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the title of the full paper:

“RESEARCH AND TRAINING IN THE FIELD: AN EXAMPLE  
OF CAD-SUPPORTED DRAWING DOCUMENTATION ON  
THE MAUSOLEUM OF BELEVI / TURKEY”

## **Abstract:**

In this article, a broad documentation work will be presented, which we as a team have led. The team comprised of two architects, 15 architectural students, and four further interns from Turkey. The 15 students were in their first to fourth year of their architectural studies at the Technical University of Vienna and/or at Turkish universities, of whom some graduated during the research year. The members cooperated for 42 weeks, a duration that was divided into five campaigns of differing lengths from 2001 to 2005.

The object to be documented was the Mausoleum of Belevi, which belongs to the best-preserved memorials from the Hellenistic period. It is often compared with the Mausoleum of Halikarnassos, one of the Seven Wonders of the World.

Through a new investigation at the site, the remaining *in situ* existence and constituent parts of the rich architectural elements should be documented and the reconstruction of the monument should be finally realized. And, parallel to that, a new knowledge about the proposal, construction, and work process of the Hellenistic period should be gained for the history of architecture. The reconstruction is a contrary design process. The original design will be regained by working on and reassembling several single parts of the ruined building.

The documentation work became an interdisciplinary cooperation between architects, geodetics, archaeologists, photographers and skilled workers. For the documentation, a CAD-supported method of drawing documentation was applied. Drawings created by manual measurements and subsequently digitalized were fit in over identical points in the already existing digital structure.

Our work encompassed various aspects, which were similar in documentation, research, practice, and teaching, such as with the concept that these fields are mutually dependent with each other and can only in exchange come into their interrelation to an intensive efficiency. In this way, it dealt not primarily with a collection of works of drawings, but rather also with a documentation of our research activities.

The documentation and research work surely brought new impulses for students and experiences, which could not be gained within the scope of normal class sessions. Some of them can be listed as following:

- “Multidimensional“ simultaneous thinking and acting

- The link between surveying and drawing
- Timing and conversion
- Orientation and positioning, etc.
- Concentration, discipline and pleasure in work

These associations occurred to a great extent and in various situations under increasing pressure and targeted encouragement of performance.

**Keywords:** The Mausoleum of Belevi, Historical building research, Structural survey, CAD-supported drawing documentation, Training in the Field.

## **RESEARCH AND TRAINING IN THE FIELD: AN EXAMPLE OF CAD-SUPPORTED DRAWING DOCUMENTATION ON THE MAUSOLEUM OF BELEVI / TURKEY**

### **Introduction**

As early as the 30's, Praschniker, Theuer and Keil (1933) had carried out academic work on the Mausoleum of Belevi and submitted proposals for reconstruction and from 1974 to 1978 Alzinger and Fleischer (1979) carried out further investigations of the mausoleum's architecture and sculpture, all of which were jointly published [1]. Hoepfner (1993) produced one article about the monument [2].

A more recent research project consisted of two part projects: Building Research and Archaeology (Krinzinger, Ruggendorfer and Heinz, 2001)[3]. The recording and reconstruction of the entire complex was the task of Building Research.

The challenge was to choose a method in such a way so as to master this complex task in a relatively short and limited time but without allowing the required quality to suffer as a result. That demanded a precise and efficient procedure for the building survey. The decision was made in favour of a low-tech surveying procedure and the use of higher technology where it was necessary. The method of manual surveying was selected, for which a large number of staff were trained. After a comprehensive introduction, great value was set on all the students being able to take on and perform their own parts of the task.

### **Methodology:**

The level of accuracy (Schuller, 2005)[4] and the requirements made of the surveying plans also to some extent determine the recording method. Measurement and drawing on site, in particular with a common work process in a joint operation, were the basis from the start. In order to achieve usable quality of representation in the research task, which is especially important to detecting the important details in the construction history, (only) manual measurements could be considered. It was obvious that the pencil scale drawings had to be produced on site (Cramer, 1984). The fine work on a drawing board in front of the structure with the direct observation and direct transfer of the findings are the most important work stages and the decisive criterion in the building research (Weferling, Heine and Wulf, 2003)[5].

Computer-aided building survey procedures such as the set-up of networks of points and photogrammetry were involved in the entire processing procedure and combined with the recordings from manual surveying. This gave rise to a hybrid technique both in the recording of ground plans and of sections and views: in well-defined points on the building and on the edges of stones, the reference points were marked and surveyed in three dimensions. This measurement was calculated with a computer program, input into the computer and printed at the desired scale (usually 1:10) by a large-format plotter and then used as a document for the manual survey drawings on site.

Scanning the manual drawings and further processing on the computer presented itself as an alternative to allow the combination of the individual drawings and convert them into readable plans for the reconstruction. In addition this allowed the “clean drawing” (the conversion of the pencil drawings into ink) to be dispensed with. With the ink drawing method there is a risk of loss of information. With the retention of pencil drawing, the graphical quality of the pencil drawing could be maintained and the accuracy of the original recordings could also be retained.

A second method was used for the reconstruction of the area of the entablature on the upper floor. There was nothing in situ as a reference point here. The numerous displaced blocks were recorded manually in the field with technical construction details only at a reduced level and transferred directly into the CAD-program. On the computer the information was transferred in a CAD-drawing via a reference line that allows the connection with the layer above and below it to be created. The assembly of the recorded blocks and their possible arrangement as adjacent blocks was first done in the CAD-drawing. Then the arrangement was once more checked on site with the original blocks and architectural trials were undertaken. In the course of this research, further details were also recorded depending on the state of knowledge and added into the block drawing files and the information in the CAD-drawings supplemented. The recordings in the form of drawings were supplemented with the comprehensive photographic recording. It was not until the various methods were combined that the requirement was met of an all-encompassing record of data capture in the sense of a building research survey.

The majority of the results was achieved in each case in the course of the project on site, during or at the end of the stage, but not at a

desk. At desks the bases for the findings on site were created and the results were made visible, clear and comprehensible for publication.

### **Selecting the scale**

Selecting a scale of 1:10 makes it possible to record the condition of every cuboid with regard to materials, traces of work and hidden qualities (Hözl, 2003). Occasionally this purpose could also be achieved with a scale of 1:20 e.g. with the recording of the dry masonry walls without anathyrosis, clamps or dowels. But with the many wall blocks with anathyrosis worked with millimetre precision it was necessary to decide on the 1:10 scale (Cramer 1984; Eckstein, 1999; Hädler 2005)[6]. In this monument, these two areas are relatively closely overlapping. Moreover, the various staff also have different levels of experience and for this reason a scale of 1:10 offers a greater degree of accuracy. In addition, there was a desire to do the stone drawings on a scale of 1:10 since the artists should not be jumping from one scale to the other and becoming irritated.

### **Structure of the geodetic fixed point field**

To support the manual survey i.e. to be able to capture the actual situation quickly and efficiently, the specialist knowledge of geodetic experts was relied upon to set up the fixed point field (Hözl 2003)[7]. Some preparation work had to be done for the geodetic survey. So firstly noticeable marks had to be made on the stones in visible positions and on the edges and corners of stones that were as well preserved as possible. Selected reference points were marked in red with paint sticks and serial numbers marked on them. The points were calibrated with their coordinates by the technical surveyors and entered into the computer file according to their absolute and relative height information. Measurement points contain the serial numbers of the measured points and their heights. At the end of the work, about 9,500 coded measurements had been taken (Fig. 1).

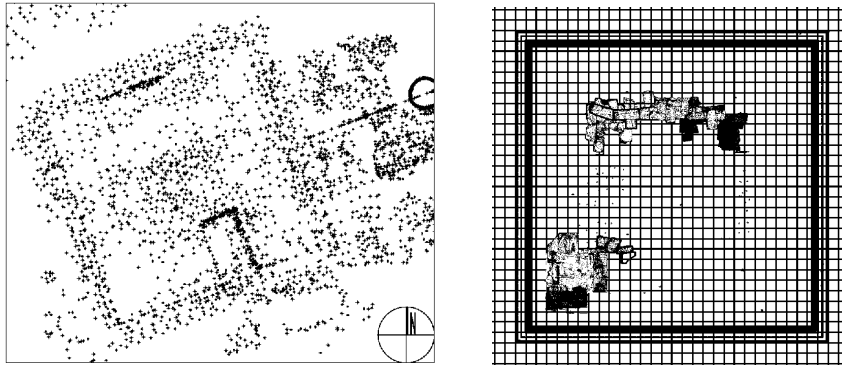


Figure 1: Triangulation stations of the monument

Figure 2: The monument with inlaid grid

The survey was started with the four corner points of the monument, which form a square. So the four outermost points of the monument were surveyed at the well-preserved positions or reconstructed intersection points and any still easily readable scratches remaining in the layers below such as near the monument's southwest corner. Since the monument with its cubic form was, so to speak, in the way, the points had to be measured and recorded in several sessions. The coordinate system of the survey points is orientated to the north but the mausoleum's orientation deviates from the north. After the square of the corner points had been established, the central axis was determined in both directions. Parallel to the mausoleum's edges and starting from the central axis, a 1-m grid system (Rottländer, 1997)[8] was laid over the entire monument (Fig. 2).

In the reprocessing on the computer it was very easy to switch between the two coordinate systems depending in which one was going to have to draw. These data determined in the office were printed by a large-format plotter at the desired scale of 1:10 in two-dimensional plans – ground plan, section or view. On the printout from the plotter in the desired scale there were only a 1-m grid and the survey points with their numbers to be seen (Fig. 3-4). These printouts formed the model for the manual recordings on drawing film.

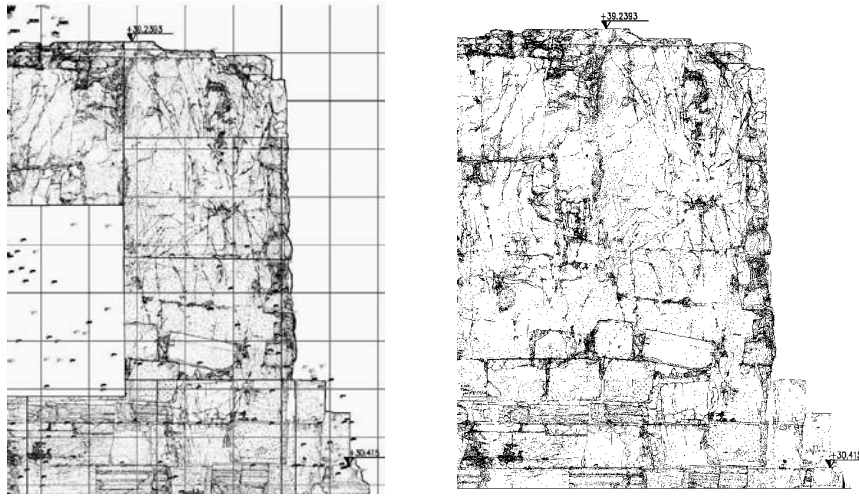


Figure 3-4: Partial survey of the south part of the W-façade

### **Manual measurement**

The manual survey which allowed for deformation [9](Dzierson and Zull, 1990) formed the main basis for the recording procedures that were the basis of the subsequent stages of the building research. Precise observations made of the building were related to each other by means of the survey (Wangerin, 1992)[10]. and recorded at a scale of 1:10. The choice of manual surveying as a major element of the method is not just based on the simple reasons that the recorders could more easily learn to do it or some of them had already managed to learn it during their training and several staff could be used simultaneously in various areas and the required equipment such as plumb line, tape measure, set square and spirit level were still the cheaper alternative but also on the fact that the human eye is still the best analyst that can extract important information from what is there, present it graphically on paper and disregard or filter out the rest and so also hold an intensive debate with the construction. Compared with the use of procedures with instruments, the long time required and the longer time spent with the structure are stressed as a disadvantage of the method of traditional manual recording (Bruschke, 2005). Thinking of this another way, one might argue that the traditional manual survey allows longer time to be spent with the structure compared with the use of procedures with instruments, which is an important aspect in adequate debate, involvement, observation and additional reflection

about the structure itself. The advantage of manual processing is a more differentiated and accurate representation in drawing. It may be the most labour-intensive process but the construction deserves to be analysed with the best method so as to exploit and use the opportunity of analysing it with the greatest precision.

The manual recordings were mostly made on to A3 transparent drawing film on which grids and points were marked. The film should not change its dimensions even in high humidity so that there would be no distortion created when two sheets were laid side by side. With each drawing a certain overlap area was necessary to prevent empty strips produced in adjacent areas.

After the marked points had been found on the monument, a start could be made on the manual recording. Once a very dense network of points was available, smaller sections could then be produced during surveying. Based on the points it was possible to conduct the survey in smaller manual triangulation measurements including the recording of technically important data [11].

It was not simply left up to the surveyors to decide what they would draw and how but instead a standard presentation method was always adopted in entering the surface work on the stone drawing [12]. After an explanation of the principles by the building researcher there was ongoing contact, enquiries and explanatory discussions on unclear points because surveying and recording themselves are a way to broad academic discovery. Survey drawings were not intended to speculate on what might be but on what could be identified with certainty. The most precise approach possible in the first stages of work leaves few open questions for later stages of work.

After the work was completed there was a drawing that could be copied and which forms a very good basis for further processing but which is not yet ready for publication.

### **Photogrammetry**

A further procedure that was available was photogrammetry. This procedure was preferred in flat areas of the façade. With the views of the south and north and parts of the western façade, digital photo-aided equalisation could be used in some sections. These positions proved to consist almost exclusively of individual gigantic wall areas, each lying in a single plane which, deprived of their cladding blocks, stood there as bare, straightened rock areas that still provide much information about the fixings and the heights of the layers.

Thanks to their even surfaces they are ideally suited to photo-aided digital equalisation in the production of view plans. The reference points (Eckstein, 1999), which were marked in situ with red paint sticks, were required again. The photography had to be as straight relative to the surface to be equalised as possible i.e. the plane of the subject had to be as perpendicular as possible to the direction of the recording. The equalised photos aided the manual survey with recording as quickly and correctly as possible, in particular in areas that have no structural peculiarities but show traces of working over large areas. Structural peculiarities and fixings were input from pure manual surveys, supplemented by remarks and descriptions. Structural joints, positions filled with mortar, scratches etc., all these detailed questions that photogrammetry cannot resolve, were subsequently manually processed in order to obtain a valuable result for the building research. To record the façade areas by drawing, scaffolding was erected in front of the façades. With the aid of the scaffolding it was possible to investigate and record the rock areas as regards the fixings and the heights of the layers in detail.

#### **Digitalisation of the survey sketches**

In order to combine several drawing sheets, all drawings were scanned uniformly. Images were created in TIFF file format with a resolution of 300 dpi for the pixel data. These TIFFs were stored on one layer for subsequent CAD processing.

Pixel images which at first had no relation to the structure had to be integrated into the coordinate system of the building via reference points. Here we cannot speak of a method entirely free from further work. But further work was not done by retracing sheets in the winter that had been drawn on in the summer. The work of drawing was not repeated but right from the next stage, work continued on matching the areas drawn with each other. The aim was to convert the pencil drawing already produced into a digital format. The idea was to try to produce a traditional clean drawing with the facilities of the image processing program without having to draw the recording sheets again in ink. As a result, documents with strong contrast were achieved compared with the original pencil drawings, which was an important precondition for printing. Combining the drawings in the computer into a plan in this way represented the last stage of the survey work, the recording of the structure converted into printable form, which then served the building researchers as the basis for further processing and reconstruction. Since the actual

plan, representing the actual situation, was not to be changed, it was laid down as the actual layer (without line drawings) and then the planning, corrections or additions, classifications, anastylosis etc. overlaid on it.

The distortions resulting from scanning were so slight that it was possible to disregard them. Slight inaccuracies could be removed with the next sheet. Because the sections were divided into relatively small areas by the A3 sheets, the deformations resulting from using a good scanner were not a matter that had to be additionally dealt with.

### **Image processing**

To prevent the cut edges from being visible, the images were processed as original files in the image processing program the overlap areas, then adjusted until these “edges” could no longer be distinguished. An attempt was made to eliminate and harmonise the differences between the artists or the years, between beginners and the experienced, even the differences in style of the very same artist in the first and last years. Combination was easy, for example, where a section was drawn in one year and at least most of it had come from one person. Here the ground plan of the podium was the biggest and most labour-intensive part.

Impurities on the documents such as dust or unclean or yellowed areas create marks on the scanned images that were not part of the recording. These required further processing e.g. the removal of these “dirty pixels,” with the aid of various filters.

### **CAD reprocessing**

The processed image in the image processing program was imported into the CAD-drawing. The image was incorporated into the system by the identical reference points and the guidelines by means of rotation into the right orientation and scaling (Schumann, 2000). This allowed the images of a façade, sectional views or the ground plan in CAD to be combined into an overall plan.

The entry of all drawings as images on the same scale has the advantage that one can combine all the meaningful and important details of the monument that were recorded with a scale of 1:1 (such as the profile of the podium, the profile of the nosing of the roof tiles or the edging profile of the burial chamber wall cladding blocks) into a single plan and associate them. Then the plans can be printed out at any desired scale. Thus for instance in CAD the entire

plan could be shown at a scale that provided an overview and another important but smaller area shown at a greater scale or prepared for the publication printing, depending on requirements. Although the areas recorded were in some cases located at some distance from each other, even from the start of recording they could be combined into an overall plan with their correct distances from each other. So it was possible, for instance, to combine the big facades or the ground plan that were in some cases uncovered, cleaned and cleared of vegetation, surveyed and recorded in sections in different years into one structure in the CAD-plan. In this way the plans recorded at a scale of 1:10 over several years by various staff could be combined in CAD into one uniform plan (Fig. 5-6).

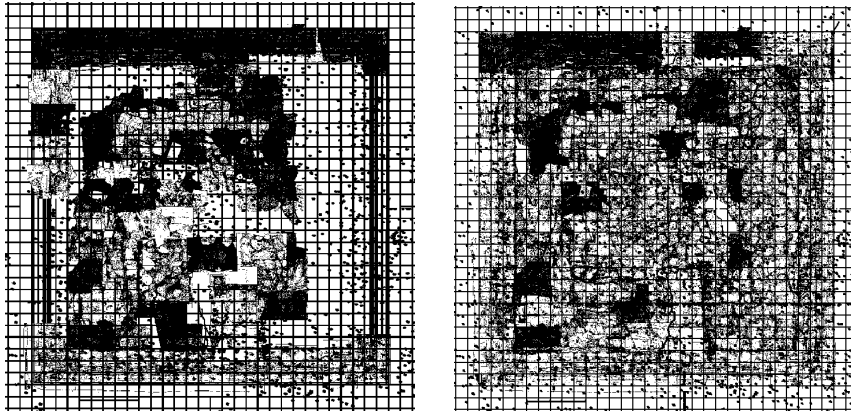


Figure 5-6: 2001-2004 growth of the recording

All the information was compressed into this plan. With a mouse click you could access the desired information in the CAD-plan via a structured layer system. All other layers that were not of immediate use could be filtered as desired. Whilst there was very good access to the plans, the original plans could remain undisturbed. The input and storage of the manual drawings in the computer created many additional opportunities for using them in CAD such as the overlay of an attempted reconstruction, the insertion of the appropriate blocks, changes to or updating of the reconstruction in line with the latest findings or the filtering out of coordinates, grids and survey points. Where necessary it was for instance also possible to highlight particular stones with different-coloured borders. Colour signatures were used especially with reconstruction. The ground plans, sections and views were related to each other in their absolute height positions by means of a zero

layer in order to check their positions or to accept the ground plan position and the height position. The overlaying of the ground plan and elevation for checking and orientation is of course done without problems and can be switched off or accessed again with the click of a mouse. Thanks to the facilities of the drawing program, all the required information on the drawings could be overlaid but then hidden again when printing so that they did not appear either in processing or in printouts. These inputs were required in order to establish their correct positions for reconstruction but it was often unnecessary to represent them in the end product since the complicated relationships would make it harder to understand the end product.

In the end, about 1,682 m<sup>2</sup> of ground and elevation areas of the monument had been recorded at 1:10. In addition some hundred displaced components were recorded on the site by drawings 1:10 or survey sketches in terms of technical construction according to their fixings, some being loaded into CAD as line drawings for the reconstruction.

### **On the students and the results**

The students came on regular or holiday period work placement to gain experience and they took on the project enthusiastically and were very committed during the work. Some of them applied for the work back during their university terms and many joined in the work because of their connections with the location.

In the first few days they were given explanations on and allocated to the project and to their task, namely the manual surveying. As it soon turned out, the opportunities were so wide that every student could find "his own task." The procedure and process of surveying and the conversion into drawings were very soon in hand. With the guidance of architects, the students performed their tasks. They also had a chance to learn to put the techniques to practical use.

Although in general they worked alone, it was not long before experience was being exchanged among colleagues. In this way they also learnt from each other without this seriously affecting the progress of the work. The aim of the project was to jointly produce a plan of the existing structure. With the individual sheets being combined year by year, one could see how the students were maturing. It was astonishing how seriously the students took their tasks and how much some of them matured on the job. Everyone in the field made progress in their techniques and skills.

For the group it was an opportunity to work under professional supervision on a project in which everyone could contribute and gain new experience. The group matured on the job although the work was not performed in groups. Here the shared accommodation, staying overnight in the excavation building clearly played a part. Doing something together in their leisure time and discussing tasks and problems was obviously from many points of view instructive for them.

There was no direct connection between their studies and the project because the excavation stages take place in the summer months outside study periods, which is usual, but they worked in the holidays so that normal student life was not interrupted.

Using the reprocessed and combined drawings (from their own independent work) as finished or in some cases partly finished plans, presentation folders were produced and the work given a clear context. The experience of success of each individual student was crucial to further successes. At the same time there also developed the courage, confidence and persistence required for architectural studies and careers (Baumeister, 2004).

It would be desirable for projects of this nature to be offered to the students now and then. The work clearly provided new impetus and experience that cannot be gained in the course of normal student training. For example:

- “multidimensional” simultaneous thinking and acting
- the link between surveying and drawing
- timing and conversion
- orientation and positioning etc.
- concentration, discipline and pleasure in work.

These associations occurred to a great extent and in various situations under increasing pressure and targeted encouragement of performance. The students soon understood that the recipe for success lies in hard work, dedication and discipline. They were instructed on looking at things in the right way and learning to see what it was all about and about independent action and implementation.

For students it was a varied learning process compared with studying. They had the opportunity not only of getting to know the professional architects but also of working with them as project partners.

## Endnotes:

- [1] Theuer (1979) proposed two different reconstructions: a solution with a pyramidal roof (in Alzinger et.al., 1979, 72 f. Fig. 51. 52) and one open-air with an inner court (ibid, 57 Fig. 42a).
- [2] Hoepfner revived the open-air solution and clearly improved the previous reconstruction, without having had the possibility to be able to perform a detailed investigation at the site.
- [3] For the building research, Heinz was responsible, for archaeology, Ruggendorfer. The general direction of the project was placed in the hands of the then director of the excavations of Ephesos, Professor Krinzinger.
- [4] Precision concerned the correct logging of the complex states of the construction site and therewith besides precise measurements, especially also precision mapping.
- [5] For the comprehensive discussion for and against the employment of modern instruments in the area of historical construction sites, please see [Weferling, Heine and Wulf (ed), 2003].
- [6] Hädler (2005) made a division of levels of precision and ranked 1:10 among the exclusive scientific objects serving construction close-ups.
- [7] Hölzl (2003) negate the necessity of geodetical support in scale 1:10.
- [8] This grid system has no direct connection with the axes of the monument. It is rather an independently set-up grid system in order to attach the orientation of the drawn plan in the foundation.
- [9] There with, it concerns itself with a reality-true portrayal of the sized object.
- [10] "Under measurement, one understands the documentation of the state of an object at a certain point in time", s.: Wangerin, (1992).
- [11] Dowel-, lewis-, clamp-, pry-holes, score lines, etc.
- [12] That means the different surfaces of the point, the toothed, etc. chisel were illustrated.

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