International Journal of Architecture and Infrastructure Planning
Vol. 1: Issue 1
www.journalspub.com

Digital Documentation Techniques as Tools for Conservation of a Buddhist Stupa through Virtual Reconstruction

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Abstract

In recent times, much advancement has taken place in digital reconstruction in architectural conservation and archaeology. The application of these techniques opened up new insights in understanding the intricacies involved in the field of heritage conservation. This paper discusses various challenges posed in the restoration of a rare 3rd century BC Buddhist "Stupa" at Sannati, Kanaganahalli Village, India unearthed by Archaeological Survey of India. The author has been involved in documentation of the monument and preparation of Heritage Conservation Plan and presents the different techniques of observation, data recording, condition assessment and digital reconstruction of the monument to ascertain the original form of the structure which is at present in a ruined and scattered condition. The paper throws light on the techniques of photogrammetric documentation, long range and short range laser scanning techniques and manual measurement techniques exclusively devised for this kind of situations. Also the paper compares the pros and cons of these techniques and elaborates on their applications in different contexts.

Keywords*: Buddhist heritage, heritage conservation, digital documentation, virtual reconstruction, photogrammetry.*

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INTRODUCTION ABOUT SANNATI STUPA

Sannati, which is a relatively lesser known small village to even the well-informed common man, is a very important discovery for archaeology, art history and by and large to the Buddhist World from the excavations under taken by Archaeological Survey of India during 1998–2002. There is no exaggeration in describing it as the rarest of rare gems in terms of missing link in completing the understanding of Buddhist heritage of the period (Figure 1 and 2).

Fig. 1: *Excavation Site of the Great Adholoka Maha Chaitya at Kanaganahalli.*

Fig. 2: *The Great Muchilinda Naga as Relief Sculpture Cladded to Western Ayaka Platform.*

The stupa built in various stages of time originally during 3rd century AD by the great Emperor Asoka and subsequently enlarged by patronage of various successors and patrons is a fine architectural marvel done in limestone. The stupa has a drum portion with lower and upper portions separated by a small *medhi* (circumambulatory path) totally measuring upto a height of the present ruins of 4m height with the limestone cladding of lower drum panels being roughly square in shape measuring 1.40 m X 1.25 m and four *ayaka* platforms in the cardinal directions. The *ayaka* platforms are adorned with a highly intricate relief-carved limestone panels depicting the various important Buddhist symbols, mythical representations of the great *Muchalinda* N*aga yakshi sree*, *vajrasana* and many important iconographic representations of early Buddhist period of *theravada* or *hinayana* Buddhism.

CHALLENGES IN DOCUMENTATION OF SANNATI STUPA

a.

b.

Fig. 3(a, b): *Present Status of Stupa Site with Its Scattered Architectural Members.*

The great stupa at Sannati has been covered under debris for nearly fourteen centuries and was found accidentally during an archaeological excavation. There was continuous agricultural practice on this mound for centuries before excavation. The possible cause of dilapidation according to the field archaeologists is due to a massive earthquake that happened sometime in 6th century AD (Figure 4(a, b)).

One can imagine the state of ruined condition of various parts of stupa from the photographs above and enormous challenges that it poses in documenting the stupa in "as – is" condition before any conservation efforts are made. After thorough investigations of the site conditions and initial assessment of the all the components of stupa, it has been decided to engage different methods of documentations have to be adapted for different applications. Following documentation techniques were adopted:

1. Manual measuring and recording systems
2. Photogrammetric techniques
3. Long range laser scanning techniques
4. White light scanning techniques

Main applications that were envisaged were assessment of possible full extent of stupa in its original condition, preparation of complete inventory of the material that is available at site as of today, condition of

the components, mending techniques of broken members of stupa, preservation and conservation of the stupa. Apart from this, the efforts to understand the historic significance in terms of architecture of Buddhist heritage from 3rd century BC as well as iconographic, epigraphic, philosophical and spiritual aspects of the site were considered[1].

Manual measuring and recording system

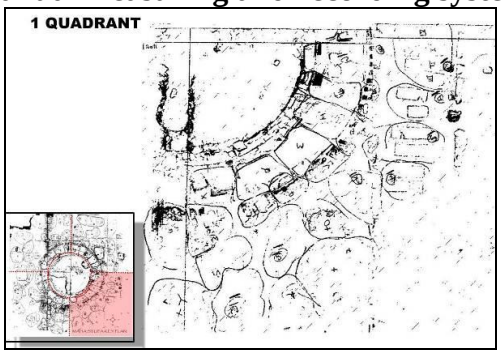


Fig. 5: *Showing Key Map of Stupa With One Quadrant Enlarged.*

Fig. 6: *Key Map of One Quadrant and One Cluster Enlarged.*

A simple numbering system was developed dividing the entire site into four quadrants and each quadrant into clusters as shown in the diagrams above (Figure 4 and 5). A detailed stone-by-stone inventory has been recorded with tabulation of physical measurements, description of the status, condition assessment and detailed photographs[1].

PHOTOGRAMMETRIC DATA

A photo-based scanning and re-creation of the objects for detailed capturing of three dimensional data was employed. Parallel photographs were taken from specified distances and angles with calibrated cameras using targets of specified sizes and location for this purpose. These photographs were processed using computer-aided programs to generate a point-cloud data, high-polygonal meshes were generated and superimposing of the photographic data was done to get the three dimensional model of the sculptural object (Figure 6, 7(a, b, c) and 8).

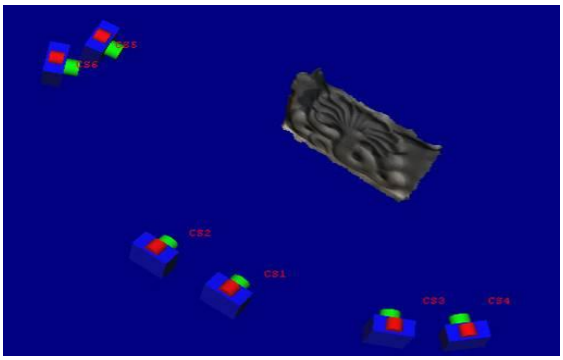
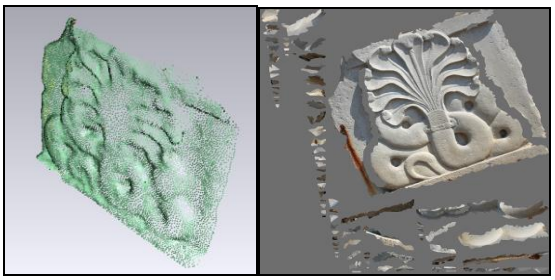
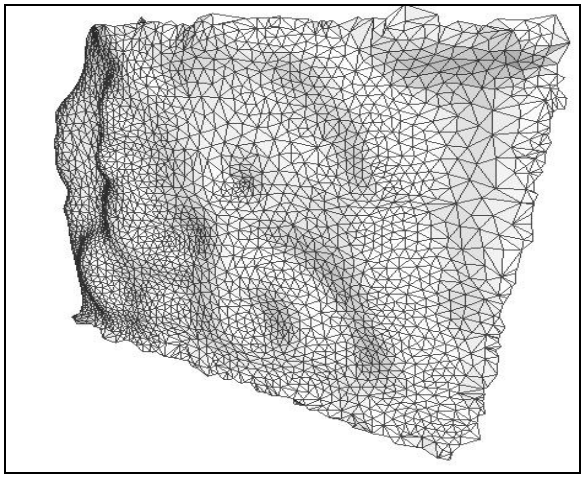


Fig. 7: *Technique for Photogrammetric Data Recording.*



a. **b.**



c.

Fig. 8: a: *Point-Cloud Data Generated for One of The Panels;* ***b:*** *TIFF Image Generated From (a);* ***c:*** *Mesh Generated From (a).*

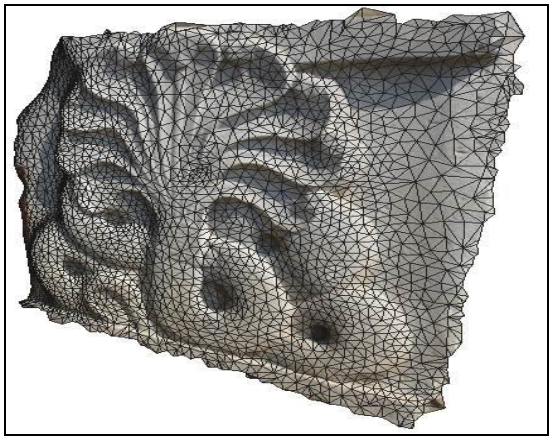


Fig. 9: *Superimposing of Photographic Information onto the Mesh.*

APPLICATION OF PHOTOGRAMMETRIC DATA

The data acquired from the photogrammetric techniques is used for assessment of the exact size and quantity and primarily used to virtual assembling of the various scattered parts in corroboration with archaeological, iconographical, epigraphical and circumstantial information to re-assemble in original condition[1, 2].

Long Range Laser Scanning

The entire site measuring approximately 90 m 100 m size to using a Faro long range (60 m range) scanner with 27 multiple station-points and finally integrated to obtain the point-cloud data to an accuracy of 2 mm (Figure 9).

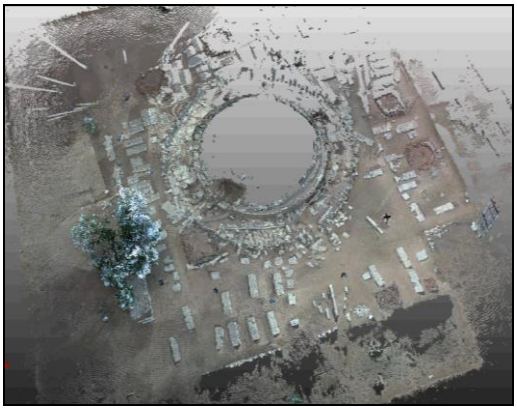


Fig. 10: *Image of Point-Cloud Data Obtained From Long-Range Laser Scanning.*

This enormous point-cloud data generated has been used to prepare the overall master plan for numbering and sliced up to generate information to micro-level to ascertain the geometry, structural details and overall condition-assessment of the stupa (Figure 10, 11 and 12).

Fig. 11: *Sliced-up Point-Cloud Information for a Panel.*

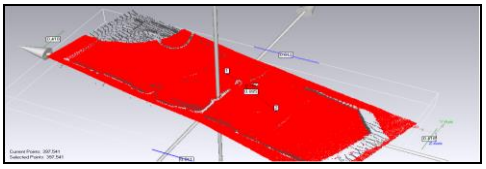


Fig. 12: *Point-cloud Data Used to Ascertain Dimensional Information in X-, Y- and Z-axes.*

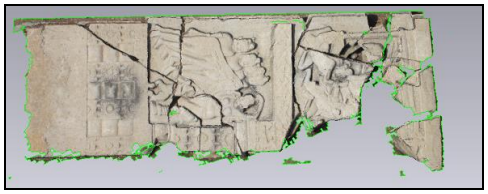


Fig. 13: *Photographic Information Superimposed for Enriched Visual Representation.*

APPLICATIONS OF LONG RANGE SCAN DATA

The reduced data has been very useful to obtain very great detail of dimensional information and using different software, the information has been converted into dense mesh. This information has been stitched together using digital sculpting software to ascertain the missing links to arrive at possible original state of the sculpture. As the data available had no textures the photographs after being rectified for perspective distortion from photogrammetric data has been superimposed to get more realistic appeal[1, 2].

SHORT RANGE LASER SCANNING FOR DETAILED RECORDING

For further detailed studies of micro level information measuring 50 microns and below, a white light scanner was used. Due to enormity of the information generated, the objects were mapped using multiple scans and the data has been compiled to get very detailed information to achieve detailed dense meshes (Figure 114).

Fig. 15: *Detailed Dense Mesh of Panel Depicting Emperor Asoka.*

APPLICATIONS OF WHITE LIGHT SCAN DATA FOR ROBOTIC MILLING

The data of short range white light scans is converted to machine program for obtaining various tool paths for different milling bits and using a seven-axis robotic arm milling machine (Figure 14, 15 and16), the data has been used to replicate the precious sculptural details using limestone of similar composition to the original construction material used in the ancient stupa[1, 2].

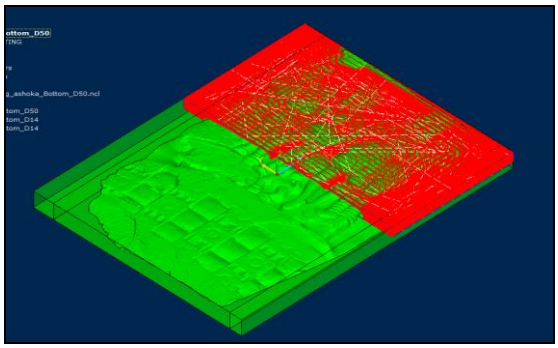


Fig. 16: *Machine Tool-Path for Milling Using 50 mm Drill Bit for Initial Rough Cut.*

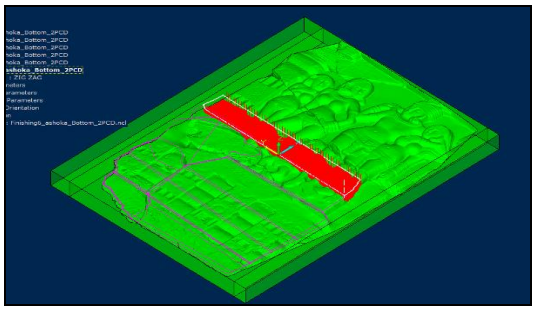


Fig. 17: *Machine Tool-Path for Milling Using 1 mm Drill Bit for Fine Cut.*

Fig. 18: *Panel Replica Produced By Milling.*

DATABASE PREPARATION

The data procured using traditional manual survey techniques, photogrammetric techniques and laser scans have been compiled to prepare a data base for various applications like numbering of the artefacts, details of various components of the structure, condition-assessment of the members of structure, virtual reconstruction of the structure and reproduction of certain important sculptural members of the monument.

CONCLUSIONS

1. The following conclusions are deduced from this study:
2. The site has been thoroughly investigated and a detailed database of the existing artifacts, structural members and ancillary members of the structure are recorded.
3. A comparative compilation of the various techniques of documentations and their relative merits and demerits has been obtained.

4. After studying the pros and cons of each technique, the results have been applied for appropriate remedial measures.

ACKNOWLEDGEMENTS

We wish to thank the Archaeological Survey of India for the opportunity to work on this rare and important site. We wish to specially acknowledge the enthusiastic support and guidance of Dr. V. Halakatti, Superintending Archaeologist, ASI (Dharwad Circle). We are indebted to Mr. Dakshat Kidiyoor and Ms. Sneha Bakshi for valuable fieldwork, data collection and compilation. The photogrammetric images were prepared by Easwar, 3-D Scan Solutions. Mr. Harish Pawaskar of Harish Designs carried out the laser scanning work. M/s GTP, Salem carried out the milling work. We thank the ASI staff at Sannati for their hospitality and the students of MIT, MSRIT, Polytechnic College of Raichur and BVB, Hubli for on-site assistance. We thank our colleagues and well-wishers at MSAP, Manipal for discussions.

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