PHOTOGRAMMETRIC DETERMINATION
OF GEOMETRICAL PARAMETERS OF SUSPENDED CABLE BRIDGES

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ISPRS Commission V.

Abstract

The basic condition for reconstruction of structures is determination of their real spatial form. From the point of view of accuracy required as well as the economy of measurement, the analytical photogrammetry is the most convenient method for determination of geometric parameters of suspended cable bridges. Coordinates of detail points of the bridge structure are transformed into the object coordinate system and yield information about the symmetry or assymetry of the structure with regard to the longitudinal axis of the bridge.

One of the main aims of the paper is the application of an analytical photogrammetric software **ORIENT** for determination of structure parameters.

Key words : Cable bridge. Reconstruction. Targeting.Metric camera. Object coordinate system. **ORIENT.**

1. INTRODUCTION

The original shape of the structure gradually deforms or distorts in time as a result of the structure corrosion, load, intermittent cross winds and similarly, as is the case of pipe line suspended cable bridges in Piestany, Nelahozeves and in the Winter port in Bratislava.

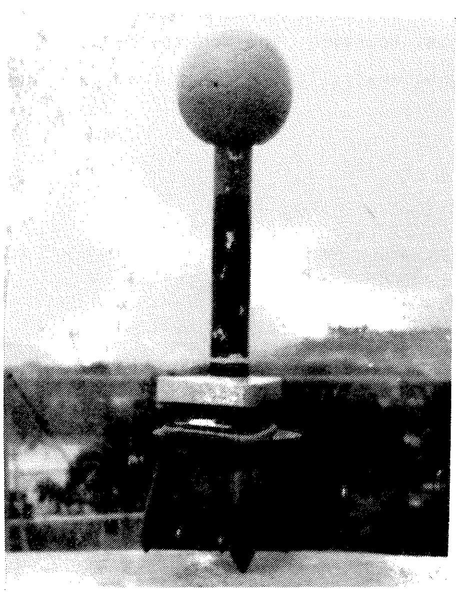

Fig.1 The ball target

One of the basic conditions for the construction as well as the reconstruction of building structures is the determination of their actual spatial shape. Out of the measuring methods that counted with regard to the applications given in this article, it turned out that the most convenient method was the terrestrial photogrammetry and that from the view-point of the required accuracy as well as the economy of measuring works.

When measuring the spatial shape of the given suspended cable bridges by means of the photogrammetric method we used the analytic modification of the intersection photogrammetry. The reason that decided in favour of the analytic solution is the possibility to identify the detail points. In the case of cable bridges the cablecoupling enables a relatively unambiguous identification of the points to be determined even when making monocular measurements on single pictures.

2. MEASUREMENT METHODOLOGY

All the given photogrammetry applications have more or less the following operations in common:
- surveying measurement -a quadrangle is the basis of the micronet created by the end points of the photogrammetric base lines,
- control point targeting - utilization of artificial as wel as natural targets,
- photography - universal wide-angle metric camera UMK 10A Zeiss Jena,
- determination of the spatial position of detail points of the structure by means of spatial intersection in the local coordinate system of one base line,

- transformation of detail points coordinates into the structure coordinate system, whereby the X - axis is identical with its longitudinal axis (Gregor, 1991).

The basic geometric parameters of the checked cable bridges are given in Table 1.

Main parameters of bridges Table 1

Suspended cable bridge	Bridge length	Distance of anchoring	Max.cable sag	Pylone height
	blocks			
	m			
Piestany	76.23	116.2	7.0	12.25
Nelahozeves	160.03	233.6	14.0	22.85
Winter port	165.95	225.9	15.4	25.05

2.1 SURVEYING MEASUREMENT

The surveying micronet in the shape of a quadrangle was created by four camera standpoints, that means terminal points of photogrammetric base lines flanking on both sides of the bridge. The quadrangle was measured by angles as well as lengths using the EOT 2000 Zeiss Jena distancemeter. By using the forced centering we secured the accuracy of point determination with a mean coordinate error m_{xy} = 0.004 m.

The surveying micronet points define partly the spatial position of projection centers for the analytical spatial intersection and at the same time they are the standpoints for determining control points that are used to adjust coordinates of the structures detail points determined by means of the photogrammetric method.

2.2 TARGETING

To target the control points we utilized partly surveying targets on a tripod (Freiberg circular target) with the possibility to turn them perpendicularly to the direction of the camera axis, and partly ball targets (Fig.1) independent from the direction of the camera axis. At inaccessible places we used points of the structure, that can be unambiguously identified, as natural targets. Together with the orientation point the optimum number gives 5 control points for one pair of photographs.

2.3 PHOTOGRAPHY

During the measurements of the given bridges the wide-angle universal camera UMK 10A Zeiss Jena proved to be the optimum camera type, whereby it was in all cases possible to take photographs with a horizontal camera axis.The photogrammetry accuracy is a function of the photograph scale, and therefore we try to choose the photogrammetric base lines as near to the measured structure as possible. However, the decisive factor is the required accuracy, in the given case less than 30mm.

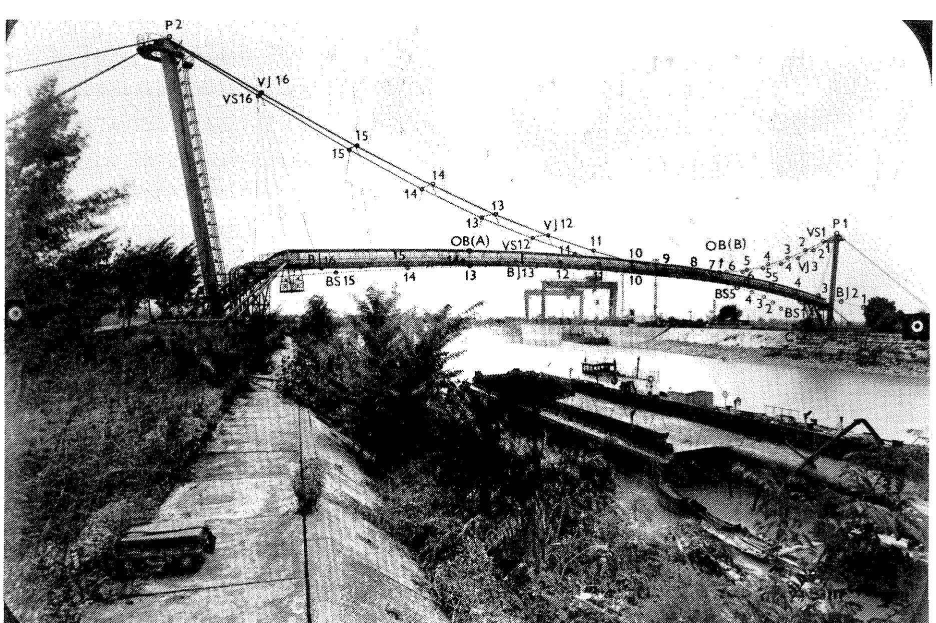

Fig.2 The numbering system of the structures detail points.

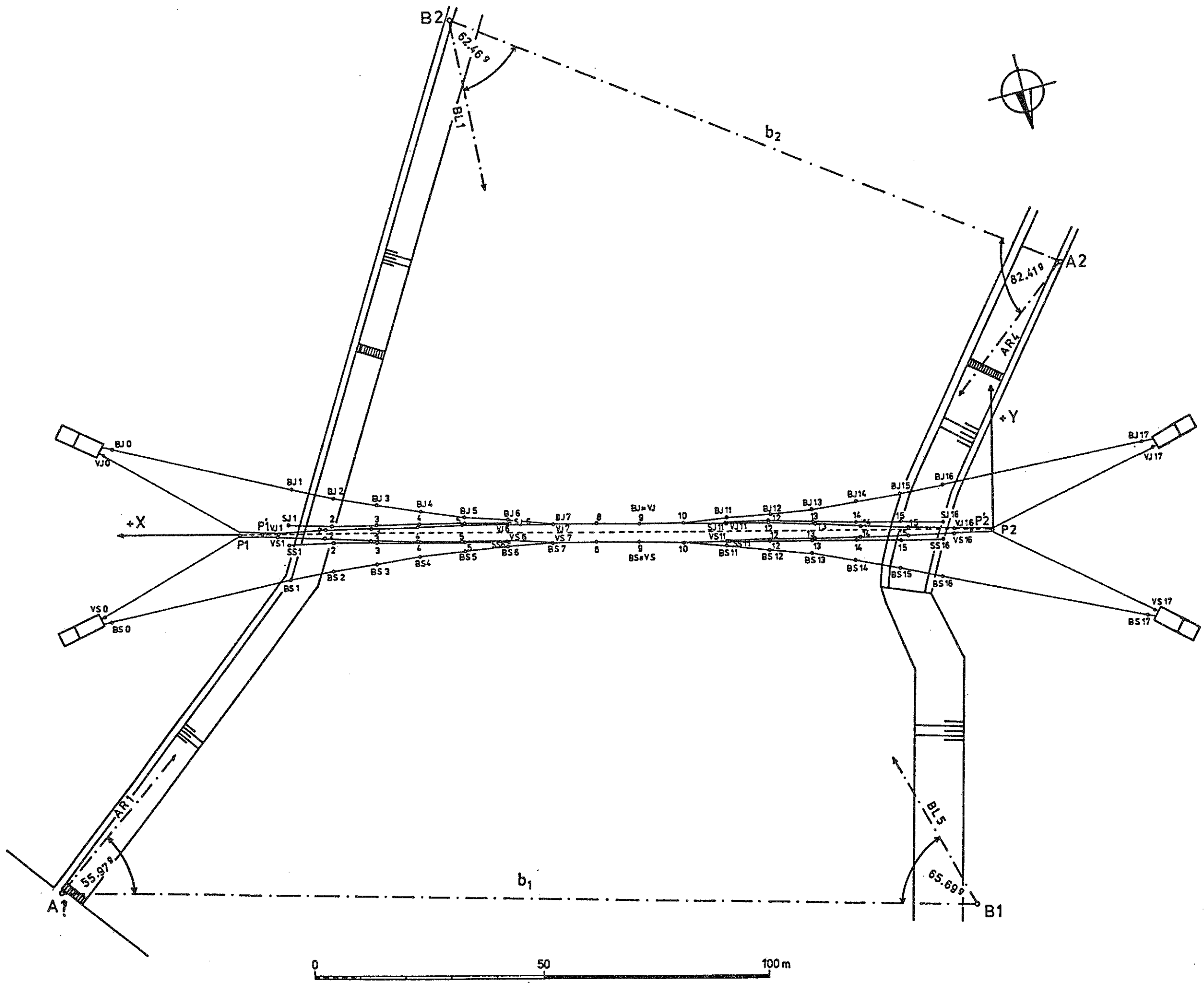

Fig.3 The coordinate system of the cable bridge

Under the condition that the whole bridge will be taken on one photograph, the distances of the base lines for the wide-angle camera UMK 10A Zeiss Jena ranged from 60 to 150 m, what partly secures the required accuracy, and partly enables to achieve the optimum ratio b/y ≐ 1.

The photographs were taken on glass plates Topo Orwo having a sensitivity of 6 DIN. The camera axes were orientated towards the orientation points targeted on the bridge structure.

2.4 COMPUTATIONS

The photograph coordinates as the basic input data were measured by means of a STEKO 1818 Zeiss Jena stereocomparator. The numbering system of the structures detail points is given in fig. 2 . The coordinates of detail points were calculated in two phases:

- determination of spatial coordinates of points in the local coordinate system of the photogrammetric base line, utilizing equations for the spatial intersection,
- transformation from the local coordinate system into the structures system with the X-axis as the longitudinal bridge axis (Fig.3).

In the case of the suspended cable bridge in the Winter port we utilized the ORIENT software (ORIENT, 1991 beside the given traditional routine. The main contribution of the ORIENT software in the given case is the determination of the actual cable course compared to its theoretical (fictitious) shape defined by a quadratic parabola according to fig. 4 . The graphical comparison is in Fig.5.

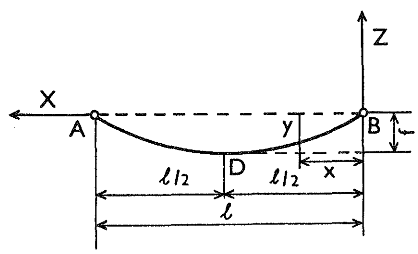

Fig.4 The quadratic parabola of the theoretical shape of cable.

The form of polynomial (1) modified for the ORIENT software calculation is following:

$$z = ax + bx^2 \qquad (2)$$

where $a = \frac{4fl}{l^2}$

$$b = -\frac{4f}{l^2}$$

As for the suspended cable bridges there are, from the view point of their spatial position, two types of cables:

- carrying cables that are in the XZ plane, as shown in fig. 5,
- lateral cables that in the case of the Winter port bridge lay in a plane inclined on the average by 31.75°.

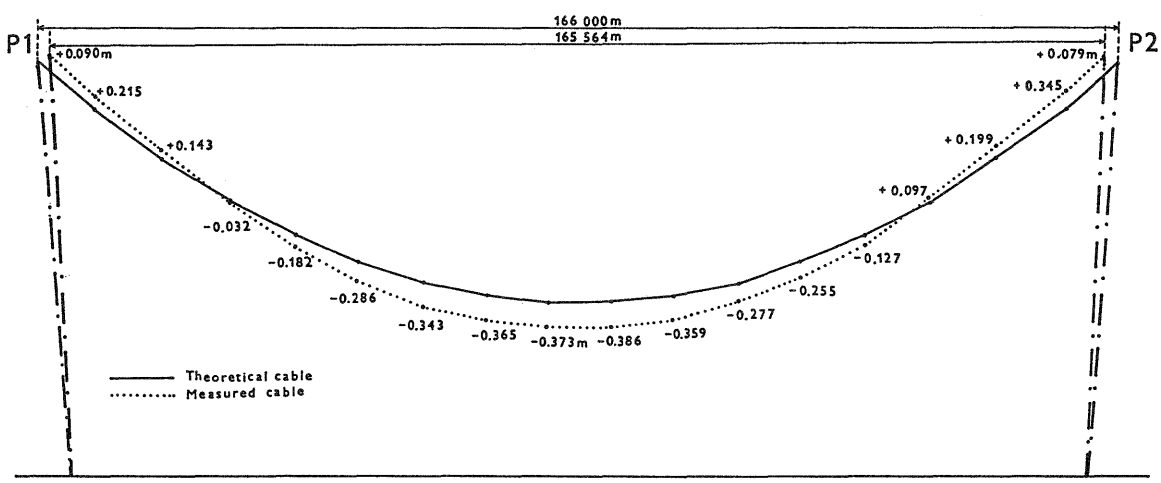

Fig.5 Theoretical and measured cable.

When having a uniformly distributed load the cable will take a position, that may be expressed by the polymonial (Agocs,1980):

$$z = \frac{4fx\ (l-x)}{l^2} \qquad (1)$$

where f is the rise of the cable
l - the horizontal cable length

3. CONCLUSION

The results of measuring the actual shape of the suspended cable bridges structures by means of photogrammetry confirm that this method is convenient for similar applications. The utilization of the photogrammetric ORIENT software is in the given case a contribution to the computation of the structures detailed points coordinates as well as to the computation and comparison of the real and fictitious shapes of the carrying and lateral cables. The results of such a comparison are valuable informations about the actual state of the structure for the designer and at the same time basic data for the reconstruction of cable bridges as well.

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