

# Concrete volume loss calculation of structures using Terrestrial Laser Scanner (TLS)

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**Abstract:** Buildings are one the major structures which have to be monitored appropriately with much importance. Any damage in the structure could be proved fatal if it is not rectified within the time. Over the course of time the structural material loses its strength. Concrete loss is a major concern as this may be a reason for the collapsing of the building. Thus the amount of concrete volume loss is an important factor to be monitored. In this research TLS (RIEGL VZ-400) has been used to serve this purpose, Terrestrial Laser Scanner (TLS) is an instrument which provides 3D point cloud of the targeted surface rapidly with more accuracy. The surface where there are abnormal depths can be found with help of variation in the points. The actual 3D surface and the simulated 3D idle surface are used to find out the exact concrete volume loss and this is compared with the ground truth validation. These results are helpful to remodel the building depending on the actual amount of materials required to renovate and to avoid further loss in the volume of the concrete, in the building. Using this technique 2 to 4 percentage of error was obtained.

**Keywords:** Terrestrial Laser Scanner (TLS), Point Cloud, Triangulated Irregular Network (TIN), Concrete Volume loss

## 1. Introduction

Buildings are one of the important structures which are to be monitored with great importance. Buildings where materials used were not good enough are more prone to the concrete loss damage. Buildings in the rural areas are less maintained than the buildings in the urban areas. Due to financial issues, non-availability of resources etc. So the livelihood in the rural are more prone in case the building collapses due to weakening of the structure, due to concrete loss in the building. This is the main area of research in this project. Due to different loads in the structure, due to water absorption, or other reasons due to which cohesive force of attraction between the concrete pile weakens (Santos et al., 2007) and fall off sometimes resultant in concrete loss. Thus concrete volume loss measurement is of much importance (Zhang et al., 2005). This measurement can be done with the help of TLS (Burton, 2007) and with much higher accuracy (Boehler & Marbs, 2003) than general method of estimation.

### 1.1 Terrestrial Laser Scanner (TLS)

TLS is a remote sensing instrument which can provide the information about the surface without being in direct contact with the target and gives us 3D point cloud of the targeted area which is to be studied. The basic principle of TLS is that it fires laser beam with high repeatability pulse and traces the return signal from the target (Pfeifer & Briese, 2007). In less time large amount of targeted area can be covered. It calculates the range, intensity, amplitude, RGB value (if the camera is mounted), etc. There has been many researches for volume estimation using TLS in the fields like soil erosion (Milan et al., 2007), estimation of waste dump (Tseng et al., 2016), excavation (Yakar et al., 2014). An automatic method for recognizing concrete mass loss using abrupt changes in the Gaussian and mean curvatures with TLS is discussed in Teza et al., 2009.

### 1.2 3D point cloud

3D data set in the form of points at discreet intervals can be referred as a point cloud. The discreet space between

the points in the point cloud is due to the angular resolution, which is programmed before the scan of the target, lower the angular resolution, higher will be the space between the points and vice versa. Time period increases proportionally with increase in the angular resolution and vice versa. The Point cloud is an exact replica of the target, it's like virtual visualization of the real scenario in digital format where one can manipulate or process accordingly based on the requirement.

### 1.3 Concrete volume loss calculation

The amount of concrete that the building has lost is to be calculated. Gap between two 3D (simulated and actual) surfaces gives you the volume. The range difference between the pixels of each surface multiplied by the surface area of the surface gives you the volume. In case of structure the volume difference is the amount of concrete loss that has occurred.

### 1.4 Accuracy assessment

The percentage of error in the calculation of concrete mass loss is calculated relative to the volume obtained by processing with the help of software and volume obtained from ground value inspection.

$$\text{percentage of error} = \frac{(V_{\text{SOFTWARE}} - V_{\text{GROUND}}) \times 100}{V_{\text{GROUND}}} \quad (1)$$

$V_{\text{SOFTWARE}}$  is the volume of concrete loss obtained using software

$V_{\text{GROUND}}$  is the volume of concrete loss obtained using ground truth validation.

## 2. Study area and data acquisition

Three different types of concrete loss in a building were identified and were selected as study area. Study area 1, was taken at the edge of the building. Study area 2, was taken as the fascia of a ventilation window. Study area 3, was taken as roof of a building (Figure 1). The positions of scans were planned accordingly to cover the whole concrete loss portion.

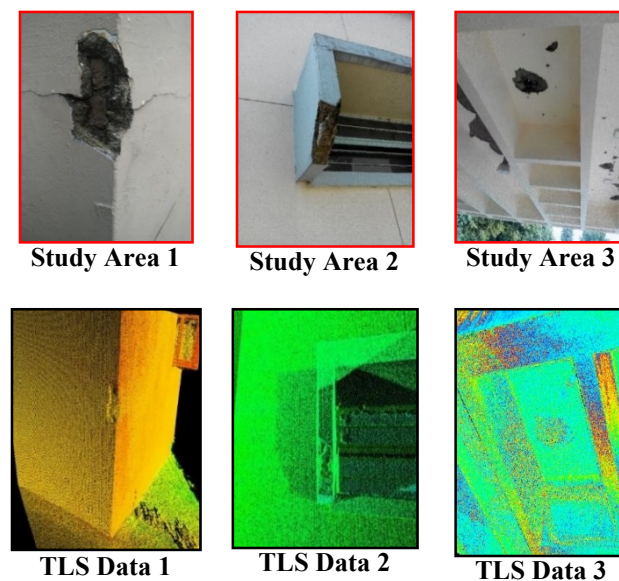


Figure 1: Study area and TLS data sets

### 3. Methodology

To get volume loss two surfaces are needed. One surface is the original (damaged) point cloud obtained from the TLS instrument with Laser Pulse Repetition Rate 100 kHz. The other surface is the simulated point cloud which is generated from the non-destructed similar surface of the structure, how it had been if there wasn't any concrete loss. Simulated point cloud was generated in cloud compare software. Noise were filtered out from the point cloud dataset and the damaged area were segmented out from the overall dataset. Simulated point cloud is the point cloud of the structure how the surface should have been, if no concrete loss had occurred. 3D point clouds were then converted into 2D raster's (continuous surface) as the point cloud is a discrete dataset which have spaces between them and to make the surface continuous. In some places pixels doesn't have values due to the absence of points in the point cloud or due to low density. These pixel values are interpolated with the neighbouring pixel value around it. Triangulated Irregular Network (TIN) surface is generated from the raster. From this Volume difference between two 3D surfaces are calculated with the help of software's (ArcMAP) and validated with the help of ground truth inspection (using clay models) (Figure 2).

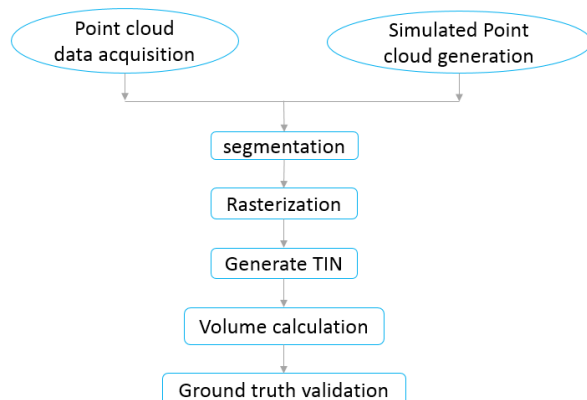


Figure 2: Methodology

### 4. Results and discussions

#### 4.1 Study area 1: Volume

Volume computed using software was obtained as 303 cm<sup>3</sup>. Whereas, volume obtained through manual process was 311.71 cm<sup>3</sup>. Percentage of error was calculated using eq. 1 and as shown in figure 3 & 4.

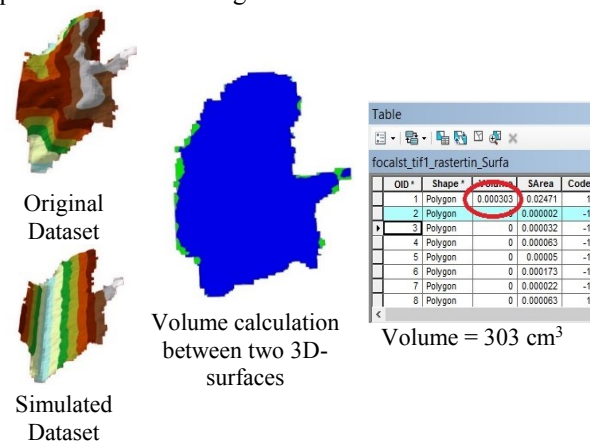


Figure 3: Volume computation using software

#### 4.2 Study area 1: Validation

Clay was used to extract the shape of the destroyed portion, clay was made to take the actual shape by inserting into the structure and by preventing any voids between them. Then the clay was carefully removed and was filled into a container with known dimensions to get the exact volume. Proper care was taken to minimise all the voids. This procedure was followed for other two study areas also. The percentage of error in study area 1 = 2.79 %

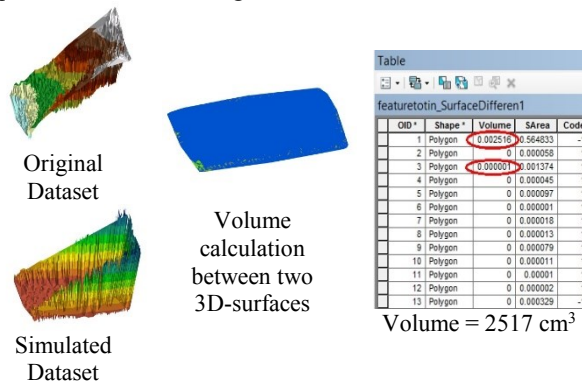


Figure 4: Volume computation manually

The percentage of error in study area 1 = 2.79%

### 4.3 Study area 2: Volume

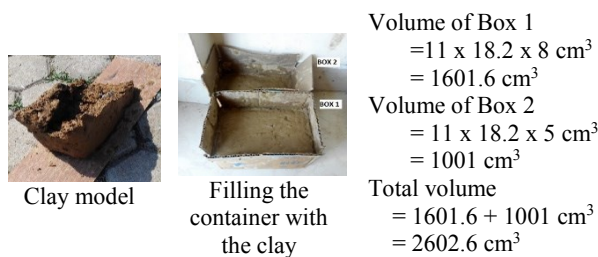
Volume computed using software was obtained as 2517 cm<sup>3</sup>. Whereas, volume obtained through manual process was 2602.6 cm<sup>3</sup>. Percentage of error was calculated using eq. 1 and as shown in figure 5 & 6.



**Figure 5: Volume computation using software**

### 4.4 Study area 2: Validation

Validation process was repeated as mentioned earlier.

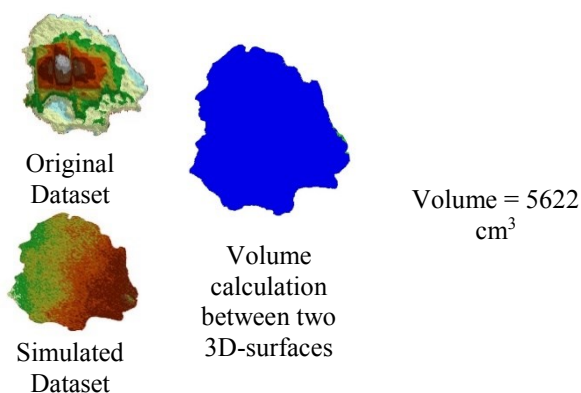


**Figure 6: Volume computation manually**

The percentage of error in study area 2 = 3.28%

### 4.5 Study area 3: Volume

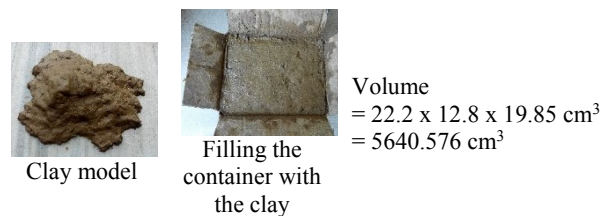
Volume computed using software was obtained as 5622 cm<sup>3</sup>. Whereas, volume obtained through manual process was 5640.576 cm<sup>3</sup>. Percentage of error was calculated using eq. 1 as shown in figures 7 & 8.



**Figure 7: Volume computation using software**

### 4.6 Study area 3: Validation

Validation process was repeated as mentioned earlier and as shown in the figures 7 & 8.



**Figure 8: Volume computation manually**

The percentage of error in study area 3 = 3.29%

## 5. Conclusions

The percentage error in concrete volume loss calculation in different study area 1,2 and 3 were obtained as 2.79 %, 3.28 % & 3.29 % respectively. Hence, TLS proves to be very effective instrument in measuring the concrete volume loss calculation of the structures.

TLS proves to be a fast, accurate and more reliable non-invasive technique to calculate the amount of concrete the building has lost. Concrete volume calculation with the help of this technique gives a more accurate amount of volume, that are needed to be used to refill or re modify to strengthen the building from further damage. TLS is a ground based instrument there may be few concrete losses above the field view of the instrument like concrete losses which can be visible only from the top of the structure. Those parts can be covered with the help of UAV Lidar. In this research, the overall accuracy of concrete volume loss estimation was obtained less than 4%.

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