3-D Controlling Technique using CAD System for Cenotaph Restoration in Hiroshima Peace Memorial Park by Close-range Photogrammetry

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Commission V

1. Introduction

The cenotaph built in 1952 in the Hiroshima Peace Memorial Park as a symbol of Hiroshima's prayer for world peace has been damaged by years of outdoor exposure and the City of Hiroshima decided to rebuild it in granite.

In this restoration project, special considerations were needed on the following.

In the first place, because of the basic concept of restoration of the existing shape of the cenotaph, the existing shape must be measured accutately and efficiently by means of some non-contact method. To meet these requirements, the use of photogrammetry was decided.

In the second place, because the structure will be changed from the prsent reinforced concrete to granite masonry, the original sectional areas must be modified to compensate for the reduced strength and the shape of the interior wall must be modified. In addition, since the visual exterior wall shape must fully represent the designer's concept, the utilization of the CAD(Computer Aided Design) system capable of 3-dimensional representation was decided.

The investigation and analysis were executed in accordence with the flow chart of Fig. 1. In the phase of concrete basic plan preparation for cenotaph restoration, opininons were closely exchanged with the designer and work was executed on the basis of agreement.

2. Cenotaph rebuilding basic plan

The basic plan was based on the following concepts:

2-1 The existing exterior shape should in principle be restored.

2-2 The structure should be changed from the existing reinforced concrete to granite masonry, to secure high weather resistance.

2-3 The wall thickness in the central section should be increased by 140 mm bulging inward, as shown in Fig. 2 to adopt to the new structure.

3. Photogrammetry

Photogrammetry is a process for measuring the shape of the object in the 3-dimensional space, on the basis of plane shapes in the form of photographs. In other words, it is a method of obtaining the 3-dimensional shape of the object from the photographed 2-dimensional images.

In these photographs, also, at least 4 to 6 accurately measured control points are photographed, to allow the position and the angular position of the camera to be calculated.

These stereoscopic photographs are processed in a coordinate measuring device called the analytical plotter and the 3-dimensional coordinates of the image points are calculated by the computer.

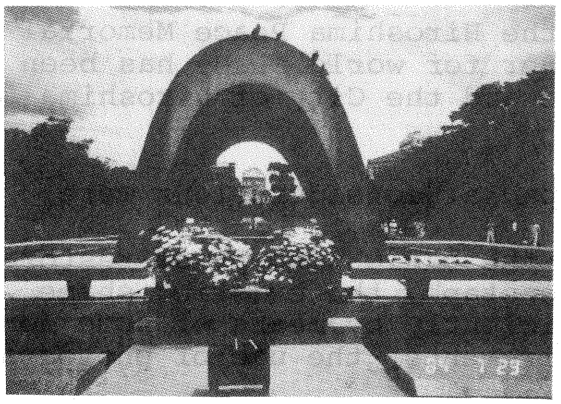


Photo 1 Old Cenotaph

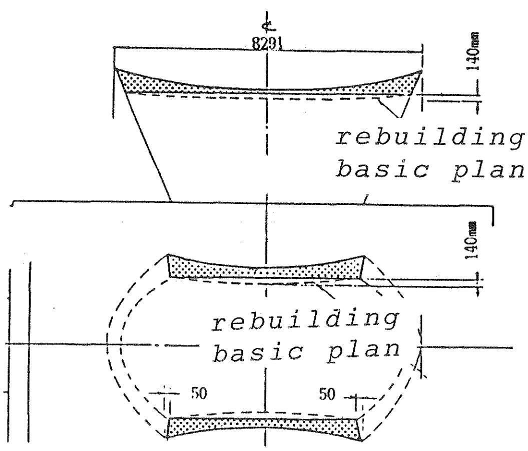


Fig. 2 Cenotaph rebuilding basic plan

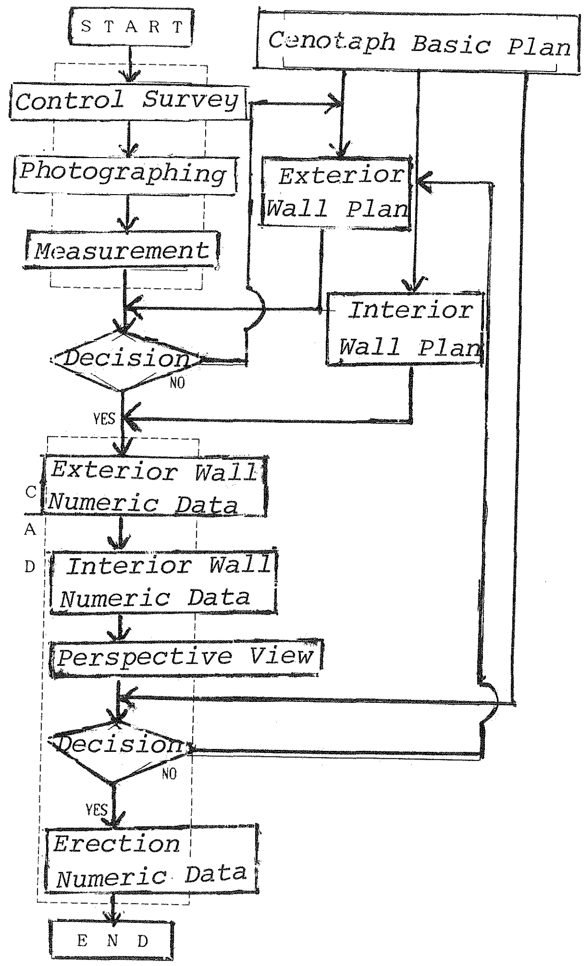


Fig. 1 Flow Chart of Work Process

3-1 Setting of Control Points

In the photogrammetry, the ground coordinates of the objects are obtained on the basis of the photographed photographic coordinates of the objects. For this, first, the coordinate conversion formula between the photographic coordinate system and the ground coordinate system must be determined. For this purpose, the marks shown in Fig. 3-1 were attached to the cenotaph for photographing. Fig.3-2 shows the positions of targets.

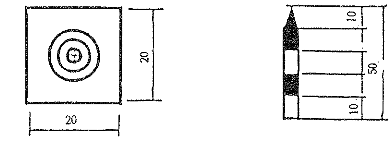


Fig.3-1 Target(unit:mm)

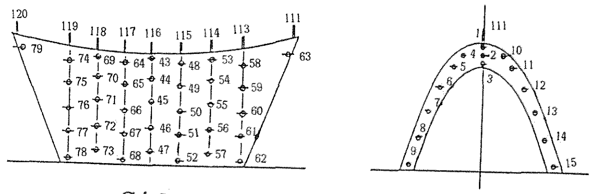


Fig.3-2 Setting position of targets

3-2 Surveying of control points

The installed marks were all measured by the method of intersection on the basis of the measuring base lines.

3-3 Photographing

The terrestrial photogrammetry camera is in two major types; the single camera and the stereoscopic camrea. For the present project, a single camera UMK 10/1318 of Zeiss Jena was used. The distance between the object and the camera, or the measuring distance, has great influence on the plotting accuracy; when too narrow, stereoscopic viewing is difficult, and when too far, distance perception is weak. Generally, the measuring distance is selected between 3 to 20 times the base length of the stereoscopic camera as practically feasible

3-4 Plotting and measurement

For the measurement process, a planicomp precision analytical plotter made by Carl Zeiss, FRG was used. This device consists of a coordinate measuring unit for accutately measuring the coordinate values of the photographed image on the plate and a computer for analytically calculating the actual 3-dimensional positions of the image on the basis of the measured coordinate values. In the actual measuring process, the analytical process utilizing several points for which the 3-dimensional coordinate values had been determined by the control points measuring was employed. As a prerequisite condition for calculating the 3-dimensional data by the computer relative to the ground coordinate system, the intersecting point of each pair of stereoscopic model pictures can be checked. In the present measurement, this parallax was more or less between 1 and 5 microns. The errors of the final ground coodinate values of all the sections given by the computer as determined by comparison with the data obtained from the known actually measured data are influenced by the coordinate measuring error on the plate, conversion error in the relative orientation, lens physical error, the plate resolution, pressing error, etc. The followings are a partial coordinate error combining all these error factors. (see Table 1)

4. Application of CAD system

In the series of the cenotaph rebuilding works, a CAD system

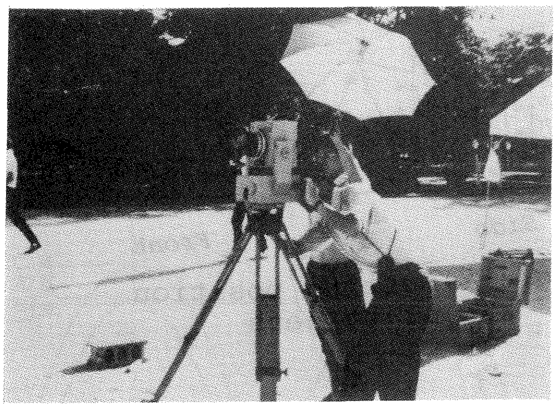


Photo 2 Camera UMK 10/1318)

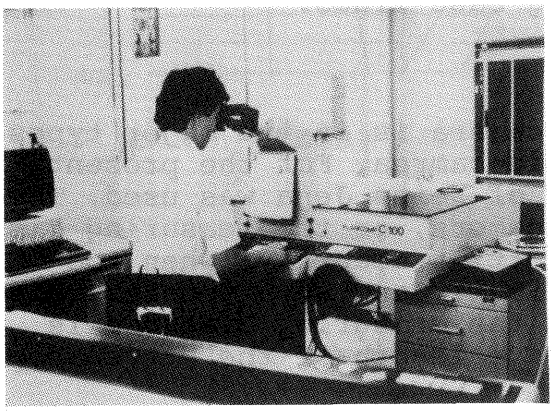


Photo 3 Analytical Plotter (Planicomp C-100)

HIROSIMA (NISI) 12M
RELATIVE ORIENTATION

WITH LEFT PHOTO FIX IN ORTHO MODE
MEASURED FY-POINTS:
USING 16 PARALLAXE POINTS

COMPUTATION BY 1 ITERATIONS
SIGMA 0= .001

RESIDUAL PARALLAXES IN PHOTO 残差縦視差

POINT	Y-PARALLAXE
1	.002
2	-.004
3	.002
4	.001
5	-.003
6	.001
7	.001
8	-.001
10054	-.000
10057	-.000
10046	-.000
10073	.000
10071	.000
10120	-.000
10116	-.000
10111	-.000
MEAN	.002
平均二乗誤差	002

単位：mm

COMPUTATION WITH 8 CONTROL POINTS

COMPUTATION BY 2 ITERATIONS 測地座標誤差
SIGMA 0= .004

RESIDUALS AT CONTROL POINTS AFTER ABSORIENT

I	POINT	DXG	DYG	DZG
1	10111	-.007	.003	-.006
2	10116	.002	.001	-.003
3	10120	-.002	.007	.001
4	10071	.003	-.000	.003
5	10073	.001	-.001	.001
6	10046	.000	-.003	.001
7	10057	.000	-.004	.001
8	10054	.002	-.002	.002
	MEAN	.003	.004	.003
	平均二乗誤差	.003	.003	.003

西　面

Table 1 Error of sectional coordinate values

4. Application of CAD system

In the series of the cenotaph rebuilding work, a CAD system was utilized for the following purpose:

(1) The numerical data alone obtained from the photogrammetric process is not sufficient to know the 3-dimensional shape fully. Perspective views from any desired viewpoints and other views must be displayed on the screen to allow the designer to easily recognize the 3-dimensional shape and to facilitate correction.

(2) As mentioned earlier, the cenotaph must have 14 cm thicker wall at the middle section, bulging inward, than the existing shape. The new wall must have the correct thickness, and at the same time, it must be visually satisfactory to the designer.

(3) The quarrying process included in the erection work requires wood patterns, and to make them, numerical data for any desired section is required.

4-1. External wall numerical data processing

A very good conformance between the external wall numerical data obtained from photogrammetry and the rebuild cenotaph design specification based on the basic design was ascertained.

As you can be seen from the contour map, the existing cenotaph has very well retained the symmetrical shape. On the basis of these two observations, the designer came to the conclusion to use the existing shape of the cenotaph, without modification, as the exterior shape of the rebuilt cenotaph.

However, the numerical photogrammetry data consisted of height values at randomly selected positions, which was defective as the data for 3-dimensional representation of perspective views, etc. as will be described later. To overcome this shortcoming, therefore, the height at all the intersections of a uniformly spaced grid set on the X-Y plane (10 cm interval in X direction and 30 cm, in Y direction) were calculated by Lagrange's interpolation. Fig. 4-1 shows the coordinate points obtained photogrammetrically. The coordinate points are random. Fig.4-2 shows the height points obtained by Lagrange's interpolation at all the intersections of a uniform grid 10 cm spaced in the X direction and 30 cm, in the Y direction.

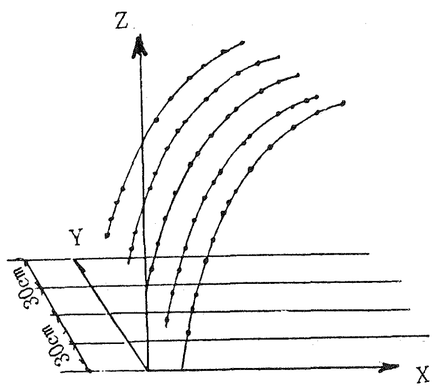


Fig. 4-1 Coordinate points obtained by photogrammetry

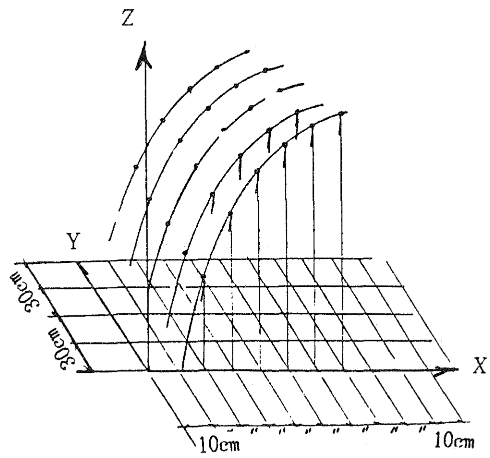


Fig. 4-2 Coordinate points obtained by interpolation

4-2. Generation of interior wall numerical data

As mentioned before, the shape of the interior wall surface must be 14 cm bulged inward from the exising wall shape, while the thickness at the edges is left unchanged. However, since the edge surfaces are slanted, the increments at the successive oblique sections must be constant.

4-3. Generation of perspective view ,e.t.c.

Perspective view, etc. were generated on the basis of the grid data for the exterior and interior wall surfaces obtained as described above, with emphasis placed on the following points.

(1) To allow the designer to recognize the shape of the object, 3-dimensional shapes are displayed on the graphic display screen, with the effective combined use of the existing system(CDS $4000) possessing ordinary display functions and a newly developed personal computer system (if800KRCCA) adapted to special data processing.
(2) For more closer comprehension of the shape, detailed drawings were plotted on an X-Y plotter at a procision of 0.1 mm(Fig. 5)

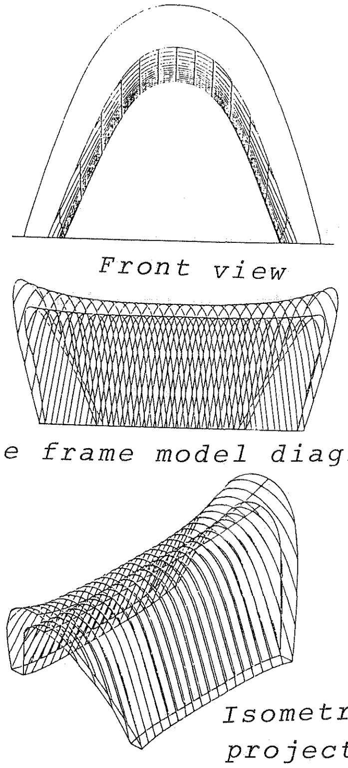


Fig.5 Graphic image generated by X-Y Plotter

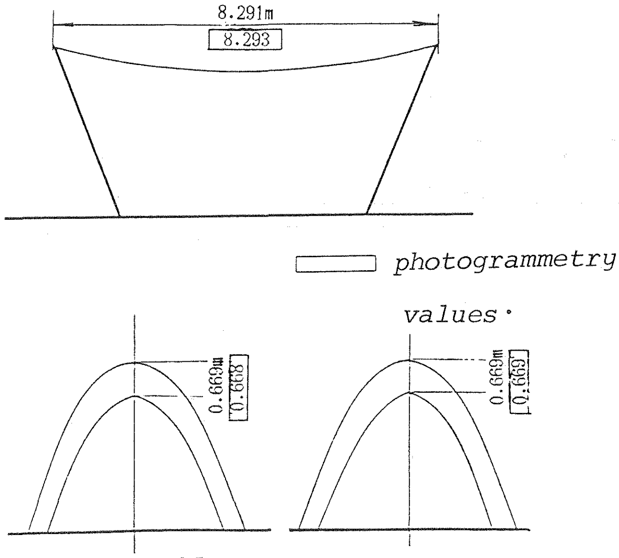


Fig.6 Comparison of design spec. and photogrammetry data

Fig.5 shows Graphic image generated by X-Y plotter from the numearical data obtained by photogrammetry. Fig.6 shows accuracy of photogrammetry by comparing the design original data.

After thorough visual examination from various angles, the designer arrived at the following conclusions:

(1) Interior wall surface shape

The interior wall surface shape formed in accordance with the rebuilt cenotaph basic plan was fully in conformance with the designer's concept and no modification was needed.

(2) Exterior wall surface shape

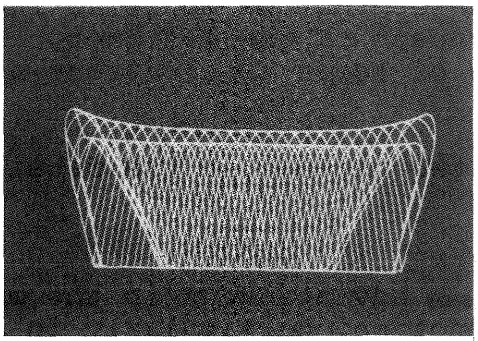
As a result of the comprehensive observation in combination with the interior wall surface shape, and examination, no modification was dound necessary.

4-4. Generation of numerical data for erection

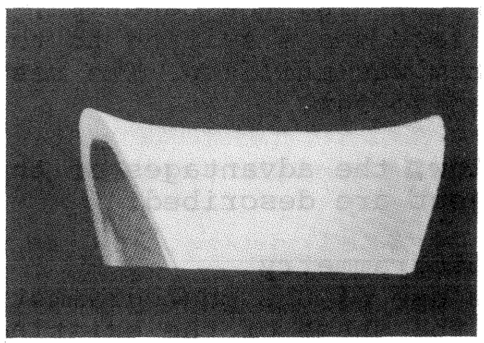
In the couse of erection, wood patterns must be made before quarring. For making wood patterns, numerical data are required for the exterior and interior wall surfaces at each grid (30 cm in both X and Y directions), and for the masonry joint surfaces. The photos (Photo 4 and Photo 5) are numerical photos prepared by the CAD system for the quarrying planning and checking.

5. Discussion

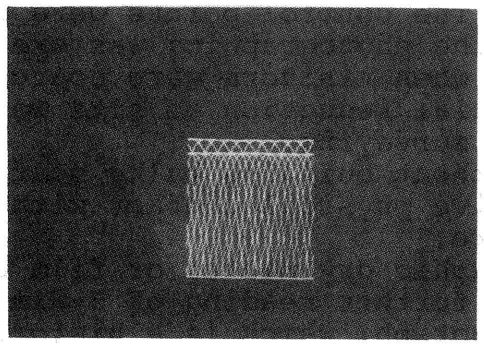
To measure the exterior and interior wall surface shapes of



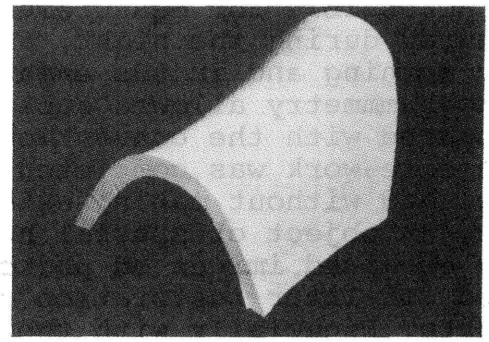
Wireframe model



Solid model



Surfacing of wireframe model



Solid model

Photo 4: Model generated from photogrammetry data

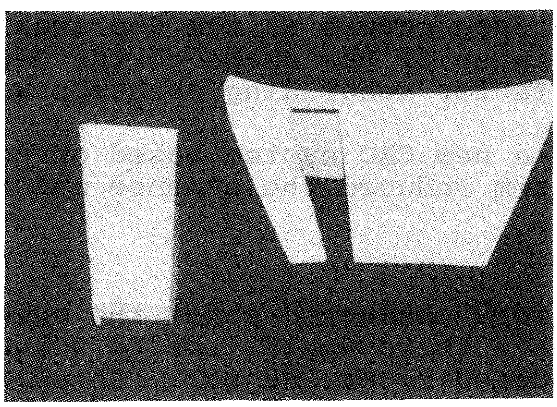


Photo 5: Granite block based on numerical data

existing cenotaph, the terrestrial photogrammetry was adopted, and in rebuilding the cenotaph, to determine the modified interior wall surface shape suiting to the concept of the designer, the CAD system was utilized. The results of these applications are described so far.

Below, the advantages of these two methods in the rebuilding project are described:

5-1. Photogrammetry

The use of the photogrammetry was advantageous in the measurement of the shape of the existing cenotaph, particularly in the following respects:

(1) The 3-dimensional shape of the cenotaph was accurately and precisely measured and numerically represented.

(2) Because of the many visitors during the daytime, the cenotaph was not accessible for measurement. The control points were set and measured during the night, and the photographing was executed in early morning and in the evening when visitors were scarce. The photogrammmetry allowed substantial reduction of site work time compared with the conventional surveying.

(3) The site-work was completed without building bulky scaffolding, etc. and without making extensive physical contact with the cenotaph, an object of special nature.

(4) The obtained images on photographic dry plates or film can be stored for later restoration and further reading of 3-dimensional data. Especially with the cenotaph, which is a historical monumental object, this feature of data record storage is of special advantages.

5-2. CAD system

The use of the CAD system in the shape determination of the rebuilt cenotaph was advantageous mainly in the followint respects:

(1) The 3-dimensional display, perspective views and the solid models formed on the basis of the grids data as derived from the photogrammetrically obtained exterior shape and arbitrarily determined interior surface curves at the top area allowed easy comprehension and decision of the shape to the designer.

(2) The numerical data for rebuilding cenotaph were obtained speedly for designing.

(3) The joint use of a new CAD system based on personal computer with the existing system reduced the expense and time of the process.

Acknowledgement

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