DEFORMATION SURVEY FOR THE PRESERVATION OF LEI CHENG UK HAN TOMB

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Abstract

The Lei Cheng Uk Han Tomb is so far the only instance of Eastern Han dynasty (A.D.25 - A.D.220) tomb found in Hong Kong. Due to its historical significance, the tomb was formally declared as a gazetted monument in 1988. In 1999, the survey division of the Civil Engineering Department, Hong Kong Special Administrative Region was requested by the Hong Kong Museum of History (HKMH) to survey the tomb chamber's details and monitor the tomb structure. The confined space inside the tomb does not allow a man of average height to stand straight comfortably. The dim environment and short sighting distance impose further difficulties when taking measurements. Moreover, drilling or any kinds of damage is strictly prohibited during the installation of control points and monitoring marks. All these site constraints made the task very challenging.

This paper describes the methodology and techniques used to monitor the differential deformation of the tomb structure. It also discusses how the incised patterns and inscriptions on the tomb bricks were recorded under a confined space environment.

1. Introduction

The Lei Cheng Uk Han Tomb was discovered in 1955 during the construction of the public housing estate in Lei Cheng Uk. The tomb resembles in many respects the structure of the other Eastern Han tombs discovered elsewhere in South China. The cross-shaped brick tomb consists an entrance hall and four chambers, namely front; rear; left and right chambers (Figure 1). The front chamber has a square base and a domed roof, while the left, right and the rear chambers have rectangular bases and barrel vaults. The major part of the entrance hall was however found destroyed when discovered. This has made the portrayal of the original appearance very difficult.

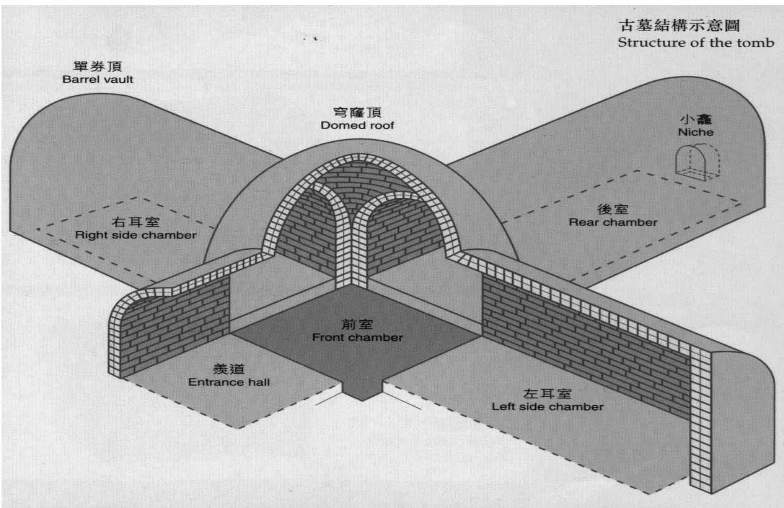


Figure 1: Structure of the tomb (Courtesy by HKMH)

The interior part of the tomb was kept open to the public till mid 80’s. Due to weathering over the past several decades, differential deformation occurred in many parts the tomb, in particular the vaults and the brick walls. To slow down the speed of deterioration, a glass screen is installed at the entrance hall to separate the interior part of the tomb from outside. Now, the tomb is sealed under a temperature and humidity controlled environment.

2. Survey Requirements and Site Constraints

The HKMH requested that the tomb needed to be monitored to an accuracy of ±3mm. Besides, a detailed plan of the brick walls with incised patterns and inscriptions at a scale of 1:500 was also required.

To prevent the tomb structure from further deterioration, the HKMH demanded that all personnel and equipment working inside the tomb must be well protected from damaging the floor. Besides, no drilling or any other kinds of damages that might occur during the installation of the monitoring marks were allowed. All these imposed constraints in placement of control stations and monitoring targets. The confined space (3.6mL x 1.4mW x 1.5mH) of the tomb chamber introduced further difficulties in survey operation (Plate 1). Illumination inside the tomb was too dark and sighting distance was so short that the theodolite could hardly focus for measurement to take place. This was particularly critical when sighting the dome roof at near-zenith angle. Furthermore, the glass screen at the entrance hall also restrained the monitoring stations from connecting to the survey network outside directly.

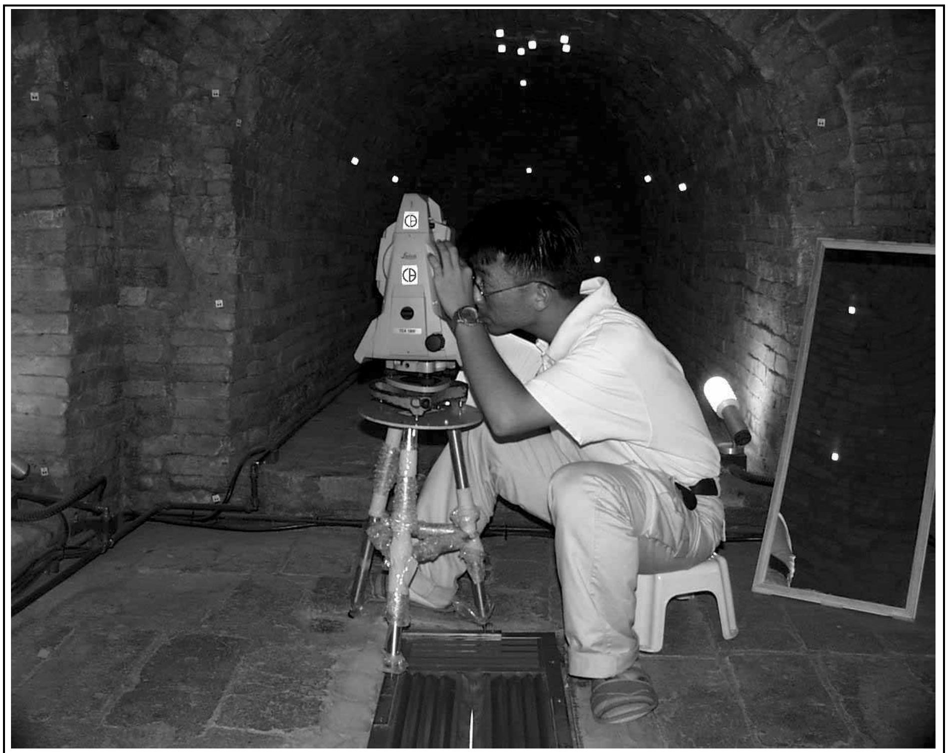


Plate 1: Observation inside the tomb

3. Monitoring Survey Scheme

Preliminary site investigation revealed that gravity and external soil pressure were the two major causes of deformation. The direction of movement was generally downward in the vaults part and inward in the sidewall. To detect the movement more effectively, the resultant settlement was resolved into three components parallel to the axes of the cross-shaped chambers (Figure 2). Monitoring marks were placed to enclose the suspected portions of the tomb. 3-D spatial intersection method is adopted to measure the corresponding changes in direction, vertical angle and distance. Detection of horizontal and vertical displacements larger than 3mm at the 95% confidence level was adopted as the accuracy criterion in designing the monitoring network.

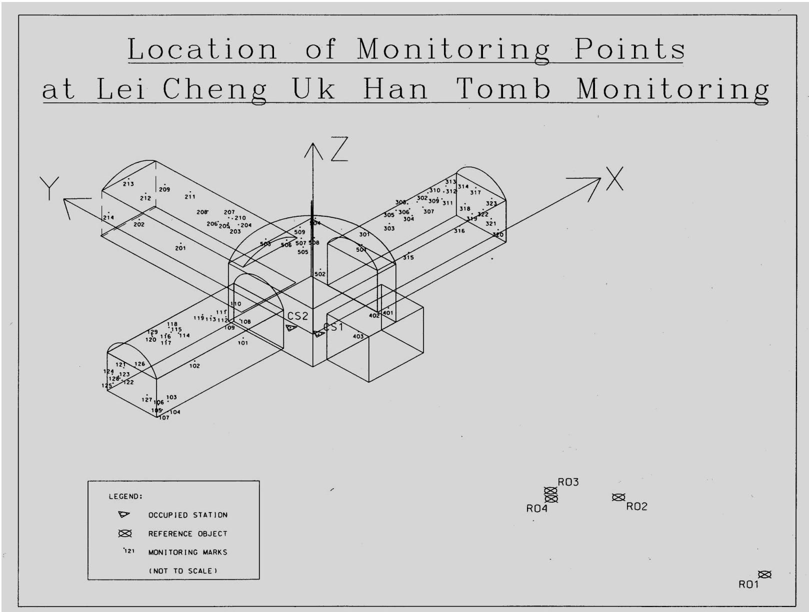
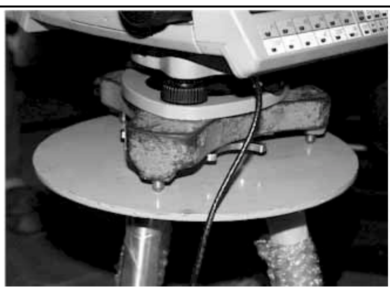


Figure 2: Location of monitoring points

3.1 Control Stations

As HKMH did not allow drilling or any other kinds of damage to the tomb, special attention was paid in the selection of control stations. Subsequent to repeated investigation and testing, a force-centering system (Plate 2 & 3) was designed to eliminate the instrumental centering error. The system comprises a 0.5m high tailor-made rigid tripod and two steel bars firmly mounted on the ventilation shaft. This whole set up together with the pillar plate and total station serves as the base station for subsequent monitoring observations.



Plates 2&3: Force-centering system

3.2 Instrumentation and Monitoring Marks

In selecting the most appropriate equipment to carry out the assignment, various types of measuring equipment were critically examined after taking account of their accuracy achievement and ease in operation. Despite the reflector-less total station had no target mounting requirements, it was eventually ruled out because of its relative low accuracy (±10mm) achievement. The Leica TCA1800 total station which is direct reading to 1 second and gives co-axial measured distance to ±1mm+2ppm was finally selected for this project. It is worthy to note that TCA1800 will give rise an error of ±3~4cm when the measured distance is shorter than 2.5 meters. To overcome the problem, a corrective short-range lens was applied on the telescope to modulate the measuring signal.

Traditional mini-prism was considered not feasible in this project because the anchorage of the prism would inevitably damage the wall face and the prism weight (39g each) would induce additional loading to the wall. Instead of the mini-prism, light-weight Nikon retro-reflector tapes mounted on supporting aluminum plates (3g each) were stuck around some critical points on the wall face (Plate 4). The only pity was that the automatic target recognition mode of TCA1800 did not work with the retro-tape that made the tedious manual bisection process unavoidable.

3.3 Observation Scheme and Deformation Results

After installing the 2 force-centering bars; 78 monitoring marks and 4 reference objects, sufficient time lapse was left to let the marks became stable. The arithmetic means of different sets of reading taken on two consecutive days were adopted as the initial reference values. Since October 1999, more than 12 sets of observation have been taken and it shows no apparent movement on of the tomb wall. The maximum magnitude recorded (Table 1) are well within ±3mm and hence be considered as the noise of survey observation.

Chamber	Dome Vault			Left Wall			Right Wall			Back Wall		
(mm)	dx	dy	dz	dx	dy	dz	dx	dy	dz	dx	dy	dz
Front	+1	-2	+2	-	-	-	-	-	-	-	-	-
Left	-2	-1	-1	-1	-1	-1	-1	-1	0	-3	+1	-1
Right	+1	-3	+1	+2	+1	0	+2	+1	0	+1	-2	-1
Rear	+1	+2	+1	-1	+1	-1	+1	+2	-1	+1	+3	-1
Entrance	0	-2	0	+1	-3	+1	-1	-3	0	-	-	-

Table 1 : Maximum deformation values recorded

4. Close Range Photography

The another objective of the project was to record the incised patterns and inscriptions of the tomb wall. With the assistance from the Photogrammetric and Air Survey Unit of Lands Department, close range photography was carried out to produce orthophotos at scale of 1:500. In view of the confined space and unique structure of the tomb, placing of targets palettes, camera positions and number of exposures have to be carefully planned for sufficient overlapping.

4.1 Photo Capture

In this exercise, an Hasselblad MKWE metric camera equipped with the Biogon 38mm super-wide angle lens was used to capture the interior wall face. As the photographs needed to be linked up to form contiguous stereoscopic pairs, target palettes were stuck at pre-defined positions to serve as the controls as well as tie points. To begin with, the camera positions were first determined based on the object distance, film format size and lens focal length (Figure 3), i.e.

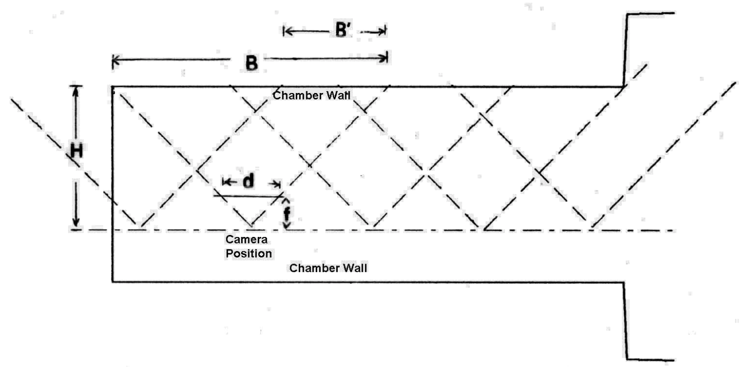


Figure 3: Wall coverage and camera position

$B/H = d/f$ where, B = wall coverage

$B = 1.00 \times 0.053 / 0.038$ H = Camera distance from wall, 1.00m

$= 1.395m$ d = film format, 53mm x 53mm

f = lens focal length, 38mm

For a 70% overlapping, the effective ground coverage, or the camera separation will be:

$B' = 1.395 \times 0.3 = 0.418m$

Hence, the target palettes should be placed 0.42m apart and along the cross-sectional plane on the double overlapping area (Figure 4). In order to take a three-dimensional photography, the camera was again tilted 45 degrees upward to capture the barrel vaults of the three chambers.

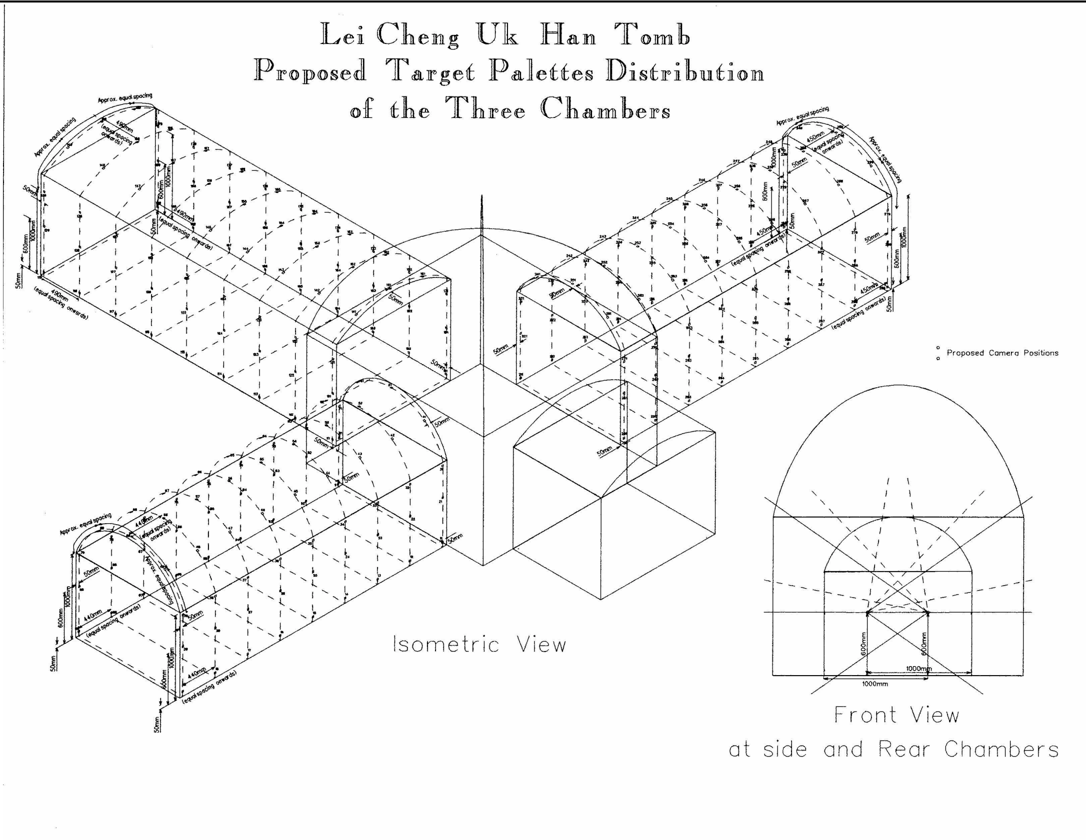


Figure 4: Distribution of target palettes

In capturing the details on the curve surface of the domed vault, the range of object distance varied significantly that the depth-of-field question should be critically examined. To ensure the sharpness of every single detail on the whole photograph, a small aperture value, say smaller than f/16, was used to achieve the greatest depth of field. Besides, bracketing technique of ±1Ev on each standard exposure was applied to ensure that the best photo performance was captured.

4.2 Results

To give a rough idea on the effort spent in this project, nearly 400 photographs had been taken at 76 camera positions. The films together with the camera lens information were sent to the Photogrammetric and Air Survey Unit of Lands Department for scanning and subsequent processing. These photo images were then used to form a digital terrain model and 41 orthophotos (Plate 5 &6) of the tomb at a scale of 1:500.

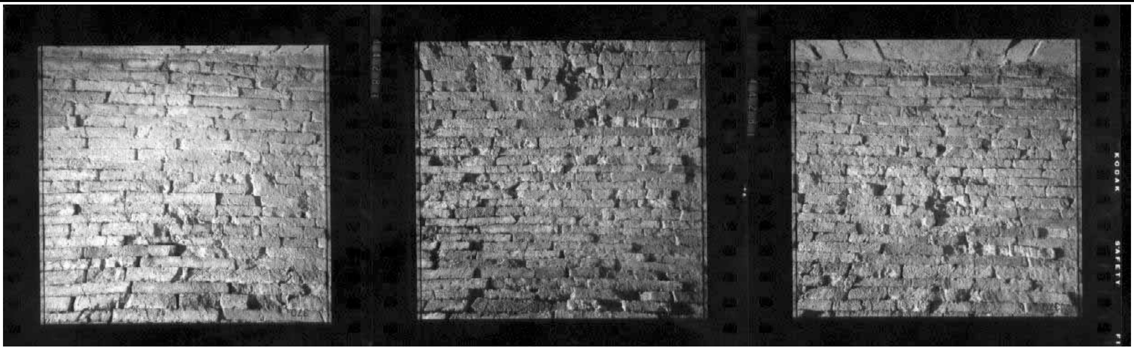


Plate 5: Photographs forming stereo pairs

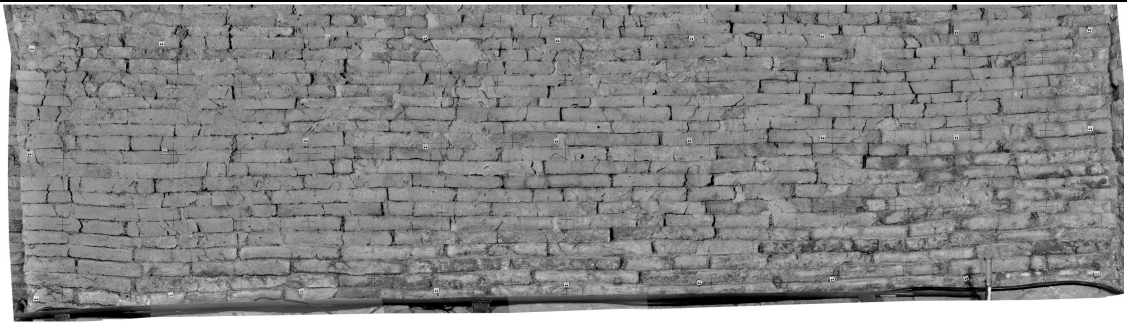


Plate 6: Orthophoto

6. Conclusions

This monitoring survey has set up a mechanism to check the structural conditions of the tomb in quantifiable terms. The survey accuracy conforms to that predicted in the network pre-analysis. Manual bisection to the target points is necessary since the automatic target recognition mode of the TCA1800 does not function with the retro-tape reflectors. Nevertheless, it is proven to be effective for the job on the whole. The observation results of the past one year revealed that there has been no apparent settlement on the tomb since October 1999. In view of this, the frequency of this monitoring exercise is now revised from monthly to quarterly intervals.

The close range photogrammetry provides a new perspective to study the pattern and inscriptions of the wall bricks. This method has the advantage over other traditional mapping means in the way that the metric photographs are rich in semantic which can be evaluated at any time with high repeatability. The orthophotos and digital terrain model produced in this exercise make the portrayal of the tomb interior appearance possible in digital form.

Unlike the heritage itself which we try to keep it unchanged, the technology used to monitor deformation is on the contrary, dynamic and ever improving. In this context, the survey division of Civil Engineering Department will continue to explore some other more effective means such as laser scanning technology to achieve the objectives in the future.

Acknowledgments

Special thanks are extended to the colleagues of Photogrammetric and Air Survey Unit, Lands Department in providing assistance to process the photographs and the subsequent orthophoto production work.