DESIGN OF FLEXIBLE PAVEMENT FOR HOT AND RAINY REGIONS

A

Project Report

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

BACHELOR OF TECHNONOLOGY

IN

CIVIL ENGINEERING

Under the supervision

Of

CHANDRA PAL GAUTAM

(Assistant Professor)

By

DIVYANSHU PANDIT (171637)

GAURAV PRAKASH NEGI (171609)

To

DEPARTMENT OF CIVIL ENGINEERING
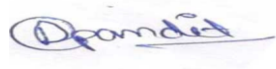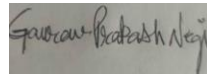
JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

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STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"(Design of flexible pavement for hot and rainy regions)"** submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **(Asst. Prof. Chandra Pal Gautam)**. 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.

Name of Student	Roll No.	Signature of Student
Divyanshu Pandit	171637	
Gaurav Prakash Negi	171609	

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat

India

Date: May 16, 2021.

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"DESIGN OF FLEXIBLE PAVEMENT FOR HOT AND RAINY REGIONS "** in partial fulfillment 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, Waknaghat** is an authentic record of work carried out by **Divyanshu Pandit (171637), Gaurav Prakash Negi (171609)** during a period from August, 2020 to May, 2021 under the supervision of **Asst. Prof. Chandra Pal Gautam** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement made is correct to the best of our knowledge.

Date: May 16, 2021

HOD
CE DEPT

Signature of Supervisor   Signature of HOD   Signature of

Chandra Pal Gautam   Prof. Dr. Ashok Kumar Gupta   External Examiner

Assistant Professor   Professor and Head

Department of Civil Engineering   Department of Civil Engineering

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'

ABSTRACT

The satisfactory performance of the pavement will result in higher savings in terms of vehicle operating costs and travel time, which has a bearing on the overall economic feasibility of the project. The profound development in the automobile technology has resulted heavy moving loads on the existing highways for optimization of the transport cost also it affects the pavement. The existing roads which are designed based on the thumb rules are not able to cater to the heavy wheel loads resulting in the deterioration of the existing roads.

The pavement gets deformed and deteriorated due to repeated movement of heavy load vehicles on the pavement along with the higher temperature that increases discomfort to the passengers as well as increase wear and tear on the vehicle. In rainy regions, excess rainfall results in the failure of the pavement.

In the project, an attempt is made to design two roads, one for plain areas with high temperature and the second one with high rainfall with adequate pavement design with the use of modified bitumen in the surface course and using super hydrophobic layer coating for hot and rainy regions respectively, to withstand with the climatic conditions and to resolve major issues due to the different climates in a particular region. The pavements are designed based on the principles of pavement design according to IRC-37 (2018). New alignment for the roads are designed and the pavement is designed as per given guidelines of IRC. The alignment of the road is done with the help of MX Road software. The length the road 1 and 2 is 1.2 km and 1.3 km respectively. The pavements are designed and analyzed using IIT PAVE software.

[*Keywords:* Pavement, Bitumen, IRC, MX ROAD, IIT PAVE]

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ABBREVATIONS

IRC	Indian Road Congress
OMC	Optimum Moisture Content
VMA	Voids in Mineral Aggregate
VFB	Voids Filled with Bitumen
DBM	Dense Bitumen Macadam
WMM	Wet Mix Macadam
GSB	Granular Sub Base
m^3	Meter Cube
BC	Bituminous Concrete
MPa	Mega Pascal
ROW	Right of Way
MoRTH	Ministry of Road Transport and Highways
SSD	Stopping Sight Distance
ISD	Intermediate Sight Distance
CBR	California Bearing Ratio
KN	Kilo-Newton
Cvpd	Commercial Vehicle per Day
VDF	Vehicle Damage Factor
e_v	Vertical Compressive Strain
N_{Des}	Cumulative number of standard axles
N_r	Rutting Life
N_f	Fatigue Life
M_{Rm}	Resilient Modulus of Bitumen
M_R	Resilient Modulus

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CHAPTER 1

INTRODUCTION

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.

Asphalt configuration targets deciding the absolute thickness of the asphalt structure just as the thickness of the individual underlying segments for conveying the assessed traffic stacking under the predominant natural conditions. Many plan techniques, from absolutely experimental to thorough logical ones are accessible and these are drilled in various pieces of the world. The plan techniques received in different nations may not be material to Indian climatic conditions. In India, the by and large embraced strategy for plan of adaptable asphalt depends on IRC: 37. Appropriately IRC: 37-2018 "Guidelines for the Design of Flexible Pavements", have been adopted.

For economic and efficient construction of highways, correct design of the thickness of pavements for different conditions of traffic and sub-grades is essential. The science of pavement design is relatively new. In India, previously road crust was designed on some rational data but more on the experience of the road engineer. Some arbitrary thicknesses of the pavements were used which lead to costly failures and wastage as in some cases, the thickness of pavements was insufficient and in the other cases expensive. As there are no proper design criteria, the construction of roads was more or less uneconomical in almost all cases. Hence judicious method of designing and calculating the crust thickness on the basis of estimation of traffic loads and bearing capacity of sub-grade, will lead to economical construction of roads.

1.1. OBJECTIVES AND REQUIREMENTS OF PAVEMENTS:

- The surface of an asphalt ought to be steady and non-yielding, to permit the hefty wheel heaps of the street traffic to move with least conceivable moving obstruction.
- The street ought to be even along the longitudinal profile to empower the quick vehicles to move securely and serenely at the plan speed.
- A asphalt layer is viewed as more viable or predominant, in the event that it can circulate the wheel load pressure through a bigger region for every unit profundity of the layer.
- The flexible disfigurement of the asphalt ought to be inside as far as possible, so the asphalt can support countless rehashed load applications during the plan life.
- It is always desirable to construct the pavement well above the maximum level of the ground water to keep the sub-grade relatively dry even during monsoons. At high moisture contents, the soil becomes weaker and soft and starts yielding under heavy wheel loads, thus increasing the tractive resistance.

1.2 Types of pavement:

Based on the structural behavior, pavements are generally classified into the following two categories:

1. Flexible pavement

2. Rigid pavement

1.2.1 Flexible Pavement:

➢ Flexible pavement can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Bituminous concrete, granular materials with or without bituminous binders, WBM, soil aggregate mixes are common examples of flexible pavements.

We have used the mechanistic- empirical design approach as per IRC-37 (2018) for the design of flexible pavement. Fig 1.1 is an example of flexible pavement.

➢ Some features of these pavements are:

- It possess no flexural strength.

- It shows the deformation of lower layers.

- The vertical compressive stress is transferred to bottom layers by grain to grain transfer.

- The lower layer are subjected to lesser magnitude of stress and therefore no direct wearing effect due to traffic loads, therefore low cost materials that are inferior can be used in the lower layers.

Flexible pavements consist of the following components:

i. Sub grade

ii. WMM course

iii. Sub Base course

iv. Bituminous Course

Fig 1.1 Flexible pavement

1.2.2 Rigid pavement

➤ Rigid pavements are those which possess noteworthy flexural rigidity. Rigid pavements are made of Portland cement concrete either plain, reinforced or pre stressed. These are designed using elastic theory, assuming the pavement as an elastic plate resting over an elastic or viscous foundation. Fig. 1.2 is an example of rigid pavement.

➤ Some features of rigid pavement:

- It possesses noteworthy flexural strength.
- Load is transferred is by the slab action and the wheel load is distributed to a wider area below.
- Flexural stresses are developed due to 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.

Rigid pavement consists of the following components:

    i.   Concrete slab
   ii.   Base Course
  iii.   Sub grade

Fig 1.2 Rigid Pavement

1.3 Cross Section and Functions of flexible pavement components:
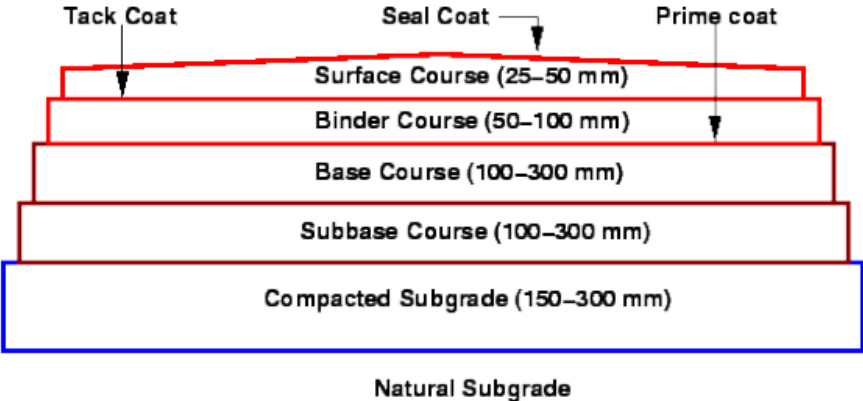
Fig.1.3 Cross Section of flexible pavement
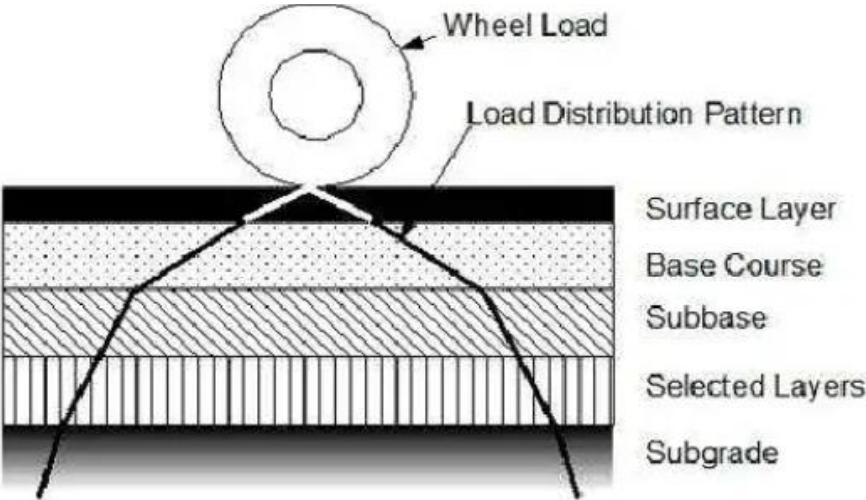
Fig. 1.4 Load distribution Pattern

1.3.1. Soil Subgrade:

- The wheel load is at last taken by soil sub evaluation and consequently for no situation it ought to be over stressed and the 50cm top layer of soil sub grade should be compacted well at O.M.C. 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.
- Common strength tests used for evaluation of soil sub grade are :
  - i.   CBR (California Bearing Ratio test)
  - ii.   Resistance value test
  - iii. Triaxial compression test
  - iv.   Plate bearing test

1.3.2. Sub base and Base course:

- These are aggregates made from crushed stone. Smaller size graded aggregates are desired at sub base course instead of boulder stones. Coarse graded aggregates with low percentage of fines (less than 5 % finer than 0.075 mm size) will serve as a good drainage layer.
- Base and sub base courses are lies under flexible pavements to improve load bearing capacity by distribution of load through a finite thickness.
- Base courses are used under rigid pavements for :
  - i.   It prevent pumping.
  - ii.   It protect the sub grade from frost action.

1.3.3. Surface Course:

- This course is provided to give smooth riding surface. Pressure exerted by the tyres and wear and tear is resisted by this layer. Also it offers water tightness.
- The dependability of wearing course is assessed by Marshall strength test where in ideal percent of bituminous material is worked out dependent on security thickness, voids in mineral total (V M A) and voids loaded up with bitumen (V F B). Plate Bearing test are additionally some of the time made use for lifting the wearing course and the asphalt all in all. Marshall Stability test and blend plan strategy has been suggested by the IRC for planning the thick bituminous blends like Dense Bituminous Macadam (DBM) course and Bituminous Concrete (BC) surface course in India.

1.4. Factors to be considered for pavement design:

The pavement design consists of 2 parts:

i.   The mix design of the material to be used in pavement layer.

ii.   Pavement thickness design and the supporting layers thicknesses.

The various factors to be considered for the design of pavement are:

1.   Sub Grade Soil

2.   Design Wheel Load

3.   Environmental Factors

4.   Pavement component material

5.   Climatic Factors

1.4.1   Design wheel load :

Following are the important wheel load factors:

(A) Maximum wheel load :

- The maximum axle load as given by IRC is 8.1t with a maximum equivalent single wheel load of 4 tonnes.

(B) Contact Pressure :

- High magnitudes tyre pressures demands high quality materials in the upper layers in pavements, however the total depth of pavement is not governed by tyre pressure.

- Generally the wheel load is assumed to be distributed in circular but it is seen that contact area in many cases is elliptical.

    As per IRC the contact pressure is taken as 0.56 MPa

(C) Equivalent single wheel load:

The impact on the asphalt through a double burden gathering isn't equivalent to multiple times the heap on any one wheel. The pressing factor at a profundity underneath the asphalt surface is between the single burden and multiple times load conveyed by any one wheel.

1.4.2 Subgrade :

- The properties of soil subgrade are significant in choosing the thickness of the asphalt to shield it from traffic loads. The varieties in soundness and volume of subgrade soil with dampness changes are to be concentrated as these properties are reliant upon the dirt qualities. Aside from the plan, the asphalt execution to extraordinary degree relies upon the sub evaluation soil properties and waste. The alluring properties of soil as asphalt materials are:
  - i. Incompressibility
  - ii. Stability
  - iii. Permanency of strength.
  - iv. Minimum changes in volume and stability under adverse conditions of weather and ground water
  - v. Ease Of Compaction
  - vi. Good Drainage

1.4.3 Climatic Factors:

- The climatic variations cause the following major effects:
  - i. Moisture content variation
  - ii. Frost action
  - iii. Temperature Variation.

1.4.4 Pavement Component Material:

- The stress conveyance qualities of the asphalt part layers rely upon the attributes of the materials utilized. The exhaustion conduct of these materials and their sturdiness under unfriendly states of climate ought to likewise be given due thought.

1.4.5 Environmental Factors:

- The ecological factors, for example, height of embankment and its establishment subtleties, depth of cutting, foundation depth, and so on, influence the exhibition of the asphalt. The decision of bituminous fastener and execution of bituminous asphalts relies upon the varieties in asphalt temperature with seasons around there. The distorting stresses in inflexible asphalts rely upon day by day varieties

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in temperature around there and in the greatest contrast in temperature between the top and lower part of the asphalt piece.

1.5 Alignment Design

1.5.1 Introduction

The position of the middle line on the highway at the ground is called highway alignment. Interstate arrangement incorporates flat arrangement and vertical arrangement. The projection of roadway arrangement in the flat plane is named as the even arrangement and the projection of expressway arrangement in the upward plane is called vertical arrangement. Alignment should be chosen so that the general expense during development, activity and upkeep is least.

1.5.2 Cross Sections Elements

These are the cross sectional elements of the road:

- Right of way (ROW).
- Road carriageway.
- Width at cross drainage structures.
- Shoulders.
- Width of drainage or footpath.
- Camber or cross fall.

The above components together comprise total street cross segment. Selection of different components in a suitable way, as per IRC rules for safe development of traffic is a significant plan necessity. These are definite in the accompanying segments.

- Roadway Width/ Formation Width:
  According to IRC 73 formation width for 2 lane carriageway configuration for State Highways in plain & rolling terrain as 7.0m.
- Shoulders:
  The normal shoulder width as per IRC: SP 73 shall be 2.5m on either side in roads passing through plain and rolling terrain, and both in open country and built-up area. 1.5 m paved shoulder and 1.0m earthen shoulder is adopted.

- Camber:

  As per IRC: 73 2.5% camber in the straight sections of the bituminous pavement surface and 3% in shoulder is adopted

- Footpath:

  At least 1.5m of footpath width to be adopted.

1.5.3 Key Parameters for Road Design

The design standards are based on IRC, as well as on MORTH Specifications and relevant international standards. Where the design standards are silent, the consultant has designed on the basis of past experiences.

The key design parameters are listed below:

- Terrain Classification :- Following Terrain classification is recommended by the IRC:38-1988 /IRC:SP:73-2007 is proposed to be adopted:

Table 1.1 Terrain Classification

Terrain	Cross Slope
Plain	<10
Rolling	10-25
Mountainous	25-60
Steep	>60

- Design Speed:

  The allowable speeds are dependent on the terrain speeds .The project road is plain and rolling terrain the road may have horizontal curves that do not accept the design speed. In the view of this, the design speed that could be achieved shall be rechecked and deciding a speed that will give a safe design and conform the design standard as per IRC to design standards within the constraints. The design speeds of 100 kmph and 80 Kmph as maximum and minimum as per IRC: SP: 73 has been adopted for road in plain terrain. Table 1.2 below shows design parameters for plain terrains.

Table 1.2 Design Parameters for Plain Areas

Sr. No	Contents	Details
1.	Design Speed	100/80 Kmph
2.	Lane width	3.5 m
3.	Camber (Pavement and Paved shoulder)	2.50%
4.	Camber (Gravel Shoulder)	3.00%
5.	Kerb Shyness on footpath (IF applicable)	0.25 m
6.	Maximum super elevation	7.00 %, Limited to 4% in urban areas
7.	Stopping sight distance (SSD)	180/120
8.	Intermediate sight distance (ISD)	360/240
9.	Minimum radius of horizontal curve	360/230
10.	Minimum radius of curve without transition curve	2200/1200
11.	Ruling maximum gradient	3.30%
12.	Minimum length of vertical curve	60/50 m

1.5.4   Horizontal Alignment

1.5.4.1 General Introduction

The horizontal alignment is the route of the road, characterized mathematically as a progression of horizontal tangents (straight street segments), circular curves, and twisting advances. It shows the proposed road area comparable to the current territory and nearby land conditions. The essential target of horizontal alignment is to coordinate these components to furnish a viable speed with the road capacity and area.

1.5.4.2 Design Elements

- Radii of Horizontal Curve:

  In general, horizontal curves consist of a circular curve portion flanked by a spiral transition on both ends. These shall correspond to the ruling minimum and absolute minimum design speeds and the maximum permissible values of super-elevation as

per IRC: 73:1980 guidelines. For the roads in plain/ rolling terrain, for the design speed of 100 kmph, the radius of more than 360 m and for the design speed of 80 km/h, the radius of more than 230 m shall be provided in design for the horizontal curves and is as per IRC:SP:73/IRC:73. Wherever possible and permissible, higher radii will be adopted.

- Super elevation:

The super elevation is needs for all the curves that have radius less than 180 meter to counteract the effect generated by the centrifugal force. According to IRC: 38-1988, the super-elevation to fully eliminate the centrifugal force is 75% of design speed, neglecting the friction that is generated laterally is used in the designed road. The maximum super elevation allowed is 7% and 4% in urban areas.

- Extra Widening :

Widening is important at sharp horizontal curves as extra width is needed because the path followed by the rear wheels are not same as of the front wheel .So as to ensure a safe passage of the vehicle extra width is provided .It is effected by increasing the width at a uniform rate along the transition curve.Extra width is continued over the full length of the circular curve. Table 1.3 mentions the value for extra widening for radius of curve.

Table 1.3 Values for Extra Widening

Radius of Curve (m)	Up to 20	21-40	41-60	61-100	100-300	Above 300
Extra Widening 2-Lane	1.5	1.5	1.2	0.9	0.6	NIL

- Transition Curve:

Transition curve offers a smooth entry to the approaching vehicle from the straight section into the circular curve. It also improve aesthetic appearance of the road besides permitting gradual application of the super-elevation and extra widening of carriageway as may be needed at the horizontal curves.

The horizontal curves with radius of curvature < 1800 m for 100 Kmph and <1100m for 80 Kmph transition curves are provided.

1.5.5   Vertical Alignment:

1.5.5.1 General Introduction

The vertical alignment is proposed to accommodate a smooth longitudinal profile reliable with configuration speed, design of the landscape and land-use. Too successive evaluation changes cause crimps and visual discontinuities in the profile.

1.5.5.2 Design Element

- Gradient

Gradients - Grades have been chosen cautiously keeping in see the plan speed, territory conditions and nature of traffic out and about. The decision and supreme most extreme longitudinal slopes are suggested by IRC: SP: 73 as 3.3% and 6.7% separately for plain territory. Essentially, for moving landscape administering and gradients are 5.0% and 7.0% separately. Profile plan of existing carriageway has been finished keeping in view to limit profile remedial course (PCC) amount.

- Minimum gradient for drainage

According to IRC 73, on un-kerbed asphalts on bank, close to even out levels might be satisfactory when the asphalt has adequate camber to deplete the tempest water along the side. Notwithstanding, in cut areas, or streets at ground level, or where the asphalt is furnished with kerbs, it is important to give some inclination to productive seepage. Suggested least inclination for this design is 0.5% if side channels are lined and 1.0%, if these are unlined. Further, a base longitudinal angle of 0.3% would be unmistakably received according to waste perspective in re-development segments.

- Vertical curves

These curve are for smooth transition for vehicles where the gradient changes.

1. Summit Curve or Hog Curves
2. Valley Curve or Sag Curves.

The length of these curves are decided on the basis of the sight distance. Curves with longer length are aesthetically better and also improves safety

1.6 Pavement design:

The mechanistic-empirical design approach is used for the design of flexible pavements. The theory selected for the analysis of pavements is 'linear elastic layered theory' in which the pavement is modeled as a multi-layer system. The bottom most layer (foundation or subgrade) is considered to be semi-infinite, and all the upper layers are assumed to be infinite in the horizontal extent and finite in thickness. Elastic modulus, Poisson's ratio and thickness of each layer are the pavement inputs required for analysis of stresses, strains and deflections produced by a load applied at the surface of the pavement.

1.6.1   Design approach and criteria of IRC:

There are three types of distresses resulting from repeated application of traffic that are considered.

These are as follows:

(i) Horizontal Tensile Strain at the bottom of Bituminous Layer.

(ii) Vertical Compressive Strain at th top of Sub Grade.

(iii) Pavement deformation with in the bituminous layer.

-The deformation with in the bituminous layer is assumed

to be controlled by meeting the mix design requirements

1.6.2 Binder selection for Surface layer and DBM

The drawn out acceptable exhibition of asphalts is impacted by the asphalt fixing materials and their properties. In bituminous asphalts other than stone totals, the bituminous cover is the key fixing which makes its choice a significant errand. It is the costliest segment of the bituminous blend. The most widely recognized issue in the exhibition of bituminous blend in with this folio was rutting during blistering summer. The bitumen turns out to be delicate in the 60 to 70°C temperature range (normal street surface temperature on a blistering summer day) and begins to push and push under stacked truck tires prompting rutting and layerings in the wheel tracks of the street. This standard has been additionally overhauled and the current standard IS: 73-2013 (Paving Bitumen-Specifications).

1.6.3 Resilient Modulus(M_r):

The Resilient Modulus (M_r) is a measure of the stiffness of the subgrade. We can estimate the modulus of elasticity or resilient modulus id=s a measure of material's stiffness. Whereas the modulus of elasticity is stress divided by strain for slowly applied load, the resilient modulus is the stress divided by the strain in case of fast applied loads– like those experienced by pavements.

It is determined using the Tri Axial Test. The test applies a rehashed hub cyclic pressure of fixed extent, load span and cycle length to a round and hollow test example. While the example is exposed to this powerful cyclic pressure, it is additionally exposed to a static restricting pressure gave by a triaxial pressure chamber. It is basically a cyclic variant of a triaxial pressure test; the cyclic burden application is thought to all the more precisely reproduce genuine traffic stacking

1.6.4 Design Parameters

- CBR Value of Sub Grade (%)

The CBR test is a penetration test that is used to evaluate the strength of the sub grade of road and pavement. On the basis of the results of this test the thickness of the pavement and its component layers are decided.

- Design traffic

  The Design Traffic is calculated in terms of msa (Million Standard Axles).

  The following inputs given below are required for the estimation of the design traffic for a selected road for a specific design period

  Initial Traffic on the road after construction in terms of the number of commercial vehicles per day (cvpd).

  (i)   Traffic Growth rate (r) during design life

  For assessing the total traffic expected to utilize the asphalt over the plan time frame, it is important to gauge the rate(s) at which the business traffic will develop over the plan time frame. The development rates might be assessed according to IRC: 108 [16]. Ordinary information needed for assessment of the development rates (r) are:

  (i)   Traffic growth in the past.

  (ii)   Request versatility of traffic as for macroeconomic boundaries like the total national output and state homegrown item) and the interest expected because of explicit turns of events and land use changes prone to happen during the design life period.

  A minimum annual growth rate of 5 per cent should be used for commercial vehicles for estimating the design traffic.

  (ii)   Design life:

  Design life is the period for which a pavement is designed. Recommended design life of 20 years is adopted for the structural design of pavement for NH, SH and urban Roads. However for other categories it is taken as 15 years

  (iii)   Spectrum of axle loads:

  The axle load data is classified into multiple classes with class intervals of 10kN,20kN,30kN for single, tandem and tridem axles for the analysis of axle load spectrum and calculation of VDF's.Its values are given in IRC 37 (2018).

(iv)   Lateral distribution of commercial traffic over the carriageway:

Lateral Distribution of the commercial traffic on a road or carriageway is needed for the estimation of the design traffic to be considered for the pavement structural design. The lateral distribution factors may be considered for roads as per given in IRC-37.

- Computation of Design Traffic:

The equation given below is used to estimate the design traffic in terms of the million standard axles during the design period of the road. The meaning of the symbols are listed below.

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

N_{DES} = cumulative number of standard axles

A = Initial Traffic

D= Lane Distribution Factor

F = Vehicle Damage Factor (VDF)

n = Design Life

r = Annual growth Rate

1.6.5 Failure Criteria:

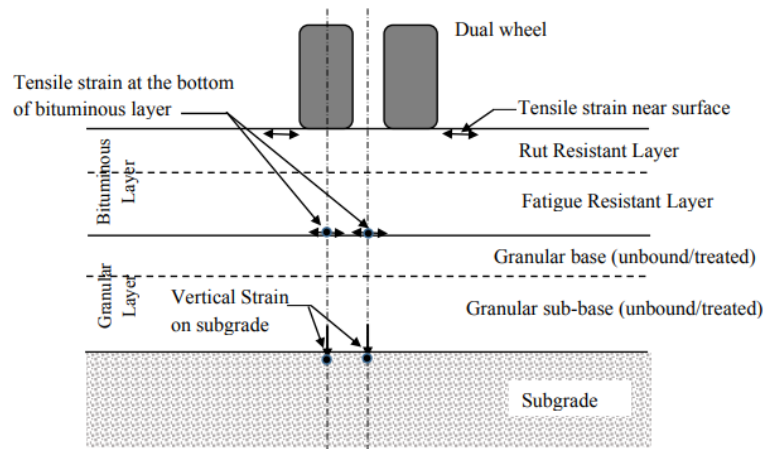o Location of critical strains in pavement:

Fig.1.5 Critical Strains Location

o Subgrade Rutting

This distress is due to the increase in the compressive strain on the top of the subgrade. An average of 20mm rut depth or more that is measured along the wheel paths is considered as a failure rutting condition. Following equation is used to calculate the rut rutting life.

$$N_r = 4.1656 \times 10\text{-}08 \, [1/\varepsilon v \,]^{\, 4.5337}$$

Where,

N_r = subgrade rutting life.

ε_v = vertical compressive strain at the top of the subgrade.

o Fatigue Cracking:

This distress is due to the tensile strain that is developed at the bottom of bottom bituminous layer .If 20% of the total area of the pavement has cracks than the it is said to be failed in fatigue. Fatigue life can be calculated by the equation given below.

$$N_f = 1.6064 * C * 10\text{-}04 \, [1/\varepsilon t \,] \, 3.89 * \, [1/MRm] \, 0.854$$

Where

C =10M

M=4.84(+Vbe-0.69)

Va =percent volume of the air voids in the mix

Vbe=percent volume of effective bitumen in the mix

N_f=Fatigue life of pavement

ε_t=Maximum horizontal tensile strain at the bottom of the bottom bituminous layer

M_{Rm} = Resilient Modulus of the bituminous mix

1.7 IRC method :

Step 1: Selecting a trial composition of the pavement.

Step 2: Bituminous Mix design and the mix resilient modulus.

Step 3: Selecting layer thickness.

Step 4: Structural Analysis of the selected pavement structure using IIT PAVE.

Step 5: Computing the allowable strains/stresses.

Step 6: Doing the iterations.

CHAPTER 2
SOFTWARE USED

2.1 MX Road

2.1.1 Introduction

MX Road is a brilliant string-based displaying software that empowers the quick and precise plan of a wide range of roads. People like structural architects, builders, surveyors can get to 3D displaying, development driven designing, and other examination across the board designing application. MX Road adds to improving the nature of plans by consolidating conventional designing work process profile and cross areas with 3D displaying innovation.

Access three dimensional displaying, assessment, asphalt format, and development pushed designing, across the board programming. MXROAD Suite makes work faster, more astute and all the more productively. MXROAD Suite empowers to improve design top notch by utilizing consolidating traditional designing work processes of plan, profile, and go-segments with progressive three dimensional demonstrating age basically dependent on parametric connections and requirements.

String- A string is a progression of focuses and might be joined by straight or bend fitted lines. A line of some structure addresses all surfaces and highlights. Any line that can be attracted level and vertical portrayal is a string.

Model- A model is a gathering of strings characterizing a surface. Models can record various sorts of data, for example, ground surface, a progression of highlights, an organization of information, or simply focuses.

Capabilities of MXROAD SUITE-

• Acquire and incorporate surveys

 • Create horizontal and vertical alignments

 • Create profiles and cross sections

• Create project base maps

• Design and analyze corridors

• Visualize designs

• Simulate vehicle path movement

 • Incorporate third-party models in civil designs

2.2 IIT Pave

2.2.1 Introduction

IITPAVE programming has been produced for the analysis of linear elastic layered system of pavement. The stresses, strains and deflection caused at various areas in pavement by a consistently single load applied over a circular contact region at the surface of pavement can be computed using this software. The impact of extra loads (which ought to likewise be consistently dispersed loads over circular contact regions) was considered using superposition rule. The single vertical load applied at the surface is depicted as far as (a) contact pressure factor and radius of contact region. For IITPAVE, wheel load and contact pressure are the heap inputs. The pavement inputs required are the elastic properties and the thicknesses of the multitude of layers IITPAVE programming, in its present rendition, can be utilized to dissect pavement with a limit of ten layers including the subgrade. In the event that the quantity of layers in the asphalt is more than ten, unique layers of comparative nature (eg. granular, bituminous) can be consolidated and considered as one layer. Cylindrical coordinate framework is continued in the program. Hence, the point of any component in the pavement is characterized by (a) height of the area of the component from the top of the pavement and the radial distance of the component estimated from the upward hub of evenness (along the focal point of the round contact space of one wheel load.

CHAPTER 3
LITERATURE REVIEWS

1. **"Effect of high temperature and traffic loading on rutting performance of Flexible pavement"** by *Zainab Ahmed Alkaissi*.

The aim of this research is to study the effect of high temperature on rutting damage of flexible pavement by imposed two models for investigation using ABAQUS.

- There is a significant effect of both thermal and traffic loading conditions on rutting damage of flexible pavement and higher temperatures will provide high rut depth.
- The combined thermal and traffic loading effects increased the vertical strain within flexible pavement.

2. **"Utilization of Plastic waste in Bitumen Mixes for Flexible Pavement"** by *Dr. S. L. Hake, Dr. R. M. Damgir,, P. R. Awsarmal.*

The aim of this research is to make use of waste plastics and to make adaptable asphalt bitumen for surface course by doing Marshall's test on asphalt made with different plastic content.

- The optimum bitumen content of the neat semi dense bituminous concrete mixes showed 10% higher when compared with modified semi dense bituminous concrete mixes with waste plastic.
- The Marshall Stability of neat semi dense bituminous concrete mixes at optimum bitumen content showed 1.6% lower when compared with modified semi dense bituminous concrete mixes with waste plastic.

3. **"Characterization of Bituminous Mixes Containing Harder Grade Bitumen"** by *Siksha Swaroopa Kara, Khusboo Arroba, ChandraKant Manib & Dr P K Jain.*

The aim of this research is to make a Higher Grade Bitumen named as VG-50 by blending softer grade bitumen VG-10 with the vacuum residue to give better performance in temperate regions.

- Harder Grade Bitumen shows higher resistance to rutting at high temperature showing higher value of resilient modulus than conventional VG-30 .
- The higher grade bitumen is substitute for better performance of bituminous base course.

4. **"Application of permeable pavements in highways for storm water runoff management"** by *Masoud Kayhanian, Hui Li, John T. Harvey.*

The aim of this research is to study the effect of Application of permeable pavements in highways for storm water runoff management.

- The highway traffic lanes are designed and constructed based on the impermeable conventional pavement, but the shoulders are designed as FDPP.
- Minimum of 0.15 m to maximum of 2.9 m aggregate base thickness is sufficient to capture all rainfall over the course of a rainy season.

5. **"Forage Ash Stabilized Shale Soil for Effective Use in Flexible Pavement"** by *fadamoro Oluwafemi, oyediran ibraham adewuvyi.*

The aim of the research is to study the effect of Performance Evaluation of Forage Ash Stabilized Shale Soil for Effective Use in Flexible Pavement.

- Increases its MDD and subsequently decreases its OMC with peak values recorded at 10% addition, which could be taken as the optimum value during the design and construction of pavements.
- There was considerable increase in the strength of the shale as seen from results of the CBR and UCS, which can be concluded that forage ash can be used to significantly improve the strength of shale soils.

6. **"Tack coats for asphalt paving"** by *N.F. Ghaly, I.M. Ibrahim , E.M. Noamy.*

The aim of the research is to study the effect of application of tack coats for asphalt paving.

- The test results indicated that the tack coat asphalt or modified tack coat asphalt emulsion has higher shear strength values compared with the cutback asphalt; improvement in bond strength dependent on application rate, viscosity and temperature.

7. "**Examination of the Effect of Super hydrophobic Coated Pavement under Wet Conditions"** by *Ekinhan Eriskin, Sebnem Karahancer, Serdal Terzi*, Mehmet Saltan .*

The aim of the research is to study the effect of examination of the effect of super hydrophobic coated pavement under wet conditions.

- SH coated samples have a bigger contact angle with water.
- SH coating delays the decrease in temperature.
- SH coated samples don't lose the property of having huge contact angle after 100 drives.

CHAPTER 4
METHODOLOGY

4.1 GEOMETRIC DESIGN

4.1.1 Data Collection

From an unknown survey of plain areas, the total station data is changed into the .txt format and GENIO file is made from which the parameters required for designing of 2 new two lane roads can be imported easily. The survey included total station data i.e. Northing Easting and Elevation at different points on the surface of area that are used for the designing of the new two lane different roads using same survey data file

4.1.2 Design Data:

By considering all the IRC specification and existing features of project corridor the following design values shown in table 4.1 are taken for executing the design of the project work by using MX ROAD software.

Table 4.1 Design Parameters

Sr. No.	Design Parameters	Road 1	Road 2
1.	Design Speed	85Kmph	80kmph
2.	Right Of Way	30 m	30 m
3.	Set back	2-5 m	2-5 m
4.	Length of Road	1.2 km	1.3 km
5.	Carriageway Width	7.0 m	7.0 m
6.	Shoulder Width	2.5 m	2.5m
7.	Camber	2.50 %	2.50%
8.	Super Elevation	7% or 0.07	7% or 0.07
9.	Ruling Radius	350m	360m
10.	Minimum Radius	230m	230m
11.	Maximum Gradient	3.33 %	3.33%
12.	Minimum Gradient	0.3%	0.3%

4.1.3 Creating of new project:

1. Open MX Road Software, the start-up box shown below will appear on screen.
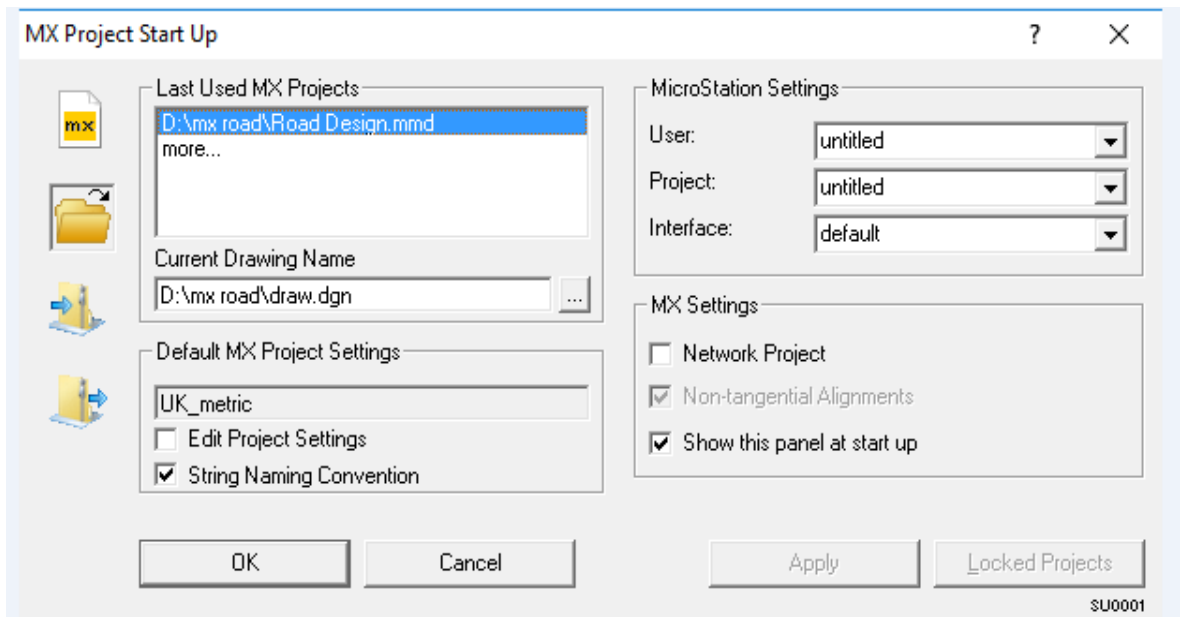
Fig 4.1 Start-up box.

2. Create a new folder in D drive as 'project' where the data will be saved >Name the project Road Design > Enable String Naming Convention and Non Tangential Alignments > Click ok.

3. Project setting dialog box will appear > Set System Parameters that are drawing scale as 1:500 and units as metric in the dialog box shown below.
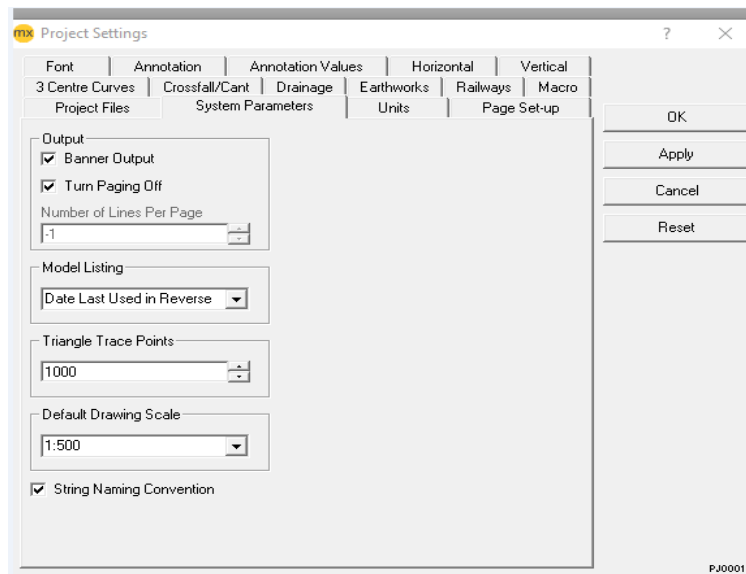

Fig.4.2 Project Setting Dialog Box

4.1.4 Importing Survey File:

1. Go to file menu > Choose ASCII File > Change the File type to GENIO format > Select Survey file > Click Open > The File is Imported to the MX window.
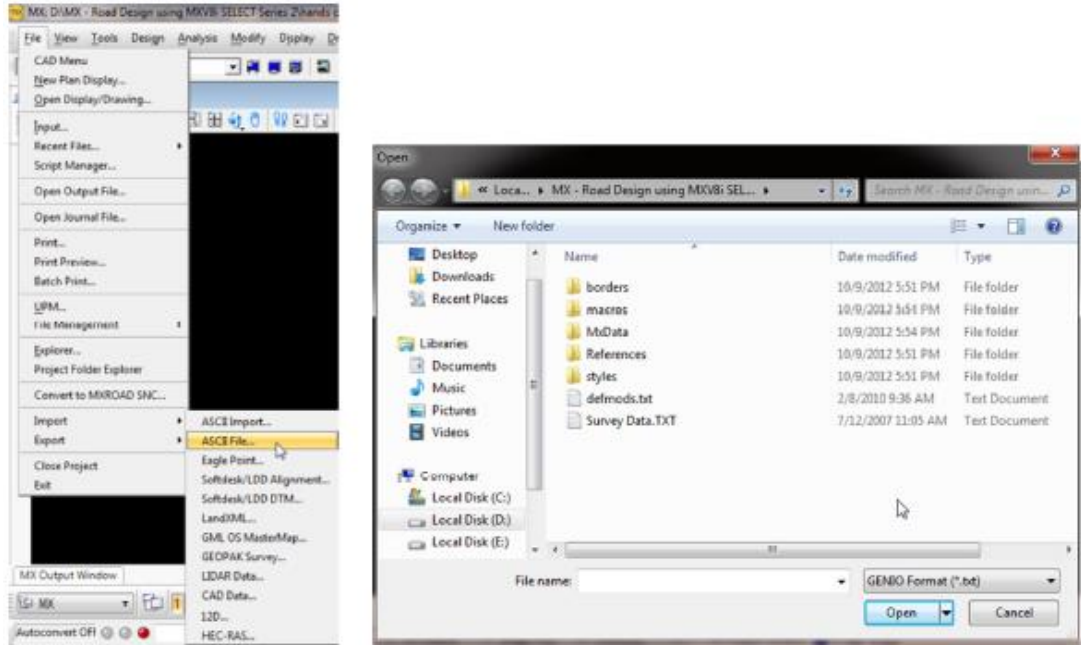
Fig 4.3 File Import.

2. Model defaults. Tools menu-> Model Defaults-> model name survey from the list and click on edit > style set name as *mfw simple survey* from the library > click ok.
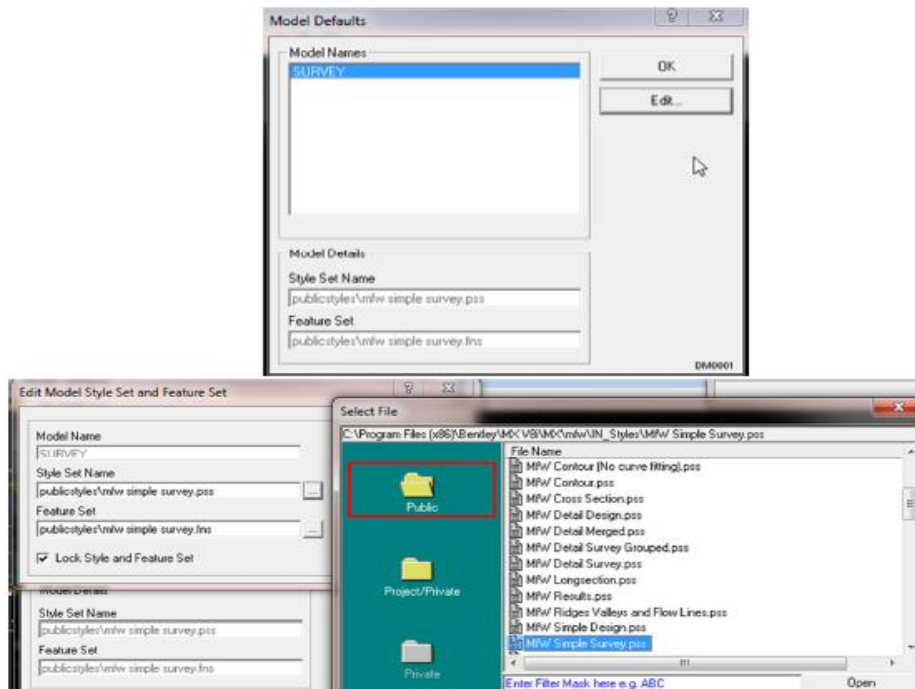
Fig 4.4 Style Set

3. To display the drawing, display menu-> plan with display styles set-> select the survey name from the drop down menu-> click ok. The file is displayed as shown in Fig. 4.6.
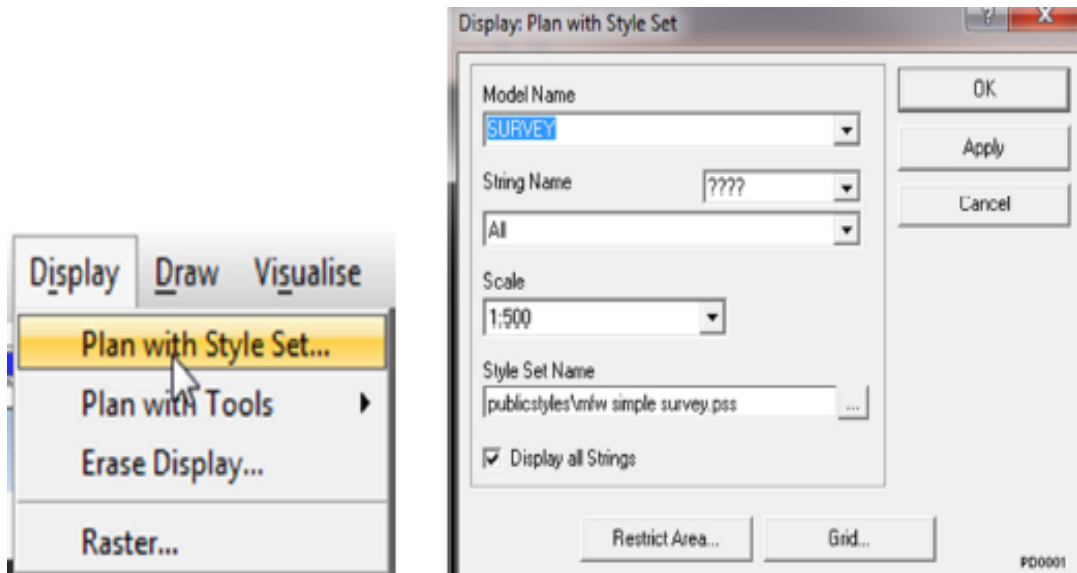
Fig. 4.5 Display Model
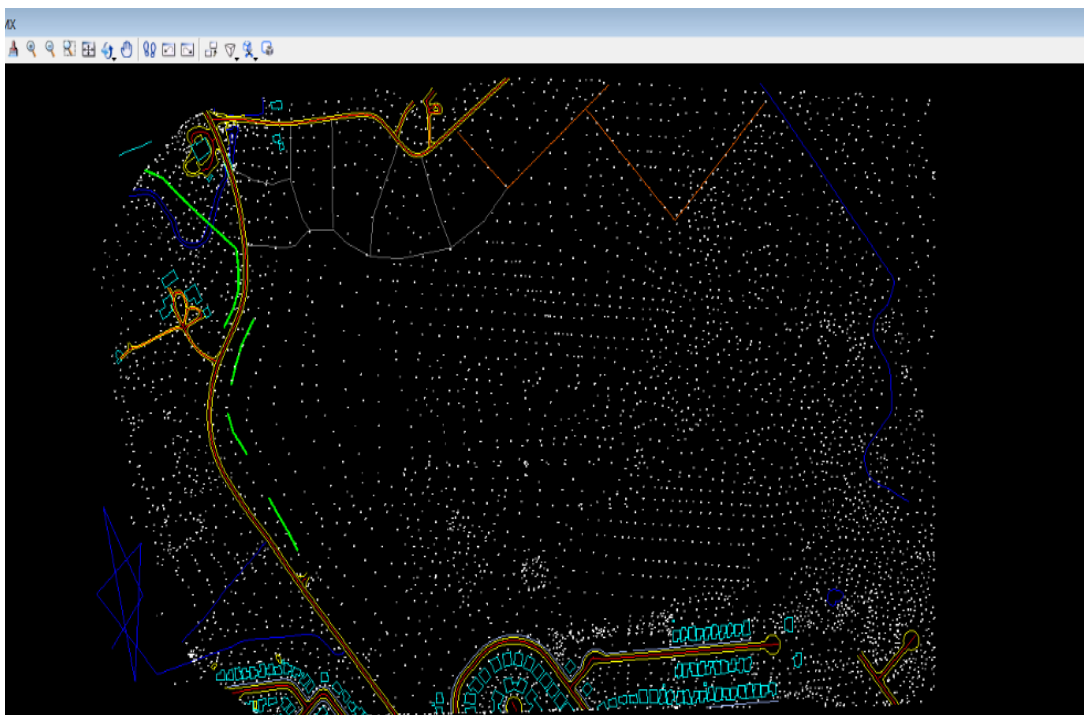
Fig. 4.6 Survey Data

4.1.5 Surface Analysis:

1. To analyze the model, analysis menu->select Surface Analysis. Select Model to analysis as Survey in dialog box shown in Fig.4.7> click next. Click Level Bands in dialog box shown in Fig.4.8 > Enter difference between 300and 310 in box shown in Fig. 4.8.
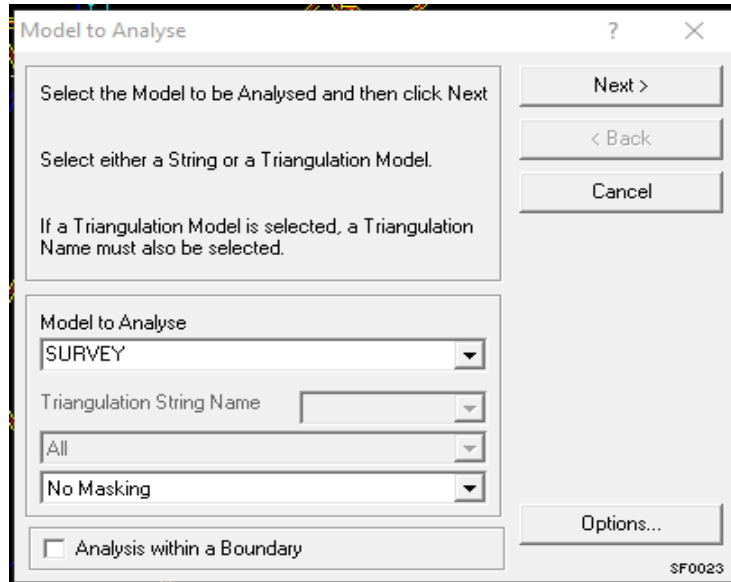
Fig 4.7 Surface Analysis – Model Selection
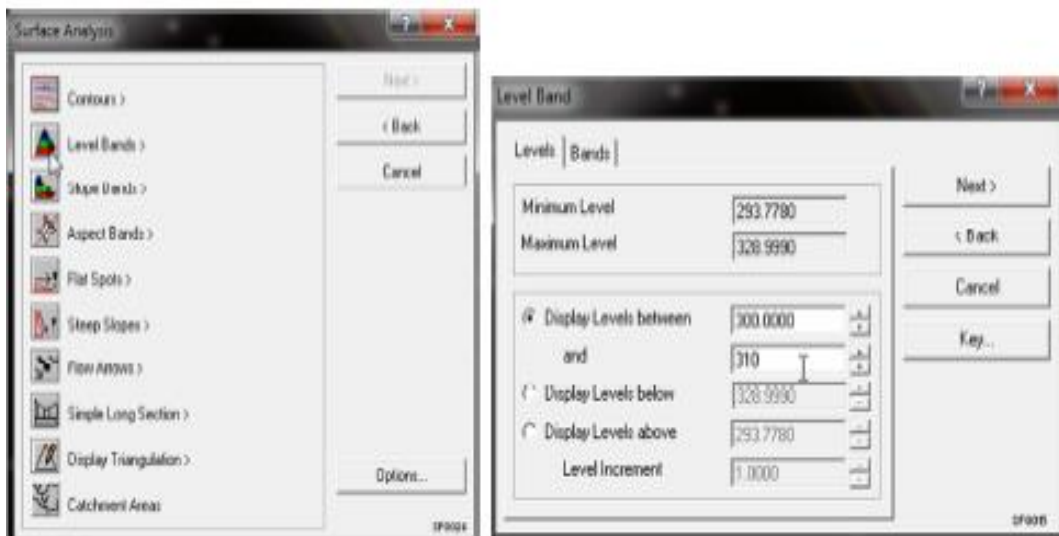
Fig 4.8 Surface Analysis – Level and bands

2. Click on the band tab > enter number of bands to 8 in dialog box shown in Fig. 4.9 > Click on key option to check level details.
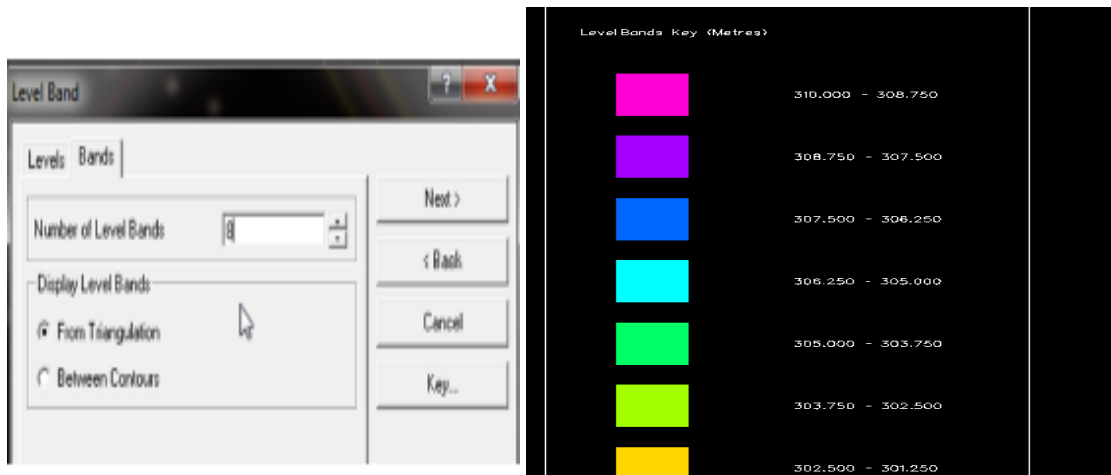
Fig. 4.9 Band Tab and Level Details.

3. Click finish > Dialog box will appear > Rename Model as TRIANGULAR> ok.

4. Go to model display > select TRIANGULAR > erase model and display selected option > Model will display on screen as in Fig. 4.10
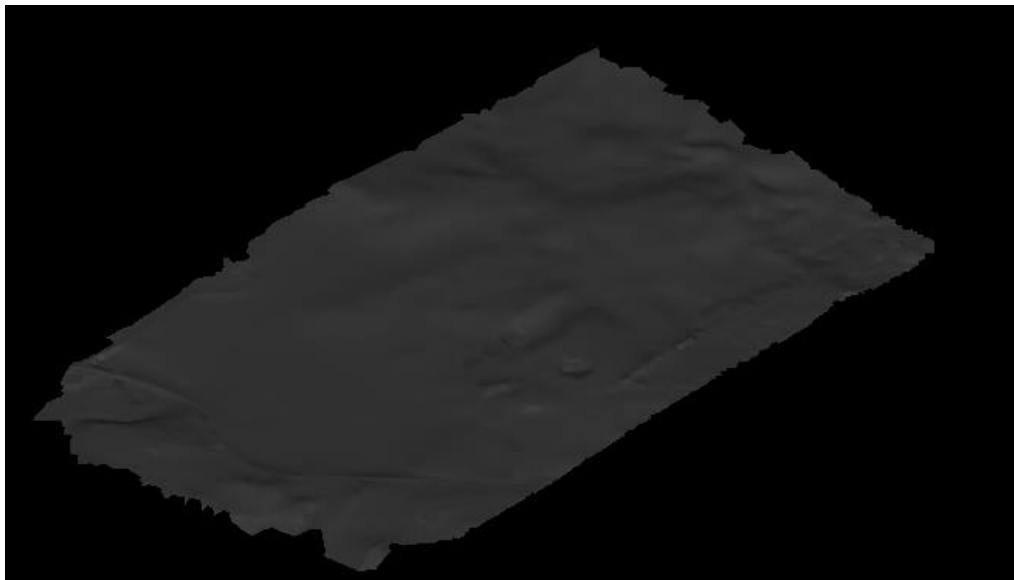
Fig 4.10 Triangular Surface with smooth and shadows display mode

4.1.6   Horizontal Alignment:

1. Select Design option from the menu bar > Quick Alignment > Model selection dialog box will appear on screen Fig 4.11 > Create model as HORIZONTAL ALIGNMENT > Select Road Centerline String MC > choose Alignment string name MC00> Next.
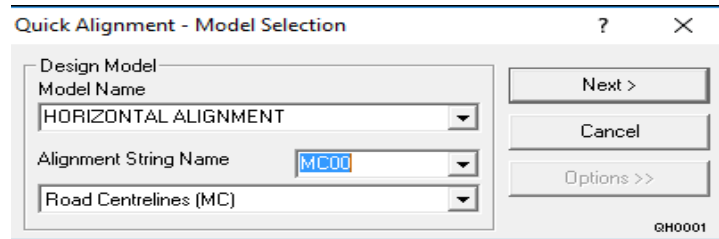
Fig 4.11 Quick Alignment -Model Selection.

2. A dialog box will appear to add Intersection Points (IP) for new center line (Fig.4.12) > Define parameters by clicking on Parameter option as shown in Fig 4.13 > Enter the values of the Design Speed and Radius of curve.

3. Add IPs with help of Add IP , construction tools or XY keyboard entry >Select Green Tick option to finish the alignment > MX Road will automatically align the center line showing the radius and chainage at curves as shown in Fig.4.14 and 4.15 if no IP will intersect.
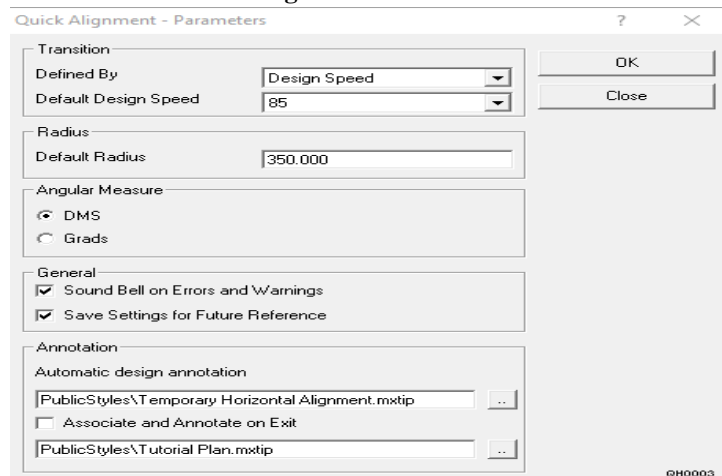

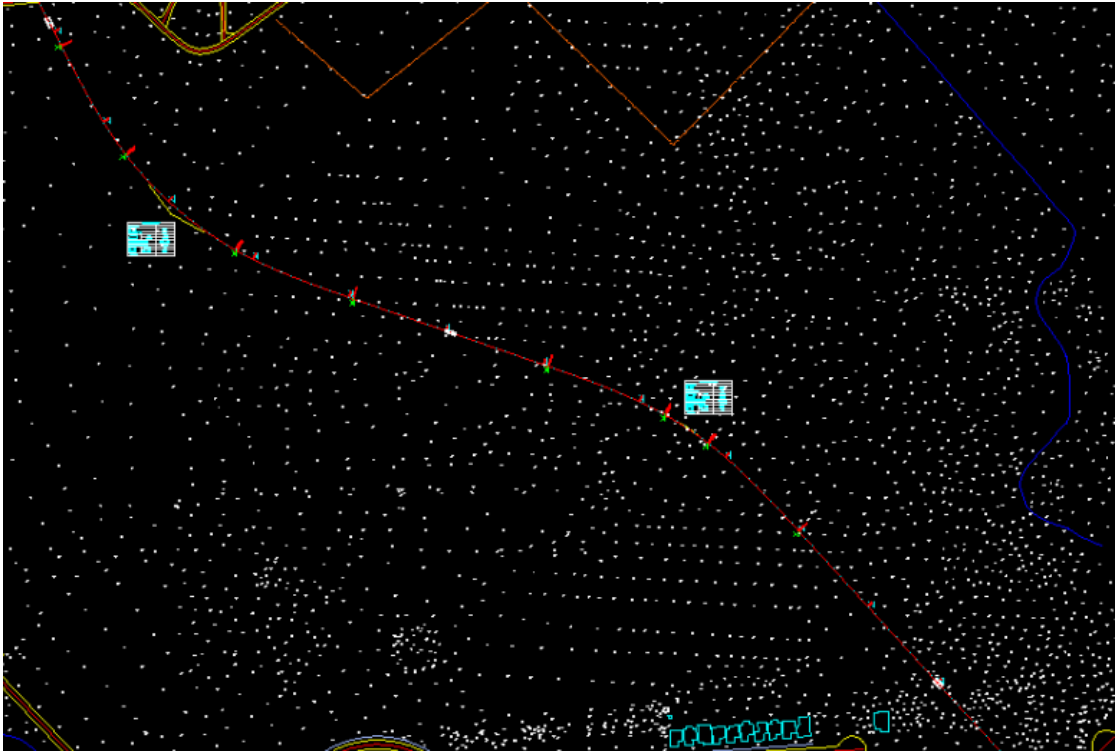**Fig 4.12** Add IP Box

Fig 4.13 Quick alignment –Parameter Box
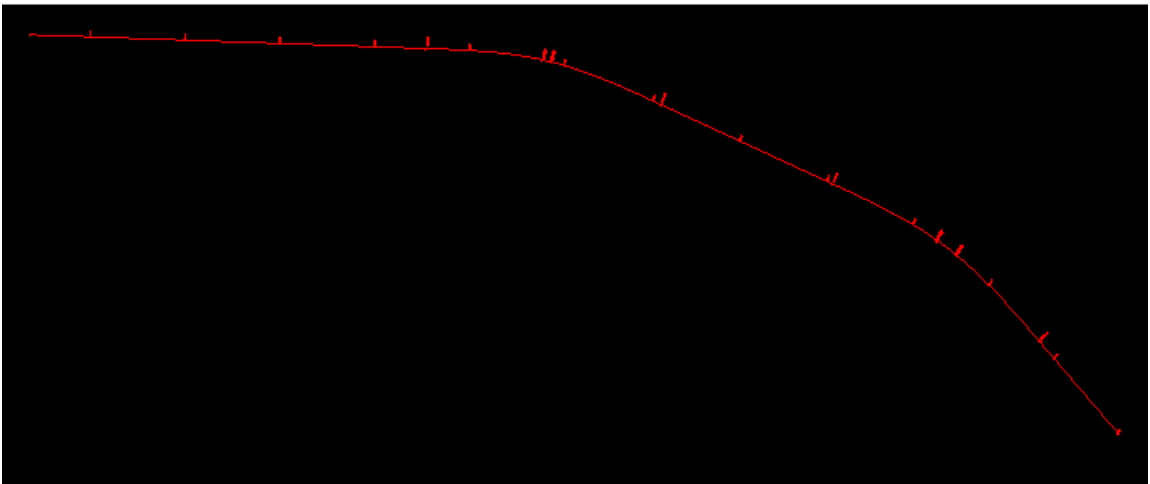
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Fig 4.14 Center line – Road 1

Fig 4.15 Center Line – Road 2

4.1.7 Vertical Alignment

1. Design->Quick Alignment-> Vertical Profile > Select the Model name: Horizontal Alignment in dialog box shown in Fig 4.16 and pick the road centerline from the model >click next.
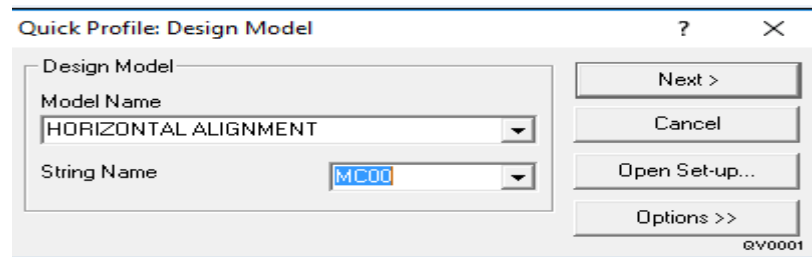

Fig 4.16 Vertical Alignment – Design model

2. Select Existing Surface: triangular Surface-> click next >Opens Add IP Mode tool box shown in Fig 4.17.

3. Select the Parameter option (Fig 4.17) in the Add IP tool box > Define the parameters as maximum gradient as 3.33 and minimum gradient as 0.50.
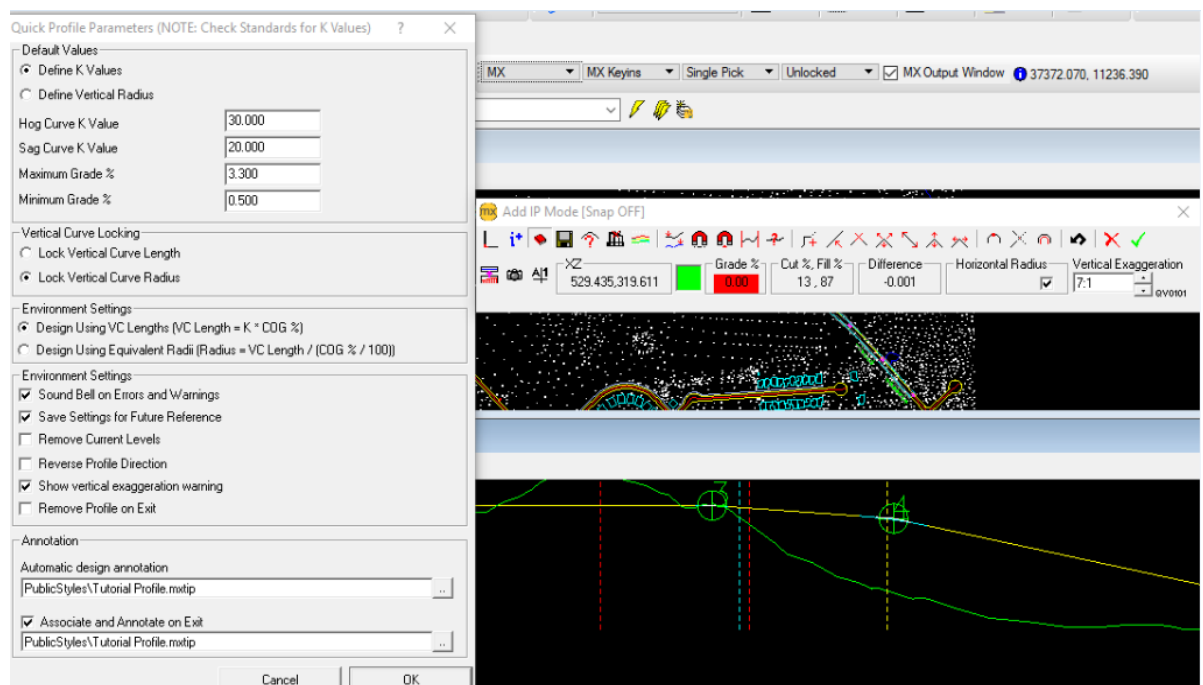

Fig. 4.17 Add IP tool box and Parameters

4. Use Add IP option > Turn on Snap > Define the IPs > Click Set Gradient Option in > Pick section between IPs Enter Values of maximum and minimum gradient in dialog

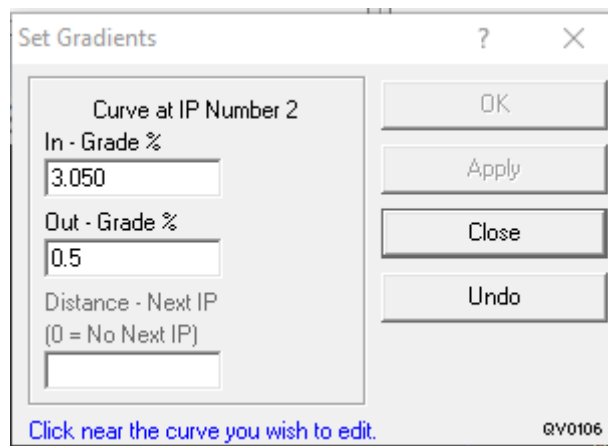box shown in Fig. 4.18 > Set Gradient between all IPs > Click on Green Tick option to finish the alignment.

Fig. 4.18 Set gradient tool box.

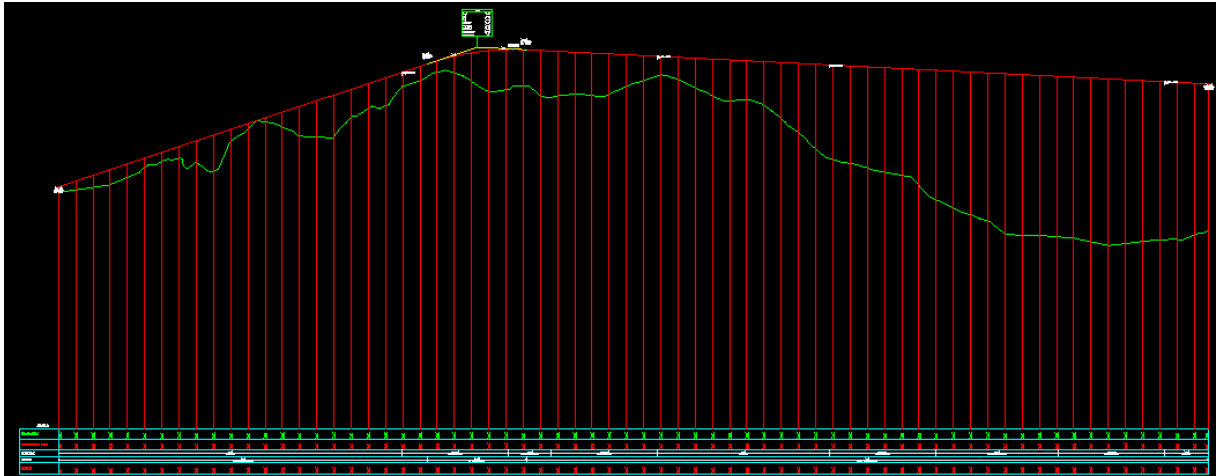5. The road is aligned as per set gradient as shown in Fig. 4.19 and 4.20.

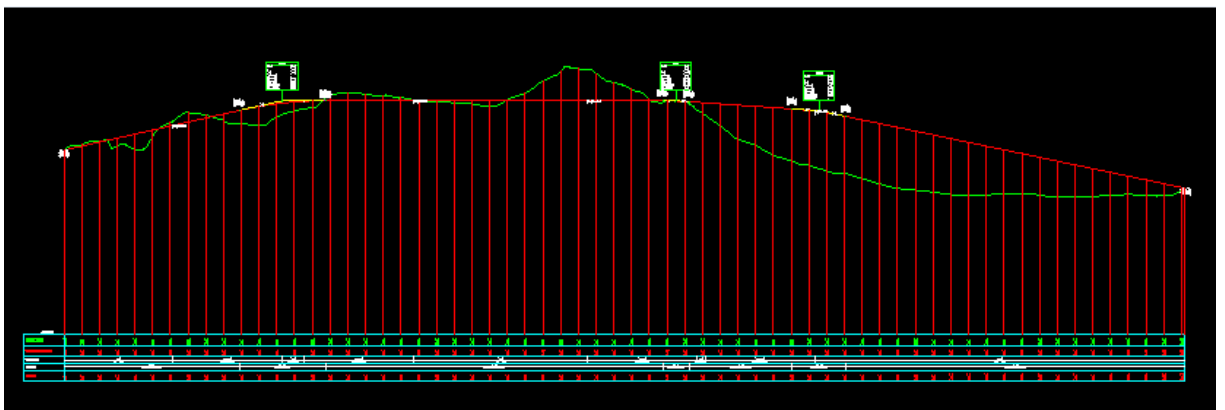**Fig. 4.19** Vertical Profile – Road 1

Fig. 4.20 Vertical Profile –Road 2

4.1.8 Carriage way Design:

1. Select Design option from the toolbar shown in Fig. 4.21 > Road design > Carriage way Design > Opens a dialog box as shown in Fig 4.22 > Select the road center line string MCOO > click next > Road profile box will appear as show in Fig. 4.23.
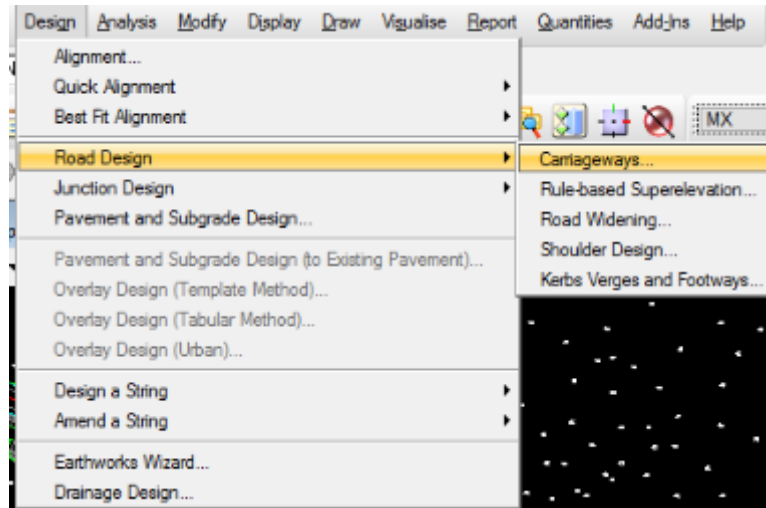

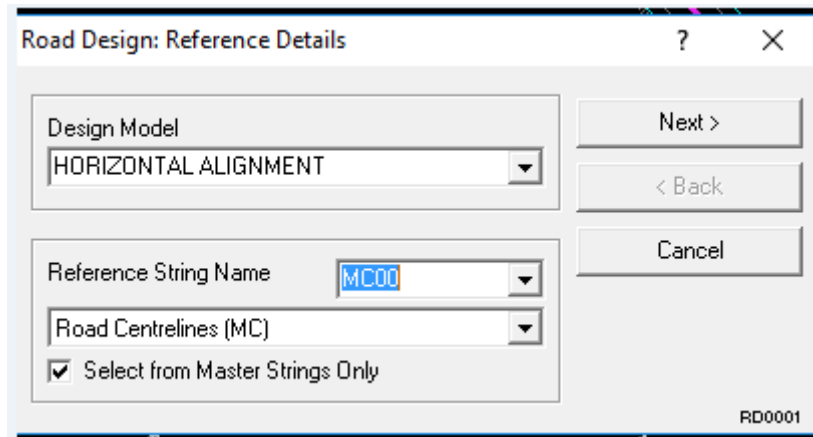**Fig. 4.21** Carriage way option

Fig. 4.22 Road Design Dialog Box
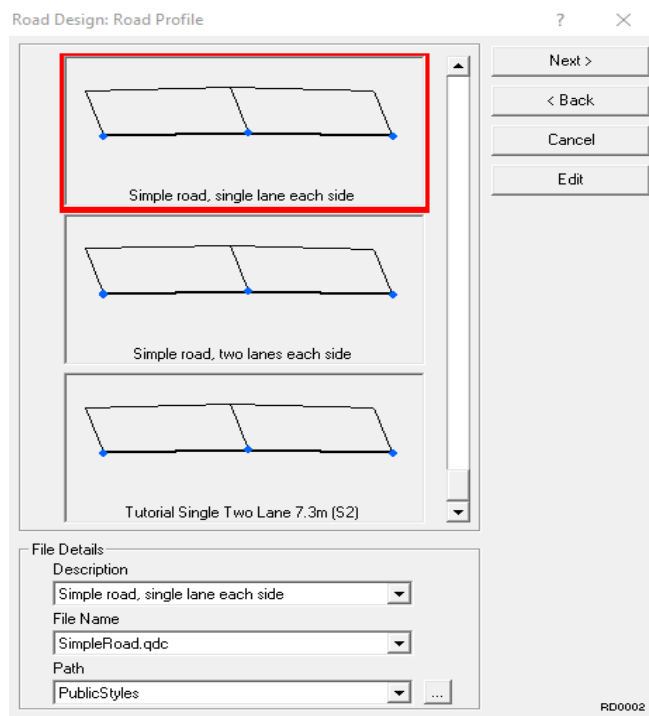
Fig. 4.23 Road profile

2. Click Edit option > Define the design details > lane width as 3.5 m to both sides and set cross fall / camber to 2.5 % or 0.025 as shown in Fig 4.24.

Fig.4.24 Design Details

3. Click next > Select the chainage start and end point in dialog box shown below > click next > Carriage way is made for the road 1 and road 2 as shown in Fig.4.26 and Fig 4.27.
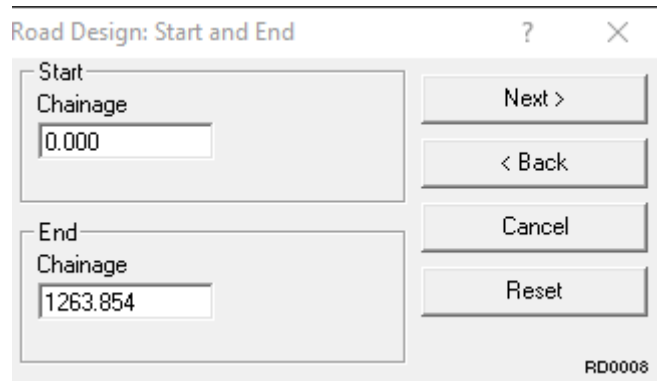
Fig. 4.25 Chainage Details
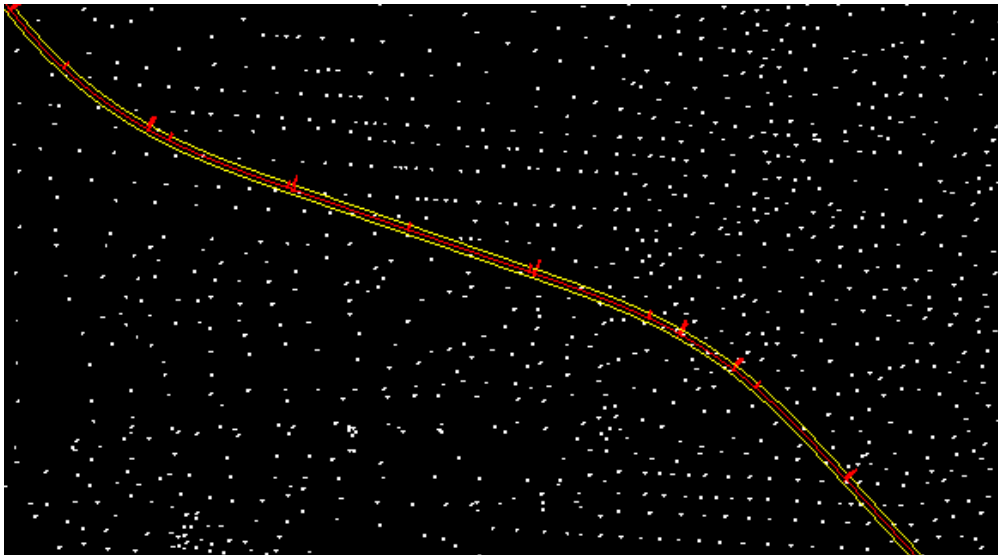
Fig 4.26 Carriageway for Road 1
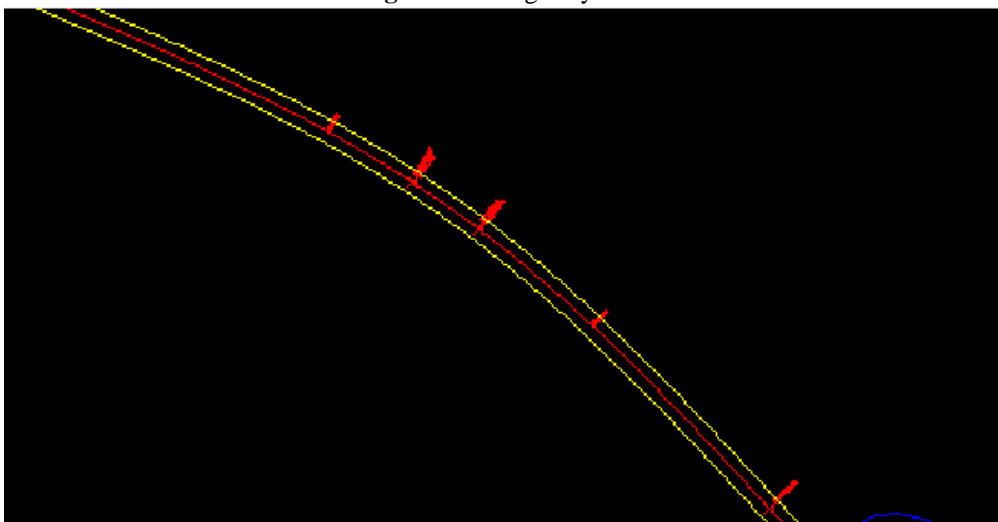
Fig. 4.27 Carriageway for Road 2

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4.1.9 Superelevation Design:

1. Select Design option > Road Design > Rule Based Superelevation.
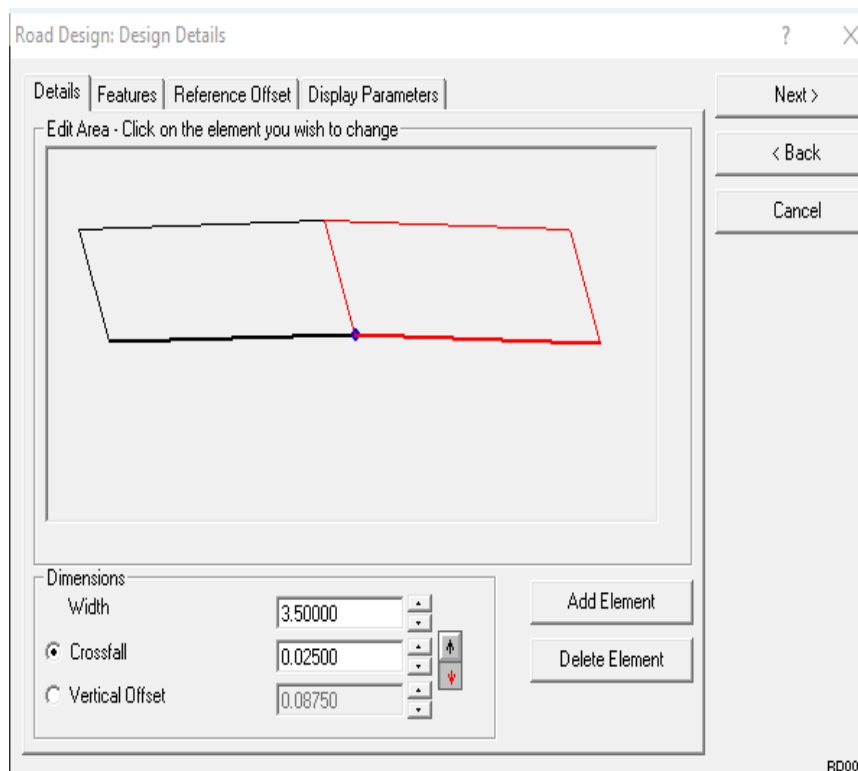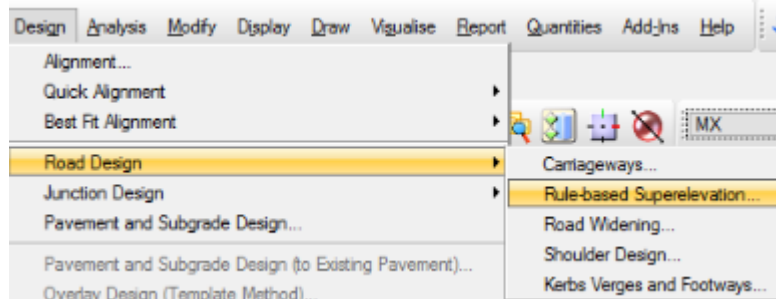

Fig. 4.28 Super elevation

2. Superelevation wizard appears on screen shown in Fig. 4.29 > Select model as Horizontal alignment > select Road Centerline MC00 > Define start and end point of chainage > Click next.
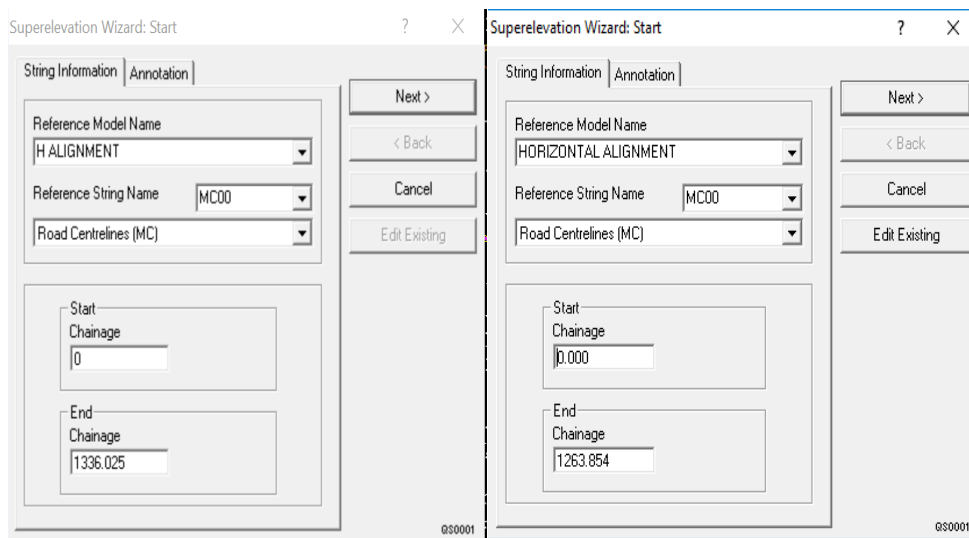
Fig. 4.29 Superelevation Wizard – Road 1 and Road 2

3. Select Superelevation rules as India 2 lane road from the list shown in Fig 4.30 > Design speed selected as 80 & 85 for Road 1 and Road 2 respectively >Click next.
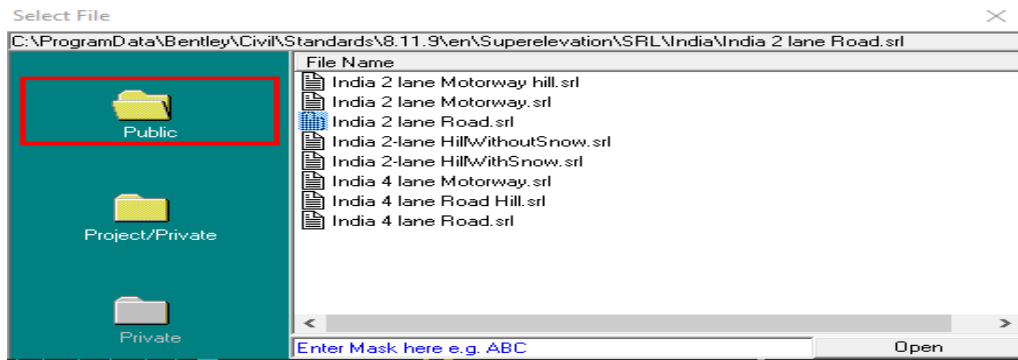
Fig. 4.30 Superelevation Rules
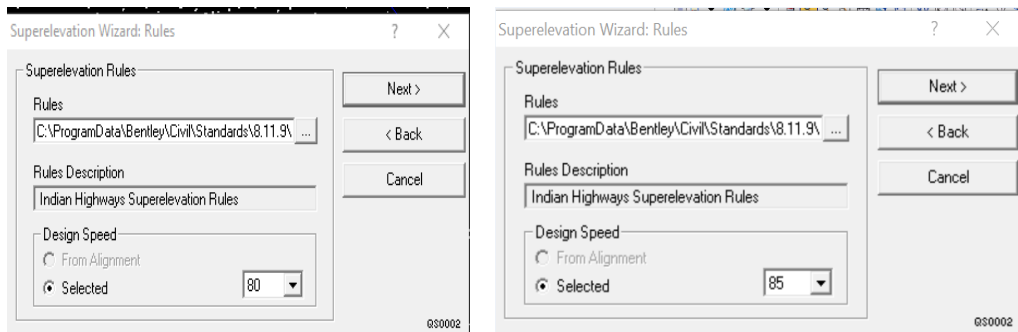
Fig. 4.31 Superelevation – Design Speed

4. Select the pivoting method (Fig. 4.32)>Click Next> Dialog box will appear Choose the edge strings of the carriage way CE 00 and CE 01 as shown in Fig. 4.31.
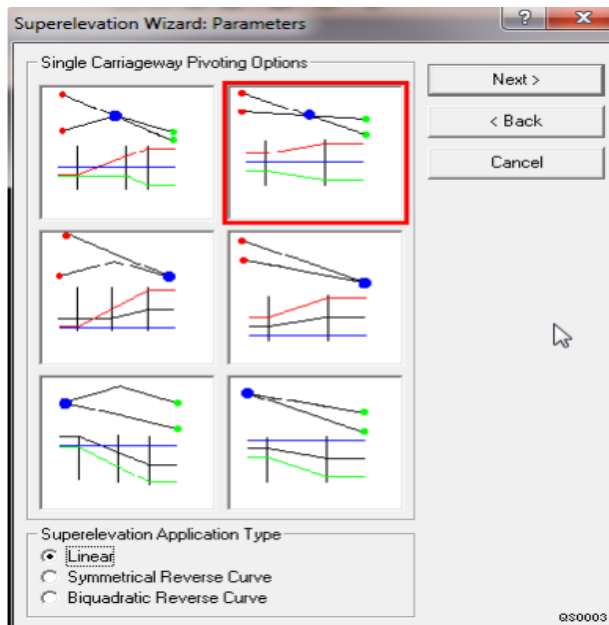
Fig. 4.32 Superelevation- Pivoting Method

Fig. 4.33 Superelevation –Carriageway Strings

5. Click Next > Super elevation is applied to the roads accordingly.

6. For the cross fall check of road on straight section and super elevation check on the curves Select Analysis > Cross Fall Checker > Pick the road Centerline MC00> A window will appear as shown below on the screen showing the cross fall and super elevation.
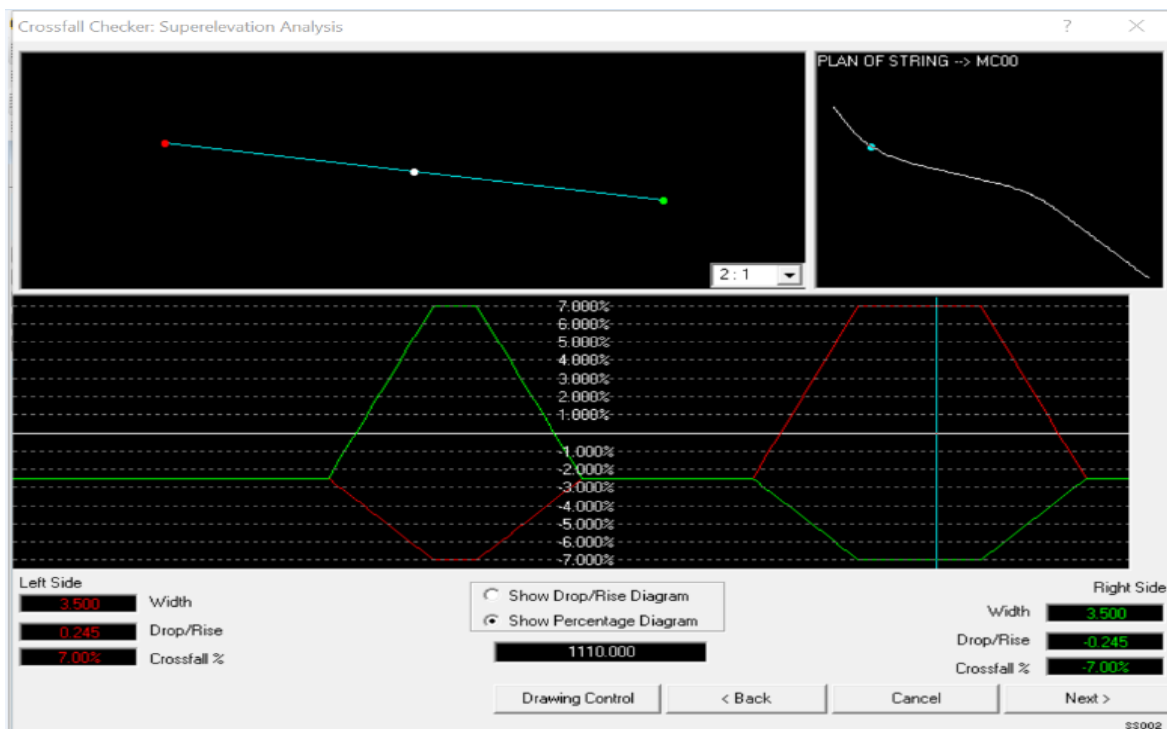
Fig. 4.34 Superelevation check - Road 1 – Curve 1

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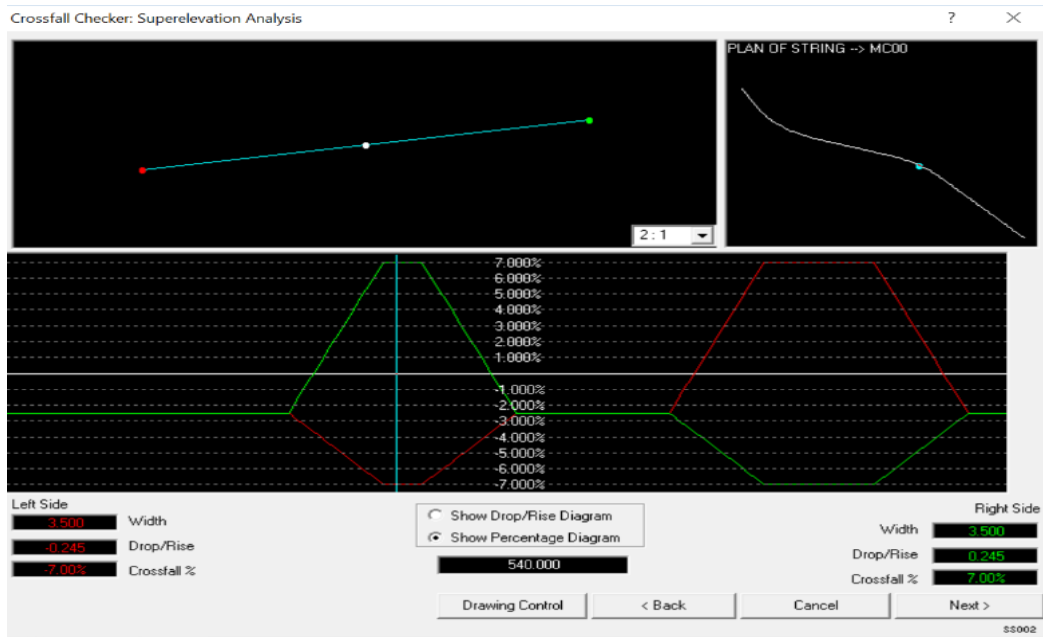
Fig 4.35 Superelevation check –Road 1 – Curve 2
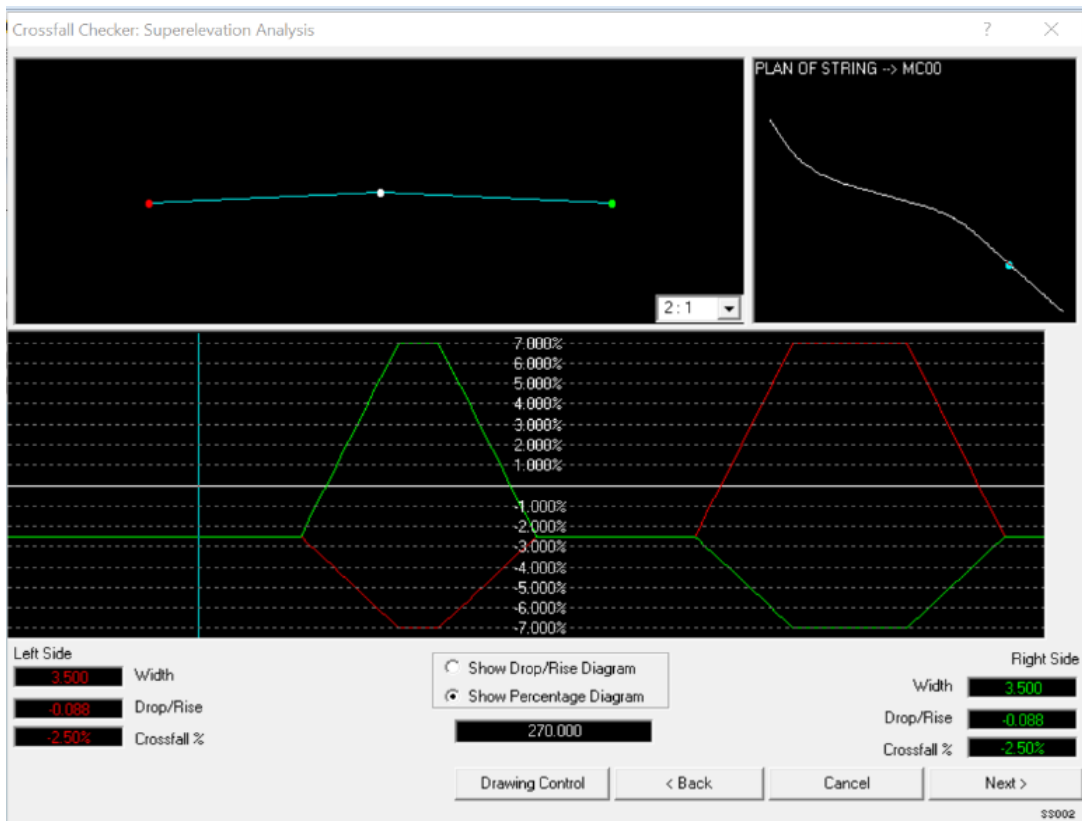
Fig. 4.36 Crossfall Check – Road 1
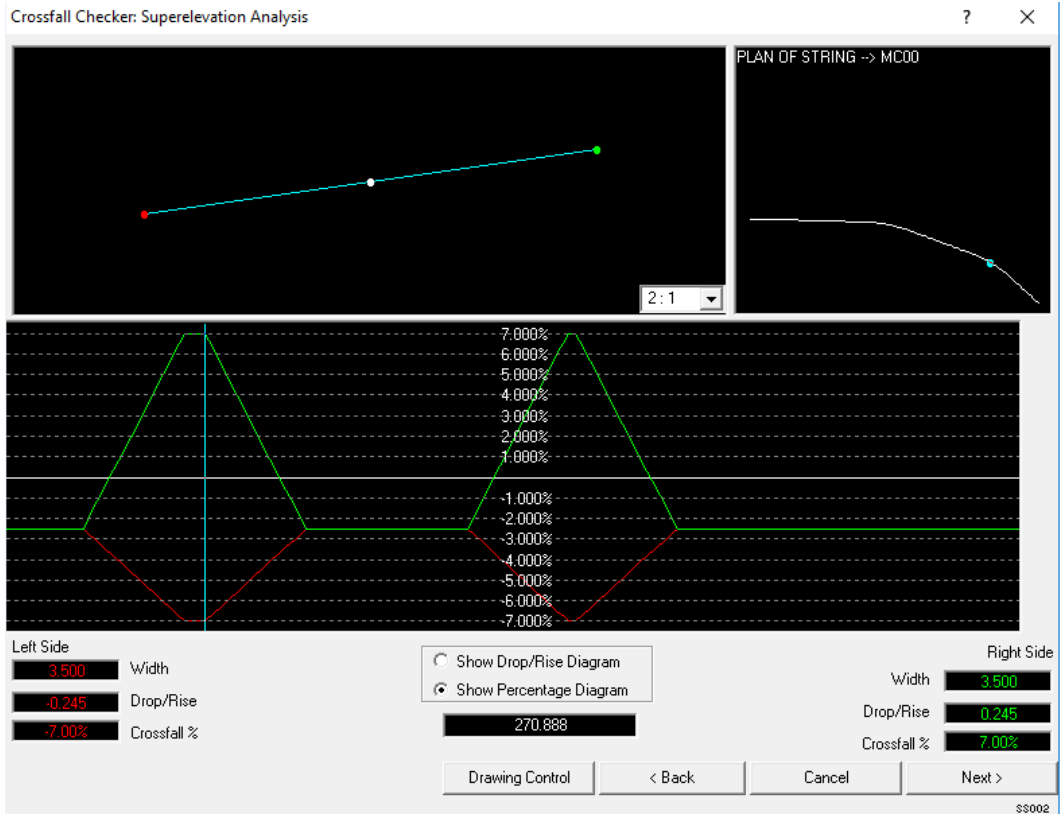
Fig. 4.37 Superelevation Check- Road 2 – Curve 1
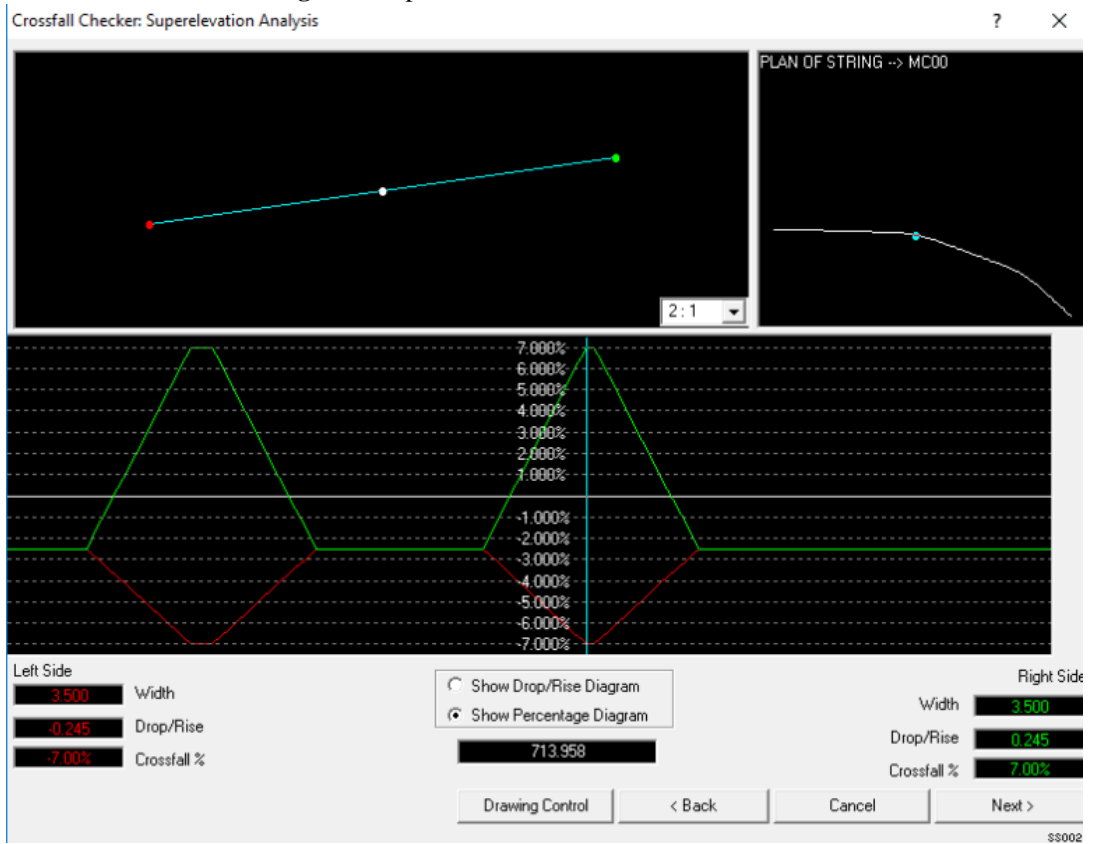
Fig. 4.38 Superelevation Check – Road 2 – Curve 2.
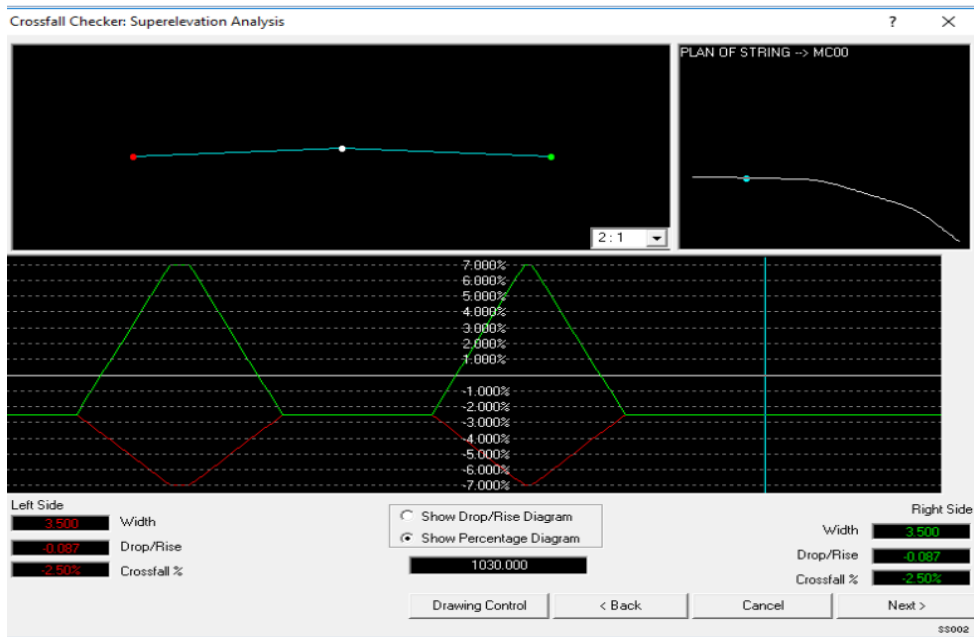
Fig.4.39 Crossfall Check – Road 2

4.1.10 Shoulders Design :

1. Click Design > Road design> Shoulder design > Shoulder design dialog box will appear on the screen as shown in Fig. 4.40.
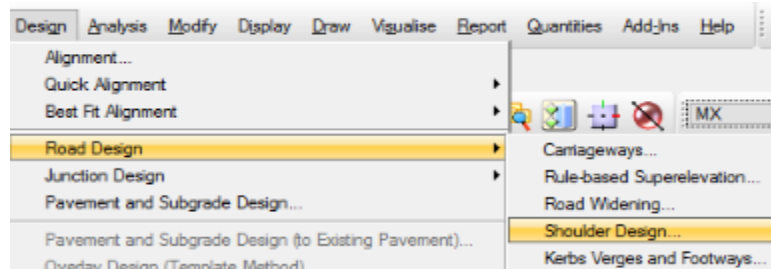
Fig.4.40 Shoulder Design

2. Choose design model as Horizontal Alignment > Select Center Line string MC00 > Select Edge String of center line CE00 > Click Next.
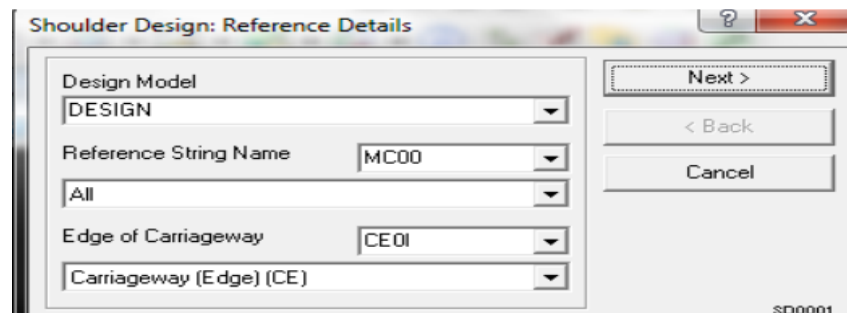
Fig.4.41 Shoulder Design – Details box

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3. In the appeared dialog box shown in Fig.4.42 select shoulder method as follow carriage way cross fall > Click next.
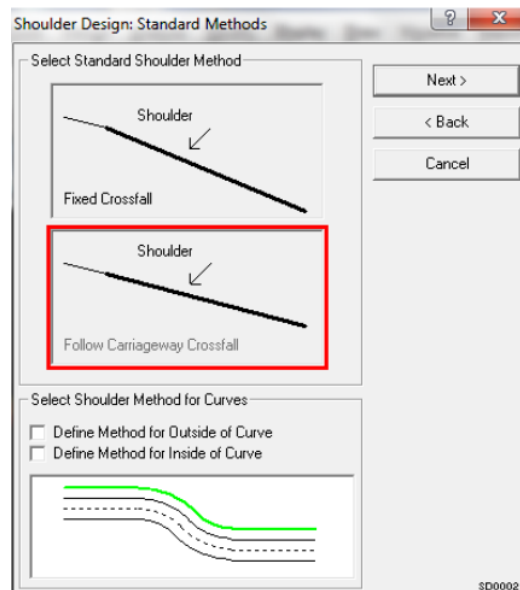
Fig.4.42 Shoulder Design Method

4. Dialog box will appear as shown in Fig. 4.43 > Enter the width of the shoulder as 2.5 > Click next > Enter the chainage 0 to 1336 for road 1 and 0 to 1263 for road 2 > Click next.
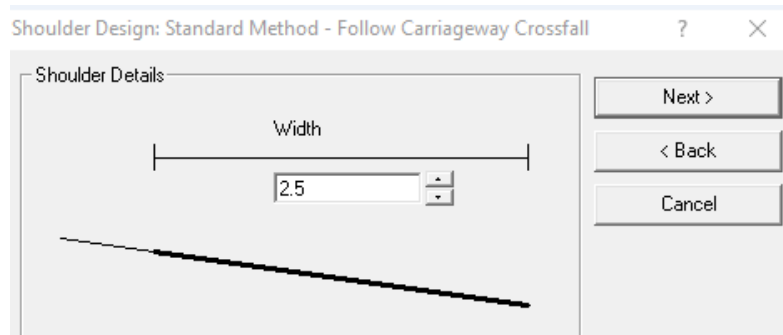
Fig.4.43 Shoulder Width

5. Same steps are followed for design of shoulder for edge string CE01.
6. The shoulder of selected width is applied to both sides of the carriage way as shown in Fig. 4.44 and Fig. 4.45.
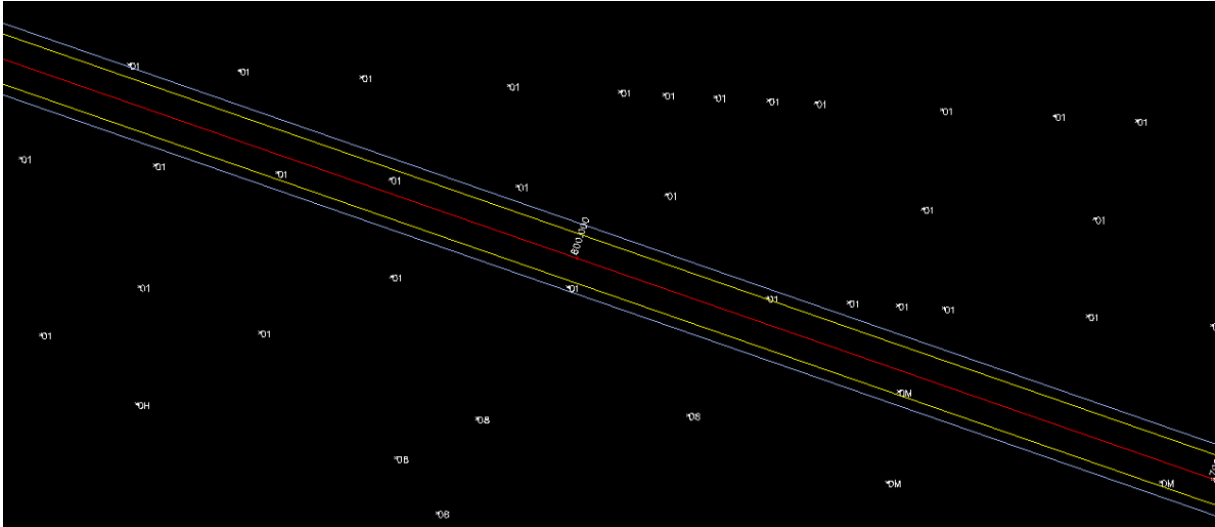
Fig.4.44 Designed Shoulder for Road 1
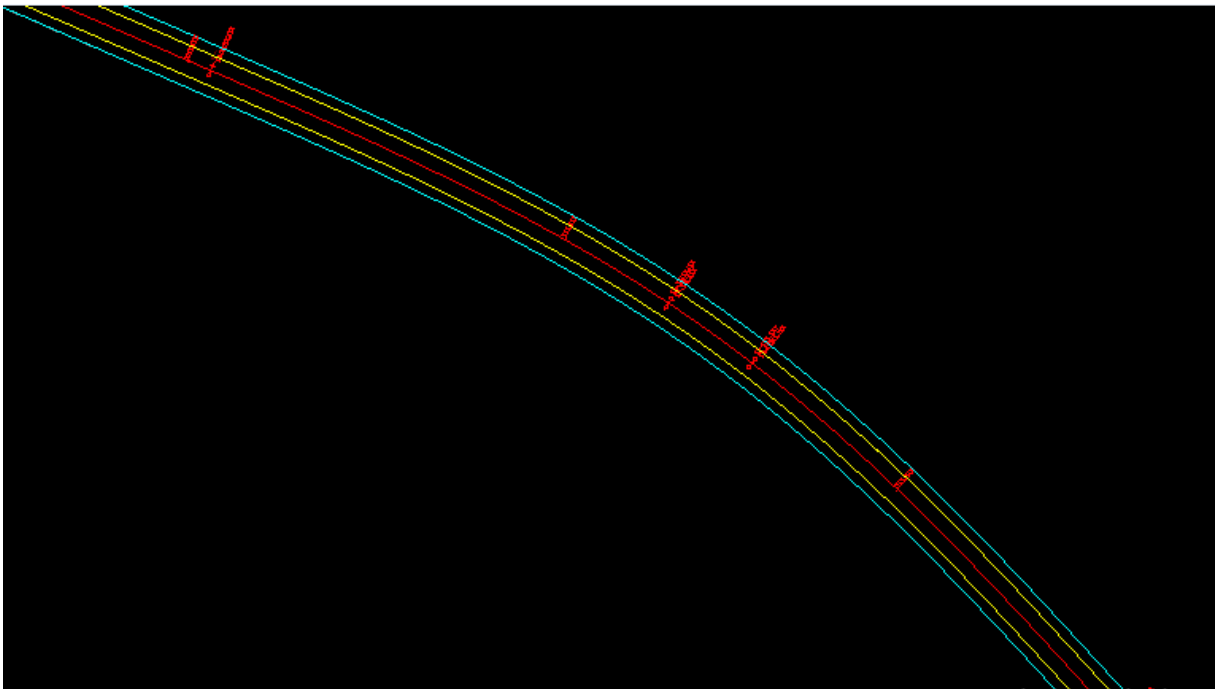
Fig 4.45 Designed Shoulder for Road 2

4.1.11 Earthwork Wizard
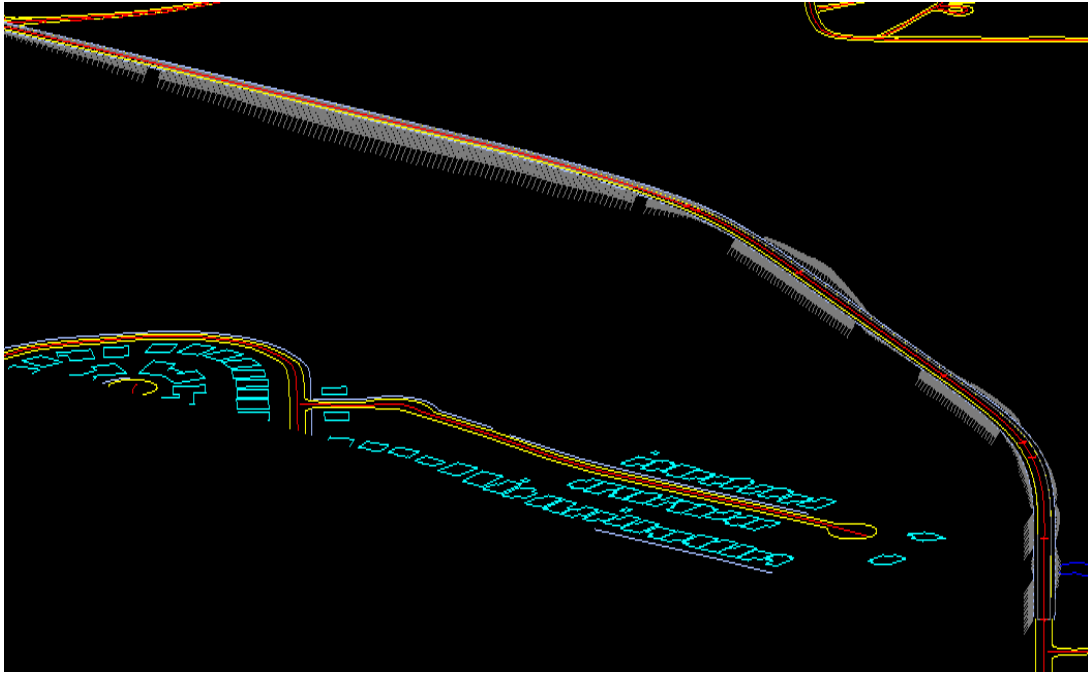
Fig.4.46 Earthwork Wizard -Road 1
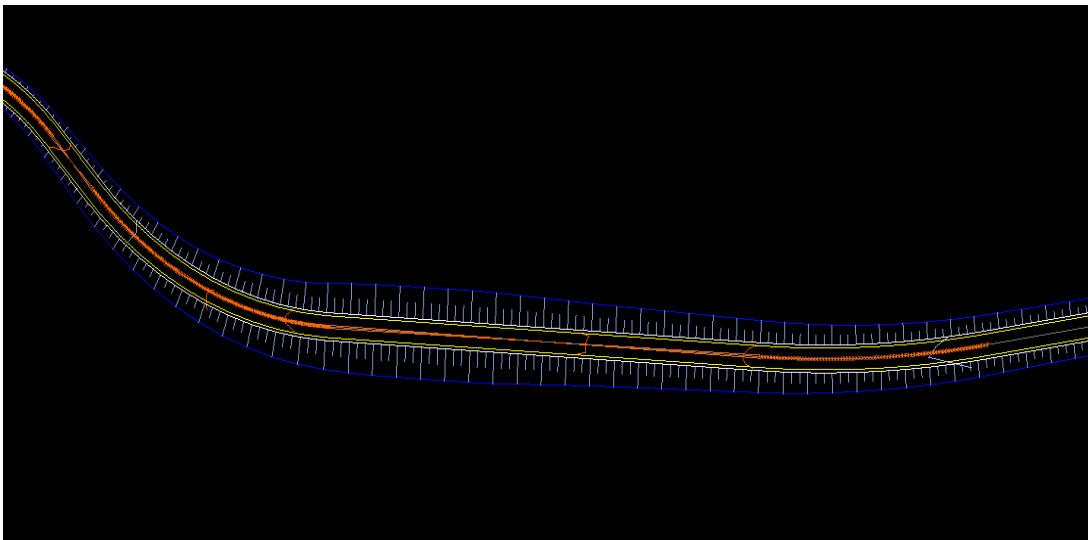
Fig.4.47 Earthwork Wizard –Road 2

4.2 Flexible Pavement Design

4.2.1 Aggregate Selection

Aggregates selected are as per the grading and properties specified by MoRTH specifications. The aggregate grading for different layers and aggregate properties specifications is shown in Table 4.2 and 4.3 respectively.

Table 4.2 Aggregate Grading

Specifications	DBM		SDBC		BC	
Grading	1	2	1	2	1	2
Nominal Maximum Aggregate Size	37.5 mm	26.5 mm	13.2 mm	9.5 mm	19 mm	13.2 mm
Layer thickness (mm)	75-100	50-75	40	25	50	25-40
IS Sieve Size (mm)	Cumulative Percentage by weight of total aggregate passing					
45	100	-				
37.5	95-100	100				
26.5	63-93	90-100			100	
19	-	71-95	100		90-100	100
13.2	55-75	56-80	90-100	100	59-79	90-100
9.5	-	-	70-90	90-100	52-72	70-88
4.75	38-54	38-54	35-51	35-51	35-55	53-71
2.36	28-42	28-42	24-39	24-39	28-44	42-58
1.18	-	-	15-30	15-30	20-34	34-48
0.6	-	-	-	-	15-27	26-38
0.3	7-21	7-21	9-19	9-19	10-20	18-28
0.15	-	-	-	-	5-13	12-20
0.075	2-8	2-8	3-8	3-8	2-8	4-10
Bitumen Content	4%	4-5%	4-5%	5%	5.2%	5.4 %

Table 4.3 Aggregate Properties

Sr. No.	Properties		Obtained Value (%)	MoRTH Specification(Max)
1.	Aggregate Impact Value		22	30
2.	Crushing Strength	Base Course	27	45
		Surface Course	22	30
3.	Abrasion Value	Base Course	26	40
		Surface Course	25	35
4.	Water absorption		0.7	2
5.	Specific Gravity		2.66	2.5 -3
6.	Flakiness & Elongation		26	30

4.2.2 Binder Selection

Higher Grade Bitumen (HGB) is used as binder in Pavement 1 and VG 30 is used in Pavement 2. The properties of both binders are shown in Table 4.4.

Table 4.4 Binder Properties

Sr. No	Properties	VG 40	HGB	Limits
1.	Penetration Value (0.01mm,25°C,100g,5s)	47	25	20-50
2.	Softening Point (Ring And Ball)	50	56	55 Min.
3.	Absolute Viscosity at 60°C	3230	5027	Grade Dependent
4.	Kinematic Viscosity at 135° C	525	645	750 cSt Max.

4.2.3 Marshall Mix Design

Marshall Mix is prepared in order to get the optimum Bitumen Content at specified void content. The mix results for both the mixes are shown in Table. 4.5.

Table 4.5 Marshall Mix Properties

Sr. No.	Properties and Particulars	Test Results		Specified Limits
		Mix 1	Mix 2	
1.	Water Absorption	0.98	1.55	2 (Max)
2.	Specific Gravity	2.48	2.66	-
3.	Marshall Stability(kGs)	2168	2357	900(Min)
4.	Marshall Flow (mm)	3.2	3.2	2-4
5.	Bitumen Content (%)	4.6	4.5	4-5
6.	Air Voids (%)	3.91	3.88	4 (Max)

4.2.4 Pavement Thickness and Analysis using IIT PAVE

Thickness for two pavements are designed and analyzed using IITPAVE. Pavement 1 is designed for hot climatic regions and the Pavement 2 is designed for rainy regions. Design Parameters for the pavement design is mentioned in Table 4.6.

Table 4.6 Design Parameters for Pavement

Sr. No.	Design Parameters	Value
1.	Design Traffic	30 msa
2.	Design Life	15 years
3.	CBR	15%
4.	Reliability	90%

IRC-37 2018 has given some trail thickness of various layers of pavements for different CBR value with different design traffic as shown in Fig4.45.
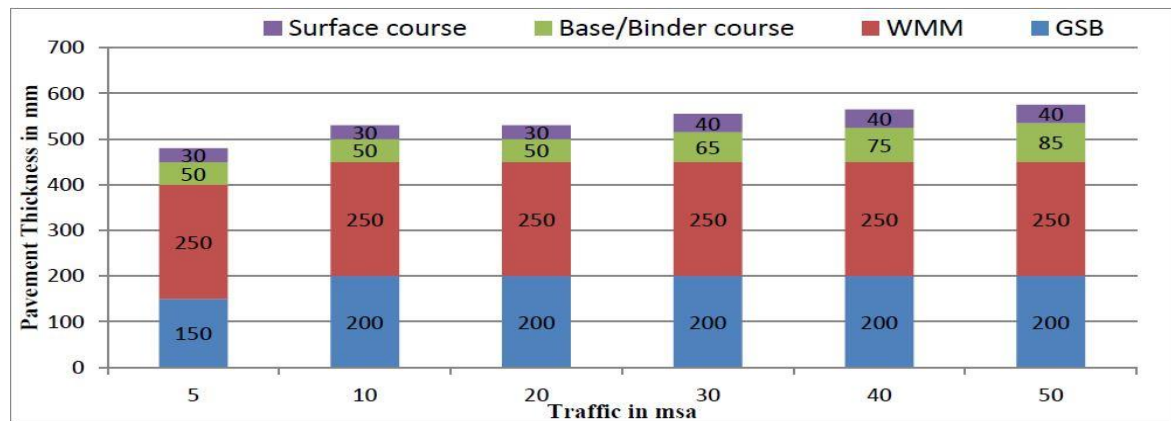
Fig. 4.48 Catalogue for pavement thickness for 15% CBR and 30 MSA Traffic

1. Pavement 1

For Pavement 1 two trials of thickness is done. First one with the indicated thickness of different layers in Fig 4.45 and the second one with the reduction of 10 mm in DBM layer .It is found that with the use of HGB the reduction in the thickness of DBM don't reduce the stability of the pavement and also contributes to an economic design. The trial thicknesses are analyzed using IIT PAVE as shown in Fig 4.46 and Fig. 4.47. The input data required for the analysis are shown in Table 4.8 and thicknesses are shown in Table 4.7

Table 4.7 Pavement Thickness

Sr. No.	Layers		Thickness 1 (mm)	Thickness 2 (mm)
1.	Bituminous Concrete(BC)		40	40
2.	Dense Bitumen Macadam (DBM)		65	55
3.	Granular Layer	Wet Mix Macadam (WMM)	250	250
		Granular Sub Base (GSB)	200	200
	Total Thickness		555	545

Table 4.8 Input data for IITPAVE

Sr. No.	Input Data		Value	
1.	No. of layers		3	
2.	No. of wheels		Dual	
3.	Wheel Load		20 kN	
4.	Tyre Pressure(MPa)		0.56	
5.	Poisson's Ratio		0.35	
6.	Resilient Modulus (MPa)	Layer 1	3280	
		Layer 2	311.27	
		Layer 3	99.58	
7.	Layer Thickness (mm)	Layer 1	105	95
		Layer 2	450	450

Fig. 4.49 Analysis for Thickness 1

Fig. 4.50 Analysis for Thickness 2

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2. Pavement 2

For Pavement 2 the design parameters are same .The thickness is shown in Table 4.9 and the input data is shown in tale 4.10. Analysis using IIT PAVE is shown in Fig 4.48

Table 4.9 Pavement Thickness

Sr. No.	Layers		Thickness (mm)
1.	Bituminous Concrete(BC)		40
2.	Dense Bitumen Macadam (DBM)		65
3.	Granular Layer	Wet Mix Macadam (WMM)	250
		Granular Sub Base (GSB)	200
	Total Thickness		555

Table 4.10 Input data for IITPAVE

Sr. No.	Input Data		Value
1.	No. of layers		3
2.	No. of wheels		Dual
3.	Wheel Load		20 kN
4.	Tyre Pressure		0.56
5.	Poisson's Ratio		0.35
6.	Resilient Modulus (MPa)	Layer 1	3000
		Layer 2	311.3
		Layer 3	99.58
7.	Layer Thickness (mm)	Layer 1	105
		Layer 2	450

Fig. 4.51 Analysis for Pavement 2

4.3 Quantity and Cost Estimation

4.3.1 Quantity Estimation

The quantity of earthwork excavation, earthwork filling and material required in the construction of Road 1 and Road 2 is estimated using MS-Excel. For Road 1 the different thicknesses of DBM and their corresponding quantities is found. The estimated quantities is shown in Table 4.11.

Table 4.11 Quantity Estimate

Sr. No	Description		Volume(m^3)		Quantity(Ton)	
			Road 1	Road 2	Road 1	Road 2
1	Earth Excavation		245	233	-	-
2	Earth Filling		550	490	-	-
	Pavement Layers					
3	Bituminous Concrete		432	468	1312	1310
4	DBM	65 mm	702	760	2065	2129
		55 mm	594	-	1804	-
5	Granular Base Layer(WMM)		2700	2925	7565	8153
6	Granular Sub Base Layer(GSB)		2880	3120	7956	8619
7	Sub Grade		7200	7800	13392	14508

4.3.2 Cost Estimation

The cost estimation is done for both the roads including the required material, machineries and other all expenses .The cost estimation is done in terms of volume as the market cost is taken in per m3. For Road 1 cost is estimated using both the DBM thicknesses and the cost difference is also shown. The estimated cost of the excavation and material is shown in Table 4.12.

Table 4.12 Cost Estimate

Sr. No.	Description		Cost in INR (per m^3)	Volume (m^3)		Estimated Cost (INR)	
				Road 1	Road 2	Road 1	Road 2
1.	Earth Excavation		75	245	233	18,375	17,475
2.	Earth Filling		100	550	490	55,000	49,000
3.	Bituminous Concrete		5,750	432	468	24,84000	26,91,000
4.	DBM	65 mm	3,550	702	760.5	24,92,100	26,99,775
		55 mm		594		21,08,700	
5.	Granular Base Layer		2,300	2700	2925	62,10,000	67,27,500
6.	Granular Sub Base		1,700	2880	3120	48,96,000	53,04,000
7.	Subgrade		450	7200	7800	32,40,000	35,10,000
					Total Estimated Cost	1,93,22,100	2,09,58,750
						1,89,38,700	
					Difference	3,83,400	

The modified thickness of the Dense Bitumen Macadam (DBM) layer from 65mm to 55 mm in Road 1 results in reduction of the total estimated cost.

CHAPTER 5

RESULTS, DISCUSSIONS AND CONCLUSIONS

5.1 Results :

5.1.1   Horizontal Alignment Report :

Road 1:

```
Horizontal Alignment Report
Model:       H ALIGNMENT
String:      MC00
Units:  Metric
Date :           05-12-2020 19:35:34


********Element 1    Straight********


********Transition********

Transition Length                  123.386

********Element 2    Arc********

Intersection Point Chainage        0+547.824
Tangent                               25.152
Arc Length                            50.218
Radius                               350.000

********Transition********

Transition Length                  123.386

********Element 3    Straight********


********Transition********

Transition Length                  123.386

********Element 4    Arc********

Intersection Point Chainage        1+091.797
Tangent                               72.510
Arc Length                           142.998
Radius                               350.000

********Transition********

Transition Length                  123.386

********Element 5    Straight********
```

Fig. 5.1 Results of Horizontal Alignment – Road 1

Road 2:


```
Horizontal Alignment Report
Model:          HORIZONTAL ALIGNMENT
String:         MC00
Units:  Metric
Date :          05/12/2020 19:13:51


********Element 1     Straight********


********Transition********

Transition Length                    123.386

********Element 2     Arc********

Intersection Point Chainage       0+258.556
Tangent                              12.343
Arc Length                           24.675
Radius                              350.000

********Transition********

Transition Length                    123.386

********Element 3     Straight********


********Transition********

Transition Length                    123.386

********Element 4     Arc********

Intersection Point Chainage       0+718.444
Tangent                               4.485
Arc Length                            8.970
Radius                              350.000

********Transition********

Transition Length                    123.386

********Element 5     Straight********
```

Fig. 5.2 Results of Horizontal Alignment – Road 2

5.1.2 Vertical Alignment Report

Road 1:

```
Vertical Alignment Report
Model:        H ALIGNMENT
String:       MC00
Units:  Metric
Date :        05-12-2020 19:10:25


********Element 1 Grade********

Gradient                              3.330
Gradient Length                     428.788

********Element 2 Vertical Curve********

IP Chainage                       0+486.238
Curve Start Gradient                  3.330
Curve End Gradient                   -.500
Curve Length                        114.900
Sight Distance                      110.125

********Element 3 Grade********

Gradient                             -.500
Gradient Length                     792.337
```

Fig. 5.3 Results of Vertical Alignment – Road 1

Road 2:

```
Vertical Alignment Report
Model:        HORIZONTAL ALIGNMENT
String:       MC00
Units:  Metric
Date :        05/12/2020 19:09:06


********Element 1 Grade********

Gradient                              3.235
Gradient Length                     197.638

********Element 2 Vertical Curve********

IP Chainage                       0+246.226
Curve Start Gradient                  3.235
Curve End Gradient                   -.004
Curve Length                         97.175
Sight Distance                      116.461

********Element 3 Grade********

Gradient                             -.004
Gradient Length                     380.284

********Element 4 Vertical Curve********

IP Chainage                       0+690.000
Curve Start Gradient                 -.004
Curve End Gradient                   -.998
Curve Length                         29.805
Sight Distance                      236.193

********Element 5 Grade********

Gradient                             -.998
Gradient Length                     116.444

********Element 6 Vertical Curve********

IP Chainage                       0+851.664
Curve Start Gradient                 -.998
Curve End Gradient                  -3.019
Curve Length                         60.634
Sight Distance                      139.094
```

Fig. 5.4 Results of Vertical Alignment – Road 2

5.1.3 IITPAVE Results

Pavement 1:

```
No. of layers              3
E values (MPa)        3280.00  311.27   99.58
Mu values                  0.350.350.35
thicknesses (mm)       105.00  450.00
single wheel load (N) 20000.00
tyre pressure (MPa)        0.56
Dual  Wheel
   Z      R      SigmaZ      SigmaT      SigmaR      TaoRZ       DispZ      epZ        epT        epR
105.00    0.00-0.1842E+00 0.7835E+00 0.6250E+00-0.1889E-01 0.3256E+00-0.2065E-03 0.1918E-03 0.1266E-03
105.00L   0.00-0.1842E+00-0.1542E-01-0.3045E-01-0.1889E-01 0.3256E+00-0.5402E-03 0.1918E-03 0.1266E-03
105.00  155.00-0.1405E+00 0.5703E+00 0.7006E-01-0.8403E-01 0.3305E+00-0.1112E-03 0.1814E-03-0.2449E-04
105.00L 155.00-0.1405E+00-0.1438E-01-0.6185E-01-0.8403E-01 0.3305E+00-0.3658E-03 0.1814E-03-0.2449E-04
555.00    0.00-0.2392E-01 0.3474E-01 0.2976E-01-0.4109E-02 0.2148E+00-0.1494E-03 0.1050E-03 0.8346E-04
555.00L   0.00-0.2378E-01 0.2402E-02 0.7609E-03-0.4106E-02 0.2148E+00-0.2499E-03 0.1050E-03 0.8278E-04
555.00  155.00-0.2565E-01 0.3727E-01 0.3368E-01-0.5687E-02 0.2212E+00-0.1622E-03 0.1107E-03 0.9514E-04
555.00L 155.00-0.2565E-01 0.2544E-02 0.1374E-02-0.5700E-02 0.2212E+00-0.2713E-03 0.1109E-03 0.9500E-04
```

Fig. 5.5 Results of IITPAVE for Thickness 1

```
No. of layers              3
E values (MPa)        3280.00  311.27   99.58
Mu values                  0.350.350.35
thicknesses (mm)        95.00  450.00
single wheel load (N) 20000.00
tyre pressure (MPa)        0.56
Dual  Wheel
   Z      R      SigmaZ      SigmaT      SigmaR      TaoRZ       DispZ      epZ        epT        epR
 95.00    0.00-0.2061E+00 0.8332E+00 0.6702E+00-0.1899E-01 0.3396E+00-0.2232E-03 0.2045E-03 0.1374E-03
 95.00L   0.00-0.2061E+00-0.2136E-01-0.3683E-01-0.1899E-01 0.3396E+00-0.5966E-03 0.2045E-03 0.1374E-03
 95.00  155.00-0.1492E+00 0.5699E+00-0.2379E-02-0.9278E-01 0.3426E+00-0.1061E-03 0.1899E-03-0.4561E-04
 95.00L 155.00-0.1492E+00-0.1865E-01-0.7296E-01-0.9278E-01 0.3426E+00-0.3764E-03 0.1899E-03-0.4561E-04
545.00    0.00-0.2508E-01 0.3655E-01 0.3105E-01-0.4387E-02 0.2198E+00-0.1566E-03 0.1107E-03 0.8685E-04
545.00L   0.00-0.2497E-01 0.2507E-02 0.6500E-03-0.4388E-02 0.2198E+00-0.2618E-03 0.1106E-03 0.8548E-04
545.00  155.00-0.2698E-01 0.3937E-01 0.3530E-01-0.6119E-02 0.2267E+00-0.1706E-03 0.1171E-03 0.9947E-04
545.00L 155.00-0.2698E-01 0.2710E-02 0.1420E-02-0.6164E-02 0.2267E+00-0.2854E-03 0.1170E-03 0.9955E-04
```

Fig. 5.6 Results of IITPAVE for Thickness 2

Pavement 2:

```
No. of layers          3
E values (MPa)     3000.00   311.30   99.58
Mu values             0.350.350.35
thicknesses (mm)    105.00   450.00
single wheel load (N) 20000.00
tyre pressure (MPa)     0.56
Dual  Wheel
    Z       R     SigmaZ     SigmaT    SigmaR     TaoRZ      DispZ      epZ        epT        epR
 105.00    0.00-0.1909E+00 0.7360E+00 0.5870E+00-0.1901E-01 0.3295E+00-0.2180E-03 0.1991E-03 0.1321E-03
 105.00L   0.00-0.1909E+00-0.1577E-01-0.3123E-01-0.1901E-01 0.3295E+00-0.5605E-03 0.1991E-03 0.1321E-03
 105.00  155.00-0.1430E+00 0.5264E+00 0.4190E-01-0.8759E-01 0.3337E+00-0.1140E-03 0.1873E-03-0.3076E-04
 105.00L 155.00-0.1430E+00-0.1439E-01-0.6466E-01-0.8759E-01 0.3337E+00-0.3705E-03 0.1873E-03-0.3076E-04
 555.00    0.00-0.2400E-01 0.3512E-01 0.2987E-01-0.4168E-02 0.2162E+00-0.1502E-03 0.1062E-03 0.8343E-04
 555.00L   0.00-0.2406E-01 0.2408E-02 0.7243E-03-0.4171E-02 0.2162E+00-0.2527E-03 0.1062E-03 0.8338E-04
 555.00  155.00-0.2596E-01 0.3774E-01 0.3402E-01-0.5722E-02 0.2227E+00-0.1641E-03 0.1122E-03 0.9603E-04
 555.00L 155.00-0.2596E-01 0.2555E-02 0.1386E-02-0.5765E-02 0.2227E+00-0.2745E-03 0.1120E-03 0.9618E-04
```

Fig. 5.7 Results of IITPAVE

5.1.4 Calculation of Structural Life

The structural life for the rutting failure of the pavement is calculated as per Clause 3.6.1 IRC-37 2018 and using the vertical compressive strain values given by IITPAVE software as shown in Table 5.1.

Table 5.1 Structural Life Calculation

Sr. No	Description	Bitumen Type	Design Traffic (msa)	Design CBR (%)	Calculated Strain Values		Structural Life (msa) In Rutting Failure
					Tensile Strain	Vertical Strain	
1.	Pavement 1	HGB	30	15	2.045E-04	2.854E-04	573
2.	Pavement 2	VG40	30	15	1.99E-04	2.745E-04	599

5.2 Discussion:

The project was executed using the MX Road Designer software and IITPAVE. In this project, two new center line for the 2 new two lane road is designed using survey data of plain area. After defining center line, Geometric Design for the new roads is done in accordance to the IRC standards using MX Road. Alignment is designed for 85 kmph and 80 kmph design speeds. .Working cross sections are developed. Super elevation has been applied. After the geometric alignment, two new flexible pavements are designed as per IRC 37 – 2018 guidelines and MoRTH Specifications. The designed pavements are analyzed using IITPAVE software.

5.3 Conclusion:

Both the roads are designed according to the IRC recommendations for the plain areas. The road is designed with less number of curves and the radius of curve is adopted as 350 m for both the roads in order to give better visibility, to prevent accidents and to provide riding comfort. High design precision and saving in time were achieved by using MX ROAD.

The use of Higher Grade Bitumen as a binder in Pavement 1 provides better stability to structure and less deformation i.e. rut depth as this bitumen is less temperature susceptible as compared to the conventional grades in market. The reduction in thickness of DBM layer makes the design more economic as HGB (Higher Grade Bitumen) provides more strength.

The Pavement 2 is designed with the VG40 bitumen grade that handles heavy traffic loading under high temperature and with the super hydrophobic coating on top surface layer, the water cannot percolate into the pavement and helps in maintaining the structural strength of the pavement in rainy areas.

CHAPTER 6
FUTURE SCOPE OF THE PROJECT

6.1 Scope

Earlier the design of any structure or a road is very complicated as this whole process is done on paper and requires a lots of time and hard work. But in the present era the designer soft wares are boons for the designers as these software eliminate the need of lengthy calculations, auto correct the errors on its own and makes the work more easier, smarter and more efficient In the project, the two new roads are designed using different soft wares. With the help of these soft wares the project is executed in a very easy, time saving and precise way. The first objective of the project i.e. Geometric Design is achieved using the MX Road designer software after this the second objective i.e. the pavement design and analysis is done using the IITPAVE software

MX Road is an excellent string-based modeling tool that enables the rapid and accurate design of all types of roads. Individuals such as civil engineers, designers, surveyors, system designers can access 3D modeling, construction driven engineering, and other analysis all in one engineering application. With the use of this software we have designed a safer and well aligned road precisely and quickly. The same work would have taken a lots of time if it is done conventionally.

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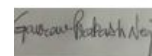**Name of the Supervisor:** Prof. Chandra Pal Gautam

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