Cologne Cathedral History through Surveying

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Cologne Cathedral

Cologne Cathedral as it shows itself nowadays is one of the most famous German architectural monuments and has been Cologne's dominating landmark for centuries. The two towers are 157,4 m tall, the cathedral is 144,6 m long and 86,2 m wide. The cathedral is the seat of the Archbishop of Cologne and is a spiritual centre of the religious life of the Roman Catholic Church in Germany. Due to its enormous size and being built up in pure original Gothic style, it is a Gothic masterpiece and, thus, is even one of Europe‘s most famous monuments. The most remarkable work of art in the cathedral is the Sarcophagus of the Magi. The large gilded sarcophagus dates from the 13th century and is the largest reliquary in the western world. One assumes that it contains the remains of the Three Wise Men. Other outstanding works of art are the Gero Cross (Gero-Kreuz) (around 970 AD), the oldest large cross north of the Alps, the "Milan Madonna" (Mailänder Madonna), dating from around 1290, located in the Sacrament Chapel. Also very important are the altar of the patron saints of Cologne with an altar piece by Stephan Lochner in St. Mary's Chapel (Marienkapelle) and further pieces of art which are to be found in the cathedral treasure chamber.

In 1996, the Committee of the UNESCO World Heritage Centre decided to inscribe the cathedral into the World Heritage List ‚considering that the monument is of outstanding universal value being an exceptional work of human creative genius, constructed over more than six centuries and a powerful testimony to the strength and persistence of Christian belief in medieval and modern Europe‘. Recently, Cologne's magnificent Gothic cathedral has been placed on UNESCO's List of World Heritage in Danger due to the plans to construct several high-rise buildings on the bank of the Rhine River opposite the Cathedral, which the organisation suspects to damage the visual impact of this masterpiece of Gothic architecture. Cologne Cathedral attracts between 2 and 3 million visitors per year.

Structural History

The Cathedral looks back on a long turbulent, still ongoing and probably ever-lasting structural history (Figure 1). In the Cologne vernacular there is a saying: ‚As soon as the Cathedral is being completed there will be the end of the world‘. The monuments structural history can be traced back to the beginning of the 4th century.

The first of Cologne Cathedral's predecessors from the early 4th century AD is assumed to be a meeting room for the Christian community covering an area of 255 square metres. After 313 AD this first Christian church at the location of the present cathedral expanded more and more until the middle of the 9th century when it burnt down completely. The early bishop's church was replaced by a

1170 AD: The Old Cathedral, predecessor of the present cathedral

1248 AD: A great fire destroys the Old Cathedral

1794 AD: City panorama with a lofty crane on the uncompleted southern spire during French occupation time

1998 AD: Celebration of 750 years anniversary

Figure 1 Cologne Cathedral's history (Source: www. koelner-dom.de) first complete new building on the site, the so-called ‚Old Cathedral' which was finished in 818 AD.

In the 12th century there was a great event when the relics of the Magi were taken from Milan (Italy) by Holy Roman Emperor Friedrich Barbarossa and given to the Archbishop of Cologne, Rainald von Dassel in 1164. The present cathedral was built up to hold the relics of the Three Wise men. During demolition work the Old Cathedral burnt down on April 26, 1248. Archbishop Konrad von Hochstaden laid the foundation stone of the new cathedral on August 15, 1248, the consecration of the choir took place in 1322. There had been a initial rapid progress in building up the monument. The relics of the Three Magi attracted pilgrims from many countries to Cologne and was the main reason for the rapid development of the city which took place at that time. In the 16th century construction work gradually came to a standstill. By the year 1560, when only a torso had been built, the chapter of the cathedral decided to stop the construction activities.

Between the 16th and the 19th centuries all attempts to complete the work failed, except some renovation work which was done in the 18th century. After years of degradation and even of humiliation – at the time of the French revolution, the cathedral was used as a grain magazine for the French army - a new romantic enthusiasm for the Middle Ages swept across Europe in the 19th century. On September 4, 1842 Cardinal von Geissel and Prussian King Friedrich Wilhelm IV laid the foundation stone to resume the construction work. The towers, still today one of the most significant features of Cologne skyline, and other substantial parts of the cathedral were added, mostly according to surviving medieval plans and drawings. Considerable financial subsidies were gained from the cathedral lottery which started in 1864. On October 15, 1880, after 632 years and two months the completion of Cologne Cathedral was celebrated.

Renovation and maintenance work already started in 1905. During the 2nd World War, the Cathedral was severely damaged. Restoration work began immediately, but it was not until 1956 that the Cathedral could be returned to its intended purpose. Even today continuous restoration work is needed to remedy damages caused by the 2nd World War and by other effects like erosion and environmental pollution.

Excavation Site

Excavation works on the site which started after 2nd World War have uncovered remains of several predecessors of the present cathedral. For archaeologists, historians and many other scientists these remains provide for a valuable source to support many research activities. Until now, many parts of the underground area of the present cathedral have been opened (Figure 2). To guarantee for the stability of the overground parts of the large filigree building all underground cavities have to be stabilised by supporting material like concrete pillars and ceilings, etc. (Figure 3).

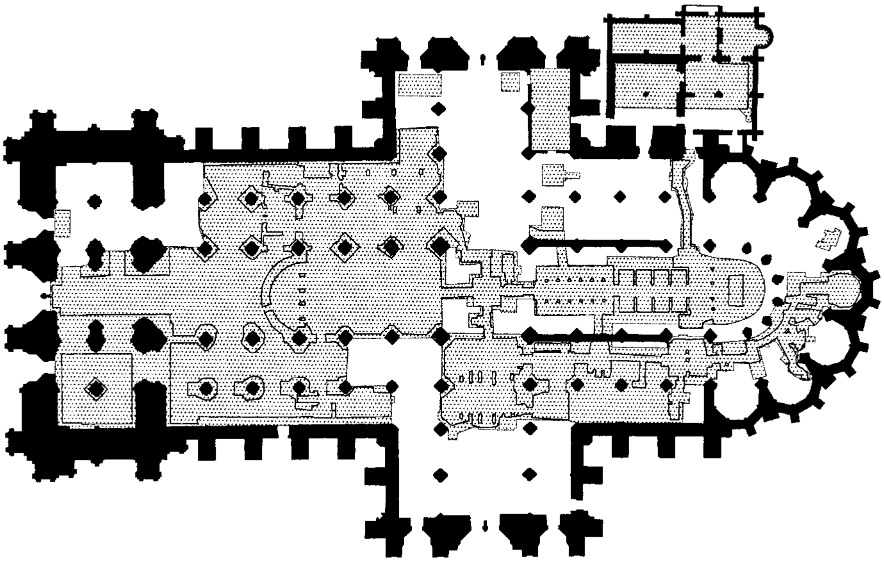

Figure 2 Footprint of Cologne Cathedral with opened excavation areas shown as raster pattern filled areas

Figure 3 View of the underground excavation site with historical (stone) and supporting (concrete) material

Methods for Archaeological Documentation

From its beginning the archaeological work results have been documented by using traditional archaeological surveying tools and methods: After a site has been subdivided by a grid system marked by strings, the location of every detail is measured with rules in relation to this grid and drawn to scale in the field. Height information is achieved with the aid of a levelling instrument. These methods, when supplemented with photographs, are effective in many cases, but have turned out not to be sufficient in this case, because the whole object is very large and many of the single excavation cavities are connected only by small tunnels and aisles. In such difficult conditions large geometric errors may and in fact did occur. So, for instance, an unintended non-rectangularity of the established coordinate system resulted in geometric errors up to 1 m in the areas far away from the origin of the coordinate system.

As an alternative method a modern tacheometer can be used to measure and record azimuth, zenith angle, and slope distance at the push of a button. The polar method is very flexible and can be adjusted to the local and even difficult site conditions. This kind of work needs special equipment and specially trained personell, however.

Thus, a co-operation between archaeologists and engineers is essential. In 1992 the co-operation between Cologne Cathedral's Excavation Department (Kölner Domgrabung) and the Department of Geoinformatics and Surveying at University of Applied Sciences Mainz started. The goal of the co-operation is to develop, to establish and to maintain a joint documentation procedure to integrate traditional archaeological and new tacheometric surveying methods. As a result, the documentation should take benefits from the advantages of both methods to deliver high quality results.

Major strengths of the tacheometric surveying method are its very high potential of geometric accuracy, its enormous flexibility in adapting itself to difficult geometric on site conditions, its capability to register shapes of non-accessible objects, etc. The main weakness is, that skilled operators are needed who, on the other hand, have few or no archaeological knowledge. Strengths of the conventional archaeological surveying method are that it is commonly used and, therefore, well known in the archaeological scientific community, that it supports the on site interpretation of findings etc. very well and, at the same time, delivers sufficient good geometrical quality in the up to 10 metres range. Main weakness in the given environment is that this method cannot maintain a sufficient level of geometric quality over the large excavation site covering an area of approx. 140 m x 90 m. That is why it was not possible to put together several detailed plans showing different parts of one and the same wall along 20 to 30 m, for instance, which is often needed to give an interpretation of the wall's original function.

To link the strengths of both methods, a hybrid approach was developed for the documentation of the Cologne Cathedral excavation site. An overall highly accurate frame work of control points covering the whole site area was established by designing and measuring a geodetic network measurement. To maintain the high-level geometric accuracy to be achieved by this method to the highest possible level also for the documentation of the archaeological objects themselves, a number of prominent points are measured directly on such objects (Figures 4 and 5). If the points to be measured on the objects are selected properly, they can be uniquely identified on all corresponding archaeological plans either already available from decades of traditional archaeological surveying or still drawn in the context of a new campaign. Scanning such a plan yields a file of raster data which can be georeferenced by using the high precision coordinates that are available for the tacheometrically measured point set. If the transformation program in use is capable to process redundant information, the transformation process can be kept under full control. Analysing the point residuals will lead to a clear decision if the plan under consideration fits into the overall reference system or not. By using this method, all manually drawn plans can be transformed into the common reference system. Additionally, a quality measure can be attached to the plans describing their geometric fidelity individually to support subsequent interpretation.

Figure 4 Historic foundations in the underground excavation site

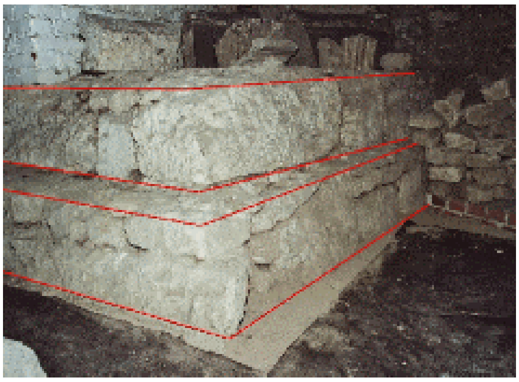

Figure 5 Tacheometrically measured shape characteristics as a geometric base for the integration of manually drawn archaeological plans

Procedure of Work

In the case of Cologne Cathedral's excavation site, a number of fixed points were marked at the concrete ceilings and connected by a geometric network with the lines of sight between the fixed points passing through tunnels, aisles and other detectable lines of visibility. An intensive geodetic network planning procedure had to be performed to generate a feasible measurement plan which guarantees for the required sub-centimetre accuracy of the fixed points positions before the measurement campaign could take place. The results of the measurements were used to calculate rectangular coordinates of the fixed points in a high-precision common coordinate system. All other detailed points, mainly on archaeological findings, are recorded using the polar method again on the fixed points of the network (Figure 6). Should any part of the area be invisible from the fixed points, additional side traverses have to be established. In that way, true scale plans of the archaeological objects can be produced from tacheometric observations with the aid of CAD software.

Figure 6 Tacheometric surveying in a difficult environment

Results
One of the first activities within the co-operation was to investigate a hypothesis stating that a Roman temple existed at the site before it converted to a Christian worship place. This information is also given in many tourist information brochures etc. Apart from other scientific arguments the hypothesis was based upon the interpretation of several remains of ancient walls found underneath the remains of the Old Cathedral.

An accurate tacheometric survey was performed within the newly established highly accurate reference frame to document the position and the shape of the currently visible parts of the Roman walls (Figure 7). The plan was interpreted by archaeological scientists who came to the conclusion that the remains most probably were not parts of a Roman temple rather than parts of a historic store house which may be thought to be the nucleus of the first Christian assembly room at the site.

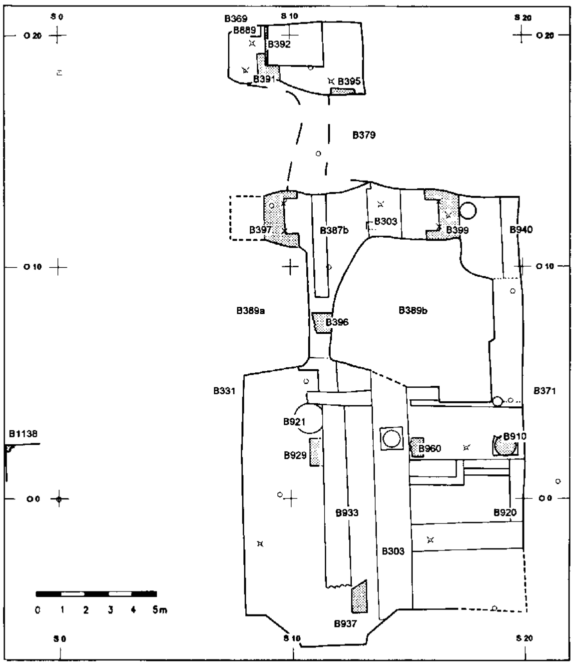

Figure 7 Documentation of Roman wall remains underneath the present Cologne Cathedral. Visible remains shown as raster pattern filled areas

Supporting Overground documentation
Up to now, the activities within the co-operation focus on the combination of archaeological and geodetic measuring methods. Moreover there are other fields where spatial measuring technology can support the documentation of historical monuments. One example is the laser scanning method which was used to generate a computer usable 3D model of the present cathedral.

In the 1990s, airborne laser-scanning systems appeared on the market as a new technology for geometric data capture. The main advantage of this method is the highly automatic data flow. An integrated GPS/INS system keeps track of the position and the orientation of the airborne laser sensor system during the flight. The laser system continuously emits a pulsed measuring beam at a high frequency. The signal is reflected by the terrain surface, so the run-time of the signal gives the geometric distance between the laser sensor system and the terrain surface. As long as the GPS/INS system runs under control of a well established geodetic reference frame, the 3D coordinates of the terrain points are obtained in the same reference system The area around Cologne Cathedral was captured by a laser scanning system at a mean point distance of about 1.5 metres. Figure 8 shows a view of the 3D point cloud as obtained from the laser measurements.

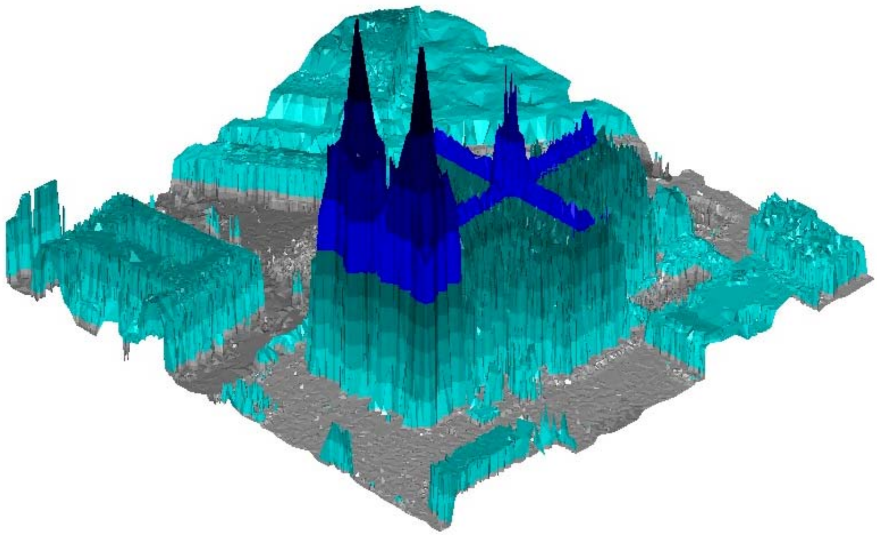

Figure 8 Cologne cathedral, view generated from airborne laser scanner data (Source: TopScan)

Conclusion

Interdisciplinary co-operation can help to generate remarkable benefits for all parties involved in a project. How such a fruitful collaboration between archaeologists and engineers takes place in practice is shown here. As a result methods have been introduced which improve the quality of the archives of Cologne Cathedrals documentation significantly.