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Earthwork Volume Calculation Using Cods Software

By

Noraishah Mustapa
Department of Civil Engineering, Politeknik Sultan Haji Ahmad Shah
25350 Kuantan, Pahang, Malaysia

Sam Toong Hai
Faculty of Business and Communication, INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
Corresponding author email: toonghai.sam@newinti.edu.my

Nor Azme Nordin
Department of Civil Engineering, Politeknik Sultan Haji Ahmad Shah
25350 Kuantan, Pahang, Malaysia

Asiah Abdul Satar
Department of Civil Engineering, Politeknik Sultan Haji Ahmad Shah
25350 Kuantan, Pahang, Malaysia

Sulzakimin Mohamed
Department of Construction Management, Faculty of Technology Management & Business, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia

Asokan Vasudevan
Faculty of Business and Communication, INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia

Xue Ruiteng
Rising Capital Sdn. Bhd., 27-1, Jalan Eco Santuari 8/1C, Persiaran Eco Santuari, 42500, Telok Panglima Garang, Selangor, Malaysia

Abstract

Volume calculation to determine accurate earthwork quantity in engineering construction work is important to estimate and evaluate project cost. Land surveyors always have precaution when they calculate the earthwork volume to ensure all information in the form of number or graphics given to their clients is accurate. Various methods and software were introduced to calculate the cut and fill values from the earthworks. Typically, survey work related to earthworks will use CDS software to calculate and determine the volume. In general, the contractors have agreed that earthwork volume calculation using CDS software is the most reliable However, dispute in volume calculation among land surveyors, engineers, and quantity surveyors remain. Hence this study are to study the method using CX and STS and to compare the effect of 5m, 10m and 20m chainage interval measurement. The methodology involved the comparison of earthwork volume calculations performed by cross -sectional and surface to surface method in which three sites of different acreage were used. The results showed that there were large differences occurring at small sites compared to large study sites between the use of cross-section and surface to surface methods using different chainage intervals. Found at 5 meter intervals a relatively large difference value will occur compared to the volume count at 20 meter intervals. The difference is more significant in the value of the 'cut' volume compared to the value of the 'fill' volume. The average percentage difference was 2.167 % for the fill value and 7.397 % for the cut value for the smallest study site area of 2.5 acres, while in a large test site area on 12.5 acres, the average difference calculated was 0.109 % for the value fill and 0.024 % for the cut value. Hence, the cross -sectional calculation method is still a reliable and best method but it is necessary to cross check the volume calculation using the surface to surface method. This findings may useful to avoid conflict among contractors and surveyors in settling the payment as well as in determining the accurate calculation of the survey work.

Keywords : Volume Calculations, CDS, Cross-section Method and Surface to Surface Method

Introduction

The relationship between housing developers, contractors and land surveyors in earthworks is mutually dependent. The contractor will make a claim for the earthworks that have been done through the data of the volume of earthworks that have been provided by the surveyor (Habibi, Kermanshachi, & Rouhanizadeh, 2019; Liguo & Caixia, 2020). Sometimes there is an issue of integrity or confidence between the developer and the contractor when the volume of earthworks did not meet their initial forecasts. This is where land surveyors play their roles to prove their work is accurate and consistent. The profits and losses of contractors often depend on the earthworks they have done. As much as possible the contractors want more profit from their earthworks process (Ezeomedo, 2019; van der Molen, 2015). Court cases involving lawsuits from developers against contractors have also occurred as a result of irregularities in land acquisition claims. So it is very important that a guideline is prepared by the land surveyors themselves to calculate the land volume work results accurately and consistently so that they are safe from the crisis between the contractor and the housing developer.

Now various software are available in the market to perform such calculations. Civil Design and Survey (CDS) is one of the most popular software and is often used in the work of calculating the volume of land, however, there are still questions raised by contractors, soil engineers, surveyors and architects. Ideally, in each field has its own software to calculate soil volume but their calculations are more focused on preliminary estimates (Goktepe, Lav, & Altun, 2009; Zhu, 2016). There are also comparisons between CDS and other software such as Carlson Survey which they have their own advantages (EL Megrahi, 2017). Yet in this study we focus on the advantages of the CDS software itself.

CDS software is one of the software that oftenly being used by land surveyors to process their survey work data. It can also be said that CDS software became the intermediary software before these data were completed in AutoCAD software. Topographic data i.e. external work details from Total Station and GPS are first processed in this CDS software. The CDS software also serves as a database to generate pre-calculation plans. Many analyzes on the data can be done using CDS software and among them can make volume calculations through 3 ways, namely ‘to a plane’, ‘surface to surface’ and cross section. Developers, contractors and Government Departments such as the Irrigation and Drainage Department, Public Works Department and Water Supply Department often want the volume data to be presented graphically so that they can see the earthwork profile in the cross-sectional plan. Chainage intervals for earthwork volume calculations have often been given by them through verbal instructions or in ‘terms of reference’ (TOR) which are necessary in accordance with the outlined specifications. The chainage interval standard used in earthwork volume calculation works is at 20m intervals and depends on the scope of work (JKR Malaysia, 1987). Sometimes 1m to 5m intervals are required to calculate the earthwork quantity in detail.

Literature Review

Construction works involving reclamation and land disposal require topographic survey work data in advance so that the volume value of the earthworks can be identified (Buffi, Manciola, Grassi, Barberini, & Gambi, 2018; Park & Jung, 2021). The calculation of land volume is also very important in the issuance of tenders to contractors because it provides preliminary information on the cost of the project (Bandi, Abdullah, & Amiruddin, 2018). Apart from the use of total station or GPS instruments to perform topographic works for the purpose of calculating earthwork data, the use of UAVs and Lidars can also be used (Park & Jung, 2021). The use of programs generated from AutoLips in CAD software has also been made on the Digital Terrain Method model to obtain the value of earthwork volume (Babapour, Naghdi, Ghajar, & Ghodsi, 2018; Mijic, 2015). Apart from Autolips, Matlab programs can also be used by using certain algorithms to obtain estimates of earthworks (Attaway, 2017; Babapour et al., 2018).

Problem Statement

The calculation of the volume of earthworks performed by contractors is very important as evidence for their work progress claims. Yet the various reasons and issues that were tried to be raised when the volume count data were presented and did not meet their initial predictions. What’s important is profit rather than the work progress demands (Babapour et al., 2018; Shen & Stopher, 2014; van der Molen, 2015). If land surveyors are not able to prove the work of volume calculations is accurate and consistent, then problems will emerge in terms of trust and credibility from all parties. However, all the calculated results must be verified by a Licensed Land Surveyor. A huge responsibility must be bear by Licensed Land Surveyors to ensure that all survey data is correct so that no issues arise in the future (Ezeomedo, 2019; Yen, 2013). A calculation method that is consistent and reviewed with other methods is always practiced to ensure that the earthwork volume calculation data is valid and reliable.

Objectives

The objectives of this study are:

1. To study CX and STS method.
2. To compare the effect of 5m, 10m and 20m chainage interval measurement data between CX and STS method.

Methodology

Extensive literatures were conducted in relation to earthwork volume calculation between cross-section and surface to surface method using CDS software. Additionally, the methodology involved as in Figure 1.

Figure 1: *Methodology*

The data collection is with the cooperation with land surveyors to obtain topographic work data for the purpose of earthwork calculation is very important. Five to six study sites are required that vary in term of area and shape of the terrain. There are works that involve cut and fill and sometimes only involve fill for example for the calculation of sand pile stock. The measurement and survey work are done correctly because any error in the survey data will cause incorrect calculation of the earthwork volume quantity (Babapour et al., 2018; Mijic, 2015). To avoid these data being measured incorrectly, a second random check should be performed in the field (Fig. 2). Chainage intervals should also be marked in the field to allow the surveyor to make measurements based on the specified chain lines (Fig. 3). Next, draft the chainage line on the pre-calculation plan to facilitate the survey work in the field (Fig. 4).

Fig. 2: *Checking*

Fig. 3: *Chainage peg*

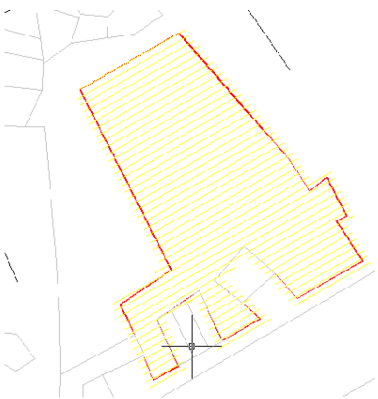

Fig. 4: *Skecth Line Chainage*

The data analyzed your data After field work measurement is completed, survey data will be downloaded in CSV Comma Delimeted File format. This will simplify the processing work because the data stored in that format is lighter and easier to be accessed because it is in the form of Ascii file and can be opened through Excell software. Civil Design & Survey software (Fig. 5) is used to display the details of the observations in graphical form and hence any analysis is easier to carry out. Data is first imported into the database for the purpose of data analysis and display (Fig. 6).

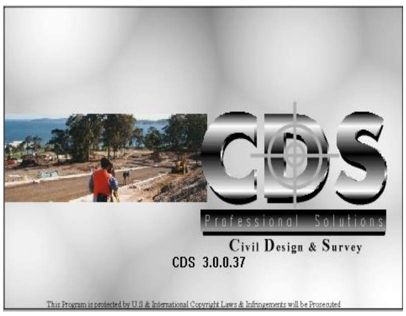

Fig. 5: *Civil Design & Survey Software*

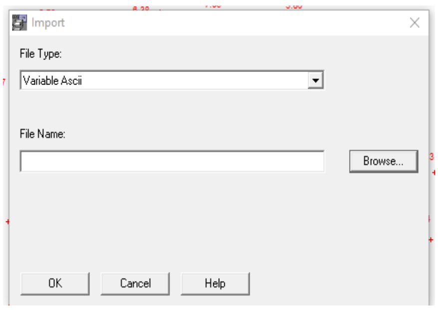

Fig. 6: *Import Variabe Ascii*

The tools or materials used in the research are carefully selected to give the best results possible and are suitable to answer the research objectives. The processing involved using the cross-section method involves plotting cross sections of the existing and proposed levels at regular intervals accross the project site (Babapour et al., 2018; Cheng & Jiang, 2013). For each of the cross sections, the cut area and the fill area is calculated. The volume between each pair of sections is estimated by multiplying the average cut or fill area of the two sections by the distance between them.

The formula to calculate the volume between two sections:

$$CV = \frac{(C1 + C2)}{2} x D$$

CV = Cut volume
C1 = Cut Area of 1st cross section
C2 = Cut Area of 2nd cross section
2 = number of sections (1 pair)
D = distance between cross sections

$$FV = \frac{(F1 + F2)}{2} x D$$

FV = Fill volume
F1 = Fill Area of 1st cross section
F2 = Fill Area of 2nd cross section
2 = number of sections (1 pair)
D = distance between cross sections

One of the great advantages of this method is that cross sections are generated in the process. The cut shown as red area and the fill area shown as blue area (Fig. 7). These provide a useful visual summary of the calculation (Fig. 8), which present the cut and fill depths across the project in a very clear way. One of the disadvantages off the method is that it can be extremely laborious to extract cross section from the drawing, and to determine the areas of the sections.

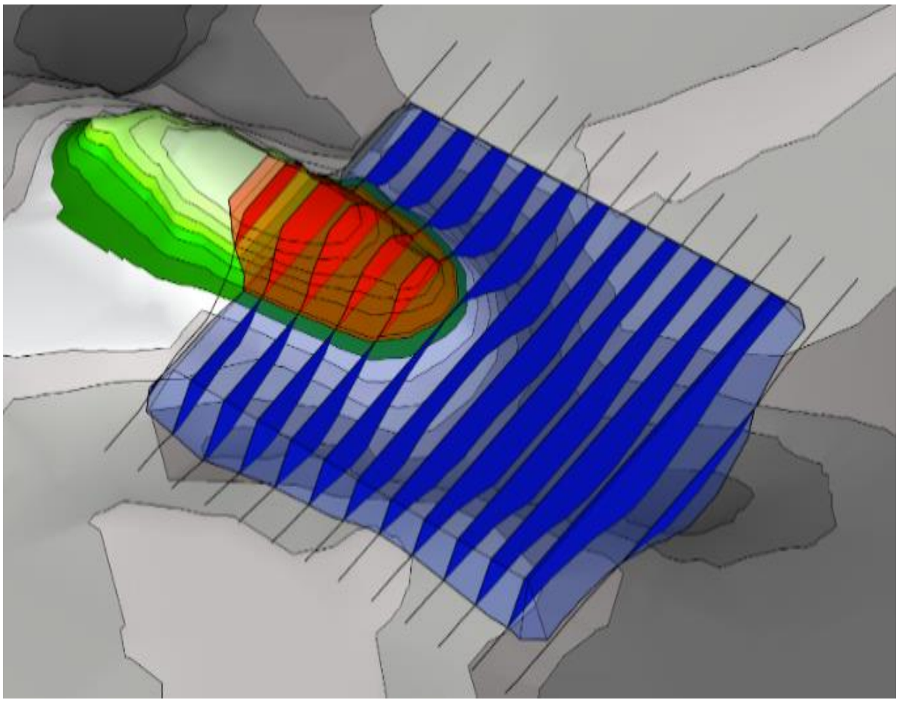

Fig. 7: *Cut and fill*

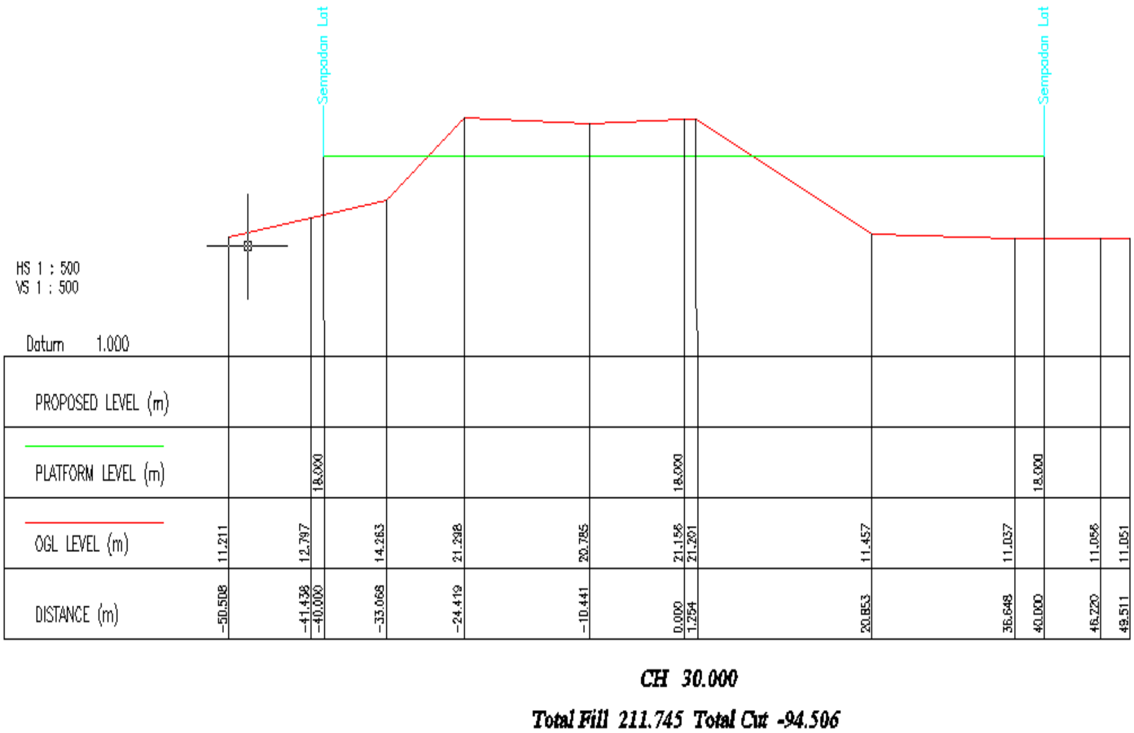

Fig. 8: *Sample visual Cross Section from Site B*

To do surface to surface calculation method, the contour must first be generated against the original topographic data and earthwork topographic data. This involves joining the points in the terrain to create connected triangles. This is known as a Triangulated Irregular Network, or TIN (Fig. 9). These two layers will then be overlaid together to obtain the values of cut and fill. Earthwork data can also be displayed in three dimensional, 3D using CDS software (Fig. 10).

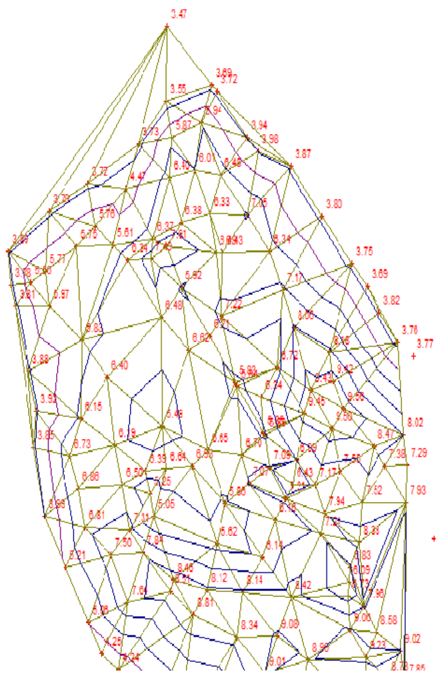

Fig. 9: TIN

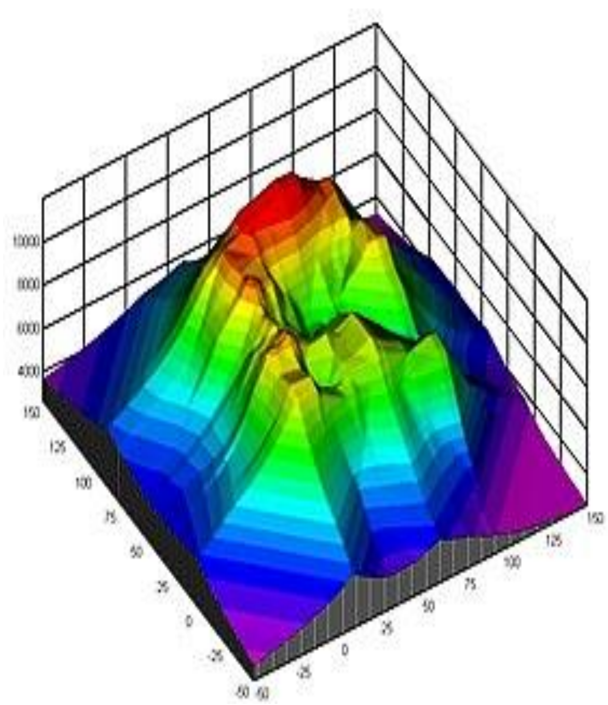

Fig. 10: 3D View

The result of the overlap between two layers of TIN will give the values of cut and fill as in Fig. 11.

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                    Foresight Software Pty Ltd
             Calculation of Volumes Between Surfaces


Base Job    : F:\VOLUME SURFACE & CROSSEC\SITE 2\db.DATA
Overlay Job: F:\VOLUME SURFACE & CROSSEC\SITE 2\db.PLATFORM

Fill Surface Area : 8208.475 sq. metres
Fill Area: 8208.475 sq. metres  Fill Volume : 38882.133 cubic metres

Cut Surface Area : 3791.525 sq. metres
Cut Area: 3791.525 sq. metres  Cut Volume : -14483.159 cubic metres
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Fig. 11: *Value of earthwork volume by surface to surface method*

Analysis

Comparison of earthwork volume data was made based on different project site areas and at different cross-sectional chainage intervals. All the data were compared with the values obtained from the calculation by the method of surface to surface. Although the initial prediction is at small chainage interval it will give relatively small different between the two methods, however the result is the other way around. It occurs in small project sites and as the project site getting bigger, it was found that the use of 5m intervals has a better result percentage. It also applies to 20 m gap values, a smaller percentage difference for larger project sites. This result supports the use of 20 meter interval measurement according to the JKR Malaysia scopes (JKR Malaysia, 1987), where a 20m chainage interval has been standardized to calculate the quantity of earthworks.

Table 1 below shows the difference calculations for the 5 m chainage interval and figure 12 shows the percentage graphs for the values of cut and fill at the 5 meter chainage interval. This clearly indicates that the larger the project site the difference between the two methods will be less.

Table 1: *Average percentage of cut and fill for 5m Cross-sectional*

Site	Area	Surface to Surf		5 m crossect			
		Fill Volume	**Cut Volume (-ve)**	**Δ Fill**	**Fill (%)**	**Δ Cut**	**Cut (%)**
A	2.5 acre	5691.242	20.499	93.797	1.648	4.857	23.694
B	3 acre	38882.133	14483.159	1077.383	2.771	887.959	6.131
C	12.5 acre	619909.923	112288.967	992.861	0.160	47.46	0.042
				Mean	1.526	Mean	9.956

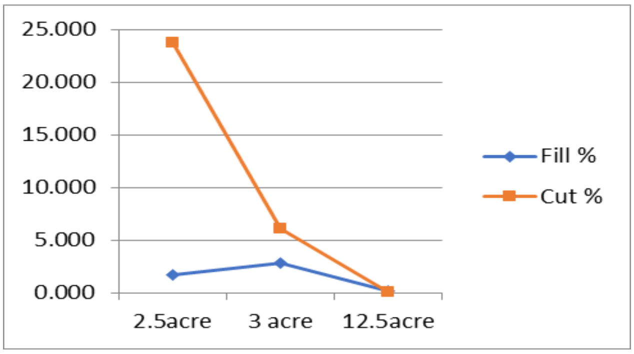

Fig. 12: *Percentage of Cut and Fill for 5m Cross-sectional*

Table 2 below shows the difference in calculations for the 10m and 20m chainage intervals and Fig. 13 shows the graphs percentage for the cut and fill values at the 10m and 20m chainage intervals. This also clearly indicates that the larger the project site the difference between the two methods will be less.

Table 2: *Average percentage of cut and fill for 10m and 20m Cross-sectional*

Site	Area	Surface to Surf		10 m crossection			
		Fill Volume	Cut Volume (-ve)	Δ Fill	Fill (%)	Δ Cut	Cut (%)
A	2.5 acre	5691.242	20.499	144.022	2.531	3.193	15.576
B	3 acre	38882.133	14483.159	1061.413	2.730	719.459	4.968
C	12.5 acre	619909.923	112288.967	1268.747	0.205	306.822	0.273
				Mean	1.822	Mean	6.939

Table 3: *Fill and Cut Volume*

Site	Area	Surface to Surf		20 m crossection			
		Fill Volume	Cut Volume (-ve)	Δ Fill	Fill (%)	Δ Cut	Cut (%)
A	2.5 acre	5691.242	20.499	132.24	2.324	-3.5	-17.074
B	3 acre	38882.133	14483.159	1700.8	4.374	692.46	4.781
C	12.5acre	619909.923	112288.967	-241.36	-0.039	-435.21	-0.388
				Mean	2.220	Mean	-4.227

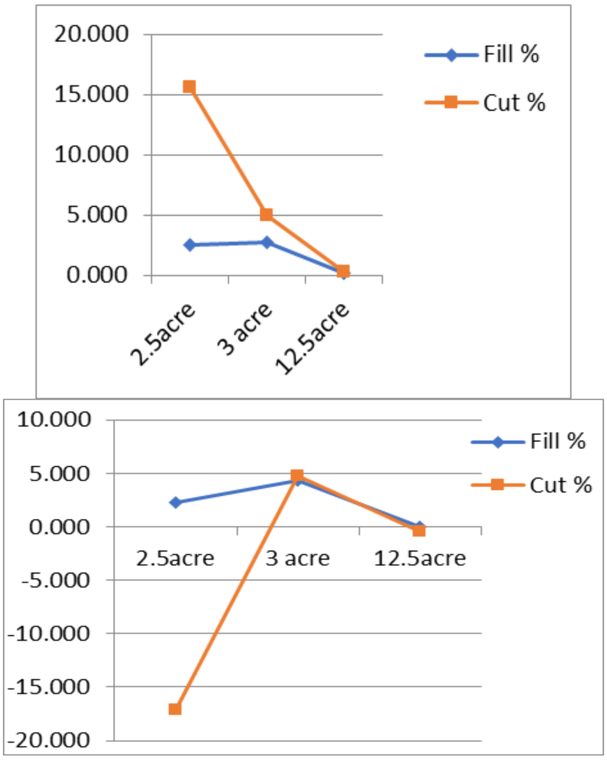

Fig. 13: *Percentage of Cut and Fill for 10m and 20m Cross-sectional*

The average percentage of difference cut and fill values for each project has also been calculated to see the area effect on the use of both methods. Calculations to the average difference also found that the larger the project site will result in less discrepancy between the STS method and the CX method. Table 3, Table 4 and Table 5 show the average values of the differences. The volume value on the cut will show a significant difference for a small earthwork friend. Compared to a more consistent fill value for each earthwork project site area.

Table 3: *Average percentage of cut and fill for Site A*

Site A (10375msq/2.5acre)						
	Fill Volume	Cut Volume (-ve)	Difference		Percentage	
			Fill	Cut	Fill (%)	Cut (%)
Surface to Surf	5691.242	20.499				
5 m crossect	5597.445	15.642	93.797	4.857	1.648	23.694
10 m crossect	5547.22	17.306	144.022	3.193	2.531	15.576
20 m crossect	5559.00	24.00	132.24	-3.50	2.324	-17.079
		Mean			2.167	7.397

Table 4: *Average percentage of cut and fill for Site B*

Site B (12123.158/3 acre)						
	Fill Volume	Cut Volume (-ve)	Difference		Percentage	
			Fill	Cut	Fill (%)	Cut (%)
Surface to Surf	38882.133	14483.159				
5 m crossect	37804.75	13595.2	1077.383	887.959	2.771	6.131
10 m crossect	37820.72	13763.7	1061.413	719.459	2.730	4.968
20 m crossect	37181.33	13790.70	1700.80	692.46	4.374	4.781
		Mean			3.292	5.293

Table 5: *Average percentage of cut and fill for Site C*

Site C (50729.892msq/12.5acre)						
	Fill Volume	Cut Volume (-ve)	Difference		Percentage	
			Fill	Cut	Fill (%)	Cut (%)
Surface to Surf	619909.923	112288.967				
5 m crossect	618917.062	112241.507	992.861	47.46	0.160	0.042
10 m crossect	618641.176	111982.145	1268.747	306.822	0.205	0.273
20 m crossect	620151.286	112724.179	-241.36	-435.21	-0.039	-0.388
		Mean			0.109	-0.024

Conclusion

In conclusion, for objective no.1, the use of the CX method is still relevant to calculate earthwork quantities. Apart from the being able to see visually on the plan, the calculation data is clearly and convincingly shown in the calculation table. However, it is better that STC method is also being used as a verification method for land surveyors to ensure that the volume calculation using the CX method can be accepted. As for objective no.2, which is to compare the effect of 5m, 10m and 20m chainage interval measurement data between cross-section (CX) and surface to surface (STS) method, study results has found that the effect on the chainage gap will give a difference in the value of earthwork volume and therefore, a guideline on how to calculate earthwork volume should be mutually agreed by parties involved. On large areas, smaller chainage intervals are better but the cost for survey work will also increase as more details in the field need to be measured. However, all parties should understand the situation and if a chainage interval standard has been agreed from the beginning, then the subsequent data should follow the interval that has been set. For example, if the initial topography has been set at 20m chainage interval as the volume calculation data, subsequent volume claimed will also use the 20m chain interval value. This is because different intervals used will result in a difference payment claims which based on the earthworks volume from the contractor to the developer. Therefore, the conflict can be avoided in settling the payment as well as in determining the accurate calculation.

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