HISTORICAL MODELS OF CIVIL ENGINEEERING IN COLLECTIONS IN AUGSBURG AND MUNICH

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Keywords

Models, Civil Engineering, Museum

Abstract

Architectural models usually serve as a support during the design process or as a sales aid for the architect, giving his client an additional, three-dimensional idea of the finished building. Since architects used to work not only as designers, but also as master builders who had to resolve complex technical problems, many of them also built models that explained how their technical ideas could be realized. These models are few in number, rarely discussed and even less often displayed in exhibitions. They frequently show waterworks, bridges, and timber frames for wall and roof constructions.

In Bavaria there are two important collections specializing in this kind of model: Augsburg's "Modellkammer" (model chamber) – originally in the town hall and now part of the Maximilian Museum – includes models of famous waterworks representing canals, weirs, pumping stations, and wells, and structural models of the buildings designed by Elias Holl (1573–1646) – all built between the early 17th and mid-19th century. The second collection – at the Deutsches Museum in Munich – contains models of early bridges and related structures like the ones designed and built by such famous master builders as Hans Ulrich Grubenmann (1709–1783), Carl Friedrich von Wiebeking (1762–1842), Leo von Klenze (1784–1864), Friedrich August von Pauli (1802–1883), William Howe (1803–1852), and Ulrich Finsterwalder (1897–1988).

These engineering models, seldom the subject of study until now, have proved to be an inestimable resource for the study of construction history because they provide an insight – unavailable elsewhere – into a very practical component of the design process. The topics addressed by these models point out the main challenges, tasks, and problems that builders were confronted with and the particular ways they chose to resolve them. At the same time, they represent an important means of education and form of apprenticeship, and may also have been used to coordinate the different crafts involved. In retrospect, they make clear the process of specialization of architects and engineers.

The focus of this paper will be a generic description of the two collections making reference to their contribution to the history of construction. Finally, this article will show, by way of example, the many and important contributions that models can offer the study of construction history.

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INTRODUCTION

Architectural and construction models have existed since antiquity. The regular use of architectural models, made especially for the design process in architecture, only became widespread from the Italian Renaissance onward (Reuter 1994: 10). One of the most famous is Brunelleschi's model for the Cupola of Santa Maria del Fiore in Florence from 1418 (Evers 1995: 13). To collect such models after the buildings in question had been completed, along with any relevant drawn and written documents, did not become common practice until the mid-15th century. Prior to that, models were considered perishable tools for builders, and not treated like documents worth preserving, as official building papers were. Technical models were produced parallel to treatises as and when these appeared during the Renaissance about architecture, mechanics, and machinery. Scientific research into these models has taken a multifaceted approach: examining their historical, technical, and manufacturing aspects, as well as their purpose (Bühler 2013).

ENGINEERING AND ARCHITECTURAL MODELS

Architects, engineers, and artisans who worked as master builders had to resolve complex technical problems. Many of them were built as test models; when they succeeded, they were used to explain how their technical ideas could be realized. While the aim of architectural models is to show the spatial distribution within a building or its decoration, construction models serve to visualize technical solutions. The precision, choice of the finest materials, and the aesthetics involved was equally high when it came to making engineering and architectural models .

As early as 1641, the German architect Joseph Furttenbach (1591–1667) mentions in his treatise *Architectura Privata* that an architect must be capable not only of drawing plans, but also of producing models of his designs (Reuter 1994: 7). Furttenbach himself owned, among other objects, models of bridges, mills, and waterworks, and he installed a "Kunstkammer" (chamber of curiosities) in his house (Furttenbach 1641: 37, 40). John Soane (1753–1837) did something similar two centuries later when he set up a museum in his home in 1833, a museum that is still open to visitors. Today, models are still present in many architects' and engineers' offices, and the fact that they are still used in our "digitized" society attests to their convenience, benefit, and value.

Collections of architectural and engineering models can be found today in museums of architecture, technical museums, and universities – and many cities collect models of their own buildings.

In Bavaria there are two important collections specializing in this kind of model: Augsburg's "Modellkammer" (model chamber) and the collection at the Deutsches Museum in Munich

THE COLLECTION OF THE MODEL CHAMBER IN AUGSBURG

The Free Imperial City of Augsburg has collected planning and remembrance models of important building projects since the early Renaissance. In 1620, Elias Holl (1573–1646), Augsburg's most famous architect and designer of its new town hall (1609–20), turned the room above the Golden Hall into a model chamber, where he also collected engineering models. This municipal model collection was handed over to the Maximilian Museum in the 20th century.

Elias Holl's idea was not really new even back then, but what makes his collection so remarkable is his particular selection of models. Holl, a traditional type of builder for those days, was appreciated more for his engineering achievements than for his architectural designs, which are what we admire today (Roeck 2004: 24). In his personal work chronicle, it is with some pride that Holl himself mentions his successful solutions to structural and technical problems rather

than his perfect architectural designs. A master mason by training, Holl was appointed the city's "master builder" in 1602. He was forever busy designing innovative construction equipment (Roeck 2004: 94) and used to collect models of his engineering achievements, such as cranes and stone-lifting devices. His main model shows the scaffold for the Perlach Tower, which was fixed to the surface of the structure without the use of clamps, thus protecting the facade of the tower from damage. The Augsburg collection was one of the first to focus not only on architecture, but also on what would come to be the engineering profession. Many models were donated to the collection later on by the St. Anna grammar school, and several bridge models came from the Building Museum, which was part of the local Building School.

Founded by the Romans in the 1st century BC during the reign of Emperor Augustus, Augsburg has always had a plentiful supply of fresh water, but the distribution of running water was not common until the end of the Dark Ages. In 1412 the city council built the first pumping station to feed the newly-installed public waterspout fountains. From then on, the city had at its disposal a double hydraulic infrastructure: a grid of canals providing the mills with hydropower, and a network of water pipes made from drilled timber ducts and fed by the pumping station.

With the establishment of its first waterworks, Augsburg became a standard for urban water supply, and the city installed a collection of models in the new water towers for interested travelers who came to learn from the "Brunnenmeister" (master of the waterworks). In *Hydraulica Augustana*, published in 1754, Caspar Walter (1701–1769), "Brunnenmeister" in Augsburg since 1741, describes the three central water towers, the well houses of the waterworks with all their technical installations, and expands on the model collection displayed in the main tower (Walter 1754: 22). Walter's description begins on the 3rd floor of the main tower, where several crankshaft models are presented. On display on the 4th floor are models of weirs, dams, and sluice gates suitable for installation in canals and rivers. Other models illustrate the use of stone, bricks, and timber in the construction of basins, gates, and pit lining. There are even models of a canal bridge, a ship for shoreline stabilization, and some roof frameworks. Visitors to the 5th floor will see a number of text panels, five models of Augsburg's famous pumping stations, a model waterwheel driving three different devices, as well as water towers, well houses, and a mill driven alternately by muscle power and hydraulic power. Also on display with a description is a model of the sluices and weirs along the branch of the Lech River known as the "Hochablass," which conducts water into Augsburg's canal system. The arc of suspense culminates on the 6th floor, with three large models of pumping stations, one of them (indexed § 6 k) is now on display in the Maximilian Museum. Different types of transmission shafts show additional practical uses of hydropower. The presentation is completed by a series of panels, showing the water distribution system and its technical installations. The 7th floor – where a small stairway leads to the viewing platform on top of the tower – contains the water tank.

Thirty-six of the 126 models listed in the model chamber can today be admired in the Maximilian Museum (Fig. 1). The collection there includes models of bridges (14), machinery and construction equipment (8), waterworks, such as pumping stations and fountain towers (25), mills (16), vaults and roof trusses (7), a scaffold (1), details of a double and a triple spiral stair (2), city gates (7), towers (8), a model ship (1), and miscellaneous models with mainly architectural content (6). The most representative models of Augsburg's architecture are the city models (2) dating from 1563 and the 17th century, and the models of the historic and current town hall (8), which are worth researching in themselves.

The distribution of fresh water to the public fountains and households in Augsburg created a need for drilled timber ducts for the supply system. Such ducts – straight timber trunks up to four meters in length that were drilled using a borer with an iron cutter head – were well known since

Roman times and used in many places, even until the end of the 19th century. The preparation of these ducts posed two main challenges to the workers. The first was how to keep the cutter head, which was usually fixed to the top of a timber or iron bar, straight while steadily drilling through the center of the trunk. The second challenge was to provide enough human or mechanical power to carry out the drilling, which was a really tough job. In this context, the functional model of an 18th-century timber duct drilling machine (Fig. 2) deserves particular consideration because it illustrates clearly how the power transmission provided by the waterwheel and the labor-saving gears are combined into a horizontal, water-powered drilling machine to perform the task. This practical machine pulls and fixes the trunks in position so that they can be drilled easily. Aside from a few drawings published in artisan treatises, this is the only three-dimensional representation of this kind of machinery. The model can be operated with a crank handle to move the waterwheel. An original socket connecting two ducts is also part of the collection.

Two of the 25 hydraulically powered machines are outstanding examples and are on display in the Maximilian Museum: The first is an 18th-century model of a pumping station, formerly exhibited in the main tower of the Augsburg waterworks and described by Walter. The model represents two water pumps, each consisting of three hydraulic cylinders. The devices were operated by a waterwheel placed between them. Water pipes conduct the water to the tank on top of the tower (not represented in this model). The main difference between the two pumping devices lies in the power transmission between the waterwheel and the pumps: on one side, the transmission is performed by a cumbersome swinging beam; on the other side, a more modern transmission is achieved by means of a cranked shaft. The model thus displays the transmission technologies used at the turn of the 16th to the 17th century (swinging beam) and the more modern transmission, introduced during the 18th century (cranked shaft). It is ideally suited to explaining the processes involved – which is what Walter intended with his model collection, and what the founder of the Deutsches Museum also had in mind some 150 years later.

Fig. 1 The model collection in Augsburg

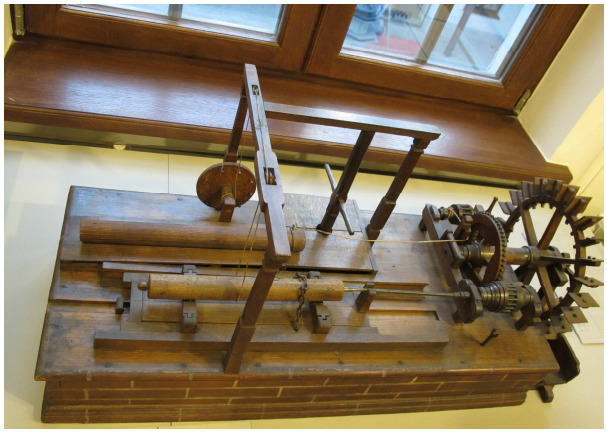

Fig. 2 Model of a drilling machine

Another enlightening model in the Maximilian Museum demonstrates several possible uses of hydraulic power. As the brass label on the base plate states, it was made by the carpenter Andreas Seuffert in 1758. It shows a central waterwheel surrounded by seven mills with 16 different types of gears. The waterwheel can be turned by a hand crank to demonstrate the operating mode of mills and gears. This sophisticated and functional teaching model was used by its manufacturer for presentations at various courts. The mills and their corresponding mechanical devices represent a flour mill, fulling mill, paper mill and an oil mill on one side of the waterwheel, and a sawing, hammering, and polishing mill on the other side. This well–manufactured model is able

to convey to us today what constituted state-of-the-art milling techniques in the mid-18th century, which makes it a precious technical document of its time.

One of the bridge models (Fig. 3) is of the cable-stayed bridge crossing the raft culvert at the "Hochablass" weir in Augsburg (Reuter 1994: 29). The original was built as early as 1821 by Franz Joseph Kollmann (1800–1894). Kollmann had this model built when he became chief engineer of the city council in 1826. The bridge itself, with a banister on just one side of the wooden deck, is supported by four wrought-iron bars on each side of the bridge. The model illustrates in detail how the bars are connected to each other, to the bridge deck, and to the bridge towers, and shows how the towers are anchored by other bars fixed to the ground. It represents an early solution for a cable-stayed bridge – a solution that has yet to be discussed in the literature.

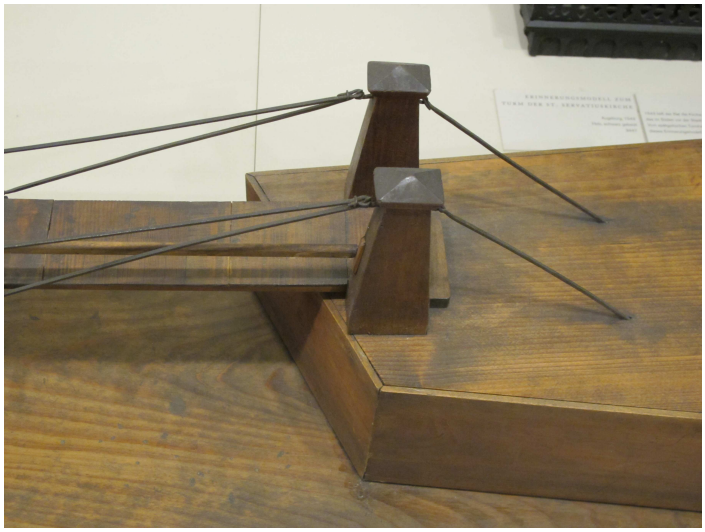

Fig. 3 Model of a cable-stayed bridge from 1821

Fig. 4 Model of a stone lifting device

No less interesting are the models of temporary constructions and the devices used during the building process, such as the model of the Perlach Tower (1614/15), with the scaffold by Elias Holl, and the scaffold used for the vaulted ceiling of the St. Anna grammar school (1747). The other models on display include a lifting device for the gentle handling of freestones (Fig. 4), a crane with a worm gear displaceable in two directions, and an automatic ram.

THE COLLECTION AT THE DEUTSCHES MUSEUM

Aside from its famous originals, the Deutsches Museum also owns a large collection of models and dioramas, many of which are on display in the various departments. However, around 85 per cent of the collection is actually stored in the museum's depots. The museum's inventory currently lists about 9,000 models and around 180 dioramas. Among them are 351 models and ten dioramas on the subject of civil engineering and 239 models and 19 dioramas dealing with construction techniques. With regard to household installations (including water supply for instance), there are 326 models and three dioramas. These numbers make no mention of the type or quality of the items, nor do they take into account those that were lost during World War II, but they do at least provide a useful rough guide to the size of what is truly an enormous collection.

The general collection was initiated in 1903, when the Bavarian civil engineer and entrepreneur Oskar von Miller (1855–1934) founded the museum. The first objects came from the Bavarian Academy of Sciences, which donated its collection of scientific instruments. Other originals

were subsequently acquired from around the world by the museum's scientific committee, set up by Miller. However, the museum's mission was not just to educate and inform the public, but also to entertain it. The Deutsches Museum's "hands on" experiments proved to be its most important innovation: explaining to visitors the basics of scientific knowledge and technical procedures. Accompanying this innovation was the idea of using models, dioramas, and sceneries to place science and technology within their historical, cultural, and everyday contexts. Given Bavaria's handicraft tradition of modeling and its many well-trained artisans, it made sense for the museum to set up its own workshops to manufacture the models. Nevertheless, a large number of models were also acquired from other collections or were ordered from other workshops. These models continue to provide the background for our exhibitions, and they are still produced to a traditionally high level of workmanship, albeit with the aid of modern techniques.

Within this domain, the models of houses, bridges, and other outstanding architectural and engineering constructions represent a major part of the Deutsches Museum's collections on building history, portraying milestones in the history of construction and technology.

Each new phase in the collection's history brought with it a new generation of models. The first models, presented in 1903, date from the turn of the 19th to the 20th century: some of them were built specifically in the museum's workshops; others originated from different collections or were bought at industrial fairs. This first collection was substantially enlarged when the exhibitions moved to the museum's current building in 1925. Between 1920 and 1936, many models were produced to cater to the then larger number of construction-related exhibitions: "Construction Materials," "Urbanism," and "Household Installations." Civil engineering was represented by "Hydraulic and Bridge Engineering" and rounded off by "Road and Tunnel Construction." The next generation of models was created after World War II for the "Civil Engineering" department, which opened in 1962. The latest models were produced in 1998 for the refurbishment of the former gallery. However, the collecting of models continues to this day. Since 1998, historical and modern models have been acquired through donations or have been specially produced for temporary exhibitions.

A few words about the manufacture of these models will help to underscore their value for construction history. First of all, the production of such models requires a good deal of scientific research. This applies both to our historic models and those of the present day. In particular, significant details have to be explored, defined, focused on, and captured correctly, in order to be accurately transferred into a physical form. Models that display processes in action must convey the "right moment"; from the many steps that make up a process, the crucial moment must be ascertained in order to show the most descriptive and representative action (Bühler 2013: 59). The choice of the appropriate scale is another crucial point that has to be considered. A further requisite of models for the museum is that they must be as self-explanatory as the current level of technology will allow.

Regarding the history of civil engineering, the models cover three main topics: "Hydraulic Engineering," "Construction Equipment," and "Bridges, Streets, and Tunnels."

The "Hydraulic Engineering" collection contains two models of waterworks donated in 1905 and 1909 by Augsburg's city council: both are replicas of the original models in the Augsburg model chamber (Fig. 5). Of great importance to the Augsburg and Munich collections are the pumping stations developed by Georg Friedrich von Reichenbach (1771–1826) for the brine ducts between Berchtesgaden and Bad Reichenhall. Two models, built in 1858, reached the Deutsches Museum in 1905. A third belongs to the Augsburg collection, where Reichenbach occasionally worked. Other models deal with water supply (6), such as wells and fountains. The impressive models of weirs (16) (Fig. 6) were built in the museum workshops between 1909 and

1930. A number of models of locks (3), a ship lift (hoist), and a ship ramp were purchased for the 1962 hydraulic engineering exhibition. Only a few models represent water towers (3). Many other models are part of the power machines section and cannot be considered in this context.

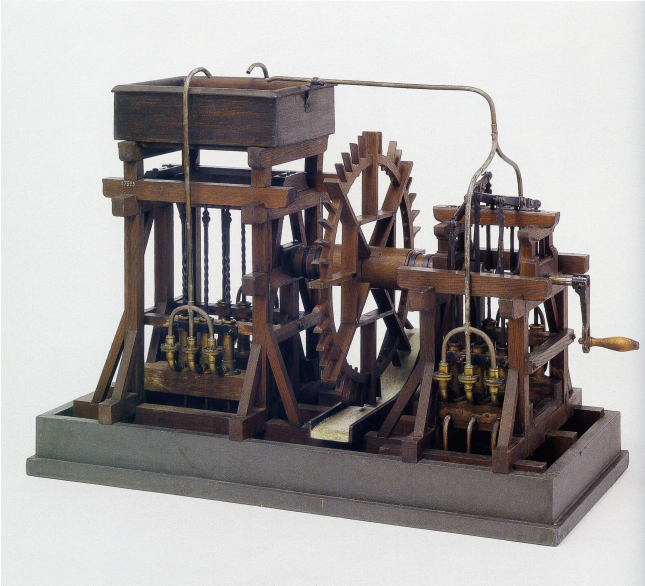

Fig. 5 Model of the pumping station in the Deutsches Museum

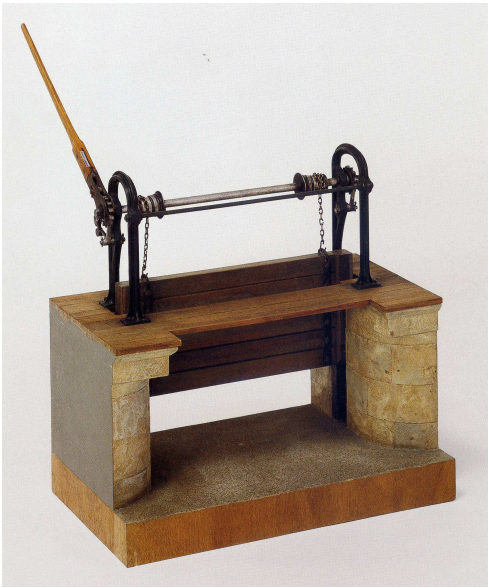

Fig. 6 Model of a weir from the 1920s

The collection gathered in the "Construction Equipment" department is unique: 11 models of manually operated rams acquired between 1905 and 1909 from the Munich Polytechnic School , the Royal Bavarian Building Authority for Roads and Rivers (including two replicas of models in the Augsburg collection), as well as six steam-operated rams. The models of early concrete mixers (5) illustrate the development from gravel washing drums to the concrete mixers of the 1930s for the industrialized preparation of concrete. Construction techniques like roof trusses (5) and a plaster mill from 1805 are dealt with to a lesser extent, while other mills are also feature elsewhere, for example in sections dealing with power machines and agricultural technology.

One of the museum's most attractive and key sections is "Bridges, Streets, and Tunnels." The 80 or so bridge models make up the largest single collection, with models dating from the late 19th century to the present day. The section also consists of 21 street and 18 tunnel models.

The Simplon Tunnel, completed in 1905, provided an attractive subject for the museum to collect and exhibit: original drilling machines and parts of the scaffold were acquired and used for a replica of the construction site, with models explaining the technical details (Fig. 7).

A series of eight models represents the development of road-building since Roman times up to the highway construction of the 1960s.

Many of the bridge models have been described in the guide to the exhibition (Bühler 2010), but there are many more, such as the 1898 model of the bridge over the Regnitz River in Bamberg (built in 1809 by Wiebeking). It was donated to the museum by the Royal Bavarian Building Authority and is the oldest model in this collection. The replacement bridge built in 1829, a chain bridge designed by Leo von Klenze, and the famous bridge at Schaffhausen from 1758 (model 1962) by Grubenmann are highlights of the group.

Fig. 7 Model of the Simplon Tunnel

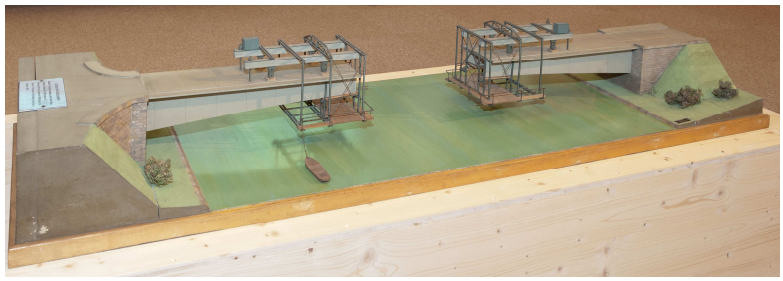

Fig. 8 First model showing the cantilever method for prestressed concrete

In addition to this, there is a series of models representing main bridge systems such as lattice and truss bridges, emphasizing Howe's and Pauli's beams. The model of the wooden fish-bellied girder bridge crossing the moat around Hanover was made by students in 1989 to a scale of 1:5. A particularly important document for construction history is the model of the Lahn Bridge at Balduinstein, used by Finsterwalder for the presentation of the first prestressed concrete bridge, built using the cantilever method. This unique model from 1950 was acquired in 2006 (Fig. 8).

CONCLUSIONS

This paper has presented the provenance, development, general content, and extent of the two collections, which have chronologically quite different origins. Their value has been described within the general context of engineering models. Further examination of all the models in the Augsburg and Munich collections, along with their structural analysis, would vividly reveal their importance during the design process, especially if accompanied by precise documentation of the relationship between model and completed building. The interaction between these models and the theory of construction deserves additional reflection, while the significance of the models in the two collections and the intentions of the men who created them also require further study. This in itself is an important and worthwhile challenge, and aside from promoting such research, this paper wishes to arouse curiosity and initiate discussion in favor of more studies on the many collections still waiting to explored and valuated.

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