

DIGITAL DOCUMENTATION, BRIDGE DECK LINEARITY DEFORMATION AND DECK THICKNESS MEASUREMENT USING TERRESTRIAL LASER SCANNER (TLS) AND CLOSE RANGE PHOTOGRAMMETRY (CRP)

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KEY WORDS: Terrestrial Laser Scanning (TLS), Close Range Photogrammetry (CRP), Point Cloud dataset, Bridge 3D Digital Documentation, Deck Linearity deformation, Deck Thickness measurement

ABSTRACT:

Bridges are one of the vital and valuable engineer structure from decades. As they play a major role in the road transportation sector. Few old bridges lacks its documents about the measurements of the structure. The study has been carried out on three different types of bridges like Truss, Beam and Cable bridges. Documenting these bridges can be utilised to reconstruct or renovate the bridge in case of any disaster or damage. 3D documentation is made from the point cloud Dataset acquired from Terrestrial Laser Scanner - TLS (Riegl VZ 400) and Close Range photogrammetry – CRP (Nikon DSLR 5300). TLS and CRP point cloud are merged together to increase the density of points. Over the duration of time the bridge gets older and due to the load on the bridge deck, linearity in the deck effects and this linearity deformation measurement is important to know the present deformation in the deck. To know exactly at which part there is more linearity deformation, deflection is calculated at sample intervals between the present linearity conditions of the deck to the idle linearity conditions of the deck. The bridge deck thickness is also measured with the point cloud dataset. A slice is cut through the deck of point cloud dataset, the difference between the top and bottom layer of the deck gives us the thickness of the deck including the road. This thickness can be used to measure when a new deck layer is constructed or during filling up of any potholes. This study is mainly focused to help the construction and maintenance authority, bridge monitoring department and researchers.

1. INTRODUCTION

Different engineering structures have different roles in the modern day to day life. Bridges play a major role in connectivity between two sides. In this study three different types of bridges are focused which are Truss Bridge, Beam Bridge and Cable Bridge. Digital documentation is very reliable method for storing the geometrical information for longer duration of time. Due to heavy traffic conditions and harsh environments bridge deterioration takes place which can be monitoring using non-contact technique like Terrestrial Laser Scanning (TLS) and Close Range Photogrammetry (CRP). Many researches has been carried out for generating photorealistic 3D models using TLS and CRP which includes documenting A'Famosa Fortress, Porta de Santiago, Malaysia, (Wei, Chin, Majid, & Setan, 2010). Joint use of TLS and Photogrammetry is used to enhance the position of the edges and linear surface features. Also generating a 3D virtual model for documenting of Al-Khasneh, Petra, Jordan (Alshawabkeh & Haala, 2006). An automatic approach for efficiently monitoring the status of buildings under construction like as-built dimension calculation and control can be done with the help of CAD models generated from lidar scans. The approach is made more efficient by increasing the registration quality by point matching method which uses iterative closest point (ICP) algorithm (Bosche, 2010). Bridge measurement documentation can be done with the help of TLS which is fast , safe and applicable to different weather conditions (Truong-Hong & Laefer, 2014). An automatic approach of workflows have been used to extract the minimum under clearance of Bridges using

laser point cloud data (Tang & Akinci, 2012). A case study to find where the minimum under clearance and the geometry of a pre-stressed concrete beam is monitored with TLS and verified with total station for its accuracy in the paper (Riveiro, González-jorge, Varela, & Jauregui, 2013). TLS has also been used to estimate Stress on a beam structure when subjected to a concentrated load and the structural responses were monitored with finite element analysis (Lee & Park, 2011).

2. STUDY AREA AND DATA ACQUISITION

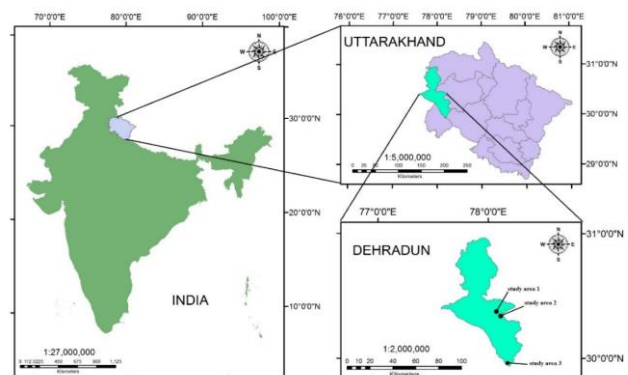


Figure 1: Study Area Map

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Three different types of bridges (Truss, Beam and Cable) were selected for this research. Their locations has been shown in the figure 1.

All the study area and the pointcloud dataset with the number of scans and images are tabulated in the table 1.

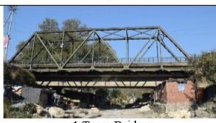
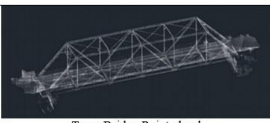


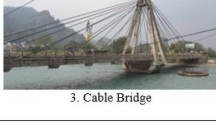
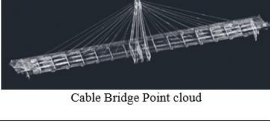
Study area	Point Cloud Dataset	No. of Scans and Images
 1. Truss Bridge	 Truss Bridge Point cloud	7 Scans 371 Images
 2. Beam Bridge	 Beam Bridge Point cloud	21 Scans 376 Images
 3. Cable Bridge	 Cable Bridge Point cloud	14 Scans 444 Images

Table 1: Bridges with Point Cloud datasets and the number of scans and images acquired

3. METHODOLOGY, INSTRUMENT'S AND SOFTWARE'S USED

The workflow that was followed during the research has been shown in the figure 2. The data was acquired from different scan positions. All the scans were co-registered together to form a single point cloud. Many overlapping images were captured at the study sites. All the images were aligned and Tie points were generated. Dense point cloud was generated with the help of Tie points. TLS and CRP point clouds were merged together. Noise and Outliers were filtered out from the merged point cloud. Then the required outputs were extracted. The values were validated with the help of laser distometer.

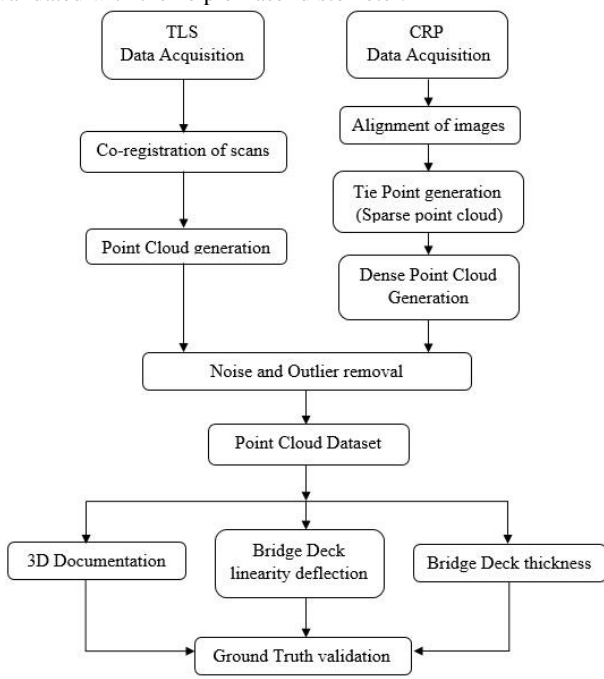


Figure 2: Methodology

TLS Point cloud was acquired with the instrument Riegl VZ 400 and RiSCAN PRO software further preprocessed in it. CRP point cloud was generated from the images in the Agisoft

Photoscan and further processed in Cloud Compare. The data was converted into AutoCAD format with the help of ReCap software.

Instrument used	Software's used
Terrestrial laser Scanner – Riegl VZ 400 Nikon DSLR D5300 Leica Distometer S910	RiSCAN PRO Autodesk ReCap AutoCAD 2018 Agisoft Photoscan CloudCompare

Table 2: Instrument and Softwares used

4. RESULTS AND DISCUSSIONS

Drawings of different views like top, bottom, side and front were extracted from different sections of the Point cloud and validated from the measurements obtained from Laser distometer.

4.1 Study area 1: Truss Bridge

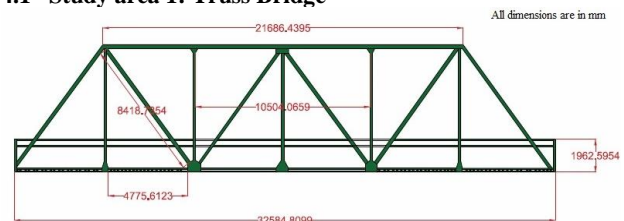


Figure 3: Side drawing of Truss Bridge



Figure 4: Top drawing of Truss Bridge

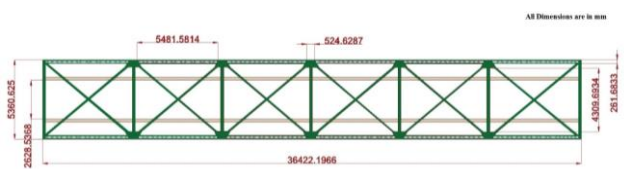


Figure 5: Bottom drawing of Truss Bridge

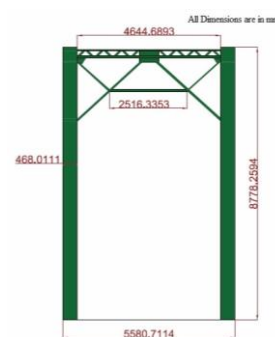


Figure 6: Front drawing of Truss Bridge

Some parts of the Truss Bridge are shown in the figure 7.

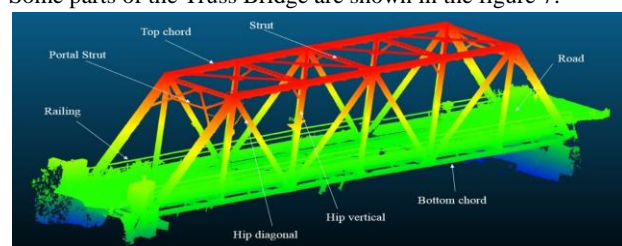


Figure 7: Parts of Truss Bridge

The measurements obtained from the point cloud and laser distometer with their difference and the mean error obtained are tabulated in the table 3.

Name of the Bridge component	Measurement in point cloud dataset (TLS + CRP)(m)	Measurement in Laser Distometer(m)	Difference between Measurements(m)
Top chord	24.124	23.989	0.135
Bottom chord	36.494	36.457	0.037
Hip vertical	6.389	6.360	0.029
Railing	36.559	36.598	0.039
Strut	4.638	4.573	0.101
Portal strut	4.680	4.572	0.108
Hip diagonal	8.496	8.588	0.092
Road width	4.694	4.705	0.011
Slab thickness	0.458	0.432	0.026
Vertical Hip width	0.109	0.106	0.003
Diagonal Hip width	0.177	0.150	0.027
Mean in the difference of the measurements			0.0552

Table 3: comparison of measurements of Truss Bridge

The deflections in the deck linearity is measured at different sample intervals between both the ends of abutment.

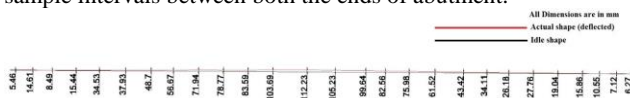


Figure 8: Truss Bridge deck linearity deflections

All the deflections obtained are shown in the graph format to easily identify the maximum deflection through out the deck. No support was present except the abutments at either ends of Truss Bridge deck.

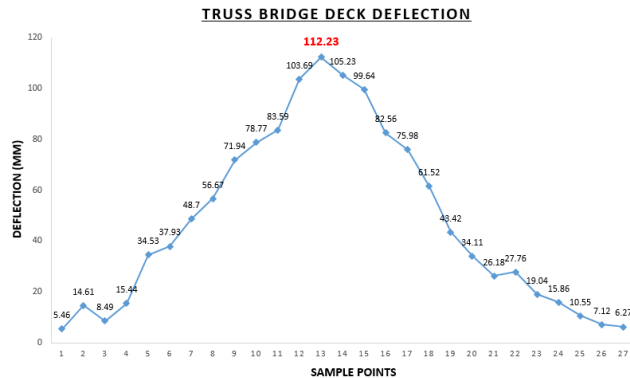


Figure 9: Truss bridge deck linearity deflection graph

The maximum Truss Bridge deck linearity deflection obtained is 112.23 mm shown in red.

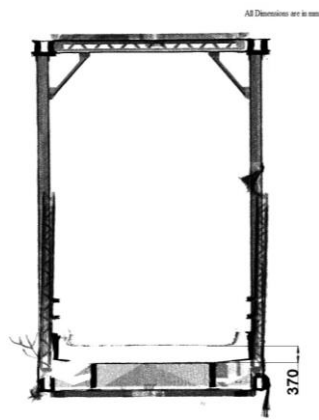


Figure 10: Bridge deck thickness of Truss Bridge

The Truss Bridge deck thickness obtained is 370mm.

4.2 Study area 2: Beam Bridge

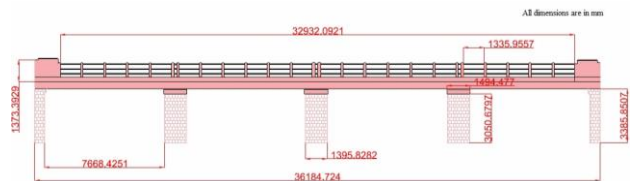


Figure 11: Side drawing of Beam Bridge

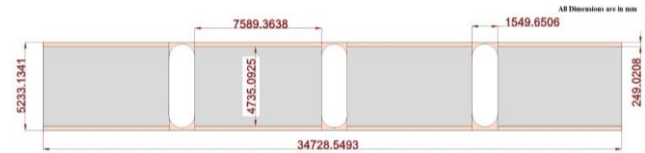


Figure 12: Bottom drawing of Beam Bridge

Some parts of the Beam Bridge are shown in the figure 13.

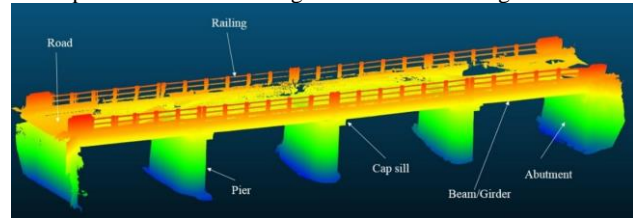


Figure 13: Parts of Beam Bridge

Name of the Bridge Component	Measurement in point cloud dataset (TLS + CRP)(m)	Measurement in Laser Distometer(m)	Difference between Measurements(m)
Beam length	35.951	35.941	0.010
Beam thickness	0.425	0.413	0.012
Beam width	3.752	3.698	0.054
Railing	32.830	32.817	0.013
Cap sill width	1.399	1.368	0.031
Cap sill thickness	0.280	0.273	0.007
Cap sill length	5.160	5.096	0.064
Pier width	1.280	1.256	0.024
Pier height	3.302	3.301	0.001
Mean in the difference of the measurements			0.0241

Table 4: comparison of measurements of Beam Bridge

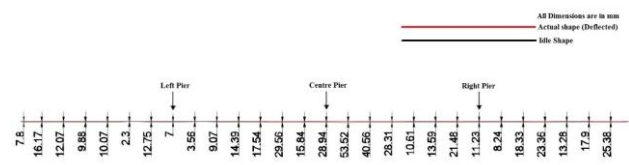


Figure 14: Beam Bridge deck linearity deflections

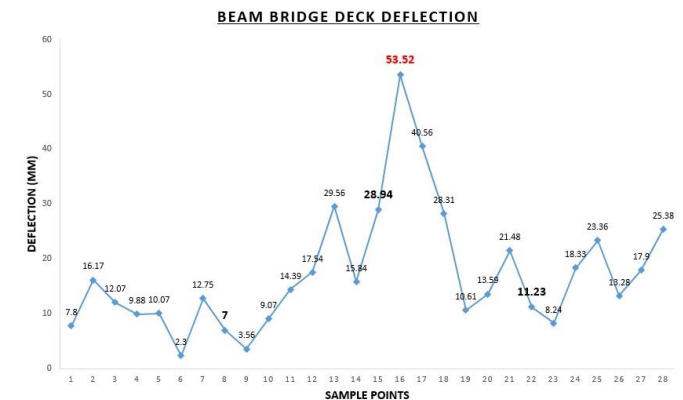


Figure 15: Beam Bridge deck linearity deflection graph

In the figure 15, the bold black values corresponds to the deflection at the left, centre and right piers of the Beam Bridge. The maximum Beam Bridge deck linearity deflection obtained is 53.52 mm shown in red at the right side of the centre pier.

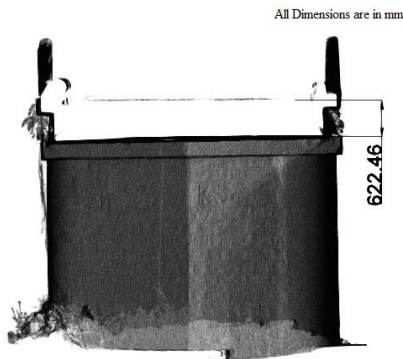


Figure 16: Bridge deck thickness of Beam Bridge

The Beam Bridge deck thickness obtained is 622.46 mm.

4.3 Study area 3: Cable Bridge

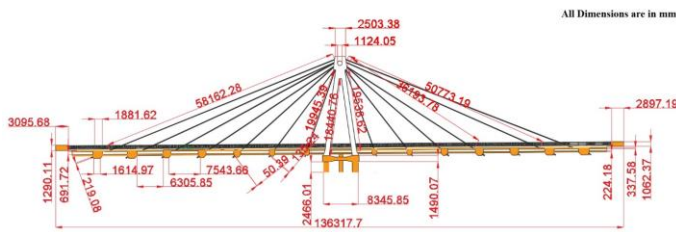


Figure 17: Side drawing of Cable Bridge

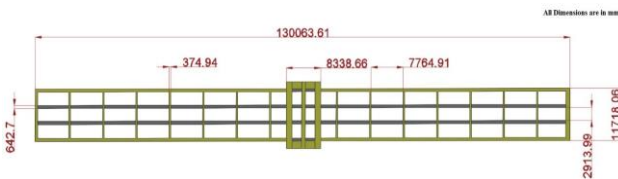


Figure 18: Bottom drawing of Cable Bridge

Some parts of the Cable Bridge are shown in the figure 19.

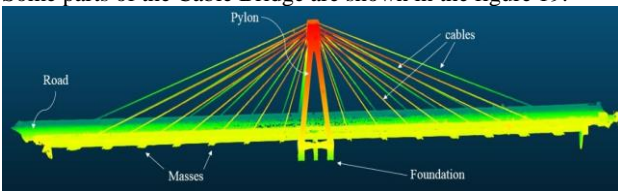


Figure 19: Parts of Cable Bridge

Name of the Bridge Component	Measurement in point cloud dataset (TLS + CRP)(m)	Measurement in Laser Distometer(m)	Difference between Measurements(m)
Pylon height	20.932	20.846	0.086
Pylon thickness	1.051	1.042	0.009
Road width	7.564	7.501	0.063
Foundation length	5.352	5.306	0.046
Foundation height	1.283	1.279	0.004
Foundation width	8.361	8.343	0.018
Deck length	130.354	130.329	0.025
Distance between neighbouring masses	6.012	5.996	0.016
Mean in the difference of the measurements			0.0333

Table 5: comparison of measurements of Cable Bridge

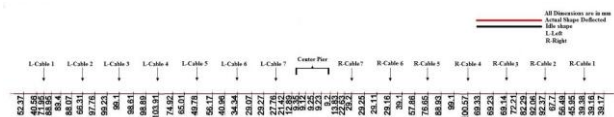


Figure 20: Cable Bridge deck linearity deflections

In the figure 21, the bold black values corresponds to the deflection at the left cables, centre foundation support and right cables of the Cable Bridge. The maximum Beam bridge deck linearity deflection obtained is 103.91 mm shown in red at the 4th left cable joint with the deck.

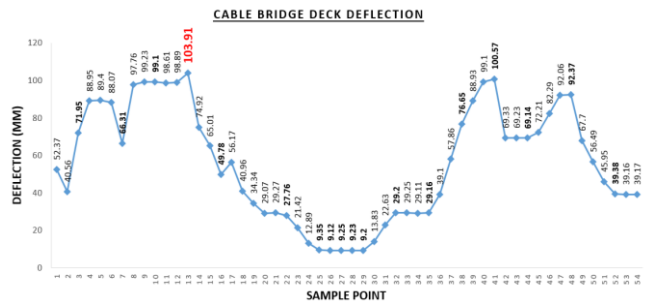


Figure 21: Cable Bridge deck linearity deflection graph

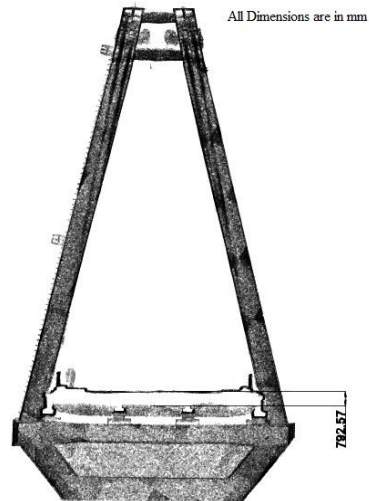


Figure 22: Bridge deck thickness of Cable Bridge

The Cable Bridge deck thickness obtained is 792.57 mm.

5. CONCLUSIONS

The 3D digital documentation prepared can be stored for longer time period and can be used for reconstruction or renovation. The mean difference between the measurements obtained from the TLS and CRP point cloud dataset with the laser distometer for the Truss, Beam and Cable Bridges are 0.0552m, 0.0241m and 0.0333m respectively. The deck linearity deflection can be used to monitor it timely. The maximum bridge deck linearity deflection obtained for Truss Bridge is 112.23 mm at the centre of the deck, Beam Bridge is 53.52 mm at the right side of the centre pier and Cable Bridge is 103.91 mm 4th left cable. The deck thickness measurement is an important factor to monitor the construction of deck or when a new layer of road is to be constructed. The bridge deck thickness obtained for Truss, Beam and Cable bridges are 370 mm, 622.46 mm and 792.57 mm respectively.

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