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A Review on The comparison of geometric design using Civil 3D software and manual method

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ABSTRACT

Roads offer a vital contribution to sustainability and economic growth, offering major social benefits. Roads are important for growth and development. Roads to open more regions and promote socio-economic development. The location of design for the centreline of the highway on the surface is called alignment. The primary requirement for alignment is to be short, easy, safe, and economical. Horizontal alignment, vertical alignment, and cross-section are the three main components of geometric design. This review paper demonstrates the usual design of the roadway with the assistance of AutoCAD Civil 3D and manual method. It is modelling software helps to accomplish modeling in a convenient and relaxed way. Civil 3D modelling is quick and easy to understand to construct alignment.

Keywords: Civil 3D Software, Geometric Design, Road, Manual Method, IRC, Design Speed, Superelevation

1. INTRODUCTION

Highway geometry elements are expected to be selected, sized and positioned in a way that satisfies such design criteria as sight distance, vehicle stability, driver comfort, drainage, economy, and aesthetics. The design process involves some drafting and a number of analyses and calculations. The tasks which are usually performed by the design engineer include: creating the road alignment and plotting the road profile using coordinates (or bearings), stations and elevations; calculation of sight distances, radii of horizontal curves, and lengths of vertical curves; computation of earthwork quantities, and numerous other analyses and calculations aimed at finding the optimum alignment while satisfying design standards and constraints.The highway cross section shows the position and number of vehicle and bicycle lanes and sidewalks along with their cross slopes; shoulders, drainage ditches, etc.The aim of the project was to demonstrate how roadway geometric design can be performed in a very short time with much ease and precision. The road design procedure using AutoCAD Civil 3D has been presented. Manual geometric design of the same road was also performed, the results of which was compared favourably with that of AutoCAD Civil 3D.

Geometric features-

The basic objectives in geometric design are to optimize efficiency and safety while minimizing cost and environmental damage. Geometric design also affects community goals, including providing access to employment, schools, businesses, and residences,

accommodate a range of travel modes such as walking, bicycling, transit, and automobiles, and minimizing fuel use, emissions, and environmental damage.The geometric design of highways deals with the dimensions and layout of visible features of the highway. The emphasis of the geometric design is to address the requirement of the driver and the vehicle such as safety, comfort, efficiency, etc. The features normally considered are the cross section elements, sight distance consideration, horizontal curvature, gradients, and intersection. The design of these features is to a great extend influenced by driver behavior and psychology, vehicle characteristics, traffic characteristics such as speed and volume. Proper geometric design will help in the reduction of accidents and their severity. Therefore, the objective of geometric design is to provide optimum efficiency in traffic operation and maximum safety at reasonable cost. The planning cannot be done stage wise in this case like that of a pavement, but has to be done well in advance.

Factors affecting geometric design-

1.1 Design speed

Design speed is the single most important factor that affects the geometric design. It directly affects the sight distance, horizontal curve, and the length of vertical curves. Since the speed of vehicles vary with driver, terrain etc, a design speed is adopted for all the geometric design. Design speed is defined as the highest continuous speed at which individual vehicles can travel with safety on the highway when weather conditions are conducive. Design speed is different from the legal speed limit which is the speed limit imposed to curb a common tendency of drivers to travel beyond an accepted safe speed. Design speed is also different from the desired speed which is the maximum speed at which a driver would travel when unconstrained by either traffic or local geometry. Since there are wide variations in the speed adopted by different drivers, and by different types of vehicles, design speed should be selected such that it satisfy nearly all drivers. At the same time, a higher design speed has cascading effect in other geometric designs and thereby cost escalation. Therefore, an 85th percentile design speed is normally adopted. This speed is defined as that speed which is greater than the speed of 85% of drivers. In some countries this is as high as 95 to 98 percentile speed.

1.2 Topography

The next important factor that affects the geometric design is the topography. It is easier to construct roads with required standards for a plain terrain. However, for a given design speed, the construction cost increases multiform with the gradient and the terrain. Therefore, geometric design standards are different for different terrain to keep the cost of construction and time of construction under control. This is characterized by sharper curves and steeper gradients.

1.3 Other factors

- Vehicle: :The dimensions, weight of the axle and operating characteristics of a vehicle influence the design aspects such as width of the pavement, radii of the curve, clearances, parking geometrics etc. A design vehicle which has standard weight, dimensions and operating characteristics are used to establish highway design controls to accommodate vehicles of a designated type.
- Human: The important human factors that influence geometric design are the physical, mental and psychological characteristics of the driver and pedestrians like the reaction time.
- Traffic: It will be uneconomical to design the road for peak traffic flow. Therefore a reasonable value of traffic volume is selected as the design hourly volume which is determined from the various traffic data collected. The geometric design is thus based on this design volume, capacity etc.
- Environmental: Factors like air pollution, noise pollution etc. should be given due consideration in the geometric design of roads.
- Economy: The design adopted should be economical as far as possible. It should match with the funds alloted for capital cost and maintenance cost.
- Others: Geometric design should be such that the aesthetics of the region is not affected.

Civil 3D Software-

AutoCAD Civil 3D is a software application used by civil engineers and professionals to plan and design the projects for building constructions, road engineering

projects, water include construction of dams, ports, canals, embankments etc. AutoCAD civil 3D associate design and production drafting, greatly reducing the time it takes to implement design changes and evaluate multiple situations. A change made in one place immediately updates an entire project, helping you complete projects faster, smarter, and more accurately. Civil 3D provides to create 3D models of the project and helps to adopt for both small- and large-scale projects. It helps to imagine the things in 3D visualization, reduces the time and budget. It also inherits many benefits of using civil 3D.

Objectives of the project-

1. To study the various geometric features of road.
2. To study the role of the geometric featuresof road.
3. To design geometric features by using civil 3D Software.
4. To design geometric features by using manual method.
5. To comparison study of geometric features using civil 3D software and manual method.
6. To determine safe geometric features of a road to minimize the accident rate.

2. LITERATURE REVIEW

In a National Highway project, the engineer has to plan, design and construct either a network of new roads or road link. Once a highway is constructed, development takes along the adjoining land and subsequent changes in alignment in geometric standards become very difficult. A badly aligned highway is not only a source of potential traffic hazard, but also causes a considerable increase in transportation cost and strain on the drivers and the passengers. Therefore, proper investigation and planning are most important in a road project, keeping in view the present day needs as well as the future development of the region. Transportation is responsible for the development of civilizations from very old times by meeting travel requirement of people and transport requirement of goods. In today's world, road and transport has become an integral part of every human being. However it is observed that fatalities have shot up by half in the last 10 years About 1.2 million Indians were killed in car accidents over the past decade; on average one every four minutes, while 5.5 million were seriously injured. In India National highways comprise 1.7% of total road network, but carry about 40% of road traffic which contribute to 29% of total road traffic accidents.

[1] Study of Geometric features of road and accident rate

Sagar B. Patil1, Saniya Attar, DivyaDugani, Tejaswi Desai, SimranMahabri (2019), The objective of the study of geometric features of road and accident rate wants to find various geometric features of road using post-& pre-analysis approach. It affects geometric features and accident rate. The study is based on traffic volume. Major accidents occurred due to speed, horizontal radius, lack of visibility, super elevation, steep gradient, vertical gradient. A total of 18749 vehicles from 8.00am to 8.00pm on Waghbil road were collected (combined vehicles), for analysis approach. The analysis shows ratio of vehicle count for every 15 mins interval. Manual calculation was the purpose for this investigation. Road & human safety are the major consideration of the project, basic methodology for better understanding. Studying, analysing and determining is the basic approach of this project.In this study, we have studied site of Waghbil for the geometric features of the road as super elevation, horizontal radius, horizontal alignment, visibility, gradient and analysis is done. Hence, we can conclude that provision of bypass, speed limit signs, diverging signs and road studs should be made for safe driving to reduce accident rate.Preventive measures for Waghbilroad : For this road traffic is high. In order to reduce traffic speed limit signs and diverging signs should be provided. To reduce accident and safe drive, road studs should be provided at the curves.

[2] Geometric Design of a Highway Using AutocadCivil 3d

S.A. Raji, A. Zava, K. Jirgba, A.B. Osunkunle (2017), Roadway geometry design involves such tasks as creating the road alignment and plotting the alignment profile using bearings or coordinates (easting and northing), stations and elevations of points along the proposed route; calculation of sight distances, radii of horizontal curves, and lengths of vertical curves; computation of earthwork quantities, and numerous other analyses and calculations aimed at finding the optimum alignment while satisfying design standards and constraints. When performed manually, geometric

design is very cumbersome, time-consuming and highly susceptible to very costly errors. Current trends are geared towards the use of computer programs for roadway geometry design. The programs offer amazing precision and save lots of time and effort. This paper presents a complete geometric design of a typical highway using AutoCAD Civil 3D software. The aim of the project was to demonstrate how roadway geometric design can be performed in a very short time with much ease and precision. The road design procedure using AutoCAD Civil 3D has been presented. Manual geometric design of the same road was also performed, the results of which was compared favourably with that of AutoCAD Civil 3D.The use of AutoCAD Civil 3D for highway geometric design makes the design process to be completed within a very short time and with much ease and amazing precision. These capabilities of AutoCAD Civil 3D eliminate the major disadvantages of the manual design approach that is cumbersome, time consuming and highly prone to costly errors.

[3] A Study to the Geometric Design of Road Project Using Civil 3D

YogeshBajpai, Er. Atul, Shivam Pandey (2019), — India is a country whose population is growing rapidly, indicating that traffic is also increases. The development of rural areas also increases its means furthering of transportation facilities are also developed. The geometric design manages the dimensions and layout of visible features of the road such as alignment, sight distance, cross-section and intersections. When geometric design performed manually, it is time-consuming and highly susceptible to very costly errors. In the present time, various software are available in market such as Bentley MX Road, HEADS, AutoCAD Civil 3D, etc are used to design the geometry of road. Current patterns are adapted to the utilization of computer programs for roadway geometry design. This software provides clarity, save times and effort to a user. The purpose of this paper is on the complete study to the geometric design of road project using Civil 3D Software. Civil 3D is a software for engineering it is used for the design, plan and manage the civil engineering works. This software is generally used by experts and civil engineers. The objective of this project is to design the road alignment in a less time with high accuracy using Civil 3D. The survey data is must be necessary for road creation. By utilizing a total station study can be completed quickly and can shorten the time. Total station is utilized for import the points in Civil 3D which is as x, y, z coordinates that are easting, northing, and elevation. These coordinates of the ground data is very useful to generate the surface, design the alignment and other geometric features.

[4] A study of geometric design of roadway using Civil 3D 2020

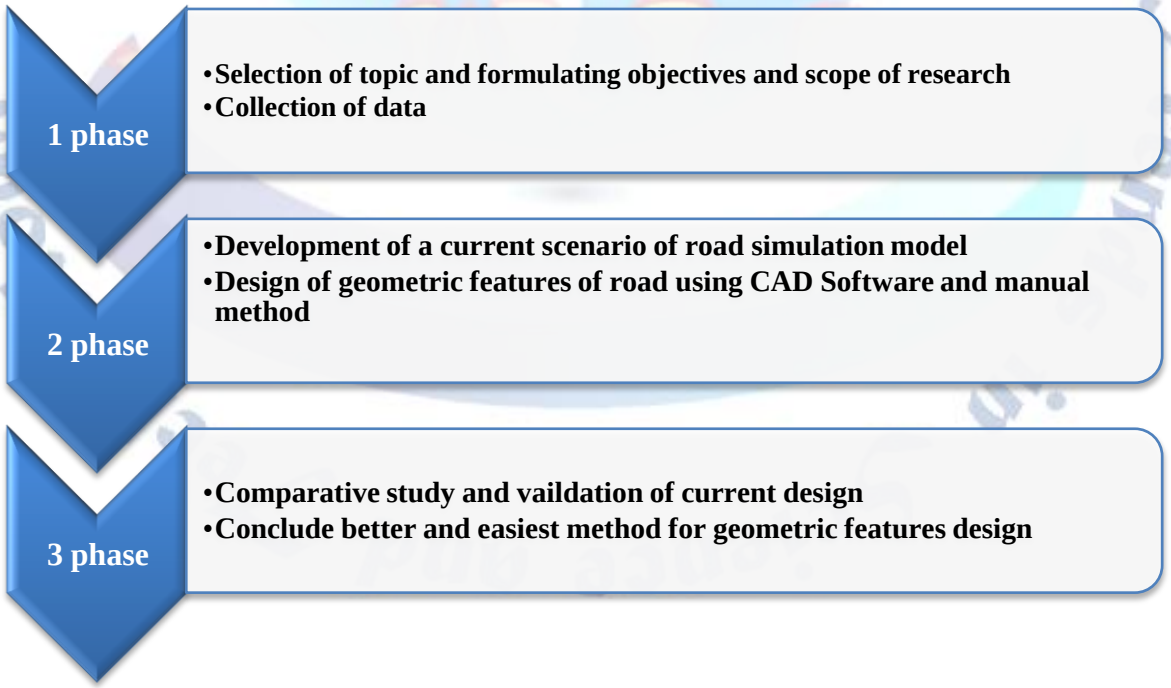
AkashSurendraKolamkar, Prof.Kalyani P. Nichat (2020), India is a country whose population is growing rapidly, indicating that traffic is also increases. The development of rural areas also increases its means furthering of transportation facilities are also developed. The geometric design manages the dimensions and layout of visible features of the road such as alignment, sight distance, cross-section, and intersections. The basic object is optimizing efficient traffic and safety of highway and minimizing cost and environmental damages. Design the road knows about the fundamental of road geometric and next step to upgrade their value is by learning software for use of the essential information. Geometric Design of road involves such tasks as creating the road alignment and plotting the alignment profile using bearings or coordinates (easting and northing), stations and elevations of points along the proposed route, lengths of vertical curves, computation of earthwork quantities, and numerous other analyses and calculations aimed at finding the optimum alignment while satisfying design standards and constraints. When geometric design performed manually, it is time-consuming and highly susceptible to very costly errors. In the present time, various software is available in market such as Bentley MX Road, AutoCAD Civil 3D, etc. are used to design the geometry of road. Current patterns are adapted to the utilization of computer programs for roadway geometry design. This dissertation presents a complete geometric design of road project using AutoCAD Civil 3D software. The main aim of the project is to display how geometric design can be performed in a very short time with accuracy. The road design procedure using AutoCAD Civil 3D has been presented. This software provides clarity, save times and effort to a user. Civil 3D is software for engineering it is used for the design, plan and manage the civil engineering works.

This software is generally used by experts and civil engineers.

[5] A Study to the Geometric Design of Road Project Using Civil 3D

Ashish Kale, Vishal Gajghate, RavinaPotey (2021), In the present trend, geometric design is an important component and having a great effect while aligning a new road. Geometric design is a backbone of any alignment of road. It deals with cross sectional elements, sight distance considerations, horizontal alignment and vertical alignment details, intersection elements and it is relaying on the important factors such as design speed, topography or terrain, traffic factors, design hourly volume and capacity, environmental and other factors. While aligning a new road, it should be short, easy, safe and economic and it is expected to be comfort and safe for the movement. The geometric structure of the roads has three fundamental parts, which are horizontal, vertical, cross-sectional orientation. Which, when combined, give a 3-dimensional road layout. Horizontal alignment consists of three geometric components, including curves, tangents, and transitions. Vertical alignment is a longitudinal section, together with geometric additives such as crest curves, sag curves, and gradients. Highway geometry formulations depend on selection, estimated and thus act by certain design standards as sight distance, vehicle stability, driver consolation, drainage, economy, and aesthetics. Numerous Computations and Measurementspursue design process. The civil 3D upgrade has modified this paradigm so that both design and development are carried out concurrently. When performed manually, geometrical design can be very cumbersome, time-consuming, and quite helpless to costly blunders, the traditional technique is also based, in particular, on a twodimensional analysis that does not ensure a pleasant layout. The goal of this study is to show how geometrical design is done quickly and perfectly in a short period to enable professionals from those in the developing world to use road design. This paper shows a typical design of the highway with the support of AutoCAD Civil 3D that saves time and energy. Highway design faces tremendous challenges without 3D modeling. It consumes a lot of effort to cut and fill that amounts. The volume computing approach can be used.

3. PROPOSEED METHODOLOGY



Geometric Design: Geometric design of highway deals with designing of physical visible features of highway those comprise of cross sectional elements, sight distances, alignment, curves, super elevation, and other allied features. Here is a brief definition of some geometric elements.

Alignment: The alignment is the route of the road, defined as a series of horizontal tangents and curves.

Profile: The profile is the vertical aspect of the road, including crest and sag curves, and the straight grade lines connecting them.

Cross- section: The cross section shows the position and number of vehicle and bicycle lanes and sidewalks, along with their cross slope or banking. Cross sections also show drainage features, pavement structure and other items outside the category of geometric design.

Sight distance: Road geometry affects the sight distance available to the driver. Sight distance, in the context of road design, is defined as "the length of roadway ahead visible to the driver."

Cross slope: Cross slope describes the slope of a roadway perpendicular to the centreline. If a road were completely level, water would drain off it.

Crest curves: Crest vertical curves are curves which, when viewed from the side, are convex upwards. This includes vertical curves at hill crests, but it also includes locations where an uphill grade becomes less steep, or a downhill grade becomes steeper.

Superelevation: To counter-act the effect of centrifugal force and reduce the tendency of vehicle to overturn and to skid laterally outwards, pavement outer edge is raised with respect to inner edge. Thus, providing a transverse slope is known as Super elevation.

Horizontal curves: Horizontal curves are provided to change the direction of centre line of the road. When a vehicle negotiates a horizontal curve, centrifugal force acts outwards through centre of gravity of the vehicle which depends upon the radius of curve and speed of vehicle.

Transition curve: To enable gradual introduction of superelevation and the centrifugal force on a vehicle negotiating a horizontal curve avoiding sudden jerk on the vehicle, a transition curve is introduced whose radius reduces from infinity at tangent point to a designed radius of the circular curve .

Radius of Horizontal Curve:

The radius of the horizontal curve is an important design aspect of the geometric design. The maximum comfortable speed on a horizontal curve depends on the radius of the curve. Although it is possible to design the curve with maximum superelevation and coefficient of friction, it is not desirable because re-alignment would be required if the design speed is increased in future. Therefore, a ruling minimum radius R_{ruling} can be derived by assuming maximum superelevation and coefficient of friction.

$$R_{\text{ruling}} = \frac{v^2}{g(e+f)} \tag{1}$$

Ideally, the radius of the curve should be higher than R_{ruling}. However, very large curves are also not desirable. Setting out large curves in the field becomes difficult. In addition, it also enhances driving strain.

Design of super-elevation:

For fast moving vehicles, providing higher superelevation without considering coefficient of friction is safe, i.e. centrifugal force is fully counteracted by the weight of the vehicle or superelevation. For slow moving vehicles, providing lower superelevation considering coefficient of friction is safe, i.e.centrifugal force is counteracted by superelevation and coefficient of friction .IRC suggests following design procedure:

Step (1) Find e for 75 percent of design speed, neglecting f,

i.e $e1 = (0.75v)^2/gR$.

Step(2) If $e1 \leq 0.07$, then $e = e1 = (0.75v)^2/gR$, else if $e1 > 0.07$ go to step 3.

Step(3) Find f1 for the design speed and max e,

i.e $f1 = v^2/gR - e = v2/gR – 0.07$.

If f1 < 0:15, then the maximum

e = 0.07 is safe for the design speed, else go to step 4.

Step(4) Find the allowable speed va for the maximum e = 0.07 and f = 0.15,

$va = \sqrt{0.22gR}$

If va≥ v then the design is adequate, otherwise use speed adopt control measures or look for speed control measures.

Extra widening (We):

Extra widening due to psychological reasons. (Wep)

While negotiating a horizontal curve, the driver has a tendency to follow the inner of the pavement. This reduces the effective width of the pavement at curves. In order to have a smooth operation at curves, you need to provide an extra widening at the curve of the road.

The IRC recommended a value of extra widening formula for psychological reasons

$Wep = V / 9.5 \sqrt{R}$

Mechanical Widening (Wem)

While negotiating a curve, rear wheels have a tendency to follow the inner track. To accommodate this, there will be a widening is provided called mechanical widening have to be provided. This is due to the offtracking of the vehicle.

The off-tracking in a highway is one the main criteria during curve widening design.

The IRC value for the mechanical widening is given by

Wem= $nl^2 / 2R$

Therefore;

Total extra widening formula is= Wep +Wem

$$We = V/ 9.5 \sqrt{R} + nl^2 / 2R$$

Where;

n=Number of lanes

l=Length of the curve

R=Radius of curve or curvature

Stopping Sight Distance (SSD):

1. SSD = vt + (1/(2fg))v^2

Here, v is the speed in m/s², t is the reaction time taken, f is coefficient of friction, g is the acceleration due to gravity.

2. SSD = vt + (v2/ (2g (f ±0.01n)))

Here, v is the speed in m/s², t is the reaction time taken, f is coefficient of friction, g is the acceleration due to gravity & n is the gradient.

5. Intermediate Sight Distance (ISD):

It is the sight distance required to provide frequent opportunities of overtaking on highways. Its value is equal to twice S.S.D (stopping sight distance)

Therefore, I.S.D = 2 x S.S.D

$$\mathbf{I.S.D} = 2\ (\mathbf{V.t} + \frac{V^2}{2gf})$$

Overview of AutoCAD Civil 3D Design Procedure-

- Import survey data (comprising easting, northing and levels and saved in Note Pad format) into the AutoCAD Civil 3D environment.
- Create existing ground surface
- Create alignment by linking points on the existing ground using polyline
- Apply the design criteria. In this project, the AASHTO design criteria was selected.
- Generate the existing ground profile.
- Create the formation level (finished) using the profile creation tools.
- Create the Assembly, which defines the cross-sectional component of the design. The assembly is constructed by connecting individual subassembly objects.
- Create the corridor, which is the resulting dynamic 3D model representation built from the combination of horizontal, vertical and cross-sectional design elements. Corridors may be used to calculate earthworks and quantity takeoffs, to perform sight and visual analysis, to generate surfaces, and to extract information for construction purposes.
- Generate volume table report.

4. CONCLUSION

Highways are expected to guarantee users' comfort and safety, to permit efficient traffic operation, and at the same time attract the least possible cost in construction and maintenance. Highways are also expected to cause minimum damage to the environment and be aesthetically pleasing in their finished form. Geometric design is the means through which these demands are met. As the American Association of State Highway and Transportation Officials (AASHTO) puts it, "geometric design focuses on the specific measures that provide for efficient and appropriate operation of the road, as well as provide for all the specific details that make roads safe and compatible with social and environmental circumstances surrounding the road".

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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