

PHOTOGRAMMETRIC RECORDING AND EVALUATION OF THE MARKET GATE OF MILETUS FOR ARCHITECTURAL HERITAGE CONSERVATION

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ABSTRACT:

The famous Market Gate of Miletus was transported to the Pergamon Museum (Berlin, Germany) in 1907/08 and rebuilt there in 1928/29. Meanwhile the historical Market Gate shows some damages, and the building itself has to be restored. Therefore, a documentation of the status of this architectural and archaeological heritage is necessary as a basis for damage mapping and subsequent restoration activities. Due to the complex architectural structure and the variety of ornaments on the Market Gate of Miletus a photogrammetric approach was selected.

During an acquisition campaign of 2 weeks the Market Gate was covered by more than 100 stereoscopic models. A high accuracy of $\sigma = \pm 5\text{mm}$ was required for object points and lines. Therefore, more than 200 control points were measured at an accuracy of $\sigma = \pm 3\text{mm}$.

The results of stereoscopic analysis are 3D data of main contour lines, ornaments and the joints of the brickwork, structured in different layers. Special vertical and horizontal cross sections can be derived from these 3D data. Some representative examples for contour mappings, upright projections and transformations will be presented in this paper.

1. Introduction

The Pergamon Museum and its neighbouring museums have to be restored in the next few years. Before starting these activities a complete documentation of the status and a report of the static of all exhibits is necessary. One of these is the famous Market Gate of Miletus which was rebuilt inside the Pergamon Museum in 1930. Due to the complex architectural structure and the considerable dimensions - the market gate has a length of approx. 30m and a height of approx. 16 m - stereo photogrammetry was favoured for data acquisition because it has proved to be suitable in similar applications (e.g. Nutto, Ringle, 2001). The demands concerning accuracy had been defined by the restoration experts (archaeologists, stress analysts etc.) quite restrictive to $\sigma = \pm 5\text{mm}$ for points and lines in object domain. Besides mapping of damages it should be possible to rebuild - if necessary - single parts of the gate based on the produced plans.

2. History of the Market Gate

The monumental Market Gate of Miletus was built between c. 120 and 130 AD in the time of the roman emperor Hadrian. This manifold decorated two-storeyed building has three doorways and was the entrance to the southern market of Miletus in Asia Minor (Figure 1). It was modified several times during the centuries, e.g. in the 6th century D.C., before it was destroyed in the 11th century by an earthquake. Parts of the market gate were rediscovered in 1903 during the archaeological excavations in Miletus by Th. Wiegand and H. Knackfuss (Knackfuss, 1924). After the acquisition the discovered parts of the market gate had been transported 1908 to Berlin by ship. For the first years they were stored in

the storerooms of the museum and the gate was rebuilt in 1928/29 inside the new Pergamon Museum in Berlin including integrations in modern materials replacing the destroyed parts. For static purposes a construction of iron girders was integrated in the gate and fixed to the wall.

3. Photogrammetric Data Acquisition

For data acquisition two campaigns - each of 4 days - were organised. Because of the specific structure of the market gate and spatial limitations inside the exhibition room (Figure 1) different photogrammetric cameras had been used. The front parts of the gate which are oriented towards the exhibition room were acquired by a UMK 1318 (Zeiss Jena) because suitable camera distances of approx. 8 m could be realised (Figure 2). Nevertheless two models had to be taken in the case of longitudinal tilt because of a ground mosaic in the centre of the room. Images of interior parts of the gate, e.g. for the extraction of vertical cross sections, upright projections and special details, were captured by stereoscopic photogrammetric cameras SMK 120 / SMK 40 (Zeiss Oberkochen).

In total more than 100 stereoscopic models were necessary to cover this complex building. For orientation purposes more than 200 measurement targets were fixed to the market gate as control points and measured geodetically with an accuracy of approx. $\sigma = \pm 3\text{mm}$. The images of the upper part of the market gate had to be taken from a mobile scaffold tower. Due to the inevitable low- and high-frequency movements of the scaffold tower (measuring 12m of height) short shutter times were necessary which was a problem considering the poor lighting conditions inside the exhibition room.



Figure 1. Reconstruction of the Market Gate of Miletus in the Berlin Pergamon Museum, c. 1930/39 (Antikensammlung Berlin, Archiv)



Figure 2. Original measurement images by UMK 1318, left: projecting columnar order to the left lower storey, right: front view lower storey

4. Photogrammetric Analyses

In order to fulfil the demands of high accuracy the stereoscopic models were processed at an analytical plotter DSR-11 (Leica). In model orientation an accuracy of approx. $\sigma = \pm 5\text{mm}$ could be obtained. The main contour lines and ornaments were acquired, separated into original and newly supplemented parts. Particularly coffered ceilings, flutes of the columns, joints of the brickwork and cracks of the building were registered.

The data were structured in different layers of a CAD system, e.g. into architectural elements like base frame, projecting columnar orders, ceilings, columns including capitals, architraves etc., as well as into different depth layers. This structure was defined in collaboration with restoration experts before starting data acquisition. Therefore, a great variety of different combinations may be created, e.g. ground data with or without coffered ceilings, or a front view of the building without columns. In principle all data were acquired digitally in 3D. Nevertheless additional analogues plans in 2D were requested by the restorers in order to draw manually different building damages into these plans while viewing directly at the respective building details. For this 2 ground plans and 2 upright projections of the ceilings of the lower and upper storey resp. were derived from the 3D data, 2 front views with and without columns, solely columns and architraves including gables, 2 lateral views and 11 vertical cross sections. Figure 3 shows the photogrammetric result in terms of a front view of the whole market gate including columns (in this case without flutes) and brickwork of the back plane. The outer thick line is the contour line of the exhibition room. Different grey values represent different depths of the architectural elements (black: front level, dark grey: middle level, light grey: back plane level). An upright projection of the coffered ceiling of the lower storey is

illustrated in Figure 4. All main contour lines of the coffered ceiling are acquired but not every ornament detail like rosettes, festons or leaf mouldings. As an example Figure 5 demonstrates one of the vertical cross sections. It contains the two-storeyed projecting columnar order on the left side (compare Figure 2).

5. Completion of photogrammetric results and damage mapping

In a next step a revision and completion of the photogrammetric results has to be done by architects and restoration experts due to few missing parts which could not be captured by photogrammetry and details of ornaments which had been excluded a priori, e.g. small parts of the backside of the columns or the ornaments on the architrave. In Figure 6 the original photogrammetric data and the completion by the architects can be compared. In this case ornaments on pediment and entablature, the capitals of the columns and a part of the roof construction have been added.

Subsequently a mapping of the existing damages based on the photogrammetric results can be elaborated by the restorers. It contains a specification of the material, state of preservation and comments about construction details (Figure 7). This information leads to the definition of necessary conservation activities (Maischberger, 2003).

Additionally an expert's report concerning the statics of the Market Gate of Miletus will be given in terms of possible damages and negative influences caused by the planned construction activities. At this moment it is not decided if the whole market gate has to be deconstructed and newly reconstructed after the rearrangement of the museums' island in Berlin.

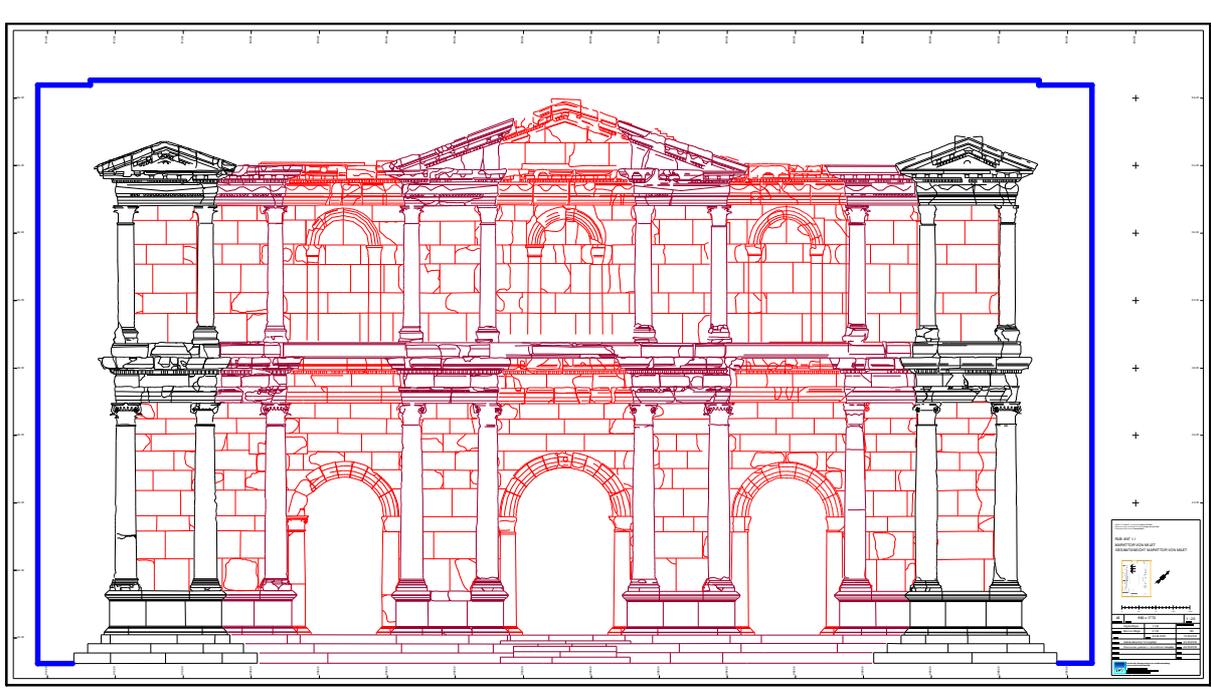


Figure 3. Photogrammetric plan of a front view of the whole market gate (thick line: contour of exhibition room)

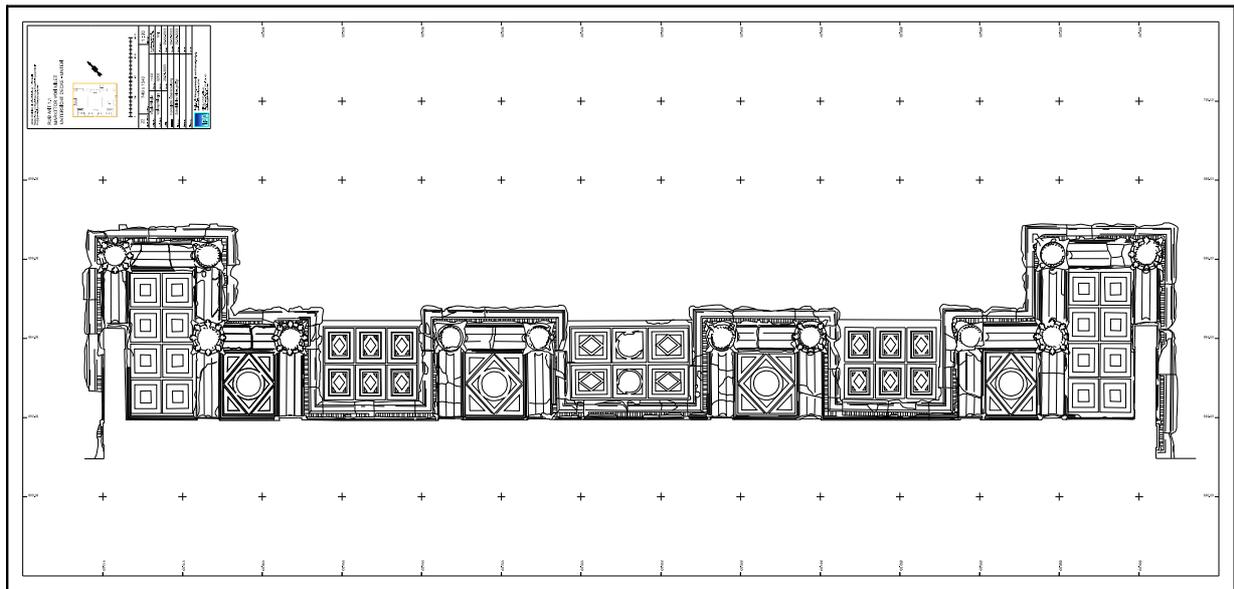


Figure 4. Upright projection of the coffered ceiling of the lower storey

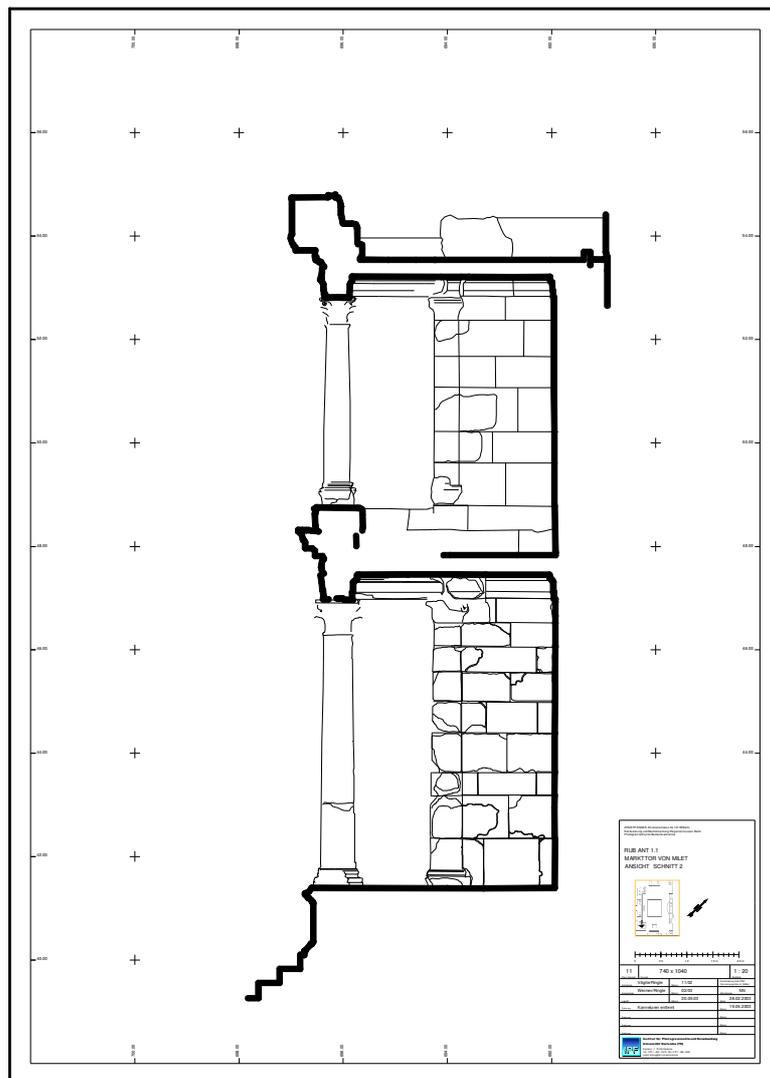


Figure 5. Vertical cross section of the projecting columnar order on the left side of the market gate

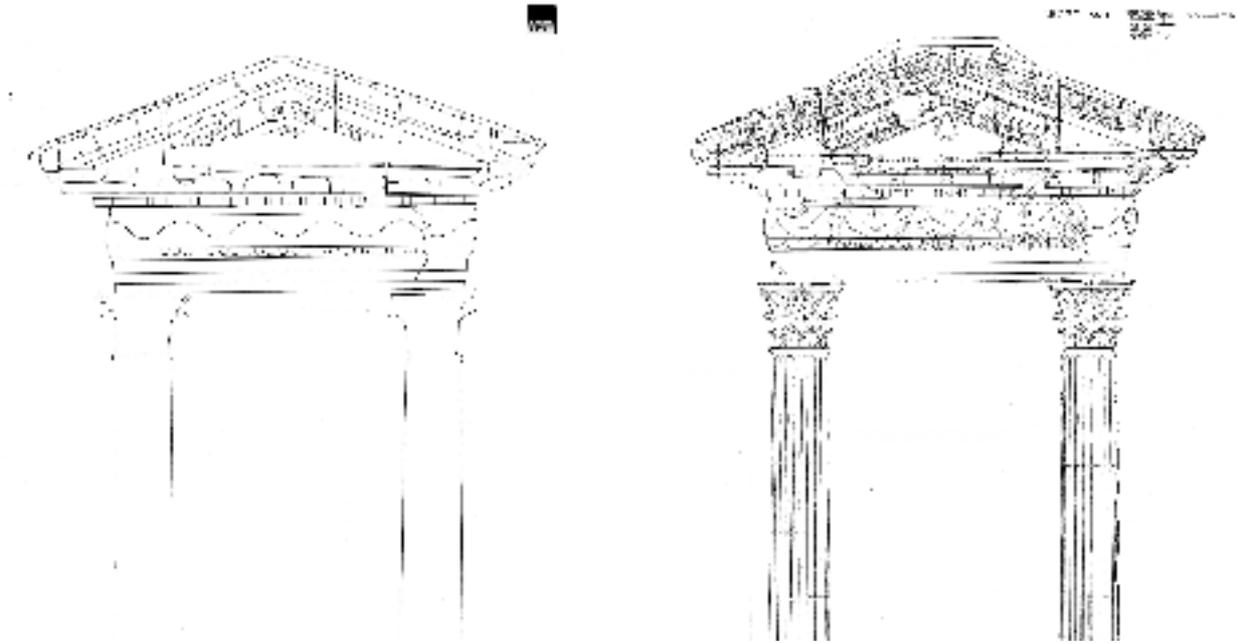


Figure 6. Original photogrammetric result (left) and completion by architects and restorers (right)

6. Conclusions

The geometry of the famous Market Gate of Milet was acquired by photogrammetry. These data are a basis for different tasks. It has been shown that restoration experts use the photogrammetric results for damage mapping by including additional information like material, state of preservation and comments about construction details. Another application based on photogrammetric data is an expert's report. Additionally an expert's report concerning the statics of the Market Gate of Milet will be created in terms of possible damages caused by future construction activities. Further planned measures are compilation of all structural parts of the building in a catalogue for originals and supplements, monitoring of cracks and measurement of deformations.

In the next future a 3D CAD model of the Market Gate of Milet will be created. To get a realistic impression a texture mapping completes this model, so a "walk" through" every part of the gate will be possible (e.g. Ringle, 2001).

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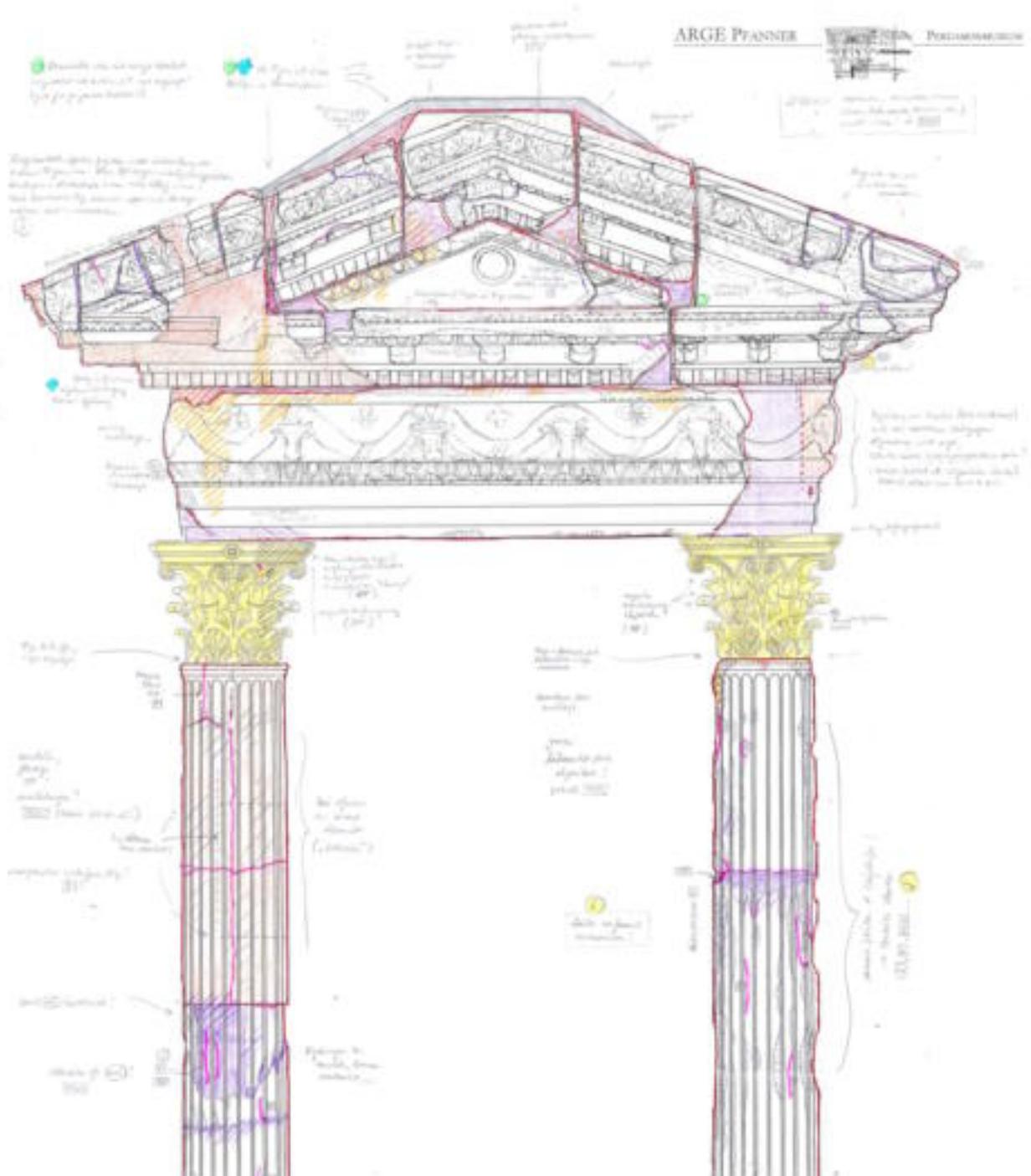


Figure 7. An example for damage mapping by architects and restorers