DOI: 10.61782/fa.2023.0777

forum acusticum 2023

BUILDING ACOUSTICS AND THE "MILLION PROGRAMME" IN SWEDEN

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ABSTRACT

The paper focus on the development of building acoustics in Sweden exemplified by the activities at Chalmers University of Technology. Developments are often initiated by incidences where people meet at a place in a certain context. So also happened in Sweden in the middle of the forties when Per Bruel came as refugee from the German occupied Denmark to Chalmers where he started the Chalmers Acoustic Laboratory. He was soon joined by Uno Ingård who later was professor at MIT. At that time Sweden was in a transformation process from an agrarian to a highly industrialized nation leading to a large urbanization. Shortage of housing and the need to increase housing standard led to the so-called million programme with the goal to build one million flats. New building technologies (e.g., light concrete walls or the use of prefabricated elements) as well as the need/wish for cost efficiency led however to buildings of varying quality with new challenges with respect to building acoustics. As consequence building acoustics was identified as important part in the education of civil engineers and in 1962 Chalmers established a professorship in building acoustics. In 1969 Tor Kihlman became the first professor in building acoustics in Sweden.

Keywords: *building acoustics, history, Chalmers University of Technology, Applied Acoustics*.

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1. INTRODUCTION

To describe the "Activities in Acoustics of European Research Centers and Companies during the 20th Century" can be an overwhelming task, even in a smaller context such as Sweden. The task becomes even more challenging having in mind that such a paper only can be a reconstruction of history and therefore not necessarily the truth, but an interpretation by the authors. To make the task at all doable the authors limited themselves in three aspects. The broad field of acoustics is narrowed to building acoustics. Instead of focusing on Sweden as a whole, western Sweden and especially Göteborg has received the main attention. Finally, the time period has been limited to the first seventy years of the 20th century.

This does not mean, that there has been no development of other areas in acoustics in Sweden or that activities in building acoustics only took place in Göteborg, or there has been no development of building acoustics later in time.

We hope, however, that the narrowed focus in this paper allow for demonstrating how an area such as building acoustics is established in a socio-economic context. It is this context which formulates the needs for a discipline and can be seen as one of the driving forces for its development. This background is described in Section 2.

In addition, the development of a new discipline needs talented people full of scientific curiosity willing to enter terra incognita. Those people met just by chance at Chalmers in the forties and fifties of the 20th century as described in Section 3. The paper is concluded with some general remarks concerning the take aways when following history of a discipline from such a distance point of time (Section 4).

2. BACKGROUND – THE DRIVING FORCES

In Sweden cities like Göteborg started to grow in the 19th century. At the beginning of the 19th century Göteborg had 13000 inhabitants which was about doubled around 1850. In 1914, however, the number has been grown to over 180000. The ongoing industrialization and globalization with Göteborg as the main harbor of Sweden attracted people from the countryside to the city. Between 1900 and 1915 companies such as AGA, SKF, ESAB and VOLVO were founded with need for labour. Because of these new establishments, Göteborg started to grow outside its original borders. Industry but also the housing for people only found adequate space in the periphery of Göteborg.

1879 the first tram line, a horse-drawn tramway, was opened and successively extended. With its electrification around 1902, the extension of the tram system gained speed. New industry and living areas were placed in the vicinity of the tram stops. This, however, led exact as in many other cities, to a very sparse city structure, which then leads to increasing vehicle traffic. After the second world war the number of passenger cars increased rapidly from ca fifty thousand in Sweden to over two million 1970 and around five million today.

According to [1] the period between 1870 and 1970 comprises the most successful part of Swedish industrialization and growth. On a per capita basis, only the Japanese economy performed equally well as the Swedish in this period.

2.1 The Million programme

Rapid economic growth and urbanisation created a shortage of housing. In addition, the standard of many existing housings was low and not considered to be valuable enough to preserve. The need to build new flats was already a political issue before the second world war. In the late forties the building activities accelerated. Figure 1 shows the number of flats built in the period between 1950 and 2020. Although the expression “million programme” considers a political decision for the period between 1964 and 1974, even before this period a substantial number of flats were built.

To build one million new homes in a country with at that time less than eight million people was an ambitious public housing programme. In addition to the economical challenge the ambition was increased by aiming on building new subareas at high quality with a good range of services including schools, kindergarten, public spaces or libraries, and meeting places for different groups of households.

Most of the apartments followed a well described standard concerning size, use of space, furniture etc. A majority of the "standard three-room apartment" (two-bedroom apartment) type of 75 m², planned for a Swedish model family of two adults and two children.

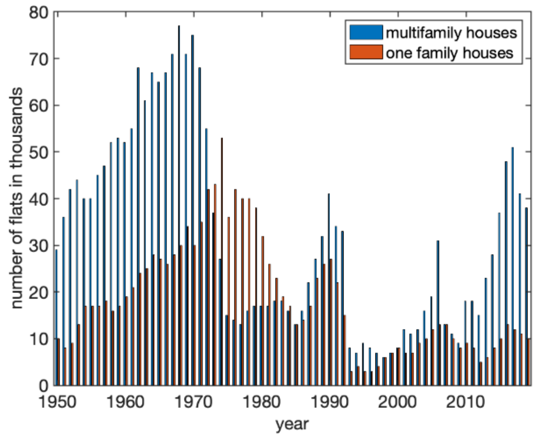

Figure 1. Number of flats built each year in multifamily houses and small one family houses in Sweden based on data from SCB (Statistics Sweden).

Not only the size was standardized but also the building materials and technologies used. Typically, prefabricated slabs were mounted in a very efficient way to multistory houses. Typical example of a building site although from the sixties is shown in Figure 2.

Figure 2. Building site 1961, typical multistory house with prefabricated elements [2].

2.2 The acoustic challenge

To be efficient from an economic perspective beside standardization, cheaper and lighter building materials were needed. The choice was light concrete slabs for building up single and double walls both as facade walls but also in between flats. This choice then turned out to create serious problems with respect to the acoustic properties of these buildings. The archive at Chalmers Applied Acoustics contains a substantial number of reports on air-borne and impact sound insulation measurements in these new buildings. Figure 3 is as illustration taken from one of these reports [3]. It exemplifies two of the main acoustic problems occurring. The negative consequences of the critical frequency around 800 Hz typical for 7 cm light concrete and leakages due to insufficient quality in the building process at high frequency.

The report was written by Tor Kihlman in 1959 at this time a 25 year old engineer who 10 years later became professor for building acoustics at Chalmers (see Section 3).

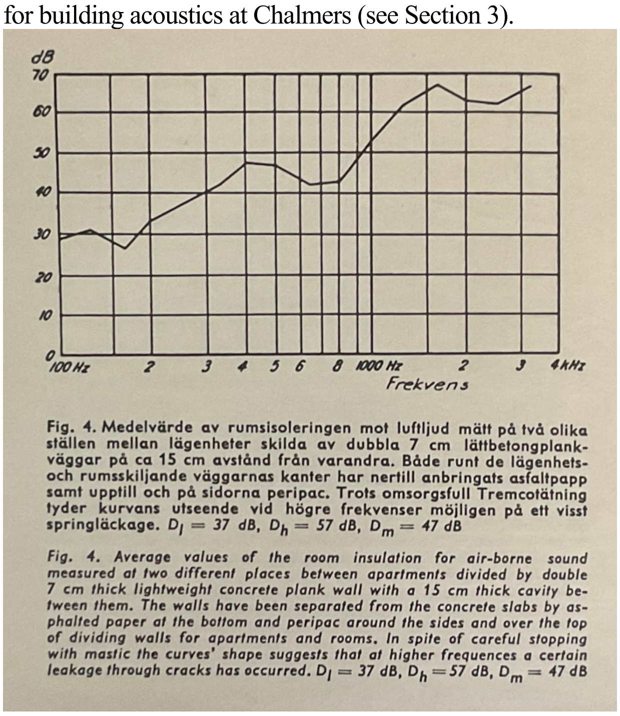

Figure 3. Measurement of air-borne sound insulation published in [3].

The problem with the critical frequency in the middle of the relevant frequency range would not surprise anyone today, but one should have in mind that Cremer's paper on the theory on "sound insulation of thin walls with oblique sound incidence" [4] has been published as recently as 1942. In addition, although education in building acoustic existed in some places as courses or parts of courses, the education of acousticians as a profession was not taking place in Sweden.

The various problems with the acoustic performance of the buildings from the fifties and sixties of the 20th century led to an increased attention for building acoustics in society. Universities like Chalmers even considered the education in building acoustics as a chance to attract more students for the civil engineering programme. This was one reason to create a chair in building acoustic (see Section 3.2)

The building boom in that period in connection with an acoustically unfortunate solution also triggered need for research and, last but not least, work for acoustic consultancies.

3. BUILDING ACOUSTICS AT CHALMERS UNIVERISTY OF TECHNOLOGY

3.1 The early days at Chalmers

The very first time acoustic is mentioned to be part of an education at Chalmers was in a course in the architecture (byggnadskonst) in 1885. The teacher was Bror Viktor Adler, professor at Chalmers, and responsible for a number of iconic buildings in Göteborg. The part of the course was called "acoustic rules" [5].

The Chalmers acoustic laboratory was founded 1943/1944 under the lead of Per Bruel. 1942 he had started the company Brüel & Kjær together with Viggo Kjær. Short after he emigrated to Sweden. Denmark was occupied by Germany and Per Bruel did not find work in Denmark he liked to do as he said in an interview [6]. In Sweden he first worked for a company where he designed absorbers for their factory halls. Then he got the question to come to Chalmers to build up an acoustic laboratory. This included two measurement rooms in a shelter in a basement at Chalmers. Later a little anechoic chamber was added for the calibration of microphones. Much of his time was devoted to build instrumentation for acoustic measurements. During that time a prototype of the famous dynamic level recorder has been developed. The Chalmers Acoustic Laboratory under the lead of Per Bruel also carried out various building acoustic field measurements. All the reports from this time are still in the archive of Applied Acoustics at Chalmers. During the review of the reports two reports from 1946 was especially interesting. The first one describes measurement techniques used by the Chalmers Acoustic Laboratory for sound pressure, reverberation time, absorption, airborne and impact sound insulation. As an example, Figure 4 documents the equipment for measuring reverberation time. In the introduction of the report, it is stated that the report was written for the Swedish Building Research Department as input for standardization of the measurement methods. It also is stated that the presented methods and equipment differ from what has been used in Sweden at this time and that the methods rather follow such developed for instance in the USA or Germany. Obviously, it was the intention of the Chalmers Acoustic Laboratory to lift measurement techniques in acoustics in Sweden to state of the art level as it was in other countries at that time. Maybe not too surprising having in mind that the lab has been started by Per Bruel.

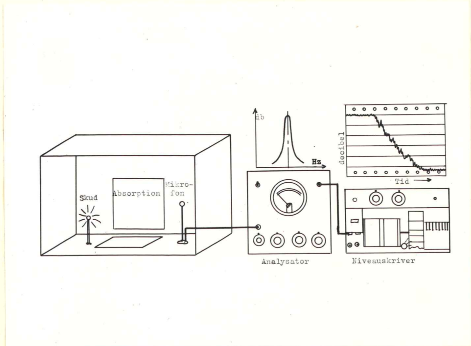

Fig. 6. Mätning av efterklangstid enligt skottfiltermetoden.

Figure 3. Measurement of reverberation time in [9].

The second report which attracted our attention describes what could have been the very investigation of peoples' opinion about the sound insulation in their houses in Sweden. It is based on a questionary which was sent to different households. At the very end Per Bruel however concluded that the number of households investigated might have been too little and he refers to a similar study carried out in London. Per Bruel stayed at Chalmers until 1948 at least part time. When Per Bruel started the lab, he got a young assistant, Uno Ingård (in his early twenties) who after the war took over as director of the lab. During this time Uno Ingård worked on his licentiate degree which he finalized in 1948 [8] under supervision of Olof Rydbeck (professor, electronic engineering) and supported by Hjalmar Granholm, professor for building technology (where the Chalmers Acoustic Laboratory was localized). With his increasing interest in acoustics but also with his enthusiasm for Phillip Morse, Uno Ingård decided to go to the MIT to get a PhD in acoustics, which he also managed. Before he left, he persuaded Stig Ingemansson, a friend of him, to take over the position as director of the Chalmers Acoustic Laboratory. After his PhD supervised by Richard Bolt, who was director of the MIT Acoustics Laboratory, Uno Ingård returned for a two-year period to Sweden to teach acoustics at Chalmers. At that time acoustics had already been part of the education for civil engineers. Uno Ingård probably wrote the very first course material for a course on building acoustics at Chalmers before he left for the MIT. In 1952 Uno Ingård decided to go back to the MIT where he later became professor of physics and of aeronautics and astronautics while the Chalmers Acoustic Laboratory continued its work under Stig Ingemansson.

3.2 The Chalmers Acoustic laboratory becoming Applied Acoustics

The laboratory has since its start in 1943 been a rather independent part of building technology at Chalmers. Activities in the fifties and sixties mainly concerned building acoustic measurements due to the expansive phase of the building boom with new building methods and building materials. The poor acoustic performance of some of the new buildings were frequently subject of reports and discussions in the daily press. This might have been a major reason that in 1963 Chalmers decided to create a professor position in building acoustics. However, the position was then announced much broader including not only architectural acoustics but other areas of applied acoustics. The open position was announced 1964, but it took until 1969 when Tor Kihlman was appointed as professor by his majesty king Gustaf VI Adolf of Sweden. In the evaluation committee for the position were beside others Per Bruel and Fritz Ingerslev, at that time already professor for acoustics at the Technical University of Denmark. The delay in filling the position at Chalmers might be explained with the difficulties to find a person with the proper educational profile. During the period between 1963 and 1968 Stig Ingemansson was acting as professor and teaching at Chalmers. However, although Stig Ingemansson was a very good acoustician and teacher, he did not have a PhD. When Tor Kihlman finalised his PhD in 1968, he was the very first PhD in building acoustics and probably in acoustics in general in Sweden.
Stig Ingemansson continued with his consultancy company (Ingemanssons Ingenjörsbyrå) which he had started in 1956 as a sideline. The company grew quickly to become the

largest acoustic consultancy in sound and vibration in Sweden and probably in the whole northern Europe.
With a chair in acoustics the Chalmers Acoustic Laboratory became Applied Acoustics as an independent unit. In 1969 Applied Acoustics moved to its own newly built facilities designed by Tor Kihlman. It included besides others an anechoic chamber, a transmission suite, and a reverberation chamber. Although this is not really correct, we often call the year 1969 the official start of Applied Acoustics.

4. FINAL REMARKS

The million programme was not only a housing programme but had the clear intention to increase the standard of living. The standardized building methods developed during the million programme made it possible to build a high number of flats in a short time. However, this also resulted in that the acoustic problems associated with the building techniques occurred in many buildings. What was intended to increase the standard of living obtained a bad reputation.
Sometime this bad reputation was not always deserved as not all buildings produced during this time period were built using e.g. light-weight concrete, but with building technologies having high acoustic standards. It is often believed that the acoustic problems were caused by too low requirements in the building legislation at that time. This is however not true; the sound insulation requirements from 1946 in Sweden are essentially equivalent to the current legislation (the main difference is that today's legislation includes frequency bands down to 50 Hz). This means that a building that was built in the fifties and that fulfil the sound insulation requirements in the 1946 legislation would also pass today's airborne sound insulation requirements. The bad reputation of the million programme buildings is thus mainly connected to the chosen construction, not to the legislation.
However, as a consequence of the bad reputation, building acoustics became an important issue in Sweden in the fifties and sixties. It coincides with a time in Europe where building acoustics made substantial progress in knowledge and also where talented people with scientific curiosity engaged themselves in the development of building acoustics as a subdiscipline in acoustics.
The start of the acoustics laboratory at Chalmers might look as being based only on a series of lucky incidents. However, on the second glance it is obvious that this would not have happened without people - not necessarily acousticians – who recognized the needs of building acoustics in society and who took the chances offered by history. They asked Per Bruel to come to Chalmers and to build up the acoustic lab when he was in Sweden. They persuaded a talented student named Uno Ingård to get engaged in acoustics although he at the beginning felt that acoustics was not what he wanted to work with. Ingård also found with his friend Stig Ingemansson the perfect person to take over the acoustic laboratory. Finally, the Civil Engineering Department at Chalmers University of Technology at that time understood the value in having a chair in acoustics. That they found with Tor Kihlman an adequate candidate was not self-evident, having in mind that until that time, in Sweden there had been no one been awarded with a doctoral degree in building acoustics.
The activities at Chalmers University of Technology (and at other academic institutions), together with the emerging awareness of acoustics being an important issue for the "normal" person, triggered a high activity of product development during the sixties. Several manufacturers of building materials started their own engineering divisions, and some of them even built their own acoustic laboratories. The curiosity and inventive skills of the engineers working at these labs drove product development, both from a scientific and from an economic point of view. The aspiration to find efficient and simple solutions to the acoustic problems was admirable. There is a waste number of reports with acoustic measurements that were published during this time period, measurement data that still is valid today. One could argue that this implicitly means a lack of technical development after that period, but the authors of this paper would rather say that the early researchers have done their tasks very well.
Over the years, the insight for the need of education and research in acoustics varied among those who make decisions in politics or at universities. However, the need in society stayed strong and one has to conclude that the challenges to create acoustic environments which support health and well-being rather increased than decreased.
Finally, the authors would like to thank Tor Kihlman, who taught us the importance to fight on all levels for a better acoustic environment in our daily life. This includes not only the education of young students as future noise and vibration specialists, the research with relevance for society, but also influencing politics for the peoples' best. Without Tor Kihlman, the acoustics at Chalmers but also in Sweden would have never developed to what it is today.

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