

DESIGN AND ANALYSIS OF CURVES IN TWO-LANE HIGHWAY USING MX ROAD SOFTWARE

A

Project Report

*Submitted in partial fulfillment for the requirement for the award of the Degree
of*

BACHELOR OF TECHNOLOGY

IN

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Under the supervision

of

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by

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DEPARTMENT OF CIVIL ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

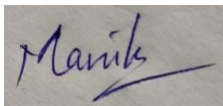
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May – 2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the project report entitled “**DESIGN AND ANALYSIS OF CURVES IN TWO-LANE HIGHWAY USING MX ROAD SOFTWARE**” submitted in partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Wagnaghat** is an authentic record of my work carried out under the supervision of **Dr. Amardeep** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Wagnaghat. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.



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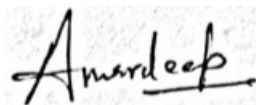
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CERTIFICATE

This is to certify that the work which is being presented in the project report titled “**DESIGN AND ANALYSIS OF CURVES IN TWO-LANE HIGHWAY USING MX ROAD SOFTWARE**” in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering, submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Wagnaghat** is an authentic record of work carried out by **Manik Sharma (171683)** during a period from August, 2020 to May, 2021 under the supervision of **Dr. Amardeep** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Wagnaghat.

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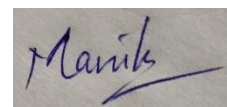
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In performing this project, I had to take the help and guidelines of some respected persons, who deserve my greatest gratitude. The completion of this project report gives much pleasure. I would like to show my gratitude to **Dr. Amardeep, Assistant Professor** for giving proper guidelines for project throughout numerous consultations. I would like to extend my deepest gratitude to all those who have directly and indirectly guided me in writing this report.

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A handwritten signature in blue ink on a light-colored background. The signature reads "Manik" in a cursive style, followed by a horizontal line that extends to the right.

Manik Sharma (171683)

ABSTRACT

The problem of Road traffic is increasing at an exceptionally fast rate, hence the traffic intensity and volume on the road is high. Improvement are required in the present road network is to accommodate the future traffic and to provide the good riding quality.

Road widening is one of the actions that can be used as the solution. However, this solution also increases the traffic performance. This is because people will switch to use the new road widened because they believe this road can accommodate the existing traffic volume. For finding out the effects of road widening toward the increasing of traffic performance and road capacity, it is necessary to conduct a research and an analysis.

Highway design concerns the design of road alignment that conforms to the site constraints and standards. The basic objectives are to optimize efficiency and safety while minimizing cost and environmental damage. Once a road/highway engineer is familiar with the basics of road geometric design, the next step to enhance their value is by learning a software for the application of these basic knowledge. The intention of this project is import road existing geometry into the software as well as relate with the design standards applied into the software. It will be able to design road geometry from checking of survey data, horizontal and vertical design, super-elevation and production of road cross sections.

Bentley MX Road is an advanced, string-based modeling tool that enables the rapid and accurate design of all road types. With MX Road, you can quickly create design alternatives to build the ideal road system. After a final design alternative is selected, you can automate much of the design detailing process, saving time and money.

The proposed road for the project is Jhalawar- Payli road (length 30.8 km), which needs to be redesigned and estimated for safety and comparison with the existing road.

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LIST OF ACRONYMS

IRC	Indian Road Congress
SH	State Highway
NH	National Highway
SSD	Stopping Sight Distance
ISD	Intermediate Sight Distance
OSD	Overtaking Sight Distance
UK	United Kingdom
AEC	Architecture, Engineering & Construction
3 D	3 Dimensional
CC	Cement Concrete
GSB	Granular Sub Base
MORTH	Ministry of Road Transport and Highways
DBM	Dense Bituminous Macadam
BC	Bituminous Concrete
IP	Intersection Point
IT	Information Technology
JUIT	Jaypee University of Information Technology
MoRTH	Ministry of Road Transport and Highway
MSA	Million Standard Axles
AADT	Average Annual Daily Traffic
CBR	California Bearing Ratio
WMM	Wet Mix Macadam
VDF	Vehicle Damage Factor
NHDP	National Highways Development Project
HS	Homogeneous Section
OMC	Optimum Moisture Content
MDD	Maximum Dry Density
LL	Liquid Limit
PI	Plasticity Index

CHAPTER 1
INTRODUCTION

1.1 GENERAL

Roads are the basic mode of transportation in India. India has a network of over 5,897,671 kilometers of roads. This is the second-largest road network in the world, after the United States with 6,645,709 kilometers. They provide transport of people and goods from one place to another. National highways are highways connecting major cities through-out the country. Indian national highways are further classified based on the width of the carriageway of the highway. The main roads in India are under huge pressure and in great need of modernization in order to handle the increased requirements of the Indian economy.

In addition to maintenance, the expansion of the network and widening of existing roads is becoming increasingly important. This would then enable the roads to handle increased traffic and also allow for a corresponding increase in the average movement speed on India's roads. This urges to the need to design the existing road profile in such a manner that the road can accommodate increased traffic and also increase the rate of movement of vehicles. With increasing road projects in India, need of a precise and fast method is required for the design processes.

Another problem is the rate of increase of accident rate due to poor profile of roads. In India, maximum of the accident are due to the lack of proper sight distance and overtaking sight distance, which arises due to curves in any road. Also, the design of curves is a lengthy and very calculative work which consumes a lot of time.

In our case, the Jhalawar- Payli road stretch is surrounded with a lot of buildings, shops, offices, schools, parks, etc. which lead to sharp curves at some points and also the curves in the road are of small radius. At some points the radius of the curve is as small as 50m where the design speed needs to be reduced to minimum.

Jesna N.M. and M.V.L.R. Anjaneyulu conducted a research on the reliability analysis of horizontal curves in two lane highways, in which they found that the reliability of a horizontal curve was directly and most dependent on the radius of the curve. The reliability index they defined was directly proportional to safety. Hence, more the radius of the curve more will be the safety of that curve.

Solution can be found in form of an analytical software such as MX Road or Open Roads Designer software designed by Bentley which enables rapid and accurate design of all road types. Softwares not only help in precision and proper calculations but also reduce time required in designing. In MX Road, the 3D rendering gives a proper idea of the designed road, earthwork design, horizontal and vertical profile of road. In the new design the horizontal and vertical alignment of the roads will be changed according to proper sight distances and increased curve radii in order to attain maximum speed safely.

Details of project area: Existing road profile of a two-lane road of Jhalawar district (Jhalawar-Payli road) was given which needed to be redesigned for safety purposes. The objective was to design horizontal and vertical alignments for the new widened road.

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

Already, various research studies and investigations have been conducted on design of highways using different analysis softwares to make the design work easy and quick. Below are some of the reports and journals presented by the authors within India and throughout the world.

2.2 STUDIES CONDUCTED

1. **Srikiran et al (2018)** made geometric design of NH-9 from Humnabad to Sangareddy (10km stretch) with the main objective of improving horizontal curves by increasing radius of curvature to four lane standards and to design vertical profile in accordance with sight distance, gradients and economical aspects.

The design speed of 100kmph was achieved for the 10km stretch by increasing the radius of horizontal curves and, in accordance with sight distance and gradient for vertical curves to achieve maximum speed.

2. **Ali et al (2018)** designed sub-arterial urban road for which stretch selected is 1.51 km and is from Devegowda Circle to Nice Road via Kerekodi Road. The alignment encountered minimum horizontal curve radius of 40m for which the design speed was restricted to minimum i.e., 30kmph. The design is formulated for ruling design speed of 60 kmph and minimum design speed of 30 kmph. MX road was used for high design precision along with rapid designing of road.
3. **Srikanth and Raveesh (2019)** designed rigid pavement from Thullar to Amravati in Andhra Pradesh in which, the main focus was on increasing radius of horizontal curves in order to reduce accident rate on the highway. The ruling design speed and the minimum design speed for the design was 100kmph and 30kmph respectively. The proposed alignment encountered minimum horizontal curve radius at two minor junctions, where the speeds were restricted to minimum. High design precision and saving in time were achieved by using MXROAD.
4. **Akshay et al (2018)** made geometric design of a stretch from Nawadih to Chandwa of NH 99 in which main objective was provision of a road that is safe to travel on for all road users at the suitable travel speed and provide vertical and horizontal geometry improvement using MX Road software. Horizontal and vertical profile was developed for the design speed of 100 kmph.

5. **Kumar et al (2015)** made geometric design of SH-131 with main objective to upgrade the existing geometric design of the SH by improving its geometric features by using MXROAD software.
6. **Malooa et al (2016)** conducted a study in Chikurde and Bhulane in Maharashtra for standardizing baseline surveys for roads and transportation sector. This framework can be used for villages in varying stages of development, with minor changes according to available tools and capacity. This can be helpful in designing or upgradation of existing road profile for villages by use of softwares like Open Roads software and MX Road software.
7. **Das et al (2016)** observed that in curves the vehicle tends to moves towards the center compared to straight stretch. . It was also observed that as the radius increases the vehicle is shifting towards the center.
8. **Nazimuddin et al (2017)** designed alignment to match with the existing alignment at major cross drainage sections. Design speeds are formulated for ruling Design Speed of 100 kmph and minimum design speed of 30 kmph. The proposed alignment encounters minimum horizontal curve radius at two minor junctions, where the speeds are restricted to minimum. Limiting gradient values are adopted for few sections where site restriction prevails.
9. **Horníček and Rakowski (2017)** designed method applying the crack propagation barrier (a geogrid in combination with underlying sand and overlying granular material) which represented an effective long-term means against the appearance of reflective cracks, applied on existing road constructions planned for reconstructions without the necessity of removing the concrete layer. The best results were reached in using a combination of a geogrid, a 100 mm layer of crushed aggregates and a 150 mm layer of asphalt. Even after the exposition of this construction to 2 million loading cycles with a contact stress of up to 0.55 MPa, only little cracks on the asphalt layer surface were detected.
10. **Kozlov et al (2017)** designed infrared toll stations. It should be mentioned that in Russia over the past decade there has been a substitution of labour consuming in operation by ease to operate toll stations despite their high maintenance costs.
11. **Yao et al (2019)** from the physical model test results concluded that the settlement of foundation will increase when the surcharge load increases. The foundation settlement will decrease as the increase of column length at the same area replacement ratio and

surcharge load. As the surcharge load increases, the settlement difference between foundation with longer column and shorter column will also increase.

12. **Kefei et al (2016)** designed Atomic Force Microscope (AFM) which can be used to measure the surface characteristic of warm mix asphalt binders and the adhesion force between the asphalt and the mineral aggregate. The method of the preparation of samples and the test method adopted in this work are valid and feasible.
13. **Hossain et al (2019)** concluded that with regard to Axle Load Spectra (ALS) distribution for the Class 9 single axle vehicles, the Level 1 peak value was found to be approximately 8 to 12% higher than the default (Level 3) values. In case of Class 9 tandem axles, the Level 1 peak values were approximately 3 to 4% higher than the default values.
14. **Dive et al (2016)** observed that number of rutting cycles increase by 4.48% with change in thickness of base layer from 300 mm to 450 mm. However, the same increase is only 2.47% when the change in thickness is from 450 mm to 600 mm. From the observations, it is concluded that the increase in thickness of the base layer and increase in its elastic modulus reduces the damage due to rutting, while it has less effect on damage due to fatigue. Also, the number of fatigue cycles increase by 5.13% due to variation of elastic modulus of base layer from 100 MPa to 300 MPa.
15. **Sabih et al (2018)** concluded that concrete strength increases with increase in elastic modulus and modulus of rupture values which results in an improved performance of concrete pavement. These material properties have significant impact on transverse cracking, slight effect on pavement roughness and no effect on joint faulting as observed from the simulation results.
16. **Martin et al (2016)** concluded that the flood-affected pavement sections had a rapid reduction in the structural and subgrade strength. The rapid reduction in structural and subgrade strength caused rapid deterioration of the surface condition, such as roughness and rutting. Pavements with weakened subgrade condition deteriorate rapidly when traffic starts to use the road again. Thus, a flooding event is directly related to the accelerated deterioration of the pavements as well as an increasing need for rehabilitation.
17. **Chen et al (2016)** designed cyclic fuzzy set model is physically intuitive and easy to visualize with the aid of membership functions. The cyclic fuzzy set model provides analytical and simple geometrical interpretation to formulate hardening, hysteresis

features, materials memory, and kinematic mechanisms without invoking complex analytical formulations.

18. **Luo et al (2016)** concluded the general equation of beam deformation on elastic foundation was deduced in this paper. Considering dowel bar encased in concrete pavement could be regarded as the modification of semi-infinite beam, the solution for deformation, bending moment and shearing force of dowel bar was obtained.
19. **Svatovskaya et al (2017)** concluded that soling, aerating and phosphating can be used for technology of soil simultaneous strengthening and detoxication.
20. **Grygierek et al (2017)** concluded that the effectiveness of geogrids application and their influence on the increase in the aggregate layer's stiffness is the subject the research continued. Authors do plan test on full scale pavement trafficked by heavy vehicles as continuation of laboratory part. Experimental section was already constructed and measurements are ongoing.
21. **Peng and Zornberg et al (2017)** concluded that the use of transparent soil and image processing techniques adopted in this study were found to be adequate to capture displacements and deformations without creating physical disturbances at the soil-geosynthetic interface.

2.3 SUMMARY OF LITERATURE REVIEW

Although many researches and studies have been conducted about design of highways but, softwares have enhanced the work in very effective way. The design and analysis for horizontal and vertical profile of road has been an easy task by the use of softwares such as MX road and Open Roads Designer. The new alignment can be designed to best fit the existing road alignment. Comparison between existing and new vertical profile can be made while designing the vertical profile. Super elevation can be defined according the codes in the software.

Baseline surveys or maps can be helpful in designing or upgradation of existing road profile for villages by use of softwares like Open Roads software and MX Road software. Softwares have made designing of safe roads, e.g., if an existing road is having curves with less radius, they can be re-designed with curves of larger radii and hence, make the road safer with decreased accident rate.

2.4 OBJECTIVE OF THE STUDY

- To keep an effective radius of horizontal curves in order to have good lateral placement of vehicles and hence, reduction in accidents.
- To study baseline maps of existing road while designing new road profile in order to save time and money.
- To provide safe sight distance and gradient in accordance to achieve maximum speed.
- To make a more safe and economic design.

CHAPTER 3
METHODOLOGY

3.1 GENERAL

In the chronological overall view of methodology, first studied research conducted in India regarding the design and software. Identified the problem and then its solution based on the learnings from the literature review. Then, accordingly collected data for new design which included the widening as well as increasing radii of curves of the highway, further selected suitable design data for the new design. Defined new centreline, for the same designed horizontal and vertical profile, superelevation, cross sections, earthwork, pavement and sub-grade design and hence, estimation.

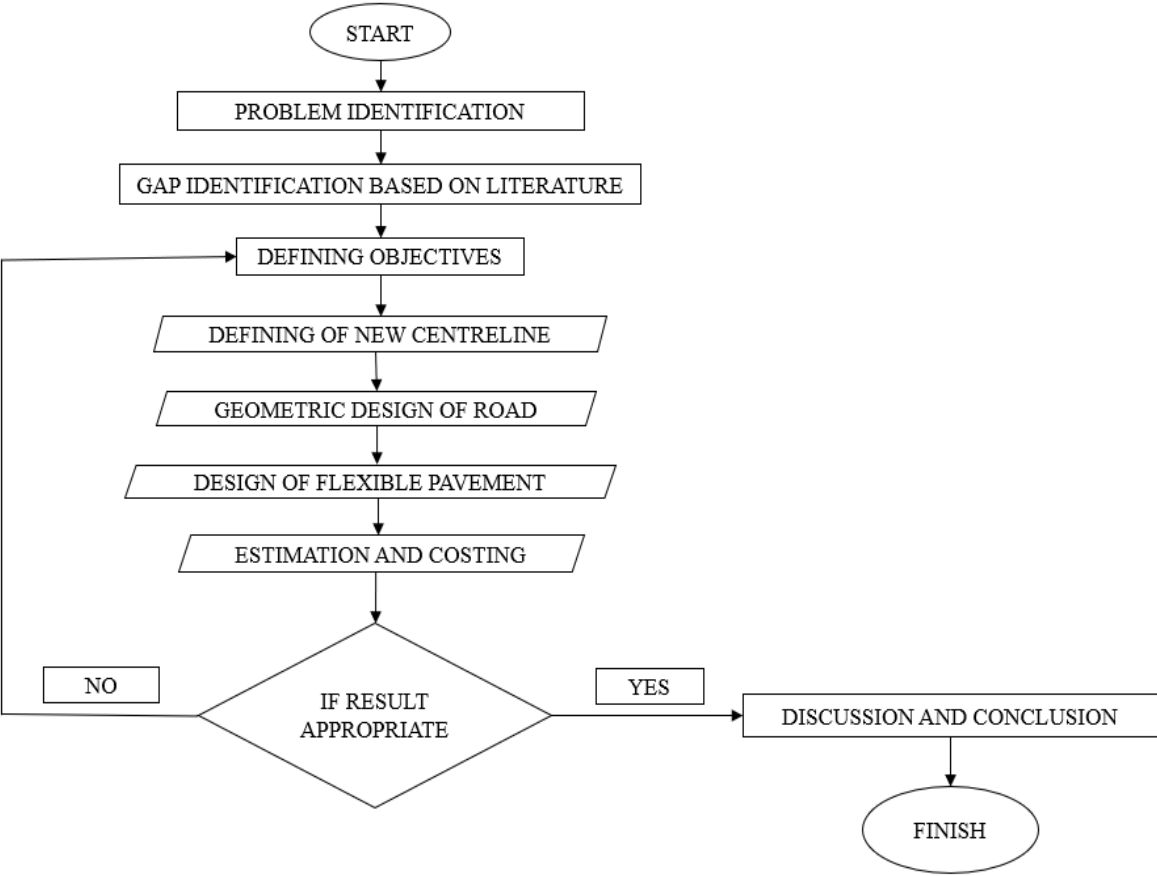


Fig. No. 3.1 Methodology flowchart

3.2 MX ROAD SOFTWARE

3.2.1 ABOUT THE SOFTWARE

MX Road has been created by Bentley Systems, a UK based company which is then upgraded in later years as per requirement to get desired accuracy with rapid designing of highways. This is an advanced string-based modeling tool that enables the rapid and accurate design of all types of road. By using MX Road, highway designer can finalize design alternatives and can automate much of the design detailing processes, saving time and money. At its core MX Road uses 3D string modeling technology a powerful yet simple method of creating 3D surfaces. The interoperable database allows engineers to create and annotate 3D project models in the most popular AEC platforms or in windows. In recent, highway projects in India are Public Private Partnership based where private investors are challenged to maintain high standards in design and construction. This scenario leads the design engineers to use specially designed software tools like MX Road.

3.2.2 APPLICATIONS OF THE SOFTWARE

It attains high precision in building the road with in the limited land width so as to minimize the land acquisition cost which is vital parameter that affects the total project cost directly. It also helps in fixing the horizontal alignment for an up-gradation project to match up with the existing align of the cross-drainage structure and in fixing the vertical profile to match up with the existing levels of the cross-drainage structures. Various geometric design elements such as carriageways, shoulder can be designed effectively by using MX Road. Other design controlling parameters such as design speed, horizontal curvature, super elevation and vertical curvature can also be effectively designed and controlled by MX Road software.

3.3 TYPES OF PAVEMENTS

3.3.1 FLEXIBLE PAVEMENT

Flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The flexible pavement layers may reflect the non-recoverable as well as recoverable deformations of the lower layers including the subgrade on to the upper layers and also to the pavement surface. Thus, if the lower layer of the pavement or soil subgrade gets deformed or undulated due to permanent deformation, the flexible pavement layers and also the pavement surface may get undulated to somewhat similar pattern.

- Some important features of flexible pavement are:
 - It has no flexural strength.
 - It reflects the deformation of lower layers.
 - It will transmit the vertical compressive stress to bottom layers by grain to grain transfer.

The lower layer has to take up only lesser magnitudes of stress and there is no direct wearing action due to traffic loads. Therefore, inferior materials with low cost can be used in the lower layers.

3.3.2 RIGID PAVEMENT

Rigid pavements are those which possess noteworthy flexural strength or flexural rigidity. These are generally made of Portland cement concrete (CC) and therefore called CC pavements. In rigid pavements the stresses are not transferred from grain to grain to the lower layers as in the case of flexible pavement layers. The rigid pavement is capable of transmitting the wheel load through a much wider area below the pavement slab. The rigid pavement does not get deformed to the shape of the supporting layer below, as the pavement slab can 'bridge' the gap or minor variations of the surface of the supporting layer below.

- Some important features of rigid pavement are:
 - It possesses flexural strength.
 - Load transfer is by the way of slab action and it distributes the wheel load to a wider area below.
 - Flexural stresses will be developed due to wheel load temperature changes.
 - Tensile stresses will be developed due to bending action of the slab under the wheel load.
 - It does not deform to the shape of lower layer, but it bridges the minor variations of the lower layer.

3.4 COMPONENTS OF FLEXIBLE PAVEMENT

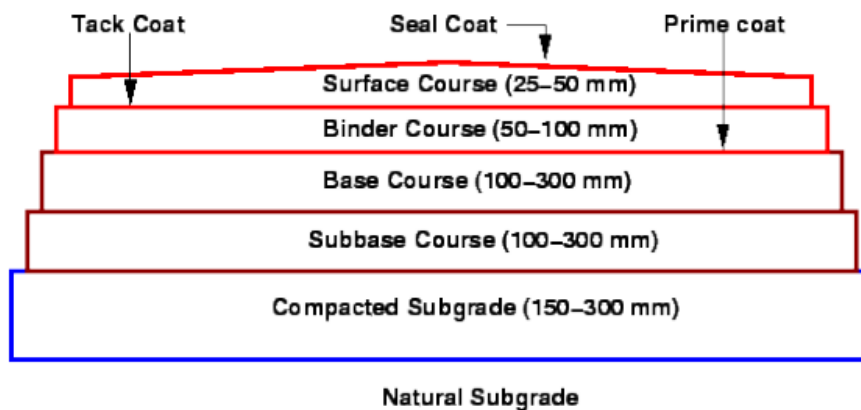


Fig. No. 3.4.1 Cross-section of a flexible pavement

3.4.1 SOIL SUBGRADE

The soil subgrade is a layer of natural or selected soil from identified borrow pits fulfilling the specified requirements and well compacted in layers to the desired density to required thickness. The subgrade is the lowest layer of the pavement layer system which ultimately supports all other pavement component layers and the traffic loads. It is essential that at no time, the soil subgrade is over-stressed. This means that the pressure or vertical stress transmitted on the top of the subgrade is such that the vertical strain produced is well within the desired limit. The minimum thickness of compacted subgrade is 500 mm on National and State Highways and major arterial roads, and 300 mm for rural roads which carry low volume of traffic, in India. It is also necessary to keep the subgrade and other pavement layers well drained so as to retain maximum possible strength of this soil to provide adequate subgrade support to the pavement structure throughout the year. This helps the designer to adopt the suitable values of the strength parameter for design purposes.

3.4.2 GRANULAR SUB-BASE AND DRAINAGE LAYER

The GSB course has to serve as an effective drainage layer of the pavements and also has to sustain lower magnitude of compressive stresses than the base course. Therefore, aggregates of lower strength having good permeability may be used in the GSB layer. Crushed stone aggregates are often used in the GSB layer of important highways as this material has high permeability and serves as an effective drainage layer. Coarse graded aggregates with low percentage of fines (less than 5 % finer than 0.075 mm size) will serve as a good drainage layer.

3.4.3 GRANULAR BASE COURSE

The granular base course is considered as the most important component of flexible pavement layer which sustains the wheel load stresses and disperses through larger area on to the GSB layer below. A good base course enhances the load carrying capacity of the flexible pavement structure. Good quality coarse aggregates are generally used in the granular base course of flexible pavements. As per the specifications laid down by the Ministry of Road Transport and Highways, Govt. of India (MoRTH), the aggregates used in the base course should have low Aggregate Impact value (less than 30 %) and low Los Angeles abrasion value (less than 40 %).

3.4.4 THIN BITUMINOUS SURFACE

The thin bituminous surface course prevents the entry of surface water into the pavement layers during the rains and thus protects the base course and other pavement layers below. With a good surfacing and an effective drainage layer, it is possible to keep the soil subgrade in relatively dry condition and retain its stability. The bituminous surfacing serves as a wearing course for the traffic and provides a dust-free pavement surface under dry weather.

3.4.5 THICK BITUMINOUS BINDER AND SURFACE COURSES

Thicker layers of dense graded bituminous surface course along with a dense graded bituminous binder course are generally adopted on stretches of Expressways, National and State Highways and other arterial roads which cater for heavy to very heavy traffic volume with a high proportion of heavy commercial vehicles. Mix design of these dense bituminous mixes used in these thick layers of binder and surface courses of flexible pavements are to be carried out to fulfil the specified mix design criteria. Marshall stability test and mix design method has been recommended by the IRC for designing the dense bituminous mixes such as Dense Bituminous Macadam (DBM) binder course and Bituminous Concrete (BC) surface course in India.

3.5 DETAILS OF PROJECT AREA

A case study of a state highway (Jhalawar- Payli road) is considered as shown in Figure. Jhalawar is a city in the Indian state of Rajasthan. It is located in the south-eastern location of the state. It has an average elevation of 312 metres (1023 feet). With existing 2 lane width of 7m is redesigned with increased curve radius for safety.



Fig. No. 3.5.1 Locating study area from Google Earth

In order to carry out this research a different method is used for both Geometric and Pavement Design of highway by use of MX Road software. The ground profile of the existing 2 lane road from Jhalawar to Payli was given using which the new 2 lane road is to be designed for the given stretch.

3.6 DESIGN DATA FOR GEOMETRIC DESIGN

Table No. 3.6.1 Design data

Sr. No	Description	Details
1.	Design Speed	80/30 kmph
2.	Carriageway width	7 m
3.	Camber (Paved surface)	2.50%
4.	Camber (Earthen surface)	3.00%
5.	Embankment slope	1V: 2H
6.	Maximum super elevation	7.00 % or 0.07
7.	Safe stopping sight distance (SSD)	120 m
8.	Intermediate sight distance (ISD)	240 m
9.	Setback distance	2- 5 m

10.	Transition lengths	30- 90 m
11.	Minimum radius of horizontal curve	230 m
12.	Radius at which no superelevation is required	1400 m
13.	Maximum gradient	3.30%
14.	Minimum gradient	0.3%
15.	Limiting gradient maximum	5%
16.	Extra widening of carriageway at curves	0.6- 0.9 m
17.	Minimum length of vertical curve	50 m

All the design values are in accordance with the IRC specifications i.e., according to IRC: 38-1988 Guidelines for Design of Horizontal Curves for Highways, IRC: SP-23-1993 Vertical curves for Highways and IRC:73-1980 Geometric Design of Standards for Rural (Non-Urban) Highways.

3.7 DESIGN OF FLEXIBLE PAVEMENT

3.7.1 EVALUATION OF DESIGN TRAFFIC

IRC: 37- 2018 pavement method require a large number of below listed parameters to be evaluated and used for the design of flexible pavement as presented in **Table 3.7.1**.

Table 3.7.1 Traffic input parameters for pavement design using IRC methods

Traffic input parameters for flexible pavement design as per IRC:37-2018
Base year traffic volumes of commercial vehicles in terms of AADT
Design period
Traffic growth rate
Composition of commercial traffic in terms of single, tandem, tridem and multi-axles
Vehicle damage factors
Lane distribution factors

3.7.2 BASE YEAR TRAFFIC VOLUMES

A detailed survey for the project road has been conducted in May, 2018 hereinafter called, “Base Year”. Detailed traffic projections over the design life and growth rates obtained for different types of vehicles are discussed in Traffic Study Report submitted separately. For the

purpose of pavement design, commercial vehicles of gross vehicle weight more than 3 tons have been considered. Such vehicles consisted of buses, LGVs, 2 axle trucks, 3 axle trucks and multi axle trucks.

Based on traffic characteristics, the project road has been divided into two homogeneous sections based on traffic estimation and the same are given in **Table 3.7.2**.

Table 3.7.2 Traffic homogeneous sections

Homogeneous Section (HS)	Existing Chainage (km)		Length (km)
	From	To	
HS-I	106+000	110+000	4.00
HS-II	110+000	129+050	19.05

Table 3.7.3 gives the base year (2018) traffic volumes in terms of AADT for each category of commercial vehicle.

Table 3.7.3 Base year traffic volumes

Type of Commercial Vehicle	Number of Commercial Vehicles (AADT) in the year 2018			
	HS I		HS II	
Direction	Up	Down	Up	Down
Mini Bus	138	138	214	185
Bus	455	496	342	354
LGV – Freight	799	955	728	839
2 Axle Truck	69	67	117	126
3 Axle Truck	13	11	17	17
MAV 4-6 Axle	2	3	17	14
Total	1476	1670	1435	1535

From above table, it can be seen that maximum traffic volume per day has been observed along HS I.

3.7.3 DESIGN LIFE

The design life is the expected of desired life of the pavement in years, from the time the pavement is constructed until it requires reconstruction. A pavement is typically designed to carry all of the traffic expected during the performance period. A design life of 15 years for flexible pavement and 30 year for rigid pavement. The selected design lives are in accordance with IRC guidelines.

3.7.4 TRAFFIC GROWTH RATES

Traffic growth rates have been considered for each category of vehicles using econometric models. A minimum traffic growth rate of 5%, in compliance with IRC: SP: 073 - 2007(Clause 5.5.4) is considered for design.

3.7.5 VEHICLE DAMAGE FACTORS

Project specific axle load surveys were conducted at two locations to assess the axle loading pattern of commercial vehicles plying on the project road. The raw data of axle load measurements collected at site using axle load pads and analysis thereof to arrive VDF are given in Traffic Study Report. The summary of VDFs is given in **Table 3.7.4**.

Table 3.7.4 Summary of vehicle damage factors

Axle Load Survey Location	Direction Towards	Vehicle Damage Factors					
		Mini Bus	Bus	LCV	2 Axle Trucks	3 Axle Trucks	MAV
110+000	Payli	2.66	2.66	0.69	3.02	4.16	0.20
	Jhalawar	1.95	1.95	0.23	0.34	8.12	0.21
127+000	Payli	2.09	2.09	0.24	0.51	8.15	0.23
	Jhalawar	2.68	2.68	0.82	4.19	6.74	0.23

3.7.6 AXLE LOAD SPECTRUM

The spectrum of axle loads in terms of axle weights of single, tandem and tridem axles have been determined and compiled under various classes with class interval of 10 kN, 20 kN and 30 kN for single, tandem and tridem axles respectively. While the detailed analysis and raw data of axle loads collected at site using axle load pads are given in Traffic Study Report submitted separately, the axle load spectrum as determined for day and night traffic is given in **Table 3.7.5**.

Table 3.7.5 Axle load spectrum

(a) Homogeneous Section-I from km 106+000 to km 110+000

Single Axle		Percentage of Single axle	Tandem Axle		Percentage of Tandem axle
205	215	0.00	420	440	0.00
195	205	0.00	400	420	0.00
185	195	0.00	380	400	0.00
175	185	0.00	360	380	0.00
165	175	0.00	340	360	6.70
155	165	0.00	320	340	0.00
145	155	9.0	300	320	0.00
135	145	7.0	280	300	0.00
125	135	4.0	260	280	0.00
115	125	0.00	240	260	13.3
105	115	9.0	220	240	0.00
95	105	7.0	200	220	0.00
85	95	0.00	180	200	0.00

<85		64.0	<180		80.0
	Total	100		Total	100

(b) Homogeneous Section-II from km 110+000 to km 129+050

Single Axle		Percentage of Single axle	Tandem Axle		Percentage of Tandem axle
205	215	0.00	420	440	0.00
195	205	0.00	400	420	0.00
185	195	0.00	380	400	0.00
175	185	3.60	360	380	0.00
165	175	0.00	340	360	5.00
155	165	0.00	320	340	5.00
145	155	0.00	300	320	0.00
135	145	0.00	280	300	0.00
125	135	7.10	260	280	5.00
115	125	0.00	240	260	16.00
105	115	17.90	220	240	0.00
95	105	10.70	200	220	0.00
85	95	0.00	180	200	0.00
<85		60.7	<180		63.0
	Total	100		Total	100

3.7.7 DISTRIBUTION OF COMMERCIAL TRAFFIC OVER THE CARRIAGEWAY

For flexible pavements, the percentage of vehicles in heaviest loaded lane can be determined as per guidelines in IRC: 37-2018:

- (i) 2-lane single carriageway: 50% of total two directional traffic as per IRC: 37-2018 and IRC: 115-2014
- (ii) 2-lane divided carriageway: 75% of total one directional traffic as per IRC: 37-2018 and IRC: 115-2014

3.7.8 COMPUTATION OF DESIGN TRAFFIC

The design traffic, in terms of the cumulative number of standard axles to be carried during the design period of the road, should be estimated using equation given below.

$$N_{Des} = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F$$

Where,

N_{Des} = Cumulative number of standard axles to be catered for during the design period of 'n' years

A = Initial traffic (commercial vehicles per day) in the year of completion of construction (directional traffic volume to be considered for divided carriageways whereas for other categories of the carriageway, two-way traffic volume may be considered for applying the lateral distribution factors)

D = Lateral distribution factor

F = Vehicle damage factor (VDF)

n = Design period, in years

r = Annual growth rate of commercial vehicles in decimal

The design MSA summary is abstracted below in **Table 3.7.6**.

Table 3.7.6 Estimated design MSA for different traffic homogeneous sections

Homogeneous Section	Applicable Stretch	Carriageway Configuration	Traffic Loading in terms of MSA			
			15-year period (2021 to 2035) (Subjected to minimum 5% growth rate)		Adopted for Design 15-year period (2021-2035)	
			Up	Down	Up	Down
HS-I	106+000 to 110+000	Two-lane	10.7	16.4	30	
HS-II	110+000 to 127+00	Two-lane	18.4	10.5	30	

Note: For both survey location HS-I & HS-II, as the estimated design traffic loading is found to be low, so as per recommendation of schedules we have adopted 30 MSA as the design traffic.

3.8 EVALUATION OF SUB-GRADE STRENGTH

3.8.1 GENERAL

Two lane divided carriageway construction of Jhalawar – Payli section of SH 1 of Rajasthan from km 106.000 to km 127.000 in state of Rajasthan, under NHDP Phase III involves the construction of new pavement on existing road with flexible pavement.

For the design of flexible pavement by IRC methods the strength of subgrade soil is represented by soaked CBR as well as in-situ CBR. For roads in fill embankments, the effective CBR at formation level governs the pavement design, which is the combined contribution of embankment soil CBR and subgrade CBR.

For new construction of sections, it is the natural ground soil (road bed soil) that must be used as the starting point for support characterization of existing roads, the borrow area soil subgrade over existing pavement crust is the starting point for support characterization.

All cases are explained in succeeding sections.

3.8.2 CHARACTERIZATION OF SUBGRADE SUPPORT FOR NEW CONSTRUCTION

Natural soils along the proposed widening portion within row have been sampled & tested to determine their suitability under embankment foundation and also to determine the strength of road bed soil in terms of CBR.

The soil samples were found to be silty gravel with sand classified as GM with few stretches having silty sand with gravel as SM in Indian Soil Classification System.

3.8.3 PROPERTIES OF BORROW AREA SOILS

As regard to the characterization of fill material, 26 borrow area sources have been explored in detail. The material available in these borrow areas consist of sandy/silty soils as revealed by tactile examination of field samples and laboratory tests.

The characteristics of explored borrow sources together with CBR results are summarized in **Table 3.8.1**.

Table 3.8.1 Characteristics of borrow area soil

S. No.	Location/ Chainage	Atterberg Limit		Soil Classification as per IS	Laboratory Compaction		CBR @ 97% MDD
		LL%	PI%		OMC (%)	MDD (g/cc)	
BA1	106.000	21	NP	GM	9.6	2	19.20%
BA2	107.000	18	NP	GM	9.1	1.98	20.60%
BA3	108.000	22	NP	GM	8.9	1.98	18.90%
BA4	109.000	21	NP	GM	9.3	1.96	20.60%
BA5	110.000	18	NP	GM	8.4	2.4	21.40%
BA6	111.000	18	NP	GM	8.1	2.3	22.30%
BA7	112.000	18	NP	GM	8.4	2.1	20.40%
BA8	113.000	19	NP	GM	8.8	2	22.10%

BA9	114.000	23	NP	SM	17.8	8.6	8.60%
BA10	115.000	18	NP	GM	8.1	2.2	24.60%
BA11	116.000	21	NP	GM	9.1	2	22.30%
BA12	117.000	20	NP	GM	8.6	1.98	21.60%
BA13	118.000	21	NP	GM	9.2	2.1	24.20%
BA14	119.000	21	NP	GM	8.6	2.4	22.80%
BA15	120.000	20	NP	GM	8.6	2.1	20.40%
BA16	121.000	20	NP	GM	8.6	1.98	23.20%
BA17	122.000	20	NP	GM	8.8	1.97	21.20%
BA18	123.000	24	NP	SM	10.8	1.89	9.20%
BA19	124.000	23	NP	SM	11.4	1.92	9.20%
BA20	125.000	20	NP	GM	8.5	2.1	21.80%
BA21	126.000	20	NP	GM	8.6	2.2	21.60%
BA22	127.000	22	NP	GM	10.1	1.98	21.80%
BA23	128.000	19	NP	GM	8.1	2.2	23.40%
BA24	129.000	20	NP	GM	8.1	2.2	21.40%
BA25	130.000	20	NP	GM	8.6	2.1	22.20%
BA26	131.000	20	NP	GM	8.2	2.2	21.80%

From the **Table 3.8.1** the following conclusions can be obtained:

- (a) Natural soil deposits (containing abundant quantities) occur at regular interval along the project road corridor on both sides. Borrow soil suitable for embankment and subgrade can be borrowed from these sources.
- (b) Quantities of soil material for use in the embankment and subgrade construction of the project road is adequate from the investigated borrow areas.
- (c) While the soils from the investigated borrow areas are predominantly silty and sandy in nature which is of non-plastic type classified as SM & GM type of IS soil classification system.

CBR of Compacted Borrow Material of 500 mm thick layer

For given CBR of roadbed soil, the required minimum CBR of 500 mm thick select material from borrow sources to achieve effective CBR. Adopted design CBR and their indicative borrow source are presented in **Table 3.8.2**.

Table 3.8.2 CBR of selected fill to achieve target CBR at formation level

Homogeneous Section	Existing Chainage (km)		15 percentile CBR	Design CBR	Indicative borrow source
	From	To			
HS I	106.000	110.000	19.8	15	BA 1 to BA 5
HS II	110.000	127.000	17.04	15	BA 6 to BA 24

3.9 PAVEMENT DESIGN

3.9.1 DESIGN STANDARD

The following design standards have been utilized in the pavement design.

- IRC: SP-73:2007 – Manual of Specifications & Standards for Two-laning of State Highways through Public Private Partnership
- IRC: 37-2018, “Guidelines for the Design of Flexible Pavements. 3rd Revision”.

3.9.2 DESIGN CRITERIA

Design Life

The design life is the expected or desired life of the pavement in years, from the time the pavement is constructed until it requires major rehabilitation such as a structural overlay or reconstruction. A pavement is typically designed to carry all of the traffic expected during the performance period. A design life of 15 years for the flexible pavement has been considered for this project which is in accordance with IRC guidelines and schedule parameters.

Reliability

For flexible pavement design, the concept of reliability is introduced in IRC: 37-2018. Reliability (R) is the statistical probability that the road pavement will perform satisfactorily for the traffic and environmental conditions for which it was designed for the duration of the design period. It accounts for the chance variation in traffic predictions, performance predictions, material properties and subgrade support conditions. It incorporates some degree of certainty into the design process to ensure that the pavements will survive the analysis period for which they are analyzed.

IRC: 37-2018 recommends two levels of reliability as under in **Table 3.9.1**.

Table 3.9.1 Adopted levels of reliability

Reliability Level (R)	Traffic Loading in terms of MSA
80%	<30
90%	≥30

Depending on the estimated traffic loading, appropriate reliability level is chosen for the design.

Strength of Subgrade

In all pavements, the load is eventually transmitted to the natural subgrade. It is natural subgrade that must be used as the starting point for support characterization. The strength of sub-grade

in terms of subgrade CBR (which in turn is correlated to resilient modulus, M_r) is required for the design of new flexible pavement as per IRC: 37-2018 method.

In this report, the subgrade support in terms of 4-days soaked CBR for flexible pavement is evaluated.

Table 3.9.2 Design CBR values applicable to reconstruction stretches of existing pavement

Stretch	Design CBR (%)
HS I	15
HS II	15

Design Traffic

The evaluated design traffic applicable for flexible pavement is given in **Table 3.9.3**.

Table 3.9.3 Summary of 15-year design traffic for new flexible pavement

Traffic Homogeneous Section	Traffic Loading in terms of million standard axles (MSA)		Adopted for Design
	Towards Payli	Towards Jhalawar	
HS I	16.4	10.7	30 MSA
HS II	10.5	18.4	30 MSA

3.9.3 DESIGN OF NEW FLEXIBLE PAVEMENT

Flexible Pavement Design for New Construction

With traffic loading, pavement support and pavement components defined as earlier, the pavement structural design of flexible pavement has been carried out. IRC: 37-2018 pavement design method utilizes cumulative ESALs during the design life and the subgrade strength as key design parameters, together with criteria for selection of materials for the different pavement layers. The input parameters used for the design of flexible pavement are discussed in previous sections of this report.

IRC: 37-2018 provides 8 plates (Plate 1 through Plate 8) of empirical design catalogues for conventional flexible pavement, from which the thickness of pavement structure for given subgrade CBR & expected traffic on the pavement can be obtained.

For this project analytical design approach using IITPAVE software of IRC: 37-2018 is used to finalize various crust compositions.

Corresponding to evaluated design subgrade CBR for this project, the structural design of flexible pavement has been worked out.

Pavement structural design as per IITPAVE calculation corresponding to each homogeneous section is discussed below in **Table 3.9.4** and final pavement recommendation for each homogeneous section is presented in **Table 3.9.5**.

Table 3.9.4 Pavement structure for new pavement design as per IITPAVE calculation

Homogeneous Section	Design traffic MSA for 15 years	Direction of traffic	Design CBR %	Bitumen type (BC & DBM)	E subgrade	Layer thickness in mm					Calculated strain value		Structural life MSA	
						BC	DBM	WMM	GSB	Total crust	Tensile strain at bottom of bituminous	Vertical strain at top of subgrade	In fatigue at bottom of bituminous layer	In rutting failure at top of subgrade
HS I	30	Towards Payli	15	VG 30	100	40	50	250	200	540	2.69E-04	3.06E-04	30.0	355.2
	30	Towards Jhalawar	15	VG 30	100	40	50	250	200	540	2.69E-04	3.06E-04	30.0	355.2
HS II	30	Towards Payli	15	VG 30	100	40	50	250	200	540	2.69E-04	3.06E-04	30.0	355.2
	30	Towards Jhalawar	15	VG 30	100	40	50	250	200	540	2.69E-04	3.06E-04	30.0	355.2

Table 3.9.5 Recommended pavement structure for new flexible pavement design

Chainage		Design life	Design Traffic MSA for 15 years	Direction of traffic	Design CBR %	Bitumen type (BC & DBM)	Layer thickness in mm				Total crust
From	To						BC	DBM	WMM	GSB	
106+000	110+000	15	30	Both	15	VG 30	40	50	250	200	540
110+000	129+050	15	30	Both	15	VG 30	40	50	250	200	540

3.9.4 COMPOSITION OF DIFFERENT LAYERS

BC: Coarse aggregate, fine aggregate, filler material and bitumen.

DBM: Coarse aggregate, fine aggregate, filler material in suitable proportions with required binder content.

WMM: Clean, crushed, well-graded granular material well mixed with water and rolled to a dense mass.

GSB: Crushed stone, crushed slag or concrete, or slate is generally used.

3.10 DESIGN PARAMETERS FOR FLEXIBLE PAVEMENT

Road Type: State Highway

Design life in years: 15

N (Cumulative no. of equivalent standard axles) in terms of MSA: 30 for traffic homogeneous section I & II respectively

Subgrade CBR: 15

Reliability, R: 90% for traffic upto 30 msa

Subgrade Resilient Modulus, M_{RS} : 100

Elastic modulus of granular layer, M_{Rgr} : 311

Elastic modulus of BC and DBM with VG-30 bitumen and corresponding to a pavement temperature of 35°C, E_{ac} : 1700 MPa

Poisson's ratio (for subgrade): 0.40

Poisson's ratio (for GSB & WMM): 0.35

Poisson's ratio (for BC & DBM) corresponding to a pavement temperature of 35°C: 0.35

Reference wheel load: 20000 N

Wheel set: Dual tyre

Tyre pressure: 0.56 MPa

Spacing between dual tyres: 310 mm (Assumed)

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 GENERAL

To design the new alignment of the road various design steps in accordance with the IRC standards were followed in the software. According to the results obtained from the various analysis, the road is widened and designed, and discussions are made. The new design of the road is compared to the normal design in terms of safety, speed and overall cost. The following are the design steps for the new road.

4.2 PLOTTING OF DATA IN OPEN ROADS

Steps:

Importing necessary data

- Rename the AUTOCAD drawing file as 'spot.dwg'.
- Create a folder in drive named 'Jhalawar road' and include two folders in it named 'Input' and 'Project'.
- Paste the 'spot.dwg' file both in Input and Project folder.
- While opening the software a dialogue box appears, click create new project. Name it as Jhalawar road and click on browse.
- In browse tab click D:/Jhalawar road/Project and click on OK.

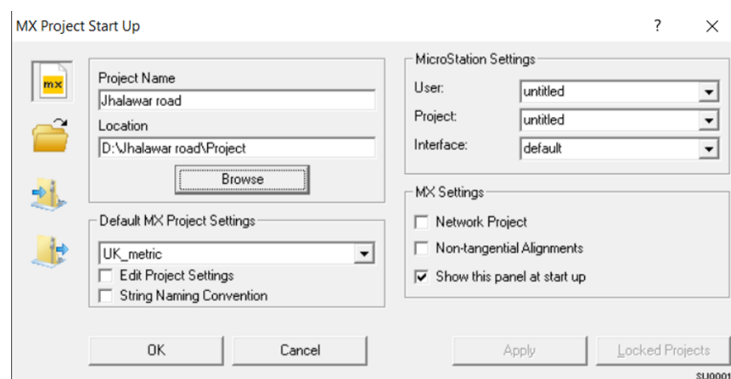


Fig. No. 4.2.1 Creating new project

- The existing model will open up.

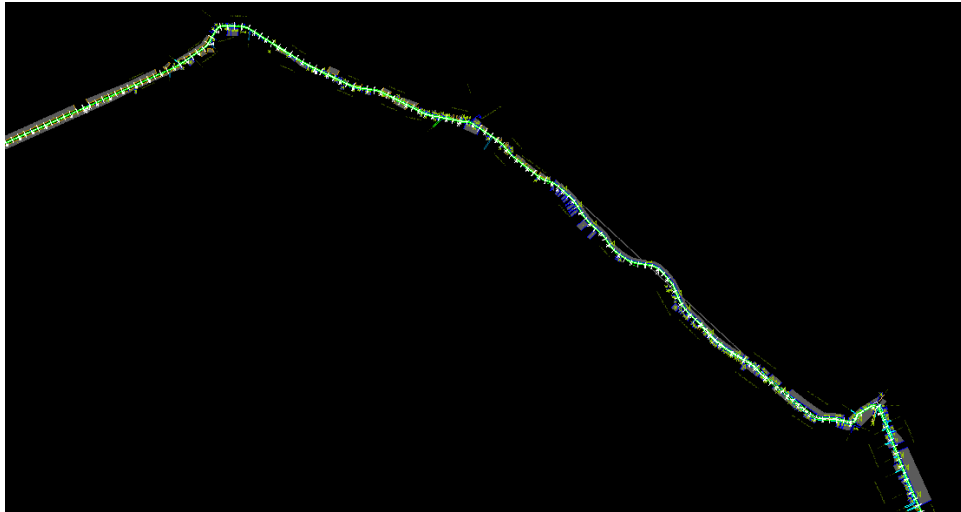


Fig. No. 4.2.2 Existing road profile

Creating new model

- In MX Conversion window create a model named 'GROUND'.
- In GROUND model define all the parameters such as Centrelines, Carriageways/ Channels, Buildings (All), Shoulders, etc. based on the requirement for the new design.
- Now, go to Display> Erase Display... and then Display> Plan with Style Set..., select GROUND model and click OK.
- New drawing will open displaying the selected parameters from the existing the road profile.

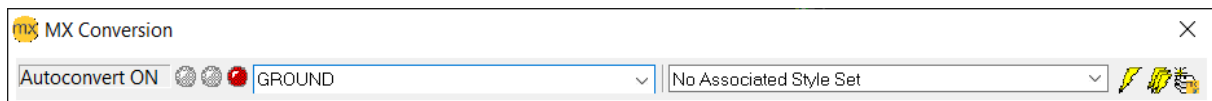


Fig. No. 4.2.3 Creating model

4.3 ANALYSIS OF HORIZONTAL ALIGNMENT

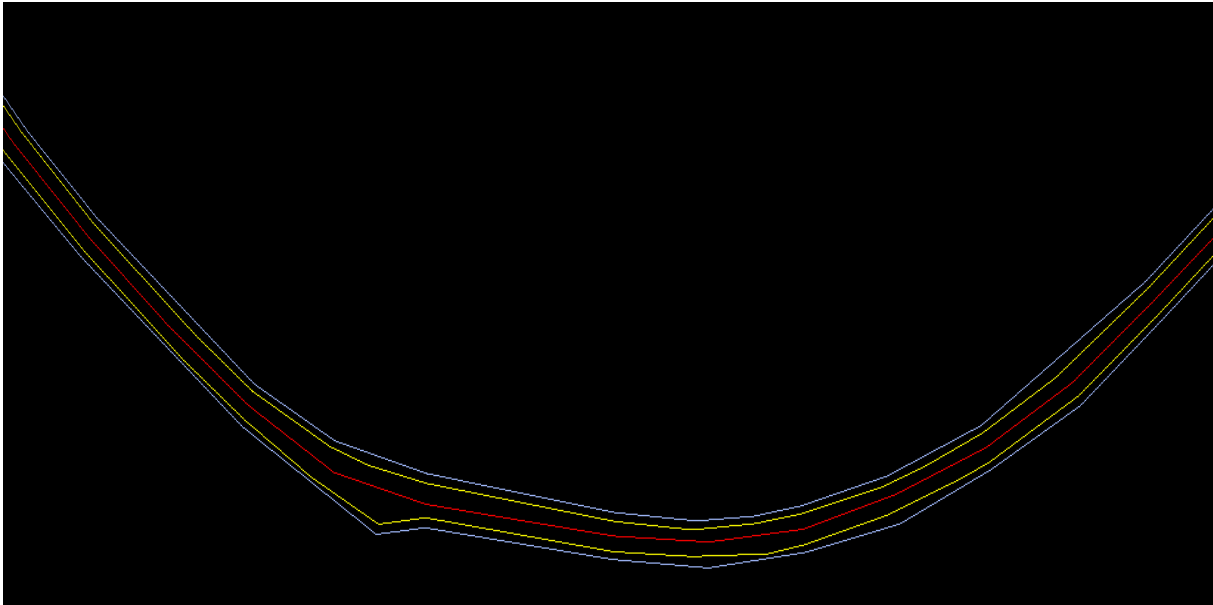


Fig. No. 4.3.1 GROUND model displaying the selected parameters for new design

Steps:

- Now go to Design> Quick Alignment> Horizontal Design..., in the displayed tab create a new model 'DESIGN' and name string as 'MC00' and click Next.

Defining Intersection points for new centreline

- A new dialogue box as shown in figure below will appear to define intersection points for new centreline of the road.

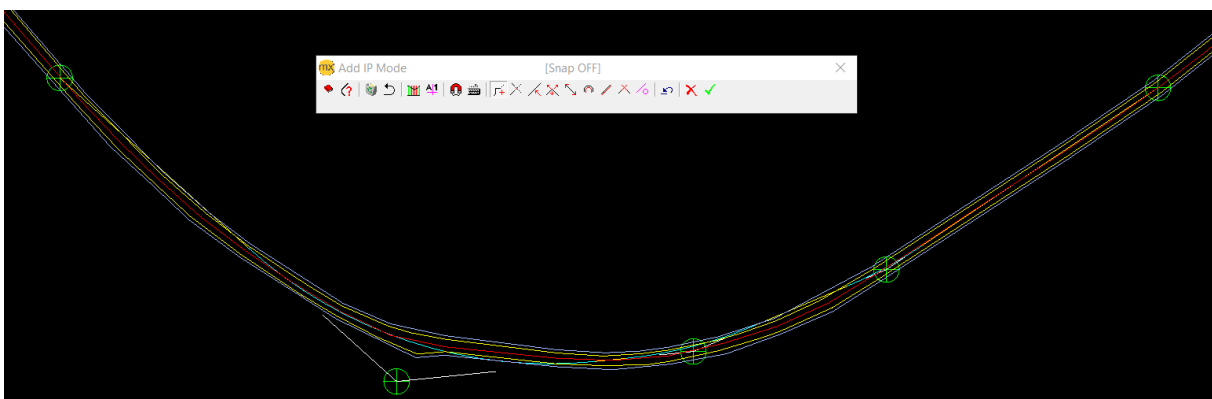


Fig. No. 4.3.2 Defining IP's for new centreline

- The radius of the curve can be defined at each of the IP's.

- After defining IP's click on tick mark, the new centreline will be shown with chainage and radius of curve if there are no IP tangents intersecting each other.

Displaying DESIGN model

- Go to Display> Erase Display... and then Display> Plan with Style Set..., select DESIGN model and click OK.

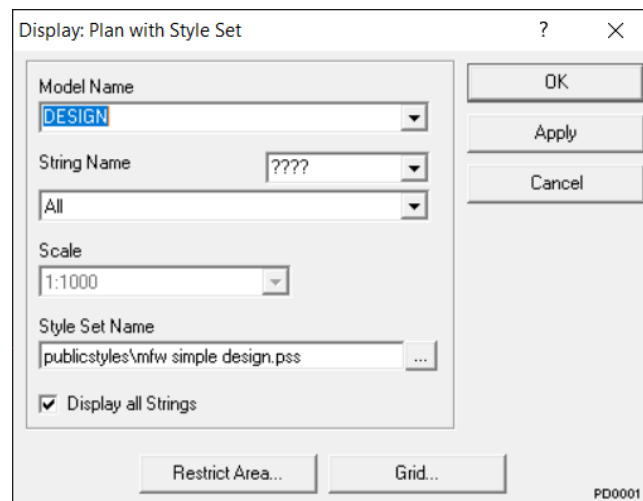


Fig. No. 4.3.3 Display DESIGN model with new centreline

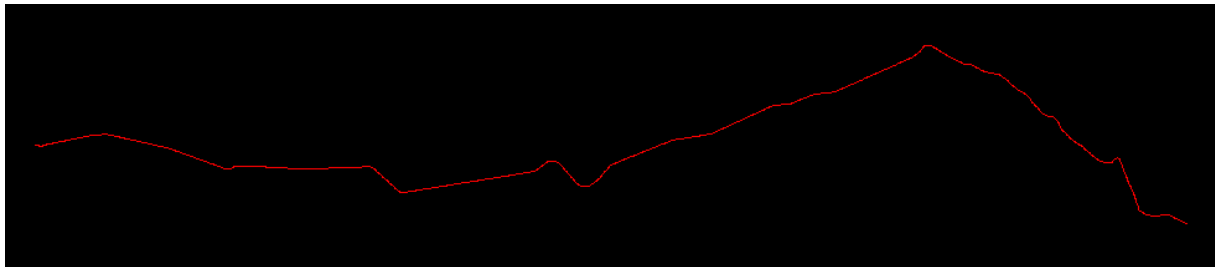


Fig. No. 4.3.4 New centreline displayed

- The horizontal profile of the road is created, the super elevation will be applied after defining the carriageway and shoulder offsets taken from centreline.

4.4 ANALYSIS OF VERICAL ALIGNMENT

Steps:

- Firstly, erase the display and display 'GROUND' model as defined above.

- Now go to Modify> Edit Strings> Create a String Dynamically... a dialogue box appears. Cover the boundary where triangulation is to be done.

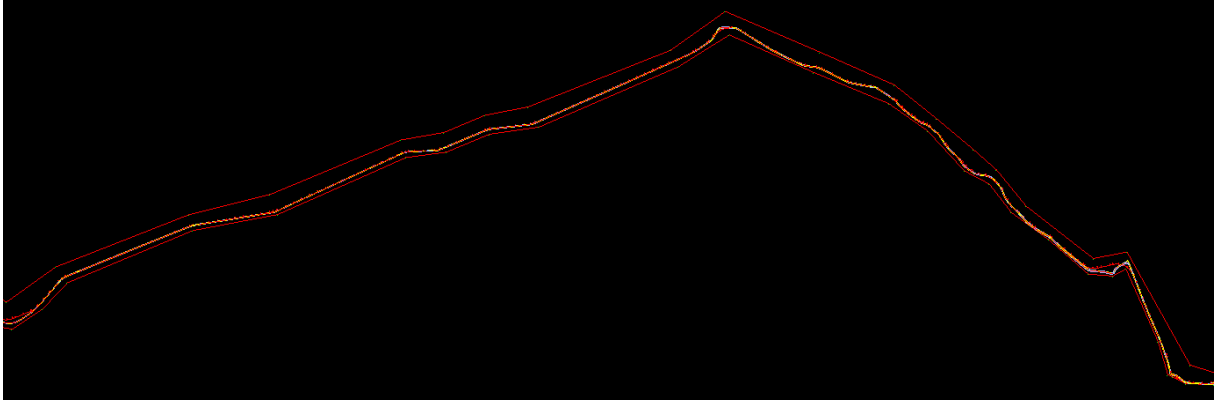


Fig. No. 4.4.1 Covered boundary for triangulation

Creating BOUNDARY model for Triangulation

- Click on save, enter model name as 'BOUNDARY' and string name 'BD00', tick Save with NULL Levels and Create as a Boundary String and click OK.
- Now go to Analysis> Triangle> Triangulation from a String Model, a dialogue box appears.
- Select model to triangulate as 'DESIGN' model and model to store triangulation as 'TRIA' and string name 'TX00', tick 'Analysis within the Boundary' and click OK.

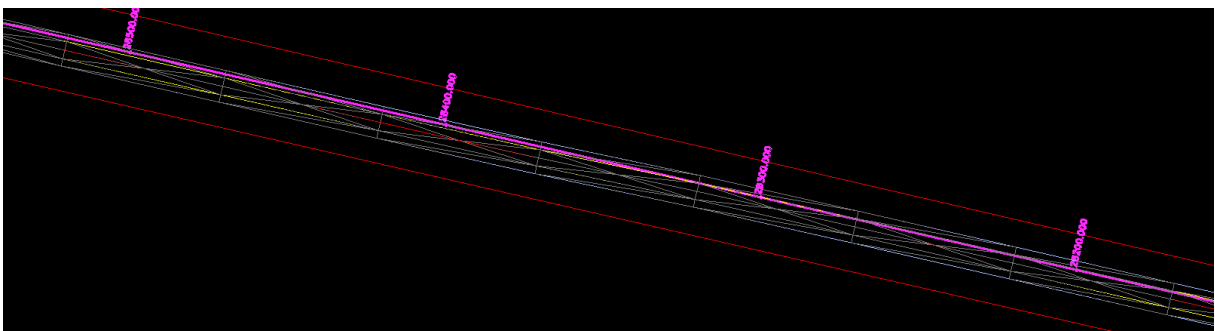


Fig. No. 4.4.2 A section of road after triangulation

- Triangulation in the selected boundary is done.
- Now go to Design> Quick Alignment> Vertical Profile..., a dialogue box appears showing Quick Profile: Design Model.

- In Quick Profile: Design Model select 'DESIGN' model and string name as 'MC00' and click Next, another dialogue box appears, select 'TRIA' model and click Next as shown below.

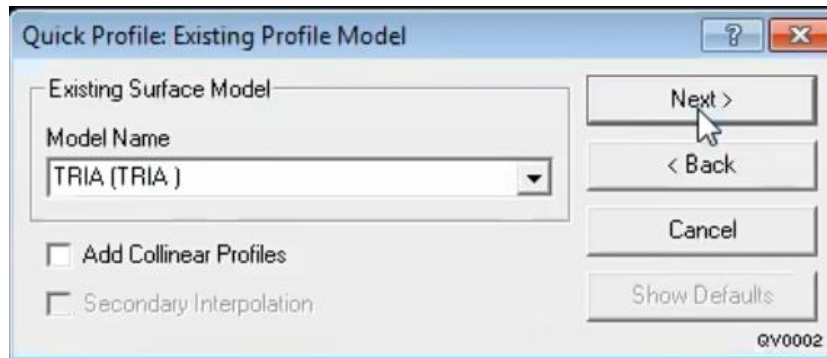


Fig. No. 4.4.3 Defining the existing profile model

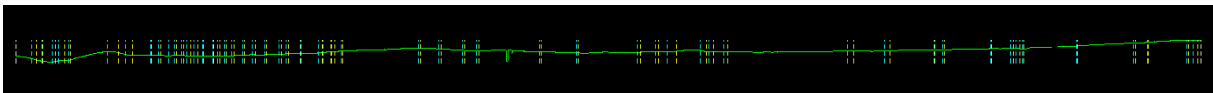


Fig. No. 4.4.4. Vertical profile of the road after analysis

- The vertical profile of the road appears in the same window as shown in the figure above.
- We can change gradient and keep it in the range of minimum and maximum gradient as shown below.

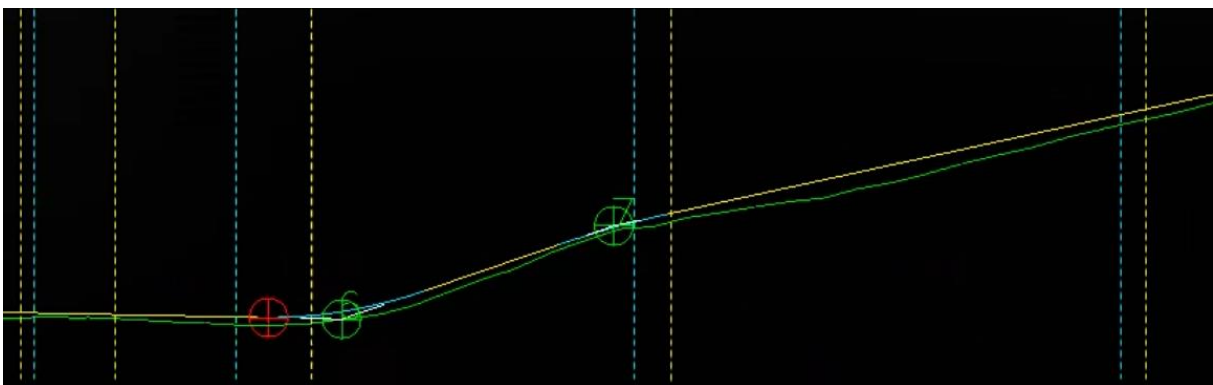


Fig. No. 4.4.5 Existing and new vertical profile after analysis

4.5 DEFINING CARRIAGEWAY

Steps:

- Before defining super elevation, the offsets for carriageway and shoulder have to be taken from the centreline.
- For this go to Design> Design a String> Horizontal Offset..., enter design model and model to store new string as 'DESIGN', reference and subsidiary string name as 'MC00' and new string name as 'CE00' as shown below in fig. 4.5.1.

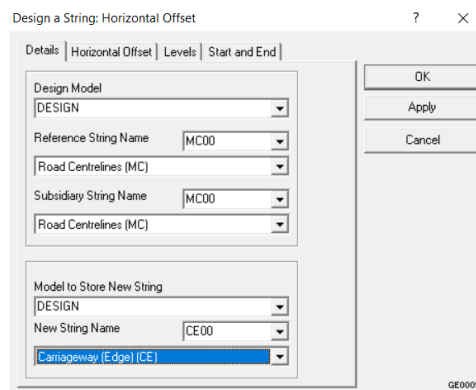


Fig. No. 4.5.1 Defining strings

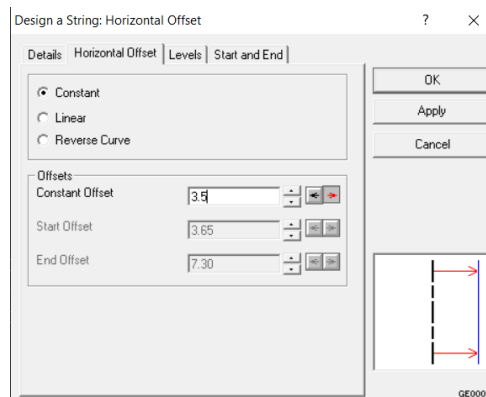


Fig. No. 4.5.2 Entering offset value

Defining horizontal offset of 3.5 m on both sides of the centre line

- Under 'Horizontal Offset' tab enter 3.5m constant offset from reference string 'MC00' i.e. road centreline, as shown above.

Defining camber for straight stretches of the road

- Under 'Levels' tab we can define the camber for road, here camber taken is 2.5% i.e. 0.025.
- In 'Start and End' tab define the start and end of the centreline and click OK.
- The offset will be shown in the same window. Similarly, define offsets for carriageway on other side and for shoulders on both the sides.

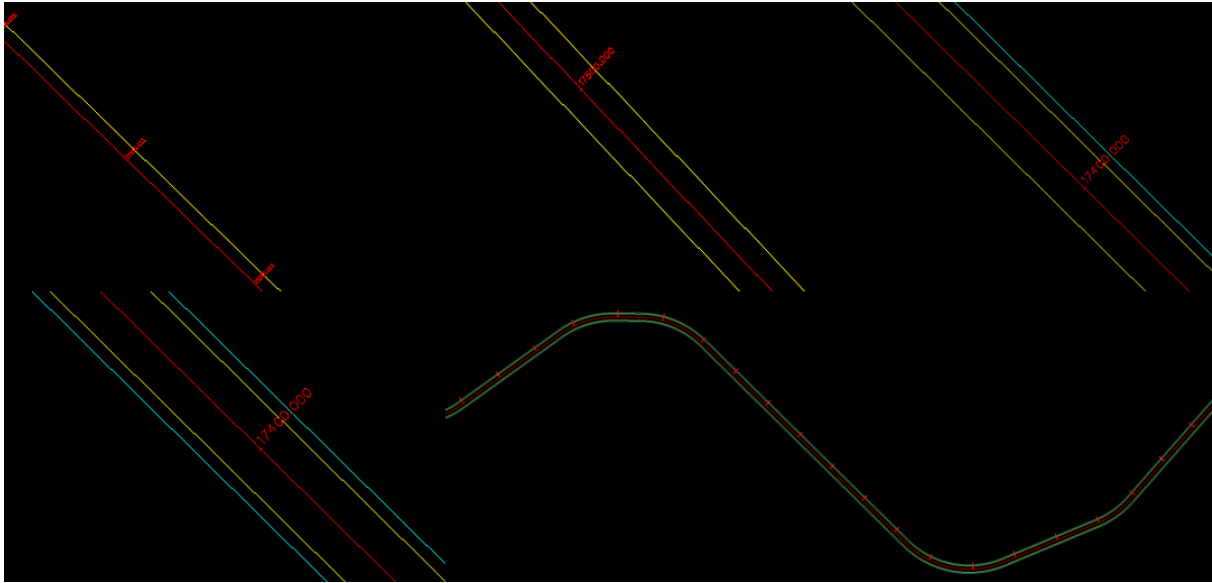


Fig. No. 4.5.3 New carriageway and shoulders

4.6 EARTHWORK WIZARD

Steps:

Defining carriageway earthwork and slope of earthwork

- Go to Design> Earthwork Wizard..., define the necessary parameters as shown below and click Next.
- Another dialogue box appears, select earthwork style and click Next as shown in figure.

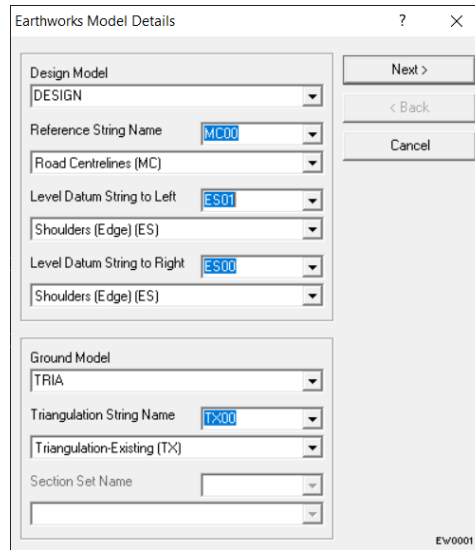


Fig. No. 4.6.1 Model details

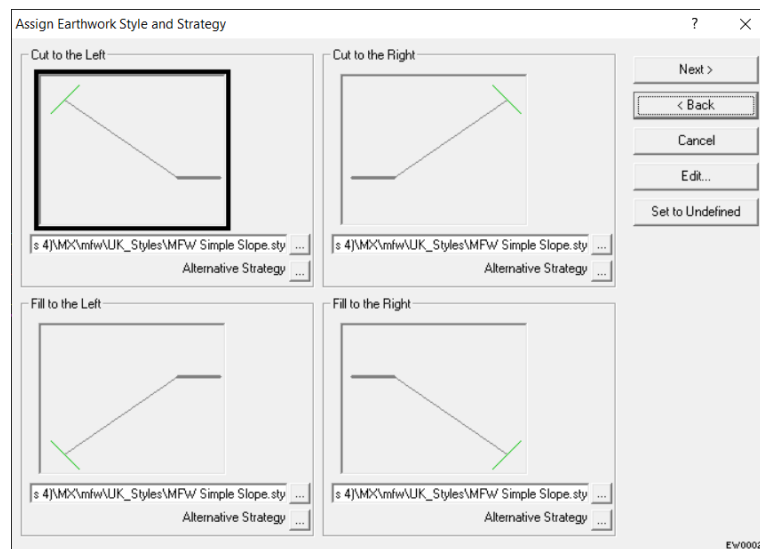


Fig. No. 4.6.2 Assigning earthwork style

- Define the slope in the next dialogue box and click Next, save the file as ‘Earthwork Jhalawar’ as shown in figure 4.6.3.

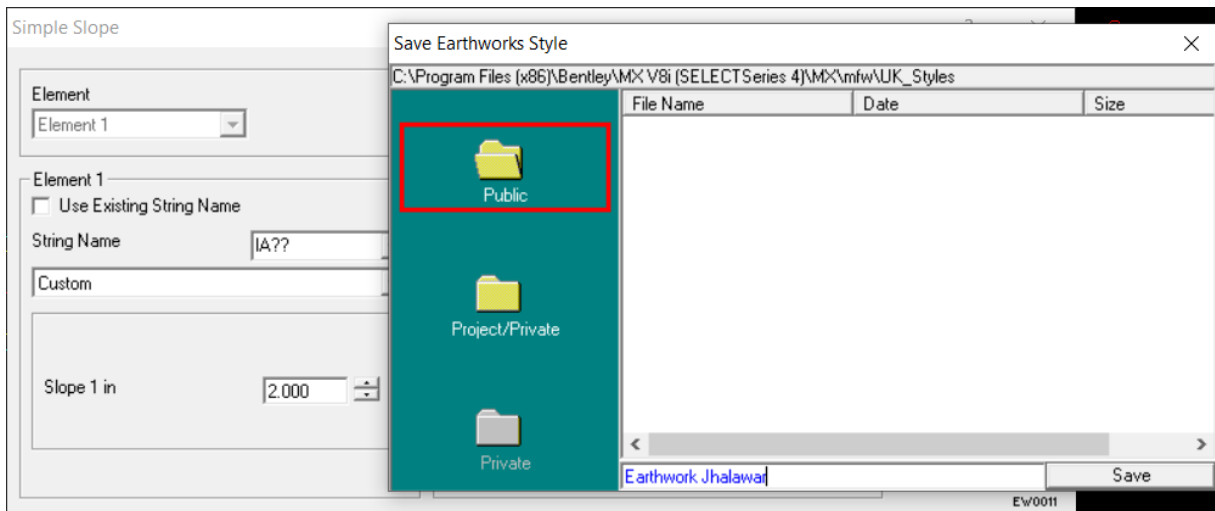


Fig. No. 4.6.3 Saving earthwork style

- Another dialogue box appears, define the start and end chainage, the details you want in earthwork and click Finish as shown in figure 4.6.4.

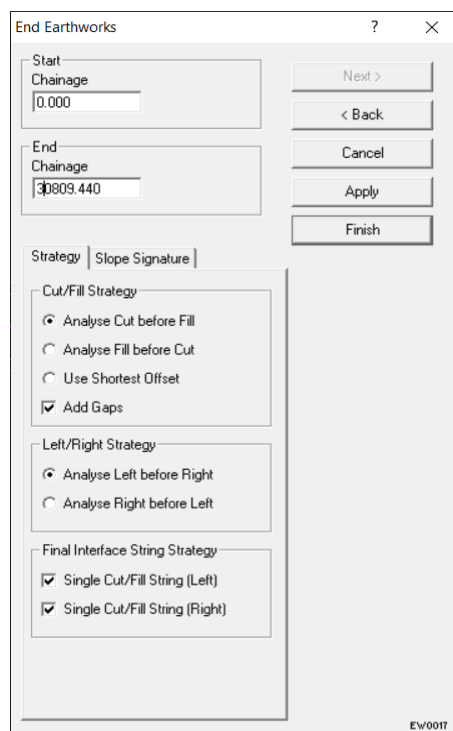


Fig. No. 4.6.4 Ending earthworks

- The earthwork will be shown in the drawing in the same window as shown below.

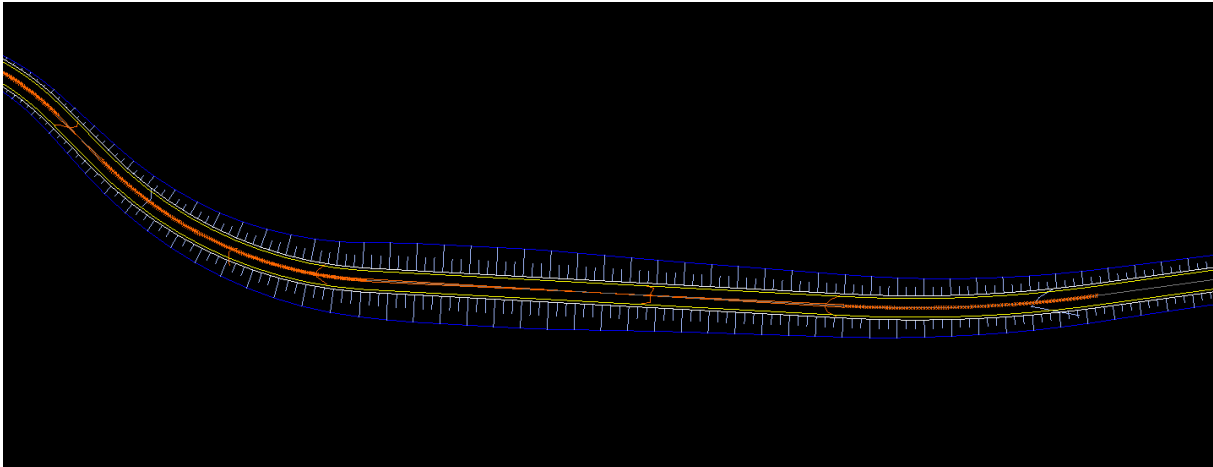


Fig. No. 4.6.5 Final earthwork after analysis

4.7 SUPER ELEVATION

Steps:

Defining superelevation, for which design speed is to be entered in the software

- Go to Design> Road Design> Rule-based superelevation..., enter reference string name 'MC00' and enter start and end chainage and click Next as shown below.
- New tab appears, define left and right edge name and click Next, another tab appears, in Rules select 'Indian Highways 2 lane', enter design speed and click Next.
- Another tab appears, select the type of superelevation to be applied and click Next. The superelevation will be applied accordingly to the road.

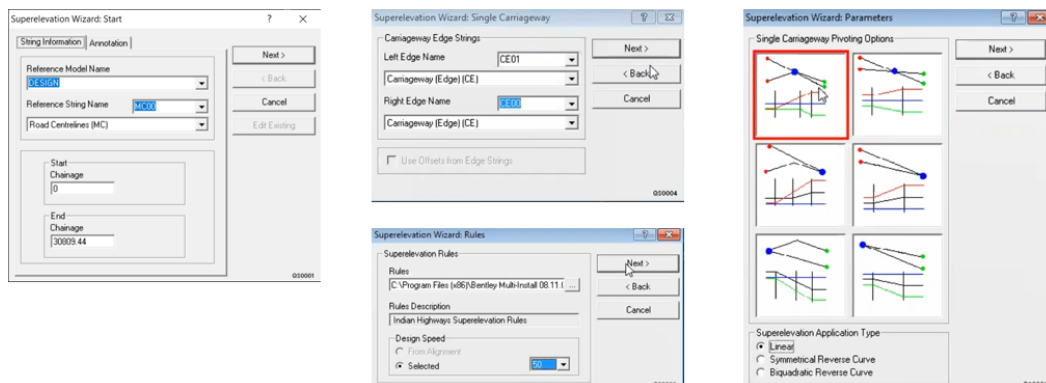


Fig. No. 4.7.1 Superelevation wizard steps

4.8 CREATING CROSS SECTIONS

Steps:

Creating road cross-sections using triangulation model

- Go to Analysis> Sections> Create Cross Sections..., enter reference string name as 'MC00' and create model to store sections as 'CROSS' and click Next.
- Now select model to section as 'TRIA' and click Finish.
- A new dialogue box appears on which click on 'Display Cross Section Pages'.
- Another dialogue box appears in which we can select what we want to display along with the cross-section drawings, after selecting all necessary parameters click OK.

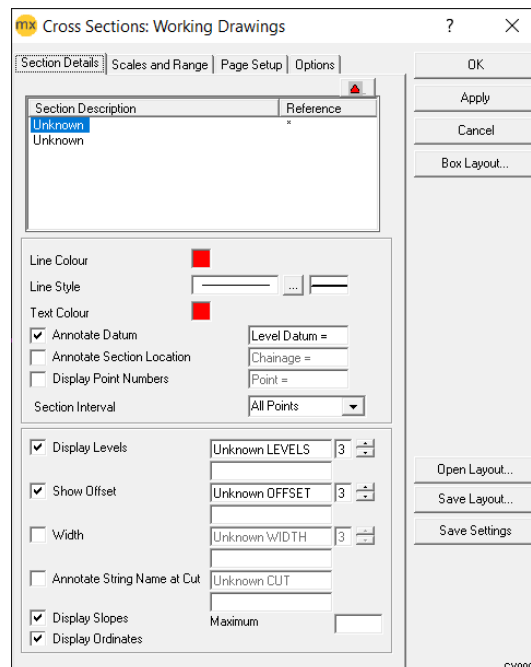


Fig. No. 4.8.1 Cross sections: working drawings

- The cross sections at different chainage will be displayed in the same window. The file can be saved in .dwg format also.

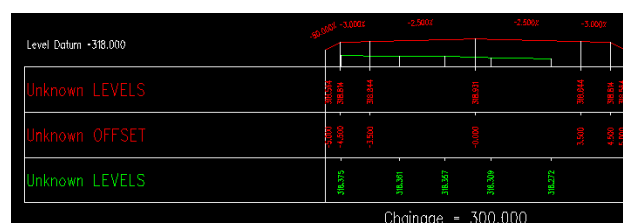


Fig. No. 4.8.2 Cross section at a particular chainage

4.9 PAVEMENT DESIGN

Steps:

- Go to Design> Pavement and Subgrade Design..., enter reference model as 'DESIGN' and reference string as 'MC00' in the dialogue box shown and click Next.

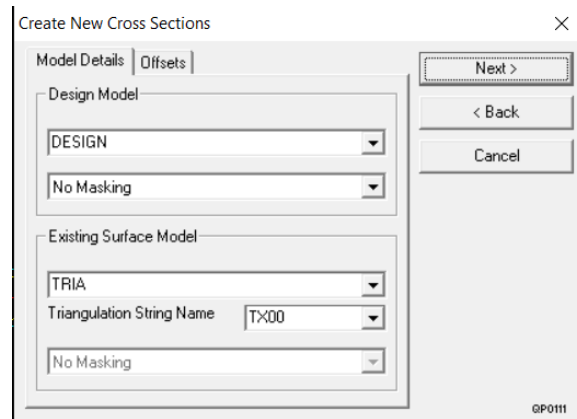


Fig. No. 4.9.1 Defining models and strings

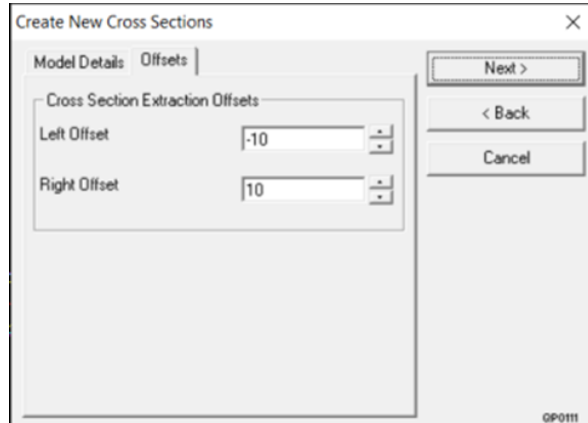


Fig. No. 4.9.2 Defining offsets

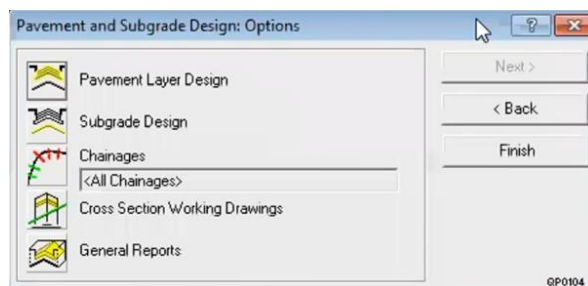


Fig. No. 4.9.3 Design options

- Select existing surface model and define offsets as -10 and 10 as shown above and click Next.
- A new dialogue box appears, click on Pavement Layer Design and now go to 'Create/Edit Style Set'.

Defining different layers of pavement

- Now click on Add new layer and define layer depth, left shift, right shift, etc. Similarly, other layers can be added and defined.
- After defining all parameters save the file as pavement design.
- Now, follow the steps of creating cross sections as described above (4.8).

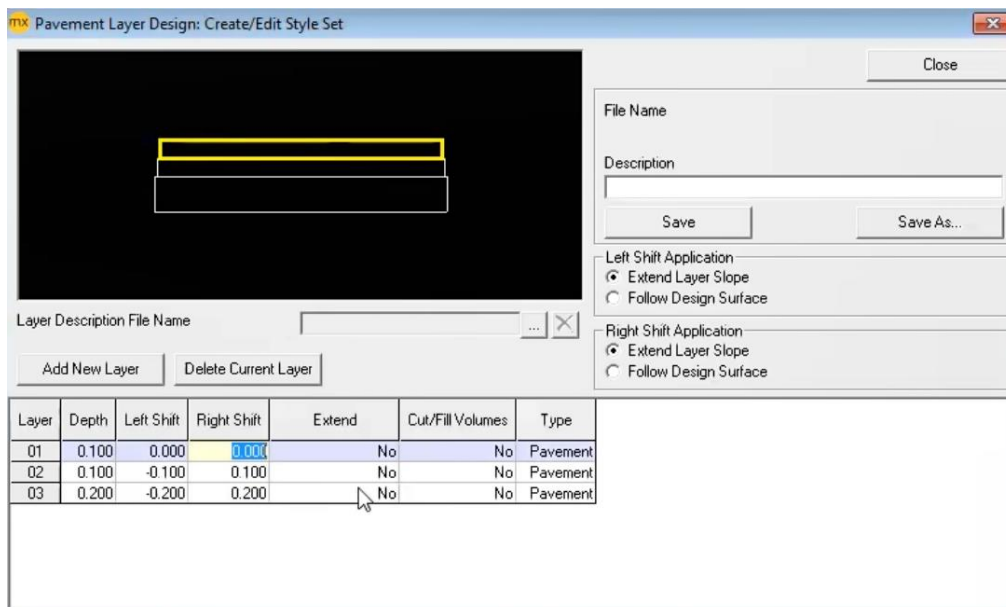


Fig. No. 4.9.4 Create/edit style set

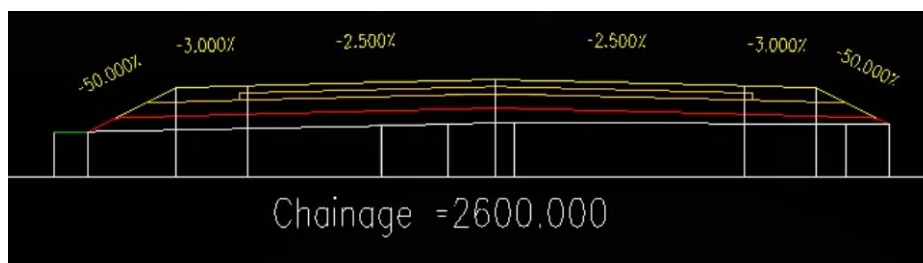


Fig. No. 4.9.5 Pavement layer final design

4.10 RESULTS

4.10.1 HORIZONTAL ALIGNMENT REPORT

The horizontal alignment for the new road is carried out as per IRC: 38- 1988 and the following results were obtained.

Table No. 4.10.1 Horizontal alignment report

Horizontal Alignment Report	Model: DESIGN
String: MC00	Units: Metric
Date: 29-11-2020 11:58:42	
	*****Element 1 Straight*****
	*****Transition*****
*****Element 2 Arc*****	
Intersection Point Chainage 0+471.933	Tangent 55.770
Arc Length 109.744	Chord Length 108.865
Arc Start Chainage 0+416.163	Arc End Chainage 0+525.907
Radius 250.000	

The vertical alignment of the new road is carried out as per IRC: SP-23: 1993 and the following results were obtained.

4.10.2 VERTICAL ALIGNMENT REPORT

Table 4.10.2 Vertical alignment report

Vertical Alignment Report	Model: DESIGN
---------------------------	---------------

String: MC00	Units: Metric
Date: 29-11-2020 12:00:15	
	*****Element 1 Vertical Curve*****
	Gradient -0.400
Gradient Length 67.860	Gradient End Chainage 0+067.860
Begin on Gradient Chainage 0+000.000	
	*****Element 2 Vertical Curve*****
IP Chainage 0+076.801	IP Level 321.606
Curve Start Gradient -0.400	Curve End Gradient -0.680
Curve Length 17.881	Vertical Radius -6400.003
Curve Start Chainage 0+067.860	Curve End Chainage 0+085.741
Sight Distance 732.403	

4.10.3 SUPER ELEVATION REPORT

The super elevation report given by MX Road software is as follows:

superelevation_100kph - Notepad

File Edit Format View Help

```

*      metric
*      Design Speed
*      100 km/h
*
*      Deg Crv Radius   Super Rate      spl lgt spl_lgt
*
*      0      2800    nc      0      0
*      0      2000    rc      20     20
*      0      1400    .025   30     30
*      0      1000    .025   40     40
*      0      720     .055   60     60
*      0      510     .070   85     85
*      0      230     .070  120    120

```

Fig. No. 4.10.3 Super elevation report

4.10.4 EARTHWORKS REPORT

740	0.017	1.658	0.03	4.94	0.03	4.94	3	345.8	348.8
750	0.005	1.331	0.109	14.992	0.109	14.992	10.9	1049.44	1060.34
760	0.005	1.237	0.046	12.903	0.046	12.903	4.6	903.21	907.81
770	0.011	1.456	0.08	13.52	0.08	13.52	8	946.4	954.4
780	0	1.508	0.057	14.86	0.057	14.86	5.7	1040.2	1045.9
784.918	0	1.521	0	7.464	0	7.464	0	522.48	522.48
785.018	0	1.501	0	0.151	0	0.151	0	10.57	10.57
789.293	0	1.302	0	5.991	0	5.991	0	419.37	419.37
790	0	1.279	0	0.912	0	0.912	0	63.84	63.84
800	0.012	0.962	0.063	11.208	0.063	11.208	6.3	784.56	790.86
810	0.047	0.641	0.294	8.015	0.294	8.015	29.4	561.05	590.45
811.168	0.056	0.603	0.06	0.726	0.06	0.726	6	50.82	56.82
820	0.113	0.485	0.744	4.804	0.744	4.804	74.4	336.28	410.68
830	0.19	0.46	1.515	4.725	1.515	4.725	151.5	330.75	482.25
840	0.011	0.633	1.008	5.463	1.008	5.463	100.8	382.41	483.21
850	0	1.981	0.057	13.069	0.057	13.069	5.7	914.83	920.53
860	0	3.739	0	28.598	0	28.598	0	2001.86	2001.86
870	0	5.255	0	44.969	0	44.969	0	3147.83	3147.83
880	0	6.875	0	60.65	0	60.65	0	4245.5	4245.5
890	0	6.856	0	68.653	0	68.653	0	4805.71	4805.71
892.878	0	6.397	0	19.071	0	19.071	0	1334.97	1334.97
900	0.107	5.599	0.383	42.717	0.383	42.717	38.3	2990.19	3028.49
Total		32.396	349.833	248.328	2642.276		24832.8	184959.32	209792.12
	Area Cut (m2)	Area Fill (m2)	Volume Cut (m3)	Volume Fill (m3)		Cut cost	Fill cost	Total cut and fill cost	

Fig. No. 4.10.4 Earthworks report (Existing road)

740	0.017	1.658	0.03	4.94	0.03	4.94	3	345.8	348.8
750	0.005	1.331	0.109	14.992	0.109	14.992	10.9	1049.44	1060.34
760	0.005	1.237	0.046	11.508	0.046	11.508	4.6	805.56	810.16
770	0.011	1.456	0.08	13.52	0.08	13.52	8	946.4	954.4
780	0.003	1.508	0.057	12.608	0.057	12.608	5.7	882.56	888.26
784.918	0	1.472	0	7.464	0	7.464	0	522.48	522.48
785.018	0	1.3	0	0.151	0	0.151	0	10.57	10.57
789.293	0	1.214	0	5.991	0	5.991	0	419.37	419.37
790	0	0.998	0	0.912	0	0.912	0	63.84	63.84
800	0.012	0.962	0.063	10.101	0.063	10.101	6.3	707.07	713.37
810	0.047	0.641	0.294	8.015	0.294	8.015	29.4	561.05	590.45
811.168	0.056	0.603	0.06	0.726	0.06	0.726	6	50.82	56.82
820	0.113	0.485	0.744	4.804	0.744	4.804	74.4	336.28	410.68
830	0.19	0.46	1.515	4.725	1.515	4.725	151.5	330.75	482.25
840	0.011	0.633	1.008	5.463	1.008	5.463	100.8	382.41	483.21
850	0	1.981	0.057	13.069	0.057	13.069	5.7	914.83	920.53
860	0	3.739	0.021	24.003	0.021	24.003	2.1	1680.21	1682.31
870	0	5.255	0	42.015	0	42.015	0	2941.05	2941.05
880	0	6.875	0	60.85	0	60.85	0	4245.5	4245.5
890	0	6.856	0	54.087	0	54.087	0	3786.09	3786.09
892.878	0	6.397	0	19.071	0	19.071	0	1334.97	1334.97
900	0.107	5.599	0.383	38.651	0.383	38.651	38.3	2705.57	2743.87
Total	31.383	347.754	235.432	2505.612			23543.2	175392.84	198936.04
	Area Cut (m2)	Area Fill (m2)	Volume Cut (m3)	Volume Fill (m3)			Cut cost	Fill cost	Total cut and fill cost

Fig. No. 4.10.5 Earthworks report (New road)

Note: The cut cost for the above is taken as Rs 100/m³ and fill cost is taken as Rs 70/m³.

4.10.5 PAVEMENT LAYERS REPORT

PAVEMENT	860 -	Layer 1	0.04	2.8	240.84	240.84	70.02	6021.61	6021.61
	860 -	Layer 2	0.05	4.32	371.5	371.5	72.02	6193.59	6193.59
	860 -	Layer 3	0.25	18.5	1591.01	1591.01	74.02	6365.62	6365.62
	860 -	Layer 4	0.2	10.28	855.9	855.9	104.37	8661.95	8661.95
PAVEMENT	870 -	Layer 1	0.04	2.8	243.64	243.64	70.02	6091.63	6091.63
	870 -	Layer 2	0.05	4.32	375.82	375.82	72.02	6265.61	6265.61
	870 -	Layer 3	0.25	18.5	1609.51	1609.51	74.02	6439.64	6439.64
	870 -	Layer 4	0.2	10.7	866.6	866.6	109.15	8771.1	8771.1
PAVEMENT	880 -	Layer 1	0.04	2.8	246.44	246.44	70.02	6161.65	6161.65
	880 -	Layer 2	0.05	4.32	380.14	380.14	72.02	6337.63	6337.63
	880 -	Layer 3	0.25	18.5	1628.01	1628.01	74.02	6513.66	6513.66
	880 -	Layer 4	0.2	10.7	877.3	877.3	109.15	8880.25	8880.25
PAVEMENT	890 -	Layer 1	0.04	2.8	249.24	249.24	70.02	6231.67	6231.67
	890 -	Layer 2	0.05	4.32	384.46	384.46	72.02	6409.65	6409.65
	890 -	Layer 3	0.25	18.5	1646.51	1646.51	74.02	6587.68	6587.68
	890 -	Layer 4	0.2	10.7	888	888	109.15	8989.4	8989.4
PAVEMENT	892.878 -	Layer 1	0.04	0.81	250.05	250.05	20.15	6251.82	6251.82
	892.878 -	Layer 2	0.05	1.24	385.7	385.7	20.73	6430.38	6430.38
	892.878 -	Layer 3	0.25	5.33	1651.84	1651.84	21.3	6608.98	6608.98
	892.878 -	Layer 4	0.2	3.08	891.08	891.08	31.41	9020.81	9020.81
PAVEMENT	900 -	Layer 1	0.04	1.99	252.04	252.04	49.87	6301.69	6301.69
	900 -	Layer 2	0.05	3.08	388.78	388.78	51.29	6481.67	6481.67
	900 -	Layer 3	0.25	13.18	1665.02	1665.02	52.72	6661.7	6661.7
	900 -	Layer 4	0.2	7.62	898.7	898.7	77.74	9098.55	9098.55
				Total cost	3555450.24				

Fig. No. 4.10.6 Pavement layers report (Existing road)

PAVEMENT	860 -	Layer 1	0.04	0.33	227.17	227.17	70.02	5811.55	5811.55
	860 -	Layer 2	0.05	0.5	350.4	350.4	72.02	5977.53	5977.53
	860 -	Layer 3	0.25	2.16	1500.67	1500.67	74.02	6143.56	6143.56
	860 -	Layer 4	0.2	1.05	809.39	809.39	104.37	8363.19	8363.19
PAVEMENT	870 -	Layer 1	0.04	2.8	229.64	229.64	70.02	5881.57	5881.57
	870 -	Layer 2	0.05	4.32	354.22	354.22	72.02	6049.55	6049.55
	870 -	Layer 3	0.25	18.5	1517.01	1517.01	74.02	6217.58	6217.58
	870 -	Layer 4	0.2	10.7	817.34	817.34	109.15	8457.99	8457.99
PAVEMENT	880 -	Layer 1	0.04	2.8	232.44	232.44	70.02	5951.59	5951.59
	880 -	Layer 2	0.05	4.32	358.54	358.54	72.02	6121.57	6121.57
	880 -	Layer 3	0.25	18.5	1535.51	1535.51	74.02	6291.6	6291.6
	880 -	Layer 4	0.2	10.7	826.34	826.34	109.15	8557.58	8557.58
PAVEMENT	890 -	Layer 1	0.04	2.8	235.24	235.24	70.02	6021.61	6021.61
	890 -	Layer 2	0.05	4.32	362.86	362.86	72.02	6193.59	6193.59
	890 -	Layer 3	0.25	18.5	1554.01	1554.01	74.02	6365.62	6365.62
	890 -	Layer 4	0.2	10.7	835.77	835.77	109.15	8661.95	8661.95
PAVEMENT	892.878 -	Layer 1	0.04	0.71	238.04	238.04	19.85	6091.63	6091.63
	892.878 -	Layer 2	0.05	1.1	367.18	367.18	20.73	6265.61	6265.61
	892.878 -	Layer 3	0.25	5.33	1572.51	1572.51	21.3	6439.64	6439.64
	892.878 -	Layer 4	0.2	3.08	845.62	845.62	31.41	8771.1	8771.1
PAVEMENT	900 -	Layer 1	0.04	1.75	230.54	230.54	47.9	6200.14	6200.14
	900 -	Layer 2	0.05	2.87	370.73	370.73	49.67	6340.99	6340.99
	900 -	Layer 3	0.25	11.64	1590.12	1590.12	50.23	6550.54	6550.54
	900 -	Layer 4	0.2	6.61	850.21	850.21	74.97	8887.37	8887.37
					Total cost	3342667.86			

Fig. No. 4.10.7 Pavement layers report (New road)

Note: The costs for different layers taken above are:

BC= Rs 4490/m³ , DBM= Rs 2484/m³ , WMM= Rs 486/m³ , GSB= Rs 722/m³

CHAPTER 5
CONCLUSIONS

5.1 GENERAL

MX road is a string-based road designing software developed by Bentley systems which is recently upgraded for faster and accurate results. Designing new centreline in accordance with the existing road profile is an easy task in the software. Further, horizontal and vertical profile for the road can be defined easily. Similarly, super elevation, cross sections, earthwork wizard, carriageway defining and pavement design were carried out using the software.

5.2 CONCLUSIONS

As compared with the conventional methods, softwares have helped in saving time as well as sources. By use of MX Road software, the time taken to design a road and estimating volumes and cost of construction is significantly reduced. In this project the main focus was on reducing the cost and increasing the safety of roads constructed. This was done by designing new centreline of the existing road and decreasing the overall length of road by increasing the radius of curves. Moreover, due to reduced distance and less curves the time taken from Jhalawar to Payli has been reduced. Hence, the new design and the earlier existing design were compared for calculating volume change and reduction in cost and summarized below.

From the above earthworks report it can be concluded that:

$$\text{Reduction in volume cut and fill} = (4688.432 - 4444.956) + (49886.17 - 47305.95) = 243.476 + 2580.22 = 2823.696 \text{ m}^3$$

$$\text{Therefore, cost reduced in volume cut and fill} = 3960875.1 - 3755912.1 = \text{Rs } 204963$$

From the above pavement layers report it can be concluded that:

Reduction in volumes of different layers:

$$\text{BC} = 4758.52 - 4352.6 = 405.92 \text{ m}^3$$

$$\text{DBM} = 7340.16 - 7000 = 340.16 \text{ m}^3$$

$$\text{WMM} = 31246.8 - 30021.46 = 1225.33 \text{ m}^3$$

$$\text{GSB} = 16967.45 - 16051.96 = 915.48 \text{ m}^3$$

Therefore, cost reduced in pavement= $67035155.94 - 63111118.68 = \text{Rs } 3924037.26$

5.3 SCOPE FOR FUTURE WORK

Softwares are the future in construction of roads, buildings, bridges and other construction works as they are easy to use and help in saving time. MX Road is a magnificent string-based displaying device that empowers the quick and exact plan of a wide range of roads and streets. It is broadly utilized by structural specialists, creators, proficient surveyors, geotechnical engineers, storm waste/water/sewer framework architects and structural designing experts. People, for example, structural architects, originators, surveyors, framework fashioners can get to 3-D displaying, development driven building, and different investigation across the board designing application.

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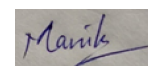
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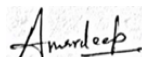
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