The Study On Efficiency Analysis of Calculating Earthwork Volume

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Abstract: *Recently, methods to accurately select an inflection point for the curve of topography that fits well with the actual topography are developed, which reduces errors. However, the existing inconvenient and inaccurate methods are still used for the estimation of the amount of earthworks in the construction field the software based process is applied to improve the existing inconvenient and inaccurate methods in the construction fields. However, most studies were conducted focusing on architectural constructions and even in earthworks, only research on overall project management or the estimation of quantities has been conducted.*

It is necessary for all the earthwork contractors to calculate the proper and accurate estimate of earthwork. If the estimate of earthwork done by contractor is not accurate then he will be unable to assign the proper construction assets he cannot formulate a project schedule as well. There are many unknowns and assumptions required in estimating the earthwork construction. And this is the reason that while doing this task the contractor is at greatest risk.

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.

Key words: *Slope Gradient, Cut and Fill, Buffer, Elevation Terrain, Surveying, Earthwork, Volume Calculation, Software.*

I. INTRODUCTION

Accurate calculation of cut and fill volume has an essential importance in many fields. This article shows a new method, which has no approximation, based on DTM & software. A relatively new mathematical model is developed for that purpose, which is implemented in the software solution. Both of them has been tested and verified in the praxis on several large opencast mines. This application is developed in Python programming language and works in AutoCAD environment.

"Csx" is a complete Section Creation and Management Solution designed to help engineers, surveyors and designers to create industry standard drawings and to generate instant calculation reports related to Road / Railway lines / Irrigation / Pipeline design / Water Network Project. It is a complete software solution for generating sections, converting point data into drawings and interpolating available data to generate drawings. Importing Data: Import data from Excel for Generating Cross Section and Longitudinal Section Drawings Import Alignment data from CAD Import data from Field Book Extensive Section Settings: Change properties like Colour / Height / etc.

Reliable and accurate earthwork volume calculation is one of the most important components in roadway engineering that can influence the choosing of roadway alignment, the cost and construction. As the appearance and widely application of CSx, roadway design has stepped into 3D era and accordingly 3D method for earthwork volume calculation is also developed. But the concept of adopting average-end-area method (hereinafter also as 2D method) is deep-rooted in roadway design. According to an investigation in US, 87% and 91% designers use average-end-area for design estimates and final quantities respectively, and 97% of the respondents recognize average-end-area in their policies, standards, and procedural documents.

All these data show 2D method still enjoys popular support (Hintz & Vonderohe [1], 2011). Obviously the result of average-end-area method is just an approximate value, and theoretically speaking, result

by calculating the volume between existing ground and design surface is the precise value of earthwork-which is also usually called surface-to-surface method that based on DTM technology. From this point of view, DTM has its technical advantage in earthwork volume calculation.

Civil CSx software package, developed by KCS India in this context, is a solution for civil engineering that can be used in Highway, Canal, Land project etc., supporting CAD for carried out volume calculation . This study chooses , CAD and Excel for carried out quantity calculation package as the tool to compute earthwork volume in 3D method.

This paper verifies the feasibility of calculating the earthwork volume in DTM method by Csx software. based on DTM and compares the accuracy difference between 2D and 3D methods for the reference of practical engineering. Moreover, the study also gives an explanation why inaccurate 2D method actually prevails in engineering and a critical interval distance to guarantee accuracy in practical use.

II. LITERATURE REVIEW

The earthwork volume is one of the most important objectives in horizontal and vertical alignment optimization, so most researches firstly focused on the cut-fill balancing to minimize the cost. Stark and Nicholls (1972) started to employ linear programming into earthwork optimization and this method was developed by Mayer and Stark (1981) and Nandgaonkar (1981). Easa (1988) [2] integrated the selection of roadway grades and the minimizing of earthwork into one problem by enumerating all technically feasible grades and solving the linear programming problem. But Easa s method couldn t guarantee the global optimality, so Moreb (1996) [3] proposed a model that succeeded not only in reducing the time problem but also arriving at global optimality based on Easa s theory. Goktepe and Lav (2003) [4] 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 researches were conducted by average-end-method.

When some researchers realized the imprecision and limitations of 2D method in volume calculation (Easa,1989 [7] & 1992 [8]), they started to develop some improvements in average-end-method. The prismoidal formula which can enhance the accuracy is the most familiar improvement to us. Anderson, Hikhail and Woolnough [9] (1985) presented a Pappus-based model to compute the volume in horizontal curved area. Easa (1992) [10] developed a mathematical model that calculates earthwork volumes based on triple integration in horizontal curve, but it was applicable when the longitudinal ground profile linearly varied between the stations and the ground cross slope between the stations was linear and constant. So Easa (2003) [11] estimated earthwork volumes of curved roadways in Monte Carlo simulation method but this model still was not extended to the case of combined roadway 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.

Aruga, Sessions and Akay (2005) [11] developed a forest road design program based on a high-resolution Digital Elevation Model (DEM) from a light detection and ranging (LIDAR) system. After a designer had located the intersection points on a horizontal plane, the model firstly generated the horizontal alignment and the ground pr0file , and then it could precisely generate cross-sections and accurately calculate earthwork volumes using a high-resolution DEM. A shortage of this model was that it couldn t properly optimize horizontal and vertical alignments simultaneously.

Li and Han [12] (2007) used DTM to calculate cross section area, but still completed volume computation by 2D rule. These programs had begun to bring DTM into roadway design and volume calculation, but actually it was not the completely 3D concept because they still use average-end-area or prismoidal method to compute earthwork volume finally.

Du and Teng (2007) [13] used 3D laser scanning and GPS technology to compute volume of landslide earthwork. They employed these two advanced technology to create the contour after landslide. The original contour of this area could be obtained from the government of the Forestry Bureau. The volume of collapse was estimated by the difference between before and after landslide of terrain contours by the contour method with the Simpson's rule. We consider this research as the transition form from 2D method to 3D method because it has the 3D concept but still solve the problem with 2D formula and procedure.

Bao (2011) [14] applied DTM on the earthwork calculation of land consolidation where the MapGIS DTM analysis function was utilized to transform the elevation points into Triangulated Irregular Network (TIN) and fixed the layout elevation by iterative calculation aimed at the balance between cut and fill. This application of 3D method could also be used in roadway design and volume calculation.

The latest report of roadway earthwork volume calculation by 3D method was conducted by Kerry, Dianne and James [15] (2012). The researchers employed three dimensional laser scanning to create a surface of the original terrain based on the finite element method. Then this surface was converted to TIN file and earthwork quantities were computed by comparing the TIN of original terrain to that of the finished project. This methodology had already shown the 3D concept and used 3D procedure, but it was only applicable for the computation of the final quantities of roadway. As to the design estimation, another methodology should be developed. Still, the new 3D method was constrained by the problems such as data size, scanning accuracy and data processing.

III. MANUALY/ 2D METHOD FOR CALCULATING VOLUME/QUANTITY (CUT & FILL)

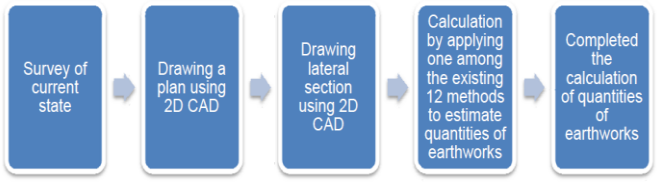

Fig. 1 Existing Estimation Process Of Quantity Calculation

The estimation method of quantities of earthworks is that

2D plan and lateral section are drawn by using CAD program with data of survey points after survey of current state. And muss diagram curve and earth volume statement are completed by using a plan and a lateral section and the quantities of earthworks are calculated.

However, the existing estimation methods of the quantities of earthworks have many problems such as densely grown trees when surveying the current state, errors in performance of survey instrument used, and mistakes in skill of a surveyor, which caused difficulties in estimation of quantities of earthworks during design and construction of roads, railroads, tunnels, bridges and housing site and lots of time and cost is required.

Manually Calculation Process Are:

A. 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)

B. Grid Method (GM)

This method is also known as Borrow Pit Method. This is the extended form of Depth Area Method (DAM) i.e. it extends DAM to an excavation of varying depths. Borrow pit levelling calculates the excavation volume by applying a grid to the excavation area. These grids are staked to squares. For each grid square, final elevations are established for each corner of every grid square. These are subtracted from the existing elevations at the same location to determine the depth of cut or height of fill at each 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)

C. 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)

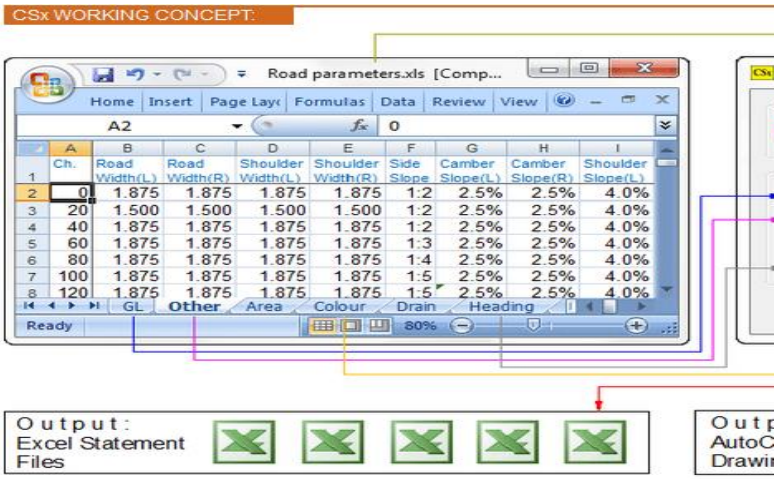

Fig. 3 CSX Concept

D. Prismoidal Formula (PF)

This formula has more accuracy than End Area Method (EAM). When ground is not uniform or irregular between cross sections then this formula is used. This method adds a midway area between two cross sections and this area is not the average between two end areas.
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).

IV. USING SOFTWARE (3D) FOR CALCULATING VOLUME/QUANTITY (CUT & FILL)

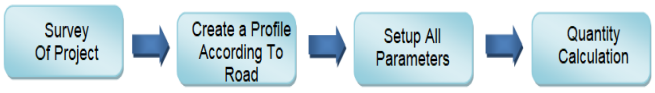

Fig. 2 Using Software Estimation Process Of Quantity Calculation

"Csx" is a complete Section Creation and Management Solution designed to help engineers, surveyors and designers to create industry standard drawings and to generate instant calculation reports related to Road / Railway lines / Irrigation / Pipeline design / Water Network Project. It is a complete software solution for generating sections, converting point data into drawings and interpolating available data to generate drawings. Importing Data: Import data from Excel for Generating Cross Section and Longitudinal Section Drawings Import Alignment data from CAD Import data from Field Book Extensive Section Settings: Change properties like Colour / Height / etc. for all the elements of a section Print Graph and Projection Lines Print Header / Footer with Scales View Sections in different Horizontal / Vertical Scale Font properties for section elements Profiles.

Author	Year Issued	Title	Contents
Selcuk Gumus	1964	Plan to improve efficiency of estimation of construction quantities.	In this study, the purpose is to calculate the volume of cut and fill with digital terrain models analyses derived from geographical information systems in order to reduce costs.
Kim and Schonfeld	2001	How to minimize the error of earthwork calculation.	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.
Goktepe and Lav	2003	Using Mathematical Formula calculate earthwork quantity.	Developed a method called weighted ground elevation that considered the material properties in grade line selection to balance the cut and fill volume
Gang in-Seok	2009	BIM utilization and application plans in the field of earth work	It looked into the overview of BIM and the status of BIM utilization in the field of earthwork, and suggested an improvement plans for vitalization of BIM in the field of earthwork in the future.

The determination of earthwork quantities is based upon field cross-sections taken in a specified manner before and after excavation. Cross-sections are vertical profiles taken at right angles to the survey centreline. Every section is an area formed by the sub grade, the side slopes, and the original ground surface.

Table 1 Review Of Previous Studies

V. 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.

VI. 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.

VII. CONCLUSION

The estimation of earthwork volume is one of important factors for reduction of time and cost when constructing

large-scaled complex and development of housing site. Actually, the balancing of cutting the ground and embankment acquires a greater importance due to the difficulty of securing disposal area at a construction field.

The existing method to estimate earthwork volume is slow off the mark according to changes, and it is difficult to estimate earthwork volume at a place with uneven topography.

Therefore, it is more convenient to estimate earthwork volume using BIM process, and it is not only possible to promptly cope with changes such as changes of design but also it is possible to deal with any kind of change, which causes rework not to be necessary so it has the advantage of reduction of time and cost.

It is necessary to study on the guideline to suggest the accurate criteria that a hands-on worker can refer at the phase of early introduction.

VII. FUTURE ASPECTS

1) Manual work is reduced.
2) Time is saved.
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. Suitability of the path can be tested easily with the terrain graph.
7) It becomes feasible to decide a fix datum with the generated readings of the terrain graph.
8) The suitability of the complete project can be checked through software.

VIII. CONFLICT OF INTEREST STATEMENT

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

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