UPGRADING THE ENERGY PERFORMANCE OF ELMEHUSET IN THE OLD PEOPLE'S TOWN

REPORT - PRODUCED FOR SBI OCTOBER 2012

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Co$_2$olBricks

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INTRODUCTION

This report was produced for SBI.

This report concerns a renovation project carried out by Copenhagen Real Estate - KEjd (Københavns Ejendomme) on Elmehuset, a building owned by the Municipality of Copenhagen (Københavns Kommune).

The project includes the renovation and conversion of a 3-storey brick building in the Old People's Town (De gamles by) in the district of Nørrebro, Copenhagen.

The exterior of this former poorhouse in solid masonry, with two-light windows with small panes and slate roof is categorised as worthy of preservation by the municipality.

Energy analysis of the building was carried out as part of the project in order to find ways to reduce the CO^2 level whilst ensuring an indoor climate that matches the applicable guidelines and requirements in the Danish Building Regulations. An interdisciplinary working group consisting of the building owners (Municipality of Copenhagen), the authorities (Center for Building and Construction/ Center for City Design), the architects (Kant architects) and the consulting engineers (Klaus Nielsen Consulting Engineers) considered which solutions to use.

This report compiles the overall conclusions from this process, and describes the interdisciplinary challenges, possible and actual solutions for upgrading the energy performance of older multi-storey brick buildings of this kind.

The aim of this report is therefore to share our knowledge and experience with other building owners who face the renovation of a multi-story building with exterior walls of solid brick. In Denmark, this type of building dates mainly from the period of 1850 to 1920 and accounts for approximately 20% of all dwellings in Denmark.

The majority of the buildings have wooden joist floors, but Elmehuset has concrete decks, which makes it ahead of its time. But the red masonry, the two-light windows with small panes and the slate roof are typical of Danish building tradition of this period.

The exterior of this kind of buildings is often considered worthy of preservation at some level, and they are generally highly valued for their contribution to the uniqueness of the local environment.




Elmehuset before refurbishment

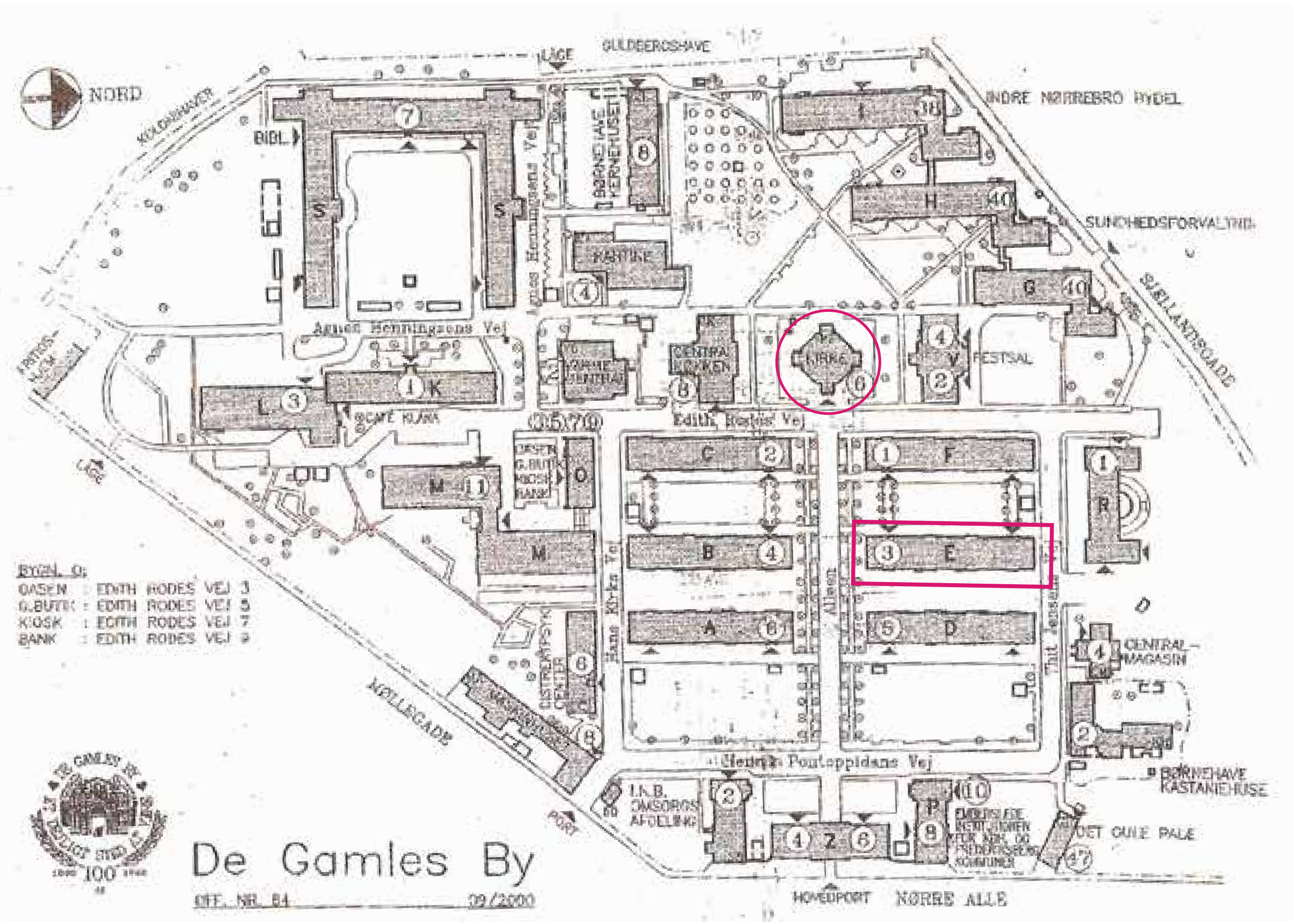
Elmehuset after refurbishment

BUILDING COMPLEX

Elmehuset was built in 1887 by the architect Wilhelm Petersen as part of the Poor Relief Hospital (Almindeligt Hospital) for elderly paupers.

In 1919 the name of the area was altered to the Old People's Town (De Gamles By), as the buildings of the Poor Relief Hospital and Copenhagen's Old People's Home from 1901 were merged. The establishment was extended by the City Architect Directorate (of the city Architect) in 1946-60, and in 1992-99 The old People's Town went through a thorough modernization to keep up with the times.

Elmehuset has continued to be a residential home for different kinds of patients. It was renovated and rebuilt in 2010 to comply with the requirements to a modern and comfortable home for the autistic children living there now.



Siteplan af De Gamles By

THE DISTRICT

Siteplan Nørrebro

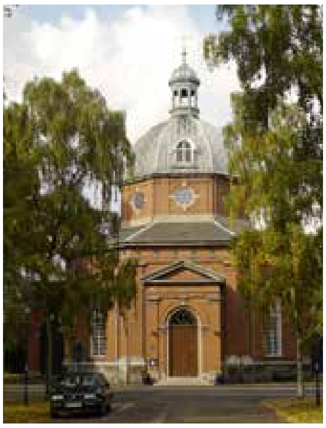
The Old People's Town is an area with nursing and residential homes and senior housing in the heart of Nørrebro, a district in Copenhagen. The area is bound by the streets Nørre Allé, Guldbergsgade, Sjællandsgade and Møllegade.

The district of Nørrebro, as we know it today, evolved around 1850 when the ramparts of Copenhagen had been demolished. The area developed into a typical working class district densely built up with housing blocks and scattered industry of all sizes. Nowadays Nørrebro is a colourful and cosmopolitan district of Copenhagen, still fairly densely built up with blocks of housing and shops, but with only small-scale industry. In most places the old tenement blocks, with their tiny flats, workshops, rubbish heaps and livestock in the courtyards have been demolished to allow more daylight into the flats and to make room for more spacious green courtyards and recreational areas. Some original built-up areas have been completely demolished and new modern housing blocks with bigger flats erected, but unfortunately with poor social and architectural effect - and heavy ghettoisation as a result.

Today the municipality tries to maintain and renovate most old buildings to preserve the area's urban uniqueness and charming originality.

URBAN DEVELOPMENT

The Old People's Town is a good example of the execution of the intention to preserve. The area, which creates a welcome sanctuary from the hectic city outside, covers approx. 50,000 m2 of public park with buildings used for residential homes. The buildings are mainly older multi-storey brick buildings from the early 1900s arranged around the Old People's Church in the centre of the area. Lawns, paths and quiet streets connect the buildings. On the edge of the area, newer buildings appeared as the Old People's Town expanded, but as they were kept along its edges, they do not interfere with the general impression of the area.


The entrance and the church at The old People's Town

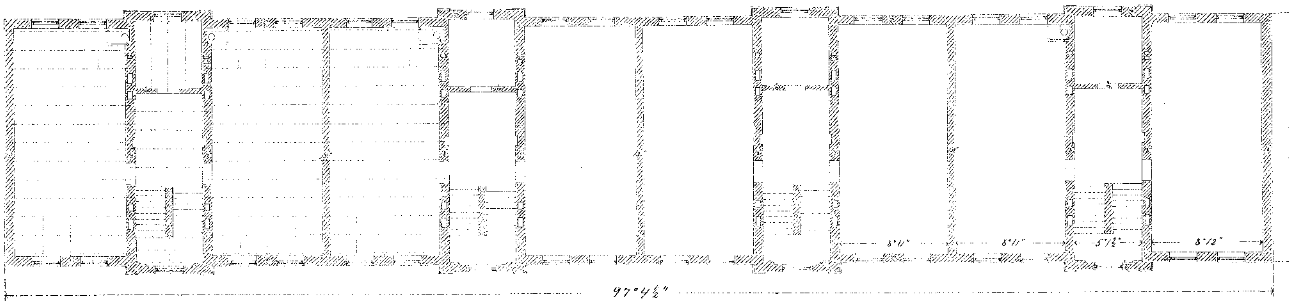
The south gable of Elmehuset

The Poor Relief Hospital (Almindeligt Hospital) is part of the oldest section of the complex. It consists of six almost identical buildings placed in two rows with three on each side of the main avenue, which connects the main entrance with the church. The buildings run almost due north-south and perpendicular to the east-west aligned avenue. This allows passers-by to catch a glimpse of the small, neat green areas between the buildings, and the long facades to benefit from the morning and evening sun.

The Old Peoples Town

History and Structural Modifications

The 3-storey, rectangular brick buildings all have slate roofs and white-painted wooden two-light windows with small panes. Two of the buildings had dormer windows added along the entire roof. At some locations along the ground floor there are large shutters which can cover the middle windows – a legacy from World War II, when the rooms behind them were used as shelters. The shutters are also subject to a preservation order.

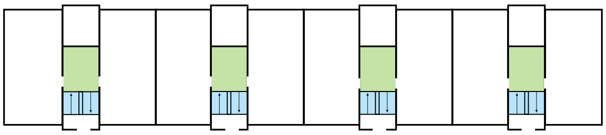


Original Layout

West facade with old shutters and new dormer windows

Shed dormer windows on building D from 1936.

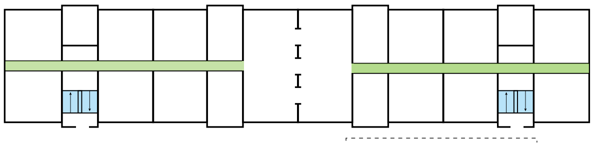
Originally, the building interiors were nearly identical, with 4 sets of stairs and entry from the eastern facade. Opposite the stairwells was a common scullery on each floor, and on each side was a large dormitory for the pauper residents.



1887

The buildings have since undergone several conversions.

Around 1921, the two middle stairwells were demolished, and on each floor the space was used for a kitchen and supervisor's office respectively. Long central corridors with smaller rooms on each side were built, ending in a common dining room in the centre of the building. The old sculleries here were converted into accommodation for couples, and those alongside the surviving stairwells were converted into toilets – 6 for each floor.

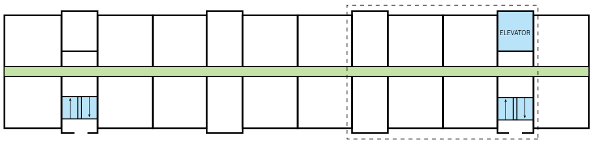


1921

Central heating was installed in 1924.

Shed dormer windows were added to buildings A and D in 1936.

In the mid-1950s, Elmehuset underwent yet another major conversion, initiated by the the Copenhagen City Architect's Office. The corridor was extended throughout the building, and the common dining rooms on the upper floors were converted into common rooms on the eastern side, and to accommodation on the western side. Almost half of the rooms were converted into small, 2-room flats for couples. Every flat had its own kitchenette.



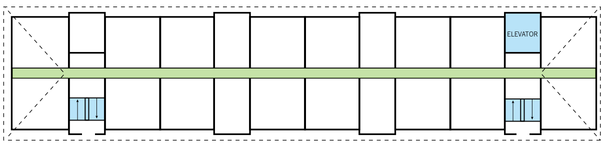
1955

About 25% of the loft was converted to facilities for the staff, including a new dining room, changing rooms, bathrooms and toilets.

Lifts were installed from the ground to the second floor by the northern stairwell. The original stairwell was replaced by pre-cast concrete stairs running right up to the loft. Skylights were fitted in the new dining and changing rooms. Mechanical ventilation was installed from the large kitchen in the basement, the changing rooms etc. The former toilets were converted to lifts and accommodation respectively, and new toilets (with partition walls) built in the old kitchen/office areas.

Between 1992-99, all 6 buildings were extensively renovated by the architect Mogens Werliin. The buildings were updated, all installations were replaced and district heating connected. New fibre-cement roofs with a new roof underlay insulated with 80 mm mineral wool replaced the old roofs.

Better handicap access and facilities were also installed.



1992-99

THE BUILDING

The building has been categorised as worthy of preservation according to SAVE registration [1].

The exterior has been categorised as category 2, which means that: "due to its exterior architecture, cultural history and standard of workmanship, the building is an outstanding example of its type". As can be seen, its preservation-worthiness depends on a number of parameters.

The preservation-worthiness of the building is closely linked to the context it belongs in: the entire Old People's Town is in the same category, and the cultural legacy of the entire complex. It progressed from a poorhouse accommodating the sick, the old and the criminal – those unable to care and provide for themselves – to a modern nursing home, home for the elderly and institutions for handicapped children, in which all the residents and users are cared for according to their needs rather than their social status.

The environmental importance of the building is classed as 2 (High), especially because of its support value for the other original buildings of the Poor Relief Hospital. Elmehuset has the same height, frontage and style, and its location in relation to the church and the rest of the complex reinforces the storytelling-value of this cultural environment, and thus its historical significance.

Its preservation-worthiness also includes the architecture, with obvious inspiration from classicism and historicism, with exemplary contemporary details of craftsmanship and construction. The degree of architectural value is high, the facade's 'rhythm' is clear and reflects its function. The architectural value is classed as 3 (High).

The preservation-worthiness is also linked to the originality of the building, which also achieves the high classification of 2, as Elmehuset still retains its original appearance as a whole and in its details, apart from the bricked-up entrances and added dormer windows.

The main avenue with elmehuset on the right and the church at the end

THE BUILDING BEFORE RENOVATION

Prior to the latest renovation programme started in 2009, which included extensive conversion, modernisation and energy upgrades, Elmehuset was a 3-storey building with a partially used loft and a low cellar.

The original facades are red brick, cross-bound with straight projections over the white-painted two-light windows.

The facade is vertically divided into 4 stairwell projections running the full height of the building, which mark the original 4 entrances and their stairwells behind. They are flanked by masonry pilasters, decorated with curved two-light windows, and arches over the main entrances. Each projection is topped by an undecorated architrave and a simply decorated frontispiece. The arched windows and entrances have been replaced by windows of the same type as the rest of the building in the 2 centre projections, where the stairwells have been removed.

East facade before

The facade is divided horizontally by an unbroken cornice between the ground and first floors, plus recesses into which the upper windows are set in pairs, forming a horizontal recessed band of fields under the roof cornice. The upper windows have continuous window ledges, and along with the dentil cornice at the top of the recesses this helps accentuate the horizontal division.

The gable ends are also in red brick, with recesses decorated with reliefs. The middle recesses form a frame around the gable windows which were installed along with the long central corridors in 1921.

The roof is a pitched slate construction, flush with the tops of the walls. The pitch is approx. 27°. As part of the major renovation works of the 1990s, the roof structure was renovated with a Haloten roof underlay and fibre cement sheets. Above the projections, the roofs were covered in zinc.

High brick chimneys rise majestically above the building, 4 for each stairwell, placed as corners of a square which is symmetrical with the roof ridge and frontispieces.

CONSTRUCTION

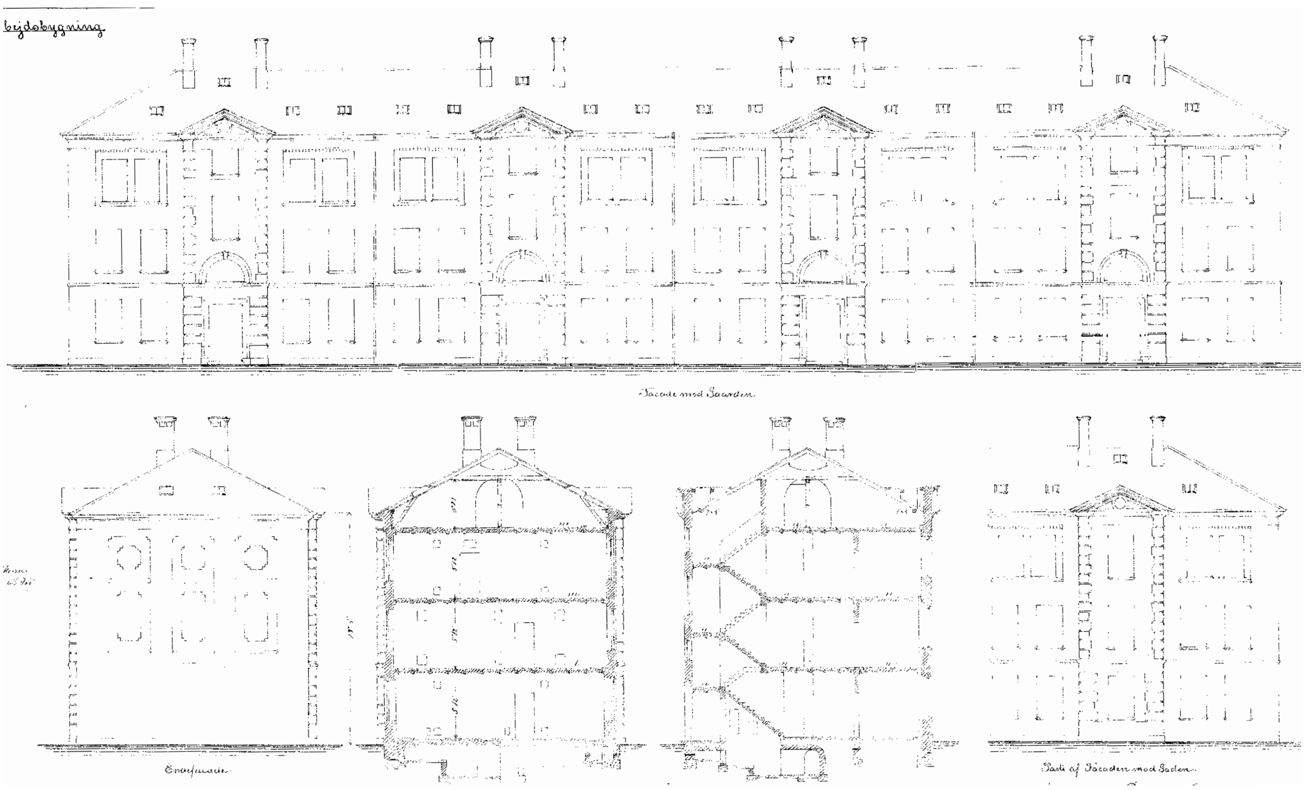
The building was constructed with solid brick outer and inner walls. The outer wall at ground floor level is 60 cm thick and 48 cm for the two upper storeys. The gable walls are 48 cm for their full height. The internal supporting walls vary in thickness from 36 cm to 48 cm.

Non-supporting partition walls are built of moler bricks.

The floor construction consists of steel beams running along the length of the building, resting on the supporting cross-walls – the 4 original stairwell cores and a wall in between each core. The spaces between the steel beams are filled with cast concrete to a thickness of approx. 15 cm.

The roof is constructed of 6"x6" tie bands, with a new Haloten roof underlay on 25x45 mm rafters, 38x56 mm battens and fibre-cement sheeting.

New secondary glazing has been fitted to the inside of the windows.



Original elevations and sections

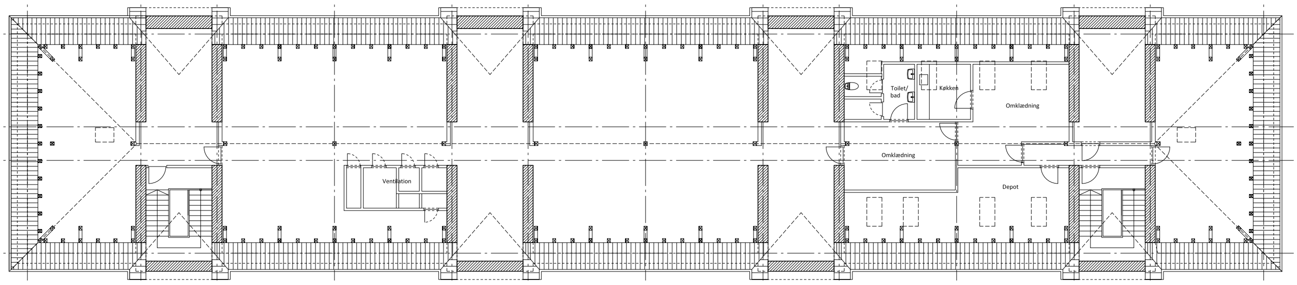
INTERIOR DESIGN

The layout of all 3 floors is still linked to the long central corridor and 4 stairwell cores, of which only the 2 outer ones still house stairs. The other areas in the stairwell cores are used variously for rooms for single persons, kitchens, sculleries, toilets and lifts. There are rooms for single persons and couples plus a common room area off the corridor with the exception of the ground floor, which has been opened up across the building to form a large dining room and kitchen around the southern stairwell.

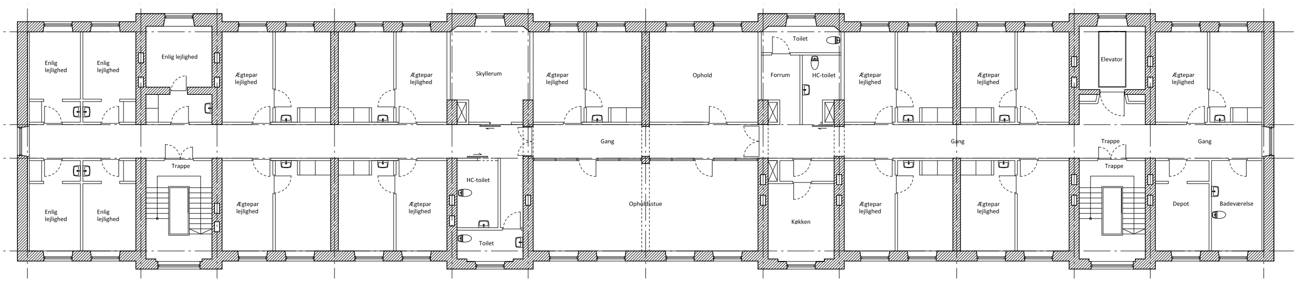
Still only a quarter of the loft area is used for the staff, and the rest is used as a general-purpose loft space.
The total gross floor area totals 2,724 m^2, with each of the 3 typical floors accounting for 724 m^2 and the loft for 585 m^2.

The net floor area is approx. 660 m^2.

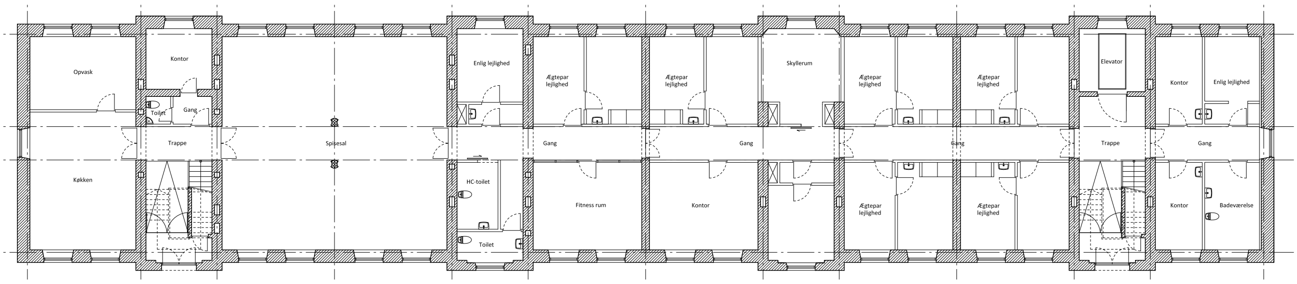
In addition, the cellar covers 250 m^2.



Third floor



First floor



Ground floor

FUNCTION AND USE BEFORE RENOVATION

Before renovation, Elmehuset (at that time known as 'E-huset') was an independent nursing home in the Old People's Town. It was a home for alcoholics of all ages with behavioural problems who could not be cared for within the normal system.

CONDITION AND ENERGY CONSUMPTION BEFORE RENOVATION

In 2009, the building was extremely run-down.

The lifts were worn out, and the bathrooms and kitchens all needed extensive renovation. All installations needed replacement and the original windows were in highly variable conditions. Some of them could be renovated and reused, whilst others had to be scrapped.

The change in function, despite the same category of use (category 6), meant a range of new requirements from the authorities concerning fire, acoustics and accessibility.

Annual energy consumption in 2009: Energy consumption per year.

Breakdown of energy use

- Heating: 294,0 MWh
- Electricity: 108,0 MWh

Total energy consumption: 402,0 MWh
Corresponding to a heat consumption: 107,9 kWh /m²

The building's energy consumption was classified as G [2])

RESTRICTIONS AS A RESULT OF PRESERVATION-WORTHINESS - AND ITS RELEVANCE TO FUTURE USE

The restrictions related to preservation-worthiness only concerned the exterior and its overall strong relationship to the surrounding buildings. Therefore conversions or renovations cannot usually add new elements to facades or roofs which do not harmonise with the surrounding buildings.

The maintenance of facades, roofs and windows must take into account the preservation of existing features, and not be seen as changes to the external appearance of the building.

However, every effort was made to retain the existing floor layout after renovation, taking into account the economy and the overall rational construction of the building. At the same time efforts were made to meet the demands to the new use to which the building would be put.

Westfacade, after renovation.

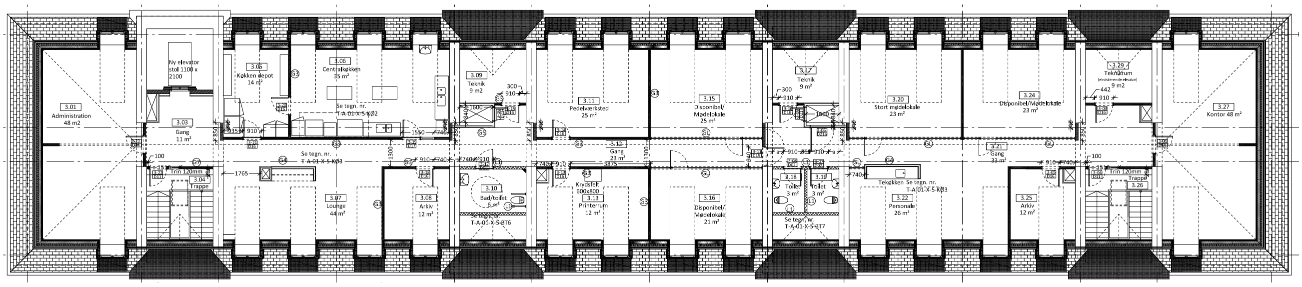
FUTURE USE – DESCRIPTION

In 2009, the Municipality of Copenhagen decided to change the function of Elmehuset from a nursing home for alcoholics to a 24-hour care centre for children and adolescents with autism spectrum disorders.

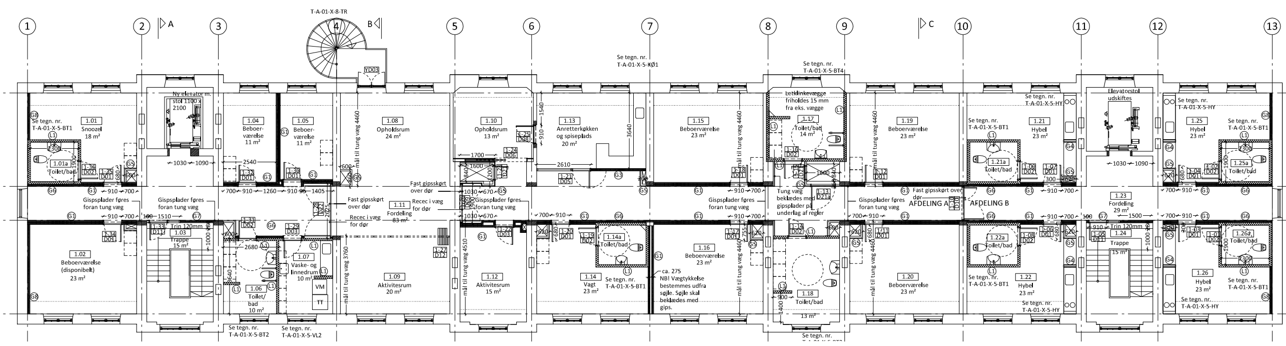
The institution has 4 different departments, with 24-hour care and acute places for minors with fundamental autism spectrum disorders between the ages of 10 and 18, physically handicapped and psychiatrically disabled children from the ages of 0 to 18, and mentally handicapped children between the ages of 0 and 18.

The new institution has 26 flats and rooms, of which the largest have their own kitchen and bathroom.

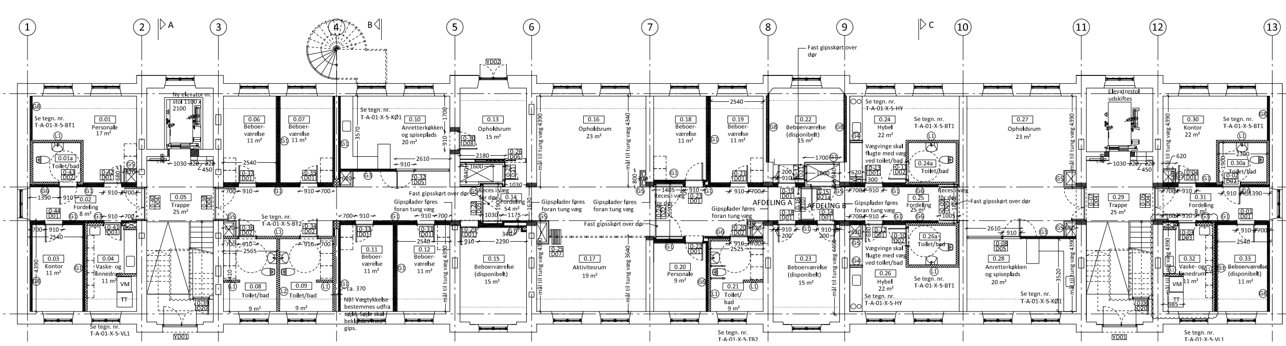
There are also common kitchens, common rooms, activity rooms, bathrooms and toilets. Administration is housed in the new loft area along with a number of activities for the children.



3.floor



2.floor



Ground floor

MAIN ELEMENTS OF THE CONVERSION

Building work required for conversion and renovation of Elmehuset:

- Renovation of the sewers.
- Sprinkler control centre was installed in the cellar, along with mandatory ABA/ABDL/Alarm systems for fire.
- New internal walls were erected as partition walls with stud profiles, clad with plasterboard. Lightweight concrete blocks were used for walls in wet rooms.
- New bathrooms were built, and concrete floors cast with a fall to the floor drain ready for tiling. Acoustic insulation was installed between the floors in the toilets and bathrooms. The bathrooms were designed to facilitate subsequent adaptation for handicap and care provision. The users' requirements to accessibility and acoustics were incorporated.
- New kitchens were fitted in each of the 4 departments.
- A large common kitchen was fitted in the loft.
- New lifts were installed in the existing cores at the north and south ends.
- The main stairwells were renovated with new floor covering and acoustic floor insulation, plus railings for protection.
- All basic installations were replaced, and ventilation installed to extract air from bathrooms, kitchens and common rooms.
- Suspended ceilings were installed in the corridors, bathrooms and accommodations.
- New floors were laid in all rooms and areas. Wooden floors laid on laths were used. Acoustic insulation was installed between the floors in rooms and areas. The acoustic levels required by the users were incorporated.
- New doors and coupled windows with double-glazing in the innermost frame were installed. Mandatory requirements for energy and preservation-worthiness were incorporated.
- A new roof structure was built, using natural slate tiles. The new roof construction was insulated according to the Danish Building Regulations, 2008.
- Dormer windows were installed in the new roof as true copies of those found on the other 5 buildings on the avenue, with zinc cheeks and roofs, plus white-painted two-light windows with small panes and glazing bars. Mandatory requirements for energy and preservation-worthiness were incorporated.




ENERGY RENOVATION – MAIN ELEMENTS

1. New insulated roof construction with dormer windows
2. Replacement of outer doors and windows:
3. Replacement of installations, lighting, heating and ventilation.
4. Internal insulation of gable ends

Estimated Heat Consumption after Renovation 2010:

- Heating: 196,3 MWh

Corresponding to: 196,3 MWh/2836 m^2 : 69,2 kWh /m^2

The building was after renovaton in 2011 given an energy rating of C in the energy rating survey, with estimated annual district heating consumption of 249.39 MWh.

The energy price used, including VAT and duties:

District heating: DKK 620.00 per MWh
Electricity: DKK 1.96 per kWh
Fixed duty: DKK 65,586.00 per anno

LIST OF THE PARTIES INVOLVED

Owner
Municipality of Copenhagen

Client and Customer: Culture and Leisure Administration (KFF), Children and Youth Administration (BUF)
Administrator and Consultant to the Owner: Copenhagen Real Estate (KEjd)
Tenant: Social Services Administration (SOF)
User: Center for Children with a Handicap (CBH)

Consultative Team
Main Consultant/Architect: Kant Arkitekter A/S
Consulting Engineer: Klaus Nielsens Rådgivende Ingeniørfirma I/S

The Authorities: The Technical and Environmental Administration
1. Center for City Design. Conservation values
Handles urban planning, urban renewal, subsidised home construction, architectural issues centring on the combination of technology, function and aesthetics, plus area-based regeneration in Copenhagen and preservation values.

2. Center for Building and Construction. The Danish Building Regulations (BR08)
Handles building permits and reports, inspects new building work in the Municipality of Copenhagen, and provides technical, practical and legal guidance for building projects in accordance with the Building Regulations, including the requirements pertaining to fire, construction, acoustics, humidity, accessibility and energy.

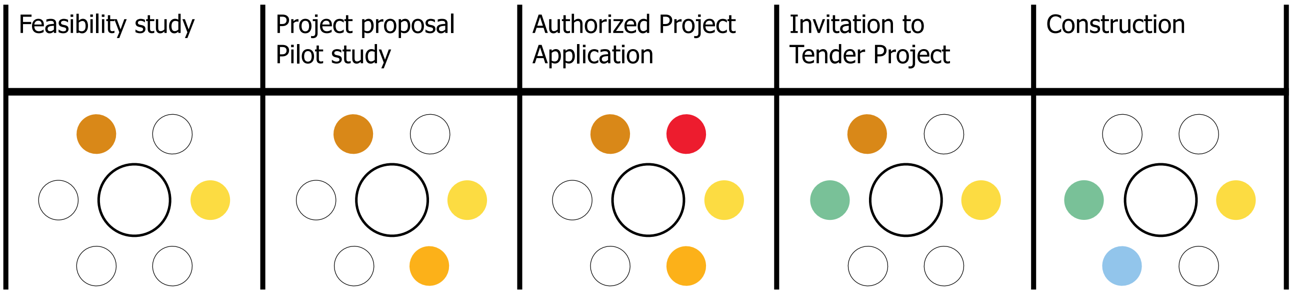
3. Copenhagen Fire Brigade, Department of Prevention.
Copenhagen Fire Brigade is the municipality's center of knowledge in the field of preparedness and safety.

Specialists
Acoustics: Grontmij Carl Bro Acoustica
Asbestos: ABVAC Steen Knudsens Bygningsentreprise ApS
Rot and mould growth: Bøgh og Helstrup
Humidity and energy calculations: Klaus Nielsens Rådgivende Ingeniørfirma I/S

Craftsmen and contractors (trade contracts)
Carpenter: Enemærke og Petersen A/S,
Bricklayers: Øens Murerfirma A/S,
Painters and decorators: Olsen og Christiansen A/S
Demolition: NKR Nedbrydning A/S
Scaffolding: AC Stilladser A/S
Plumbing and sanitation: Real VVS ApS, and
Ventilation: Villingshøj og Messerschmidt
Electricity: Bjerregaard El ApS
Sprinklers: Flindtholt's VVS

Manufacturers
Dorma/windows/lifts/ventilation

THE PARTIES INVOLVED THROUGH PHASES



THE PARTIES INVOLVED

DESCRIPTION OF PHASES

FEASIBILITY STUDY

The parties involved: Client (BUF), new tenant and architects.

The feasibility study was prepared in 2008 as a collaborative building programme between BUF, SOF and Krydsrum Arkitekter. The study was commissioned by the Social Services Administration of the Municipality of Copenhagen (SOF).

The study defined the requirements of the working group, and consideration of the general problems for this type of institution, such as capacity, acoustic problems and the well-being of both the staff and residents. The main aspects studied were the layout and floor allocation for the new residents and staff.

However, the building programme contained no financial projections, and was more in the nature of a 'wish list' than a feasibility study of the project in relation to finances, requirements and options.

Considerable work on the building's structure plus the building of large new shed dormer windows was proposed.

After calculations, the costs of the proposed project turned out to be almost double the budget allocated.




PROJECT PROPOSAL AND PILOT STUDIES

The parties involved: Client (BUF), administrator and consultant to the owner (KEjd), architects, engineers and specialists within moisture, rot & mould growth plus asbestos.

The project was put out for tender as an EU invitation to tender, and Kant Architects won the contract. Kant Architects was appointed Main Consultant for the Project Proposal, developed from the feasibility study in consultation with Klaus Nielsen Consulting Engineer, BUF and KEjd.

The project was trimmed down to within the budget, which involved simplifying the floor layout so that the proposed extensive changes in the supporting structure could be omitted.

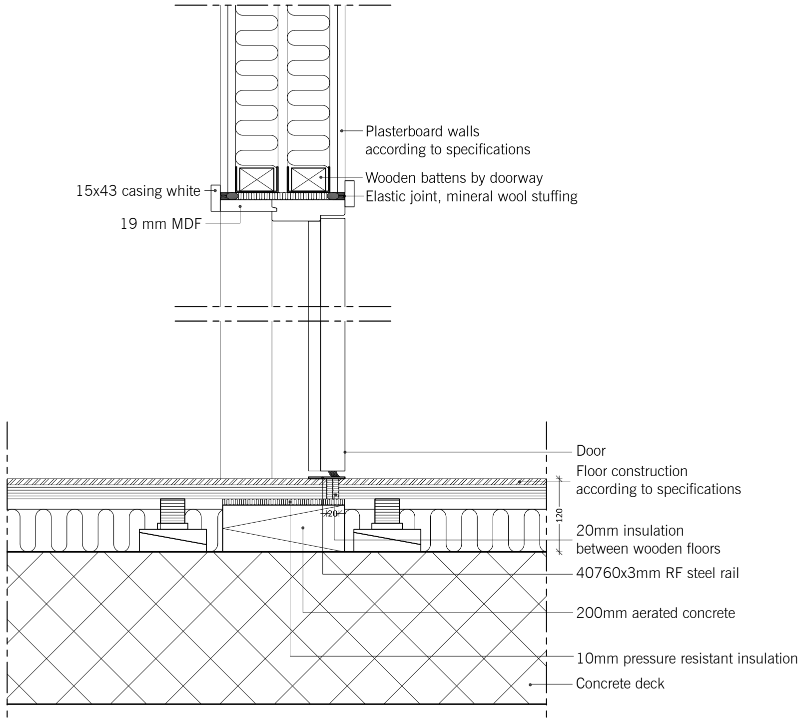
To do so, retaining the existing roof construction and roof covering became a precondition. The dormer windows were altered to match the shed dormer windows from 1936 on buildings A and D, and could thus be approved in relation to the preservation values as a recognisable element of the building complex.

Two new entrances were opened in the West Facade, in the northern and southern cores, opposite the existing main doors in the East Facade.

The roof was to have extra insulation in accordance with BR08, as the loft would become part of the future floor area.

Future users, CBH, demanded special acoustic insulation of all accommodation, common rooms, kitchens and bathrooms, as the residents can be noisy and sensitive to noise. Acoustic experts from Acoustica Klaus Møller Pedersen were therefore brought into the project, and commissioned to perform the necessary measurements, calculations and descriptions to ensure that all acoustic requirements were met.

This would involve special acoustic insulation of all floors, which entailed extensive conversion work, as all doors had to be raised and extra steps built in to the stairs. This was yet another reason for replacing the lifts.



Floor/ wall detail

Stairs with extra step in front of door (raised floor)

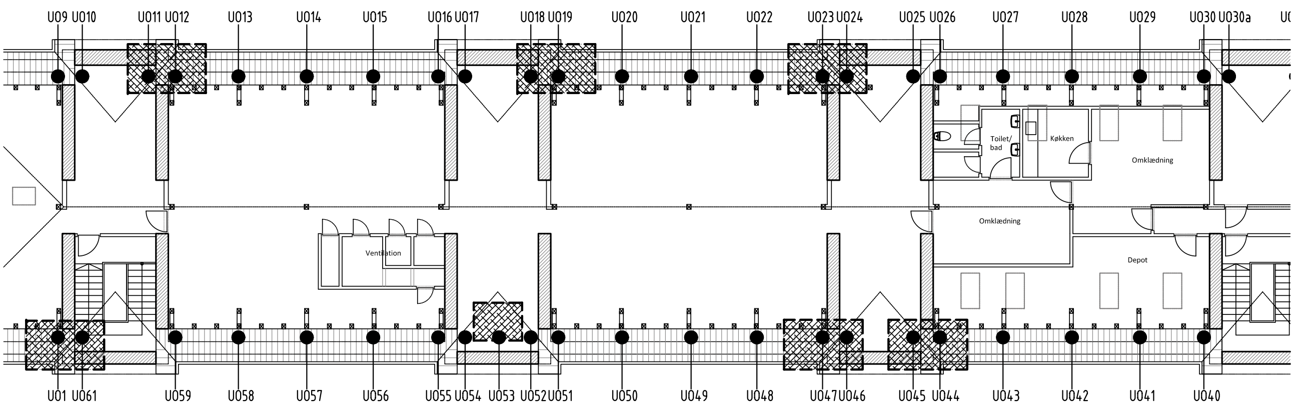
The mandatory requirements by the authorities were described and included in the project, specifically with regard to additional insulation and acoustic insulation, accessibility and fire (including sprinklers and evacuation routes). The building would remain in the same category of use in relation to fire and rescue[3], despite the change of function from a nursing home to a 24-hour institution.

PRELIMINARY INVESTIGATIONS

Preliminary investigations of the roof construction's condition were initiated during the same phase, as there was a suspicion of mould attack.

A preliminary investigation into the possible presence of asbestos was also performed, as the age of the installations indicated that a risk might exist.

White dry rot



Registration of mould and dry rot attack in roof structure

AUTHORISED PROJECT APPLICATION, AND THE RESULT OF THE PRELIMINARY INVESTIGATIONS

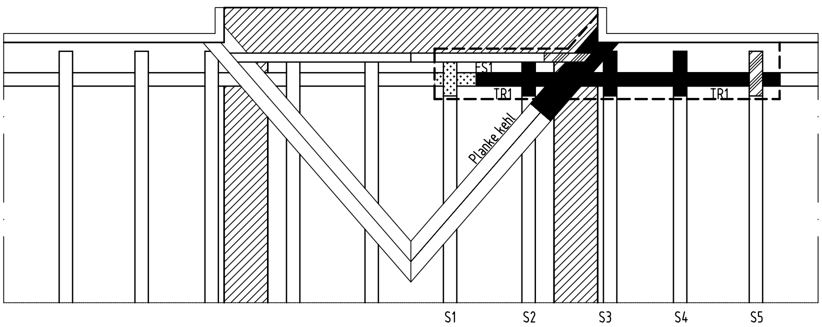
The parties involved: Center for Building and Construction, Center for City Design, the fire authorities, the client and administrator, architects and engineers, including specialists within moisture, energy and cost-effectiveness calculations.

An application for an Authorised Project for conversion work at Elmehuset was submitted. Change of function and conversion work was described. New utilisation of the loft, including additional insulation, new dormer windows and lift were main points.

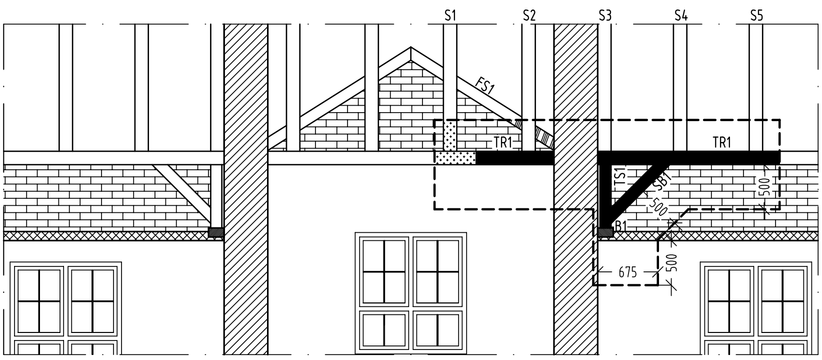
The preliminary investigations immediately revealed several environmental problems which would have to be tackled.

Asbestos was found in installations around pipe elbows and in the grout seals of indoor glazing. All existing installations and the indoor glass partition walls were therefore removed during the subsequent asbestos removal programme. The process was performed separately before the start of building work to avoid extending the building period.

The preliminary investigations around the roof showed that the roof structure had been heavily attacked by white cellar fungus, mould growth and dry rot because of faults in the roof underlay, guttering etc. This meant that the entire roof covering, underlay and battens had to be replaced, and the framework repaired. As new insulation was to be applied, which requires increased rafter depth, and the straightening of existing rafters on the outside and inside was required, it was deemed to be more rational to budget for a totally new set of roof rafters. The administrator (KEjd) therefore decided to replace the entire roof structure.



Rafter construction with mould attack, white dry rot



Facade (from inside) area with mould attack, white dry rot

It also transpired that the existing windows could not fulfil the functional requirements of the new users. Users such as psychiatrically-ill children have to be prevented from falling out of the windows, which therefore required a safety system which would have been difficult to integrate into the existing coupled windows with their inward-opening frames.

The insulation value was another aspect which was to be upgraded.

KEjd therefore applied to an internal energy efficiency fund at Copenhagen Real Estate for a grant to replace roof and windows in parallel to the application for an Authorised Project.

After submitting its application for an Authorised Project, KEjd received a grant of DKK 4.6 million to upgrade the energy performance of Elmehuset. This made it financially viable to replace the entire roof, the windows and outer doors. This work was included in the Authorised Project and forwarded as an addition to the application.

The newly included replacement of roof and windows represented the renewal of approx. 34% of the building envelope, thus triggering the requirement in the Building Regulations for upgrading of the entire building envelope to BR08 standard as long as a cost-effective and proper structural solution could be found.

This requirement comes into effect once the retrofit or renovation involves 25% of the building envelope. The authorities require documentation for the structural solution and cost-efficiency calculations.

Insulation of facades

The options for additional insulation were considered by the consultancy group, and calculated by engineers specialising in moisture and energy calculations.

Additional external insulation of the facades was neither possible nor desirable, because of the preservation-worthiness of the building, and its links to the other buildings in the Old People's Town, as it could not be done without covering the existing facade. It is unlikely that such a solution would have been approved by the Center for City Design, and none of the parties involved deemed it necessary to pursue this aspect.

Architects and engineers recommended internal insulation of facades with 200 mm mineral wool, which would fulfil the requirements of the Building Regulations, and that mechanically balanced ventilation was provided.
The fears of the administrator and the consultants concerning the internal insulation centred on the following:

- By how much the additional insulation reduces the floor area?
- Does additional insulation require balanced ventilation in all rooms?
- Is additional insulation cost-effective?
- How high is the risk of mould growth at a possible dew point on the inside of the old outer wall?
- Can the vapour barrier be watertight and remain so?
- How can cold bridges in the floors, the supporting and solid transverse partition walls be reduced?

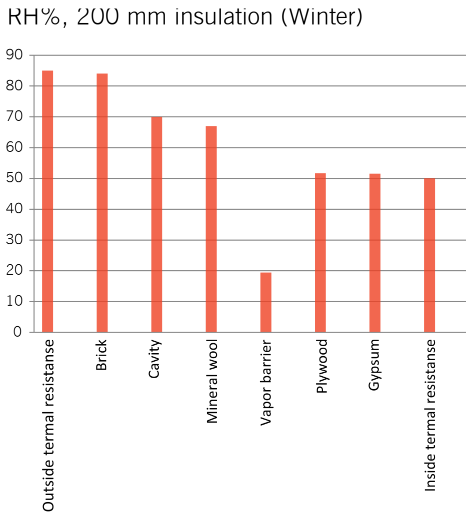
An additional 200 mm of mineral wool insulation would reduce the accommodation area on a standard floor by approx. 40 m^2 if in the form of a secondary wall of 290 mm.

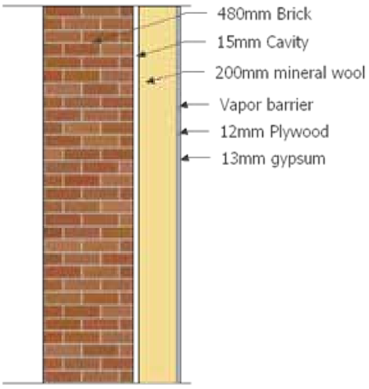
This would give a remaining net floor area of (1982 m^2 - (3 x40 m^2)) = 1862 m^2, equivalent to a reduction of approx. 6%.

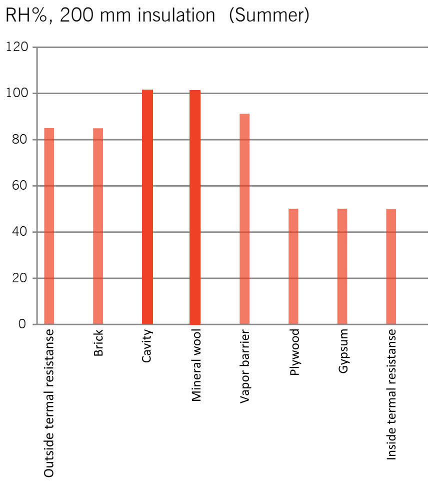
This could have given problems for letting the premises, as it would reduce the income for a landlord, making the cost of additional insulation an expense which cannot be included in the cost-effectiveness calculations, but which could have a major impact on the building owner. In this instance, a change in the thickness of the facade could prevent the reasonable and flexible interior design of several of the rooms intended for accommodation.

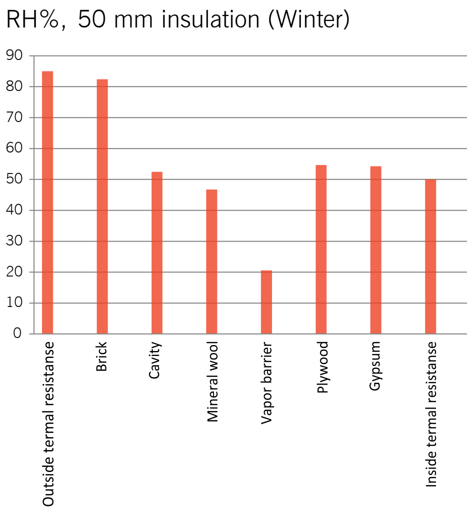
Such a high level of insulation requires mechanically-balanced ventilation to be able to maintain air humidity at a level at which there is no risk of condensation in the structure, and the subsequent development of rot and mould growth.

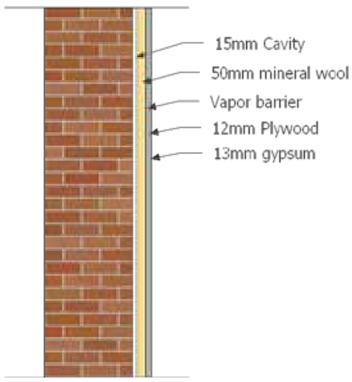
The contact areas where the stabilised brick inner walls and concrete floors are in direct contact with the outer wall construction represent a significant area – and a large cold bridge. This means that the dew point is pushed back into the building's construction, creating further need for ventilation. The cold bridges cannot be reduced without extensive work on the construction.

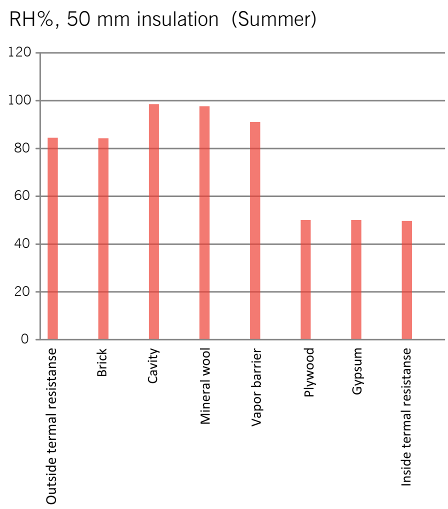








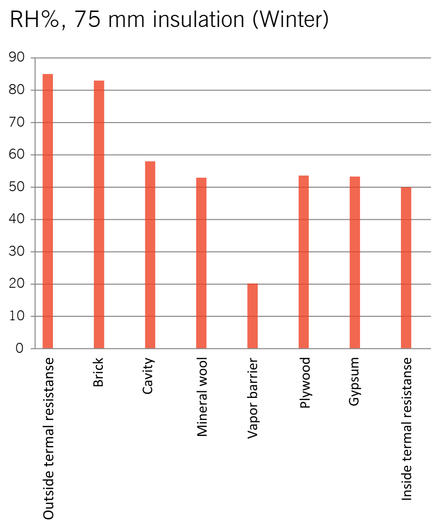


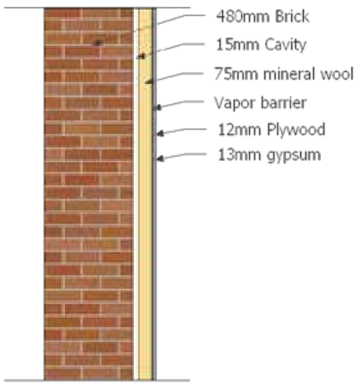


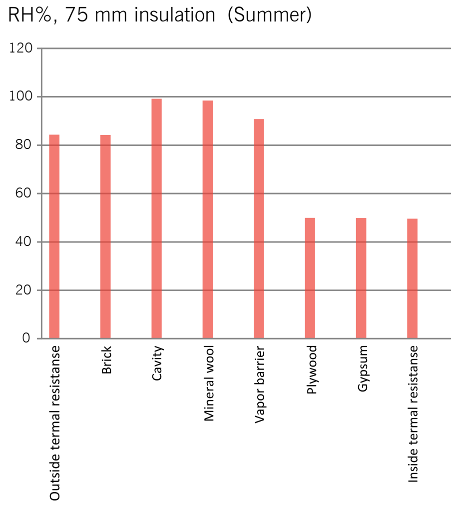
Establishing mechanically-balanced ventilation proved to be very expensive, and would involve extensive work on the building. Along with the other costs for building work connected with the additional insulation, the solution using 200 mm mineral wool would not be financially viable.

Consequential repairs included the adaptation of window openings to the new wall thickness, restoration of wall surfaces including the removal and re-mounting of panels and skirting boards. The relocation of radiators, various installations and pipes on outer walls are normally consequential repairs, but as they were to be replaced anyway in this renovation project, the costs were not included in the cost-effectiveness calculation.

The option of additional insulation without mechanical ventilation was considered, for which new calculations were made particularly with regard to the dew point within the construction if a lesser amount of insulation was used. The calculations showed that right down to approx. 75 mm additional insulation would be required before an acceptable result was achieved with a guarantee of no accumulation of moisture in the building because of additional insulation.



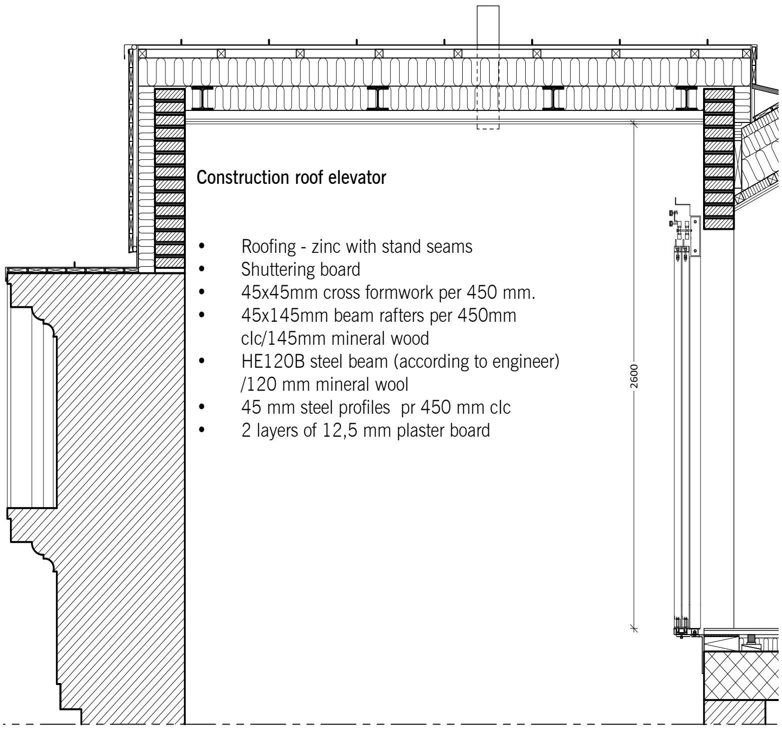




The cost-effectiveness factor for 50 mm insulation was calculated to 1.24, which is lower than the 1.33 deemed to be cost-effective according to BR08. The cost-effectiveness factor for 75 mm insulation was calculated to 1.36.

The solution using insulation of 75 mm mineral wool could comply with the dew point calculations, but was not deemed to be cost-effective because of the inherent risks of the construction, even though the calculations showed that it was just possible, in theory. A further precondition was that there would be no unforeseen expenses for cost-effectiveness to be achieved, which is improbable for the renovation of an older building.

As it was not cost-effective to add insulation in a technically sound manner, the mandatory requirement no longer applied and the Administrator (KEjd) therefore chose not to add insulation to the inside of the building facades.



Section, lift tower, top floor

Dispensation was also sought for the excess height of the lift tower. Dispensation was granted by the Center for Building and Construction.

INVITATION TO TENDER PROJECT

The parties involved: The administrator and consultant to the owner (KEjd), architects and engineers

As the mandatory requirement for additional insulation up to BR08 standard had not lapsed when the invitation to tender was sent out, it was included for all outer walls in the tender invitation documents. However, the bid prices received simply confirmed what the calculations had already shown: that it would not be cost-effective to add insulation to the inside of the facades, and it was completely withdrawn from the project.

For the sake of comfort, KEjd decided to add 75 mm of mineral wool insulation to the gable end walls on the advice of the architects.

The consequential work involved was less than for the facades, as there are no windows facing into the rooms in the gable end walls. The gable end walls in the corridors were not fitted with additional insulation.

The strict requirements to noise suppression led to all floors being raised, including the stairs, which meant in turn that all doors had to be replaced. The existing floors consisted of linoleum laid directly on concrete, and a new lath layer was laid with pressure-resistant insulation between the wooden floors. The new lifts were also realigned to the modified floor levels.

Additional requirements to noise insulation for installations were also complied with, proof of which was required by the client and new users.

Other measures considered for the energy upgrading were the installation of photovoltaic panels, heat pumps and solar heat panels, but according to the cost-effectiveness calculations by Energi Focuser Aps, who performed the energy rating survey for the building, none of them were cost-effective.

Stairs with raised floor

CONSTRUCTION

Implementation of the Selected Energy-Saving Measures

The parties involved: Architects, engineers and contractors.

1. NEW INSULATED ROOF CONSTRUCTION WITH DORMER WINDOWS

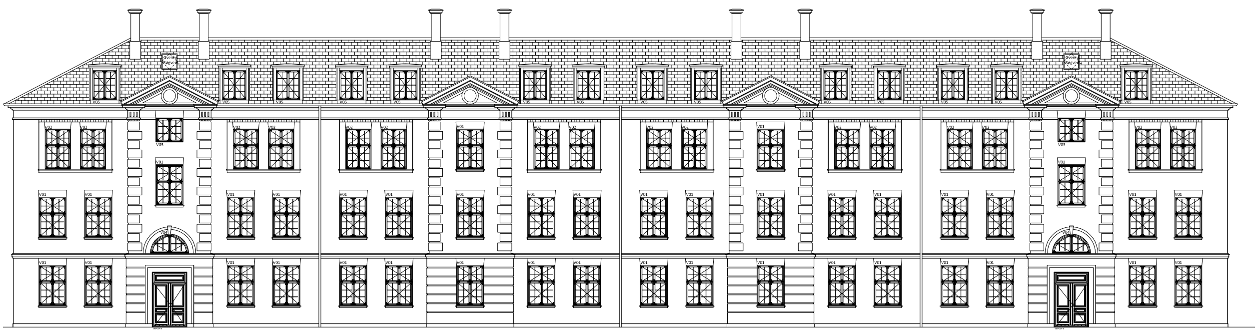
The roof construction needed replacing due to rot and mould attack. The scope and location of mould damage indicated that the existing roof construction had been installed incorrectly, and that the Haloten roof underlay prevented the necessary level of ventilation. Extra focus was therefore placed on the sealing and ventilation of a new roof construction.

The roof covering was replaced with dark natural slate tiles to return the building to its original architectural style, matching the other buildings in the complex.

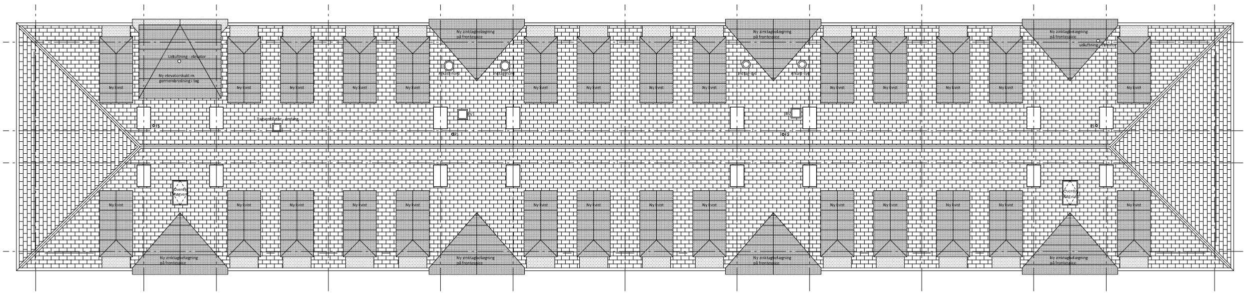
Dormer windows - identical to the ones in the neighbouring building - were fitted. The roof was insulated with an extra 300 mm mineral wool, to fulfil the mandatory requirements, and the loft converted to offices and common room.

The floor area of the loft was reduced by the addition of insulation from 585 m^2 to 552 m^2, despite the new dormer windows. The new roof construction comprised a rafter structure resting on a new jamb wall.

Before, west facade

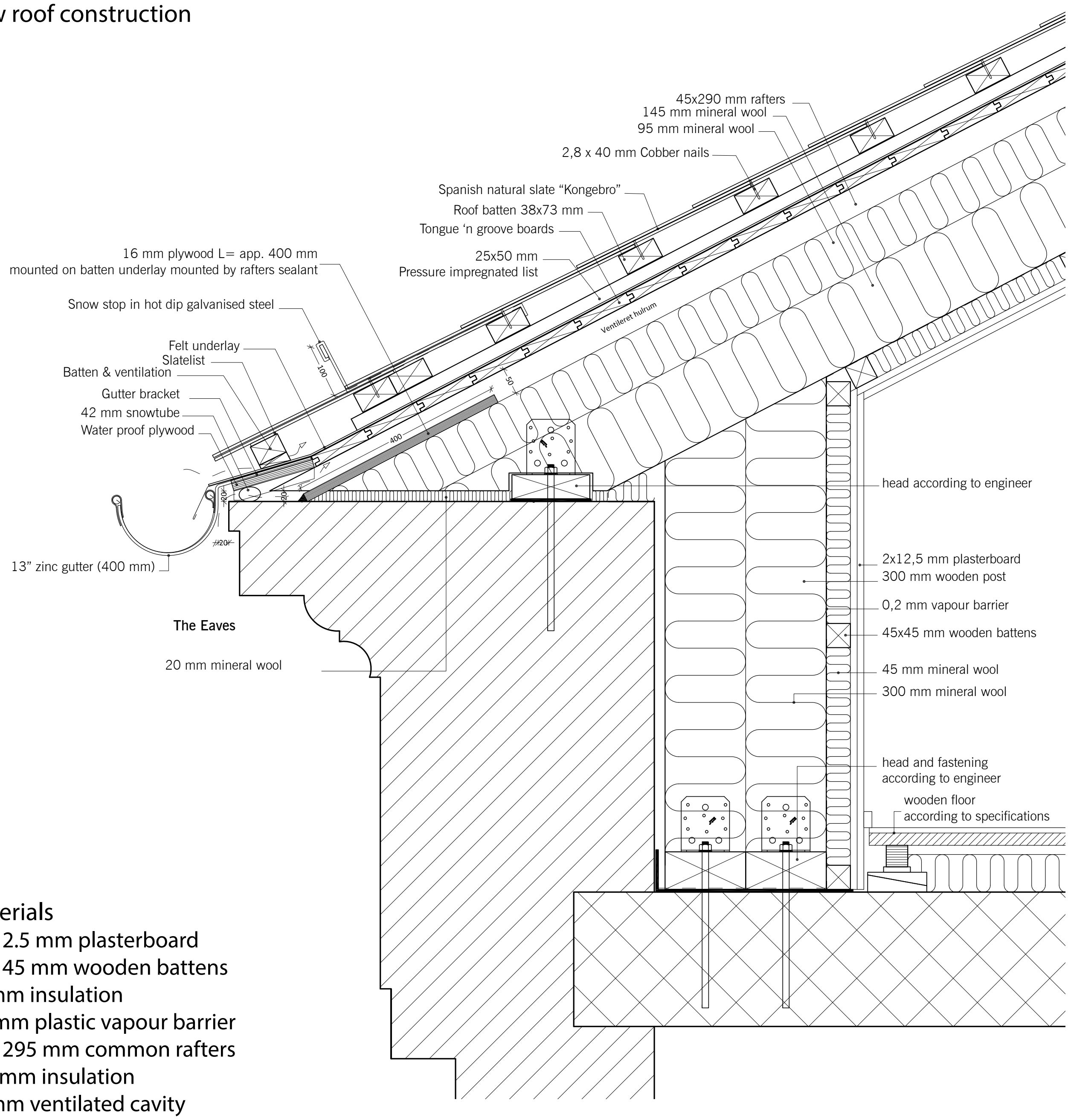


After, west facade



After, Roof

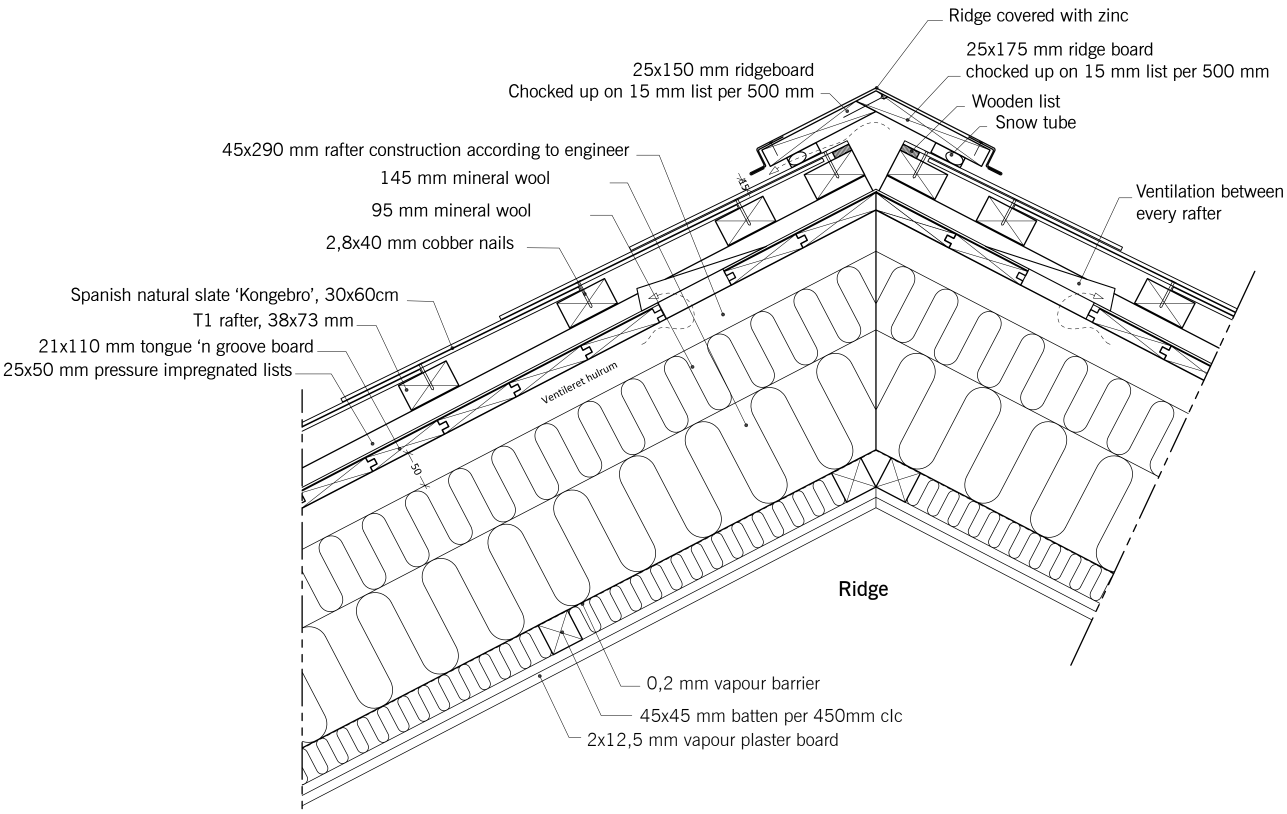
New roof construction



Materials
2 x 12.5 mm plasterboard
45 x 45 mm wooden battens
45 mm insulation
0.2 mm plastic vapour barrier
45 x 295 mm common rafters
250 mm insulation
50 mm ventilated cavity
25 x 110 mm fixed roof underlay, coarse-planed tongue and groove boards
1 layer of roofing felt
25 x 45 mm spacer strips
38 x 73 mm T-1 battens
21 mm waterproof plywood footboard
Natural slate tiles

Execution
New roof covering in dark blue/grey natural slate tiles as the outer layer of the whole roof.

The slates were fastened to the roof battens using copper nails. The battens used were pressure-impregnated spacers resting on the roof underlay. All necessary jambs or trimming in the roof structure for mounting windows and ventilation cowls were fitted.

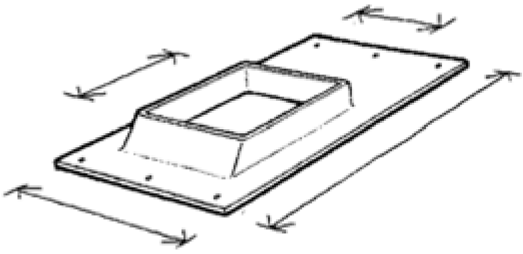


Detail section in roof ridge

A 30 mm air gap was formed under the ridge.
An underlay was fitted for the roof apron on the cornice, with a ventilation gap above and below the apron.

Ventilation openings were made and spaced evenly across the roof surface 30 cm under the ridge. Where the roof surface is penetrated by guttering, dormer window, skylights, pipes etc., ventilation is provided, either by drilling holes in the construction when they are installed, or by mounting vent stacks.

Drain gullies were installed above all roof windows and other roof penetrations.
Butyl-rubber based sealant was used around the holes and the cowl of the vent stacks.
Exhaust pipes and downpipes pass through the roof underlay using a DE-Flex bushing in the battens between the roof trusses. Between the DE-Flex bushing and the roof underlay, adhesive asphalt was used as a seal.



DE- Flex bushing

Tongue and groove planks were mounted as underlay for the roof underlay. The felt underlay was constructed using Icopal Fastsafe and was adapted specifically for skylight windows. The felt was folded around all penetrations to achieve tight seams. The felt was folded upwards onto the penetration, and adhered using asphalt adhesive.
The felt underlay was adhered to zinc surfaces using asphalt adhesive. The felt was laid along all edges and either secured or welded to achieve a 100% seal everywhere, including around skylight openings and at the walls, where it extended under the flashing.

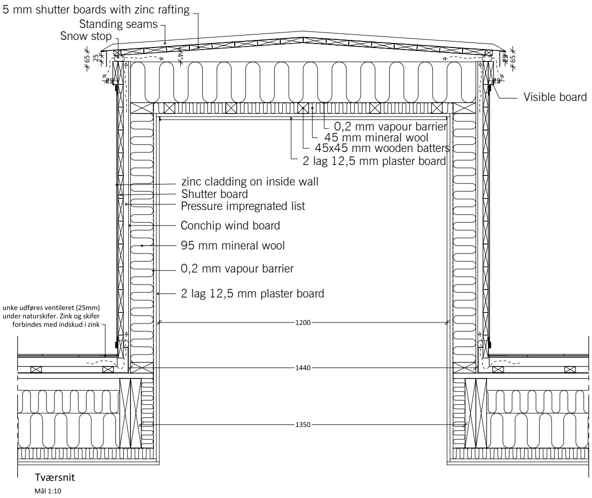
Insulation of the roof was achieved using FlexiBatts fitted so that there was always a minimum 50 mm gap between them and the roof underlay. The vapour barrier was laid immediately on top of the batten underlay for plasterboard, approx. 70 mm into the final construction. As sealing surface, a double layer of plasterboard with the outer layer either as robust sheets or as wetroom sheets was mounted, depending on the use the room would be put to.

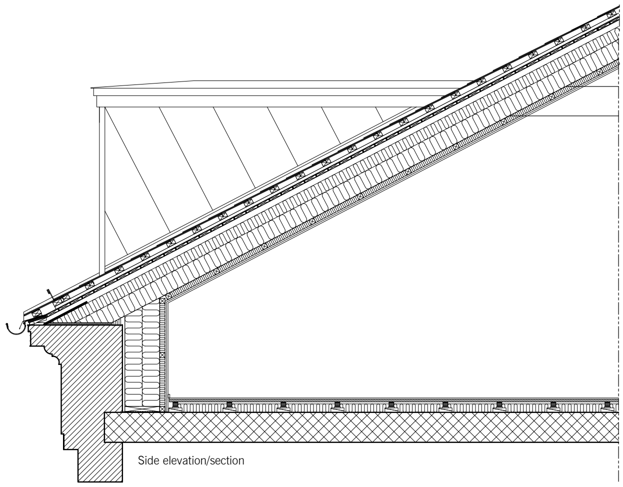
Zinc cladding was applied to the dormer windows and lift tower.

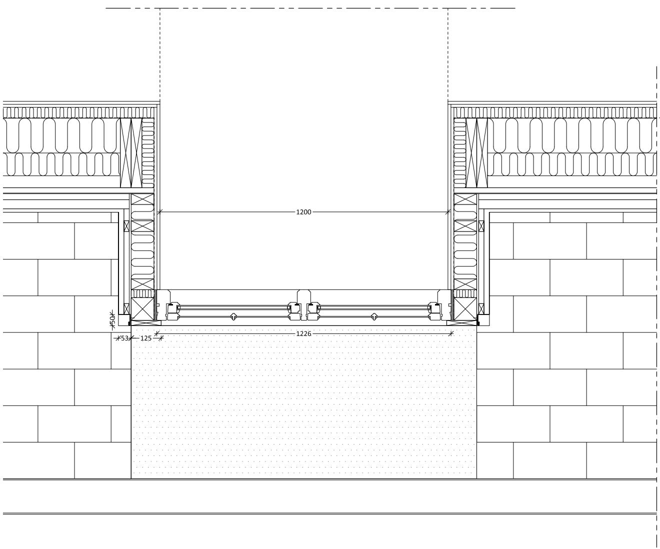
After renovation, section and north facade

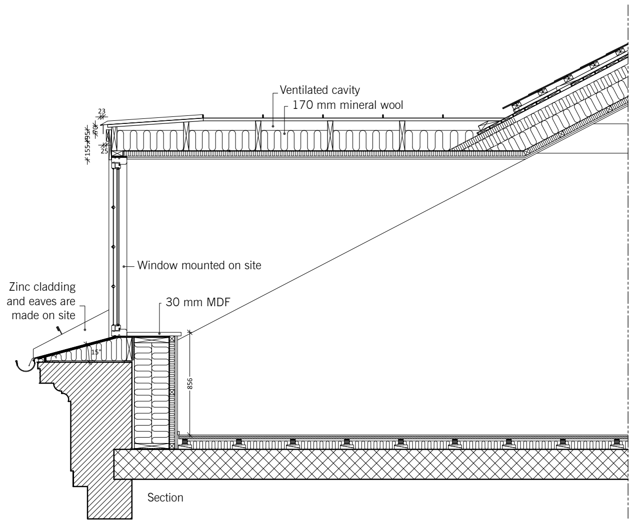
NEW DORMER WINDOWS

28 new, prefabricated dormer windows were mounted on the new roof construction, with the same appearance as the existing dormer windows on the neighbouring building. The window frames for the dormer windows were supplied by the same manufacturer who supplied the other windows in Elmehuset to ensure the same appearance and quality.









Execution

The dormer roof construction was as follows, from the inside and out:

- 2 x 12.5 mm plaster (the outer layer of a robust plasterboard)
- 45 x 45 mm battens
- 45 mm mineral wool, class 37
- 0.2 mm plastic vapour barrier
- 170 mm mineral wool, class 37
- Trusses in dimensions 45 x 245mm
- 22 x 95 mm underlay tongue and groove boards
- Zinc cladding (zinc 14) with vertical fold

The dormer cheek construction was as follows, from the inside and out:

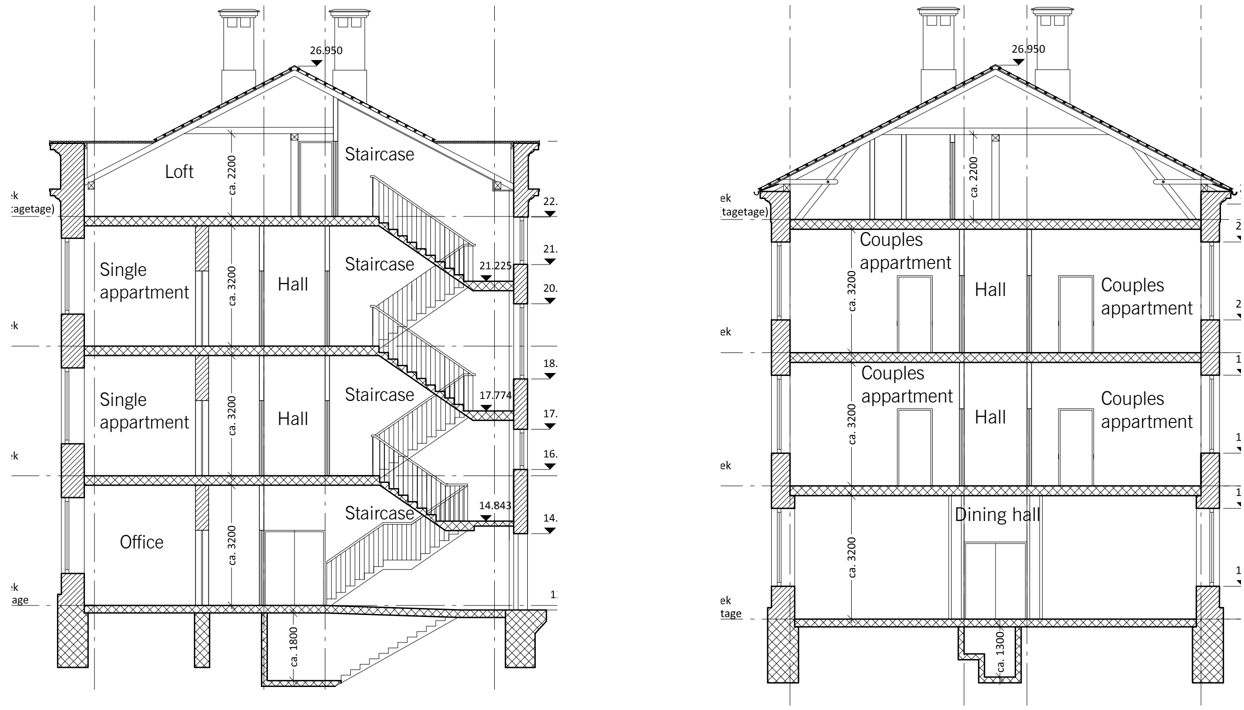
- 2 x 12.5 mm plaster (the outer layer of a robust plasterboard)
- 0.2 mm plastic vapour barrier
- 95 x 95 mm wooden corner posts
- 45 x 95 mm wooden posts per 300 mm
- 95 mm mineral wool, class 37
- Wind barrier sheet, 8 mm Conchip fibre cement sheets
- 25 x 50 mm pressure-impregnated spacer strips – ventilated cavity
- 22 x 95 mm underlay tongue and groove boards
- Zinc cladding (zinc 14) with blind fold

After installation, the vapour barrier was sealed tight to the vapour barrier of the roof. Plasterboards were mounted on site.

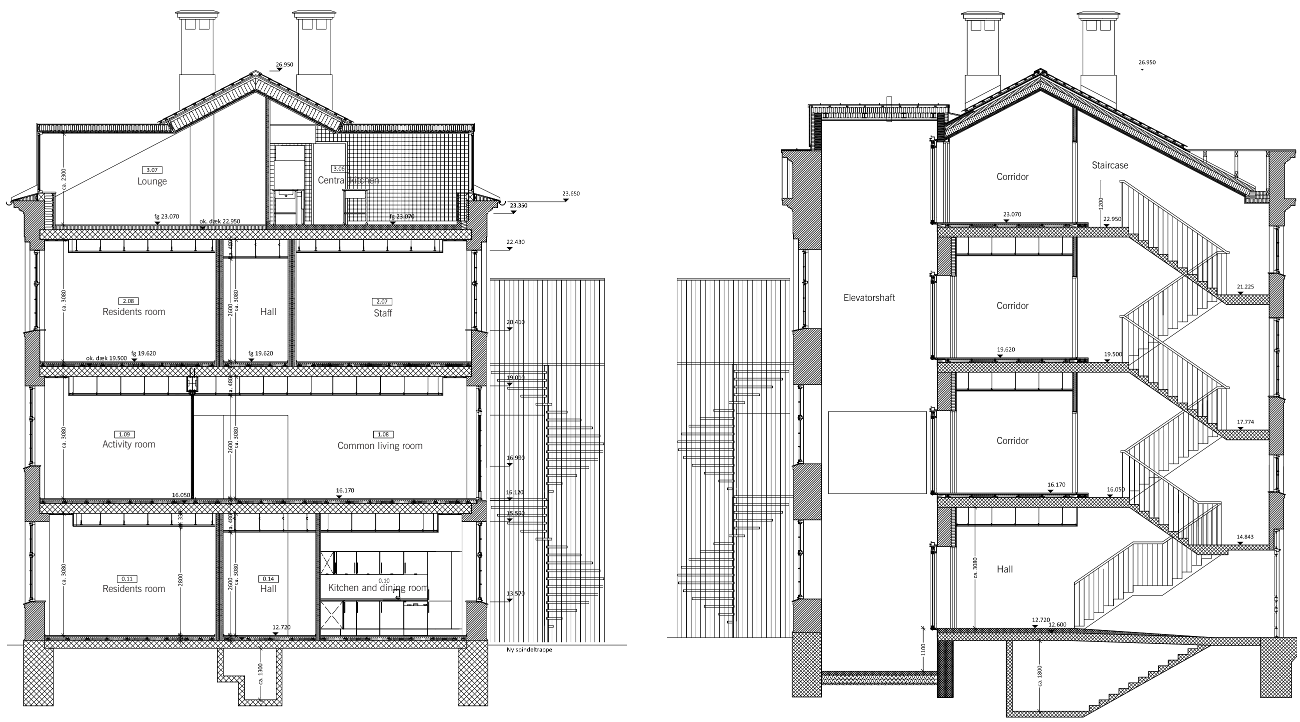
Roof with dormer windows

Velux window in new insulated roof

Interior, 3rd floor

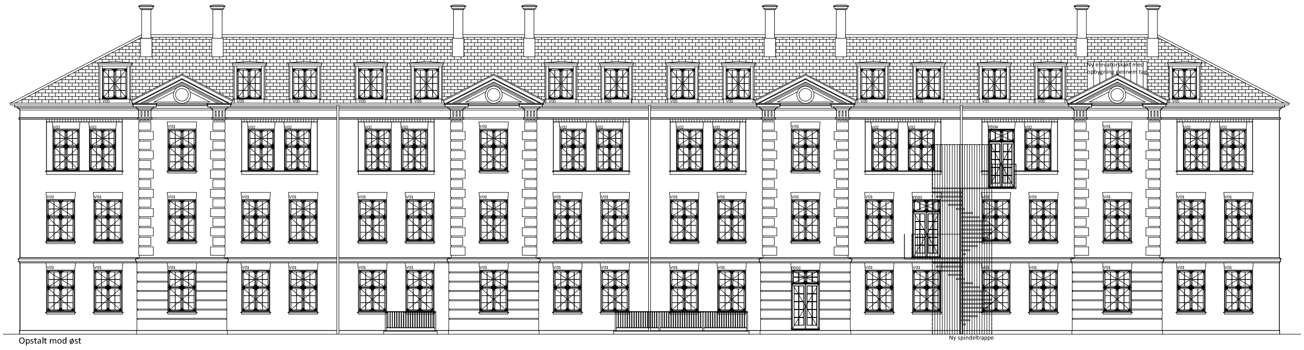


Before, cross-sections



After, cross-sections

2. REPLACEMENT OF WINDOWS AND OUTER DOORS

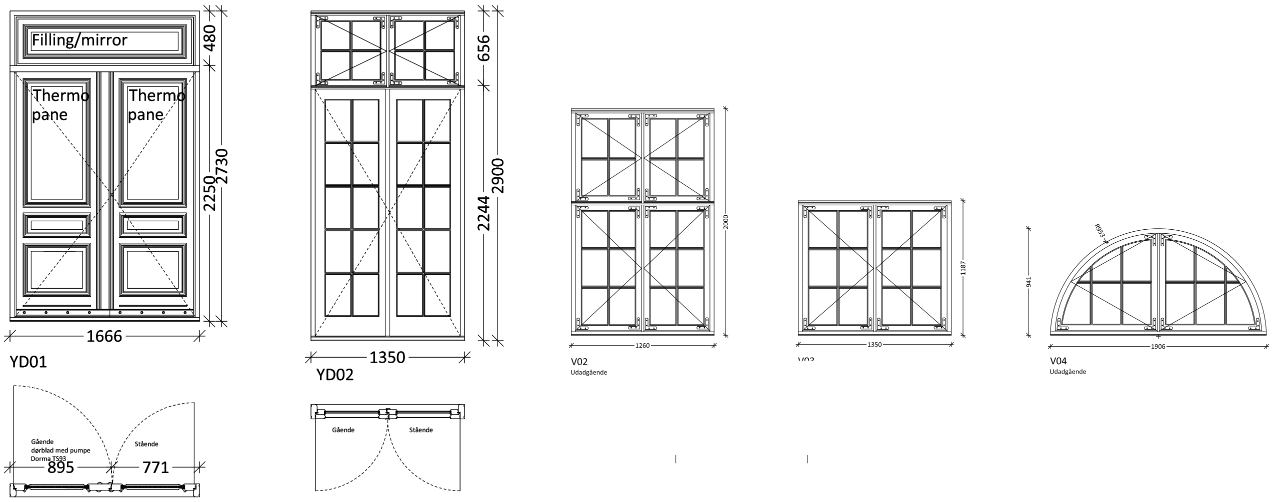


East facade

Windows were replaced mainly to fulfil demands made by users to new functions, and to increase comfort levels by better insulation of the building.

The building's windows were replaced by new two-light windows with small panes and coupled frames and putty beading, with exactly the same appearance as the previous windows. However, the glazing in the outer frame is low-energy glazing with putty and small glazing bars. The internal frames have no bars, and contain double-glazing with a warm edge. All windows were supplied with a frame vent.

External doors were replaced by new ones with optimised insulation value, although with exactly the same appearance as the previous moulded doors.



New doors and windows

External doors

Two new main entrance doors with double glazing and insulated moulded panels, plus 3 outward-opening double doors with transom windows and casement door leaves, plus doors for new door openings in the cellar.

The shape and surfaces of the windows were approved by the Center for City Design.

Materials

The windows had 54 x 128 mm frames in finger-cut heartwood, with bevelled edges.

The external frames (34 x 54 mm) had 1 layer of 5 mm low-energy glazing with putty beading and 19 mm putty-sealed bars on the existing windows.

The internal frames (42 x 50 mm) had 16 mm double glazing 4-8-4 with a warm edge. The internal glazing had no bars.

White-painted corner bands were fitted to all external window frames and hinges were galvanised Hamburg fittings.
Cremone handles with locking casement stays and window brakes were fitted to all window frames.
The cremone handles are lockable using keys, to prevent young residents from opening the window.

All windows were fitted with a concealed vent (Trim-Vent) with a 38 cm^2 opening. The vent has a concealed air intake in the horizontal centre post.

Weather strips with welded corners were fitted to all edges.
All new windows were painted white to match the previous windows.

Before After Before After

3. REPLACEMENT OF INSTALLATIONS, LIGHTING, HEATING AND VENTILATION

Heating

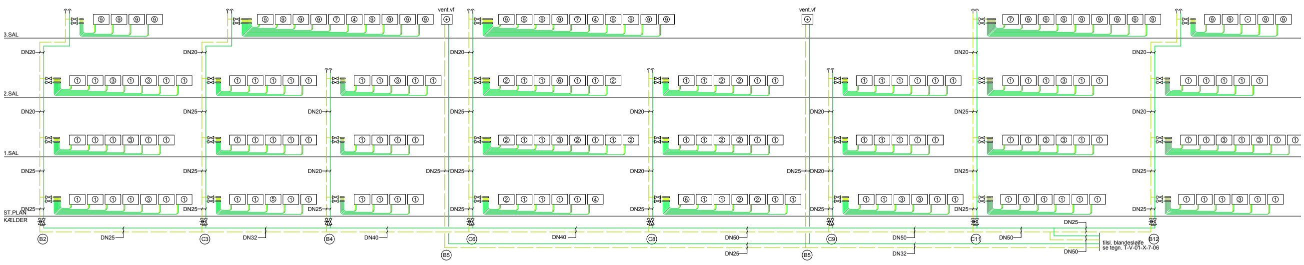
New radiators were fitted throughout the building, including new pipes connected to the existing district heating system.

Heating via district heating from the Old People's Town's own central heating plant in an external building was a requirement. The new heating systems fulfil BR08.

- Distribution system

The heat distribution pipes are a two-string system. A single 450 W Grundfos Magna 40-120 automatically modulating pump was fitted to the heat distribution system.

Two automatically modulating 85 W Grundfos Magna 25-60 pumps were fitted on the heating surfaces of the ventilation system. The heat distribution pipes before the return shunt were clad with 30 mm of insulation. The distribution pipes in the cellar were clad with 40 mm of insulation.



- Automation

CTS heating controls were fitted to control the supply water temperature to the heating installation depending on the outdoor temperature, and also thermostat regulation valves on the radiators to regulate the correct room temperature.

Hot water

The building is supplied with hot water from the central heating plant of the complex.
Hot water pipes in the cellar were clad with 30 to 40 mm of insulation material.
The hot water risers were clad with 30 mm of insulation material.

Plumbing and sanitation
New water-saving fittings were fitted in wet rooms and kitchens.
Water-saving toilets with large and small flush options and thermostat-regulated taps with water-saving aerators were fitted.

Bathrooms

Ventilation
A new ventilation system with heat recovery was fitted to fulfil the requirements of the Building Regulations.

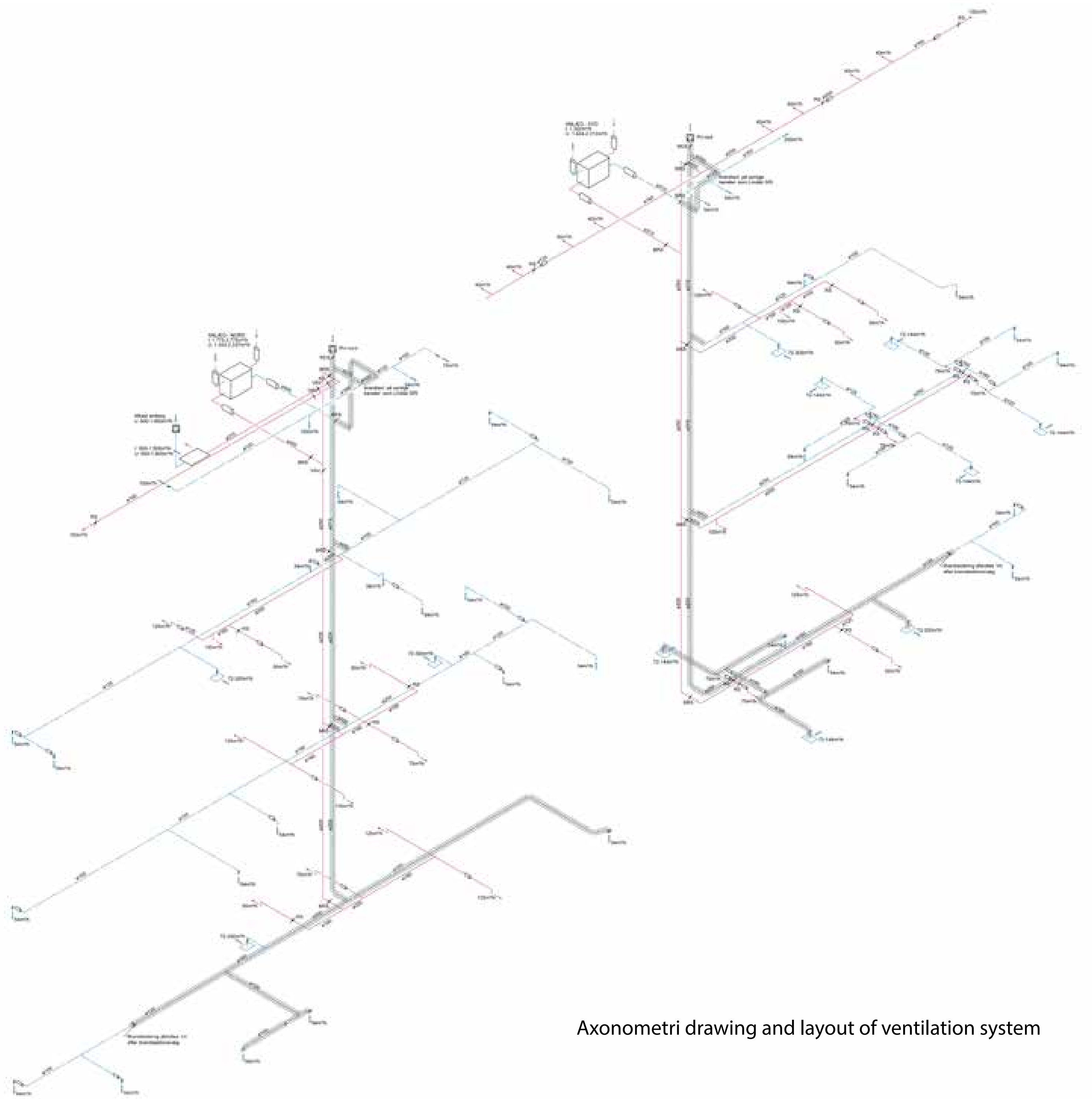
Ventilation is split into two systems – North and South, both with heat recovery and air intake/exhaust through the roof.

The vertical ventilation ducts run through each of the two former stairwell cores, from where supply and extraction are branched to each floor. The horizontal ducts are placed above the suspended ceilings in the corridors.

Supply air is piped to the corridors, common rooms and residential rooms with kitchenettes, and extracted via exhaust ducts in the kitchens and bathrooms.

The mechanical ventilation units are Exhausto VEX150 and VEX140.
The units are fitted with timers and frequency control of the fans.

Exhausto VEX150



Axonometri drawing and layout of ventilation system

Electrical and light fittings

The building was re-wired, including the main cables, switchboards and conduits, and other electrical installations in the building were replaced. All lighting installations were replaced, and emergency and panic lighting installed. New cabling and outlets for high voltage installations were installed, along with new kitchen appliances and machinery. PDS, ABA/ABDL/Alarm, access control and door telephones and TV aerial were all included in the contract.

New, low-energy lighting was installed throughout the building.

Lights are kept on in corridors and common areas around the clock, as the children have to have access to these areas at all times and feel safe. The lighting is generally manually-controlled in all areas where the residents have access. The same considerations applied to the decision to not install motion sensors – PIR sensors – or daylight-activation in those areas.

Lights in offices and stairwells were fitted with low-energy bulbs and manual switches. The stairwell lighting is controlled by a dusk sensor switch. Lighting in the common rooms now consists of fluorescent tubes and LED spots.

Lighting in the toilets consists of compact fluorescent lights with manual switches, although PIR sensors are used in the staff toilets. Other lights consist of fluorescent lights with manual switches.

Light fittings in common room and office

General

In the project, stricter requirements were applied to sound travelling between residential and other areas. These applied in particular to penetrations through walls for pipes, cables etc., which were sealed with an elastic sealant, and were never fastened directly to masonry walls, concrete decks or steel columns.

Mufflers were fitted in the ventilation duct system to fulfil the acoustic requirements, and to prevent the transport of sound between rooms in accordance with the Building Regulations.

Acoustic seals for electrical cabling were applied after the last cables were passed through walls.
Acoustic seals were tested at selected locations.

Minimum acoustic insulation required was:
Vertical >= 55 dB
Horizontal >= 55 dB

4. INTERNAL INSULATION OF GABLE ENDS

Comfort insulation was added to the inside of rooms with gable end walls.

The engineers usually recommend external insulation, which could not be used in this case because of restrictions applied by the conservation authorities.

The consulting engineers pointed out that it is always difficult to install additional insulation inside a building, as there will always be a risk of condensation forming, and it is very difficult to ensure a 100% seal using a vapour barrier – which may also risk being holed by new installations etc. over time.

In accordance with dew point calculations, a solution using 70 mm additional insulation of the gable end proved acceptable.

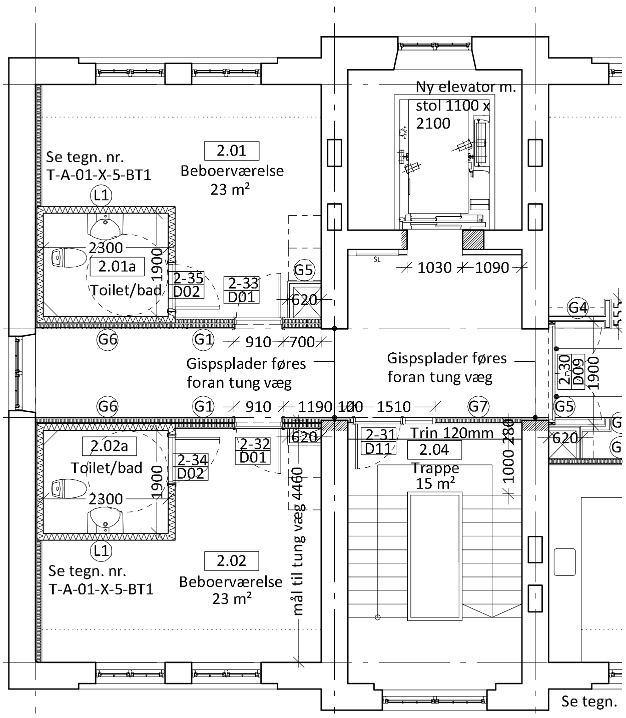
A risk of condensation forming still exists, which is why the insulation was fitted with extra controls to ensure that the secondary wall was not in contact with the heavy outer wall at any point – where condensation could be expected to form according to the calculations.

The vapour barrier was also installed with extra care to ensure it formed a complete seal all over. In the walls to be insulated, there were no windows or other elements to complicate installation of the vapour barrier, which made the certainty of a 100% seal very high.

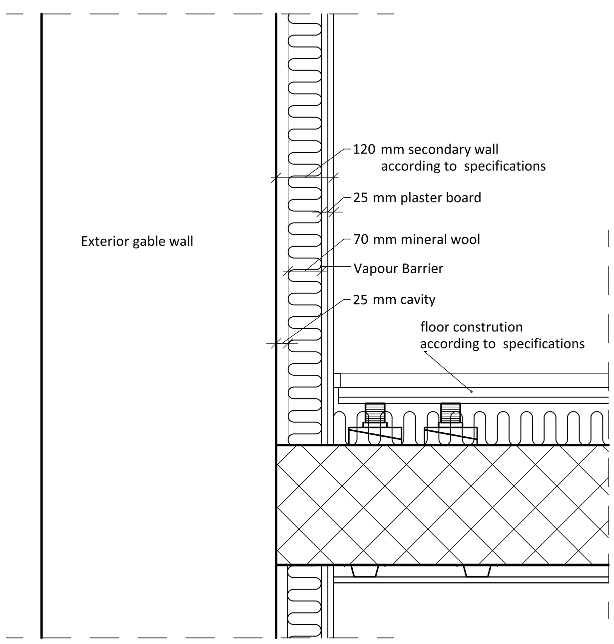
In addition, the structural floors in Elmehuset are made of concrete and not wood, which eliminates the risk of rot in beam ends due to moisture, for example.

Vent openings in windows plus mechanical extraction from the other rooms on the floor ensure continuous ventilation of the room to keep air humidity down.

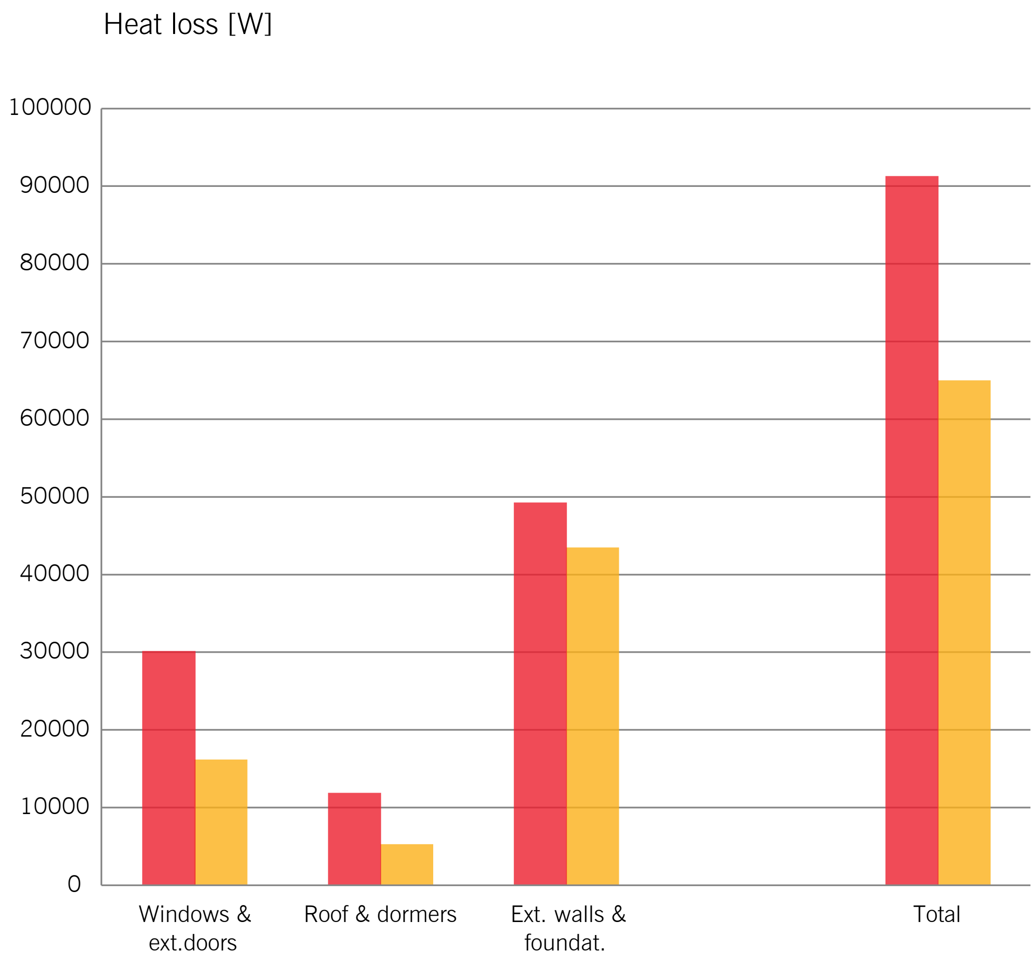
The secondary wall is a 120 mm thick stud wall, into which 70 mm mineral wool insulation was inserted. The structure stands 25 mm from the heavy outer wall across its full width and height. A vapour barrier was fitted and the wall clad with two layers of 12.5 mm plasterboard, with the outer layer in robust sheets. A soft grout was applied in the joints between adjacent building elements.



Insulation at gable end walls



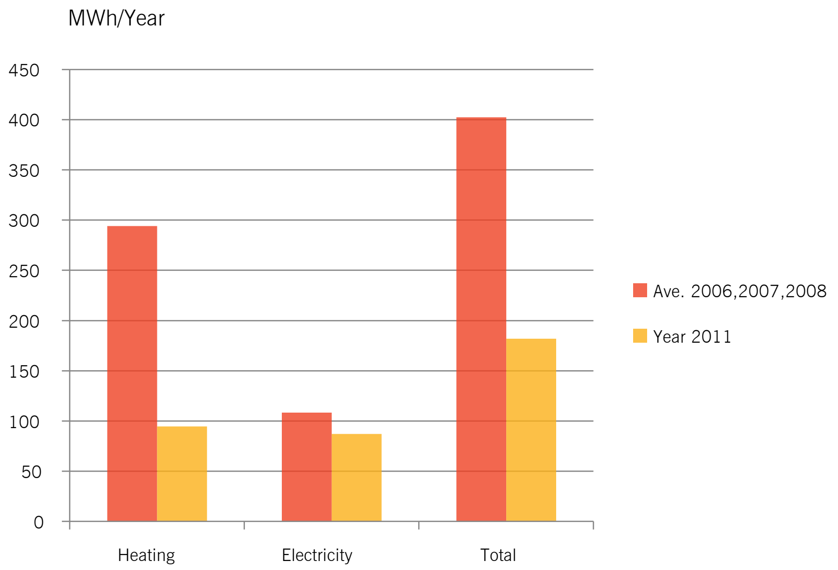
Insulated gable end wall, section



Heat loss frame:
Calculated heat loss through specific construction parts before and after refurbishment

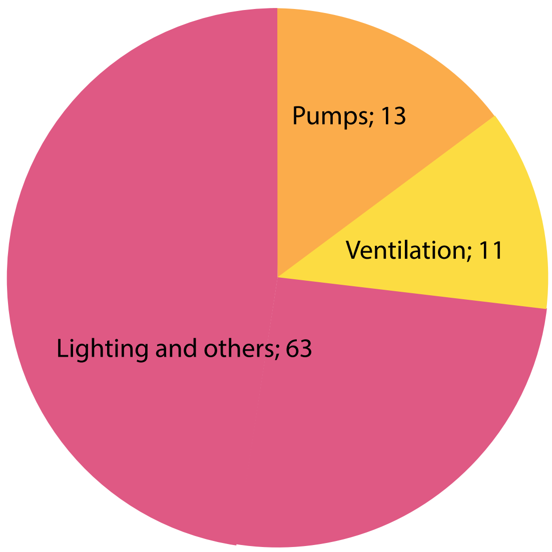
- Before refurbishment
- After refurbishment

Yearly consumption MWh	Heating	Electricity	Total
Average 2006,2007,2008	294	108	402
Year 2011	95	87	182
Difference	199	25	220



Consumption 2011	
Electricity	
Pumps	12,9 MWh/Year
Lighting & others	63,7 MWh/Year
Ventilation	10,5 MWh/Year
Total Electricity	87,0 MWh/Year
Heatconsumption	94,5 MWh/Year
Total consumption	181,5 MWh/Year

Electricity MWh/Year 2011



Electricity pumps & ventilation	23,4 MWh/year
Heating	94,5 MWh/year
Total	117,9 MWh/year
Area	2836 m^2
Total pr. year kWh/m^2	41,6 kWh/m^2

BR08 requirement:	Annual max. consumption
klasse 1	35,4 kWh/m^2
klasse 2	50,6 kWh/m^2
klasse 3	70,8 kWh/m^2

BR10 requirement:	Annual max. consumption
klasse1	30,4 kWh/m^2
klasse2	53,1 kWh/m^2

CONCLUSION

Improvement of the Building Envelope

The problem with windows and doors mainly concerned their appearance in relation to preservation value and function for the users, but replacement also fulfilled the requirements of the authorities for energy savings, and has contributed to significant improvement of the scale of the heat loss (heat loss framework) of the building. Furthermore, it had a positive comfort effect for day-to-day use of the building.

Replacement of the roof and dormer windows was necessary because of rot and mould damage and fulfilled all requirements from the authorities with regard to the new usage and energy savings. The additional insulation took up considerable room, especially with regard to ceiling height. As can be seen from the graph above, heat loss through the building element fell by half, about the same as for the windows and doors.

Discussion concerning the upgrading of the building's energy performance mainly centred on additional insulation of the facades.

Heavy costs are associated with internal insulation – there are the obvious ones related to the work involved and subsequent adaptation of adjacent surfaces, installations and maybe door/window openings. And there are the less obvious costs for increased mechanically-balanced ventilation, plus the loss of space to the same.

But there are also long-term costs in the form of lower rent from reduced floor area.

The uncertainty factor with regard to the calculation and execution of a technically sound structure in terms of moisture was a decisive factor, and so was the inability to reduce cold bridges from supporting inner walls and floors.

Internal insulation of the facade was deemed to be non-cost-effective, and consequently the requirements of the authorities no longer apply. Therefore it was decided to fit additional insulation only to the gables.

The insulation of the gable ends has no major effect on the scale of the heat loss (heat loss framework), or estimated energy consumption. The incentive for adding insulation was to increase comfort levels in the building, which it succeeded in doing. Energy savings here can be seen as a bonus achieved without any major investment and without the loss of too many m^2.

Replacement of Installations

The replacement of installations was made necessary because of the discovery of asbestos, and due to a general desire to modernise, given the change in use of the building.

Energy Consumption

Earlier energy consumption indicates that the energy upgrading has had a positive effect on the total energy consumption, which today totals 220 KWh per year.

The preliminary energy consumption measured after the energy upgrading took place indicates that the energy consumption has further decreased in relation to what was estimated. It is therefore assumed that the new tenants generally have a lower consumption than the previous ones.

Economy

The conclusion therefore is that to upgrade this type of building with regard to energy consumption, the fact has to be accepted that it will also be a building in which the technical installations play a much greater role. Additional internal insulation cannot stand alone.

Its function and reliability are conditional on investing in mechanically-balanced ventilation, heat recovery systems and possibly the control of ventilation and windows to ensure an indoor climate that is acceptable in terms of moisture and comfort.

KEY TO NOTES

1) SAVE REGISTRATION

Compilation of the Heritage Agency of Denmark's 'cultural heritage atlas' requires the registration of all buildings by the Danish Agency of Culture, with the award of SAVE ratings (Survey of Architectural Values in the Environment).

Buildings are rated from 1 to 9 based on a range of criteria:
Architectural value
Cultural history value
Environmental value
Originality
Condition
Architectural value

Architectural value concerns the building as a whole. Its proportions are considered and also whether it is harmonically and consistently built within its style. It can – for example – be a unique example of a new building style, or have a special form of construction.

Cultural history value
Whether the building is a prime example of a local building tradition is considered here, either within a given style or some characteristic use of materials. If the building also has some particular historical importance can also be significant, for example, if it played a key role in its local area, had some form of special function, etc.

Environmental value
The environmental value is determined based on the building's relationship with the dwellings and buildings around it. For instance, if it helps emphasise or give a neighbourhood or an area some form of special characteristic.

Originality
Originality is judged by whether the building has maintained its original look, and the condition it is in. Whether it has been renovated is not important, but such renovations and other modifications must emphasise its originality.

Condition
The condition of the building is also taken into overall consideration, as it is an indication of whether it has been well maintained or neglected.

2) ENERGY RATING

Energy rating of public buildings is mandatory in Denmark. The objective is to profile total energy consumption, and the options that exist for saving energy in public buildings.
Total energy consumption covers heating the building and running its fixed installations.
By implementing the report's proposals for improvement, it is ensured that the building is in good condition in terms of energy, and that energy costs for running the building will be as low as possible.

Every building is given a rating from A to G.

3) FIRE

The number of the category of use classifies the building in relation to fire and rescue. Category 6 covers building sections in use during the day time, and can also include night time, when the people in the building section are unable to reach safety unaided. It includes treatment facilities and wards in hospitals, nursing homes, prisons, dwellings and institutions for the physically handicapped, psychiatrically disabled and children's institutions.