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Geometric Design of Tipper Road, Oko, Anambra State, Nigeria

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Abstract
Geometric design of highways in Nigeria has always been treated like a footnote when it comes to road infrastructures, and more often than not, lack of good geometric road design poses a critical number of risks to road users. In this research paper, highway survey studies and a practical geometric design of Tipper Road was done by taking the northings, eastings and elevations of the proposed road was taken at a distance of 0+000 – 1+500Km and the road width being 10.5m. The basic geometric design control (Design Speed) was determined, while the horizontal alignment (plan) and the vertical alignment (profile) at slopes ranging from 4-6% according to the IRC was designed using the CivilCAD software. In the process of the design, transition and circular curves were introduced at appropriate points on the road to avoid sharp bends and counter the effects of centrifugal force acting on vehicles. From the experiment results, the proposed road (as per the original ground level) is a hilly terrain, and due to the topographical nature, appropriate cross slopes and superelevation values were imputed into the design data.

Keywords: Vertical Alignment, Horizontal Alignment, Civilcad, Transition Curve and Circular Curve.

Introduction
Since the attainment of independence, Nigeria has witnessed rapid economic and social development, which has open up the need for travelling between cities which led to increase in the need for good and safe road. 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 "liveability" 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. The need for road construction came up with the invention of the wheel some 5000 years ago. Prior to this invention, people and transportation beast simply moved on tracks which were only wide enough for their comfort. With the invention of the wheel, there was the need for improvement on the existing tacks to provide firmer and wider surfaces with better riding qualities to accommodate higher volume of traffic. These improvements were carried out in order to increase the safety and speed of conveying people and goods from one place to another for social and commercial purposes. In the late-19th century roading engineers began to cater for cyclists and pedestrians by building separate lanes alongside roadways. From the beginning of the 20th century, roads were increasingly built for tourism and also to create jobs. A typical example of the stimulation of tourism is the Great Dolomite Road, while the creation of the panoramic coastal road Strada Costiera between Duinoand Barcola in 1928 was very much focused on creating jobs. Road transport is one of the most common mode of transport. Roads in the form of track ways, human pathways etc. were used even from the pre-historic times.

Materials and Methodology

The materials used in the collection of survey data for the design are:

I. **A Nikon DTM-322 Total Station:** A total station is an optical surveying instrument that uses electronics to calculate angles and distances. It combines the functions of a theodolite with that of a transit level and electronic distance meter (EDM). It also has an integrated microprocessor, electronic data collector, and storage system that allow measurements to be stored on the device (which can be uploaded to a computer for further processing).

II. **Plumb Bob:** A plumb bob (sometimes referred to as a plummet) is one of the oldest, most fundamental tools in surveying work, dating back to the ancient Egyptians. Even today, they are the basic tool for determining verticality with respect to gravity, usually with a pointed tip on the bottom, suspended from a string and used as a vertical reference line, or plumb-line. Used to place an instrument over an exact point in space to accurately set markers.

III. **Tape:** Tapes are used in surveying for measuring horizontal, vertical or slope distances. Tapes are issued in various lengths and widths.

IV. **Tripod Stand:** A tripod is a portable three-legged frame or stand, used as a platform for supporting the weight and maintaining the stability of a number of surveying instruments, such as theodolites, total stations, levels or transits.

V. **Reference Pegs:** These are used to mark the alignment and/or the levels of the road. Usually, they are made of wood, steel or plastic.

VI. **Prism Poles:** Prism poles are a common tool for land surveying, because they can be used to measure elevation and grade through the use of a sight level.

VII. **Reference Pegs:** These are used to mark the alignment and/or the levels of the road.
Usually, they are made of wood, steel or plastic.

Road Surveying and Data Collection Procedures

The following procedures were adopted so as to ensure the accurate collection of survey data on the field:

I. **Establish and mark a point of reference:** The point of reference for the project was established, and measured using conventional means. The points were measured with the tape at 025m intervals and marked with a stake or nail.

II. **Set up the tripod at the reference point:** The tripod was set over the point of reference, and the centre of the tripod positioned roughly over the stake.

III. **Adjust as necessary:** Tripod was set to level, and directly placed over the point of reference.

IV. **Place the total station on the tripod:** The total station device was attached to the tripod, while being careful not to move it off-centre.

V. **Connect cables:** The battery pack and controller was connected to the total station using the appropriate cables.

VI. **Power on and start controller:** The device was turned on and the fine-level functionality was opened using the controller.

VII. **Make fine adjustments:** The device was adjusted using the fine level to get to directly over the survey marker on the stake. Also, ensure that it is perfectly levelled. The Northings, Eastings and Elevations, width of roadway and other relevant data were collected.

Design of Proposed Road with Civil CAD

Civil CAD is a Silvan, AutoCAD enabled civil engineering software that provides the basic horizontal, vertical and Superelevations design of highways through the use of survey data. It can also be adopted for pipeline and complex drainage designs. The data gotten from the surveying of the proposed road were typed in an excel format,

and inputted into the Civil CAD software. The drawings are made in the AutoCAD software, and dimensions of the drawing as well as other relevant information are supplied to the civil cad. Once the Civil CAD receives the imputed data, it processes it then displays it on the Civil CAD working environment.

The general workflows of the AutoCAD civil CAD are as follows:

- Import points
- Create existing ground surface
- Create the proposed alignment
- Modify the proposed alignment (transition curves)
- Create the proposed profile, and add data bands
- Modify the profile (cut and fill volumes, and design levels)
- Create the proposed assembly
- Create corridor
- Create sample elevation views
- Modify profile (Add Super-elevation data)
- Create multiple section views.

  The vertical alignment shows the areas where there are vertical curves, and areas of cut or fill. The cross section shows the centre line of the proposed road, proposed drawing at each chainage as well as places for cut and fill.

Minimum Radius of Curvature

Minimum radius of horizontal curvature is the lowest possible radius that a car negotiating a curve (bend) will run through without losing its frictional resistance as a result of centrifugal force acting on the vehicle. Minimum radius is given by; R (min) = $0.037v^2$. Moreover, if radius is large enough, it increases the friction of the road for counter reaction, but when radius is small, frictional resistance may not be enough to hold the vehicle in position, as a result skidding may occur.

Table 1: Recommended values for minimum radius per design speed

Radius	**12**	**30**	**40**	**50**	**60**	**65**	**80**	**100**
Design speed (km/hr)	30	40	60	100	150	180	250	400

Absolute minimum radius = $0.037v^2$

Discussion of Results

Survey Data

The survey data table consists of the following:

- Control points (CP):- This denotes the area on the proposed road which the surveyor does not want to be disturbed while collecting data.
- Northings ("X"):- This refers to the geographic Cartesian coordinates for the Northward - measured points.

- Eastings ("Y"):- This refers to the geographic Cartesian coordinates for the Eastward - measured points.
- Elevation ("Z"); which is gotten from the vertical distance above the surface of the reference plane selected.

Table 2: Survey Data Presentation

Points	Northings	Eastings	Elevations
FP 6	515266.538	228414.435	186.0
FP 5	515283.506	228224.141	189.0
CP 1	515226.350	228208.850	193.0
CP 2	515254.780	228201.390	198.0
CP3	515240.020	228134.572	204.0
CP 4	515397.048	228155.682	210.0
CP 5	515594.347	228113.021	212.0
CP 6	515670.966	228049.646	215.0
CP 7	515748.671	227930.367	218.0
CP 8	515849.358	227839.259	221.0
CP 9	515933.035	227828.547	225.0
CP 10	516069.502	227844.325	227.0
CP 11	516158.807	227827.884	229.0

Table 3: **Horizontal Alignment Data (**as designed on Civil CAD)

The horizontal alignment is the centreline of the roadway as shown in plain view, and it consists of two basic components:

- Transition curve: It's a curve in plan which is provided to change the horizontal alignment from straight to circular curve gradually
- Circular curve radius: It's used to join intersecting straight lines (or tangents).

The values are shown below:

Control points	IP points	Transition curves (m)	Circular curves
CP 2	IP 1	71.66 64.54	3m
CP 3	IP 2	176.33 168.37	10m
CP 4	IP 3	333.09 327.90	15m
CP 5	IP 4	538.18 526.22	25m
CP 8	IP 5	915.64 903.34	20m

CP 9	IP 6	1001 996.2	20m
CP 10	IP 7	1134.74 1127.20	25m

As seen above, the higher the distance of the transition curve, the higher the Circular curve radius, and vice versa. This is because in order to smoothen the shift from the straight line to the curve, transition curves are provided on either side of the circular curve so that the centrifugal force is built up gradually as the super elevation slowly runs out at a uniform rate.

Table 4: Vertical Alignment Data (as designed on Civil CAD)

The curves in a vertical alignment differ from the horizontal alignment curves in that they are parabolic curves instead of circular curves. The curves are categorized as sag (an increase in grade) or crest (a decrease in grade).

The values are shown below:

Distance	Ground level (m)	Design level (m)	Cut (m)	Fill (m)
0+000	193.00	194.00	-	1.00
0+060	197.65	197.80	-	0.25
0+120	201.20	200.40	0.80	-
0+180	204.14	203.30	0.84	-
0+240	206.52	206.00	0.52	-
0+300	208.90	207.76	1.14	-
0+360	210.28	209.52	0.76	-
0+420	210.90	211.10	-	0.20
0+480	211.52	212.33	-	0.81
0+540	212.06	213.55	-	1.49
0+600	213.99	214.78	-	0.79
0+660	215.60	215.91	-	0.31
0+720	216.86	217.03	-	0.17
0+780	218.13	218.14	-	0.01
0+840	219.46	219.26	0.20	-
0+900	220.79	220.40	0.59	-
0+960	222.38	221.60	0.78	-
1+020	224.00	222.80	1.20	-
1+080	225.61	224.00	1.61	-
1+140	227.20	225.27	1.93	-
1+200	228.52	226.54	1.98	-
1+220	228.96	226.96	2.0	-

Table 4: Vertical Alignment Data

It is important to try to match the existing terrain as closely as possible with the design level, and it is done through cut and fills as shown above. The cut and fill values are gotten by subtracting the value of the original ground level from the Design level. If the value of the Design level is greater than that of the Ground level, then the area has to be filled, but if the value of the Ground level is greater, then the area has to be cut. Additionally, there are requirements for maximum grade and curve lengths specified by the

IRC (Indian Road Congress). These are selected using the roadway's design speed and are set to ensure a driver's comfort and to meet sight distance.

Table 5: Vertical Alignment Slope (as designed on Civil CAD)

The last thing to consider when designing a vertical alignment is the minimum slope of the roadway. Typically, slopes higher than 5.0% are not used because slopes too high will not provide adequate drainage and could cause ponding in the roadway. The vertical alignment slope values are shown below;

Stations	Elevation	Slope (%)
0.000	196.000	-
240.000	206.000	3.333
400.000	210.693	2.933
610.875	215.000	2.042
880.000	220.000	1.858
1080.000	224.000	2.000
1221.74	226.999	2.116

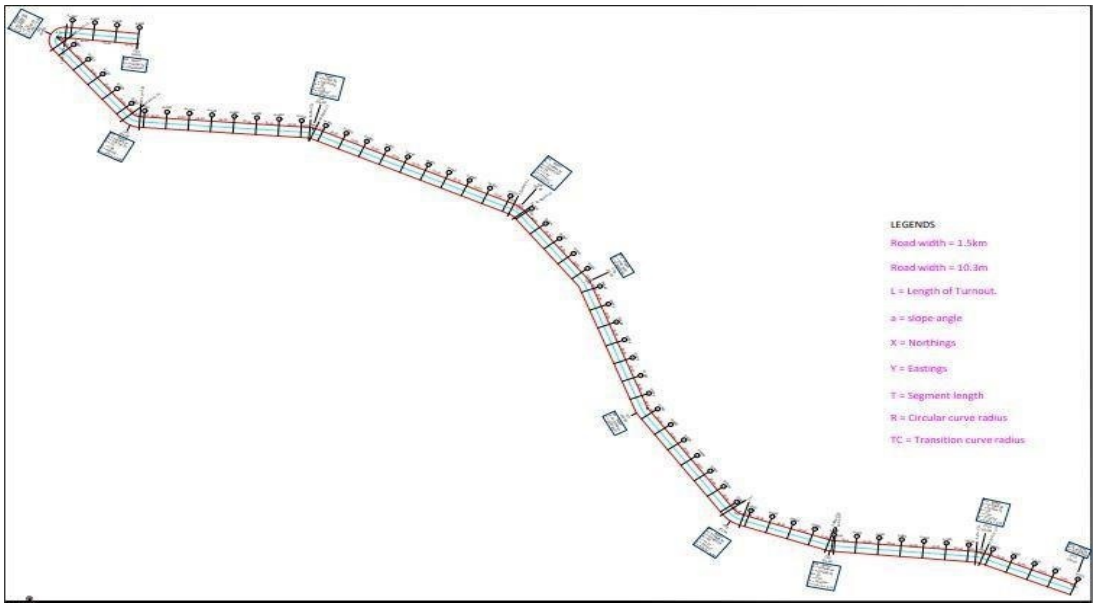


Fig. 1.0 Horizontal Alignment (Plan) as seen on Civil CAD Design.

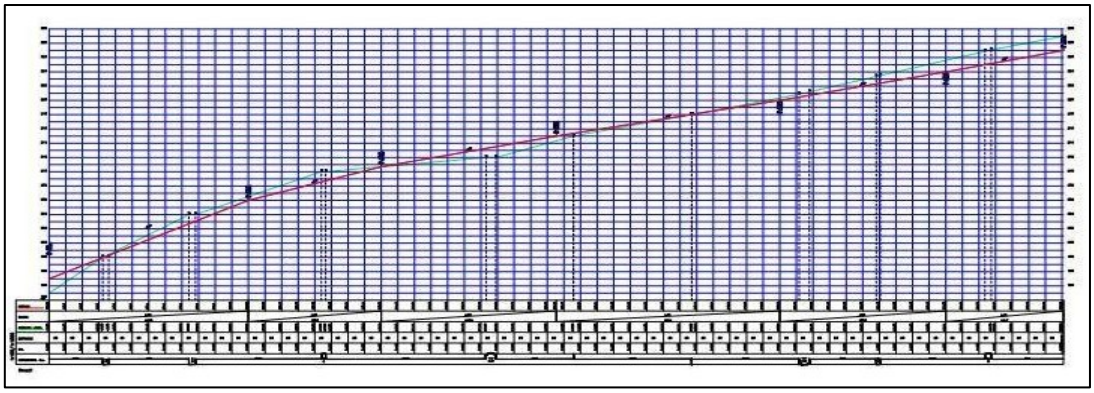


Fig. 2.0 Vertical Alignment (Profile) as seen on Civil CAD Design.

Conclusion

Road infrastructures are the most used facilities everywhere in the world, and it is imperative that a considerable amount of efforts and consideration is put into the design, planning and as also the construction phase. A lot of road casualties are caused due to poor planning and lack of good geometric design of highways. The basic design controls such as: design speed, sight distances, terrain types, transition curves and Superelevations, should always be the first point of guidance and consideration for the highway design engineer. It is also important to note that, some design controls are inherent characteristics of the facility while other basic design controls are selected or determined by the designer, working with communities and users to address a project's purpose and need. Selecting appropriate values or characteristics for these basic design controls is essential to achieve, safe, cost effective, sustainable and user sensitive design.

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