

## Photogrammetric documentation of the historical castle of Heidelberg and results of deformation measurements (1997 – 1999)

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### Abstract

*The castle of Heidelberg is one of the most famous German buildings and known all over the world. The existing castle was built on the ruins of the second castle which was destroyed in the middle of the 16<sup>th</sup> century. In the end of the 17<sup>th</sup> century the castle was destroyed by the "Palatinate War of Succession". Nowadays you can see the ruins in upright position from the 16<sup>th</sup> until 18<sup>th</sup> century and it is kept in this state as a national document. In order to preserve the ruins of the castle a concept for restauration and documentation has been developed. This concept is the result of an interdisciplinary cooperation between archeologists, architects, civil engineers, stress analysts, geologists and geodesists. On the basis of special geological relations the area of the east casemates (see figure 1) with the big east wall, the tapered casemates and the fragments is endangered. Few years ago several cracks were arisen and they continue to increase. Parts of this works were the exact documentation, the surveying and the evaluation of the east casemates by means of photogrammetry and the knowledge about the movements of the stonework by means of geodetic precise measurements.*

### 1 Architectural photogrammetry

Figure 1 shows the east view of the castle together with the east casemates.

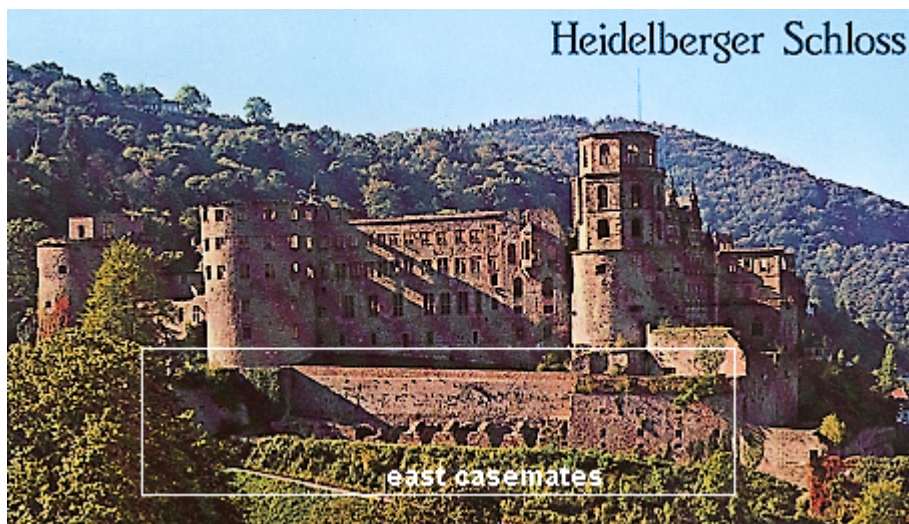


figure 1: castle of Heidelberg

The casemates which are partitioned in 13 parts are about 80 m long. Unfortunately 6 parts are heavily destroyed. In addition to the east casemates there is a 25 m long tapered casemate which is combined with the other casemates. But the position is across to them. The height of the east wall is 12 m. The stereo photograph contained the complete external walls and the casemates (internal and external). The cameras Pentax PAMS 645, UMK and SMK 40/120 (stereometric camera) were put at our disposal. Also the digital camera Polaroid PDC 2000 came into operation. Because of the close relations inside about 260 „stereomodels“ (model area in two photographs) were taken totally and about 1430 control points were surveyed (5-6 register marks each stereomodel). The necessary register marks were measured with geodetic equipment. The point determination is described in chapter 3. In addition the topography complicated the surveys because a scaffolding had to be put up.

## 2 Photogrammetric evaluation of results

The photogrammetric evaluation is separated in two parts. For the illustration of all casemates elevations, longitudinal and cross sections were created in the scale factor 1:50 and in the detail 1:20. Furthermore the stereo photogrammetric evaluation was realized on the analytic plotter DSR 11 (Leica).

The plans establish the basis for a damage map and for a redevelopment measure. The calculated data were used for further „3D-CAD“ applications (AutoCad Map 2000). Also the data were edited for visualisation of the building damages and the cracks in the wall. In addition the data establish a basis for analysis of deformation in detail.

The accuracy of the evaluation is 1 cm (max. error of points). The results are to be fed in an informationsystem and made available for the users. The longitudinal section of the „north wall“ is described in figure 2.

Figure 3 represents a cross section of the tapered casemate. Here you can see the move direction which is represented by the arrow. The length of the velocity vectors is depending on the movement of the landslide of the underlying slope. This is an exact documentation of the supporting walls by means of photogrammetry.

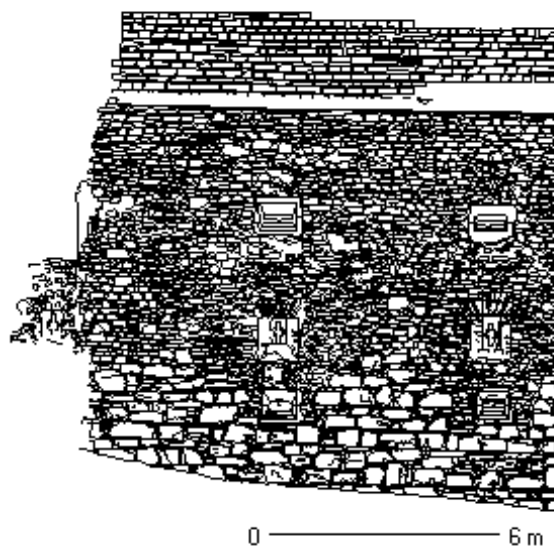


figure 2: north wall in detail

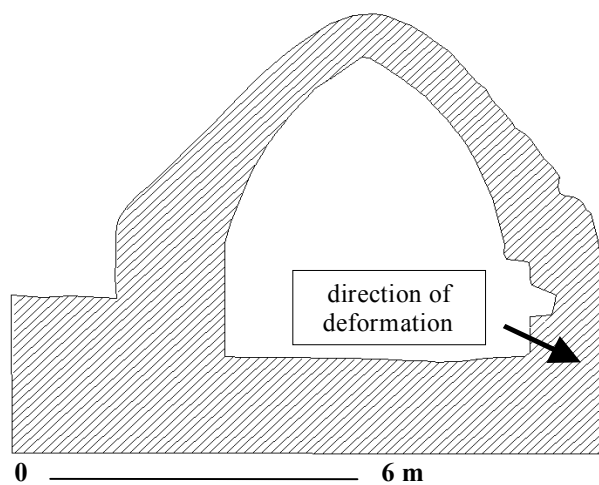


figure 3: cross section of the tapered casemate

## 3 Geodetic aspects

The task of geodesy was divided in several parts:

1. buildup of a local network with classical geodetic methods (the geodetic network is separated in a 2-dimensional position and a height component).
2. transformation in a global network (Gauss-Krüger coordinate system).
3. integration of GPS measurements.
4. precise levellings to record the vertical movements.
5. relative measurements to record the horizontal movements with a calliper rule.
6. control point measurements for the restitution of the absolute orientation (photogrammetry).

The local network which totally includes 22 points was created around the eastside of the castle. The area of this network is 110 m long and 60 m wide. The average accuracy of the „free network“ solution is 2 mm (rms).

The next task was to integrate the local network into the horizontal control network of Germany (National Triangulation System). But it wasn't possible to find any official fixed points around the castle. Therefore the decision was to start a GPS campaign to integrate the network in a global frame. The global network which is suffixed on the land system includes a total number of 10 stations (6 fixed points and 4 local points) which were occupied by using a set of 4 TRIMBLE 4000 SSE receivers.

Figure 4 shows an overview of the different networks around the castle.

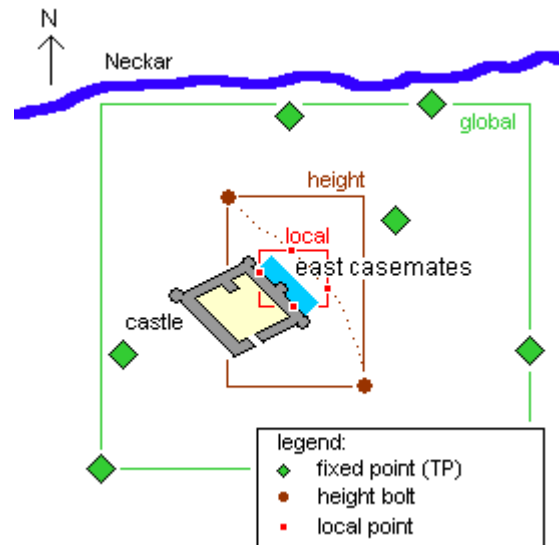


figure 4: survey map

The evaluation was realized with the standard software from TRIMBLE and the adjustment was executed with „NETZ2D“ (software from the Geodetic Institute Karlsruhe). The average accuracy of the „dynamic network“ solution is 1.5 cm (rms). This result meets our expectations because the mean deviation of the TP coordinates (TP = official fixed point) is 2 cm. All the other local points were calculated with a similarity transformation (Helmert). The average residual after transformation is 8 mm.

#### 4 Precise surveys to realise deformations

During the campaign it emerged that the east casemates which are fixed on the eastside wall of the castle are in movement. The following geological and geodetic exploration resulted:

- the east casemates aren't built on the salient rock.
- the eastside wall is deformed.
- the east slope is sliding approximately 1-2 cm each year.
- the biggest cracks on the casemates arised from the frost.



figure 5: deformation of the entrance in the closed casemate 9



figure 6: crack in east casemate 7

Therefore precise measurements were realized biannual. Two height bolts which have the official height (NN) were incorporated in the precise height network (see fig. 4) which includes 33 points totally. The digital levels from Leica (NA 2002) and Zeiss (DiNi 10) came into operation. The adjustment was computed by the software

„HEIDI 2.0“ (GIK). The average accuracy in this field is 0.3 mm (rms). The vertical settlement of the bottom was registered with the precise height network, too. Figure 7 shows the vertical average settlement of the casemates since 1997. The average height of the eastside foundation wall is 180 meters. The strong movement (4 mm) between Okt. 98 and May 99 can be assigned to the beginning of the construction work.

For the static calculation (exploration of external forces, shearing, consolidation and tilt) it was very important to get the values of the absolute deformations of the casemates which was realized with the technology of photogrammetry and the relative deformations on the cracks which were measured with geodetic instruments. Therefore the horizontal drift of the cracks was surveyed with a calliper rule. The advantage of this equipment is to have a high accuracy (0.1 mm). In order to compare the horizontal measurements several screws were fixed around the cracks. Figure 8 shows the horizontal average drift (mm) of the cracks (the values are added up).

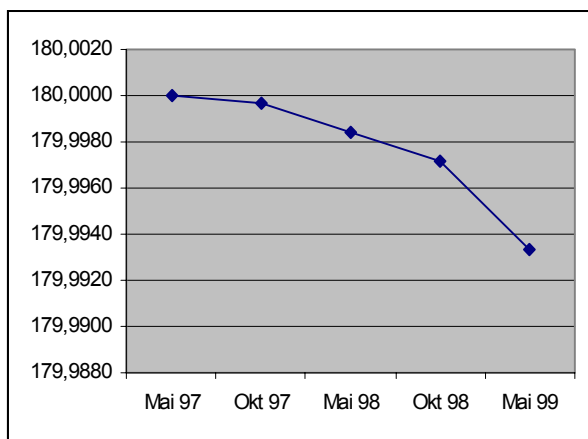


figure 7: precise levelling

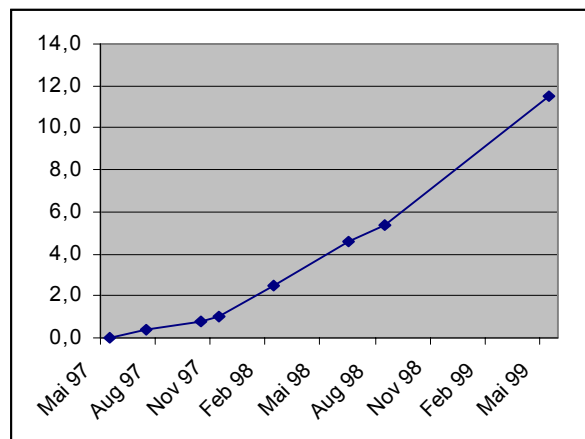


figure 8: crack movement

The measurements of the control points were made with the tachymeter TC1010 from Leica. In order to avoid errors of observation the control points were observed from two positions. The coordinates were calculated using spatial intersection. The accuracy of the control point coordinates fulfilled the condition „5 mm rms“. On the basis of this result the absolute accuracy of the photogrammetric evaluation of the total east casemates was 2 cm.

## 5 Prevention of deformations

Before the construction work was started, the whole east part was closed for tourists because of the dangerous structure of the wall. The results show definite deformations respectively movements in the stonework which are continuing presently. The photogrammetric and geodetic works serve as a control of the stability of the masonry. Furthermore the data are needed for securing operations such as to place the anchor for rocks.

Two main steps were taken for the maintenance and repair of the east casemates:

- Sealing of the casemates against the water. The complete wall and the casemates (internal and external) were treated with cement.
- Horizontal fixing of 13 anchors (with a length of 13 meters) which are attached to the foundation rock (see figure 9).

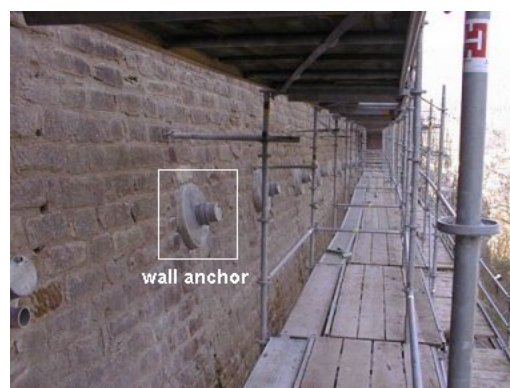


figure 9: construction work on the east wall

## 6 Final remark

The evaluation was focussed on the detailed acquisition of the object. Special attention was – apart from geometry – paid to semantics. As the photos should not only be used for the archives but also for restoration purposes, it is necessary to built up an information system which combines geometric and semantic data.

The photogrammetric and geodetic results are summarized and presented by using CAD-technologies. Deformations on the building are especially illustrated. These results establish an important fundament for the restoration of the east casemates.

In future, focus will be put on visualisation by means of modern technology. Therefore a model which will be presented in the internet should be developed by using appropriate software products like Photo Modeler. Nowadays modern procedures like digital photogrammetry, presentation in the internet or digital information systems are not optimally used. This contribution shall show a way how to integrate modern tools in order to document and preserve historically important buildings.

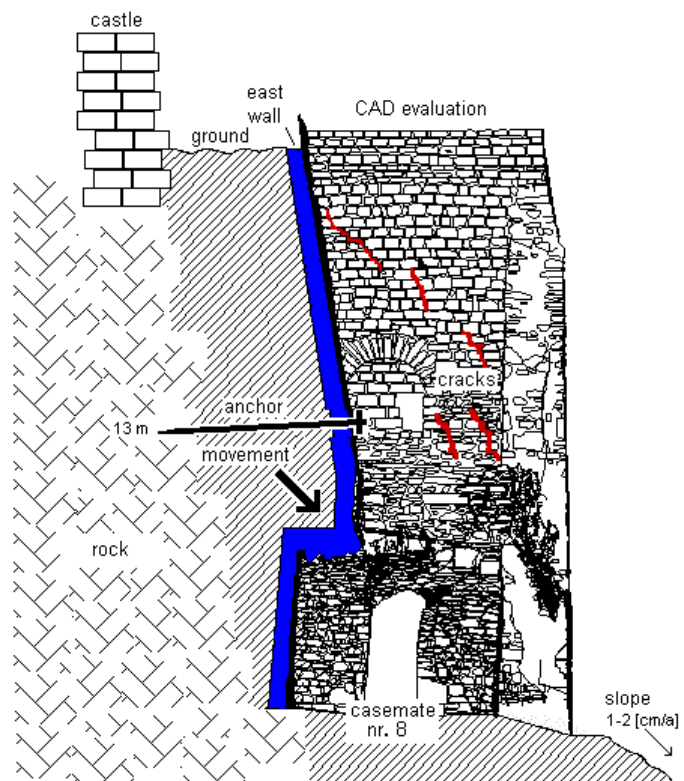


figure 10: combined evaluation – part of the casemates

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