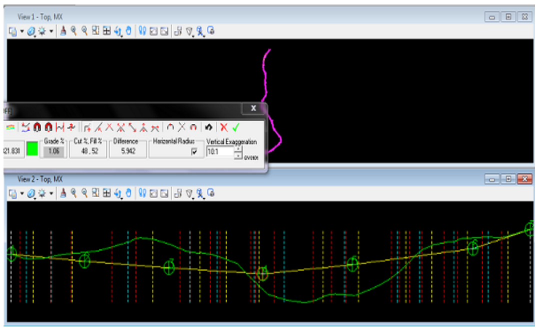

Fig -21: Vertical Alignment Preview

Table -6: Vertical Alignment Report Curve 1

Vertical Alignment Report
Model: DESIGN
String: MC00
Units: Metric
Date: 16/04/2018 at 10:55:32 AM
********Element 1 Grade********
Gradient -.765
Gradient Length 210.218
Begin on Gradient Chainage 0+000.000
Begin on Gradient Level 831.602
Gradient End Chainage 0+210.218
Gradient End Level 829.994
********Element 2 Vertical

Curve*******
Algebraic Difference .142
Curve Start Gradient -.765
Curve End Gradient -.623
Curve Length 2.549
K Value 18.000
Curve Type Sag
Vertical Radius 1799.995
Curve Start Chainage 0+210.218
Curve Start Level 829.994
Curve End Chainage 0+212.767
Curve End Level 829.976

- Super elevation

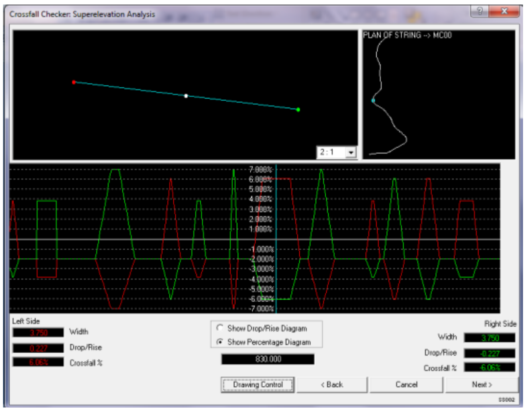

Fig -22: Cross fall checker Preview of Super Elevation

Table -7: Superelevation Report of Curve 1

Super Elevation Values Model Name = DESIGN Reference String = MC00 Rules = PublicStyles\India 2-lane UrbanRoad.srl Design Speed = 60 Pivot Method = 4 Slope/Gradient Units = Dec %				
	Curve Section Type			
	1 Normal Crown In	1 Full Super In	1 Full Super Out	1 Normal Crown Out
Chainage Defined	25.619	43.701	44.407	62.489
Chainage Rules	25.619	43.701	44.407	62.489
Left Slope Defined	-0.0200	0.0381	0.0381	-0.0200
Left Slope Rules	-0.0200	0.0381	0.0381	-0.0200
Right Slope Defined	-0.0200	-0.0381	-0.0381	-0.0200
Right Slope Rules	-0.0200	-0.0381	-0.0381	-0.0200
Length Defined	18.082			
Length Rules	18.082			
Grade Defined	0.0120			
Grade Rules	0.0120			
Radius	105			

- Extra Widening

For Curve 1,
$W_e = 0.86$
TD = 10.15
TM = 16.92

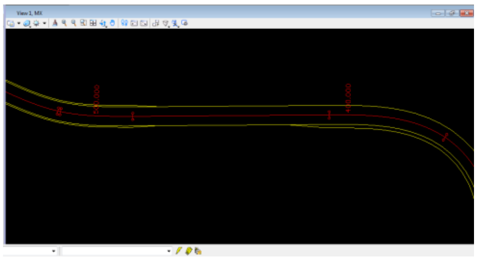

Fig -23: Widening Preview

- Shoulder

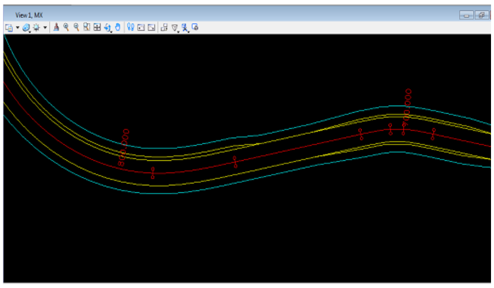

Fig -24: Shoulder Preview

- Kerbs, Verges and Footway

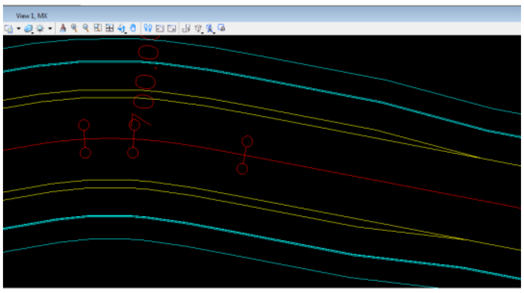

Fig -25: Kerbs, Verges and Footway Preview

- Earthwork

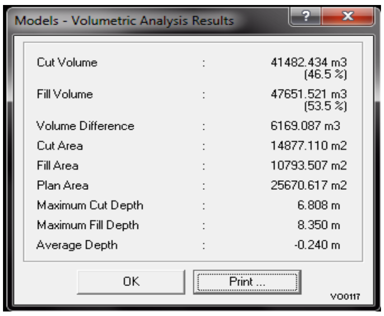

Fig -26: Earthwork Result

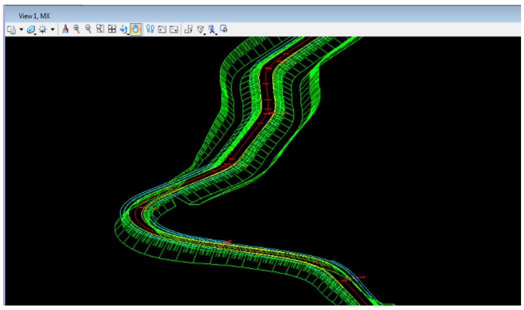

Fig -27: Earthwork Preview

- Pavement Design

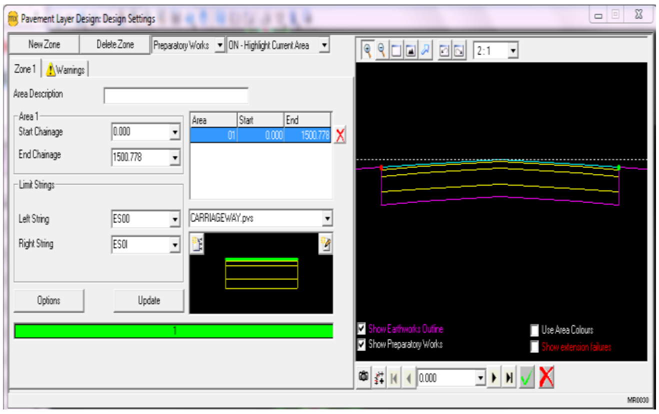

Fig -28: Pavement Design Parameter

Table -8: Pavement Design Report for 0 to 20 Chainage

	Chainage	Description	Depth	Volume	Plan Area
Pavement	0	binder course	0.041	0	0
	0	dense bituminous macadam	0.102	0	0
	0	granular base	0.25	0	0
	0	granular sub base	0.2	0	0
Pavement	10	binder course	0.041	4.72	115.02
	10	dense bituminous macadam	0.102	11.73	115.02
	10	Grgranular base	0.25	28.75	115.02
	10	granular sub base	0.2	23	115.02
Pavement	15.469	binder course	0.041	2.58	62.91
	15.469	dense bituminous macadam	0.102	6.42	62.91
	15.469	granular base	0.25	15.73	62.91
	15.469	granular sub base	0.2	12.58	62.91
Pavement	20	binder course	0.041	2.17	52.99
	20	dense bituminous macadam	0.102	5.4	52.99
	20	granular base	0.25	13.25	52.99
	20	granular sub base	0.2	10.6	52.99

5. CONCLUSIONS

- The proposed alignment is designed to match with the existing alignment but got some deviation considering IRC value.
- Design speed are formulated for ruling design speed of 60 km/h and minimum design of 30 km/h.
- Alignment proposed encounters minimum horizontal curve radius of 40m at two junction where speed is restricted to minimum.
- To increase the driver's and passenger's comfort ability on each curve, super elevation up to 7% and widening up to 1.43 m is suggested.
- High design precision along with rapid designing of the road is achieved by MXROAD.

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BIOGRAPHIES

Ali Ashraf has creative approach of problem solving. He is interested in Highway and Transportation. He aims to be a Professor for further research and to use Civil Engineering application for betterment of the nation.

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