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MEASURING VOLUME OF STOCKPILE USING IMAGING STATION

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ABSTRACT

It is crucial to know cutting and filling volumes in many surveys, mining, quarry and engineering field of works like dredging and embankment project. Generally, volume calculation is completed using conventional surveying methods. The trapezoidal method and classical cross sectioning have been presented in the literature. In other way around, by using conventional surveying methods, the volume calculation required a lot of time, laborers and risky as the big machineries running around the work areas. Digital close range photogrammetry has been insufficient for the volume calculation of the material need to calculation of volume in risk areas or in short time. In this case, long range surveying and scanning method is an alternative method to volume calculation. By the development of scanning and imaging technologies, Topcon Imaging Station (IS) used for three dimensional modeling (3D) surveying of objects in many field such as topographic survey, mining, construction and as-built survey, etc disciplines has become a productive, faster and accurate method. This study concern is getting the stockpile volume by using Topcon IS known as advanced technology instrument which promotes both scanning and long-range surveying. The instrument, a highly-developed technology specialized with Image Master Software; distinctive software that provides capabilities to reconstructed 3D modeling after the volume data was processed. Three dimensional (3D) surfaces are created through Triangulated Irregular Network (TIN) method that supports time saving and more accurate volume calculation. The volume calculated by Image Master (IM) then compared with the volume calculated by 12D software which the data obtained by using total station and prism. The results have been analyzed with respect to different volumes, density factor, three dimensional (3D) models of stockpile and time taken for data acquisition and data processing.

Key words: Volume Computing, 3D model of stockpile and Laser Scanning Technologies

1.0 INTRODUCTION

In brief, many formulas can be used to compute the volume of stockpile. For examples, trapezoidal method for rectangular or triangular prism, classical cross-sectioning for trapezoidal, Simpson's and improve methods using Simpson-based, cubic spline and cubic Hermite formula used for conventional method calculation (Yakar and Yilmaz, 2008). The calculation involving many points is more difficult when using the complicated surveying methods and formulas. This will cause the error between the measured volume and the actual volume of stockpile, thus contribute to a large impact to the work (Yanalak, 2005).

With the evolution of surveying technologies the demand for accuracy and precision in earthwork volume calculation has become utmost important. It's a surveyor's nightmare to calculate the volume accurately each time using the conventional surveying method. Cone stockpiles often pose a safety risk to the surveyor. Conventional surveying methods may be impossible due to the rapid reeling of the stockpile and also because the stockpile is often fed from above and extracted from below. All these issues were answered with the introduction of Topcon Imaging Station. As the name implies, Topcon IS uses a laser to rapidly collect huge amounts of three-dimensional data by scanning a given scene (Singha, 2004).

Scanning technology enables the observation points of the volume observed from distance where volume data are observed at particular control point of Imaging Station (IS) was setup. Topcon IS was the instrument that combines the digital imaging with the total stations several years ago. The IS advanced 3D modeling capabilities allows for 3D model reconstructed with image integration and volume measurements (Wallace, 2008).

In the real world of volume calculations, there are small changes on surface angles due to slumping of material and other factors. Because laser scanning collects so many points, these measurements are recorded and translated to the final model (Mangold, 2010). Laser scanning is used to quickly create 3D surface models of mining bulk-earthworks operations. Periodic scans of mine excavation and ROM stockpile for example allow surveyor to accurately calculate volumes of material moved while mining engineers are able to monitor site productivities, accurately reconcile the movement of material and assess features such as the condition and grades of dumps, ramps, benches and haul roads. Volume calculation between different 3D surfaces is another important feature. The results are shown in numbers as cut and fill volume and can be also visualized by coloring the 3D surfaces according to height differences (Russell, 2009).

1.1 Topcon Imaging Station

The Imaging Station (IS) will dramatically improve field productivity. When used in conjunction with the built-in scanning features, it provides a dynamic system that provides the automation of a much-higher precise laser scanner (**Figure 1**). Additionally, the instrument laser scanning function has been useful for conducting topographic surveys (www.topconpositioning.com). The Topcon IS is equipped with Image Master Software (IM) developed to supplement laser scanning by generating 3D images. The Topcon IS collects points and the software is used to develop real-time images based on TIN consisting of irregularly space points and breaklines with their own x, y and z (surface) value (Talend, 2009).

Figure 1: Topcon Imaging Station

2.0 METODOLOGY

Research methodology is an important element of research in order to achieve the objective of the study. **Figure 2** shows the research methodology is divided into four phases; work planning, data gathering, data downloading and processing data. For the last phase include two element which is results analysis and conclusion.

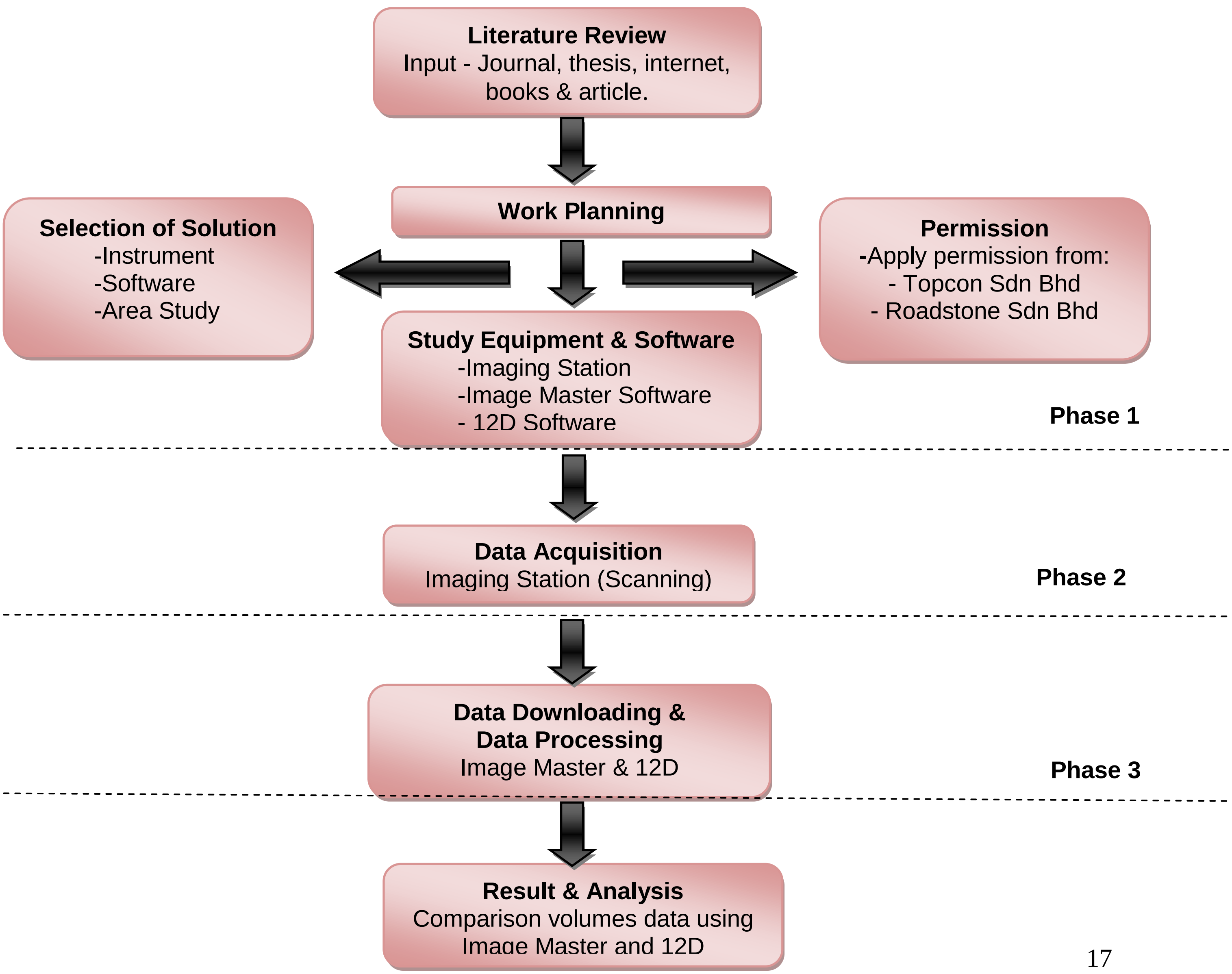

Figure 2: Flow Chart of Research Methodology

2.1 Work Planning

In initiating a research, planning and preparation should be done first because it would give effect to whole process will be conducted from the beginning to end of the research. The process involved in preparation as a following ; selection of suitable equipment for obtaining data purposes, determine the software will be use for data processing, explore the equipment and software for data collection and data processing purposes and make sure the author follow the methodology for carry out the study. In order to get information about the research, the author need to find some book, journal, magazines, articles and other sources related with the research. It is important because to make sure the author understand clearly about the study and select appropriate method, equipment, software and area to do the research.

2.2 Data Acquisition

Data acquisition was carried out at Negeri Roadstone Sdn. Bhd. situated at Negeri Sembilan on 07 December 2010 and 08 December 2010 (**Figure 3**). This study followed the work flow chart to ensure the data acquisition process flow smoothly (**Figure 4**). This study is more concerned on getting the volume of the stockpile. For this study, the scanning method and conventional method is made for the same stockpile. The author performed the scanning method with two different density which are 0.3m density and 0.1m density. Before the actual data acquisition takes place, site-survey was made to prepare the required information for observation like preparing the control points, reference station, stockpile selection, method to applied, and to be familiar with the actual condition of the site.

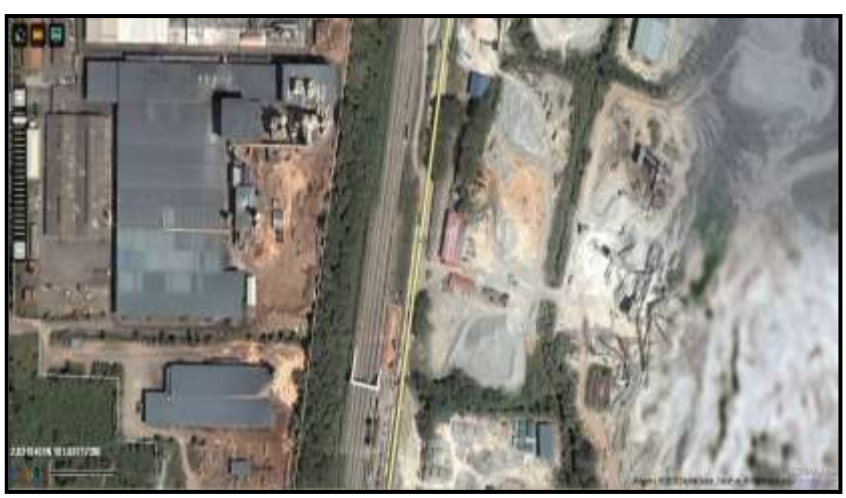

Figure 3: Location Negeri Roadstone Sdn Bhd (googlemaps)

Next, the data observation was made after all the required data from site was hand-in. Resection method was applied during 3D data collection where the density of point clouds depends on the set of grid value at Topcon IS The IS have good capability that combines the real time image of stockpile with 3D data and better scanning ability compare to conventional method which results faster data collection. Three control stations for each scanning session were built around the stockpile to ensure the capture-image process and scanning process will flow smoothly. Data acquisition is divided into two major steps; establishment control/reference station and scanning.

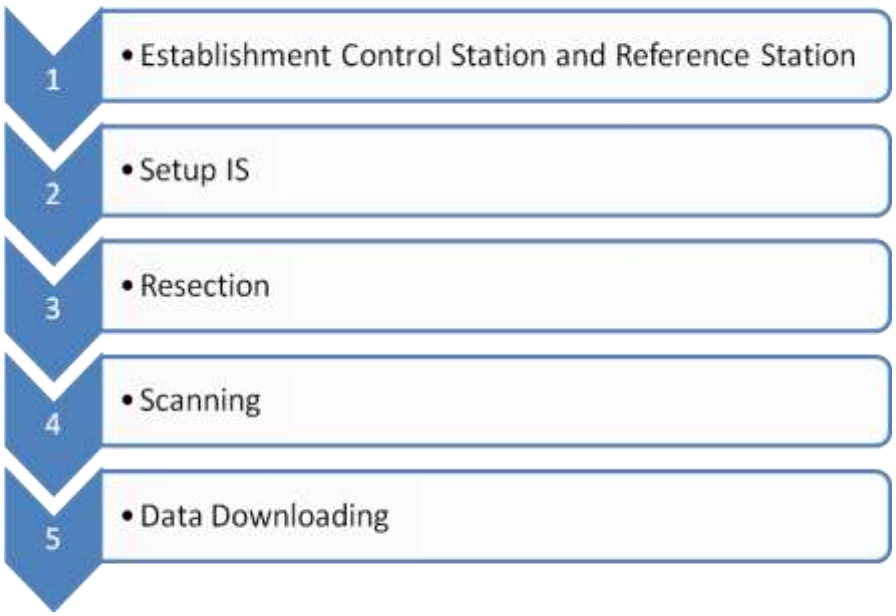

Figure 4: Work Flow Chart

2.2.1 Establishment Control Station and Reference

Based on the site-survey been made, it is best to locate the position of control station between the stockpile and reference station. This is because every control station that established uses the same reference station to determine IS location (coordinate), which determined by resection method. Establishments control station depend on the shape of the stockpile that scanned where if the shape is large, therefore more control station required to gain enough information and data. Based on **Figure 5**, six control stations were built around the stockpile that represents by the red triangle for the first set data while the blue triangle for the second set data.

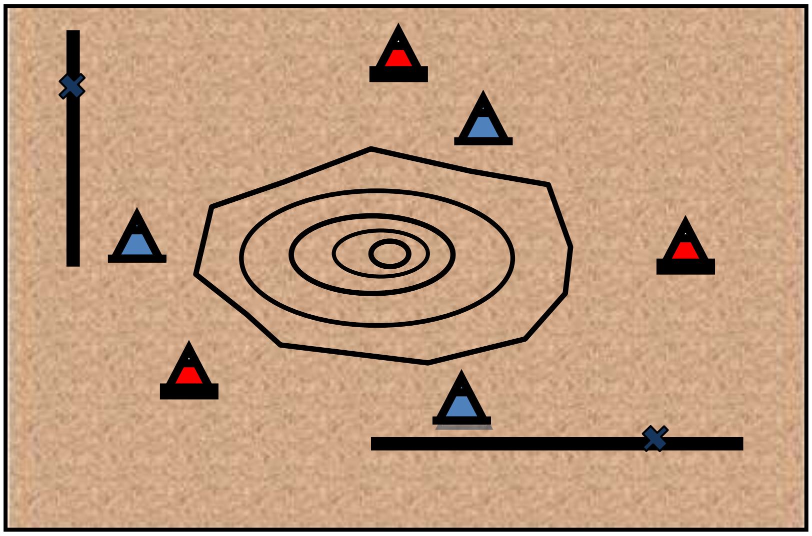

Figure 5: Determine the position of IS using resection method

These control stations refers to two reference stations that marked on permanent structure where one of the stations was marked at building wall and the other at car park's crossbar. It is necessary for the target to be marked on noticeable location from any control station where the location of the reference station was used to determine the control station's coordination (**Figure 6**).

Figure 6: The reference station was marked

2.2.2 Scanning

Scanning process can only be made after the coordinate of the control station was identified where in this study; the resection method was applied to determine the coordinate. Two sets of data created on the same stockpile but different density and control station location where the first set data used grid 0.3×0.3 meter while the second set data used grid 0.1×0.1 meter.

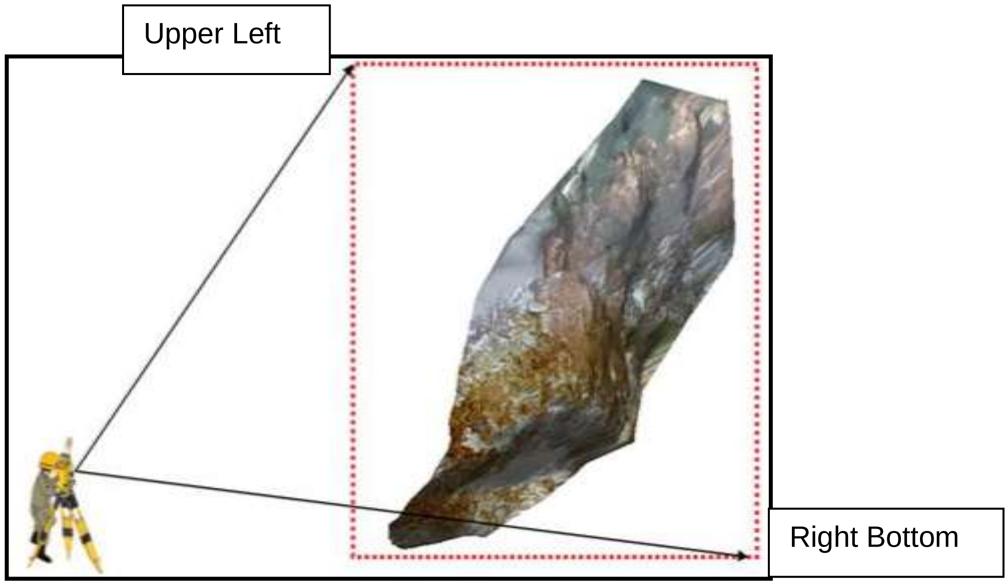

Figure 7: Identify Scanning Range

Scanning session started with the second set data followed by first set data. Before the scanning process begin, the available IS station coordinate must be confirmed by using menu observation; where the IS position can only be reconfirm with observed the second reference station. The coordinate after the confirmation must be ensured within the limit set which is 10mm-20mm from the actual coordinate. The confirmation is to ensure that the IS instrument was situated on right position. For trouble-free scanning process, the IS instrument was directed toward the stockpile surface. Identify the upper left and lower right extents of stockpile area on the image shown on the screen (**Figure 7**). By using scanning technology, IS instrument capable to scan the stockpile surface according to scan interval grid that set by the author (see **Figure 8**). The grid was set based on the size of the stockpile. **Figure 9** shows the IS instrument captured the real-time image according to the chosen scanning range before the whole scanning process begin.

Figure 8: IS was setup with grid before process scanning begins

Figure 9: Topcon IS during scanning process

2.2.3 Conventional Method

Conventional methods used for data acquisition namely are total station and prism. Survey assistant established some point in the stockpile surface, and the readings recorded. The calculation of volume has been done using 12D software in which the volume will be compared with the observed volume using Imaging Station. On the other hand, conventional method data are provided by Negeri Roadstone Sdn Bhd but during the observation, author was there to participate and join the observation. **Figure 10** shows the survey assistant climbed up on the stockpile.

Figure 10: Conventional Method for data acquisition

2.3 Data Downloading

All the data obtained from observation was downloading into computer. The scanning application in Topcon Imaging Station is used for capture the point clouds of stockpile for post processing application.

2.4 Processing Data

Processing data is the process to get the results after the data acquisition at field. It divided into two processes which are scanning method and conventional method for data is provided by Negeri Roadstone Sdn Bhd. The data was processed for the scanning method using IM software; the data was processed stage by stage to reach the final product which is the stockpile volume. On this stage, data processing is divided into 6 stages which are importing the scanning data, viewing and editing the points, developing a triangulated irregular network (TIN), texture, volume calculation and creating the contour lines.

After the scanned data have done imported, the point clouds data appeared and the data can be viewed in 3D on the screen. Then, the scanning data needed to be edited because while doing the scanning process, some unnecessary data are also scanned and stored as a point clouds. Since IS also capture real time image before scanning process begin, these unnecessary point easily deleted based on the image. For this study, the unnecessary points only are deleted at stockpile surroundings as its existence would bothered the stockpile surface-developing process which TIN. This process is crucial because it shows the actual shape of the stockpile after the creating 3D model process done (**Figure 11**).

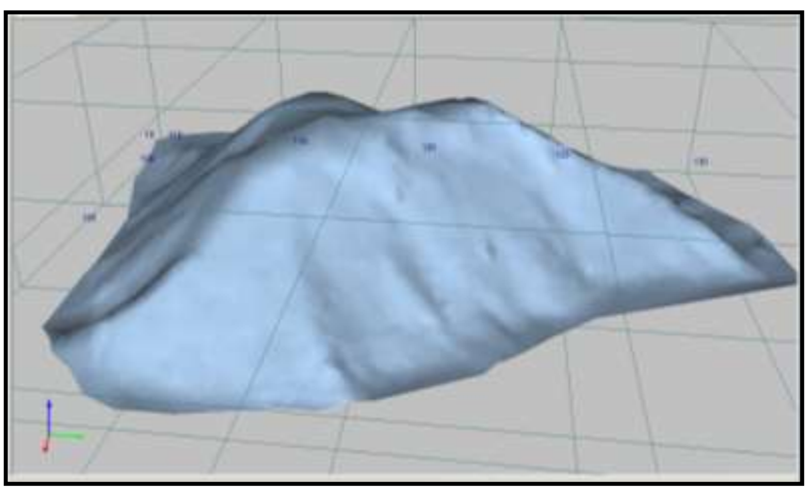

Figure 11: 3D model of stockpile

Once the 3D model of stockpile is created, texture mapping process needs to be added to visualize the stockpile in a realistic form. Since the setting of the built in camera are known during the scan, images captured are geo-coded and scaled as well. Based on the created 3D model, the images are applied onto the surface to create a realistic 3D model of the structure.

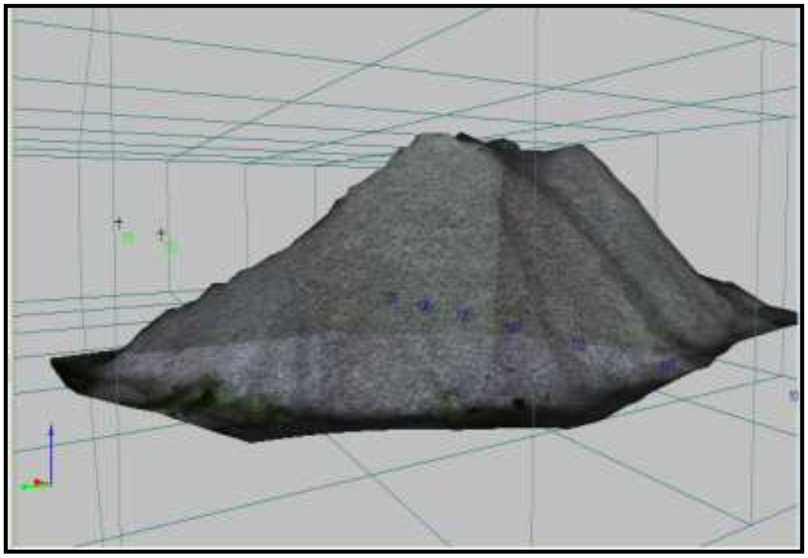

Figure 12: Image applied onto the 3D surface

The texture mapping applied is having integration with real time image (**Figure 12**). After that, the volume calculation is beginning. The volume of the stockpile must be calculated accurately. The stockpile calculations are based on the 3D model of stockpile where the quantity volumes are the difference between the top and the bottom form the same references plane surface model. The references plane can be randomly chosen but the above value from the bottom of surface model must be considered. As there are two sets of data with different density, the referenced plane used 11.2 meter. The final stage is creating contour lines. The contour interval chosen depends on shape of 3D surface of stockpile because if the value is small, maybe the 3D surface is having too many contour lines. This contour interval for major and minor is constant for this 3D surface (**Figure 13**). For the conventional method, data processing used 12D software. The process stages are also same with the IM except editing and texture stages are not done in conventional data processing.

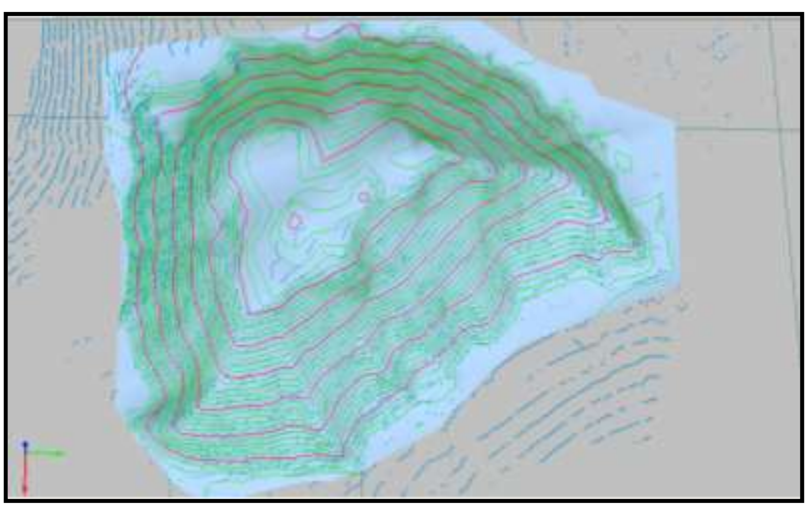

Figure 13: Contour creating using IM

3.0 RESULTS AND ANALYSIS

The results of this research are obtained the three volume of same stockpile calculated by IM Software with the different density and also the volume with conventional method calculated using the 12D software. The analyses of the difference of the volume were made in between scanning method used density 0.3 meter and conventional method. Next, both of the volume would be compared with density of 0.1 meter (assumed the density as the actual volume). Besides, few analyses were made against factor density and 3D model of stockpile which one of the scanning method that applied 0.3 meter density and conventional method. Time taken for the data acquisition and post processing are also compared.

3.1 Result of Stockpile Volume for Scanning Method and Conventional Method

There are two sets of scanning processed data; the first data set with 0.3 meter density which include three station; SP1, SP12 and SP130 meanwhile the second dataset with 0.1 meter density also include three control station ;check 1, check2 and check 3. **Figure 14** and **Figure 15** indicates the calculated volume results for density of 0.3 meter and 0.1 meter by using Image Master. Meanwhile, for the conventional method, the volume of the stockpile was calculated by using 12d software (**Figure 16**).

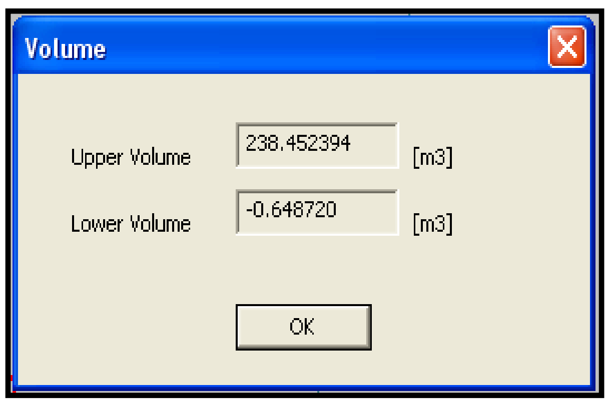

Figure 14: Volume of stockpile using 0.3 meter density

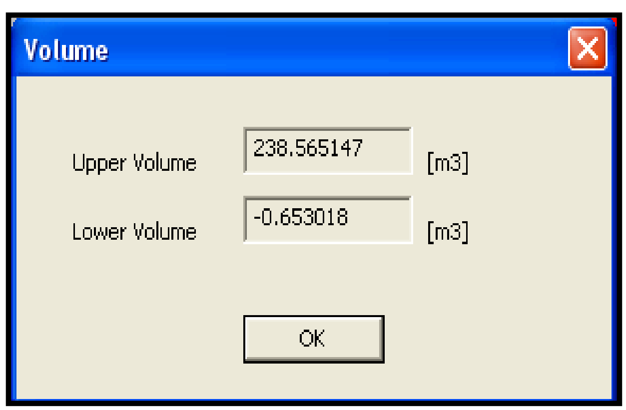

Figure 15: Volume of stockpile using 0.1 meter density

Figure 16: Stockpile volume using conventional method

3.2 Analysis on Volume Computing

Analyses were made based on few factors that might affect the stockpile volume results. The analyses would be briefly explained in sub chapter 3.2.1, 3.2.2, 3.2.3 and 3.2.4.

3.2.1 Comparison in term of Stockpile Volume for Scanning Method and Conventional Method

The information in **Table 3.1** shows the difference of the stockpile volume by scanning method and conventional method at density of 0.3m followed by comparing the stockpile volume that using the density of 0.1m (assumed the density as the actual volume).

Table 3.1: Comparison Stockpile Volume for Scanning Method and Conventional Method

Index	Scanning Method	Conventional Method
Volume (m^3)	238.45 m^3	225.83 m^3
Actual Volume	238.56 m^3	238.56 m^3
Difference Volume	0.11 m^3	12.73 m^3
Percentage	99.95%	94.66%

Based on the information provided in **Table 31**, the calculated volume of the stockpile was taken from the reference surface that set at elevation of 11.2 meter from the ground. This height was chosen by considering the lowest height of the stockpile for both of the methods applied. There was a 0.05 percent difference between the volumes calculated for density 0.3 meter versus actual volume. In contrast, for the conventional method, the percentage was 5.34 percent different from the actual volume. By using scanning method, the percentage shows that the scanning method are more accurate during stockpile volume calculation as the results were approximately with the actual volume. The result far exceeds the speed and accuracy of conventional methods.

3.2.2 Density Factor

The accuracy of the stockpile volume depends on the point clouds at field. Generally, the density of the stockpile changes significantly from one point to another. For scanning method, the mass of the points would be more systematic by referring to the set grid on the instrument; 0.3m at first set data and 0.1m at second set data. Meanwhile for conventional method, the mass of the points depends on the location of the points itself that determined by the assistant surveyor while placing the pole on the surface of the stockpile. **Figure 17** and **Figure 18** shows density of stockpile by using scanning method while **Figure 19** shows location points of stockpile by conventional method.

Based on the figures below**,** it can be seen that the factor density affect the stockpile volume. The denser of the data collected for the stockpiles, the more accurate the calculated volume of the stockpile. This is because the dense of the points is compulsory in order to present the actual shape of the stockpile. It can be seen that the volume of the calculated stockpile via scanning method is different although the collected data of the boundary stockpile are same.

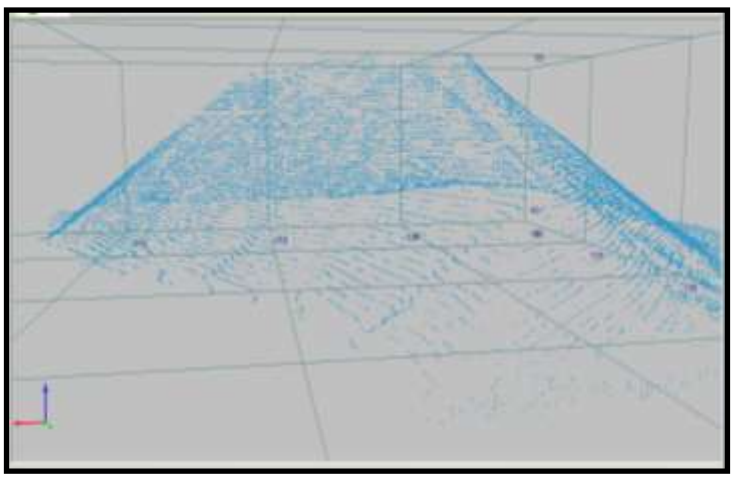

Figure 11: Scanning data by using 0.1 meter density

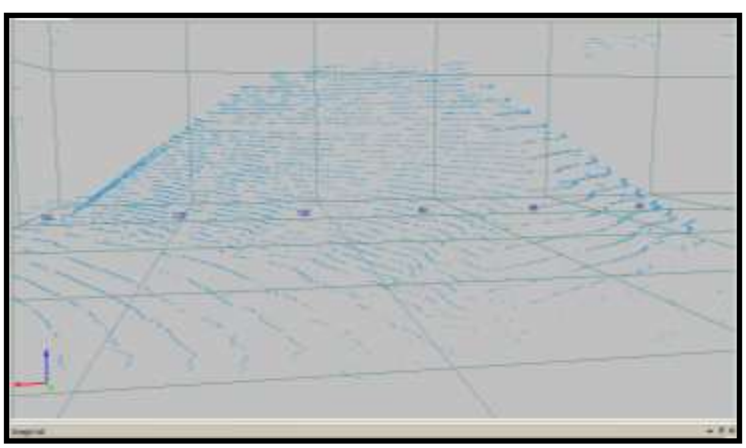

Figure 12: Scanning data by using 0.3 meter density

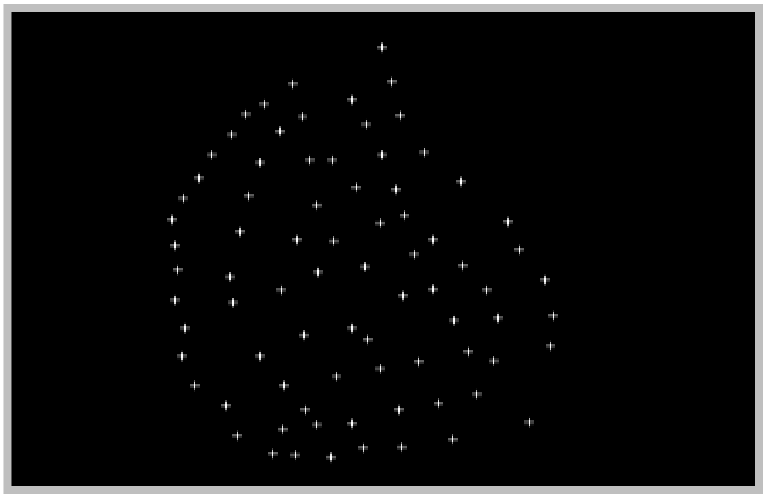

Figure 13: Location point by conventional method in 2D

Moreover, the accuracy of the volume depends on the method applied. By scanning method, it shows that the total of the collected points at density of 0.1m is 18,658 points meanwhile at density of 0.3m is 14,796 points. In the mean time, by conventional method, there were only 87 points collected for the same stockpile. The rapid change of the points after 2 methods applied is due to difficulties faced by the surveyor during collecting the data by using conventional method. Meanwhile, by scanning method, the solidity of the data depends on the ability of the instrument providing scanned data according to grid prepared. It shows that the change density factor might influence the total of the collected points and therefore affect the whole calculated volume.

3.2.3 3D Model of Stockpile

Reconstructed 3D model stockpile process is one of most compulsory process as determinant for accurate stockpile volume. The collected data which in forms of point-like are not suitable for direct apply during 3D application; it ought to be transformed into one form of model by using TIN method. **Figure 14** and **Figure 15** indicates 3D model by applying scanning method (density 0.3m) and conventional method, while Figure 16 indicates the real image captured during data collecting process.

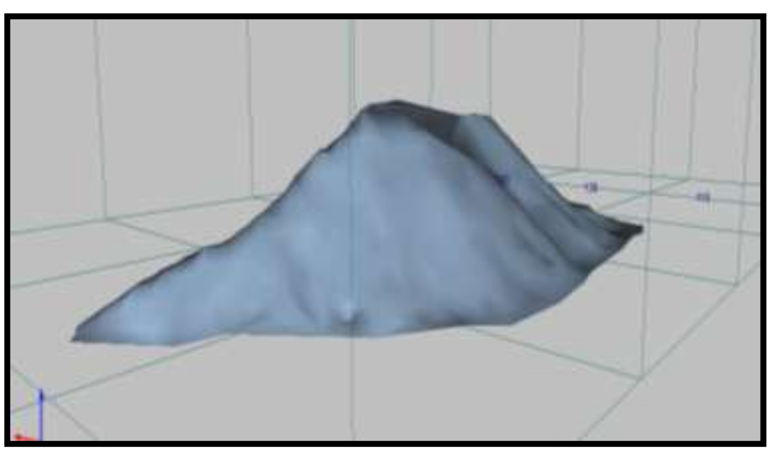

Figure 14: 3D model by using scanning data

Figure 15: 3D model by using conventional data

Figure 16: Real image capture during the observation

Based on **Figure 14, Figure 15** and **Figure 16**, it shows that the scanning method is most likely to produce the fairly accurate shape with the real stockpile. As to prove, we can compare the 3D model from one particular view with the image capture during observation. From **Figure 14**, scanning method provides the almost similar shape with the real stockpile (**Figure 16**). This is because the collected point clouds from every station facilitate TIN formation that would present the stockpile shape. Furthermore, the stockpile surface that generated via scanning method is more smoothed compared to conventional method. This is due to the limited data collected from conventional method that caused uneven surface generated which led to inaccurate conventional data.

3.2.4 Time taken for data gathering and data processing

Table 2 shows the comparison of the time taken for data gathering and post processing data for both scanning method and conventional method.

Table 2: Comparison between Scanning Method and Conventional Method for Data Acquisition and Post Processing

Items	Technique		
	Scanning Method		Conventional Method
Density	$0.1m^3$	$0.3m^3$	-
Time Taken for Setup Equipment	10 minute	10 minute	15 minute
Time Taken for Observed Data	53 minute	30 minute	1 hour 10 minute
Time Taken for Post-Processing	1 hour	44 minute	30 minute

Based on the information provided at **Table 2**, it can be seen that the time taken for scanning method and conventional method is different. By scanning, it shows that the time taken is influenced by the chosen density value. The smaller the density value, the longer the scanning process takes place and thus, the longer the time taken during data processing. In other word, smaller density provides more data compare to large density. At the mean time, by conventional method, it takes longer period as it takes much time during preparation and the whole data collecting process. Based on information above, the conventional method takes 30 minutes for the surveyor to place points on the stockpile and another 40 minutes during points surveying. In addition, it takes shorter time during data processing while applying scanning method as there is no editing process required.

4.0 CONCLUSIONS AND RECOMMENDATIONS

As the conclusion, the objectives of the study were achieved in which the author had the opportunity to make observations using the Topcon IS and then completed the processing data individually for obtaining the stockpile volume. With the development in technology, laser scanner technology provides several advantages over conventional surveying method for quarry application. Limited time on a site and the elimination of the need to physically access a site drastically increases safety for all concerned. In addition, the vast volumes of data obtained offer far greater accuracy than conventional method and jobs can be completed in days rather than weeks.

This study only focused on volume calculation using IS and the data process used IM and 12D software, it is recommended that further study to do the comparison of stockpile volume is calculation using AutoCAD land desktop and Suffer software of the same stockpile by using the grid method of volume, composite volume and end line volume. Besides, comparing the 3D model and the volume of the stockpile with the same density using Topcon IS scanning laser and using other products in the market such as Topcon GLS-1000 also recommended. Finally, comparing the stockpile volume using the normal camera image captured from a particular location with the laser scanner IS for data acquisition in the field.

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