Revitalising Building Archaeology

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Published in:
Hands on

Publication date:
2020

HANDS ON

THE VALUE OF BUILDING CULTURE

Cover: Smokehouse, Hasle, 2019.
Photo, Victor Boye Julebæk

REVITALISING BUILDING ARCHAEOLOGY

Thomas Hacksen Kampmann. As the looming climate crisis is becoming directly apparent to most people, there is an increasing focus on how our buildings affect nature. This raises the question of whether it is better to demolish the existing buildings and replace them with new low-energy buildings or gently insulate the old buildings. Of course, they will have a higher energy consumption for heating, which is increasingly covered by renewable energy, but on the other hand they have already strained nature during construction perhaps many years ago. Lifespan is therefore a very important parameter for assessing the overall environmental impact. Restoration architects are used to researching existing buildings to find out when they were built and what alterations they have undergone in the period up to now. This article attempts to investigate whether such archaeological investigations can be helpful in assessing the future lifetime of buildings for use when making overall Life Cycle Assessments.


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Abstract. The purpose of this study is to investigate whether archaeological building studies can help us estimate the overall life expectancy of building parts for use in Life Cycle Assessments (LCA). At KTR we teach and research how to reuse the existing building stock and, as part of this of course, how to reduce energy consumption in buildings. As buildings account for a very large part of our total environmental impact, and because we believe that older, energy-optimised buildings have a much lower overall environmental impact than building new, it seemed obvious to take an interest in making accurate calculations of buildings' total environmental impact. Especially the comparison between brand-new high-insulated buildings and older buildings that usually cannot be pre-insulated to such a high standard – but where, on the other hand, the physical building already exists.

To find a building's total environmental impact one uses the established method for LCA, which consists of a systematic analysis of the accumulated environmental impact of products during their entire life cycle. This includes production, use and disposal during the whole life cycle and thereby the total environmental impact divided by lifetime – or, to put it differently: the longer the lifetime, the less impact will it have per year.

This shows how important it is to be able to estimate the possible future lifetime of a building and its building components in order to perform a credible LCA.

Architects with specialised knowledge of building archaeology know how to determine the age of historic buildings and therefore can tell how long they have lasted so far and thus establish their durability. Furthermore, they can evaluate the historical, aesthetic values, provide instructions on how to refurbish and energy-improve, and from this give a qualified estimate of the building's life expectancy.

In order to investigate whether our assumption that it is less environmentally harmful to restore/transform than to make new construction, we decided that the semester assignment in the spring of 2019 should include an LCA calculation in addition to our usual training programme.

KTR had got in contact with 'Dansk Håndværk', a Danish employer association for small and medium-sized enterprises within the construction, crafts and woodworking industry, who had recently purchased a small house on Bornholm, an island in eastern Denmark, with the purpose of creating an 'Apprentices' House' for the training of young artisans.

In order to provide a reliable LCA we entered into collaboration with the Technical University of Denmark (DTU), so they could make a proper energy frame and LCA calculations.

The fieldwork took place on site in the house on Bornholm, and we managed to find the age of the whole building and all the important building parts. Unfortunately, we did not succeed in calculating the energy frame, making an LCA much less relevant, including our estimates of the life expectancy of different building parts.

Fortunately, this autumn a crop of students at DTU used the Apprentices' House as an example for making an LCA, and the preliminary results show that the environmental impact is much less for renovated buildings compared to new buildings, despite the fact that lifetimes for all materials were set to the same.

The study clearly showed that a building archaeological survey almost certainly provides an invaluable tool for qualifying the future durability of older buildings – and this means a completely new way for architects to use building archaeological surveys.

The study also called attention to the fact that a similar qualified lifetime assessment is lacking for newer buildings and building components listed after the 1950s, as well as for completely new buildings.

This suggests that building-archaeological surveys should also be made for newer buildings, which is not common practice today. Such a survey can both highlight the environmental impact of replacements in newer buildings and help us make more accurate assessments of the life expectancy of new buildings.

Previous page, figure 1: Example of different colour layers on an inner door, work done by the conservator.
Above, figure 2: Historical view of the house, as seen from the north. Bornholms Ø-arkiv.
Middle, figure 3: 'The Apprentice's House' as it appears today with corrugated fibre-cement roof, emulsion painted walls, plinth and timber-framing, of which some is applied directly on the wall.
Bottom, figure 4: Marking of horizontal level with water hose – the surface of the water is at the exact same height at both ends of the water hose.

Introduction. Often the lifetime of building components entered in LCA calculations matches very poorly with real-life experiences. Part of a traditional restoration architect's work is to make building archaeological surveys, e.g. in connection with major restorations, remodellings or transformations.

Since a substantial part of architectural assignments deal with remodelling/renovation/restoration of the existing building stock, and this is exactly what we are doing at KTR, it is only natural to investigate how different transformation scenarios will affect the the potential climate impact of different transformation scenarios. Generally, restoration architects have wide experience in assessing the lifetime of building components. To use the findings from traditional building surveys or archaeological surveys as input in LCA calculations therefore makes so much sense.

However, since there is not yet an established tradition or knowledge among architects on how to make an elaborate LCA, we tried to seek a collaboration with the DTU, which have precisely these competencies. We succeeded in getting a collaboration started, and the question was then how we, as architects, could contribute to these calculations.

An architectural survey of an existing building provides information on the structure of the building and, for example, the areas and wall thicknesses needed to calculate heat loss. Once a project is done, you also have an idea of the amount of materials to be disposed of and the amount and kind of new materials to be added.

In addition, a traditional building archaeological survey will attempt to date all the essential parts of a building to get a picture of the development of the whole building from when it was first built and right up to the present day. The ages of the various building parts are important to make a reliable valuation, which you need when assessing which parts can be replaced and which parts contain the essential preservation values. Thus, you get a complete age estimate of all the building parts that says something about how long they have lasted so far and what technical state they are in today.

At KTR, the education in each semester is built around a selected building that is being worked on throughout the whole period. In the first third of the semester, most of the education takes place directly on the site where the students make a careful building survey, analyze and assess the essential architectural values and make a photographic record (phenomenological study). In the next third of the semester, they come up with their first preliminary suggestions for the future use of the building based on their observations and drawings, which will culminate in their final project in the last third of the semester.

In 2017, KTR had received a request from the trade association Dansk Håndværk (Danish Craftsmanship), which had purchased a small, neglected timber-framed house in a place called Sandkås on the island of Bornholm. The purpose of the house purchase was to create a place where young people can come and get an introduction to various crafts. The idea of the project originated from the fact that the craft sector currently experiences a waning interest among young people, and thus a poor influx of new apprentices. Therefore, KTR decided to use this building as an object of study in the spring semester of 2019. (Fig. 3)

Field Survey. A group of 21 architecture students, four engineering students, one conservator student and several teachers went to Bornholm at the beginning of February 2019 and began recording the building.

Measuring the building. The actual survey work was carried out by architects only. The students were divided into two-person teams, and the work started with a very quick sketch survey of the house in scale 1:50, done in just one day.

The sketch survey quickly gave us an idea of which parts would have to be measured, a rough indication of the size of the building and a valuable basis for the collaboration with the conservator and the engineers. After getting an overview of what drawings we had to make, each team was assigned a drawing set; however, the floor plan and the longitudinal section were divided into two teams.

On this assignment, we chose that the actual surveying should be done in the traditional way with measuring tapes, plumbs, double right angle prism, braided mason line and clear vinyl water hose. This is a time-consuming method of measurement, and it takes about a third of the total surveying time just to set up the measurement system. On the other hand, one gets an incomparable insight into all corners of the building.

Survey 1:1 and 1:10. In order to make the most of our time, and to ensure that all students quickly became familiar with measuring accurately, we started by selecting important details such as doors, windows, timber joints etc., and these were also assigned to the various survey groups who could then immediately start surveying. The advantage of this method is that everyone can get started right away, but it also increases the awareness of which building elements have been added when and enables us to start estimating their age.

The first preliminary measuring of plans was also used to record numbers on all doors and windows throughout the building, so that everyone was aware of which detail they were working on.

For each of the building elements we examined which parts it consisted of and then measured it in scale 1:1. For doors and windows, this meant that the profiles of casements, frameworks and mullions were measured together with metal parts such as hinges, handles and anchors.

When you have accurately measured these details in 1:1, it is relatively easy to make the 1:10 drawings where you use the profile drawings together with the key measurements of the door or window.

Once a profile is measured in scale 1:1, and not before that, it is relatively easy to find other doors and windows with similar profiles and thus determine if they date from the same building period. All doors and windows were scrutinised and assessed in this way. To provide us with a comprehensive overview, a detailed door/window diagram was prepared, in which each element was given its own column. (Fig. 5)

All the selected building components were drawn to a scale of 1:10, the drawings consisting of plans and cross sections as well as exterior and interior elevations. This served as a basis for the execution of the 1:50 drawings. You only have to measure the position of each door and window in the 1:50 drawings and then insert the detailed drawing – after simplifying to ensure that the lines do not overlap. While all the details were being measured, work was done on setting up the measurement system.

Survey 1:50. The actual measurement of the building was done using the traditional method popularly known as the 'knife and fork method.'
Here everything is measured from a measuring system consisting of

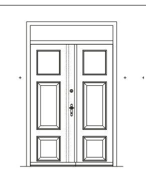
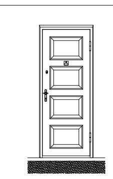
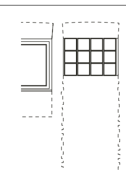
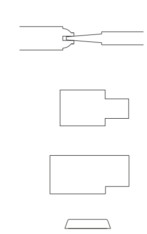
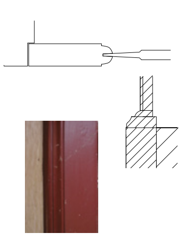
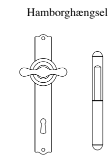
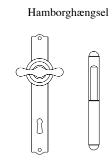
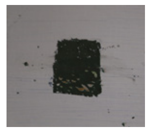
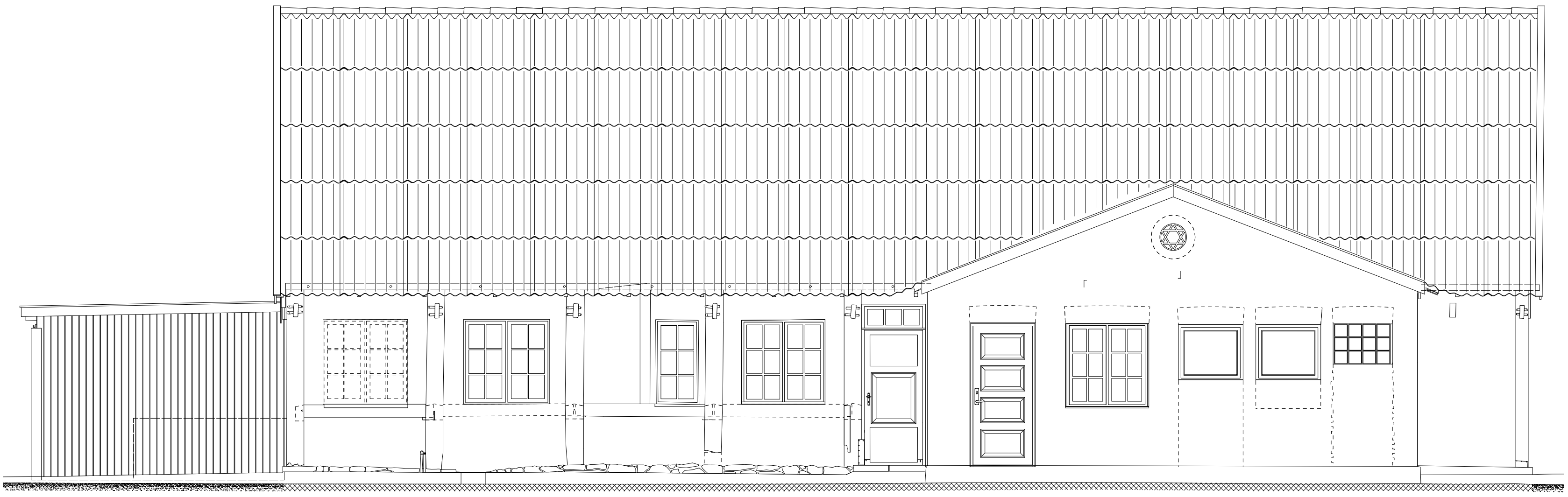
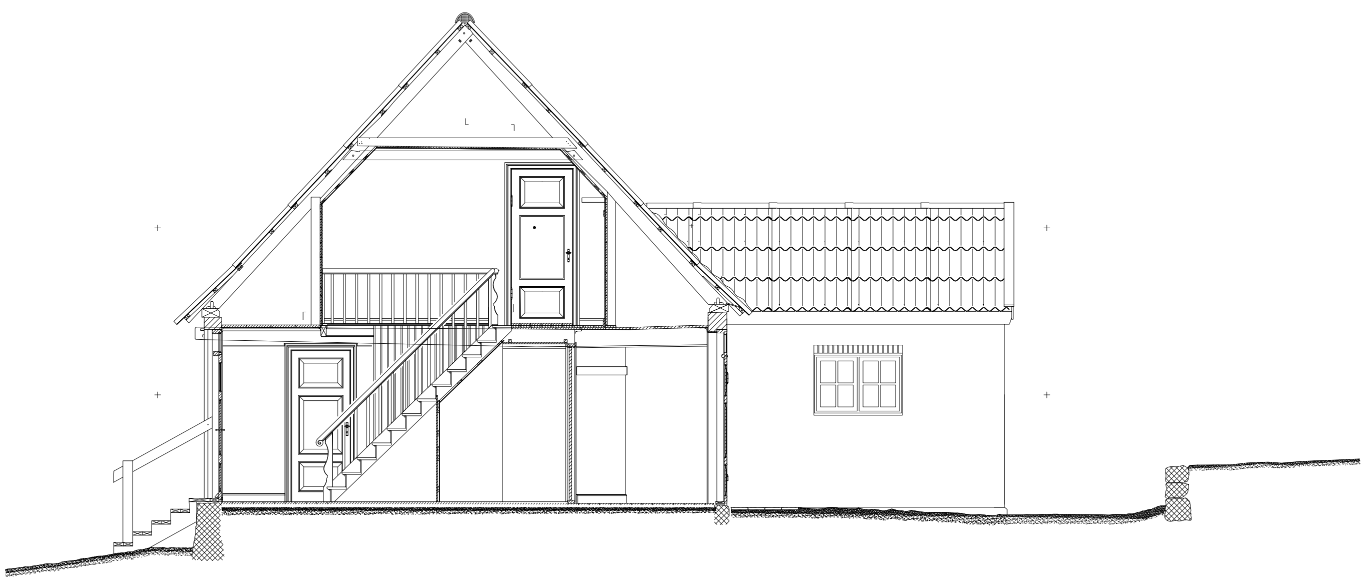
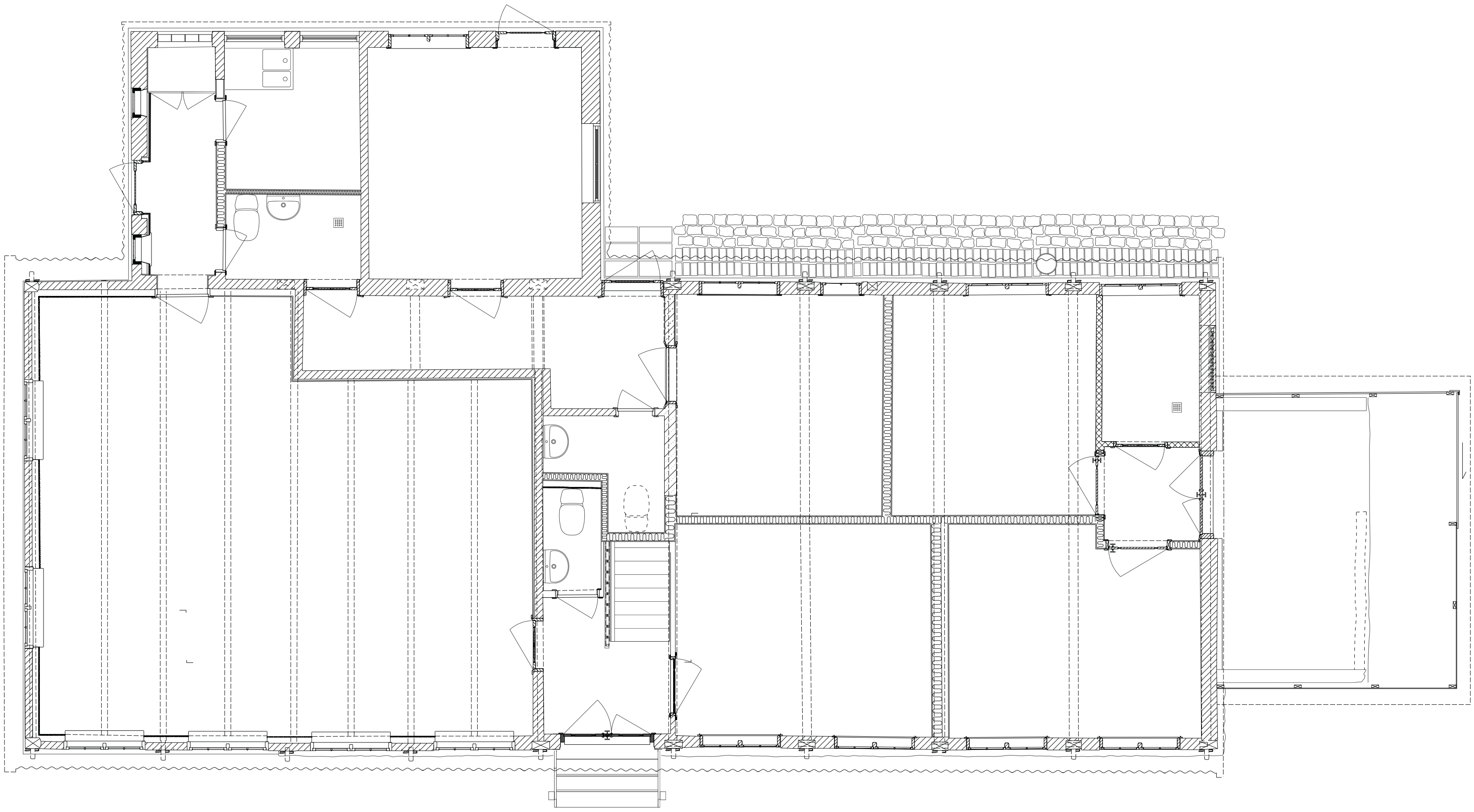
DØR NR.	D.1.1	D.1.2	D.1.3
TYPE	Tofløjet hoveddør, med vindue over	Etfløjet hoveddør	Blændet dør
ANSLÅET ÅRSTAL / BYGGEPERIODE	1920 / V	1950 / VIII	Der har tidligere været WC. det er med på næsten alle de gamle tegninger.
FALSMÅL CM	128 X 192	73 X 197	
RAMME SAMLINGSMÅDE	Kontrakehlovet	Kontrakehlet	Nu V1.9
ANTAL	4 fyldninger, 2 ruder ovenvindue, 1 rude	4 fyldninger	
TEGNING / FOTO			
SPEJL-, RAMME- / REVLEPROFIL KARMPROFIL EVT. TVÆRPOSTPROFIL INDFATNINGSPROFIL			
HÆNGSEL- / STABELTYPE	Hamborghængsel	Hamborghængsel	
GREB / LANGSKILTE			
LUKKE / LÅSETYPE	Udenpåliggende nyere lås	Udenpåliggende nyere lås	
FARVELAG / BEMALING			
KOMMENTARER	Sandsynligvis en "kopi" af D1.7 ramme om et af vinduerne er udskiftet med en uden profil. Karm, tværpost og overvindue er formentlig fra da væggen ved stalden blev bygget.	F 26, farveprøve af dørramme	

Figure 5: Example of door/window diagram.







horizontal braided mason lines and measuring tapes. First, we selected the height in which the plan should be drawn and then made accurate horizontal measuring points throughout the building exterior and interior using a clear vinyl water hose. (Fig. 4) KTR had just acquired a multi-line laser, but the water hose proved more useful, being more accurate on an unstable wooden floor and moreover able to measure around corners.

Once the horizontal level was established, cords were mounted on boards, fastened with screws, and then with measuring tape and angular prism cords parallel or perpendicular to the exit line around and inside the entire house. A similar system was done on the second floor with plumbs and measuring tapes all linked to the measuring system on the first floor. The cords were set up so that all structures, plans and sections could be measured from them. The fact that all cords are set up accurately as part of the same measuring system means that everyone can work simultaneously with them for all the different drawings, even several teams on the same drawing at a time.

Selection of the scale 1:50 drawings. Traces of earlier building stages are measured and indicated on all drawings, with different hatchings signifying different kinds of building materials. Hidden constructions are presumed where they cannot be seen – to show that these are only assumed, there is no outline here.

Note the narrow post in the third section from the left on the southwest elevation; this indicates that there was supposed to be a partition behind the post. This is the only original partition that did not follow the stringent modular pattern. (Fig. 6)

Collaboration with the School of Conservation. KTR has long been hoping for a collaboration with the School of Conservation. Conservators, who are now part of the education at KADK, are experts at uncovering paint, layer by layer, on both joinery details, i.e. on doors or windows, and on walls. This expert skill, and their further ability to analyze which pigments and binders have been used in both paints and mortars, make conservators invaluable partners in all restoration tasks. (Fig. 1)

Building Archaeological Studies. Making a building archaeological survey is like doing detective work with the object of decoding the entire history of the building. The building archaeological survey combines measuring with archive studies to give you an idea of the year of construction and any important rebuilds and renewals. Archive studies consist of finding cadastral numbers, historical maps, old photographs (Fig. 2) and paintings of the building, compiling a list of all owners of the house as far as you can go back in time and, based on this list, investigating deeds, fire assessments etc.

These data can then be combined with the traces found in the building to provide an overview. It is also very important to get in touch with people who have visited the house, have rented it, or even remodelled it, to learn all the changes from 'man's memory'. Major alterations are mostly confined to the period since the middle of last century. Based on this it is often possible to give a complete list of the history of the building.

Measuring a building means that you stay in it for a long period of time, and as the survey progresses, you get into every corner of the building. If you compare your knowledge from the archives with the traces you find during the survey, you can gradually begin to piece together the history of the entire building. It goes without saying that the more there is left of the original building, the easier it is to make an informed survey.

Ideally, the archaeological survey, which is often very complex and comprehensive, is presented through spatial drawings of the development of the house through all the various stages from the construction to the present day – unfortunately we did not have time for that.

Fortunately, it turned out that many of the original building parts had been preserved. The entire roof structure with all the rafters is the original, and from this we could see that the building was first built with only seven bays, but later extended with two more bays. Likewise, the vast majority of the original doors and windows are preserved, since it is only the south-eastern part of the building, a former barn, which has been comprehensively renovated with e.g. new windows, floor, tie beams etc.

Timber-framed buildings are normally assembled with interties, the horizontal pieces of timber between the posts just below the windows, joined by tenons and pegs, but in this house there was only one single peg. It turned out that the interties were attached according to a rather special method known at Bornholm from the 1840s.[1] (Fig. 20)

Once the method of assembly was recognised, all posts were examined to see whether there were any traces of tap holes as these would suggest the previous existence of an intertie instead of the present outer door.

Findings. *The age of the building.* Determining the age of the building proved tricky as the tusk tenoned timber joint normally belongs to the late 1700s. However, here the special assembly method with the interties, door and window profiles and gables erected without timber frames, combined with the archive studies, showed that the building was erected on site in 1887, and the absence of older traces in the timber shows that this is not recycled timber from another house.

Description of the way we found the time periods. The Apprentices' House is characterised by many additions and rebuilds, and the house has undergone some heavy-handed modernisation, in particular during the past 30 years.

The south-eastern end of the building has been remodelled with partly new walls, beams, doors and windows, and the roof is a re-adjusted, corrugated fibre-cement roof everywhere.

A search through the archives did not produce as much material as one could have hoped, but some pictures from around 1930, most of which must have been recorded on the same day (windows and doors are open/closed the same way in all the pictures). The oldest sources, which date back to 1887, describe a house of seven bays, but the building is equipped with tusk tenons that is a building style usually associated with the late 18th century.

What really made the pieces fall into place was the study of the roof construction. By examining all the roof trusses from one end, it was found that the northwest gable was made out of pine, which is normal for roof constructions. Since this gable is clad with both older boards and later plywood, it was not possible to inspect it from the outside, but it could be

Figure 9: Construction detail at north-western gable. Here, the rafter is made from pinewood and provided with a groove originally intended for the attachment of gable boards. The pinewood rafter is typical to roof constructions and in contrast to the other rafters, presumably made from poplar.
Photo, Thomas Kampmann, 2019.

Figure 10: The top joint of rafters in the roof construction in the apprentice house. The timber mark, here on rafter no. VI, indicates a seven-bay house of two gable in pinewood rafters and 6 numbered rafters in between in poplar.
Photo, Thomas Kampmann, 2019.

Figure 11: Joint between rafter and collar beams. The rafter and the collar beams are made from the same type of wood.
Photo, Thomas Kampmann, 2019.
Opposite page top, figure 6: Elevation SW
Opposite page middle, figure 7: Section BB
Opposite page bottom, figure 8: Plan, ground floor

established that the boards had not originally been nailed on the outside but instead notched into a groove in the rafters themselves. (Fig. 9) No timber marks were found on this rafter, but the next rafter had 'VI' scratched into the wood. (Fig. 10) This rafter and the next ones were all numbered in a descending scale down to No. I. The rafters were roughly processed with an axe and not made from pine, as is normal practice, but presumably made from poplar. The collars beams that were preserved were also numbered and made from the same type of wood as the rafters. (Fig. 11)

Following rafter No. I came another pinewood rafter, as with the first pinewood rafter with no visible timber marks. This matched the description from the archive of the original seven-bay house – two gable rafters without a number and six numbered rafters in between – and exactly matched the extent of the boulder foundation on the north-eastern side. (Fig. 17) The next rafter was another unnumbered pinewood rafter ending with a stronger pinewood rafter at the south-eastern gable.

These observations gave a clear picture that the original rafter structure has been preserved despite the roof having been relayed with new corrugated fibre-cement plates – the roof construction has only been reinforced with new auxiliary rafters between the old ones and then provided with readjusted laths all over.

The original extent of the building cannot be found by examining the outer walls as the wall on the north-eastern side in this part of the house has been rebuilt to a wall with no timber frame, and to the south-west, the outer wall has been hidden/disappeared because of the extension here.

Above, figure 12: Historical building changes over time. The colours on walls, doors and windows indicate how old they are – the red ones are the original from 1887, the orange are extensions from about 1895, the green from after 1916, the blue ones from after 1947, indigo from 1967, and purple is 1970s remodellings.

Below, figure 13: Overview of the historical stages of the building.

Historical stages	Colour	Owner	Building changes
I 1887 – 1888	**Red**	Emil T. Bohn	Erected, 7-bay, 4-bay living room and 3-bay stable
II 1888 – 1912	**Orange**	August O. Funch	The stable is expanded by 2 bays and the porch built sometime around 1895
1912 – 1913		Mathias C. Funch	
III 1913 – 1947	**Green**	Martin Silberstein	1916 1920 + stairs and dormers for a room courage north-west of the stairs on the 2nd floor and an extension in full wall towards the sw.
IIII 1947 – 1967	**Blue**	O., A. & C. Andersen	
V 1967 – 1999	**Indigo**	Knud Fiil	Housing and rental for barmaids Maybe the chimney was gone with dormers Water damage 1973–74
VI 1999 – 2017	**Violet**	Bill R. Hansen	Reception for rental of holiday apartments
VII 2017 -		Dansk Håndværk	

Furthermore, there were only a few remnants of the original tie beams in this end of the building, as these have been replaced with new beams throughout the great room. This part of the house used to be a stable/storage room since the building was erected and this has probably been quite hard on the house.

The investigation made it clear that the present building is the one that was first mentioned in 1887 – consisting of seven bays: a dwelling of four bays in the north-western end and three bays stable to the south-east. The addition of two bays to the south-east probably means that the original gable has been completely replaced; at least there are no traces of the gable other than the pinewood rafter in the ceiling. The tusk tenons, which usually indicate a building from the end of the 1700s, are thus a sign of a conservative approach – which, in fact, was typical of Bornholm at that time. (Fig. 21)

The dating to 1887 was supported by the fact that the north-western gable, which is still intact, is not made as a timber-frame construction but as a full-brick wall, by the distinctive collection of interties in the posts and by the fact that the walls were originally limewashed in a rose-pink colour.[2]

The oldest windows and doors are all assembled with mitre joints, and thus planed by hand, as well as with hand-forged steel. This dates back to an older age but the number and proportion of fillings on the doors confirm that they are from the late 1800s. (Fig. 12, 13)

Historical drawings. Remarkably, there were quite a lot of historical drawings of the house. The first shows a combined survey of both 1st and 2nd floor. (Fig. 14) This is the most accurate drawing, probably made on site and with 'odd' cm dimensions, which fit well with our measurements.

The next drawing has rather imprecise measurements, especially when it comes to the original kitchen, but they probably mixed up the cross- and longitudinal dimensions here. Note that the text is in both Danish and German. (Fig. 15)

One drawing was a bit of a puzzle. (Fig. 16) This drawing was among the archive material for the Apprentices' House delivered from 'Bornholms Ø-arkiv' (Bornholms island archive) but is apparently dated 1825 – and thus before the construction of the house! Or could this drawing of a well be from 3.9.1895, where the number 9 is first written incorrectly? It fits with the initials A. F. as August Funch was the owner at that time, and the fact that humans are in metres and not inches which one would expect in 188

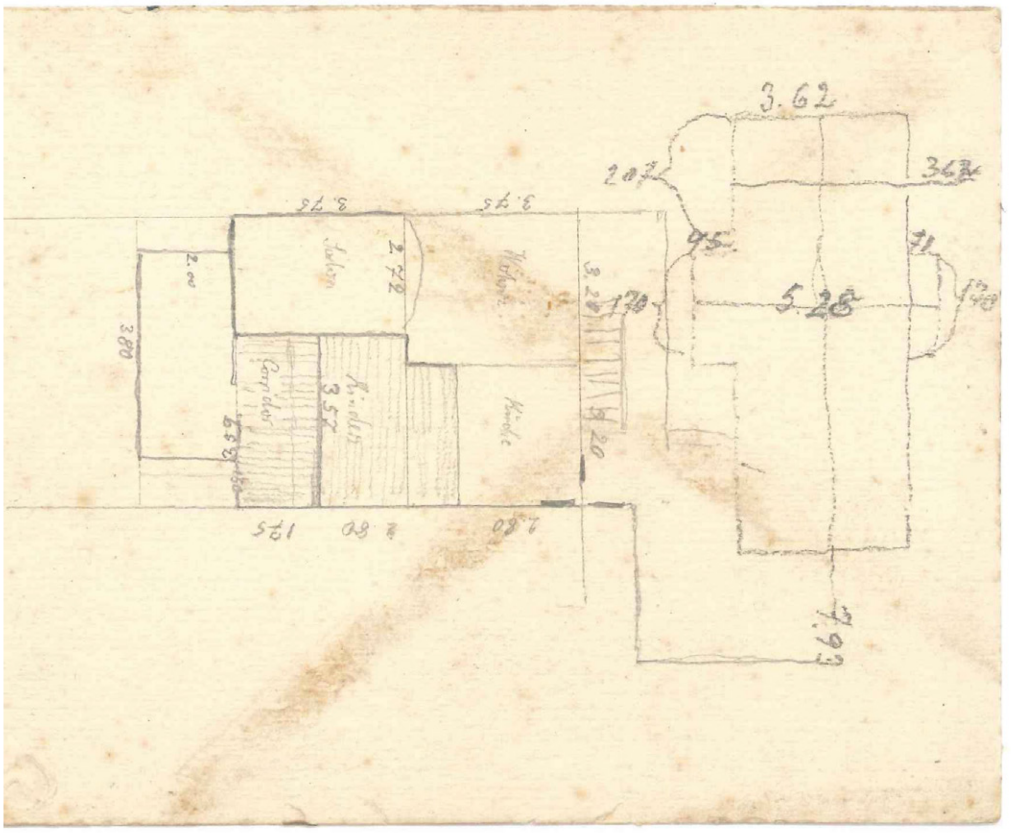
Two other 9's in the drawing are also fixed and the cartoonist's 2's are round at the top like his 9's. The drawing seems to indicate that there was a porch already then (Fig. 2) and a door with a window above and railings, suggesting a balcony on top of the porch. Note, that there are no dormers. This indicates that the porch and the extension with two bays were added at roughly the same time, around 1895. Both sections are built with cast foundations.

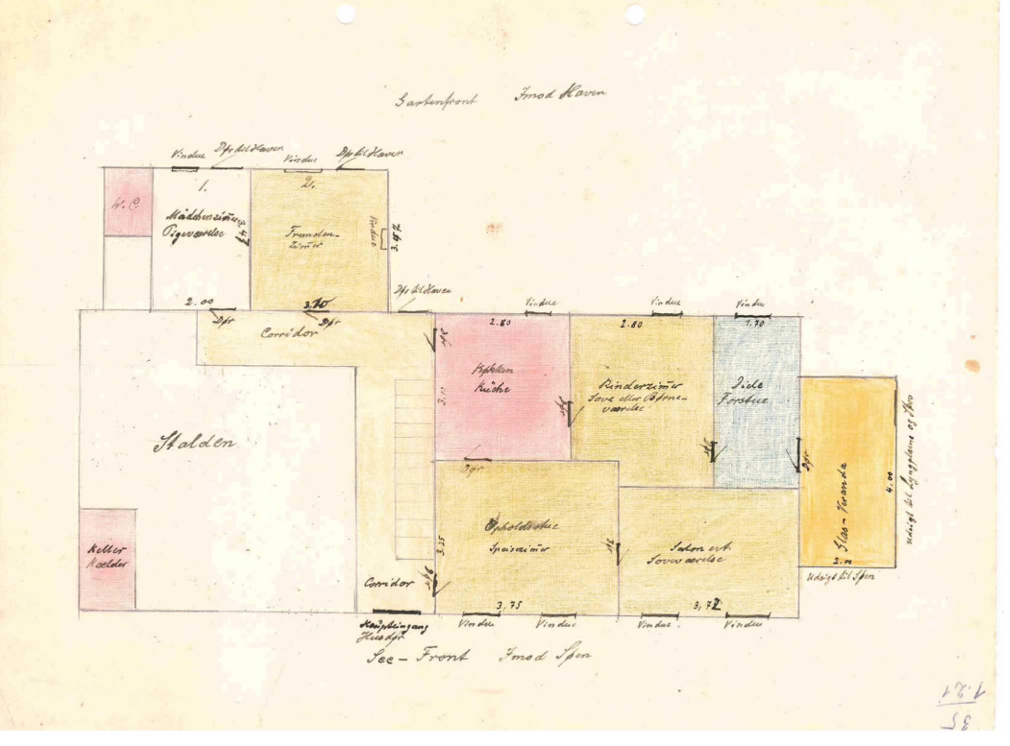
Summary. As can be seen, all construction periods could be dated fairly accurately and at least with considerable accuracy with regard to assessing the lifetime of the important building parts.

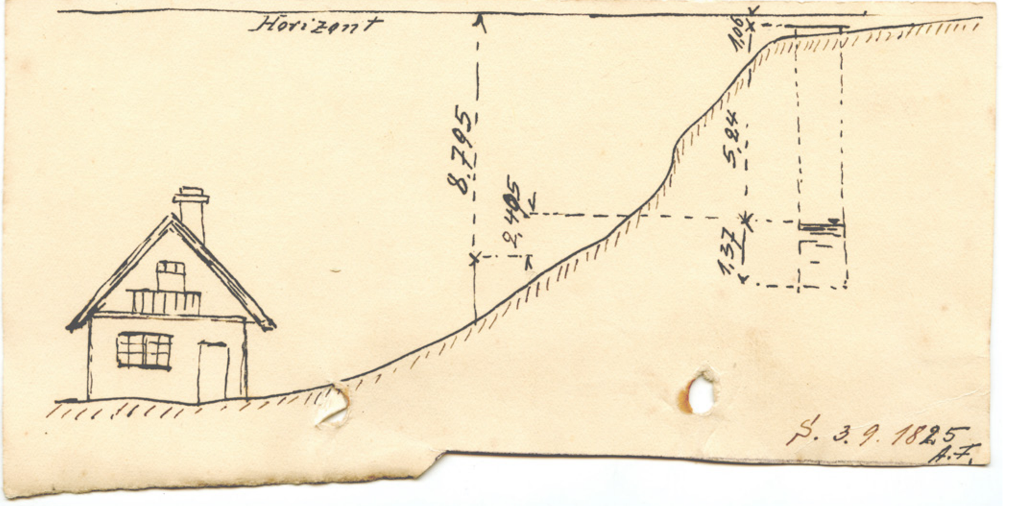
The current corrugated fibre-cement roof may well contain asbestos and it is scheduled for replacement, both for the sake of health and for architectural reasons.

The timber frame is made from oak, while fired bricks have been used as infill in the panels; these were originally limewashed on the outside. Strangely, the bricks are not laid in lime mortar but in pure clay mortar, and the inside of the walls is lined with standing bricks on the entire surface so that they also cover the timber. (Fig. 21)

The original partitions, made from unfired bricks, were unfortunately destroyed around 1970 as a result of frost damage, and virtually all of them have been replaced by new light plaster walls on a wooden frame with glass wool fillings.



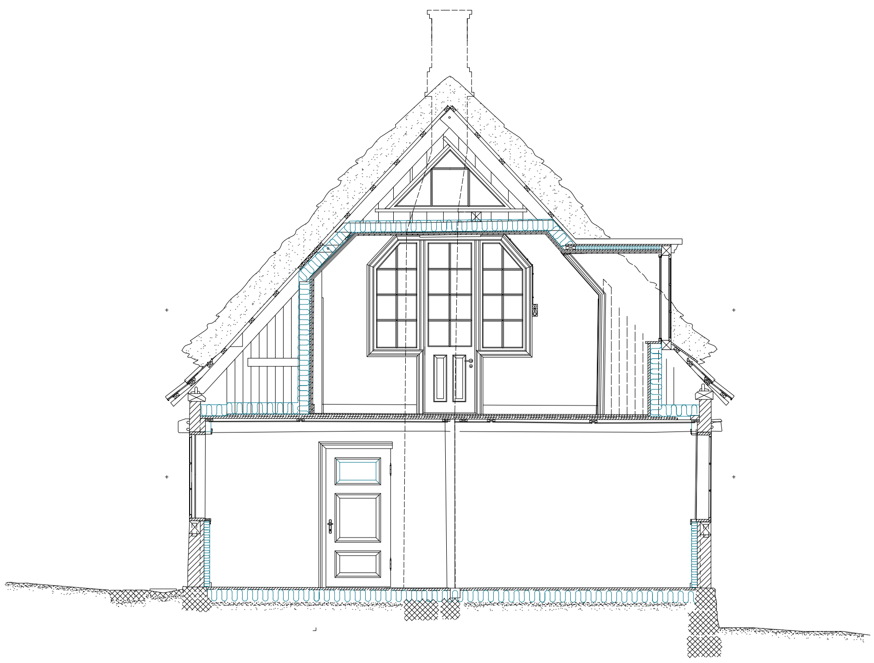


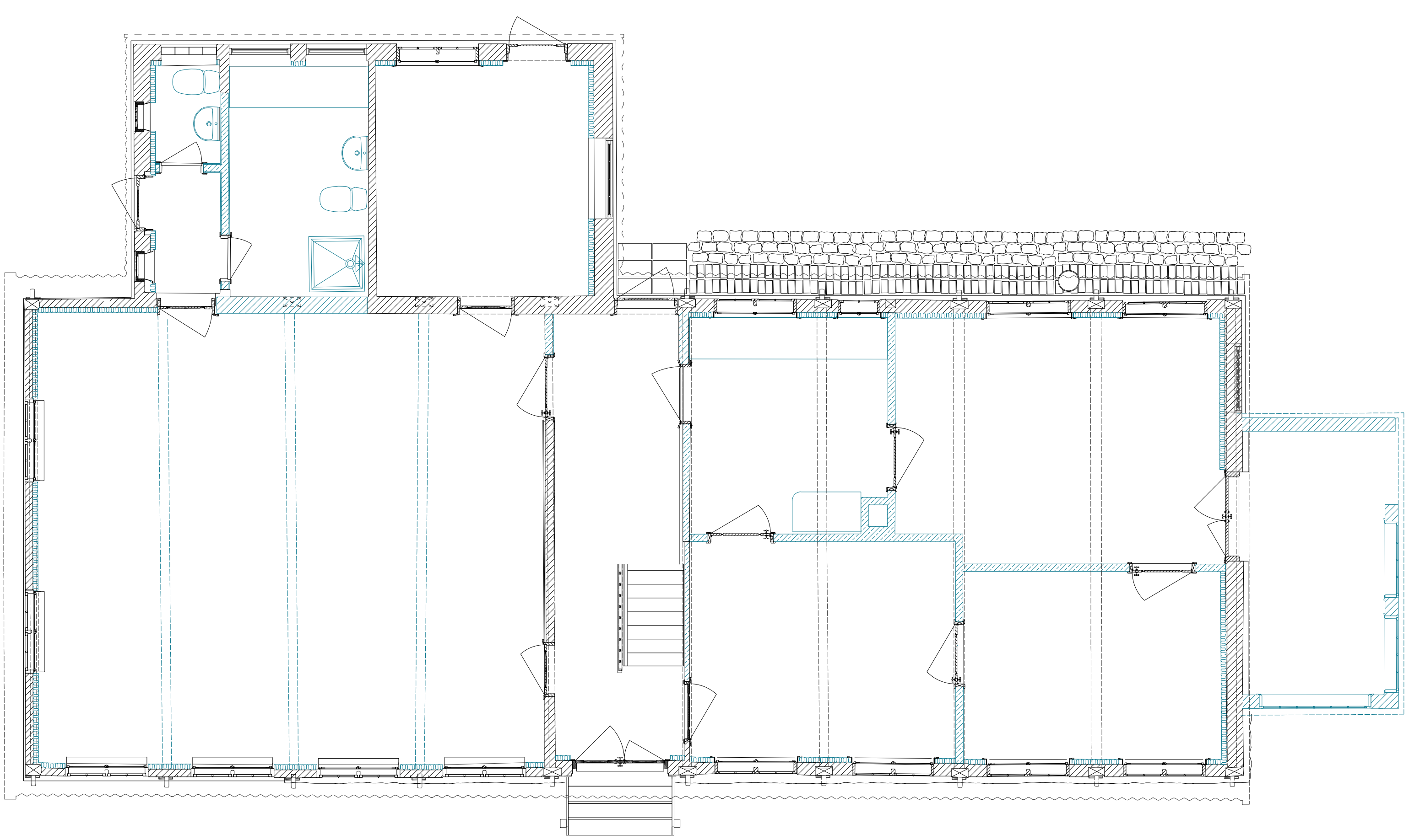


Top, figure 14: Probably the first survey of the building. Note that the 2nd floor is rotated 90 degrees compared to the 1st floor?

Middle, figure 15: Drawing texted in both Danish and German. Probably done by the German owner Martin Silberstein.

Bottom, figure 16: Sketch survey of the northern gable in connection with the establishment of a well, probably dated 1895.





Judging from old photos, the full-walled extension from about 1920 probably had concrete roof tiles, which were later replaced with a corrugated fibre-cement roof; this was probably renewed around 1980.

The building is amazingly old-fashioned for the time of construction, but this is probably due to the local materials having been easy to get hold of for a not so wealthy artisan.

All the original building parts that have been preserved are thought to have a high architectural and technical value, whereas most of the redevelopments that took place in the 1970s and later are very unfortunate and therefore recommended for removal**.**

End of the survey on Bornholm. The building survey on Bornholm was finished after three weeks with the drawings partially done. Back in Copenhagen, the drawings were completed together with the door/window diagram, drawings of details and archive studies.[3]

The conservator carried out her studies in parallel with the architects, and the study of pigment types complemented the overall picture of the building archaeological sequence.

Collaboration with DTU. By then, the collaboration with DTU had begun to crumble and it was of course a problem that the final drawings and building-archaeological studies were not completed until relatively late for the engineers – and that the architects started their sketch projects immediately after having completed the survey.

Due to various circumstances, it ended up with neither a heat loss calculation nor a LCA calculation of the building – and thus no discussion about the durability of building materials!

Fortunately, the collaboration was resumed in the fall of 2019 by five teams of engineering students using the Apprentices' House as an example to calculate an LCA. The students were in their 3rd semester and this was their first introduction to the making of LCA's.

We set up two scenarios for the calculations: Scenario I, in which the project was carried out as if the building had been protected, i.e. a restoration with the least possible interference with the existing building, roughly similar to the looks shown on the two old photographs (Fig. 2); and Scenario II, in which we imagined it as renovated by architects/technicians/engineers/craftsmen in the usual way.

The drawings show Scenario I, the restored house, where most of the recent alterations (the purple colour in figure 12) have been removed, such as the interior plaster walls, the plywood-covered north-west gable, the shed here as well as the roofing.

The main features of the restoration were to refurbish all doors, windows, walls and roofing, as well as mounting secondary glazing with energy glass in front of all windows, rebuild the chimney and the partitions (in unfired bricks), insulate exterior walls and ceilings moderately and replenish thatch on the roof with two rows of roof tiles at the bottom. We also made an estimate of how much of e.g. the timber and bricks in the walls would have to be replaced/repaired.

In Scenario II, all windows and exterior doors were replaced with new Velfac windows, the roof was tiled and all exterior surfaces were insulated with Rockwool in accordance with the standard of the Building Regulations 2018.

We followed the DTU students' reviews, but as they have not yet submitted their reports at the time of writing, it has not been possible to assess the results properly, especially with respect to how they have estimated the lifetime of the different materials.

It was not clear from their reviews, but all building parts are, presumably, supposed to last for 100 years – which seems reasonable for the original building components but very optimistic for the newer building parts, such as new doors and windows.

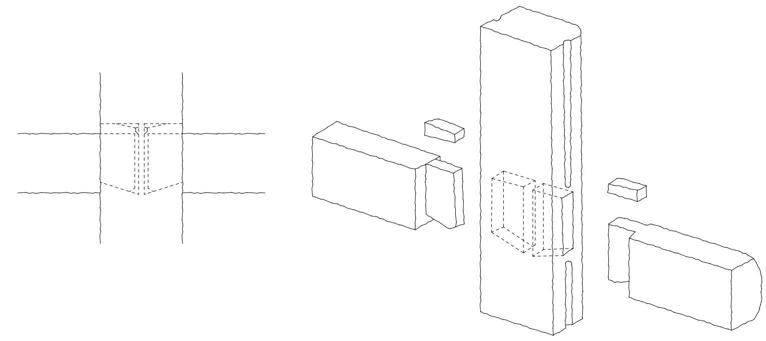
Perhaps there was also a misunderstanding when the students figured out how much climate change the building would inflict if one rebuilds the house as it stands today – what no one probably wants to do.

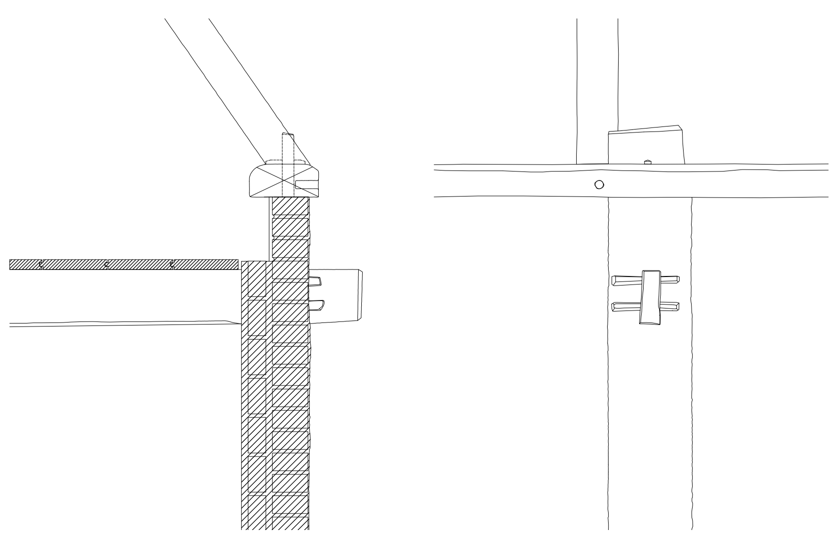
The preliminary observations on the students' work from their professor was as follows:

'Five teams of engineering students made a life cycle calculation (LCA) at the Apprentices' House in the fall of 2019 as part of an assignment at DTU. The calculations were made on the basis of two scenarios: 1: restoration consisting of post-insulation, thatched roof, windows etc. and 2: renovation consisting of post insulation with Rockwool according to BR2018, replacement of windows, roof tiles etc.

Their calculations showed that restoration is much better than renovation in terms of the parameters of CO_2 emissions, human health and resources, while renovation is slightly better than restoration in terms of ecosystems. The latter is due to the thatched roof occupying a large land area during the growing season. The conclusion was that restoration is significantly more environmentally friendly than renovation.

Discussion. The Building Archaeological Survey of the Apprentices' House clearly showed that it was possible to place all important building elements within a historic time frame of ten years, which is considered sufficiently accurate for an LCA, at least when the age is more than 50 years. The building archaeological method for examining the existing building stock has been used by restoration architects for decades, and there is reasonable consensus on how they are performed and described. This represents an important knowledge – the only problem is that it is not compiled in one place but lies unavailable in different case files at various private architectural firms or public and educational institutions.





Above top, figure 20: Detail of post, the vertical piece of timber is supported by two interties. These are kept in place by the tenons being inclined at the bottom and then locked with wedges at the top. This is a rather unusual construction, here reproduced from 'Rural building traditions on Bornholm' by Niels-Holger Larsen.

Above bottom, figure 21: Detail of post, tie beam secured by two pegs trough the wall plate and the lower part of the rafter. The method of using tusk tenons was abandoned after the late 1700s – except on Bornholm where it, as here, appears in the very last timber framed houses from the late 1800s.

Opposite page top, figure 17: Scenario I, northeast elevation with rebuilt porch and chimney.
Opposite page middle, figure 7: Scenario I, section with reopened gable window, thatched roof and dormer.
Opposite page bottom, figure 8: Scenario I, 1st plan as if the building had been protected.

Of course, the age of a particular building part does not say anything about how long it can continue to last with its original intended use, it can only give an indication. However, the estimate of the future lifetime of a building and its building parts can be qualified when its present age is combined with the condition assessment of how the element is now, how it can be repaired and maintained correctly and possibly how it can be improved to reduce energy loss.

Taking windows as an example, which has been studied for many years, we have many windows that are 100–250 years old and which can still be advantageously repaired and used. They can even easily be energy enhanced[4] so they lose less energy than similar new windows and in the same way; this is even cheaper[5] and gives better noise reduction.[6] These renovations and energy improvements have been practiced for decades, and this experience indicates that they can continue to meet all the requirements for a beautiful, functional window for many years to come.

However, if you continue with the window example, most of the windows in the existing building stock are now replaced, but this is not because they could not advantageously be refurbished or energy-enhanced, but rather because of a desire to 'get new'. Furthermore, there is the problem of the amount of money involved from the consultant's and the craftsman's side, and that the climate impact is not taken into account at all. The price of polluting is very low!

While older buildings erected before World War II are generally made from relatively few and well-known materials, developments have since then moved toward more and more industrialised and complex construction with significantly more materials. We have extensive and well-known experience in the renovation and maintenance of older buildings, but with the newer ones, they have become so complex that it is often very difficult or directly impossible to maintain the entire building or a large part of the building elements. During this period, PCB and asbestos have also been used in large quantities, which is very difficult and associated with high costs to remove.

Often, such a renovation will only preserve a small, load-bearing part of the building,[7] so the residual life of newer buildings is probably much shorter in practice than for older ones. However, no studies are known about this area, but it will be essential to have reliable lifetimes for newer buildings that can be used in an LCA, both for the whole building and for the important building elements. The next big question is how long a life new buildings can be expected to have?

Of course, it is impossible to predict precisely, but one can get an indication by looking at how newer buildings perform after 1, 5 and 10 years, as well as by examining a typical building element's ability to be repaired and modernised. This will probably be the best way to assess future durability. You can also get an idea of future lifetime by looking at the guarantee the supplier gives, whether it is possible to purchase spare parts and if the producer offers the possibility of maintaining their products for a longer time than the rather short period of guarantee usually given.

Going back to the example of windows, modern windows are very complex and often built of extruded profiles that can only be replaced as long as they are still in production, and in practice they are only very rarely repaired but instead replaced – with the a resulting great climate impact.[8] Apart from the fact that wooden windows can be easily repaired with established, widespread knowledge, they also bind carbon as long as they sit in the building.

Concluding Remarks. It turns out, perhaps not surprisingly, that a building archaeological survey is very well suited to finding out how old the different parts of a building are. The knowledge of how to make a building archaeological survey is often limited to a very small circle of architects and probably very seldom combined with an assessment of future life based on a recommended repair method to be used in an LCA.

Unfortunately, archaeological investigations are not as widespread outside the restoration world, but they can be, not least in view of how useful it is as a tool for a qualified LCA calculation.

In addition, a thorough building archaeological survey will often raise awareness of the qualities a building contains both historically, technically and architecturally, thus shifting focus away from the widespread replacement/new construction and over to repair/improvement, which can lower our climate impact significantly.

So far, building archaeological investigations have only been carried out on historic buildings, but this should be extended so that it applies in principle to all types of buildings, including relatively new buildings. This is also very important to sharpen the awareness that there can also be many valuable building elements in this type of buildings, and to learn that the future new buildings are not erected without awareness of how they are aged, maintained and used in the future.
Consequently, building archaeological investigations should be carried out and combined with condition assessments, restoration proposals, energy improvement recommendations and future life assessments in connection with all major renovations/alterations/transformations/restorations.

Since such work is quite extensive, calculations should at least first be published for a range of common buildings types to give an indication of how similar buildings will affect the climate if there is no means to have a proper LCA done.

A further argument for making valid LCA studies, based on realistic lifetimes, is that today's climate impact is of little economic consequence for the individual construction case – as yet, we only have the honour or shame to help us limit the negative impacts!

The work with the Apprentices' House also made it very clear to us how important it is to have a very close collaboration between architects, who can do a building archaeological survey and architectural assessment, and engineers, who can do qualified heat loss calculations and LCA investigations. It is simply necessary for architects to gain an understanding of how to calculate LCA and learn to do it themselves, or at least participate in the calculations, not least to assess the lifetimes.

Thank You. Thanks to Amanda Stevne Pihl, archivist at Bornholms Ø-arkiv, for sending the museum's archives of old photographs and drawings regarding 'the Apprentice's House'.

Thanks to former owners Bill Richemeier Hansen and Gitte Fiil for information on the latest part of the building's history as well for coffee and cookies to all the students.

Thanks to architect Niels-Holger Larsen for sharing his great knowledge of Bornholm's building practices and for references to 'Rural buildings traditions on Bornholm' and 'Building traditions on Bornholm, a graduation project 1979' with the invaluable descriptions of historic buildings. These are a treasure trove of information about older buildings – throughout the country! They can be freely downloaded from the web.

Thanks to architect Jens Riis Jørgensen for great help with finding archive studies.

1 Niels-Holger Larsen, 'Bornholmsk Byggeskik' (Diploma project, Royal Academy of Fine Arts, 1979), accessed 18 February 2020, http://www.kulturarvbornholm.dk/uploads/1/1/2/5/11258347/bornholmsk_byggeskik._afgangspr._1979._niels-holger_larsen.pdf.
2 Niels-Holger Larsen, *Bornholmsk byggeskik på landet* (Rønne: Bornholms Museum 1983).
3 'Lærlingenes hus', Building survey (Copenhagen: KADK, 2019).
4 Thomas Kampmann, 'Unfair Building Regulations for Windows? An examination of how multi-framed and/or secondary glazing windows are treated in the Danish Building Regulations 2018 – and in the rest of the Nordic countries' (Conference paper in review, Nordic Association of Architectural Research, 2019).
5 Thomas Kampmann, 'Hvad koster et vindue? Totaløkonomisk valg af vinduer' (Lyngby: RAADVAD, 2004), accessed 18 February 2020, https://www.bygningsbevaring.dk/uploads/files/vinduers_totaloekonomi_GI_arktikel_4.pdf.
6 Thomas Kampmann, 'Støjgener! Hvordan opnås den bedste støjisolering af vinduer?' (Lyngby: RAADVAD, 2004), Accessed 18 February 2020, https://www.bygningsbevaring.dk/uploads/files/vinduers_lydisolation_GI_arktikel_2.pdf.
7 'Ørkenfortet', *Building survery* (Copenhagen: KADK, 2018).
8 Thomas Kampmann, 'Vinduers samlede miljøbelastning Livscyklusanalyse af fire vinduestyper – eller hvordan man billigt og bekvemt begrænser CO_2-udslippet mærkbart!' (Lyngby: RAADVAD, 2004), accessed 18 February 2020, https://www.bygningsbevaring.dk/uploads/files/vinduers_livscyklusanalyse_GI_artikel_2.pdf.

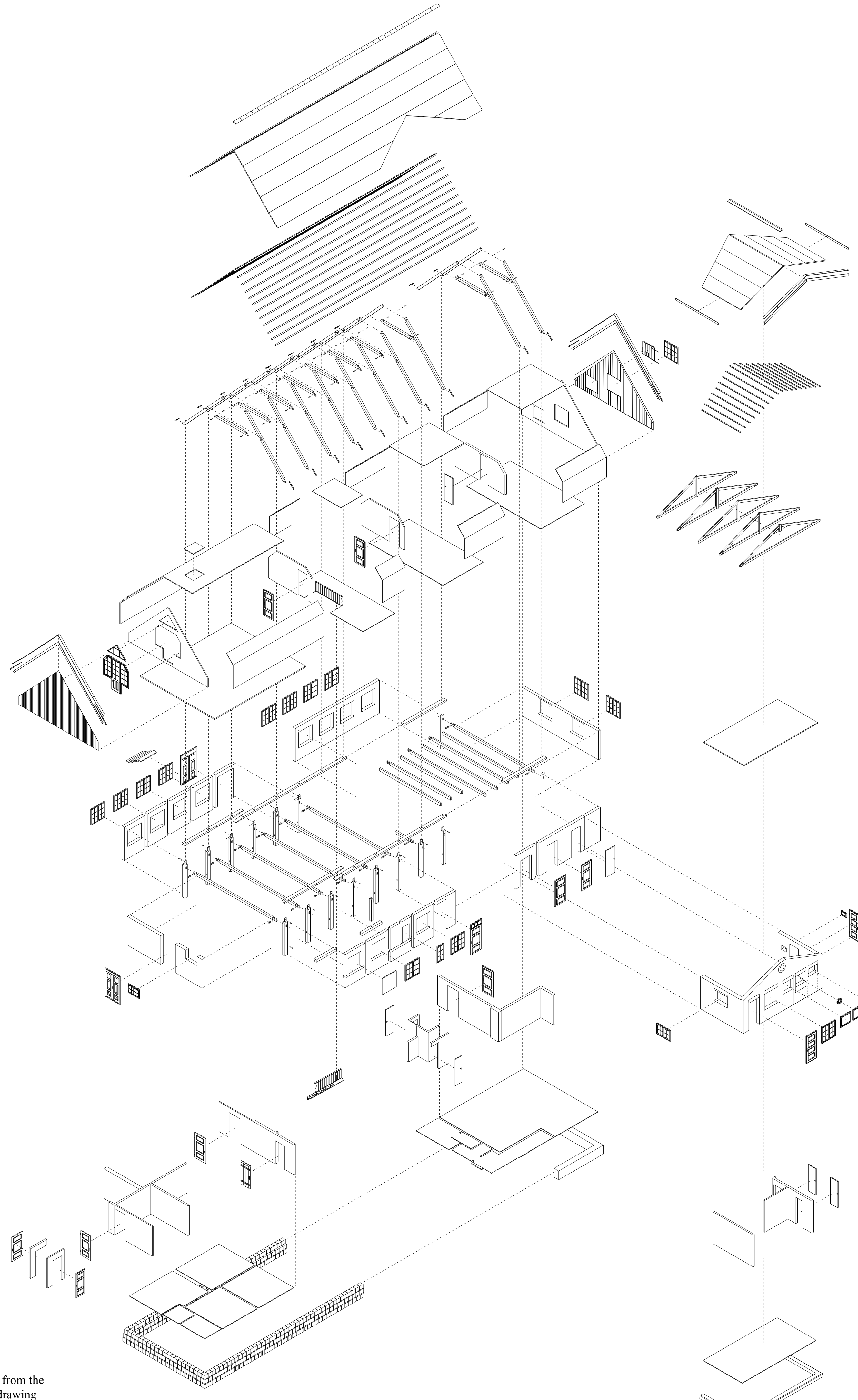


Figure 22: Exploded axonometry seen from the west showing the house in 2019. This drawing makes it more practicable to draw the house in the various construction phases – one will 'just' have to remove the various newer elements in order to reproduce the building as it looked at the time of construction.

Hands On The Value of Building Culture

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Institute of Architecture and Culture – Master's programme for Cultural Heritage, Transformation and Conservation.

Editors: Morten Birk Jørgensen and Victor Boye Julebæk with Christoffer Harlang

Graphic design: Morten Birk Jørgensen and Victor Boye Julebæk

Peer review: Professor Uta Graff, Technische Universität München
Copy-editing: Cornelius Holck Colding

Printing and binding: Narayana Press
Font: Times New Roman, Helvetica Neue
Paper: Munken Print White

ISBN: 978-87-7830-999-0

This publication is a part of the research effort FORAN – a partnership between Realdania and KADK – The Royal Danish Academy of Fine Arts Schools of Architecture, Design and Conservation.

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