

STONE TOPOGRAPHY – USEFUL TOOL IN MONUMENT RESTORATION PROCESS

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ABSTRACT. The surface of building stones on historic buildings often bears traces of the original craftsmanship. These are an integral part of the visual appearance of the monument and thus its value, which needs to be protected. For studying and identifying traces and subsequent reconstruction of stonemason's tools, we use the methods of traceology and mechanoscopy. Using modern imaging techniques, we can identify the stonemason's tool used, reconstruct the shape of its blade, and determine how it was used. The obtained results can be used in the process of monument care, especially in the process of preparation and implementation of restoration interventions on the objects, but they are also useful for completing the historical context of the monument. Our research is focused on a systematic study of the surface topography of stone monuments in Prague. The obtained results were systematically divided according to individual historical periods. As a model example of the use of the above-mentioned methods and approaches, we present the topography of stone elements and the development of stonemason's craft in Gothic Prague. The development of the stonemason's craft within one city in a given period can be documented on selected examples arranged chronologically in succession.

KEYWORDS: Stone topography, stonemason's tool, Gothic Prague.

1. INTRODUCTION

Topography is a discipline concerning the configuration of a surface, including its relief and the positions of its natural and artificial features. In common practice, we encounter topography in terms of shapes on the surface of the Earth or other celestial bodies. It deals, among other things, with their description, measurement, display, and mapping. In our case, however, we are talking about the topography of surfaces of much smaller scales whose formation is due to human activity [1]. Our object of interest is the surface topography of historical building stone that bears traces of historical craftsmanship. Each tool trace represents a valuable source of historical information. Each work is specific in its own way due to the unique pattern imprinted by the hands of the stonemason. From our extensive experience, we know that the traces on individual historic objects show, among other things, the influence of stonemason's workshops and local traditions. They also often reflect the economic and social conditions of the time e.g. [2]. Traces of working are also an integral part of the visual appearance of historic buildings and thus of their value, which needs to be protected. Within our project "Building stone surface topography and its application in the field of stone features restoration" Nr. DG20P02OVV021 founded by Ministry of Culture of the Czech Republic, we focused,

in particular, on the investigation of the craftsmanship of selected historical stone artefacts of the Prague Conservation Area, on which we identified working traces using traceologic and mechanoscopic methods. These methods allowed us to identify the traces of historical tools, create 3D models of them, and then identify and reconstruct the stonemason's tools used and the actual reconstruction of working with them. The obtained results can be used in the process of monument conservation, especially in the process of preparation and implementation of restoration interventions on given objects, however, they are also useful for completing the historical context of a given monument. The paper is, therefore, a summary of the results of our research in the field of documentation and identification of traces of historical craftsmanship. Like other crafts, the craft of stonemasonry has evolved over time and has been a subject, among other things, to fashion and social pressures. Some techniques are thus typical for certain historical periods, while others were rarely or never used in other periods. This fact can be used, for example, when dating disputed stone objects.

2. TRACEOLOGY OF TRACES AND THE TOOL USED

As we have already mentioned above, we use the methods of mechanoscopy and traceology for the iden-

tification of the traces themselves, on the basis of which we are able to reconstruct the tool and the working process itself. Both methods are based on forensic science and are used for criminal identification of traces. According to Mašková [3], mechanoscopy is based on expert knowledge of mechanics, physics and proven knowledge of the design and function of tools and instruments. It deals with the identification, way of use and mechanism of tools and other similar instruments. In criminalistics, traceological expertise deals with the examination of the traces themselves (e.g. the suspect's shoe prints). These traces can be either areal or volumetric. In our case, traceology deals with the blade of the tool itself, especially its shape, and in the case of analytical traceology, the identification of its metallic abrasions [4]. For this reason, this method is very popular in archaeology and related fields [5–7]. In addition to the analyses themselves, in traceology, there is a need to create a system of trace catalogues and also to make copies of supposed tools and to verify the excavated traces on them. The methods used in our traceological research are briefly described below.

2.1. RELIEF PHOTOGRAPHY

Relief photography is one of the important documentation photographic methods, where images of a given object are taken with lateral illumination. The light is set perpendicular to the processing traces, whereby each trace creates a shadow that highlights the corresponding raster. This method is primarily used for basic orientation on the surface of the stone being imaged. Photographs with direct illumination alone do not give any idea of the state of the surface working under examination. Lateral illumination can be achieved either with a steady light or with a flash. When adjusting the illumination intensity, it is necessary to pay attention to the illumination intensity so that the surface is not overexposed in the final photograph [4].

2.2. MECHANOSCOPY

The interpretation of data in terms of determining the actual trace is called mechanoscopy. The aim of this analysis is to identify tool traces, reconstruct the tools that produced them and outline the stone working process. As a result of the analyses, an attempt is made to reveal the process and working technique of the historical craftsmen in the making of the work concerned. Mechanoscopy works with 3D imaged materials, so it is necessary to create a 3D model of the object under study. Currently, two techniques are used for 3D modelling – laser scanning and photogrammetric scanning. For the purpose of our modelling, we use multi-frame photogrammetry. The basis of this method is spatial analytical geometry in a chosen coordinate system. First, we perform a focusing of the main points on the object to be photographed. The method of determining these points is trigonometric

calculations in the polar coordinate system. The azimuth height angles are determined using the camera, where the software calculates both angles from the position of the point on the sensor. The essential information is then the determination of the unknown position of the camera. This can be calculated by the software by creating a continuous strip of images with a minimum overlap of 50%. Once all the necessary data are obtained, a finer structure consisting of a triangular mesh can be constructed from the original point cloud. This is a simple approximation of the shape of the object. Such a mesh can then be replaced by the corresponding cutouts in the photograph [4].

The quality of photogrammetric imaging is mainly determined by the software and the quality of the sensor. The lens projects an image onto the sensor, which is made up of a mosaic of photocells called pixels. The sensor is essentially a photoelectric element that produces a voltage and corresponds to the intensity of light. The photocells are connected to a computer that is able to focus any photocell in X, Y coordinates. Ideally, the computer transfers the pixels in the matrix to memory, so that each memory cell should correspond to one X, Y pixel. In our case, however, everything depends mostly on the quality of the sensor. In practice, the sensor does not capture every pixel in X, Y, but with little intensity. Therefore, it helps itself significantly by sensing the immediate surroundings of the intensity of a given point. The result in the computer's memory is, therefore, not the intensity value of the X, Y point, but the arithmetic mean of its surroundings [8]. Laser scanning works on a similar principle, except that the scanning is done directly. The laser is emitted from a static head and oscillates on the object. Again, this is not a point focusing, but a numerical averaging of the point's surroundings. For this method, the distance of the sensor from the object is decisive. The greater the distance, the greater the oscillation of the laser. In manual scanning, the range of the beam is controlled by the camera system. However, if we have a good quality camera and lens, then the focus is at a high level, the area around the intensity of the point is reduced and the surface texture of the object is focused quite accurately. In contrast, with laser handheld scanners, where the scanning range of the laser is stable, there is a considerable blurring of the image detail. Such a method, therefore, precludes working in millimetre dimensions. Currently, photogrammetric examination of an object is significantly more suitable for mechanoscopy [9].

The photogrammetric documentation itself can be performed using a high quality, high resolution digital SLR camera, a fixed focal length lens and a set of lights that allow for a choice of directional and diffuse surface illumination. The lights themselves can be shone continuously or used in flash form. A 3D model of the surface with its topography is created from sets of photographs using Agisoft Photoscan Professional [11].

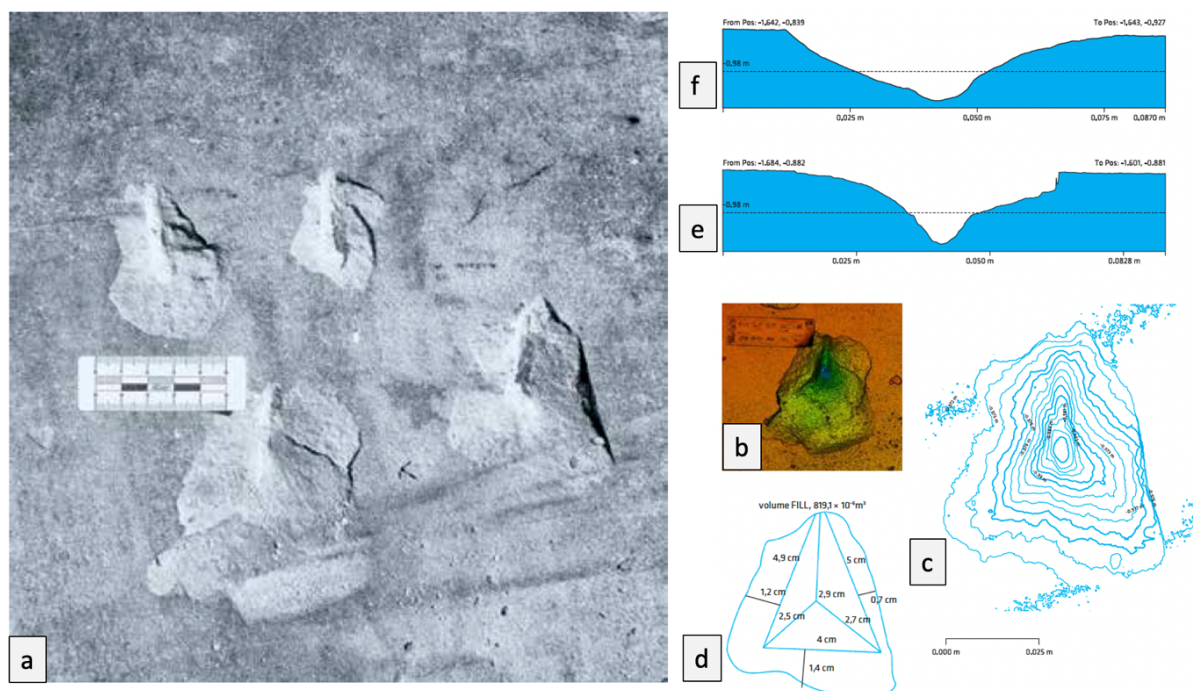


FIGURE 1. Experimental traces created by double-pick on the Mšeno sandstone (a), hypsometric image of the trace (b), its contour model (c) used to calculate the excavated volume (d), transverse height profile of the trace (e) and longitudinal height profile of the trace (f) (M. Cihla, adapted from [10]).

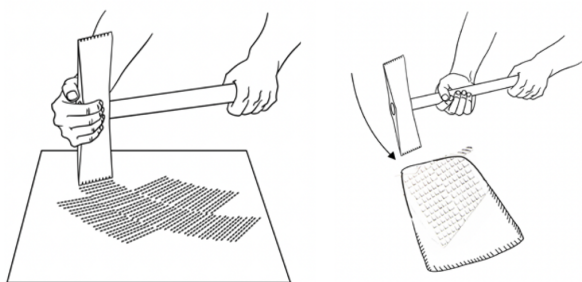


FIGURE 2. Traces of an almost perpendicular strike with an axe with flat pointed teeth (left), strikes with the same axe on a tilted face (drawing by A. Musilová, taken from [10]).

To study the surface sections and profiles, we use the Global Mapper software, in which the data are further processed using hypsometry or contouring. The selected trace is sectioned both longitudinally to determine the dynamics of the strike and transversally to generate the optimal shape of the tool blade (see Figure 1).

Every trace of a stonemason's tool found requires verification. This is only possible by experimenting with the tool itself. That is why there are copies of the stonemason's tools in question and attempts to imitate the way they work. Each work with a given tool has its own characteristics, which are reflected in the traces on the related surface (see Figure 2). The creation of a catalogue of historical stone processing traces is then the result of the knowledge of stonemason's ways of stone processing with tools in a historical context.

3. MODEL EXAMPLE – STONE PROCESSING OF GOTHIC PRAGUE

One of the main objectives of our research was a systematic study of the surface topography of the stone monuments of Prague. The obtained results were systematically divided according to the individual historical periods and clearly organised into a database [12]. As a model example of the use of the methods and approaches described above, let us consider the topography of stone elements and the development of stonemason craft in Gothic Prague.

Building activities in Prague during the 13th century continued the previous Romanesque architectural achievements [14]. The stone craftsmanship tradition continued to the full extent in the intentions of the so-called Prague School. Surface faces were cut in diagonally centred rasters, and the axe with a pick was still the most commonly used stone tool, just as in the Romanesque period. In the 1330s, a major building contract was ordered for the construction of a stone wall, part of the fortification of the Old Town. This monumental undertaking required not only an adequate quantity of material but also a change in the approach to its processing [13]. According to current knowledge, the material used in the construction of the wall, except for two short sections, was “opuka” [15]. This stone can be characterised as sandy-marly siltstones or sandy-silty marlstones or silicified marlstones and or marly silicites [16]. It was broken in so-called quarry “flatbreads” and then split into the necessary small blocks. The “opuka” building blocks were usually worked by stonemasons only on the load-



FIGURE 3. Old Town – Old Town Walls, between 1230 and 1253. Above, photo by M. Cihla, individual stages of working (drawing by A. Musilová, adapted from [13]).

ing surfaces, i.e. in the areas necessary for the stone to settle into the row. In this way, the common perimeter masonry was very simply designed. In contrast, the corner reinforcement of the tower walls was much more carefully manufactured in terms of craftsmanship [17]. The “opuka” blocks were of larger dimensions, around 30×30 cm. The tool traces testify to the fact that these blocks were first roughly modelled with the pick of a handled tool and then a circumferential path was made with a 1.5 cm wide straight-edged chisel. Finally, the surface was realigned in an oblique grid with a straight-bladed axe with a blade size of approximately 4 cm (see Figure 3).

The height of the stonemason’s craft in Prague at that time was the construction of the St. Agnes Monastery, whose first construction phase was completed with its consecration in 1234 [18]. This phase, which falls into the period of late Romanesque construction, prefigured a completely new trend that carried throughout the Middle Ages. It is clearly the

dominant use of toothed tools. The perimeter masonry of the Church of St Francis in the Convent of St Agnes still shows the receding approach typical of the Romanesque period, edging with a double-pick or other pointed handed tool and then resurfacing with an axe in areas of protruding material. In contrast, corner armatures and other architectural features are modelled with extreme precision using chisels or an axe with fine flat teeth. In architectural profiles, surface worked with toothed tools is also beginning to be used as a decorative grid (see Figure 4).

The orientation of stonemason’s work towards the straight-edged chisel, which reflected European trends, came in the late 15th and early 16th centuries. Rough stone modelling still used a pointed handed tool. The paths tend to be narrow, cut with a straight chisel, and in some cases, still visible. However, the final realignment of the face is always done in an angled grid, in parallel rows with a straight-bladed chisel. An example of such a precise work is the processing of the



FIGURE 4. Old Town – Agnes Monastery, refectory, after 1234. Surface processing with toothed tools in a decorative grid (photo by M. Cihla, taken from [13]).



FIGURE 5. Malá Strana – Malostranská Bridge Tower, 2nd half of the 15th century. Final realignment of the face in an oblique grid in parallel rows with a straight-edged chisel (photo by M. Cihla, taken from [13]).

blocks of the perimeter masonry of the Malostranska Bridge Tower (see Figure 5).

4. CONCLUSION

All of the above methods of surface working are more than typical and accompany the construction activity in the Gothic period. Like other crafts, stonemason craft developed and evolved over time. We have illustrated this development in the Prague Conservation Area with the example of the processing of Gothic stone elements. It is clear that the way of stone elements working and the traces of individual tools create the visual perception of a given monument and are indeed an integral part of its value. This value needs to be protected as a valuable part of the cultural and historical heritage. The use of new modern methods enables the precise identification of the tool traces, their reconstruction and even the reconstruction of the working process itself. The working process itself can also be seen as a cultural heritage of our ancestors. Furthermore, systematic research and documentation

of traces is an important source of information in the process of heritage conservation.

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