Development of mortars in Sweden during the period 1800 to 1950

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Abstract: The objective with the present project was to combine studies of textbooks and masonry constructions with laboratory analyses of historical mortars from the time period 1800 to 1950. The objective was to investigate the development of knowledge and craftsmanship of the mason during this period. The three different sources display the same trends from binder rich to binder poor and to mortars based on cement and lime mixes. There was a change from a complex and varying use of different mortars in the 19th century to a simplified and standardized use in the 20th century. This process also includes a change to a centralised and industrialized production of binders. A consequence of this was that a loss of the craftmans knowledge of how to handle different hydraulic binders and pozzolans. The later part of the period was characterised in a loss of knowledge in this aspect for all actors working with masonry and renders.

Introduction

The focus of the project was to compile and compare information from textbooks, observations on buildings related to restoration projects and results from mortar analyses. Those who are interested in the older literature in Swedish are referred to Eriksson for references [1]. The aim with the multi method approach applied was to provide a deeper insight in materials and methods used during the studied time period. It is possible, based on this, to discuss the development of the role and knowledge for the mason during the studied period.

While 19th century displays an increase in complexity and variation of binders and mortars has the 20th century a reduced variation in the types of binders mortars. This reflects an aim to industrialize and standardize the building process. This was related to the increase in the built volume not least in urban areas. A consequence of these changes was first reflected in an increase followed by a loss of knowledge among masons and other actors working with renders and masonry.

Development of mortars

The general development of mortars in Sweden can be described with the aid of the simplified Fig. 1: "Development of mortars in Sweden". This shows the various types of mortar used in Sweden and their development from the 11th century until the present day. The table is illustrated with images, mostly of early examples of still existing and good preserved buildings and their development, focusing on the period 1800–1950 (from Pasch and the Göta Canal to Nycander and others and Stockholm South General Hospital). This table was first presented in Sölve Johansson's doctoral thesis in 2006 [2], but has been supplemented as a result of further studies that the relationships are complex [3].

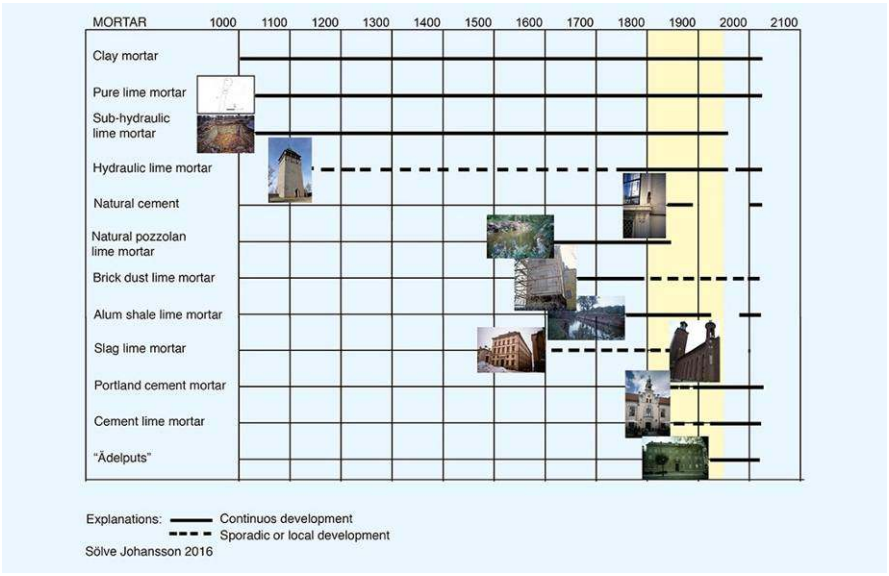

Fig. 1 Development of mortars in Sweden

First of all clay mortars was used all time in Sweden. But here we are only dealing with lime-, pozzolan- and Portland cementbased mortars. During the period 1800–1950, pure, sub-hydraulic and hydraulic lime mortars were widely produced and used in Sweden following their introduction in the 11th and 12th centuries [4]. More recently, pure lime mortars and hydraulic lime mortars have come to be used primarily in building conservation. Sub-hydraulic lime mortar is now no longer used. The use of these mortars was originally a craft process but gradually became more industrialised.

In the 17th and 18th centuries there was a need for high-strength mortars for projects such as water management. This demand was initially met by importing pozzolana from countries such as Italy to manufacture natural pozzolan lime mortar, and from the 1770s by producing alum shale lime mortar, based on burned alum shale, an artificial pozzolan, usually in combination with hydraulic lime based on a formula developed by the chemist Gustaf Erik Pasch for the construction of the Göta Canal (1810-32) [5]. The import of

pozzolana from Italy ceased around 1850 and alum shale lime mortar was used primarily until the 1880s. This type of mortars was replaced by Portland cement.

One type of mortar used in Sweden was brick dust lime mortar, but this was limited to prestigious building projects during the 17th and 18th centuries. Another type, slag lime mortar, which used materials such as blast furnace slag as pozzolan, was introduced in the 17th century, but has only been used sporadically or local since then. Slag lime mortar was used as pozzolan in the tower of Stockholm City Hall (1911–23), together with a hydraulic lime mortar, to produce a stronger mortar than in other parts of the building.

During the period 1800–1950, several new types of mortar were introduced in Sweden – natural cement, Portland cement, cement lime mortar and "Ädelputs" – as part of a rapid phase of industrial development in the industry.

Natural cement was imported from England and used for the first time in Sweden when the mercantile exchange was built in Gothenburg in 1844–49 (Fig. 2). The masons came from Hamburg in Germany. Natural cement was then used primarily in western Sweden until the 1880s due to ease of access to England from where it was exported. This in turn was superseded by Portland cement.

Portland cement, often mixed with lime as cement lime mortar, was introduced to Sweden in the mid-19th century, imported from countries such as England. One early application was at the Old Town Hall in Skövde (1853), in Västergötland, a region that has extensive lime deposits and where the lime industry developed at an early stage. This mortar appears to have been manufactured on site. Domestic production of Portland cement began in Skåne in the 1870s.

"Ädelputs" was a render made primarily from standard and white Portland cement, ground dolomite, pigment and usually mica. It was first produced in the 1910s, and is still in use today. The illustration used for this type of mortar in fig. 1 is the Handelsbank building in Vänersborg, designed by Ivar Tengbom (1919–23).

Finally we come back to cement lime mortar, which in its modern, industrially produced, form it has a very specific composition that was developed in the 1930s
and 1940s mainly by Sven Nycander, a civil engineer and Einar Leckström, a mason instructor [6]. Stockholm South General Hospital (1937–44) was an early application of this type of mortar (Fig. 3). Modern cement lime mortar was used on a large scale.

Fig. 2 The mercantile exchange in Gothenburg

Fig. 3 The southern general hospital in Stockholm

The craftmans role in a changing building process

As a part of the construction of the Göta Canal a commission was given to Pasch in the early 19th century to investigate limestones and the possibilities to produce hydraulic limes and pozzolans [5]. The investigation was performed in the period 1818 to 1822 and included both empirical research and a literature study [5]. Pasch performed both chemical analyses and empirical experiments on several limes. The chemical analyses aimed at quantifying the amount of lime and hydraulic components in the binder. In a Swedish perspective was this quantitative definition of the limes a new approach. Pasch argues however that the qualitative empirical results were the most significant and that the quantitative chemical analyses were supplementary. The applied quantitative methods and procedures were typical for the time. He introduced quantitative and qualitative types of descriptions and recommendations that were applied by several authors during the 19th century. The work by Pasch can be considered as a starting point for a change in the way of describing mortars, going from a qualitative description based on the masons experience of handling the mortar to a quantitative description based on measurable properties such as chemical composition of the binder and strength of the hardened mortar. This development continued and by the mid 20th century was the quantitative description of mortars the standard.

Textbooks from the mid and later part of the 19th century describe a situation with complex variety of binders including pure lime, subhydraulic and hydraulic lime and the use of artificial pozzolans. The limes were mostly used locally. A variety of dry and wet slaking methods adapted to the different limes were described. A large part of the process was performed at the building site. The use of a complex variety of materials and methods in the building process were often dependent on situation based assessments by the mason. This requires a high skill of the mason as well as an understanding of the whole process.

The textbooks also describe a change towards more aggregate rich mortar mixes. The average recommended mix proportion for different authors was 1:2 for pure lime and 1:1.5 for sub-hydraulic and weakly hydraulic mortars. Renders were built up in two or three layers with a maximum total thickness 12 mm. The recommended maximum particle size

of the aggregate was 2 mm for pure lime renders and for sub-hydraulic and weakly hydraulic 1.3 mm. At the later part of the century Portland cement was introduced in Sweden. Cement was soon considered as the modern, rapid and strong material which was highly appreciated by architects at the time.

The textbooks reflect a dynamic change in the building process during the 19th century. There was a change from local small scale towards large scale centralized industrial production. This was a response to the dramatically increased building volume and the demand for a more rapid building process. A consequence of this was that the masons lost contact with the lime production resulting in a reduction in the masons knowledge about the materials used and the production process.

Complaints about increasing damages on external renders led to an investigation performed by the engineers Westlund and Gedda in the late 1930s. No general conclusion was reached. Of 30 possible causes were 22 related to the performance of the work. But the investigation also pointed at the wide variation of binders and mortars that were used and caused problems. The wide variation in burning and slaking methods was also identified as a part of the problem. The use of dry slaked lime was recommended aiming at more exact mix proportions. Also recommendations for mix proportions were given. Westlund and Gedda argued that standardized ideal size distribution curves should be formulated and that coarser aggregate should be used. It was argued that the rapid building process required mortars that were adapted to this. One recommendation was the use of lime cement mortars which also was supposed to give a more durable render. There was a consensus in the literature at the time that the rapid building process was an important factor for the observed damages on the lime renders. It was also argued that mix proportions and application techniques was too dependent on individual actors such as producers and masons.

It was argued that research based on the practical application in combination with laboratory investigations was needed. This resulted in development projects based on the cooperation between masons and engineers. The result of this was reflected in the handbooks and recommendations produced at the time. During the time period 1945-1966 were a number of handbooks produced. These handbooks formed the base for a change in production methods, materials and applications used for renderings [6]. They formulated how mortars should described and provided the procedures that been dominating until present time in Sweden.

Both dry and wet slaking methods were common. Feebly hydraulic limes were slaked in a similar way as pure air hardening limes. The better durability of the weakly hydraulic lime compared to pure air hardening lime was described by several authors before 1950. The weakly hydraulic lime were only stored for some days. The recommended minimum storage time for the pure air hardening lime was 1-2 weeks preferably longer.

In the 1950s was wet slaking of limes at the building site replaced by industry produced dry slaked lime. It was emphasized that this dry slaked lime had higher quality and was more pure which results in more precise mix proportions. This change reflected an expressed need for quality control of materials and mixes.

A higher aggregate content was recommended after 1945. The properties of the sand were described quantitatively by the size distribution curves. The recommendations given in the literature in the period 1920-1966 describes a change in mix proportions from 1 part

binder to 3 parts aggregate to 1 part lime and 4 parts sand. The maximum particle size increase and the thickness of the mortar layers generally increase from 15 to 20 mm.

The science based industrialized production of pure dry slaked limes resulted in a uniform binder that could be used in a more industrialized building process. This cut the chain of assessments and decisions that could be related to the varying properties of the limestone. This was a change from an approach where the methods were adopted to the properties of the materials as described in the 19th century to the standardized production described in the 20th century. The accumulated effect of the described changes was a loss of craftsmans knowledge in the chain from limestone to the applied render. This loss of knowledge has been recognized by the heritage community in Sweden and has also been described as an important research area.

The information from laboratory analysis

The laboratory analysis of mortar samples has been performed using chemical and microscopical methods [7]. The presented results are based on about 70 analyses from 1800 to 1920. The analytical results confirm that the recommendations given in the literature of the time also were applied in practice. It also provides information of materials of which is not known from the literature and were the craftsmanship tied to these materials has been lost.

The analyses confirm that the use of hydraulic binders and pozzolanic materials were successively more common from the mid 18th century. Brick dust as well as slag from production of forged iron was used. These were later replaced by alum shale ash used as an artificial pozzolan. In the early stage were alum shale ash mortars mainly used for water constructions and military constructions. In the late 19th and early 20th century were these mortars used mainly for general house building while cement based mortars were used for the more demanding constructions.

Renders and bedding mortars containing blast furnace slag were used at least sporadically from mid 19th century in steel producing areas. Little has been reported in the literature concerning the early use of milled blast furnace slag in binders. Other types of industrial waste ashes have been identified in mortars from a few buildings Stockholm. In the south western part of Sweden occur mortars with artificial pozzolans composed of different types of industrial byproducts that were locally available at the time.

In the time period 1870 to 1910 binders and pozzolans used in Stockholm show a wide variation. On one and the same building can several different mortar types with widely varying properties occur for the same application such as jointing mortars.

The mix proportions for lime mortars as recorded by the analysis changed during the period to more aggregate rich mixes. The analyses of samples from the first half of the 19th century range from 1:1.6 and down to slightly less than 1:0.5 given as volume proportions binder:aggregate. In mortars from the time period 1850 to 1920 are the typical range 1:1.2 to 1:3. This agrees with recommendations given in the literature in the later half of the 19th century. The lime cement mortars that occur from approximately 1860 show no time related trend in their mix proportions. Their mix proportions ranges from 1:0.7 to 1:3. Pure cement

mortars occur during the same time interval and show a range from 1:0.8 up to 1:3.5 with a typical range around 1:2 to 1:2.5 given as volume proportions cement:aggregate. Mortars with ashes as pozzolans show a wide variation in mix proportions with binder and pozzolans to aggregate given in volume proportions from 1:0.4 to 1:5.5.

Discussion

The different sources of information used in this compilation al show a similar pattern in the development of renders and masonry in Sweden during the studied time period. In the early 19th century the development reflects the mercantilist ideas at the time with a strong focus on projects such as water infrastructure for transport. From the mid 19th century increases the built volume as a response to the industrialisation and urbanisation. In the 20th century the development of masonry techniques was manly concentrated to house building. The development of binders and mortars reflects this. The period was characterised by a trend from production on the building site to a more centralised and industrialised production. Parallel was a trend from situation based assessments made by the mason on the building site to standardised materials and methods. A consequence was that the knowledge among masons was lost in response to this development. Seen from a restoration point of view has this resulted in a loss of knowledge concerning historic materials and methods.

References

1. Eriksson J (2015) Bruk av kalk och sand ur ett hantverkligt perspektiv (In Swedish with summary in English). Licentiate thesis.
2. Johansson S & Lindqvist JE (2010) Historic mortars with burned alum shale as artificial pozzolan. HMC2010 proceeding on CD. Historic Mortars Characterisation, Assessment, Conservation and Repair Series: RILEM Book series, Vol. 7 Válek, Jan; Hughes, John J.; Groot, Caspar J. W. P. (Eds.) June 2012, Springer 77-88.
3. Johansson S (2007) Hydraulic lime mortar Its Production and Utilisation in Sweden in Buildings from the Middle Ages to present Time. Göteborg Studl Conserv. 20 (In Swedish with summary in English).
4. Lindqvist JE & Johansson S (2009) Sub-hydraulic binders in historical mortars. Workshop RILEM TC RHM Repair Mortars for Historic Masonry hosted by TU-Delft. *Ed. Caspar Groot*. RILEM Proceedings pro067 Repair Mortars for Historic Masonry, p 224-230.
5. Pasch GE (1824) Berättelse om de vid Motala station anställde murbuks-försök, inlämnad till Göta Canals Direktion år 1818 och 1822. Jernkontorets analer Stockholm 1824.
6. Nycander S & Bährner V (1945) Modern putsteknik: med särskild hänsyn tagen till användningen av puderkalk och cement. 4 uppl Malmö: Svenska cementföreningen.
7. Lindqvist JE & Sandström M (2000) Quantitative analysis of historical mortars using optical microscopy. Materials and Structures vol 33, 612-617.