Error Analysis for Volume Calculations Using Spot Reduced Levels

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Abstract— *The volume calculation of soil to be excavated is important in construction projects for the cost estimation prior to the construction. Generally, it is carried through the spot heights, using a hypothetical grid drawn across the area to be excavated. The volume enclosed by grid lines is normally calculated by multiplying the average heights of the spots by the area of the grid. The area of a grid is generally selected as three of four. The actual volume varies with the section of unit grid and more over that, with the surface variation which is not reflected by spot heights. The study was carried out to investigate the error in volume calculation due to surface variation. A physical model was developed to generate different surfaces for unique grid with constant spot heights and the error was correlated to middle height to introduce an accuracy index. It was found that the developed physical model provides an acceptable estimation of volume, according to the middle height. The outcome of the research would facilitate the construction professionals, to identify the range of volumes to be excavated, with a higher accuracy.*

Keywords— **Volume-calculation, Spot-height, unit grid**

I. INTRODUCTION

The volume calculation using spot heights is extensively used in calculating excavation volume in construction projects and calculating the capacity of a reservoir. In both of above cases, a greater accuracy can be achieved when the interval between the spots become smaller. But practically, it is difficult to measure the reduce levels or depths at closer distance. Therefore the calculated value deviates from the actual value creating an error. This error affects for incorrect cost estimation and material volumes in construction projects and erroneous capacities in reservoirs.

Consideration of the average spot height multiplied by the selected grid area is the most widely used technique to calculate the volume using spot heights. A triangular or square grid is very common in this stage. There is no any specific guideline to select triangular grids in a series of spot heights but different selections will provide different volumes. Therefore it is obvious that the final volume depends on the selection of unit grid where an issue of accuracy arises.

The variation of surface is also one crucial factor affecting the accuracy as there can be different surfaces between same spot heights. It is assumed that there is a plane surface for the unit grid whose average height is used for volume calculation. This assumption is controversial when square or rectangular unit grids are selected as it cannot be ensured a plane exists between four points in the space. Therefore triangular unit grids are usually recommended since a planer surface can be assumed between three points. Therefore the surface variation affects the errors in calculated volume.

This study was conducted to analyse the error in volume calculation due to surface variation and to generate an accuracy index using the middle height of the grid. A physical model was developed with relevant calibration and it was confirmed that this index can be used to increase the accuracy of volume calculation.

II. LITERATURE REVIEW

Several techniques are used to calculate a volume such as spot heights, contour maps and cross sections. Fundamentals equations and advanced computer models have been developed in order to calculate the final volume and many researches have been conducted to improve the accuracy of the final outcome.

The Simpson's rule and trapezoidal rule which are considered as basic equations of volume calculations were used by Yanalak (2005). The results were compared with cubic spline and cubic Hermite formula in order to calculate the volumes in borrow pits. The results were used to compere the accuracy caused by different techniques.

The error due to the non-linear variation of ground profile was investigated by Easa (1988). The study suggested that the Simpson's rule can be modified and used to estimate the volume to a higher accuracy even with different intervals between spots. The results provide a solution when there is non-linear variation along the grid lines.

The selection of unit grids and assuming a planer surface for each unit grid causes sharp irregularities along the grid lines and it divides the total area into smaller pieces. This drawback is addressed by Easa (1998) developing a direct formula for volume computations based on a smooth approximating surface. This method provided more accurate and easy approach by avoiding complex integrations.

Many 3D models have been developed to calculate the volume with the use of advanced applications with computer software. Losier (2007) introduced a 3D model generated with GPS measurements which can be used to rural locations where finer survey can not be performed. But the results of digital models too are controversial as the basic rules and approximations are used in there.

III. RESEARCH METHODOLOGY

A physical model was developed with sand to fill the volume which was considered as actual volume and a calibration model was used to calculate the sand volume..

A. Calibration Model

Cubical volumes with different dimensions were filled with dry sand sieved from number 200 sieve. The heights of the models were selected in the range of physical model and the drop height of sand was maintained below 1 cm to avoid the error due to the compaction. The used sand volume was measured with a measuring cylinder and the dimensions of the cubes were measured to calculate the volume in cubic centimetres. The results were used to correlate the sand volumes in physical model.

B. Physical Model

An open box was created with a square base and four vertical walls. The heights of the four corners were selected with different quantities and variation of heights along the grid lines made linear as shown in figure 1.

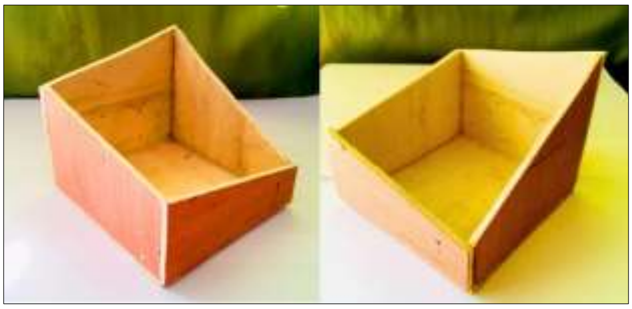

Figure 1. The physical models

The volume was then filled with dry sand by following the same procedure used in the calibration model. Different top surfaces were generated in different trials ensuring the four outer edges coincided with the wall edges. This condition confirmed that spot heights and variation of heights along the grid lines remain unchanged for each trial. The middle height which was supposed to be used as an index of error was measured by using a verier calliper downward from fixed vertical height. The sand volume used to fill the chamber was finally measured using a measuring cylinder.

IV. OBSERVATION AND RESULTS

A. Calibration Model

The dimensions of calibration models and measured volumes are illustrated in Table 1 as follows;

Table 1. Measurements in calibration model

Trial	Dimensions (cm)	Volume of sand	
		By dimensions (cm^3)	By measuring cylinder
1	0.8	9.80	10
2	1.4	17.15	20
3	2.0	24.50	25
4	2.4	29.40	30
5	3.0	36.75	40

The actual volumes were calculated using the dimensions and the two volumes were compared by using Figure 2;

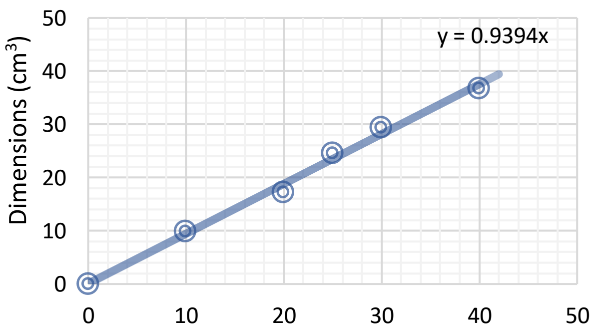

Figure 2. Correlation of volumes

According to the figure 2, the correlation factor used to convert the sand volume to actual volume was 0.9394

B. Physical Model

The middle height measured was compared with average height and the difference between measured height and average height was used as middle difference which was used as an index of surface variation as it varies with different surfaces.

The calculated volume which is constant for all the trials was determined using Simpson's rule. The error was calculated by comparing the actual volume calculated with sand volume and the volume given by Simpson's rule. The calculated volume the physical model used in this study was 597.83 cm^3.

The volumes obtained in each technique for different trials are given in Table 2 as follows;

Table 2. Volume measurements in physical model

Trial	Middle difference	Measured volume	Error	% error
1	0.80	526.064	71.766	13.64%
2	0.14	535.458	62.372	11.64%
3	0.01	540.939	56.891	10.51%
4	0.32	549.549	48.281	8.78%
5	-0.42	558.943	38.887	6.95%
6	-0.81	568.337	29.493	5.18%
7	-1.41	582.428	15.402	2.64%
8	-1.63	596.519	1.311	0.21%
9	-1.82	605.913	- 8.083	-1.33%
10	-2.06	615.307	-17.477	-2.84%

The variation of percentage error against the middle difference is illustrated in Figure 3.

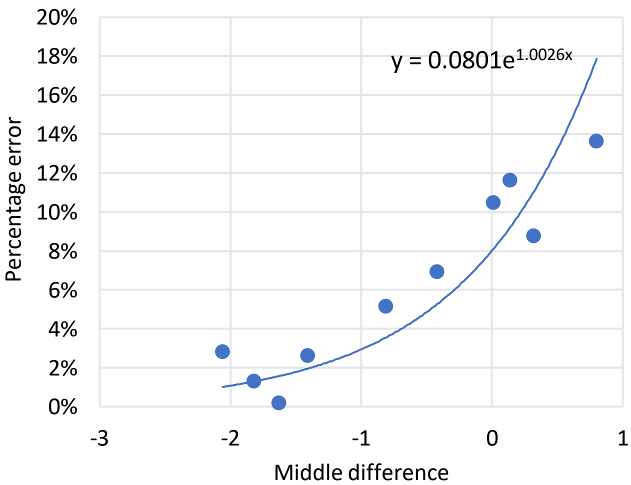

Figure 3. Variation of error against middle difference

V. CONCLUSION

The technique used in the study to measure the volume is a successive approach to volume measurement specially for irregular bodies.

The error due to the surface variation in the volume calculation using spot heights can be analyzed using the middle height of the unit grid.

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