Calculation of Quantity of Earthwork and Generating Sectional Drawings with – Robust Software CSx

***Asif Ahmad Ansari*[1], *Dr. Shubha Agrawal*[2*]**
[1]Research Scholar, [2]Professor and Head
Department of Civil Engineering, LNCT, Bhopal, India.
****Corresponding Author***
E-mail ID:-*asifansari19@gmail.com[1], shubha188@gmail.com[2]*

ABSTRACT
In a new highway project, the engineer has to plan, design and construct either a net – work of a new road or a road link. There are also projects requiring re-design and re-alignment of existing roads for upgrading the geometric design standards. In most of frequently used methods for earthwork quantity calculation, the valuation of accuracy may contain some uncertainties. This article discusses the relationship between the manual process and digital process data for earthwork calculation and how to easily create a better profile for any road construction for smoothness in driving with safety parameters. The main purpose of this research is to propagate error. In this a formula is formed which expresses the earthwork quantity relationship that how the errors of manual data effects the accuracy of earthwork calculation using the digital approach. By setting the different values of the parameters, we can calculate the relative errors. At last, we have also discussed the calculation of earthwork quantity using the software sources as well as focused on profile of road, cross section, slope and gradient also etc. The work of profile correction and earthwork is the main step in any highway Engineering. So, it is very necessary for any contractor to carry this work with full precautions and complete the work without any errors in the calculation. The highway and road works or the drainage constructions are very important constructions as it shows the economy of a country. It beautifies the surrounding of a place. If the design of road and profile is not done properly then it may lead to many accidents and other major losses can occur. So, it is important for all the road profile designers to design a proper profile by which the vision, sight distance and curve gets clear technically. And with this we have to make sure that the quantity of earthwork according to road condition should be economically suitable. But seeing today's scenario which is coming up in Advance Technology Construction field, such as heavy machinery equipment which can complete any work in a short time and in a situation, where work need to be completed in short time, it would be very difficult to calculate the quantity in the old way and if the old way is adopted then it will take a lot of time to complete the work so that to get rid of problem and to bring progress and accuracy to work, we get a lot of help from this software.

Keywords:-*Slope Gradient, Cut and Fill, Buffer, Delimited Text Layer, Elevation Terrain*

INTRODUCTION

"Csx" is a comprehensive section creation and management solution that is designed to help the engineers, surveyors and designers to create the industry standard drawings and to generate quick calculation reports related to road construction, Railway line, Irrigation, Pipeline Design, Water Network Project also. It is a type of complete software solution for generating L - sections and Cross section, converting surveying data into the drawings. For creating the drawing, we have to import the survey data from the Excel sheet such as L section and cross section. The parameters of design are also included in software such as camber, side slope, thickness parameter, berm slope, widening layer etc.

Road work or drainage work need lots of construction. The major parts in earthwork is cut and fill which should be done properly so that further construction part can be carried out easily. In CSx the cut and fill of any path can be calculated easily.

Once the road alignment is created on the elevation map then that path can be processed to calculate the total cut and fill. There is certain mathematical formula through which cut and fill of the path is calculated at any point. This process done with the help of software helps in further process.

The main advantages of these Software calculations are:

1. Less or no manual work will be required.
2. Quick calculations and results.
3. Complete earthwork is calculated easily without any cumbersome calculations and errors.
4. Estimates of earthwork can be prepared.
5. Total cost of project can be estimated once the earthwork is calculated.
6. More than one path can be tested through the software.
7. Suitability of the path can be tested easily with the terrain graph.
8. It becomes feasible to decide a fix datum with the generated readings of the terrain graph.
9. The suitability of the complete project can be checked through software.
10. We can easily draw Longitudinal profile of road according to RL's and as well as create Cross Section of road as per field requirement.
11. Help for improving better riding quality on road CSx give us option for gradient and slope maintain function.

LITERATURE REVIEW

Hintz & Vonderohe (2011)

Reliable and precise calculation of earthwork quantity is one of the most significant elements in pavement engineering that can affect the selection of road alignment, price and design. As the Digital Terrain Model (DTM) appearance and widespread implementation, highway design has entered the 3D era and 3D technique for earthwork quantity calculation is also being created. But in highway design, the idea of adopting average-end-area technique (hereafter also as a 2D technique) is deeply rooted. According to a U.S. inquiry, 87 percent and 91 percent developers use average-end-area respectively for design estimates and final volumes, and 97 percent of participants acknowledge average-end-area in their policies, norms and procedural papers.[1]

Ragab Khalil (2015)

Typical applications in civil engineering are volume estimation and earthworks calculation of borrowing pits in road construction. Although several techniques have been implemented for quantity estimation, the average end area technique remains the prevalent technique used by engineer and contractors Average end area technique is time consuming and tedious. The volume of terrains that do not have a periodic geometric structure can be more correctly achieved by using 3D surface models with regard to technology development such as GIS. The grid method & point distribution method are important factors in modelling of earth surfaces used for quantity calculation. This study shows the reliability of 3D volume calculation based on GRID system or Triangular Irregular Network (TIN) using the GIS. The effects of interpolation method and point distribution in defining a terrain surface were also investigated. For this purpose, an artificial surface with a known volume that used by Chen and Lin in their paper is employed. For both surfaces represented by TIN and GRIDs, the 3D surface and volume are calculated using 6 distinct method. And the resulting volumes were compared with the exact volume calculation estimated by using average end area method. Furthermore, a comparison between cut volume and fill volumes required for grading the study cases at a positive elevation was done. Finally, the results show that for slope surface, Triangular Irregular Network and all interpolation techniques provided results very close to the exact calculation. For steep slope terrain, Kriging interpolation gave the best results. Comparing earthwork volume to the average end area method, TIN surface, IDW, Topo to raster and Nearest Neighbour methods gave the best results [2].

Selcuk Gumus

In Turkey, forestry studies are carried out in separate parts of the nation on a region of 20 million ha. Working in such a widespread and mostly mountainous region is only feasible if these regions have a well-built forest road network. And the forest area road construction works grounded on General Forest Road Network Strategies began in Turkey country in 1964 & ended in 1974. At present, only 60% of the forest area roads we need have been completed.

The aim of this research is to calculate the cut and fill quantity with analyses of digital terrain models obtained from geographic information systems to decrease expenses. Four forest road projects were selected as study locations within the boundaries of Antalya Forest Regional Directorate, Sütleğen and Lengüme Forest Enterprise. The results for each portion of the highway were achieved by calculating the cut and fill difference between the cut volume and fill volume quantities and determining the surface area. The grades of the slopes in the land where the streets were built were achieved using a digital terrain model. Calculating cut and fill volumes, and using these calculations in the phase of determining various choices within the planning process, considerably reduces the expenses and the time spent on the plans and projects of forest roads. These calculations should be taken into consideration before the roads are constructed [3].

The earthwork volume calculation is the most important points in vertical and horizontal alignment optimization, so the most studies firstly focused on the cut and fill volume balancing to minimize the expenses. Stark and Nicholls (1972) began using linear earthwork optimization programming, and Mayer and Stark (1981) and Nandgaonkar (1981) created this technique Easa (1988) [4] incorporated road grade selection and earthwork minimization into one issue by listing all technically viable grades and solving the issue of linear programming. But the technique of Easa could not ensure worldwide optimality, so Moreb (1996) [5] suggested a model which not only succeeded in decreasing the time issue but also in achieving worldwide optimality based on the principle of Easa. Goktepe and Lav (2003) [6] then developed a method called weighted ground elevation that considered the material properties in grade line selection to balance the cut and fill volume. All this research was conducted by average-end-method.

When some scientists realized the inaccuracy and constraints of the 2D technique in quantity calculation (Easa, 1989 [7] and 1992 [8]), they began to create some changes in the average end technique. The most familiar enhancement for us is the prismoid formula that can improve the precision. Anderson, Hikhail and Woolnough [9] (1985) submitted a Pappus-based model for the horizontal curved region volume calculation. Easa (1992) [10] created a mathematical model that calculates earthwork quantities on the basis of triple horizontal curve integration, but it was relevant when the longitudinal ground profile varied linearly between the stations and the floor cross-slope between the stations. Thus Easa (2003) [11] estimated earthwork volumes calculation of curved roadways in Monte Carlo simulation technique but this model has not yet been expanded to mixed road alignments (where horizontal and vertical curves overlap). Kim and Schonfeld (2001) [12] introduced two methods using vector and parametric representation for precisely estimating cross sectional areas of excavation or fill to minimize errors in the total earthwork cost calculation.

In 2004 Yachiyo Engineering Company, Ltd. of Japan began adopting 3D design for a wider range of projects using Autodesk's Civil 3D. Yachiyo claims using 3D design allows for faster completion and more efficient designs, taking on tasks in house that would otherwise need to completed by outsources, and improve precision of route selection.

The first 3D-designed project developed by Yachiyo was for a hilly region highway engineering, including three kilometres along a ridge. Yachiyo confronted a significant challenge with rigid public regulations and the cost constraints. Yachiyo started using the 3D design by inputting longitudinal 3D data and used the cleanup function of Civil 3D to generate a polyline from existing drawings automatically and to add elevation data. Designers continued by created horizontal alignment using a topographic model. It took only 20 hours to produce final output of longitudinal and cross section diagrams for the new route.
Thus, 3D design greatly expedited the design process for Yachiyo Engineering Company, Ltd. The head manager of Techology Division 1 at Yachiyo also stated, "Civil 3D is great for other tasks, such as calculating soil volume" [13].

MATHEMATICAL STANDPOINT FOR CALCULATING VOLUME/QUANTITY (CUT & FILL)

Depth Area Method (DAM)

This is the simplest method for calculating the earthwork volume. In this method, the thickness of strata to be excavated is multiplied by the surface area of the strata. This can be done with any reasonable accuracy but the stratum has to be consistently thick and area extent must be known. It is suitable for estimating the amount of top soil to be stripped at a consistent depth (usually 15 cm).
Formula: V=T*A*(1/27)
Where,
V= volume (cubic yards)
A= surface slope area (square feet)
T= thickness of strata or even cut (feet)

Grid Method (GM)

This method is also known as Borrow Pit Method. This method is the extended form of the Depth Area Method (DAM) i.e. it extends DAM to an extent of varying depths. Borrow pit levelling calculate the volume by using a grid to the excavation area. These grids are arranged in the form of squares. For every grid square, final elevation established for every corner of the grid square. These are subtracted from the existing elevations at the same Point to evaluate the depth of cut or fill of every corner.
Formula: V= ((D1+D2+D3+D4)/4)*A*(1/27)
Where,
V= volume (cubic yards)
A= area of grid square (square feet)
D= depth of cut or fill at each corner (feet)

End Area Method (EAM)

It utilizes the area of parallel cross sections at regular intervals through the proposed

earthwork volume. They are aligned perpendicular to a baseline that extends the entire length of the excavation area. These cross sections can be generated by CADD or drawn by hand.
Formula: V= L*((A1 + A2)/2)*(1/27)
Where,
V = volume (cubic yards)
A = area of adjacent cross section (square feet)
L = distance between cross section along the baseline (feet)

Prismoidal Formula (PF)
This formula is more accurate than the Method of End Area (EAM). If ground surface between cross sections is not uniform or irregular then this formula is used. This technique brings between two cross-sections a midway region and this region is not the average between two end fields.
Formula: V = L*((A1 + (4*Am) + A2)/6) * (1/27)
Where,
V = volume (cubic yards)
A1, A2 = area of adjacent cross sections (square feet)
Am = area of midway cross section (square feet)
L = distance between cross section along the baseline (feet).

SOFTWARE STANDPOINT FOR CALCULATING VOLUME/QUANTITY (CUT & FILL)

Objective
The objective is creating the better profile for road construction for overcome the inoperable gradient of road and as well as minimized the earth work calculation so to exactly estimate the amount of cut and fill in the construction area.

Study Area
The study area is 'MHOW NEEMUCH HIGHWAY TO RAJASTHAN BORDER' located at 23°44'01"N 75°03'56"E project under the MPRRDA, Project Implementation Unit, Ratlam.

METHODOLOGY

STEP 1 (Data Source):-The source of data is observed cross-sectional points by Auto level at every 10m apart.
STEP 2 (Data Formatting):- For data formatting we are calculate all of the RL's related to the road survey arrange as per change wise either manually or with the help of software.
In software RL CALCULATION is command This command is available for vertical data format only as shown above. Now we want to calculate RL values in column 'G' & H.I. in column 'F'. start AutoCAD. Type 'rlcalcu' and press enter or select 'RL Calculations' command from 'CSx' menu

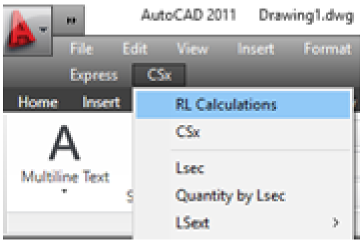

Fig.1: *RL Calculation*

STEP 3 (Draw L-Section):- The Longitudinal design of roads is concerned with the positioning of the physical elements of the roadway according to standards and constraints. The basic objectives in longitudinal design are to optimize efficiency and safety while minimizing cost and environmental damage.
For creating L Section firstly check all of the RL's carefully according to the height and depth of the place where road is constructed and after that go to AutoCAD open new blank file. Give 'Lsec' command or select 'Lsec' from 'CSx' menu again. A box will display:

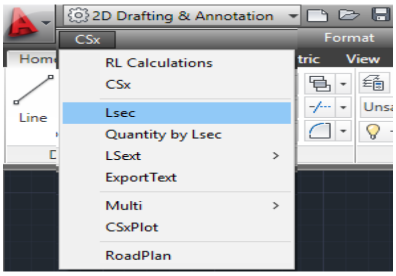

Fig.2: *L-Section Command*

After this step a box will open where insert all the parameter related to the L-Section like, RL values, range etc. After giving all parameters, select 'OK' button. After few seconds following prompts will display in command prompt area:Give Range for L section

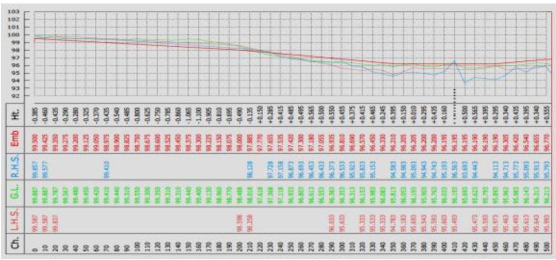

Fig.3: *L-Section*

STEP 4 (Quantity Calculation):- For quantity calculation we are using the Csx command for calculating the quantity of cut and fill of uneven surface and as well as create Cross Section drawing also.

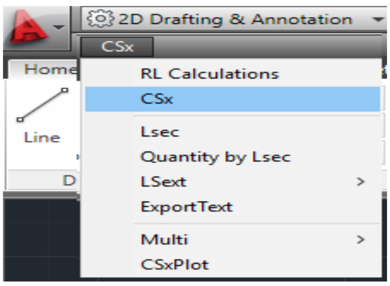

Fig.4: *Csx Command*

After that a box will open fill up all the parameter related to the csx command now 'GL', 'Other', 'Colour' and 'Heading' sheets are ready. Save the XLS data file. Open a new blank file in AutoCAD. Give 'CSx' command to generate all cross sections and quantity statement file. Type 'CSx' in command prompt and press enter or select 'CSx' from 'CSx' menu. This will display:

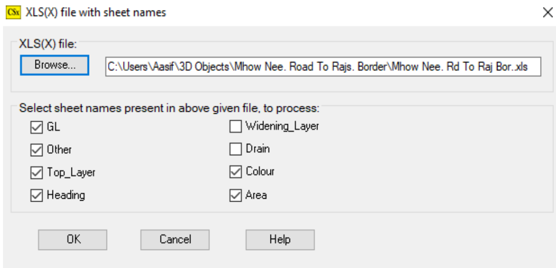

Fig.5: *Csx Menu*

Click 'Browse' button to select your XLS data file if required. On 'Other', 'Heading' and 'Colour' switches. 'GL' switch is always 'ON'. Select 'OK' button. Give a range for example if you want quantity from ch. 0 to ch. 1000, type '0-1000' and press enter. Here we want quantity from start to end, hence press enter for <All>. This will display:

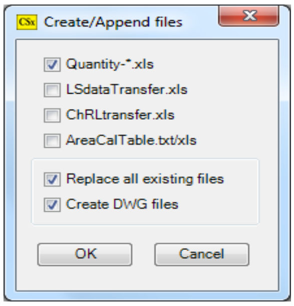

Fig.6: *Quantity Calculation Command*

Parameters

1. Quantity-*.xls :- Gives a quantity statement file.
2. LSdataTransfer.xls :- Gives a file contains centre RL of all layers. 'ChRLtransfer.xls' gives a file contains all RLs of all layers.
3. AreaCalTable.txt/xls :- Gives 'AreaCAlTable.xls' file for banking and cutting area calculations.
4. AreaCAlTable.txt :- file for all layer's area calculations.
5. Replace all existing files:- To replace all old 'DWG' and above mansion files, if you repeat the same project.
6. Create DWG files :- to make cross

section DWG (drawing) files. If you off this, DWG files will not create and only quantity will display quickly, because time to be required to make DWG files will save.
Click ‘OK’ button.
After creating all cross sections one by one in few seconds, this will display:

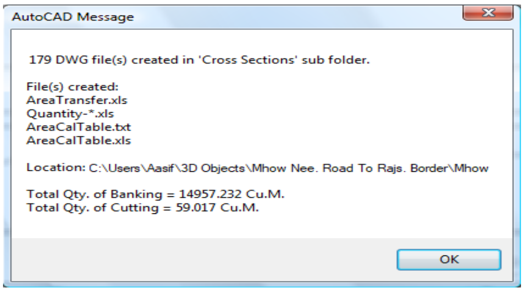

Fig.7: *Quantity Calculation Result*

Cross Section

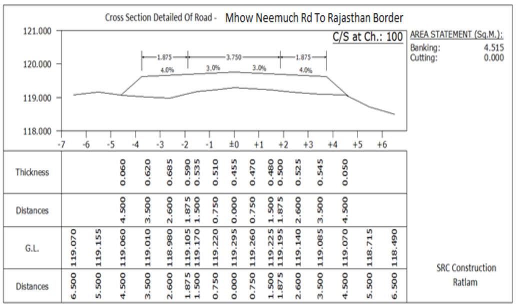

Fig.8: *Cross Section*

RESULT

From the above procedures followed in software approach and formulas used in mathematical approach, it is crystal clear that calculating the volume of cut and fill in earthworks is a time taking and long procedural task. From the software approach it is inferred that by sitting at one place one can plan the construction of any canal, road works or river interlinking. The software approach makes it easy for the engineer to estimate the amount of work that has to be carried in constructing any canal, road or river interlinking path. The software approach leads to easy problem-solving methods. Selection of proper datum for the process of cut and fill is very important step in software approach. Here we have decided some datum and got the values of cut and fill at different points on the selected path. These values can be used for further process of estimation.

The graph generated after the creation of path on the elevation map of the study area helps in deciding the datum. Datum value can vary from person to person. But datum selection should be such that minimum cut and fill is required. In this way the project becomes economical.

DISCUSSION

From the above discussed software approach, it becomes easy for any user to calculate the cut and fill of any respective path. But this calculation through software is never 100% accurate. As mentioned earlier that any estimator has to visit the site for proper estimation of earthwork volume. Due to continuous change in physical strata no software can achieve 100% accuracy in calculating the volume of cut and fill. Software approach although saves time and the mathematical calculations are accurate but the process of visiting the site is not eliminated completely. This CSx software has accurate calculations but the on-site calculations are very necessary so that any earthwork that has to be constructed is safe and sound. Once the calculated values match the on-site calculations, the work can be proceeded. Hence for the construction of any earthwork, estimator or contractor must cross-check the values obtained through manual calculation and software calculations.

CONFLICT OF INTEREST STATEMENT

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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