GEOMETRIC DESIGN OF HIGHWAYS BY USING CIVIL 3D

MARRI.SRINIVASA REDDY[1], KOTAPATI.KRISHNA REDDY[2]

[1]Assistant professor, Department of Civil Engineering, Nalanda Institute of Engineering and Technology, Guntur, A.P, India.
Email: srinivasareddy.marri0@gmail.com, krishnareddykotapati.krk@gmail.com.

ABSTRACT

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. 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.

I. INTRODUCTION

The geometric design of roads is the branch of highway engineering concerned with the positioning of the physical elements of the roadway according to standards and constraints. The basic objectives in geometric design are to optimize efficiency and safety while minimizing cost and environmental damage. Geometric design also affects an emerging fifth objective called "livability," which is defined as designing roads to foster broader 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. Geometric roadway design can be broken into three main parts: alignment, profile, and cross-section. Combined, they provide a three-dimensional layout for a roadway.

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

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

- Factors affecting the geometric design,
- Highway alignment, road classification,
- Pavement surface characteristics,
- Cross-section elements including cross slope, various widths of roads and features in the road margins.
- Sight distance elements including cross slope, various widths and features in the road margins.
- Horizontal alignment which includes features like super elevation, transition curve, extra widening and set back distance.

OVER VIEW CIVIL 3D

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. Rural road is a road network with a low volume traffic and low design speed which provides market access to farms, employment and connects different communities.

Rural roads are classified into other district road (ODR) and village road (VR). These roads are able to reach the group of villages in rural area of the country and to provide connectivity. It is owned by local authorities. 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.

GEOMETRIC DESIGN

The geometric design of highway includes the principle elements of highway alignment, x-sections and adjacent road side environment. The three dimensional physical location determined through calculation of horizontal and vertical alignment of highway centerline, based on variety of operational considerations results in the geometric design and represent all visible features of highway or street.

Controls and Criteria for Geometric Design

- Design Vehicles
  - Passenger cars, buses, trucks, RVs
  - Physical characteristics: weight, dimensions
  - Establish intersection radius, pavement markings
- Vehicle Performance
  - Operating characteristics: accel/decel
  - Impacts air quality, noise, land use

Driver

- Information handling
- Reaction time
  - Time to perceive + react to a hazard in vehicle's path
  - Expected/unexpected
- Speed
- Driver errors
- Traffic
- Composition and volume
  - Average daily traffic (ADT) is not adequate
  - Design hourly volume (DHV)
  - 30th-highest hourly volume (30HV) in one year
  - K-factor (% of ADT; 8~12% urban, 12~18% rural)
- Speed of the vehicles
  - Operating Speed (typically the 85th percentile speed)
  - Free-flow Speed (close to zero density)
  - Running Speed (actual speed)
  - Design Speed (as high as practical)
- Capacity
  - Maximum hourly flow rate (per lane) under prevailing conditions
  - Determines adequacy of existing roadways
  - Helps select roadway type
  - Helps define needs
  - Design level of service (LOS)

II. LITERATURE REVIEW

Hameed Aswad Mohammed (2013). He had stated that shoulder wider than 2.25m give additional safety. Average single vehicle accident rate for highway curves is about four times the Average single vehicle accident rate for highway tangents. Horizontal curves are more dangerous when combined with gradients and surfaces with low coefficient of friction. There is only a minor decrease in the speed adopted by drivers approaching curves of radii which are significantly less than the minimum radii specified for the design speed. Horizontal curves are more dangerous when combined with gradients and surfaces with low coefficient of friction. Horizontal curves have higher crash rates than straight sections of similar length and traffic composition. The difference becomes apparent at radii less than 1000m. the increase in crash rates becomes particularly significant at radii below 200m. small radius curves result in much shorter curve lengths and overall implications for crashes may not be as severe as would first appear.

Neeraj and S.S.Kazal (2015). They were presented formulas in pavement widening on horizontal curves. To prevent off tracking, extra widening of pavement is provided at horizontal curves which is called mechanical widening. Wm= nl2/2R Wm is mechanical widening "R" is mean radius of curve "n" is number of lanes "l" is length of wheel base Wps= v/(2.64√R) "v" is design speed in metre per second Min-Wook Kang et al. (2013). A fuel consumption model is developed based on highway geometric characteristics like grades, length and location of crest& vertical curves, speed& road surface type& condition.

The output of fuel consumption model is the amount of fuel consumed by the vehicle while it travels along a highway at cruising speed. Fuel consumption model limitations: It is only for passenger car units.

It will be update with consideration of other type of vehicles. It is does not yet consider the effect of intersections & junction points with existing roads. It is not suitable for vehicle travelling along highway curved sections where acceleration and deceleration are needed due to variety design speeds.

Asok Kumar et. al (2015). They stated that for designing geometric elements designing MX ROAD software is high design precision and saving time. Vikas Golakoti (2015). His thesis includes geometric factors of road and data collection and analysis of geometric parameters. The aim of this study is to find the role of the geometric factors of road on accident rate in the case of plain terrain and also find the extent to which these factors affect the accident rate for rural areas. The study aims to find the impact of factors like extra widening, horizontal radius, sight distance, K-value, super elevation, horizontal arc length, vertical arc length, vertical gradient on the accident rate and aims to study the significant factors causing accidents and to find the values for future design of roads.

American Association of State Highway and Transport Officials (2005). This policy states standards for highway designing elements. In addition to that vertical clearance, cross-section, structural capacity of bridges and about tunnels. Government of the People's Republic of Bangladesh Ministry of Communications Roads and Railways Division (2000). It states design standards for different road classifications, traffic volume and capacity, design speed, and sight distances along with design procedure. Indian Road Congress 73:2005. It gives specifications of highway geometric elements, terrain classification, and design speed for different types of highways and design traffic and capacity. United Nations Highway Safety Information System (1999) gives basic methodology involved the development of crosssectional models. For each State, individual models predicting crash rate per kilometer for typical sections of two-lane, four-lane undivided, and four-lane divided (nonfreeway) roadways were developed. Over-dispersed Poisson models were fitted to the data. Crash rate per kilometer differences between pairs of road classes were then calculated as a measure of safety effect.

Abo El-Hassan M. Rahil et al. (2014). They got three approaches to relate accident rate to geometric characteristics and traffic related explanatory variables: Multiple Linear regression, Poisson regression and Negative Binomial regression. Various models have been intensively tested and validated. The adjustment of the models is based on historical accident data and on the characteristics of experimental sections selected from the road network. For example, Multiple linear and Poisson regression were used. In order to estimate accident rates using traffic and geometric independent variables. Moreover, developed a model to identify the most significant traffic and geometric elements in predicting accident frequency. They used both the Poisson and negative binomial regression models. It should be pointed that, in using such models for future forecast one has to be careful as this entails extrapolating outside the range where the real observations were made. These models can be used for short-term forecast of 1–3 years. It is advisable that whenever data is available, these models should be updated through recalibration.

Matthew G. Karlaftis and Ioannis Golias (2001). They focused on relationship between rural road geometric characteristics, accident rates and their prediction, using a rigorous non-parametric statistical methodology known as hierarchical tree-based regression. Their goal is twofold; first, it develops a methodology that quantitatively assesses the effects of various highway geometric characteristics on accident rates and second, it provides a straightforward, yet fundamentally and mathematically sound way of predicting accident rates on rural roads. The results show that although the importance of isolated variables differs between two lane and multilane roads, 'geometric design' variables and 'pavement condition' variables are the two most important factors affecting accident rates.

III CIVIL 3D

INTRODUCTION

AutoCAD Civil 3D engineering software provides civil engineering professionals with targeted solutions for a wide variety of infrastructure projects, including land development, transportation, and water projects.

Figure: A Civil 3D road corridor model

ABOUT CIVIL 3D CORRIDORS

Corridors combine surface, alignment, profile, and assembly information to create dynamic three-dimensional representations of route-type features, such as roads, railroads, channels, and bridges.

Corridors are the main design object of road modeling and simulation in Civil 3D. They rely on interaction with other model objects and they help to simulate behavior prescribed by assignable and customizable parameters, such as daylighting, lane widening, and superelevation schemes.

A corridor is created by applying an assembly along the horizontal and vertical path defined by the combined information of the alignment and profile. To complete the corridor, targets are specified to achieve daylighting. The type of corridor, such as a trench, a channel, a path, a road, or a bridge, is determined by the assembly configuration that is applied along the baseline at desired intervals. The assemblies that are used to create the corridor may contain sophisticated behavior such as conditional targeting, widening, and superelevation.

The result is a 3D model that extrudes the specified assemblies along the desired path. Feature lines connect similar points from assembly to assembly. These feature lines establish the longitudinal edges of the 3D model. Individual points in the assembly may also be assigned behavior that automatically follows prescribed targets, such as curb return alignments or lane-widening feature lines. The resulting corridor model may be used to generate cross-section sheets, earthwork and material volumes, feature lines, and surfaces. Surfaces derived from the corridor can represent finished grades, subgrades, or any number of underlying component surfaces. These surfaces may be used for visualization, material quantity, and construction purposes.

COMPONENTS OF THE CORRIDOR OBJECT

The corridor object is built using baselines, assemblies, regions, parameters, and optional surfaces. Figure 1.2 shows a portion of a corridor and the components used to create it.

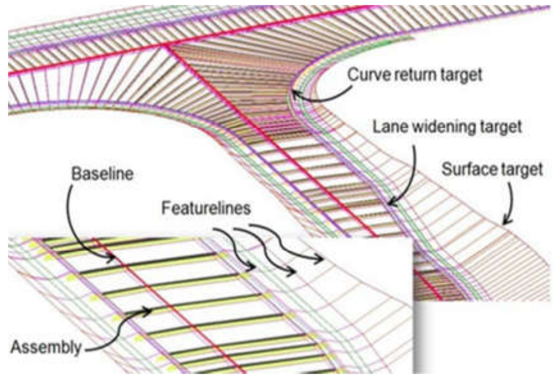

Figure.: A baseline is defined by the alignment and profile that control the horizontal and vertical aspects of the road. An assembly is then inserted to follow this path.

ABOUT RULE-BASED DESIGN

Using AutoCAD Civil 3D, you can compare the design of road elements against recognized industry standards or user- defined standards. As designers work to lay out designs, the software provides graphic alerts and/or notification tips to help alert you when standards are not met. This capability helps provide many benefits, including greater time savings, reduced rework due to fewer review comments, more consistency, and, above all, sound engineering design. This is made possible using design criteria and design check sets.

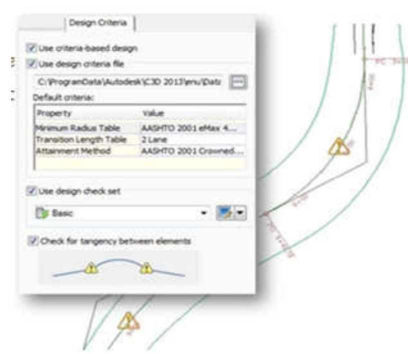

Figure.: Design criteria and design check sets are options of Alignment and Profile Properties

Rule Violation Warnings

Warnings appear in several locations to help give the designer notification when a violation to the applied criteria or design checks occurs. Alert symbols are displayed at locations along the alignment or profile where the violations occur.

Hovering over the symbol displays the tool tip, which gives a brief summary of the violation. The display of the warning symbol is controlled by the alignment style.

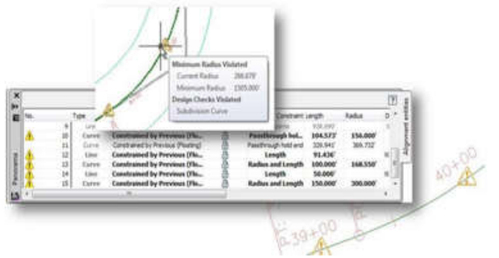

Figure: Violations of design criteria and design checks appear in several places to warn users.

STUDY AREA

Location

The study area is located in Ajjampudim, **Mandal Name** : Gannavaram, **District** : Krishna **State** : Andhra Pradesh , **Region :** Andhra Length of stretch is 5.3km. Project area passes through plain terrain and rolling terrain. Existing study area consists of asphalt road and Soil road. The alignment comprises of significant horizontal curves which would require geometric corrections.

Figure – Satellite image of selected area of the project

AUTODESK AUTOCAD CIVIL 3D

AutoCAD

Civil 3D is a civil engineering design and documentation tool developed by Autodesk. AutoCAD Civil 3D software supports Building Information Modeling (that is, digital representation of the physical and functional characteristics of a facility). It is used for modeling, analysis and design of a variety of civil infrastructure project types, including roads and highways, land development, rail, airports, and water. AutoCAD Civil 3D helps civil infrastructure professionals improve project delivery, maintain more consistent data and processes, and respond faster to project changes, all within the familiar AutoCAD environment [8] Autodesk lists the features of AutoCAD Civil 3D as follows:

BIM tools for civil engineering design: AutoCAD Civil 3D supports Building Information Modeling (BIM) and helps reduce the time it takes to design, analyze, and implement changes.

Efficient civil design: AutoCAD Civil 3D performs faster design iterations with an intelligent, 3D model-based application that dynamically updates related civil design elements when changes are made. It streamlines time-consuming tasks for corridor design, parcel design, and pressure and gravity network design.

It improves civil drafting and documentation. Connecting design and documentation helps boost productivity and deliver higher-quality designs and construction documentation. Changes to design elements are captured in documentation, minimizing manual updates.

GPS surveying tools for faster processing. GPS surveying and data collection tools in AutoCAD Civil 3D can help you update your processes for improved project delivery.

v. Integrated storm water management and geospatial analysis. AutoCAD Civil 3D helps the designer to improve project delivery and make more informed decisions using visualization, simulation, and water analysis integrated with the design process for storm water management, geospatial analysis, and model analysis.

IV RESULTS

Table: MERLIN Results from Test Sections

Stretch	Run1	Run2	Run3	Run4	Avg. m/Km
Stretch A	8.49	7.82	8.44	7.93	8.17
Stretch B	6.48	6.95	6.72	6.68	6.71
Stretch C	5.61	5.58	5.49	5.6	5.57
Stretch D	7.658	7.762	7.746	7.684	7.71
Stretch E	8.96	8.317	8.78	8.45	8.63
Stretch F	4.12	4.18	4.08	4.12	4.13
Stretch G	5.83	5.53	5.31	5.28	5.49

Table: Bump Counts from Test Sections

Stretch	Run1	Run2	Run3	Run4	Run5	Avg
Stretch A	394	379	388	401	398	392
Stretch B	312	327	306	334	298	315.4
Stretch C	245	231	237	221	242	235.2
Stretch D	365	348	357	355	373	359.6
Stretch E	520	512	514	545	519	522
Stretch F	118	135	112	142	123	126
Stretch G	213	221	203	228	208	214.6

Regression analysis was then performed on the results with the bump counts (measured by the MWUI) as the independent variable from which roughness in terms of a standard index is to be estimated.

Table: Regression Analysis

Stretch	Bump Counts	IRI
Stretch A	392	8.17
Stretch B	315.4	6.71
Stretch C	235.2	5.57
Stretch D	359.6	7.71
Stretch E	522	8.63
Stretch F	126	4.13
Stretch G	214.6	5.49

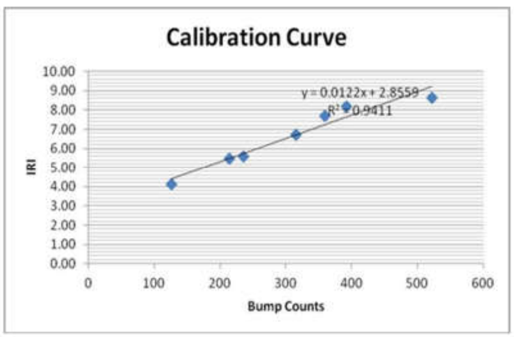

Chart -1: Calibration curve

IRI = 2.8559 + 0.0122 * BI Counts

Where,
IRI = the roughness index in m/km
UI = the unevenness index, mm/km
BI counts = the bump counts per km
Table: Stretch data

Stretch	UI Mm/ Km	Cracking, Sqm	Patch Sqm	Rut depth, mm	PCI
1	2547	123.1	153.0	13.5	90
2	2235	54.04	61.0	10	84
3	2083	32.96	20.0	8.3	82
4	2568	189.1	202.0	16.2	94
5	2258	82.11	67.0	13.1	88
6	1778	24.64	13.0	6.2	73
7	1749	7.18	11.7	5.8	71

ROAD ROUGHNESS

Though there is not a single definition for pavement roughness, it is generally defined as an expression of irregularities in the pavement surface that affects the ride quality of the vehicle. American Society of Testing and Materials (ASTM) definition (E867) for roughness is "The deviations of pavement surface from a true planer surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage, for example, longitudinal profile, transverse profile and cross slope". However it is found that the drainage and ride quality is unrelated to each other.

Roughness is an important indicator of pavement riding, comfort and safety. However the different wave lengths on the surface profile affect differently on the ride quality depending on vehicle characteristics and driving speed.

Generally, roughness may cause due to one or more of the following factors;

- construction techniques,
- Traffic loading. (For example repeated loads in a channelized area may cause pavement distortion by plastic deformation),
- environment effects,
- construction material, and
- non uniform initial compaction and built in construction irregularities.

Short wave length roughness is normally caused by localized pavement distresses such as depressions and cracking. On the other hand long wave length roughness is normally caused by environmental process in combination with pavement layer properties.

DATA COLLECTION

Survey Data Collection, the existing ground surface data are required for designing the geometry of highways. The survey information of the proposed route was obtained from the firm handling the development of the road. The survey information included Easting, Northing and elevations of points along the proposed route. Collecting the data and quantifying the information from a survey in the field or the study area in a systematic path in order to get proper and scrupulous picture of an area of interest, also to analyze and evaluate the outcomes and retort to the research problems.

- Surveying Surveys are carried out before starting the project such as Map study, Reconnaissance survey, Preliminary survey, Final location. Map study is to have a rough idea of the field. Reconnaissance survey is to visit the site and scrutinize the main features of the area but not in detail. The data derived from the reconnaissance surveys are normally utilized for planning and programming the detailed surveys and investigations and few possible alignments can be chosen for any alteration or changes. In Preliminary surveys, survey specialists and party performs field surveying duties using total station and collects all data which are necessary like latitude, longitude, elevation and other required measurements and data in the alternate alignments proposed. At last, final locating the centre line of the ground.

- Traffic Volume count To decide the number of lanes and roadway width, pavement design, economic analysis traffic surveys are conducted. The main focus of traffic survey is to determine of vehicle composition in traffic stream which helps to design geometric features of the road.

Cumulative ESAL applications over 10 years @ 6% growth rate,

N = T0 × 365 × (1+r)n – 1 × L r

Where,

T0 = ESAL per day = number of commercial vehicles per day in the year of opening × VDF L = Lane distribution factor = 1 for single lane / intermediate lane Assuming a uniform annual growth rate "r" of 6% over the design life (n) of 10 years Cumulative ESAL applications (N) over the design life can be computed by substituting the values, = 317.39 × 365 × (1+0.06)10 – 1 × 1 r = 1526960 Therefore, ESAL = 152696 ESAL 152696 Category T9 For Cumulative ESAL applications >1,500,000 – 2,000,000 Traffic comes under category T9 as per IRC: SP- 72 - 2015 "Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads".

AUTOCAD CIVIL 3D

Autocad civil 3D is a tedious process but after several rehearsal it will be easy, needs a training, taken a lot of practices to become fluent, and prepared to get this technique right. Below flow chart shows the general review of AutoCAD civil 3D design procedure

Select the file of the survey points which is saved in notepad or in excel sheet to import the points to AutoCAD civil 3D. Create the surface for the existing ground surface, create alignment for the profile and select criteria based design, create corridor to run corridor in 3D view, develop sample lines and assembly to create cross sections and to generate volume report. All these can be viewed in object viewer. The below figures shows the design procedure

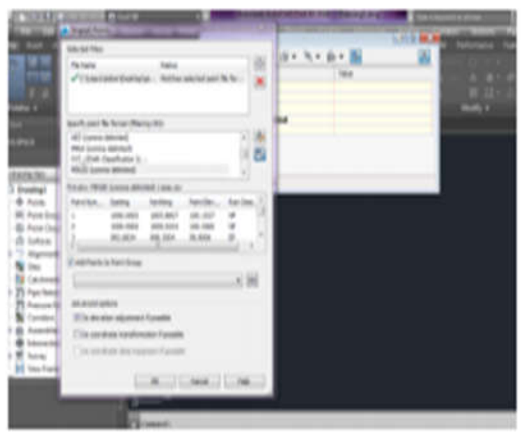

Fig.: Import Point File

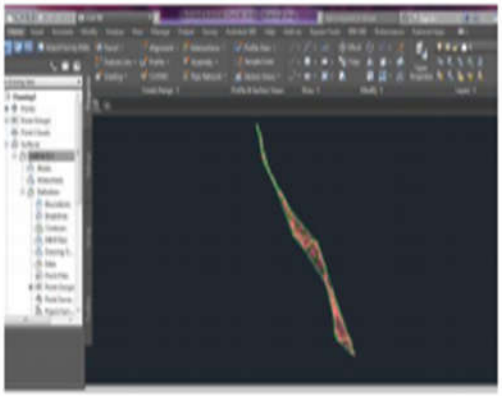

Figure - Surface Creation

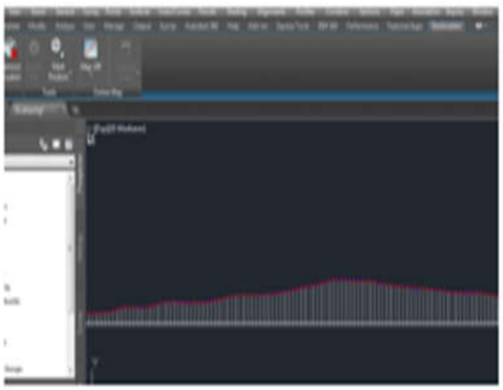

Figure. - Profile creation

Figure. - Cross sections of the road alignment

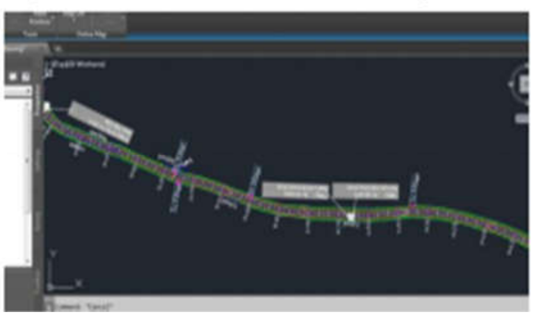

Figure - Corridor creation

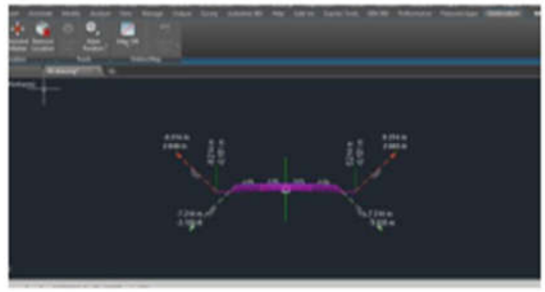

Figure. - Assembly creation

Figure. - Object viewer

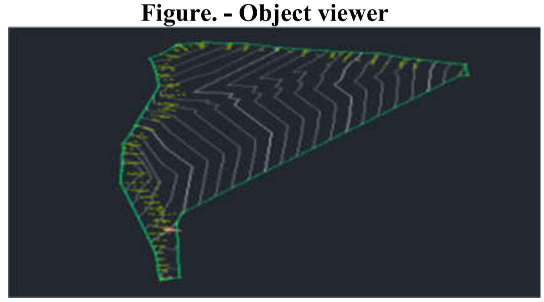

Figure. Existing Ground Surface produced by AutoCAD Civil 3D.

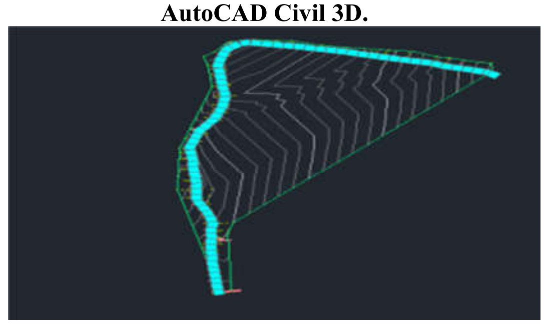

Figure. Horizontal Alignment produced by AutoCAD Civil 3D

V. CONCLUSIONS

CONCLUSION

Merlin and auto levels are normally considered to be simple devices for measurement of road roughness. An attempt has been made in this study to design and develop a new device. Experiments have been carried out using this device and at the same time using other two types of equipments on the same road stretches. The results of the experiments on road roughness in terms of IRI using these three devices have been compared among the three methods considered. It is observed that auto level has an error% of 3.95% when compared with the IRI values obtained from Merlin. All the three instruments have its unique importance in the calculation of the road roughness.

The upgrade MWUI was tested for calibration error and satisfactorily proved that it served that both repeatability and reproducible. the calibration developed and its variation was assumed as linear regression analysis is conducted between the IRI values obtained the calibration equation for MWUI obtained it as

IRI= 0.0122 (bumps counts)+ 2.8592

the distress parameters, age , traffic volume and rainfall data were considered for the development of the model developed for roughness is as follows

ui = 1519 + 3.73 (crk) + 3.27 (patch) + 11.34 (rd) + 0.92 (ravel) + 0.24 (traffic)

By the regression analysis it was observed that the parameters viz. age of the pavement and rainfall were statistically insignificant in prediction of roughness. it was also observed that the distress parameters and traffic were significant at 95% confidence level. also, as distress increases, the roughness value increases.

FUTURE SCOPE

It is proposed that the following works using this new device can be taken up in future.

1. A good number of experiments using these three experiments are to be conducted and the results to be statistically reviewed and compared.
2. The device is to be further modified to suit various roughness conditions.
3. The same stretches should be tested for roughness by using other roughness measuring methods such as bump integrator and RTRRM in order to establish the validity of this new setup.

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