

Photogrammetric Measurement of Deformations During the Load Test of Brick Vault

Petr Kalvoda, Miroslava Suchá, Josef Podstavek and Jiří Vondrák¹

¹Department of Geodesy, University of Technology, Brno, 602 00, Czech Republic,
vondrak.j@fce.vutbr.cz

Summary

The area of constructional element strengthening and subsequently strengthening of construction has been researched many times. These techniques lead so far to dimensional redesigning of the construction. Usage of the new technological procedures and especially utilisation of new materials allows keeping existing dimensions of the construction. This project is part of research project focused on additional strengthening of engineering construction particularly on monolithic concrete and brick construction. Integral part of project is quantitative determine of deformation, which are observed during the load test of tested constructions. Few methods where used parallel together: tensiometric measurement, electronic tacheometry, very precise levelling and digital method of close range photogrammetry. The method of close range photogrammetry was used again as a complementary method just for data comparison and for photogrammetric technology improvement in application demanding high precision.

KEYWORDS: Photogrammetric measurement, deformations, load test.



Petr Kalvoda, Miroslava Suchá, Josef Podstavek and Jiří Vondrák

1. INTRODUCTION

Whole experiment is part of research project, which is intent on additionally strengthening of building constructions. In our project, we deal with quantitative determining the deformations of testing constructions during the load test. For this purpose were currently used following methods: tensiometer wire with potentiometers, polar method, precise levelling and method of close range photogrammetry.

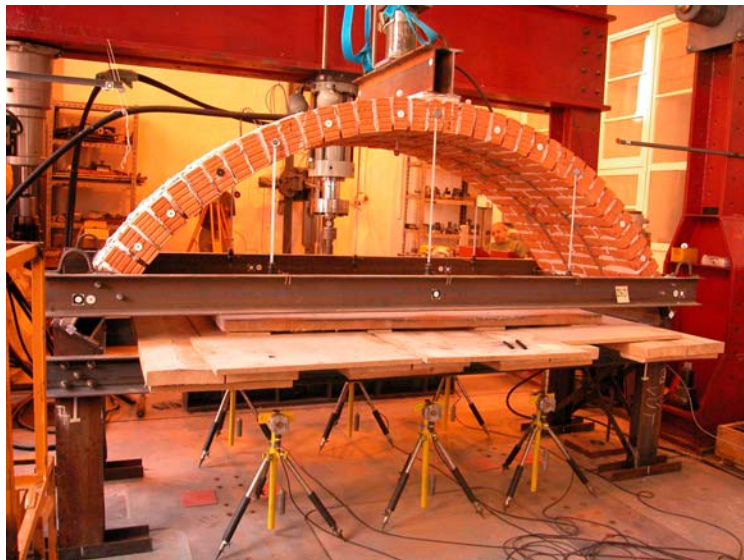


Figure 1. Brick vault

Measurement marks

Before the experiment has started, it was decided that processing would be run on two different photogrammetric software: Orpheus 3.2.1. and PhotoModeler 4.0. This decision has radical effect on selection of measurement marks. Software PhotoModeler provides automatic subpixel measurement, but software Orpheus not (at least not the version we have at our institute). For this reason, two types of measurement marks were used. The first type is suitable for subpixel measurement and second type is suitable for manual measurement (fig.2). For manual measurement were used black steel circular targets with diameter 28 mm with centric hole (diameter 2.5 mm). On both sides of vault (front – side „A“, back – „B“) was the same configuration of targets fig. 3.



Photogrammetric Measurement of Deformations During the Load Test of Brick Vault

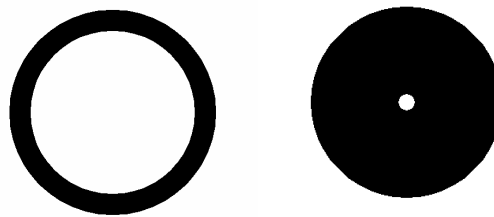


Figure 2. Types of measurement marks

2. OPTION AND MEASURING OF CONTROL POINTS, IMAGING OF THE VAULT CURVE

There were stabilized 23 control points on the vault. Due to use of two target types, there is a great number of control points. The control points were determined by polar method, for distance measurement was used reflecting foil, which was placed on targets. Images were taken by calibrated camera Nikon Coolpix 5000 with resolution 5 Mpix. Method of multi-image photogrammetry was used and images were taken from distance 3-4 m.

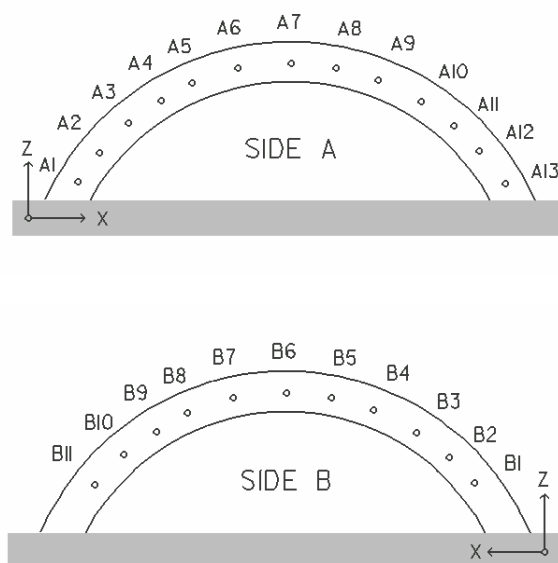


Figure 3. Orientation of line coordinate axis, placement and marking of points



Petr Kalvoda, Miroslava Suchá, Josef Podstavek and Jiří Vondrák

3. TECHNIQUES OF THE PROCESSING

Local coordination system was designed for processing, axis X along console of the vault, axis Z vertically and axis Y perpendicular to X and Z. Deformations in direction of axis Y were not evaluated. Coordination system was designed, so that most of the errors affect coordinate Y, which was not the subject of the measurement.

Photogrammetrical measurement consists from comparing X and Z coordinates, which are computed in individual load states with basic zero state (without loading). Images were taken in all load states. For processing, images were chosen so that all points were at least on three images.

First processing phase consists of computation of spatial coordinates in all load states by means of software PhotoModeler 4.0. Precisions 0.6 mm, 1 mm, 0.5 mm were determined to individual coordinates X, Y, Z. The goal is to use strictly the automatic subpixel measurement, which PhotoModeler provides. For purpose of the polar method, three targets on both sides of the vault were exchanged by the other type of the targets. The new targets were improper for automatic subpixel measurement and they derogated the results. This operation was not consulted with group of photogrameters. During the second phase of processing we dealt with computing by means of the software Orpheus 3.2.1. Input precision of the control points was kept the same as precision in first phase. Spatial coordinates of the zero and tenth load states were computed in this software and only manual measurement was possible to use.

4. COMPARISON OF THE DETERMINATED DEFORMATIONS

Differences in X coordinate of individual points between shifts, which are determined by photogrammetry (with usage of software PhotoModeler) and polar method in all load states, are presented in table 1. Manual measurement was used for all of the points as it was explained above. Standard deviations of these points did not exceed value 1.5 mm.

Differences between shifts in Z coordinate, which was determined by photogrammetry (using PhotoModeler again) and precise leveling, are presented in table 2.



Photogrammetric Measurement of Deformations During the Load Test of Brick Vault

Table 1. Comparison of shifts, which are determined by photogrammetry and polar method

ΔX [mm]							
Method	Point	Shifts in the load states					Average deviation [mm]
		2	4	6	8	10	
Photogrammetry	A4	1.3	1.0	-0.1	-2.6	-8.8	
Polar method	A4	-0.3	-0.7	-2.0	-3.6	-6.6	1.7
Photogrammetry	A7		0.2	0.3	0.0	-1.2	
Polar method	A7	0.1	0.0	0.3	0.3	1.6	0.8
Photogrammetry	A10	1.1	1.0	2.8	6.0	8.1	
Polar method	A10	0.3	0.7	2.2	4.0	10.9	1.3
Photogrammetry	B3	0.4	-2.2	-1.4	-4.6	-9.4	
Polar method	B3	-0.3	-0.7	-2.2	-3.9	-7.3	1.2
Photogrammetry	B6	-0.3	-0.2	0.6	0.2	-1.0	
Polar method	B6	0.0	0.0	0.0	0.0	1.3	0.7
Photogrammetry	B9	-1.2	1.4	2.5	4.4	8.5	
Polar method	B9	0.2	0.7	2.4	4.2	11.1	1.0

Table 2. Comparison of shifts, which are determined by photogrammetry and precise levelling

ΔZ [mm]							
Method	Point	Shifts in the load states					Average deviation [mm]
		2	4	6	8	10	
Photogrammetry	A4	1.1	2.3	4.4	5.9	6.7	
Precise levelling	A4	0.1	0.4	2.3	4.5	8.9	1.7
Photogrammetry	A7		-2.9	-3.5	-5.2	-19.3	
Precise levelling	A7	-0.8	-1.9	-4.9	-8.1	-17.4	1.8
Photogrammetry	A10	1.6	2.7	4.7	7.3	14.3	
Precise levelling	A10	0.1	0.6	2.5	4.8	13.8	1.8
Photogrammetry	B3	1.1	3.1	3.5	5.5	6.7	
Precise levelling	B3	0.2	0.6	2.5	4.6	9.0	1.5
Photogrammetry	B6	-1.6	-2.3	-2.9	-5.3	-20.1	
Precise levelling	B6	-0.8	-1.8	-4.8	-7.9	-17.4	1.7
Photogrammetry	B9	0.6	2.9	3.3	5.0	9.8	
Precise levelling	B9	0.1	0.7	2.3	4.4	12.8	1.5



Petr Kalvoda, Miroslava Suchá, Josef Podstavek and Jiří Vondrák

Comparison of the shifts, which were acquired by precise leveling (PL) and shifts acquired by photogrammetry, (processed in software PhotoModeler or software Orpheus), are presented in table 3. It is evident, that by Orpheus were achieved results much closer to values achieved by precise levelling, than results achieved by the PhotoModeler. Standard deviation in the Z coordinate didn't exceed value 0.8 mm while using Orpheus.

Table 3. Differences between shifts from precise levelling, from PhotoModeler and from Orpheus in the Z coordinate.

ΔZ [mm]					
Point	PL	PhotoM	PL-PhotoM	Orpheus	PL-Orpheus
A4	8,9	6,7	2,2	7,5	1,4
A7	-17,4	-19,3	1,9	-18,9	1,5
A10	13,8	14,3	-0,5	12,7	1,1
B3	9,0	6,7	2,3	8,1	0,9
B6	-17,4	-20,1	2,7	-17,4	0,0
B9	12,8	9,8	3,0	14,4	-1,7
Average deviation [mm]		2,1		1,1	

The same comparison as in the table 3 is presented in the table 4, but for X coordinate. The standard deviation of the X coordinate, with usage Orpheus, did not exceed value 1.0 mm.

Table 4. Differences between shifts from polar method, from PhotoModeler and from Orpheus in the X coordinate.

ΔX [mm]					
Point	PM	PhotoM	PM-PhotoM	Orpheus	PM-Orpheus
A4	-6.6	-8.8	2,2	-5,2	-1,4
A7	1.6	-1.2	2,8	1,2	0,4
A10	10.9	8.1	2,8	9,7	1,2
B3	-7.3	-9.4	2,1	-7,7	0,4
B6	1.3	-1.0	2,3	0,5	0,8
B9	11.1	8.5	2,6	11,2	-0,1
Average deviation [mm]		2.5		0.7	



Photogrammetric Measurement of Deformations During the Load Test of Brick Vault

5. CONCLUSIONS

The goal of our experiment was to determine shifts of the individual points with standard deviation under 1 mm by software PhotoModeler and Orpheus. We also compared results, gained from PhotoModeler and Orpheus, with results achieved from precise leveling and polar method. We expected that better results would be achieved by usage of automatic subpixel measurement in the PhotoModeler. In spite of that, we could not keep strict usage of automatic subpixel measurement and that is why the shift results are worse. The standard deviation of the points exceeded value 1 mm only when the manual measurement had to be use. The greatest difference between shifts from PhotoModeler and from precise leveling in the Z-coordinate is 3.0 mm. Amazingly, better results were achieved, while using Orpheus, which allows only manual measurement. The standard deviation didn't exceed value 1 mm for all the points. Final shifts in the Z-coordinate differed, from results achieved by precise leveling, not more than 1.7 mm. Significantly better results are given especially when one has the possibility to select individual parameters and characteristics of the precision. At present, only zero and tenth load state is processed by the software Orpheus, but the experiment is still running. It is evident, that using photogrammetry leads to less accurate results in comparison with results from precise leveling. On the other hand, only photogrammetry method gives information about process of deformation in the whole extend of the vaults curve.

References

1. PODSTAVEK, J. Fotogrammetrické měření deformací panelů, Aktuální problémy fotogrammetrie a DPZ, Praha 2003 (in Czech)
2. PODSTAVEK, J. SUCHA, M. KALVODA, P. Fotogrammetrické sledování deformací při destruktivní zátěžové zkoušce cihelné klenby, Aktuální problémy fotogrammetrie a DPZ, Praha 2004 (in Czech)
3. PODSTAVEK, J. MACHOTKA, R., VONDRÁK, J. Integration of Orientation Systems and Cameras in Photogrammetry, tests and calibrations, , ISBN 86-85079-01-2, Republic Geodetic Authority, Republic of Serbia, Belgrade, Serbia, 2006
4. SUCHÁ M., KALVODA P., BRKL L., Fotogrammetrické sledování deformací při zatěžovací zkoušce, Sborník konference Juniorstav 2005, Brno 2005 (in Czech)

